CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Fifteenth meeting of the Conference of the Parties
Doha (Qatar), 13-25 March 2010

CONSIDERATION OF PROPOSALS FOR AMENDMENT OF APPENDICES I AND II

A. Proposal

Inclusion of all species in the family Coralliidae (*Corallium* spp. and *Paracorallium* spp.) in Appendix-II of CITES. *C. rubrum, C. secundum, C. lauuense (C. regale), P. japonicum, C. elatius, C. konojoi,* and *C. sp. nov.* qualify for listing in Appendix II in accordance with Article II, paragraph 2 (a) of the Convention, and satisfy Criterion B in Annex 2a of Resolution Conf. 9.24 (Rev. CoP14)[1]. The other 24 described species qualify for listing in Appendix II in accordance with Article II, paragraph 2 (b) of the Convention, and satisfy Criterion A in Annex 2b of Resolution Conf. 9.24 (Rev. CoP14).

Inclusion in Appendix II, with the following annotation: The entry into effect of the inclusion of species in the family Coralliidae in Appendix II of CITES will be delayed by 18 months to enable Parties to resolve the related technical and administrative issues.

Annex 2a, Criterion B. *It is known, or can be inferred or projected, that regulation of trade in the species is required to ensure that the harvest of specimens from the wild is not reducing the wild population to a level at which its survival might be threatened by continued harvesting or other influences.*

The species listed above qualify for inclusion in Appendix II under this criterion because they are intensively harvested to supply international demand for jewelery and other products and their life-history characteristics (extreme longevity, late age of maturity, slow growth and low fecundity) make them particularly vulnerable to over-exploitation. For sessile (attached), colonial organisms such as the Coralliidae, successful reproduction and maintenance of healthy populations are critically dependent on colony size (larger colonies have lower mortality and exponentially higher levels of reproductive output) and density (a minimum density is required for successful reproduction). Selective removal of the largest (oldest), most commercially valuable colonies or of all colonies in a particular location, as is common in many Coralliidae fisheries, significantly reduces reproductive potential, often results in local extirpations, and makes these populations much more vulnerable to other stressors. These species are also at increased risk due to their specific habitat requirements (hard substrate and low sedimentation) and historic and ongoing use of destructive collection methods has resulted in habitat degradation in many areas. The greatest threat to Coralliidae populations worldwide is harvest to supply international trade, with declines in the size structure of fished populations equivalent to 80-90% of the reproductive modules (polyps) and declines in landings that exceed 60-80% since the 1980s. Unfished stocks, including deep water populations, are likely to experience similar declines unless international trade regulation provides an incentive to introduce or improve monitoring and management measures to provide a basis for non-detriment and legal acquisition findings.

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[1] The United States believes that, where indicated, the criteria and definitions must be applied with flexibility and in context. This is consistent with the "Note" at the beginning of Annex 5 in Resolution Conf. 9.24 (Rev. CoP14): "Where numerical guidelines are cited in this Annex, they are presented only as examples, since it is impossible to give numerical values that are applicable to all taxa because of differences in their biology." The definition of "decline" in Annex 5 is relevant to the determination of whether a species meets either criterion in Annex 2a of the resolution. Nonetheless, the United States believes that it is possible for a species to meet the criteria and qualify for listing in Appendix II even if it does not meet the specific parameters provided in the definition of "decline." Where quantitative data are available, they should be used to evaluate a species' status. However, where data on population abundance are not available but there are indications that over-exploitation is or may be occurring (i.e., "it is known, or can be inferred or projected") and the regulation of trade could benefit the conservation of the species, listing should be supported.

Annex 2b, Criterion A. *The specimens of the species in the form in which they are traded resemble specimens of a species included in Appendix II under the provisions of Article II, paragraph 2(a), or in Appendix I, such that enforcement officers who encounter specimens of CITES-listed species, are unlikely to be able to distinguish between them.*

B. Proponent

Sweden, on behalf of the Member States of the European Community, and The United States of America[*]

C. Supporting statement

1. Taxonomy

1.1 Class: Anthozoa

1.2 Order: Gorgonacea (Alcyonacea)

1.3 Family: Coralliidae

1.4 Genus, species or subspecies, including author and year:

Corallium (24 species). See Table 1.

Paracorallium (7 species). See Table 1.

1.5 Scientific synonyms:

C. rubrum: *Madrepora rubra* Linnaeus 1758; *Isis nobilis* Pallas 1766; *Gorgonia nobilis* Linnaeus 1789; *P. secundum*: *Pleurocorallium* Gray 1867; *C. johnsoni*: *Hemicorallium* Gray 1867; *C. lauuense: C. regale* Baco and Shank 2005; *C. lauuense: C. laanense* Bayer and Cairns 2003.

Recent taxonomic revisions divide the family Coralliidae into two genera, *Corallium* and *Paracorallium* (Bayer and Cairns 2003). There are currently 31 recognized species, in addition to several un-described species and one listed as *Corallium* sp. nov (Midway deep coral). Note that the taxonomy of the un-described Midway coral has not yet been clarified, and there are some indications that Midway coral may represent several species of the family Coralliidae (Grigg 2001). *C. lauuense* and *C. regale* are listed as separate species in the U.S. Precious Coral Fishery Management plan, but these species are usually considered synonymous (Parrish 2007). It is recommended that the Parties adopt Bayer and Cairns 2003 as an official nomenclatural reference for Coralliidae.

1.6 Common names:
English: pink coral, red coral, noble coral, angel skin coral, Sardinia coral, midway coral
French: corail rouge, Corail Sardaigne, Coral Sciaca
Spanish: coral rojo, Coral Cerdeña,
Japanese: Aka Sango (red), Momo Iro Sango (pink), Shiro Sango (white), boke coral

1.7 Code numbers: 3Alpha Code: COL

2. Overview

The family Coralliidae includes over 30 pink and red coral species, the most commercially valuable precious corals. These taxa have been fished for millennia, and millions of items are traded internationally each year. The greatest threat to populations of Coralliidae is fishing to supply international trade, with declines in landings that exceed 60-80% since the 1980s, and declines in the size structure of populations in fished areas equivalent to a loss of 80-90% of the reproductive modules (polyps). International demand has contributed to serial depletions of most known populations of pink and red corals, and new stocks

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[*] *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat or the United Nations Environment Programme concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

have been rapidly exhausted shortly after their discovery. Once stocks are depleted, they are not known to recover in an ecologically meaningful time frame (Tsounis et al. in press).

All species in the family Coralliidae exhibit life-history characteristics typical of low productivity organisms that make them vulnerable to overfishing. This includes a sessile (attached) growth form, slow growth rates, relatively late reproductive maturity, reproductive output that exponentially increases with size, long life spans, and limited dispersal potential. Commercially known Coralliidae beds are discrete, genetically isolated patches that occur in restricted, often deep water habitats, with colonies exhibiting a low density. Populations are primarily self-recruiting, exhibit low rates of gene flow, and are separated by large areas of unsuitable habitat and high currents. Commercial harvest has decreased genetic diversity within and among populations of Coralliidae*,* and shifted the size and age structure to populations dominated by small colonies that lack the recruitment potential necessary to sustain the population. In addition, bottom trawls and dredges used to harvest coral or for food fisheries on seamounts and other preferred habitats of Coralliidae destroy bottom features and remove all benthic sessile organisms in their paths, causing extensive damage to coral ecosystems.

Management measures implemented in U.S. waters (Hawaii) and in parts of the Mediterranean for Coralliidae fisheries include no-take areas, rotational harvest, minimum sizes, quotas based on maximum sustainable yield (MSY), licensing, and restrictions on non-selective gear types. These measures are absent from other locations, including international waters, and even when applied they are inadequate to ensure sustainable management of fisheries and trade. FAO scientific consultations since 1988, recent red coral workshops, and new research demonstrate that: 1) these corals grow at rates of one half or less than previously reported and also reach sexual maturity 2-3 times later, effectively cutting the MSY by at least 50%; 2) no-take MPAs are too small, too few in number, and improperly placed to accommodate the limited dispersal potential and high degree of genetic variability among populations within close proximity; 3) rotational-harvest strategies are of limited value, unless areas are left alone for many decades to centuries, as evidenced by the presence of colonies that are still less than half their historic size within areas that have been closed for 1-2 decades or more; 4) MSY for *C. rubrum* is not achieved until colonies are 98 years old, although the current practice is to remove colonies only 7-10 years old; 5) 80-90% declines in size structure of harvested populations in the Mediterranean from 300-500 mm height to 30-50 mm height, and 10-30 mm diameter to 5-7 mm diameter; 6) gradual shift has occurred in Mediterranean SCUBA fisheries from shallow (30-50 m) to deeper water (60-130 m) because populations at <80 m depth that formerly supported fisheries are over-exploited with few colonies larger than the legal minimum size; 7) scientific data from deep areas are restricted to a few surveys off Sardinia (Italy) and Costa Brava (Spain), including a single genetic study that suggests deep water corals are genetically distinct, and there is no information on growth, reproduction, recruitment, or other relevant information needed to determine sustainable harvest levels; 8) technology to extract colonies from these deep areas (mixed gases and the use of ROVs to identify sites with coral) allows targeted exploitation that may eliminate all large colonies critical to persistence of populations; and 9) poaching and take of undersized colonies has occurred in shallow water, and there are difficulties in enforcing management measures.

Regulation of trade in Coralliidae is required to ensure that the harvest of specimens from the wild is not reducing wild populations to levels at which survival might be threatened by continued harvesting or other influences. The original population structure throughout the Mediterranean has been altered by fishing pressure, with declines in landings and in population structure that exceed the level required for an Appendix-II listing. There have been large shifts in size structure and population dynamics of shallow water *C. rubrum:* 1) from a mean size of 100-150 mm and colonies present of 300-500 mm height to a mean size of 30-50 mm and few colonies over 100 mm height; 2) to occurrence of dense, short-lived populations with a high turnover, which are more susceptible to mass mortalities when fishing pressure is combined with global climate change (especially temperature anomalies); 3) to a dominance in shallow water (30-70% of the corals) by immature individuals and reproductively mature colonies that contain only about 100 or so reproductive modules (polyps) versus tens of thousands of polyps in larger colonies, which is the most relevant measure of viability of colonial animals like those in the family Coralliidae. Pacific populations appear to be in even worse shape, as evidenced by: 1) low reported landings from international waters around Emperor Seamounts (1-5 m t/yr vs. 100-450 t/yr in the 19860s-1980s) and failure to identify large, viable beds during extensive 2008 submersible surveys; 2) occurrence of coral densities off Japan that are 10-100 times less (0.05-0.005 colonies/m^2) than reported in an unfished population off Hawaii (0.5-1 colony/m^2); and 3) landings by Taiwanese fishermen that consist of 80% or more dead colonies, which is indicative of areas previously damaged and over-exploited by trawling that contain few remaining live colonies.

3. Species characteristics

3.1 Distribution

Species in the family Coralliidae are found throughout the world in tropical, subtropical, and temperate oceans, including the Atlantic Ocean, Mediterranean Sea, Indian Ocean, Eastern Pacific Ocean, and western Pacific Ocean at depths of 7-1500 m (Grigg 1974, Weinberg 1976, Bayer and Cairns 2003). The only known Coralliidae populations large enough to support commercial harvest are found north of 19º N latitude, including seven Pacific species and one Mediterranean species. All known species in this family occur at low abundances (Grigg 1982). *Corallium rubrum* is endemic to the Mediterranean, primarily around the central and western basin (7-300 m depth, but most commonly at 30-200 m) with smaller populations in deeper water in the eastern basin, and to the eastern Atlantic off the coast of Africa (Carpine and Grasshoff 1975, Weinberg 1976, Carleton 1987, Chiuntiroglou et al. 1989, Garrabou et al. 2001, Santangelo et al. 2004, Rossi et al. 2008). For more detailed information on the distribution of species, see Annex Table 1.

3.2 Habitat

Species in the family Coralliidae occur as geographically isolated populations called beds or patches. Certain species have a relatively wide distributional range, although they typically occur as fragmented populations due to specific habitat requirements and individual populations or beds rarely contain more than one species. These corals require hard substrates for settlement and are most commonly found on rocky bottoms, banks and seamounts, in areas with high currents and low levels of sedimentation (Baco and Shank 2005). These rocky, high relief habitats are generally small in size, occur within a limited depth range, and are separated by large expanses of unsuitable soft bottom habitat.

In the Mediterranean, *C. rubrum* coexists with other gorgonians, large sponges, and other benthic invertebrates. *C. rubrum* colonies are most abundant in and around dimly lit caves, dark overhangs, vertical cliffs and crevices at depths of 20-50 m, and generally occur in small patches that may be less than 1 m diameter. In deeper water (50-200m), they occur at lower densities (<1 colony/m^2) on exposed outcrops and other rocky structures (Marchetti 1965). Although the depth distribution of *C. rubrum* was reported to be 5-300 m, isolated colonies were recently found in three sites in the Straits of Sicily to depths of 600 m (Taviani et al. 2009); nevertheless, this coral occurred only in aggregations that were large enough historically to support fisheries from about 30-200 m depth, and recent data suggest that exploitable, healthy populations now occur only at about 60-130 m depth. A scleractinian coral (*Lophelia pertusa*) occupies much of the available habitat in deeper water (below 90-120 m) and *C. rubrum* is very scarce (Rossi et al. 2008, Angiolillo et al. 2009,), possibly due to widespread harvesting in deep water using coral dredges prior to the ban on such gear beginning in 1989-1994.

Pacific species occur primarily on outcrops, ridges, and pinnacles with more than 2 m vertical relief (Grigg 2001). Habitat requirements include strong bottom currents (1-3 knots), slopes of less than 20º, low rates of terrestrial sedimentation, and an absence of sediment accumulations. Light levels influence larval settlement and control the upper depth limit of their distribution. The two richest depth zones for Pacific Coralliidae are 90-400 m and 1000-1500 m, primarily around seamounts and offshore shoals. Colonies are most abundant adjacent to channels and on the outer rim of seamounts where currents are greatest. Different species of the family Coralliidae typically occur in non-overlapping habitats. These species can grow on both carbonate and basalt/manganese substrates, although *C. secundum* occurs on uniform low-relief exposed substrates, whereas *C. lauuense* (*C. regale*) prefers encrusted, uneven rocky-bottom habitat (Parrish 2007). Both species are absent from shelf areas (<400 m depth) off populated islands, where substrates are periodically covered by shallow lenses of sand and silt (Grigg 1993). Preferred habitats include many of the most isolated benthic marine habitats in the world (Baco and Shank 2005).

3.3 Biological characteristics

The most critical biological aspects for a sessile (attached) organism that forms complex, branching colonies and can live for 100 years or more are colony size (larger colonies have lower rates of mortality and exponentially higher levels of reproductive output, which indefinitely increases with size and age) and density (a minimum density is necessary for reproduction).

The family Coralliidae is composed of sessile coelenterates (cnidarians) that are permanently attached to the bottom except for a short period during their larval stage. After this planktonic period, the larva settles and metamorphoses into a polyp that attaches to a hard substrate and begins to lay down a calcium carbonate skeleton. The polyp then divides into two polyps; after a period of growth each of these divides again, repeating this process over time to form a branched, tree-like colony. Each polyp is connected to other polyps by a series of canals that are responsible for the translocation of water and nutrients, allowing all polyps to function together as a single, larger organism. These colonies must reach a certain size before they become sexually mature, but once that size is achieved they can reproduce indefinitely. Reproductive output increases exponentially with size and the largest colonies in the population are thought to produce 90% or more of the offspring (Babcock 1991, Coma and Gili 1995, Beiring and Lasker 2000, Santangelo et al. 2003, Torrents et al. 2005).

All species in the family Coralliidae are benthic suspension feeders that consume particulate organic matter, with occasional capture of larger zooplankton (copepods and crustaceans). Unlike shallow corals, they lack symbiotic algae in their tissues (azooxanthellate). They are primarily k-selected with life-history characteristics that make them particularly vulnerable to over-exploitation, including extreme longevity (75-200 years; Andrews et al. 2005), late age of maturity (7-12 years or possibly up to 25 years based on newer measurements), slow growth (<1 cm/yr), and low fecundity. In the absence of fishing pressure they can attain heights ranging from 300 mm (*P. japonicum, C. konojoi*), 500-600 mm (*C. rubrum*), to over 1 m (*C. secundum, C. elatius*). *Corallium rubrum* exhibits average growth rates of 0.2-2 cm/yr in length and 0.24-1.32 mm diameter, with growth rates declining with age. Historically, *C. rubrum* colonies frequently attained masses greater than 2 kg, heights of 500 mm, and basal diameters of 30-100 mm. Apart from few known deep-water populations, today colonies of *C. rubrum* rarely exceed 100-200 mm in height and 20 mm basal diameter at depths of 60 m or less, with most populations dominated by 20-50 mm tall colonies as commercial take has removed most large colonies (Barletta et al. 1968, Liverino 1989, Rossi et al. 2008). Restoration of this population structure would require removal of fishing pressure for decades.

Aspects of reproductive biology have been studied for *C. secundum, C. rubrum,* and *C. regale (C. lauuense)*. These species have separate sexes and an annual reproductive cycle. *C. secundum* and *C. regale* are broadcast spawners that reach sexual maturity at 12-13 yrs (Grigg 1993) or possibly twice that (25 yrs), based on recent radiometric growth rates which indicate these species grow at half the rate previously thought (Roark et al. 2006). Mature colonies release eggs and sperm into the water column and fertilization is external. The pelagic larvae may spend several weeks in the water column before settling onto the bottom and forming a new colony.

All species except *C. rubrum* were identified as low-productivity species in a previous FAO review. In that review, it was suggested that *C. rubrum* was a medium-productivity species since it can reproduce at a small size (20-30 mm tall) and young age (2-8 yrs, depending on growth estimates). However, this species exhibits many unique reproductive aspects that suggest it is a low-productivity species, with certain adaptations that allow it to survive frequent disturbance events in shallow water. For example, the actual age of first reproduction is probably 7-10 years or more, based on more accurate estimates of growth (Marschal et al. 2004). *C. rubrum* may reach sexual maturity at 20-30 mm height and 3-10 yr age; however, colonies this small often contain a mix of mature and immature polyps, and those that do reproduce often produce fewer numbers of larvae than polyps of larger colonies (Tsounis et al. 2006b, Torrents et al. 2005, Santangelo et al. 2003). A 20-30 mm tall colony may produce 10-100 planulae, while a colony that is 200-300 mm may produce 10,000 planulae. *C. rubrum* is a brooder with internal fertilization, a longer development stage inside the parent, and short-lived passive larvae. Planulation in *C. rubrum* occurs once per year, over a period of about a month during summer. Larvae exist in the water column for a few hours to days (4-12 days in the laboratory) before settling in close proximity to parent colonies (Santangelo et al. 2003). This may enhance survival, because larvae are settling in an area where their parents were successful, but it minimizes exchange between populations such that a damaged population (one experiencing a mass mortality event, or removal of all commercially viable corals from an area) may require decades or more for recovery, and in some heavily fished areas small patches that contained *Corallium* are now depleted (Tsounis and Rossi, pers. comm.).

In non-harvested shallow-water areas (<40 m depth), recruitment rates of *C. rubrum* ranged from 0-32 recruits/m^2 per yr from 1995 to 1999 (Linares et al. 2000), and 0-12.5 recruits/m^2 per yr from 1979 tp 2000 in another site (Garrabou et al. 2001), although recruitment was sporadic and occurred in pulses with several years of no net recruitment. Certain shallow populations of *C. rubrum* were thought to reproduce at a relatively young age (3-10 years) and small size (20-30 mm height).

However, these small individual colonies have not developed a branching morphology, and consist of relatively few reproductive polyps which produce only low numbers of gametes (10s of gametes per colony) once per year. *C. rubrum* colonies reach 100% fertility once they are 60 mm in height, but still produce a relatively small number of gametes at this size (Torrents et al. 2005, Tsounis 2005). At roughly 7 years, *C. rubrum* colonies are unbranched sticks no more than 20-30 mm tall, with a basal diameter of 5-7 mm, each with a maximum of 100 polyps capable of producing tens to no more than a few hundred larvae annually. After a century, they can grow to be 500 mm tall with hundreds of branches and thousands of polyps, which can release hundreds of thousands of larvae each year (Bruckner 2009, Tsounis 2009). For a modular organism that characteristically forms highly complex, branched colonies, a shift from historic measures of 200-500 mm height to >90% of colonies that are less than 50 mm tall equates to a loss of 80-90% of the reproductive modules of individual colonies.

Local populations of Coralliidae species are self-seeding and genetically distinct (Santangelo and Abbiati 2001, Santangelo et al. 2004), with occasional long-distance dispersal events maintaining connectivity between sites for some species (Baco and Shank 2005). Several studies have identified significant genetic isolation and limited larval dispersal between populations, with individual beds relying primarily on local recruitment (Weinberg 1979, Abbiati et al. 1993, Baco and Shank 2005). New data from Sardinia also show a high degree of genetic differentiation and distinct population segments in deep and shallow water, which reduces the likelihood that these deep populations serve as a refuge for over-exploited shallow populations. Thus, over-exploitation of individual Coralliidae beds can affect the genetic diversity of the population as a whole, and reproductive failure may delay or prevent recovery.

Species in the family Coralliidae are in the low-productivity range as colonies are relatively slow-growing and long-lived, with population turnover estimated to occur once every 15-25 years (Grigg 1976) or longer, based on more recent estimates of age (Marschal et al. 2004).The density of *C. rubrum* recruits can be fairly high in shallow water (0-32 recruits/m^2 per yr from 1995 to 1999 in Spain (Linares et al. 2000), and 0-12.5 recruits/m^2 per yr from 1979 to 2000 in France (Garrabou et al. 2001)), although recruitment occurs in pulses with no successful settlement in some years, up to 95% of the larvae die before settling (Tsounis 2005), and 66-70% of the new recruits die over the first four years of life (Bramanti et al. 2005). Corals that broadcast their gametes are thought to have even lower survival of larvae (<1%), even though they produce many more gametes which remain viable for a long period and are fertilized in the water column. *C. rubrum* requires successful internal fertilization that relies on a male colony being close enough to the female for a chance encounter; this may occur less frequently in deep water when densities of colonies are further reduced by fishing pressure. Growth rates vary among location, depths, and habitats (Garcia-Rodríguez and Massò 1986, Abbiati et al. 1992, Cerrano et al. 1999, Garrabou and Harmelin 2002, Bramanti et al. 2005). Age had largely been determined by counting growth rings, but use of *in situ* measures of growth and staining of the skeleton demonstrates that colonies are substantially older, and first reproduction occurs at a much older age, than previously thought (Marschal et al. 2004, Garrabou and Harmelin 2002, Roark et al. 2006). Previous reports underestimated *C. rubrum* age by a factor of 2-4, with growth rates 2.6-4.5 lower than earlier estimates; colonies with a basal diameter of 7 mm may be 30-40 years old (Marschal et al. 2004). Due to their older age of maturity and slower growth rates, the existing minimum legal harvest size of *C. rubrum* colonies in managed populations does not allow for optimal levels of reproduction prior to harvest (Bruckner 2009).

3.4 Morphological characteristics

Species in the family Coralliidae are octocorals with a solid, longitudinally striated calcitic axial skeleton that is branched and fan-like or bush-shaped. Colonies range in color from pure white to shades of pink, salmon, blood red, and orange, and have white transparent polyps, each with eight tentacles and fine pinnules. The central organic gorgonin found in other octocorals is replaced by a solid axis of fused calcareous spicules composed of a very hard calcium carbonate structure with high magnesium content. Gross morphological characters and color easily distinguish the family Coralliidae from other coral families.

3.5 Role of the species in its ecosystem

Species in the family Coralliidae form tall, highly branched colonies. They are referred to as habitat-forming corals as they enhance the three-dimensional complexity of their habitat and consequently increase biodiversity where they occur. These colonies provide valuable habitat for sessile invertebrates by protecting them from strong currents and predators. They provide structural relief that fish and mobile invertebrates use as feeding, spawning, and resting grounds. *C. rubrum* formerly played a paramount role in structuring the Mediterranean coralligenous zone through their trophic activity and biogenic structure, creating one of the most complex communities in the region with a wide variety of suspension feeders and a high species richness and functional diversity (Gili and Coma 1998). *Pseudosimnia* spp. are highly specialized gastropods known to lay eggs on *C. rubrum*. A rare crustacean (*Balssia gasti*), only known in the Mediterranean, attaches to colonies of *C. rubrum* (Santangelo et al. 1993).

4. Status and trends

4.1 Habitat trends

With the exception of select areas off Hawaii and in the Mediterranean, very little information is available on the overall extent of habitat or how it has changed over time. Nevertheless, new research off the coast of Japan and its associated islands, as well as benthic videos produced by coral harvesters, illustrate some of the important features within habitats utilized by these species, as well as the general low density of these taxa and their overall rarity (Iwasaki 2009.). Loss of habitat is of minor importance, with the exception of suitable habitats close to coastal areas that may experience increased sedimentation. However, the major concern is the degradation of these habitats due to destructive collection methods and bottom tending gear (trawls and dredges).

Deep water habitats occupied by pink and red corals have been impacted by dredges and trawls used to collect corals, and by trawl fisheries targeting seamount and deep sea associated fishes. These gear types scour the bottom, alter bottom features, re-suspend sediment, dislodge attached organisms, and cause incidental damage to corals through removal as bycatch. With the exception of limited harvest by submersible in several Pacific locations and collection using SCUBA in the Mediterranean (which largely replaced the coral dredge there in 1989-1994), most coral has been harvested using heavy dredges consisting of nylon netting tied to an iron bar or cement stones that are dragged across the ocean floor. These gear types are still used legally by fishermen from Japan and the island of Taiwan, and illegally in some Mediterranean areas. Coral is entangled in the nets and pulled to the surface, a destructive and wasteful process that often breaks and dislodges coral, with 60-90% lost and detached during collection and which consequently dies. Dredging operations also dislodge and remove all sessile invertebrates in their paths, including undersized precious corals of low value that are subsequently discarded. They can also destabilize the bottom, reducing availability of hard substrates for future settlement of larvae. Dredges used to extract *C. rubrum* are known to have caused extensive habitat impacts to the coralligenous zone in the Mediterranean (Chessa and Cudoni 1988). The use of both coral dredges and intensive SCUBA fishing has degraded the three-dimensional “forest-like” structure created by large, highly branched *C. rubrum* colonies to a “grass-plain-like” structure dominated by unbranched colonies 10-50 mm in height. The original forest-like structure was still apparent 20 years ago (Garcia-Rodríguez and Massò 1986, Tsounis et al. 2006, Rossi et al. 2008).

4.2 Population size

The total number of colonies for all species in the family Coralliidae is unknown, although most examined locations with suitable habitat and/or beds of pink and red corals tend to have a relatively low number of colonies (hundreds to thousands of colonies per patch). Most often, colonies occur at low densities (low number of colonies per unit area, generally <1 per square meter), a low overall abundance (number of colonies) within an individual bed, and a small area of occupancy within individual areas of suitable habitats. The few larger, commercially exploitable populations reported from the Mediterranean and western Pacific (Grigg 1974, 1993, 2002) are also characterized by low densities and a relatively small number of mature, economically valuable colonies. The only exceptions are certain shallow-water habitats in the Mediterranean that are no longer considered commercially viable, as these populations are now dominated by small (10-50 mm tall) colonies that never achieve a size large enough to support legal collection.

Mediterranean: In shallow water (<50 m depth), *Corallium rubrum* is found at relatively high densities within small patches, but the total number of actual colonies present is very low within this depth range, as is the mean density of colonies throughout the available habitat. For instance, densities are reported up to 127 colonies/m^2 in Spain (Tsounis 2005), 200-600 colonies/m^2 in France (Garrabou et al. 2001), and 1300 colonies/m^2 in the Ligurian Sea, Italy (Cerrano et al. 1999) above 50 m depth. At Costa Brava, Spain (20-50 m depth), individual populations (patches) cover a small area (mean=0.43 m^2), and the number of patches is relatively few (0.063 patches/m^2), with an overall density of *C. rubrum* estimated at 3.4 colonies/m^2 (Tsounis 2005). In comparison, several decades ago densities of 55 colonies/m^2 were observed at a depth of 40 m (Palma de Mallorca), 20 colonies/m^2 at 60 m depth along the Costa Brava, and 90-100 colonies/m^2 in Corsica (FAO 1984). These different densities also reflect different morphologies and a possible response to frequent perturbations. Dense, shallow- water Ligurian colonies are thin and slender, whereas less-dense colonies can develop more extensive branching patterns. It is also of note that these corals were much larger and more resilient to natural stressors, as they could survive disturbances with partial mortality and then exhibit re-growth, whereas smaller colonies are more likely to experience total mortality (Santangelo et al. 2007). In deep water, larger colonies are still found, but they occur at much lower densities than in shallow water, forming small aggregates (typically no more than 20-30 colonies on one outcrop and an overall density of <1 colony/m^2) on individual banks and hardground areas, with colonies concentrated on the exposed surfaces facing into high-current areas (Rossi et al. 2008; Cannas et al. 2009).

Pacific: U.S. Coralliidae beds off Hawaii have been found in 16 areas at depths of 380-575 m, but only three of these are considered large enough to support commercial fisheries (not currently active) (Annex Fig. 1; Grigg 2002, Baco and Shank 2005). These three beds exhibit low densities and total numbers of colonies, and are relatively small in size. Makapu'u Bed, the largest of these beds at 4.3 km^2 (in the Molokai Channel off Oahu), has a density of 0.3 colonies/m^2 and a total population size of 120,000 *C. secundum* colonies; the estimated MSY would be 1500 kg/yr. The second largest bed (Cross Seamount, 6 km in diameter) was estimated to contain 2500 legal-sized colonies, mostly *C. regale*, with an estimated MSY of only 35 kg/yr (Grigg 2002). Keahole Point Bed covers an area of 0.96 km^2 and contains up to 7000 legal-sized *C. regale* colonies, with an estimated MSY of 90 kg/yr (Grigg 2002).

Using only colony abundance and density as an indication of population size and viability can be misleading, as dense populations are limited to only *C. rubrum* and these tend to be dominated by small, reproductively immature colonies. For colonial organisms, change in population structure (size frequency distribution) is a more suitable measure of decline than changes in the absolute numbers of colonies. Commercial extraction primarily eliminates the largest corals, followed by smaller colonies over time but it is the largest, oldest colonies that contribute most to the replenishment of the population. Furthermore, shifts in the size structure of populations due to fishing pressure can be directly compared, while density and abundance cannot. This is because these measures differ depending on how they are assessed (colony density measured over the entire suitable habitat is much less than the density of small patches occupied by the coral within this habitat), and the life stage of the population. In fact, a less-dense population is likely to represent an older, more stable and viable population as open substrates of suitable habitat can support high numbers of recruits, but these exhibit size-related survival that increases as the colonies get larger. Thus, populations with a high abundance and density, such as those seen in Mediterranean shallow water, are an indication of frequent continuing perturbations responsible for rapid turnover of populations and a persistent state of early-stage recovery. This is similar to observations of other corals that brood their larvae; however, most other corals that are brooders are considered early colonizing, “weedy” species, while *C. rubrum* is a long-lived species that may be attempting to adapt to increasing localized (direct human impacts) and global stressors (climate change). These types of populations are much less resilient to other stressors and are more likely to exhibit localized extirpations when compounded by fishing pressure than populations that contain a mix of small (10-50 mm tall), medium (60-140 mm), and large (150-500 mm) colonies, like that formerly observed in the Mediterranean and still present in some deep-water areas that have not been targeted by fisheries for several decades.

4.3 Population structure

Mediterranean: The size and age structure of unfished *Corallium rubrum* populations in steady-state recruitment are reported to be structured by a monotonic curve with a negative exponent (Santangelo et al. 1993), which means that the population contains a large number of small colonies and progressively fewer colonies of each larger size class. A severe lack of larger (older) colonies, as observed in all areas with Coralliidae fisheries where surveys have occurred, is an indicator of high mortality due to harvesting, and not natural disturbances which would have a greater impact on small (young) colonies, while large colonies would persist with only partial mortality. Since recruitment potential is directly linked to the number of polyps per colony, heavily fished populations dominated by young colonies are more likely to be driven to local extinction when compounded by other stressors, unless there is an external source of larvae (Santangelo et al. 2007).

C. rubrum can be found in depths of 5-700 m, though more commonly at 30-200 m (Carpine and Grasshoff 1975, Rossi et al. 2008, Taviani et al. 2009). These deeper-water Coralliidae populations have become increasingly important targets for fisheries as shallower populations are fished out. At a recent expert consultation held in Italy (Red Coral Workshop: Naples, Italy 2009), consensus was reached that shallow populations in the Mediterranean are over-exploited and should be protected from fishing, while deep areas still contain large colonies that could be harvested. However, it appears that deep populations may exhibit a very short period of high commercial viability, as corals occur at lower densities at these depths, and at more exposed positions, making them more vulnerable to fishing pressure. These populations are more likely to experience extirpation due to the potential for reduction to densities below that required for successful fertilization (Allee effect). There are also reports that several *C. rubrum* populations located in deep water have been depleted since the 1980s (Tsounis et al. in press), and have not yet recovered from centuries of heavy dredging. In addition, part of their habitat is occupied by a competing scleractinian coral, *Lophelia pertusa,* which is faster growing and can monopolize deep-water habitats (Rossi et al. 2008, Tsounis et al. in press). Expansion into deeper water of SCUBA fisheries using mixed gases (such as is reportedly occurring in Sardinia as shallow populations are depleted) may be problematic as there is a complete absence of data on growth rates, natural mortality, and recruitment for these populations, and quantitative data is lacking on the distribution and abundance within these areas. Furthermore, because larval dispersal is limited to short distances, genetic differences observed among populations at spatial scales of 10s of meters suggest that deeper populations are only likely to reseed nearby populations (del Gaudi et al. 2004, Calderon et al. 2006, Costantini et al. 2007, Abbiati et al. 2009, Costantini et al. 2009, Tsounis et al. in press). *C. rubrum* in shallow water forms dense, patchy populations consisting of small (mean size=30 mm), short-lived (<10 years) colonies; less than half of these are reproductive, most of which produce tens of planulae per year. These shallow populations structured by small colonies may produce the bulk of the planulae (albeit at lower numbers than equivalent populations with larger colonies), but synergistic impacts that are increasing in severity due to growing human pressures and climate change may drive these populations to extinction. In deeper water, *C. rubrum* colonies are larger but less abundant (Tsounis et al. 2006a, Rossi et al. 2008). Large, older colonies may produce hundreds to over 10,000 planulae per year (Santangelo et al. 2003, Bruckner 2009).

Pacific: Populations of *C. secundum* in Makapu'u Bed (Hawaii) were dominated by colonies that were 15-20 years old; the largest colonies were 700 mm in height and 80 yrs old, and natural mortality rates in absence of fishing were estimated at 6% (Grigg 1984, 1993), although the initial surveys were undertaken after several years of fishing.

4.4 Population trends

It is likely that precious corals become economically extinct before they reach biological extinction, as they are widespread colonial animals that are highly resistant to total colony mortality once a large size is achieved, and unlike non-colonial animals they can survive even with partial mortality. However, these species tend to occur where natural physical impacts are rare and exposure to unsustainable fishing pressure can and has resulted in removal of the most critical segments of the population for persistence of those populations (large colonies), followed by continued (illegal) removal of smaller colonies as the demand increases and the resource declines (Rossi et al. 2008, 2009).

Global harvest statistics from 1950 to 2001 provide an indication of the rapid decline in abundance of Mediterranean and Pacific species corresponding with the discovery, inception of commercial fishing, increase in landings, over-exploitation, and, ultimately, exhaustion of the resource (Annex Table 2, Fig. 2, 3, 4, FAO 2008). A large bed discovered in 1965 (300-500m depth) and a second bed discovered in 1978 (900-1500 m), both on the Emperor Seamounts, were fished by 100s of boats during peak years (1965-1970, 1979-1981, 1982-1988), and production neared or exceeded 300 metric tons (t) during several years (Grigg 1993; Bruckner 2009). Although there were periods of inactivity as wholesale prices of *Corallium* from these areas dropped to uneconomical levels, it increased to unprecedented highs in the late 1980s and 1990s. Landings crashed by 1989 and have remained below 5 t/yr for the last 19 years. Recent submersible surveys within these former coral beds identified isolated colonies, many of which were broken, dead, and with no remaining large populations (Annex Table 3).

Population viability of Coralliidae depends on stock structure, including extent of dispersal between populations, rates and patterns of reestablishment, and basic life-history patterns. Although isolated colonies may survive heavy fishing pressure, due to their sessile nature they may become reproductively isolated if densities of colonies are reduced (the Allee effect). Data on larval biology and genetic population structure denote a low rate of exchange between local populations and persistence of populations via local recruitment (Torrents et al. 2005). Recent genetic studies suggest that Pacific species of Coralliidae may be self-recruiting with only limited long distance dispersal events. Low heterozygosity observed in populations suggests the species may be suffering from inbreeding depression (Baco and Shank 2005).

<u>Mediterranean</u>: *C. rubrum* populations have shown a dramatic decrease in size, age structure, and reproductive output over the last 20 years. Most remaining shallow-water populations are characterized by the absence of large colonies and an overall shift to dominance by colonies below the smallest legal size for commercial harvest (mean colony height throughout the region is now 30 mm; Liverino 1989, Garrabou and Harmelin 2002). These populations consist of colonies with few branches and few polyps, of which only a small percentage are reproductively mature and produce fewer larvae per polyp than polyps in larger colonies (Tsounis 2005). The current, extremely young population structure is a direct result of over-harvesting (Santangelo et al. 1993, Santangelo and Abbiati 2001, Tsounis et al. 2007, Tsounis et al. in press). This is a concern mainly since colony size in a population, not abundance, is the primary indicator of population status and health, as these are colonial animals made up of polyps that exhibit higher survival and an exponential increase in larval production as the colony gets larger and produces more branches. In Spain, 89% of the colonies in fished areas above 60 m depth were below legal size for harvest, 96% showed only rudimentary branching patterns (primary and secondary branches only), and 91% were less than 50 mm in height (Tsounis et al. 2006). Mean basal diameter of colonies declined from 7.2 mm to 4.8 mm, with mean height decreasing from 61.8 mm to 27 mm from 1986 to 2003 (Tsounis et al. 2006). Even in areas protected from fishing for over 14 years, the largest colonies rarely exceeded 200 mm in height and the average basal diameter was only 4.8 mm, corresponding to an average age of 7.5 years (Tsounis et al. 2006). Colony height increases with depth to 40 mm height at 25-50 m and 60 mm at 50-90 m; the largest colonies (130-160 mm height) are found in non-harvested areas >50 m depth (Rossi et al. 2008). In contrast, colonies collected in the 1950s and 1960s were frequently up to 500 mm height and 20 mm diameter (Liverino 1989). A 1962 collection off Costa Brava, Spain, consisted of colonies with basal diameter of 10-45 mm (mean=16 mm) and height of 100-500 mm (mean=115 mm) with the largest corals estimated at 50-80 years in age (Garrabou and Harmelin 2002).

In France, colony size (basal diameter and height) in non-harvested sites was four times larger and average height was two times greater than that of corals in harvested areas (Garrabou and Harmelin 2002). Relative to historic records of colonies that were 300-500 mm in height and 10-30 mm diameter, colonies in fished areas today are of 30-50 mm height, which equates to a mean of less than 10% of the historic number of polyps per colony and 20-30% of the number of polyps per colony within areas protected from fishing for 10-15 years; these smaller colonies will produce less than 10% of the offspring per colony that was observed historically (Bruckner 2009). Populations examined in 1998 in fished areas off France (Riou archipelago) were also larger (mean height=60 mm, range=40-130 mm) than that reported for Spain (although small colonies were not examined in this study). These colonies were still only about half the size of a similar habitat in France protected from fishing since 1983 (mean=118 mm, range=80-170 mm).

The first deep-water study (Rossi et al. 2008), conducted in Spain, reported an increase in the size structure of corals that is directly related to water depth from about 30-50 mm height in shallow water (<30 m depth) to 100-150 mm at 80-120 m depth, with larger corals found below areas currently targeted by SCUBA fisheries. More recently, deep areas examined off Sardinia also contained larger corals. Extensive surveys were conducted off the northwest, west, and south coasts, all of which contained larger corals than similar habitats in shallow water, but differences were still noted from the degree of fishing pressure. Of importance, 1) fishing is now restricted to these deep beds because shallow populations are over-exploited, 2) there are new, more conservative management measures in place, and 3) landings from these areas constitute up to 99% of the coral landed in Italian waters since 2000 compared to 35% in 1983 (Cannas et al. 1983), yet more than 50% of the landings were below the minimum recommended diameter (10 mm) established for this location based on a sample size of over 200 colonies (Chessa and Scardi 2009). This suggests larger colonies, while present, only make up a small portion of individual populations, and continued pressure on these resources in absence of more thorough information on population status and trends is likely to result in rapid depletion of these resources as already experienced in shallow water.

<u>Pacific</u>: In 1971, following two brief periods of commercial harvest, Makapu’u Bed (off Hawaii) was estimated to contain 79,200 colonies of *C. secundum*, with colonies occurring at a mean density of 0.02 colonies/m^2 (Grigg 1976). From 1974 to 1979, about 40% of the standing stock (17,500 kg) was harvested (Grigg 1988). Six years after harvesting ceased, colony density was similar to pre-harvest

levels (0.022 colonies/m^2) although colonies were younger and smaller, and colonies over 35 years of age were absent. By 2001, the percentage of older size classes (20-45 years) increased, but the oldest colonies (45-55 years) were still under-represented (Grigg 2002),[2] even in the absence of any fishing pressure over this period.

4.5 Geographic trends

Official FAO landings data from the last 45 years (1962-2007) illustrate the characteristic boom and bust cycle of Coralliidae fisheries, with rapid increases in effort and landings shortly after a discovery of a new precious coral bed, followed by sharp declines a few years later once the bed is depleted (FAO 2008). This trend has repeated itself in all locations known to support commercial populations of these corals throughout the history of the fishery; although, since 1990 no new large commercially viable beds have been discovered and landings have remained at historically low levels that are 10-0% of that reported in the late 1980s (Carleton and Philipson 1987, Grigg 1989, Santangelo et al. 1993, FAO 2008). Changes in landings can be related to a decline in the resource as well as a decline in the wholesale value of the product, both which could render fisheries uneconomical. For instance, markets were flooded with low quality Midway deep-sea coral in 1981-1982, which caused a dramatic drop in the price (Grigg 2002). Japan and China (island of Taiwan) are reported to have abandoned fisheries in the central Pacific due to high costs of harvesting in deep water and increased landings of low quality coral. Presumably, fisheries were not abandoned due to a strong decline in abundance or biomass (Kosuge 2007). However, if abundant coral resources still remained off the Emperor Seamount Chain, landings should contain living, large, old-growth colonies rather than only low quality coral as reported by Kosuge (2007). Also, declines in the density and abundance of the coral would trigger increases in the amount of effort needed to harvest the same amount of coral, driving fisheries costs up. Even though taxa known only from the Emperor Seamounts still show up in FAO data (*Corallium* sp. nov.), commercial coral draggers have been seen fishing in these areas, and market prices are at unprecedented highs, production over the last two decades is less than 1% of the yield in the 1980s (FAO 2008) suggesting that the dramatic and permanent (15-20 year) decline in landings is the result of the collapse of populations located in international waters around the Emperor Seamounts. In fact, extensive deep water surveys were conducted by Japan in this area over the last several years, including areas that once supported large populations, and only isolated colonies were observed (Fisheries Agency of Japan 2008).

Most western Mediterranean populations of *Corallium rubrum* were also depleted within 4-5 years of their discovery, leading to termination or relocation of fishing effort as new beds were discovered. Mediterranean populations of *C. rubrum* off Calabria, Naples, Sardinia, Corsica, and parts of the French and Spanish seacoasts all had significant Coralliidae banks in the 1950s, but most have been over-exploited and are no longer commercially viable. *C. rubrum* has also been extirpated from at least one location, east of Graham Bank (Sicily Channel) (Liverino 1984). During the 1980s, at least 25 locations still supported the harvest of *C. rubrum*, while today the only known commercially viable beds are found along the African coast from Morocco to Tunisia, in the Bonifacio Strait off western Sardinia, Italy, and off Costa Brava and Mallorca, Spain (Tsounis et al. 2007).

Numerous exploratory dives and trawl surveys for precious corals undertaken throughout the Indian, Pacific, and Atlantic Oceans over the last three decades have revealed the presence of corals in the family Coralliidae, including identification of new species, although the material has generally been of low quality, low abundance, and low commercial value. The only instances involving discovery of large, valuable Coralliidae beds occurred from the 1960s to the 1980s in the far west Pacific, primarily around Emperor Seamounts and the Hawaiian Islands. Additional locations with Coralliidae have been identified in Hawaiian waters over the last decade using submersibles and ROVs, although only three of these are large enough to support commercial extraction, including one with an MSY estimated at only 35 kg per year (Grigg 2002). Furthermore, locations in the Emperor Seamounts that were once productive fishery grounds are now over-exploited and two species are close to commercial extinction (Fujioka 2004, 2008).

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[2] Grigg (2002) suggests that Makapu'u Bed increased in size by 20% and colony abundance was much greater in 2001 (0.3 colonies/m^2), compared to earlier surveys in the 1970s and 1980s. However, surveys were more extensive and covered areas that had not been previously examined.

5. Threats

General sources of Coralliidae mortality include smothering by sand, detachment and toppling caused by organisms that weaken the site of basal attachment, predation by gastropods (*Pseudosimnia* sp.), eucidarid sea urchins, and crustaceans (*Balssia* sp.), and encrustation by hexactinellid sponges, including at least 10 species of boring clionid sponges (Grigg 1993, Garrabou et al. 2001). These sponges can affect up to 50% of the colonies by associated detachment and bioerosion (Corriero et al. 1997). Secondary human impacts include pollution, sedimentation, tourism and recreational diving (Mediterranean), and incidental take or habitat degradation associated with longline fishing and bottom trawling (western Pacific). The benthic impacts of mobile fishing gear have been likened to clear-cutting techniques in old-growth forests (Watling and Norse 1998), with nets removing octocoral colonies from the rocks and boulders where they grow.

The primary, direct threat to species in the family Coralliidae is over-harvesting for the precious coral trade, an industry characterized by boom and bust cycles for over 5000 years in the Mediterranean and about 200 years in the Pacific. Fisheries impacts are further exacerbated by destructive collection practices, especially non-selective gear such as dredges and trawls, as well as SCUBA fishing when operated in a pulse fishing mode which removes all colonies above a minimum size from individual patches. Fishing impacts are worsened by natural stressors and climate change, especially in shallow water where mass mortality events have been documented. Ocean acidification and decreasing aragonite saturation levels are of growing concern for deeper populations, as colonies may begin producing weaker skeletons and may experience extended periods where no calcification occurs.

In the Mediterranean, intensive harvesting within the last 200 years has caused a severe depletion of most commercial *Corallium rubrum* stocks, resulting in a general consensus that shallow populations to 50 m depth are now over-exploited throughout the region (Garrabou et al. 2001, Santangelo et al. 1993, Santangelo and Abbiati 2001, Tsounis et al. in press, Red Coral Workshop: Naples, Italy 2009). Some of the earliest reports of resource depletions are from the 1880s following discovery of large beds between Sicily and Tunis; this led to an unprecedented rush of almost 2000 vessels, which rapidly depleted the grounds (Tescione 1973). Mediterranean landings data compiled by FAO also illustrate a precipitous (80%) decrease from 98 t in 1978 to 20.5 t in 1998 (Annex Fig. 3, FAO 2008). Some suggest this is due to a shift from non-selective dredging to SCUBA gear use, but: 1) the dredge was first banned in Sardinia in 1989 and the rest of the Mediterranean in 1994, while the largest drop in landings (nearly 60%) occurred between 1978 and 1984; 2) landings show rapid fluctuations within individual countries which do not reflect management changes; and 3) as SCUBA fishing was introduced in the 1950s, most shallow-water landings reflect SCUBA harvest and not the use of the dredge. Furthermore, there are historical reports of coral harvest by free divers which continued into the 1980s in some nearshore areas, but these locations now largely lack colonies that have reached the minimum size of legal harvest. While this partially reflects a decrease in total catch weight, it is also due to an absence of large colonies and a resulting increase in small colonies taken. Off Costa Brava, Spain, where legal minimum harvest size is 7 mm, the mean basal diameter in a professional harvest was 7.8 mm, an indication of nearly depleted stocks (Garcia-Rodríguez and Massò 1986), and in a fishery independent study mean basal diameter was only 4.8 mm (Tsounis et al 2006). Trends observed by Garcia-Rodríguez and Massò in 1986 are now occurring in Morocco, where the average height of colonies in two harvested stocks, Topo - Cala Iris and Sidi Hsein, was only 72.5 mm and 64 mm, respectively (Abdelmajid 2009, Zoubi 2009, Tsounis et al. in press).

It is also important to note that landings have increased over the last 10 years from a low of 20.5 t in 1998 to 40.5 t in 2006. These recent spikes in landings may be due to the exploitation of new areas off Morocco, Algeria, and Croatia, as well as deeper areas off Sardinia not historically targeted, while increases in other countries are thought to be due to the harvest of an increasing number of colonies of a smaller size (Tsounis et al. 2006a). FAO landings data are aggregated by weight and provide no indication of the size or age of individual colonies. However, both biological assessments and reports from fishermen provide evidence that colonies are substantially smaller than that reported historically (Bruckner 2009). The current practice in the Mediterranean of harvesting coral with a minimum basal diameter of 7 mm results in harvest of coral that is approximately 11 years old. Harvesting coral at 11 years of age prevents colonies from realizing their maximum potential reproductive output (Tsounis et al. 2007). In one site last harvested in 1977, the largest colonies had yet to reach commercially viable size 23 years later (Garrabou and Harmelin 2002).

Rapid over-exploitation of Coralliidae beds shortly after their discovery is also reported for most fishing grounds in the western Pacific. This occurred near Okinawa at the Miyako grounds in 1963 (Morita 1970), and again in 1965, when Japanese coral fishermen discovered a large pink coral bed at 400 m depth on the Milwaukee Banks in the Emperor Seamount Chain (Grigg 1993). Coralliidae harvest first peaked between 1965-1968 (300-370 t/yr), dropped precipitously in 1968 (103 t), climbed to 222 t in 1969, and then fell precipitously and remained low for the next years until a deep-water species was discovered at depths of 900-1500 m (Grigg 1993, Fisheries Agency of Japan 2008). During the peak years of this fishery in the 1980s, over 100 coral boats harvested up to 240 t annually from these seamounts. Yield reached another peak in 1981, dropped sharply in 1982 due to a collapse in market prices, then increased to its highest level ever from 1983-1985, and then dropped to unprecedented lows by 1989 when deep beds were exhausted, even though value was at an all time high (Western Pacific Regional Fishery Management Council 2001, 2003, Grigg 2002).

Non-selective harvest using dredges and trawls is banned in the U.S. and most of the Mediterranean, but it is used in international waters of the Pacific and around Japan, Okinawa, and Bonin Islands by fishermen from Japan and the island of Taiwan. The highly destructive St. Andrew’s cross was completely banned in the EU in 1994, but there are still numerous anecdotal observations of its use – in Corsica there have been complaints about Sardinian boats and it may be used illegally in Algeria and Greece (Harmelin 2007 for IUCN, Dounas et al. 2009). Furthermore, although most *Corallium rubrum* fishermen are now using SCUBA, they are exploiting increasingly smaller colony sizes and using highly destructive methods affecting the whole size range of populations (Santangelo et al. 2003), completely removing their bases and reducing the chance for re-growth.

New sources of disturbance to *Corallium rubrum* populations and increased severity of these perturbations have been observed since the late 1990s, including several mass-mortality events linked to elevated temperature anomalies and mechanical disturbance due to increased recreational diving (Mediterranean) and souvenir collection (Garrabou et al. 1998, 2001, 2003). Computer simulations show that mass die-offs, which have occurred during recent exceptionally warm summers, can eliminate shallow-water populations already stressed by over-harvesting (Santangelo et al. 2007). Healthy populations will probably recover from such setbacks, but over-exploited ones may not. Large, mature corals are the most fecund and best able to replenish areas following disturbances; furthermore, large colonies are more likely to experience only partial mortality and will survive large-scale disturbances such as thermal anomalies, while smaller colonies exhibit much higher rates of total colony mortality (Tsounis 2009). An event in 1999 caused extensive mortality to shallow-water populations (<30 m depth) along 50 km of coastline in the Provence region of France, with overall losses estimated in the millions of colonies. This unusual die-off was attributed to a fungal and protozoan disease and linked to temperature anomalies (Cerrano et al. 1999, Perez et al. 2000, Romano et al. 2000, Garrabou et al. 2001). A comparable mass-mortality event occurred in 1987 on deep reefs (>80 m depth) between Marseille and Nice (Rivoire 1991), and in shallow populations at La Ciotat in 1983 (Harmelin 1984). These threats may be pushing red coral populations, especially in shallow-water habitats, towards risk of local extinction in the near future, especially when combined with human impacts associated with legal and illegal fishing (Torrents et al. 2005, Santangelo et al. 2007, Tsounis et al. 2007).

6. Utilization and trade

Precious corals in the family Coralliidae include species highly valued for jewelry and art objects. The value of Coralliidae specimens depends on the species harvested (*C. rubrum, C. secundum, P. japonicum, C. elatius, C. konojoi* and *Corallium* sp. nov are most valuable and make up the bulk of landings; Cairns 2007), and the size, color, and condition when collected (from highest to lowest value: alive, dead but attached, dead but fallen, and “worm” eaten).

6.1 National utilization

Precious corals in the family Coralliidae are harvested in the western Mediterranean Sea and the western North Pacific Ocean, including areas off Japan and the island of Taiwan, Midway Island and Emperor Seamounts in international waters, and Hawaii. Pacific Coralliidae is harvested in two general depth zones, 200-500 m and 1000-1500 m. Most Mediterranean harvest of *C. rubrum* is from 30-120 m depth, with much of the shallow harvest (30-60 m) occurring in Spain, Morocco, France, and other countries, while deeper areas are now targeted off Sardinia and other locations as shallow populations no longer support commercial harvest. Commercial landings of precious coral (all species and locations) peaked in 1984 at 450 metric tons (t), declined to 40 t by 1990, and have fluctuated between 28 and 54 t over the last 15 years (Annex Table 3).

Mediterranean: For over 5000 years, *Corallium rubrum* supplies fluctuated depending on discovery of new beds, demand, and political and economic stability of the surrounding countries. Some of the earliest records of use are from the Roman times when ground Coralliidae powder was used as an antidote for poison (Wells 1981). Industrial-scale exploitation for red coral began during the early

1800s. By 1862, 347 boats were harvesting coral in this area. Within a few years, there were 1200 vessels and 24 Italian factories processing coral, employing about 17,000 fishermen and jewelers (Tescione 1973). Genoa and Naples (Italy) became the early centers of the coral fishery, with harvest occurring off the North African Coast. By 1870, most coral fishing in Italy had shifted to Torre del Greco, with smaller fisheries based out of Livorno, Genoa, and Corsica (Torntore 2002). Following discoveries of extensive coral banks off Sicily from 1875 to 1880, the number of boats increased once again, levels of harvest quadrupled, and the number of processing factories increased to over 80. Beginning in the 1830s off Italy, and continuing at least until 1989 off Sardinia and 1994 in the rest of EU waters, dredges and nets, particularly the Saint Andrew's cross, were most often used to land coral (Council of the European Union 1994). SCUBA (mixed-gas diving) collection was introduced in the 1950s. Most effort today in Spain's Costa Brava is directed at shallow depths (30-50 m) (Tsounis 2005), while SCUBA fishing in Italy has moved into deeper water (around 80-130 m). Bans on harvest in shallow water (>80 m depth) were recommended at a recent workshop held in Italy, because of recognition that shallow areas have been over-exploited; however, only Sardinia has legislation banning harvest in shallow water (Red Coral Workshop: Naples, Italy 2009).

Total landings of Mediterranean *C. rubrum* reported over a 30-year period (1976-2006) totalled 1250 metric tons (t) with 33.5% from Italy, 17.6% from Spain, 15.3% from Tunisia, and 9.9% from France. Landings from these four major source countries show a decreasing trend over 15 years (>85% decline from 97 t in 1976 to 12 t in 1992), with the largest declines reported from European countries, mainly Italy (70 t in 1978 vs. 8 t in 1986). Total annual landings for these four countries fluctuated between 12 and 18 t from 1992-2003, with progressive increases to 26 t by 2006. Annual landings from all African countries show irregular fluctuations from 5 to 30 t, with Tunisia reporting a total of 68 t over four years (1979-1982), and Morocco and Algeria reporting about 88 t from 1988-1992. Landings for six other countries have been <5 t/yr with the exception of a short-lived increase in landings off Greece (1987-1990) and Croatia (1992-1994). The Croatian fishery experienced a sharp fall in landings after 1994, and then increased sharply in 2005 and 2006. A limited amount was landed in waters off Yugoslavia and Turkey in the early 1990s, while small amounts of *C. rubrum* were reported in landings data for Montenegro for the first time in 2006 (FAO 2008).

Pacific: Commercially valuable colonies of *Corallium* and *Paracorallium* were first discovered in the Pacific off Japan in the early 1800s, but the fishery didn't flourish until after the Meiji Reform in 1868 (Kosuge 1993). Most Pacific landings over the next century were from beds at 100-400 m depth off Japan (Okinawa and the Bonin Islands) and China (island of Taiwan). At the peak of the industry, about 200 fishing vessels operated in this area, each making up to 7 trips per year (Grigg 1977). Following discovery of Coralliidae beds on banks north of Midway Island in 1965 and over the next 20 years, most of the world's harvest came from the Milwaukee Banks and surrounding seamounts in the Emperor Seamount Chain. Landings from the Milwaukee Banks reached about 150 metric tons in 1969, rapidly dropped off until discovery of a previously undescribed species (Midway deep-sea coral, *Corallium* sp. nov.) in deep water (900-1500 m) off Midway Island. This discovery led to another short-lived "coral rush" with peak production of about 300 t in 1981. Markets were flooded with coral by 1981-1982, prices fell, and >80% of the vessels dropped out of the fishery until demand increased once again and landings peaked at a historic high of 400 t in 1988 (Grigg 1993). By 1991, these beds were exhausted and landings dropped by over 90%, with only 3 t recorded Pacific-wide, even though wholesale value of coral had climbed to unprecedented levels (FAO 2008).

Landings of *Corallium* and *Paracorallium* from the Pacific reported by Japan and China (island of Taiwan) show five major peaks over a 45 year period (1962-2007). Reported landings from Japan were highest from 1965-1967 (1030 t total), 1969 (100 t) and 1975-1978 (280 t). Since 1976, landings by fishers from the island of Taiwan 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), and a peak in landings of *Corallium* sp. nov. from Midway Islands between 1983-1986 (564 t). Landings from the island of 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 the island of Taiwan and the Philippines. Annual yield from Japan in the 1960s consisted of *C. konojoi*, while 70-90% of landings from 1979 to 1984 (57-91 t/yr) consisted of Midway deep-sea 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). Less than 10 t have been harvested annually from the Pacific over the last 15 years (FAO 2008).

A much smaller fishery was initiated in U.S. waters off Hawaii in 1966, following the discovery of *C. secundum* off Makapu'u, Oahu. Using tangle-net dredges, approximately 2000 kg of Coralliidae was harvested from 1966 to 1969. In 1969, Hawaii's precious corals industry produced approximately US$2 million in retail sales, partially from domestic harvest and the remainder consisting of jewelry imported from the island of Taiwan and Japan (Grigg 1993, Simonds 2003). Manned submersibles were used to harvest the Makapu'u Bed from 1972 to 1978, but discontinued in 1978 due to high operating costs and a diving accident (Grigg 2002). In 1988, one domestic fishing vessel used a tangle-net dredge to harvest beds at Hancock Seamount. Its catch consisted mostly of dead or low-quality pink coral, and the operation was soon discontinued. For the next 20 years, Hawaii relied on imports of Coralliidae from Japan and the island of Taiwan. The U.S. fishery was revived in 1999-2000, by use of one-person submersibles with 700 m depth range. In 2000, 1216 kg *C. secundum* from the Makapu'u Bed and 61 kg of *C. regale* (*C. lauuense*) were collected from exploratory areas off Kailua, Kona (Grigg 2002). No harvest occurred from 2001 to 2009. Currently all known Coralliidae beds in international waters around Midway Islands and Emperor Seamounts have been depleted and are not supporting any large-scale commercial fisheries, although small amounts of this taxa (<1000kg/yr) are reported in FAO landings data and coral harvesting vessels were seen operating in this area as recently as 2007 (Grigg, pers. comm.). While fishing pressure is unlikely to have affected the geographical distribution of individual species, it has resulted in commercial extinction of individual beds and a loss of biodiversity due to limited connectivity and dispersal between these subpopulations (Baco and Shank 2005).

6.2 Legal trade

Coralliidae is traded as: 1) whole, dried colonies; 2) unworked branches and branch fragments; 3) beads and polished stones; 4) manufactured jewelry; and 5) powder, pills, granules, ointment and liquid. Small colonies traditionally were rejected by the high end fashion jewelry industry, which uses neither small sized corals nor reconstituted coral embedded in epoxy (FAO 1984). However, the demand for smaller corals and fragments, available at less cost, has risen due to their use in both the ethnic and tourism markets.

The trade in Coralliidae, primarily in the form of beads, dates to at least the Classical period, with major exports from Rome to India. By the 17th century, the major coral trade centers were Naples, Marseilles, and Livorno-Leghorn, with exports to India and West Africa. Exports of *C. rubrum* continued into the late 1800s, when Italy began importing large quantities of western Pacific Coralliidae from Japan and re-exporting processed coral beads to Asia and Africa (Torntore 2002). Currently, the Italian industry imports around 70% of its raw Coralliidae material from Pacific sources, particularly Japan and the island of Taiwan (Castiligliano and Liverino 2004, FAO 2007, Torntore 2009). The average annual value of coral exports from Torre del Greco amounted to nearly US$30 million in 1988 (Torntore 2002). Today, Torre del Greco and the Naples area have roughly 300 small- and medium-sized enterprises, with revenues of about 150 million Euros (US$214 million) per year (Carlson and Ascione, pers. comm.). Superior beads fetch prices of up to US$50 per gram and necklaces cost up to US$25,000.

Centers for processing Coralliidae expanded in the 1970s to India, China, Japan, and the United States. In 1982, the annual value of the pink coral industry on the island of Taiwan and in Japan was about US$50 million (Castiligliano and Liverino 2004). Japan imported 28 t in 1987 (US$8 million), up 77% by quantity and almost 200% by value over 1983 coral imports; coral imports declined to 18 t (US$4.4 million) in 1988. Historically, the island of Taiwan has been the major supplier of coral to Japan, accounting for about 56% of the value of Japan's 1988 coral imports. France, Italy, Spain, and Tunisia also export coral to Japan. The U.S. is the number one consumer of all precious corals; from 2001 to 2008, the U.S. imported unworked skeletons and processed Coralliidae products from 55 countries, mostly from China, the island of Taiwan, and Italy (Annex Fig. 4). In 2002, there was a spike in the export of *Corallium* spp. from Italy into the U.S. about five times higher than both the 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 the island of Taiwan sent 84% of 1,807,357 pieces of coral imported into the U.S. in 2006. Imports of Coralliidae products included over 26 million worked pieces and 51,456 kg of manufactured items, and 428,644 skeletons and 6742 kg of raw (unworked) Coralliidae consisting mainly of *C. elatius, P. japonicum*, *C. rubrum,* and *C. secundum*.

6.4 Illegal trade

Foreign poaching in U.S. waters has been a problem in the past. Some estimates suggest that nearly half of the global production during the 1970s and 1980s was poached from Hawaiian territorial waters. During the 1980s, coral vessels from Japan and the island of Taiwan continuously violated the U.S. EEZ near the Hancock Seamounts. In 1985, about 20 coral draggers from the island of Taiwan poached approximately 100 t of Coralliidae from seamounts within the U.S. EEZ north of Gardner Pinnacles and Laysan Island (Grigg 1993). Poaching in the Medas Reserve and illegal harvest of undersized corals by licensed fishermen is being reported with increasing frequency off Costa Brava, Spain (Zabala et al. 2003, Tsounis et al. 2007). A lack of large *C. rubrum* colonies has made coral of any size saleable, demonstrated by a recent rise in the market value of small branches, below the minimum legal basal diameter of 7 mm, to as much as US$180 per pound (in contrast, large diameter, high quality coral goes for nearly US$700 per pound; Tsounis 2009). Ideally fishers would cut the red coral base, but studies have shown that up to 60-70% of poachers' confiscated catches consisted of the entire colony with the base and pieces of the underlying substrate still attached (Hereu et al. 2002, Linares et al. 2003).

6.5 Actual or potential trade impacts

Recent exploitation pressures, resulting mainly from demand for the species through international trade, have caused extensive and range-wide population depletions.

7. Legal instruments

7.1 National

The European Union: Corallium rubrum is listed in Annex V of the European Union Habitats Directive (species of Community interest whose taking and exploitation in the wild may be subject to management measures). *C. rubrum* is listed in Annex III of the Bern Convention, and Annex III of the Protocol concerning Special Protected Areas and Biological Diversity in the Mediterranean (under the Barcelona Convention). The Spanish Government has established reserves for the protection of *C. rubrum* in the Mediterranean Sea (Hunnan 1980). In 1994, the European Union banned the use of the *ingegno*, or St. Andrew's cross, for the Mediterranean harvest of Coralliidae (Cicogna and Cattaneo-Vietti 1993, Council Regulation No 1626/94, Council of the European Union 1994). In 2006, the Spanish Ministry of Agriculture, Fisheries and Food published a new *Ministerial Order for the Integral Fisheries Management of the Mediterranean*, which bans the use of bottom trawling, purse seining and drag netting to 50 m depth.

The United States: The Western Pacific Fishery Management Council's (WPFMC) Precious Corals Fisheries Management Plan (FMP) has regulated the harvest of Coralliidae since 1983. The FMP imposes permit requirements valid for specific locations, harvest quotas for precious coral beds, a minimum size limit for pink coral, gear restrictions, area restrictions, and fishing seasons. Areas open to commercial coral harvesting include the Main Hawaiian Islands, American Samoa, Guam, Rota, Tinian, and Saipan. The Northwest Hawaiian Islands (NWHI) National Monument prohibits taking of all precious coral within the Reserve. The State of Hawaii prohibits the take or sale of pink coral without a permit and has established a minimum size (254 mm). California prohibits the commercial harvest of Coralliidae, and Guam prohibits the commercial harvest of all coral species without a permit.

China: Harvest regulations for the island of Taiwan were renewed in January 2009. Vessels harvesting Coralliidae are regulated by licensing and harvest zone and maximum harvest days per year are established. VMS (Vessel Monitoring System) data, daily logbooks, designated landing ports, centralized auction markets, and observer programs are used to monitor the fishery and to enforce the regulation. Fifty-six vessels are licensed to harvest *Corallium* and *Paracorallium* legally and harvest and export quantities are limited to 200 and 120 kilograms, respectively, per vessel per year. Confiscation of fishing gear and suspension of the *Corallium* and *Paracorallium* harvest license can be imposed for violations.

Japan: Corallium and *Paracorallium* harvest in Japan is regulated 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. Both fishermen and vessels are licensed and legal harvest zones are designated. No specific harvest season or quotas exist.

7.2 International

In 2008, China listed four species of Coralliidae on Appendix-III of CITES *(P. japonicum, C. elatius, C. konojoi, C. secundum).* There are no other international trade controls or management measures.

8. Species management

8.1 Management measures

Few management measures for Coralliidae fisheries have been implemented or enforced in the Pacific, particularly in international waters, with fishing patterns characterized by exploration, discovery, exploitation, and depletion (Grigg 1976). The types of management approaches proposed or implemented for species in the family Coralliidae include area closures, rotational harvests, fishery seasons, minimum size, and bans on the use of non-selective dredges, although the specific measures and their effectiveness vary by location. Management has been hampered by enforcement and jurisdiction problems, the multinational character of the fishery, presence of precious coral beds in waters not under the jurisdiction of any State, and a lack of knowledge of population status and biology of Coralliidae.

Area closures and rotational harvests are effective tools for conservation of reef fishes with pelagic dispersal of larvae. However, for sessile, slow-growing organisms like *C. rubrum*, area closures are less effective unless they are permanent, as these species are likely to require up to 100 years or more for full population recovery (Francour et al. 2001). There are currently four marine protected areas (MPAs) in the northwestern Mediterranean that protect red coral (France: 3, Spain: 1) (Francour et al. 2001). After 14 years of closure in the Medas Islands MPA off Spain, populations have not rebounded to their natural state, as colonies over 200 mm height are still absent. In addition to the need for permanent closures, no-take MPAs must be large in size and established as networks surrounding fished areas. Their placement must be based on the potential connectivity between fished and unfished sites to ensure dispersal of larvae, given the high degree of genetic variability between relatively close sites and typical larvae settlement patterns (short-distance dispersal and settlement near parent colonies). At this time, there is no evidence that the number, size, and placement of existing MPAs is adequate to protect or sustain populations of *C. rubrum.*

Another harvest measure widely used in the Mediterranean is a minimum basal diameter of 7 mm. It is 10 mm in Sardinia, but a 20% variance is allowed. Recent fisheries landings data showed >50% of the colonies were under 10 mm basal diameter (Chessa and Scardi 2009). Since fertility and number of larvae is known to increase with colony size (height and number of branches), the current harvest size for *C. rubrum* colonies is inadequate to protect reproductive stocks. These small colonies can reproduce only 2-3 times at most before harvest, and their small size and relatively limited branching pattern limits their reproductive potential. In several FAO consultations undertaken since 1988, scientists have suggested that, due to the very slow growth rates and longevity of colonies, an increase in the legal minimum size is needed to ensure sustainable harvest. This need is further demonstrated by new age and growth studies. Earlier studies reported reproduction in colonies that were 2-4 years old (Santangelo et al. 2003), but it is now suggested these colonies may be at least 7-10 years old (Torrents et al. 2005) before they reproduce. In a population in Spain, Tsounis et al. (2007) estimated MSY of 98 years; whereas the current practice of harvesting colonies once they achieve a 7 mm basal diameter (11 years old) results in only 6% of the potential yield. Most recently, Rossi and Gili (2007) suggested that minimum size would need to be increased to at least 8.6 mm diameter and 100 mm height so that colonies can develop third-order branching patterns to ensure a reproductive output that might compensate for fishing pressure.

In U.S. waters, MSY was established based on presumed rates of growth and abundance of corals within surveyed areas, with a minimum allowable size (height) of harvest. In the one bed easiest to access and the site of study, the Makapu’u Bed off Hawaii, low levels of selective harvest from 1972 to 1978 caused a decrease in the proportion of large colonies that was still apparent 20 years later, even though no additional harvest occurred during this period (Grigg 2002). U.S. MSY is based on a minimum harvest size of 254 mm height, but with recent radiocarbon dating indicating that colonies grow 2-3 times slower than previously assumed, colonies that are 280 mm tall may actually be 67-71 years old, or approximately 3 times that reported by Grigg (2002, Roark et al. 2006).

8.2 Population monitoring

There are no comprehensive monitoring programs for Coralliidae.

8.3 Control measures

8.3.1 International

In 2008, China included four species of Coralliidae in Appendix-III of CITES *(P. japonicum, C. elatius, C. konojoi, C. secundum).* This is the only international instrument for the conservation of Coralliidae; it is not listed on any other international wildlife or fisheries agreements and has no international legal status. In 2004, the member States of the United Nations agreed to take urgent action for the protection of vulnerable marine ecosystems (VMES), such as coldwater corals. The non-binding U.N. General Assembly resolution measures prohibit destructive fishing practices, including bottom trawling, that have adverse impacts on VMES. Such measures are important given that Coralliidae is not managed by any existing regional fisheries management organizations.

8.3.2 Domestic

See Consultations below.

8.4 Captive breeding and artificial propagation

Currently there are no comprehensive captive-breeding programs for Coralliidae. A method for coral propagation on artificial substrates has been developed at the University of Pisa, Italy and a small project to rear *C. rubrum* on artificial substrates and transplant into the wild has shown relatively high survival (Cattaneo-Vietti et al. 1992, Bramanti et al. 2005, Santangelo et al. 2007), but to date restoration efforts remain in infancy and have not been widely applied (Tsounis et al. in press).

8.5 Habitat conservation

A number of refugia are closed to harvest in the Mediterranean and U.S. Pacific. However, these are not interconnected in a way that ensures gene-flow among colonies, and in the Mediterranean these protected areas are mostly small in size and too few in numbers.

9. Information on similar species

Bamboo and sponge corals have appeared on international markets as jewelry, often being died pink or red and sold as Coralliidae. Unworked Coralliidae have distinct growth patterns that are apparent under microscopic examination. Bamboo coral’s nodes with black gorgonin substance and sponge coral’s porous structure and distinctive two-color reticulated pattern exclude their identification as Coralliidae (Torntore 2009). Features sufficient for reliable identification at the species level within the Coralliidae family do not exist for skeletons or as manufactured jewelry and curios, which is the bulk of the trade. Taxonomic identification of octocorals requires microscopic analysis of shape, size and color of sclerites (tiny calcified skeletal elements) embedded in the coenochyme and in the organic matrix of the axial skeleton; these are lost when processed for jewelry. Therefore, it may only be possible to identify worked specimens to the family level (Coralliidae), particularly where worked specimens contain multiple species. As the family was recently divided into two genera, and future taxonomic revision may create more, it is difficult to readily identify worked specimens to genus level. As such, it is justified to use higher taxon names on permits for worked specimens (Res. Conf. 12.3 Part XIV.e.i). Where raw or dead corals are concerned, these can usually be identified to species level. Reconstituted coral pieces can be identified through either chemical analysis or using a microscope to examine growth rings (Smith et al. 2007). For coral powder that might be in trade, species may not be readily recognizable unless labelled as such, in which case it would fall under the provisions of Res. Conf. 9.6 (Rev.).

10. Consultations

Canada: Species have not yet been found in Canadian waters, but it is possible that populations may exist on seamounts or steep slopes in Pacific or Atlantic. There is no known harvest of *Corallium* or *Paracorallium* in Canada, and future viable commercial harvest is unlikely.

Cape Verde: According to the documents/information available on the corals existing in Cape Verde waters, there is no information available about the existence of the family Coralliidae (genus *Corallium* and *Paracorallium*) in Cape Verde.

Republic of Croatia: Corallium rubrum is protected by Nature Protection Act (NPA) (Official Gazette 70/05, 134/08) and Ordinance on the proclamation of protected and strictly protected wild taxa (Official Gazette 99/09) and is listed as a critically endangered species on the Red list of corals of Croatia. The Ministry of Agriculture, Fisheries and Rural Development regulates *C. rubrum* fisheries, including: seasonal closure; maximum of 200kg gathered per year per license *(Regulation on commercial fishing on the sea (Official Gazette 6/06, 46/06, 66/07, 121/08,146/08))*; gathering can be done by hand with or without diving gear and other tools which include only ones powered by human strength; maximum 2 axes for coral detachment (*Regulation on fishing gear* (2006)); species, fishing tools, and fishing zones open to license holder have to be indicated in the license *(Regulation on licenses for commercial fishing on the sea and license register (OG 155/05, 135/06, 133/07))*. No new licenses issued for commercial fishing (including coral extraction) until scientifically based indicators of their status are available *(Regulation on commercial fishing on the sea (Official Gazette 6/06, 46/06, 66/07, 121/08, 146/08)).* Preliminary research in Croatian waters reveals how this renewable resource is being non-sustainably exploited. The review of all available data suggests that the shallow water stocks in Croatian waters are mostly depleted. Furthermore, recent trends in poaching of juvenile colonies and mass mortality events because of thermal anomalies or pollution threaten the survival of the shallow water populations. The impact of fishing on the populations can only be estimated with a thorough understanding of fishing methods, that is, not only the yield per dive and diver, but also at what depth, during what season, and other data accessible only through gray literature and interviews with fishermen.

Gibraltar: Red coral is fully protected in Gibraltar under the Nature Protection Act 1991Annex V and Schedule 1. All trade in the species is forbidden under the Endangered Species Act 1990. The species is now considered very rare in Gibraltar waters, having disappeared from the shallower waters near the territory. Trade is likewise rare.

Italy: Information on population status and management were not provided through the range state consultation process.

Mexico: Data on *Corallium* and *Paracorallium* species are very scarce. There are no records of these genera in Mexico, and apparently only *C. ducale* (not internationally traded) is found in the Mexican Eastern Pacific Ocean, although very few data are available. These genera are not included in the Endangered Species Regulation (NOM-059-SEMARNAT-2001). No permits have been issued to harvest and there is no information on illegal activities concerning these species.

Monaco: Corallium rubrum habitat is protected and no exploitation is allowed.

Montenegro: Corallium rubrum is protected under the Decree on putting the protection of certain plant and animal species (“Fig. CG Gazette" no. 76/06) issued by the Institute for Nature Protection 12.12 2006. Recent requests for collection permits have been rejected because of the protected status of coral and vulnerability of the population.

Morocco: Since its discovery, red coral has been subject to intense exploitation of which the harmful effects have become apparent. A survey of abundance in 2003 showed that one area of Xauen and Tofino had no traces of red coral. Another zone in this region is predominantly rocky substrate and is a zone of red coral concentration. The most productive yield was between 80 and 90 m depth where red coral has an intermediate size of 113.6 mm and aggregate distribution. As red coral is a limited resource of great longevity and very slow growth, this resource requires rational and adequate exploitation that is commensurate with the production capacity of the ecosystem. In 2005, the Department of Fisheries promulgated a decree 2-04-26 of the 6 hija 1425 (January 17, 2005) setting conditions and procedures for harvesting coral. A fisheries decree 2.655-06 of the 21 choual 1427 (November 13, 2006) regulates red coral by quota.

New Zealand: Several undescribed species occur in NZ's EEZ but there is little reliable data on conservation status. *Corallium* is now listed as a vulnerable marine taxon (VME) in the SPRFMO areas. All species of red coral are, under Schedule 7a of the Wildlife Act 1953, "marine species declared to be animals," and are therefore absolutely protected throughout New Zealand and New Zealand fisheries waters. There are no trade data. Bycatch of *Corallium* occurs in trawl fisheries operating on seamounts. Records of benthic bycatch (including *Corallium* taxa) are retained; observers are required to return sub-samples of corals. Observers are provided with detailed identification handbooks to improve at-sea identification. Fishers are also required to report the landing of all corals.

Republic of Slovenia: Species in the family Coralliidae do not exist in Slovenian waters, and are therefore not protected under Slovenian law.

Thailand: Species are protected under the Wild Animal Protection and Reservation Act; however, species have not been reported in Thai waters; species are not traded.

Turkey: Harvest of corals is prohibited by law within Turkish waters through legislation/regulation governing fisheries. There is a lack of scientific information on the current status of the corals.

11. Additional remarks

11.1 Implementation Issues

Introduction from the sea (Article IV, paragraphs 6 and 7) is not expected to be a significant issue for Coralliidae in the Mediterranean Sea or the Atlantic Ocean. It is unclear to what extent it may be an issue in the Pacific.

Identification of products in trade. In recognition of the fact that identifying finished Coralliidae products to the level of species is difficult, we have proposed, in CoP15 Doc.XX, that the Parties agree to amend Resolution Conf. 12.3 (Rev. CoP14) to allow worked specimens of Coralliidae to be identified on CITES permits and certificates at the genus or family level. In addition, an identification guide for precious corals, with a focus on products in trade, is in preparation and will be available by the effective date of the listing, should the proposal be adopted. A table indicating the geographic distribution (by country) of species in the family Coralliidae is also in preparation and will be available at CoP15. It will be important, during the 18-month delayed implementation period, to develop reference collections, identify experts that can be available for consultation, and provide training to assist border officers in identifying specimens in trade.

Pre-Convention specimens. A number of entities involved in the red coral industry maintain stockpiles of raw and semi-finished Coralliidae specimens. During the 18-month delayed implementation period, Management Authorities in the countries where these entities are located will need to work with the industry to develop a process for preparing inventories or otherwise accounting for the pre-Convention material. This has been an issue for other CITES-listed species and Management Authorities should be able to draw on past experiences in establishing the necessary procedures.

Personal and household effects. We have recommended, in CoP15 Doc.XX, that the Parties agree to amend Resolution Conf. 13.7 (Rev. CoP14) to include an exemption from CITES permit requirements for personal and household effects of up to seven finished Coralliidae specimens where the total weight does not exceed 2 kilograms.

Non-detriment findings. To assist Parties that may need to conduct non-detriment findings for these species we draw your attention to the proceedings of the November 2008 Expert Workshop on Non-Detriment Findings held in Cancun, Mexico (see AC24 Doc. 9) including the report of the working group on aquatic invertebrates and the case studies for black corals (Antipatharia) and stony corals (Scleractinia). Where management and enforcement measures need to be implemented or improved, Parties should utilize the 18-month delay period to institute such changes. Recommendations for improved management measures can also be found in the Proceedings of the First International Workshop on Corallium Science, Management, and Trade (Bruckner and Roberts, eds. 2009) and in the proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean (in press).

11.2 Reduction of the Wild Population

Abundance and biomass are usually important factors in assessing population status and trends of fishery species. However, for sessile colonial species, size and relationships with density are more important measures, as size is a major determinant of first reproduction, reproductive output, and colony survival, and density is related to the likelihood of fertilization. As colonies get larger, they develop more complex branching patterns which result in an exponential increase in individual polyps. Abundance data cannot be directly compared among populations or within individual beds over time, due to their patchy occurrence within these beds, differences in the available habitat within an area occupied by this coral, and highly variable features such as crevices and outcrops that are not uniformly distributed throughout the habitat. Also, numbers of colonies per unit area are unlikely to provide an indication of the population status or trends due to their life history traits, which include: 1) a sessile (attached) existence; 2) high rates of recruitment within localized areas that result in dense populations of small, unbranched colonies that exhibit high rates of early mortality; and 3) the formation of large, highly branched, three-dimensional colonies that are long-lived and will reproduce annually for the duration of their lifespan, in the absence of physical disturbance (collection).

In the case of *C. rubrum*, smaller colonies tend to occur in large aggregates because they settle relatively close to their parent; these smaller-sized colonies lack a branching morphology and exhibit higher rates of natural mortality. As they increase in size, they require more space, but survival also increases with size. If they are able to reach a large size, populations will ultimately become less dense, with a lower overall abundance throughout a bed but potentially a higher number of polyps overall. For instance, a single large colony 300-500 mm in height can contain more polyps than 100 or more small colonies that are 30-50 mm height, like those found today in the Mediterranean. The increase in polyps is partially related to size (larger colonies have more polyps overall, but they lack polyps at the basal portions and polyps may be more dense but smaller at the branch tips), but most importantly increases with degree of branching, which is much more extensive in large colonies. For these reasons, size/age structures give a better indication of population decline, as the fishery is size-selective (largest colonies are removed first) and a decline in the number of large colonies may result in an increase in small colonies as more space becomes available to support settlement of larvae. Data on the population structure are also more useful in identifying a changing proportion of mature/immature colonies, which is more functional as a basis for management decisions that need to ensure minimum recruitment, especially for sessile animals that require a certain density to ensure fertilization success (Bruckner 2009, Tsounis et al. in press).

Density can be an important measure but it must be combined with size data. These species exhibit density-dependent reproduction, and since they normally occur at low densities may become reproductively isolated if their density is further reduced. All known Pacific species and deep water populations of *C. rubrum* occur naturally at a relatively low density (typically <1 colony/m^2), and any further reduction in density will double or triple the distance between colonies, which could result in an Allee effect. While low density is less of a problem for *Corallium* species that broadcast their gametes (because all colonies synchronously release a pool of gametes into the water), *C. rubrum* requires internal fertilization which will not occur if a male colony is separated from a female colony by too great a distance.

While landings data alone do not provide information on effort, documentation of rapid increases in the numbers of vessels shortly after a discovery of a new Coralliidae bed correspond to increases in reported catch data. With each new discovery, catch began to decline after several years of intensive fishing until the fishery was no longer economically viable and particular beds were abandoned, perpetuating a boom and bust cycle. Since the late 1980s, no new beds have been discovered and reported catch has remained at low levels, especially from the Pacific. In the case of precious corals, arguing that one cannot deduce biomass decline from a yield decline is unfounded. There were isolated instances where the market was flooded with low quality coral, and prices did drop driving the fishery to uneconomic levels. However, prices rapidly rebounded, and landings increased at least for a short period, before collapsing due to depletion of Coralliidae stocks. As in most cases, prices increase parallel to the decreasing yield, with no laws limiting the fishery effort in international waters. The only three exceptions have been a peak in 1968 of *C. konojoi* from mid-depth beds in Emperor Seamounts, the first Midway peak in 1981-1982, and the discovery of dead coral beds at Sciacca banks. Therefore, in most cases it is safe to say that rapid increases followed by precipitous declines reported by a particular country signal a depletion of the resource (Bruckner 2009, Tsounis et al. in press).

While total catch is at least partially related to harvest effort, catch reported by weight provides no indication of quality and age of corals. It is possible to achieve the same yield by taking a larger number of small colonies, already seen in the Mediterranean. Although catch data (total weight) from the Mediterranean has increased slightly over the last 5 years, there are reports of increased take of smaller colonies, emphasizing the growing pressure on the resource to support international trade (Tsounis et al. 2007).

11.3 International Workshops on Coralliidae Science, Management, and Trade

In response to issues raised at CoP14 in relation to the Appendix-II listing proposal, the United States provided partial funding for and participated in two workshops on the science and management of, and trade in species in the family Coralliidae. The first was held March 16-20, 2009, in Hong Kong, and the second was convened September 23-26, 2009 in Naples, Italy. International experts from governments, academia, NGOs, FAO, industry, and the CITES Secretariat shared information on biological, fisheries, and trade data.

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Table 1. Species in the family Coralliidae. Species with * have been recently reassigned to a new genus, Paracorallium (Bayer and Cairns 2003). Species of commercial value are in bold (Torntore 2002). [3] refers to two un-described species from Midway Island in deep water: garnet coral occurs at depths of 700-900 m and deep sea coral occurs at depths of 800-1500 m. Additional species include *C. boshuense*, *C. niveum*, *C. porcellanum, C. pusillum, C. vanderbilti, and C. variabile,* as well as at least seven unconfirmed named species.

SPECIES	DISTRIBUTION	Depth (m)	CITATION
C. abyssale	Hawaii		Bayer 1956
C. borneense	Borneo		Bayer 1950
C. ducale	Eastern Pacific Mexico		Bayer 1955
C. elatius	W. Pacific; northern Philippines to Japan and the island of Taiwan; Mauritius; Palau	150-330	Ridley 1882
C. halmaheirense	Indonesia		Hickson 1907
C. imperiale	Eastern Pacific; Baja California	600	Bayer 1955
*P. inutile**	Japan, Tonga[2]	100-150;300-350[2]	Kishinouye 1903
P. japonicum*	W. Pacific around Japan, Okinawa and Bonin Islands; Vanuatu[2]	80-300; 250-450[2]	Kishinouye 1903
C. johnsoni	Northeast Atlantic		Gray 1860
C. kishinouyei	E. Pacific		Bayer 1996
C. konojoi	W. Pacific from Japan to northern Philippines; Palau; Chinese islands of Hainan, Solomon Islands[2]	50-200; 262-382[2]	Kishinouye 1903
C. lauuense (C. regale)	Hawaii	390-500	Bayer 1956
C. maderense	Eastern Atlantic		Johnson 1898
C. medea	Western Atlantic: Cape Hatteras to Straits of Florida; oceanic seamounts off Brazil	380-500	Bayer 1964, Castro et al. 2003
C. niobe	Western Atlantic		Bayer 1964
*P. nix**	New Caledonia	240	Bayer 1996
C. reginae	Indonesia		Hickson 1905
C. rubrum	Mediterranean and E. Atlantic: Greece, Tunisia, Corsica, Sardinia, Sicily, Portugal, Morocco, Canary and Cape Verde Islands.	5-300	Linnaeus 1758, Weinberg 1978
*P. salomonense**	Chagos Archipelago, Indian Ocean	217-272	Bayer 1993
C. secundum	W. Pacific waters around Hawaii, Japan and the island of Taiwan; Chinese islands of Hainan, in 'straights' of Hong Kong	350-500 (few colonies at 230 m)	Dana 1846
*P. stylasteroides**	Mauritius; western Samoa[2]	136; 350-360[2]	Ridley 1882
C. sulcatum	Japan		Kishinouye 1903
*P. thrinax**	New Caledonia	240	Bayer 1996
*P. tortuosum**	Pailolo channel, Hawaii, Tonga[2],	153-173; 325[2]	Bayer 1956
C. tricolor	Eastern Atlantic		Johnson 1898
***C. sp. nov*.** [3]	Midway Island to Emperor Seamounts	700-1500	Grigg 1982

Detail: In the Western Pacific, the family Coralliidae is distributed from Japan to the northern Philippines (19ºN-36º N) and from the Hawaiian islands (20º N) to Milwaukee Banks (36ºN; approximately 3800 km) (Grigg 1974) at two depth zones: 90-575 m and 1000-1500 m (Grigg 1974, Baco and Shank 2005). This includes 1) *C. secundum* and *C. regale*, which are found off the Hawaiian archipelago from Hawaii (20°N) to the Milwaukee Banks (36°N) at 350-475 m depth; 2) *Corallium*. *sp. nov*., found from Midway Island to Emperor Seamounts, 28^o-36^oN at 1000-1500 m depth; 3) *P. japonicum*, found in Japan off Okinawa and Bonin Islands, on banks between Okinawa and the island of Taiwan, off Pescadores Islands near the island of Taiwan, and in the South China Sea, 26^o-36^oN from 100-300 m depth; 4) *C. konojoi* from the Northern Philippines to Japan 19^o-36^oN latitude, at 50-150 m depth, and 5) *C. elatius* from the Northern Philippines to Japan,19^o-36^oN latitude, at 100-330 m (Grigg 2002). Isolated colonies of Coralliidae also occur off Australia, the Solomon Islands, Vanuatu, Fiji, Kiribati, Tonga, Samoa, and the Cook Islands at 200-500 m depth (Harper 1988), in international waters on the New England Seamount Chain (Atlantic Ocean), and in U.S. waters off Florida (in *Lophelia* beds in the Florida Straits), California (Davidson Seamount), Alaska (Gulf of Alaska Seamounts), Guam (Grigg 1974, Tiffin 1990, DeVogelaere et al. 2005, Etnoyer and Morgan 2005), and three locations in American Samoa (Carleton 1987).

Fig. 1. Locations of 16 precious coral beds in the Hawaiian Archipelago known to contain populations of *Corallium lauuense* and *Corallium secundum*. The size of the bed and the relative abundance of *Corallium* is indicated by the size of the pie diagram. Source: Hawaii Undersea Research Laboratory.

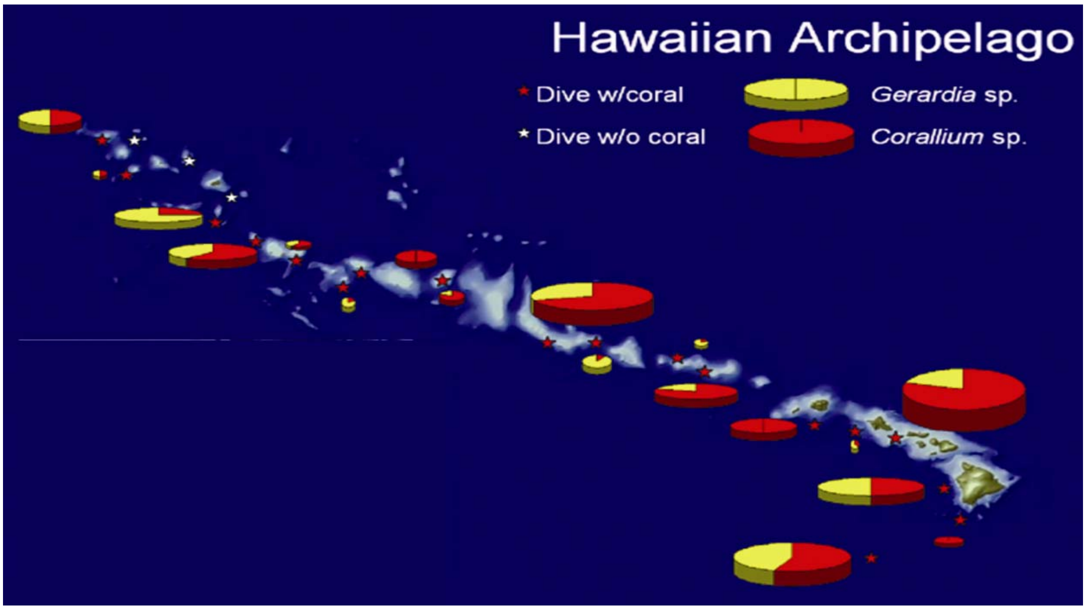

Table 2. Total harvest (kg) of *Corallium* from the Emperor Seamounts in the western Pacific. Japan's harvest for 'Western Pacific' and 'Midway grounds' was through use of dredges, whereas harvest in 'All areas' was by submersible. [1]Harvest data for Japan for both submersibles and dredges are combined in 1990 and 1991. Source: Grigg (1993).

	Japan			island of Taiwan
Year	Western Pacific	Midway grounds	All areas	All areas
1979	14,516	76,988	0	123,000
1980	10,227	74,228	0	154,000
1981	5,381	30,484	775	254,000
1982	3,000	52,166	551	69,200
1983	2,947	51,087	306	109,000
1984	3,315	33,164	634	157,000
1985	2,366	9,322	816	214,000
1986	1,268	1,650	1,261	141,000
1987	1,986	585	425	106,000
1988	1,605	217	1,082	50,000
1989	1,057	1,961	938	5,400
1990			2172[1]	1,000
1991			1390[1]	1,000

Table 3. Annual harvest of *C. secundum* from Makapu'u Bed, Hawaii, United States. Data for 1999-2000 include 61 kg of *C. lauuense* harvested from exploratory areas off Kailua, Kona. Source: Grigg (1993).

Year	Gear	Harvest (Kg)
1966-69	Dredge	1,800
1970-72	No harvest	0
1973	Submersible	538
1974	Submersible	2,209
1975	Submersible	1,385
1976	Submersible	400
1977	Submersible	1,421
1978	Submersible	474
1979-1998	No harvest	0
1999-2000	Submersible	1,216
2001-2009	No harvest	0

Fig. 2. A. Landings of *Corallium* and *Paracorallium* reported for the Pacific and Mediterranean from 1965 to 2007. The two largest peaks (1960s and 1980s) reflect massive landings of two taxa from international waters, both of which are now rarely landed due to their scarcity. Sources: FAO (2008), with additional information from Fujioka (2008) for Japanese landings in the Emperor Seamounts from 1965 to 1976.

A.

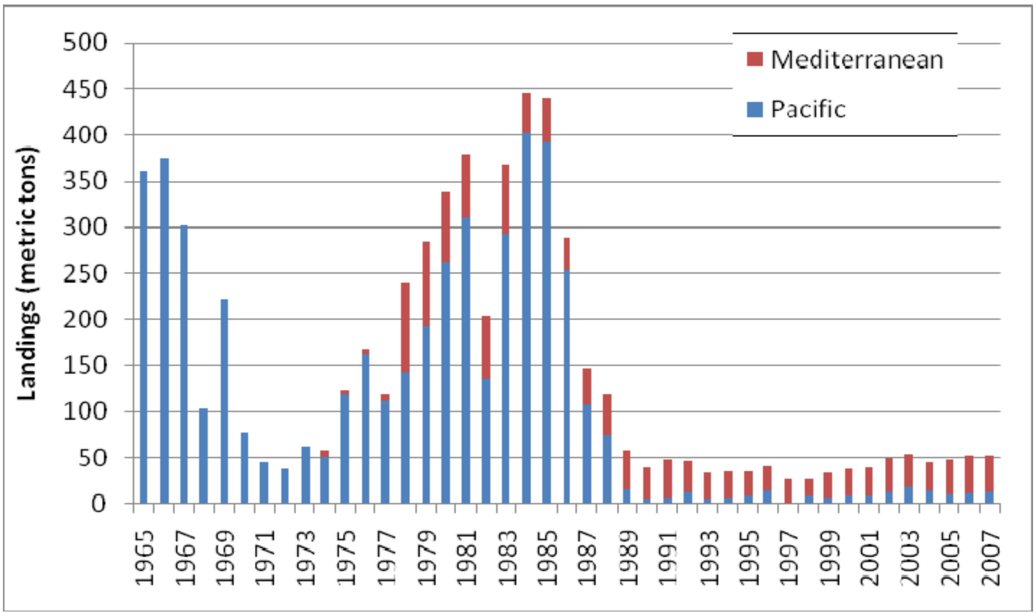

Fig. 2. B. Reported landings for five major Pacific species (*C. japonicum, C. konojoi, C. elatius, C.* sp. nov.) and one Mediterranean species (*C. rubrum*) from 1968 to 2007. Sources: FAO (2008); Data for *C. konojoi* from 1965 to 1976 are from Fujioka (2008).

B.

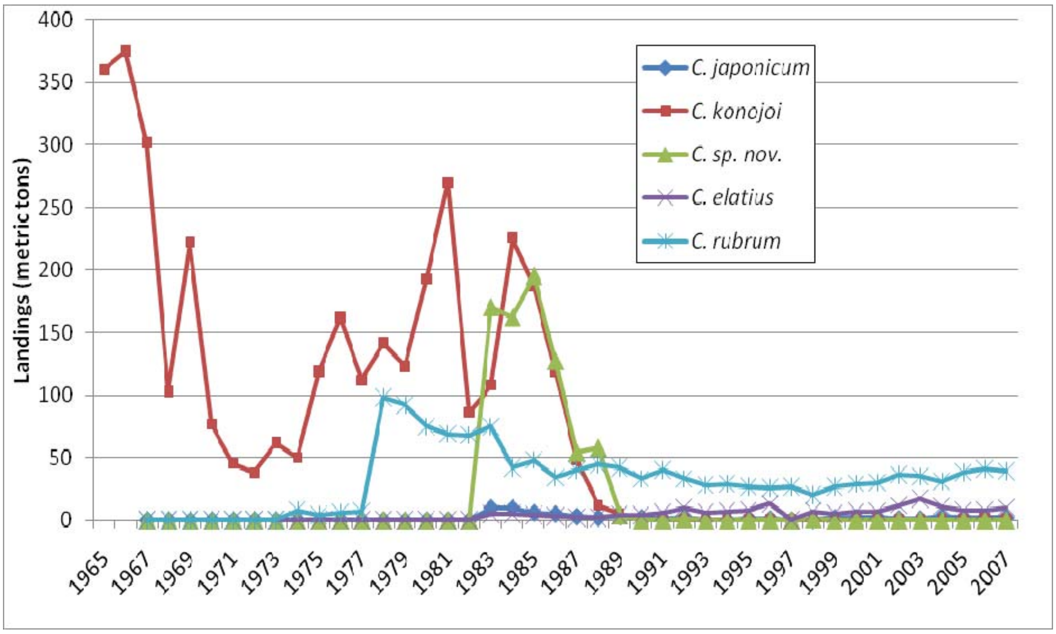

Fig. 2.C. Reported landings from 1989 to 2007 for the four Pacific taxa listed in B. Source: FAO (2008).

C.

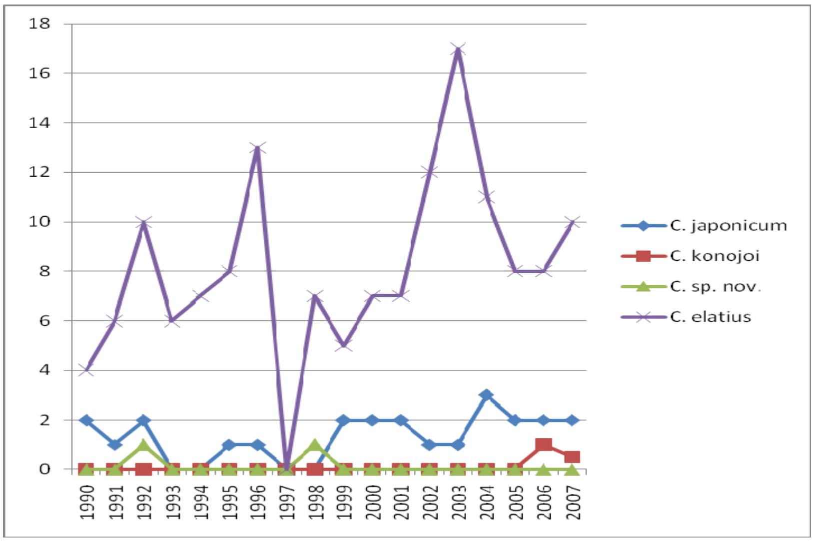

Fig. 3. Landings of *Corallium rubrum*. **A.** Landings reported by European countries (black squares) and African countries (diamonds) from 1978 to 2007. **B.** Landings for the four largest sources of *C. rubrum* including Italy (diamonds), Spain (squares), France (triangles), and Tunisia (cross hatch). **C.** Landings for Morocco (diamonds), Algeria (squares), Greece (triangles), and Croatia (cross hatch). Source: FAO (2008).

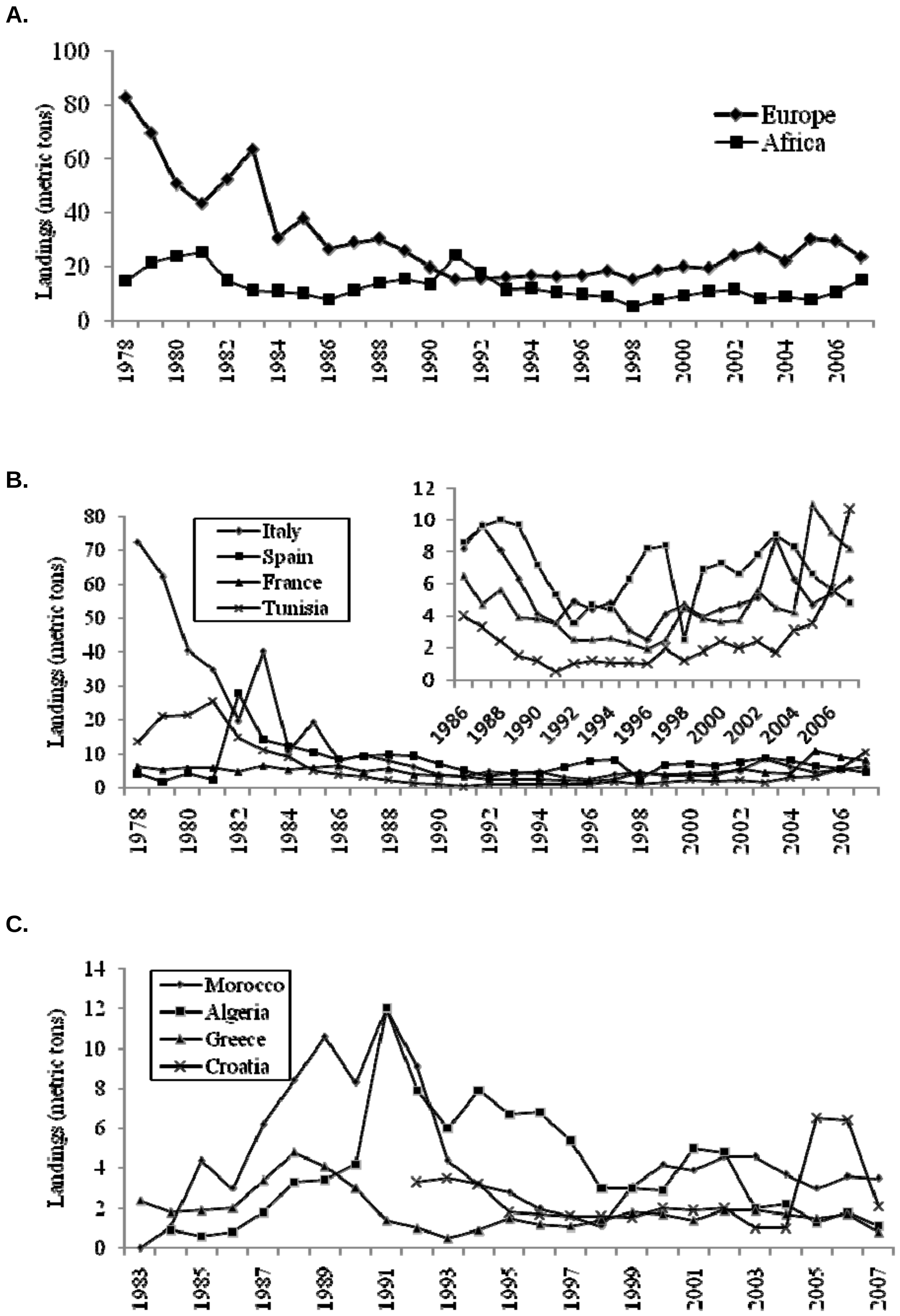

Fig. 4. Imports of five species of *Corallium* into the United States from 2001 to 2008. *C. elatius* = *Celat, C. rubrum* = *Crub, C. japonicum* = *Cjap, Corallium sp. nov.* = *Csp, C. secundum* = *Csec*. **A.** Total imports of manufactured *Corallium* reported by piece. **B.** Total imports of unprocessed *Corallium* skeletons reported by kg. Source: U.S. Fish and Wildlife Service import data.