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Short Communication

Management hurdles for sustainable harvesting of *Corallium rubrum*

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ABSTRACT

Declining fishing yields of the highly valuable Mediterranean red coral indicated overexploitation by the 1980s. In response, the UN Food and Agriculture Organization (FAO) established management guidelines in the late 1980s, such as daily quotas, minimum size, and most importantly, the ban of dredging for coral in 1994. However, recent data led to new concerns about the sustainability of coral harvest by highlighting previous and ongoing overexploitation. The US and EU reacted in 2007 and 2009 by proposing to include the family Corallidae in CITES Appendix II to regulate trade. However, the proposals were rejected based on the hope and promise that local management would provide a less obtrusive solution. This article argues that limited resources and insufficient interdisciplinarity limit the research needed to improve management guidelines, while a lack of human and financial resources hinder local management and efficient enforcement. In particular, illegal fishing is out of control and threatens the future of the industry. Furthermore, there is no consensus on the concept of sustainability of coral fisheries. The most alarming recent development is an increasing pressure by the industry to be permitted to harvest deep populations using remote operated vehicles, which will risk depletion of the last stocks left that have not been overharvested.

1. Introduction

The Mediterranean red coral *Corallium rubrum* is one of the most valuable marine living resources as larger specimens of this gorgonian can be prized several thousand euros/kg. The fishery follows a historic tradition including an artisanal industry specialized on carving and trading artistic objects and jewellery made from the red calcium carbonate skeleton of red coral [1]. Several centuries of intense commercial harvesting led to a decline of yield before more stringent management rules were set up in the 1980s [2]. Most coral fisheries followed a mining strategy where one stock was depleted, before moving on to explore new areas and harvest new stocks. Recent data revealed that most stocks are overharvested to an extent where debates about extinction of the species arose [3,4]. While the risk of global species extinction is debatable, the industry certainly faces the threat of local or even economic extinction of its resource [4,5]. This raises the question of whether the management rules in place are insufficient, or merely not efficiently enforced to assure sustainable exploitation. In order to elucidate this question, this article summarizes the recent data on the state of the stocks, and compares them to the major milestones in development of *C. rubrum* fishery management. Specifically this text considers the set up of the management framework in place since the FAO responded to the *crisis* in the early 1980s (a 60% decline of the overall Mediterranean yield), and more recent efforts within the last decade that addressed more dramatic concerns about the future of the resource. The final goal is to reveal future directions for the evolution of coral fishery management.

2. Origin of the principal management measures

The coral fishery in the Mediterranean still relied heavily on dredging in the 1970s, when data recorded by the FAO revealed that yields began to decline sharply [6–8]. Manual harvesting by SCUBA divers was already common, as in the 1950s it quickly proved a useful method to selectively harvest larger colonies hidden in crevices and caves that were inaccessible to dredges [9]. In response to the declining yields (Fig. 1), the FAO promoted technical consultation meetings in the 1980s [10,11] that introduced new rules that were eventually implemented Mediterranean-wide (Table 1).

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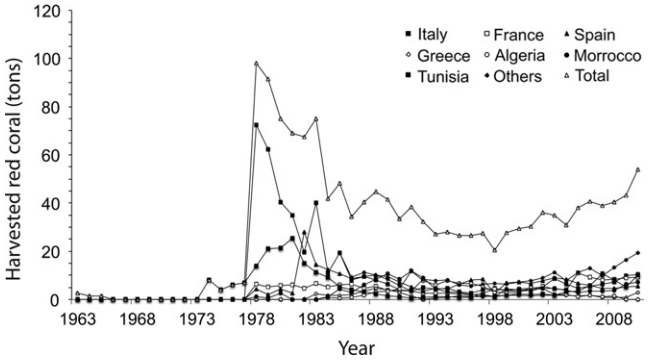

Fig. 1. Yield data for *Corallium rubrum* in the Mediterranean countries. Data from FAO Fishery Statistics online.

Table 1
Evolution of the main management measures that were implemented more or less Mediterranean-wide, based on FAO GFCM guidelines.

Year	Management rule
ca. 1983	First countries adopt the FAO recommendation of 7 mm minimum diameter
ca. 1983*	Daily or annual quotas
1986	Ban of dredging in Sardinia and Spain
1994	Official ban of dredging in the whole Mediterranean
2011	Ban of harvesting in shallow water, i.e. shallower than 50 m depth
In preparation	Recording of size data of coral colonies
Next decade	Application of advanced population dynamic models to match harvesting and population growth rates

* Quotas have probably been always in place one way or another, but based on taxation and commercial considerations, rather than on fisheries biology.

The most important change was the ban of dredging, which Sardinia and Spain implemented in 1986 and was finally established Mediterranean-wide in 1994. For several centuries before that, the fishing fleet consisted of small sailing or rowing boats, from which fishermen manually lowered rather small, wooden crosses to which nets were attached that entangled the corals [11]. Thousands of these vessels made considerable excursions of many days in search of new stocks [9]. However, by the 1970s an industrialized fleet began using large motorized vessels lowering winch operated 7 m long, 800 kg metal dredges down to 180 m depth [11], causing considerable damage to the habitat and coral populations [12], while providing only a low fishing efficiency (the majority of the coral colonies detached by dredging remain on the bottom) [11]. In the 1980s, Spain proposed the inclusion of *C. rubrum* in the Convention on International Trade in Endangered Species (CITES), to address uncontrollable poaching of Sicilian fleets at Alboran [13].

Banning dredging was a major step forward, as manual harvest by SCUBA divers is size selective and can potentially leave small colonies in place, which is beneficial for the recovery of the stocks. A previously voluntary minimum size of 7 mm basal diameter was eventually established as a binding rule, which coincided with the industry's lower demand of coral smaller than 7 mm [10]. On the other hand, the recommendation to increase the minimum size to 8 or 10 mm [14,15] still remains widely ignored although some single fisheries have implemented it [2].

3. Recent data reveal unsustainable fishery

Until the beginning of this millennium, there was no evidence to fully assess the unsustainability of the fishery. One reason was that, unlike other fisheries, the size of the landed corals was not recorded. During the last decade the yields remained low but stable (Fig. 1), creating the false illusion that the fishery was sustainable. The reason that yield has nevertheless been stable is due to a geographical extension of the fishery opening new fishing grounds, and also moving towards ever-deeper layers of existing beds. During the last five years yields even increased slightly, perhaps as a response to fishermen's concerns that soon the stocks will be either protected by CITES or depleted, so that they harvest while they still can.

Table 2
This summary of the stepwise overharvest of *Corallium rubrum* stocks in the Mediterranean explains stable yields during the last decades.

Period	Concept
1950s–1970s	Depletion of corals in access of dredges. Continuing harvest of corals in crevices accessible only to divers
1970s–present	Extending fishing from European Mediterranean to the North African shores and neighbouring North Atlantic coasts.
1970s–present	Harvesting ever-smaller corals after depleting larger size classes
1970s–present	Harvesting in ever-deeper waters, now at the limit of human SCUBA capabilities
Next decade	The next transition would be deep harvesting with remotely operated tools (ROVs)

In a historical context, the yield has been able to remain stable or increase thanks to four types of transitions (Table 2): (a) Depleting corals in access of dredges and continuing harvest of corals in crevices accessible only to divers. (b) Extending fishing from Europe to the North African Mediterranean and Atlantic coasts, Turkey and the Eastern Adriatic Sea. (c) Harvesting ever-smaller corals after depleting larger size classes. (d) Harvesting in ever-deeper waters, now at the limit of human physiology and SCUBA technology [16]. Since SCUBA divers have depleted shallow populations and are forced to dive down to more than 100 m to find large corals, the next transition is on the horizon and will consist in harvesting with remotely operated robotic tools.

This way, it has gone unnoticed by managers that the stocks have been harvested down to very young size classes. However, the extremely young populations recorded by recent surveys unmistakably demonstrate the real state of overexploitation of many populations [4,5,15]. Today shallow populations are generally composed of dense populations of small corals with a low economic value [5]. Deep populations (<80 m) on the other hand still contain large colonies, albeit at lower densities [16].

The industry meets the demand for jewellery by complementing up to 70% of its supply for raw coral through the import of pacific species in Japan and Taiwan [17]. Thus concerns arose over the sustainability of not only the Mediterranean *C. rubrum* fishery, but Corallidae worldwide [18,19]. In response, the US proposed the inclusion of the genus *Corallium* in Appendix II of the (CITES) in 2007, and in 2009 the US and EU proposed again to include the family Corallidae in App. II. Both proposals failed to receive an absolute majority vote by the parties, based in large part in the hope and promise that local management headed by the FAO GFCM may be a more efficient and less stigmatizing alternative to sustainable management and conservation of Corallidae [20–22].

Local management is however hindered by organized poaching that authorities are unable to control, as patrolling the sites is unfeasible, and penalties are inefficient. In the Costa Brava (Spain) there is a core group of 5 known poachers who collaborate with and train others, reaching a total number of 15 divers [23]. In comparison, the number of licenses in the same region fluctuates at around 10. There is furthermore alarming evidence of illegal dredging at the North-African Mediterranean coast and

even in Sardinia (G.S., pers. obs.). Given the extremely slow growth [24,25] and limited dispersion capabilities of red coral [26], such practices will quickly lead to local extinction of *C. rubrum* in shallow water [2,5].

4. Progress of local management

Responding to the call for improved local management as an alternative to trade control through CITES, the FAO General Fisheries Commission for the Mediterranean (GFCM) began to convene further workshops in 2009 to elaborate a management plan that is passed on to the fishery departments of the member countries [27–29].

During the two years after the discussions about inclusion into the CITES, it seems the two major accomplishments were the ban of shallow water fishing, and the need to study the deep stocks before those are opened to use through "robotic" harvesting, using remote operated vehicles (ROVs). Another was the agreement to increase the minimum size to 10 mm in the whole Mediterranean, and identify funding sources for coordinated further research, specifically on the deep populations [27].

Unfortunately, these initial breakthroughs were subsequently annulled: Unison decisions of all attendants such as the protection of corals shallower than 80 m depth [18] were reduced to 50 m on petition of industry representatives [27]. Commercial harvesters hardly visit shallow water anymore, so this ban of shallow water fishing is meant to allow these populations to recover (if poaching can be controlled).

The accepted new minimum size of 10 mm was an enormous step forward [18], but was then taken back, returning to 7 mm during the latest workshop [29], contradicting studies on the biology of *C. rubrum* [14,15]. The argument during the workshops often is that individual countries may adopt stricter measures if they see it necessary, but the reality is that fishery departments are not staffed and funded to possess the necessary expertise, so they rely on GFCM recommendations. An exception is the fishery management of Sardinia (Italy), which indeed specifies 10 mm as the minimum diameter, and banned fishing in less than 80 m depth. Unfortunately fisheries in other countries are reluctant to follow the Sardinian example. However, enforcement remains a problem, as there is no evidence of an effective enforcement occurring even in this Italian region with the most advanced rules.

At the two most recent workshops, industry representatives petitioned for the legalization of remote operated vehicles (ROVs) to harvest coral without exposing humans to the depths where large corals remain [29]. ROV were previously used for prospecting only during limited time windows. While SCUBA diving at 100–130 m depth imposes a drastic physiological limitation on diving time, ROV harvest provides access to the corals without any limitation of depth or time. Managers have to consider whether quotas can be effectively enforced without physiological limitations on the divers. Unfortunately, the current reality indicates that this is highly unlikely. Illegal fishing by poachers, but also licensed fishermen that do not follow rules, can hardly be controlled as it is [23]. Furthermore, harvesting deep populations means that $>99\%$ of the world's *C. rubrum* populations would be subjected to fishing pressure (i.e. except $<1\%$ that are protected areas), so that overharvesting these last viable stocks would lead to economic extinction. In light of these alarming new facts it does appear that international trade control through CITES might offer an important means of controlling illegal activities [18,30].

5. Lack of concept

C. rubrum management measures have traditionally been arbitrary and inconsequent, as they are ignoring recommendations provided by ecologists since the 1870s [1]. Many meetings and workshops have been held about the ecology of *C. rubrum*, yet less than a handful of studies propose sustainable management guidelines in practical terms. Analyzing the workshop proceedings regarding Corallidae management, it becomes apparent that criteria for sustainability in line with fishery biology are rarely mentioned. For example, the "survival of the species" is often mistaken for the final objective, in order to avoid extinction. But this point of view has unfortunately permitted the continuation of the "boom and bust" mining exploitation that depletes one stock one after the other. A sustainable fishery shall provide by definition the same amount of yield perpetually from any stock, and the scientific community is challenged with providing managers with the diagnostic tools to steer the fishery accordingly. This will require an interdisciplinary approach joining coral ecology with fishery and demographic modeling [14,5,15]. Furthermore, the holistic concept of habitat-based management that manages single species in consideration of the impact on nursery services and overall system productivity and biodiversity is being neglected.

This is due to the fact that coral harvest and jewellery manufacture is a small niche industry that disposes of a smaller funding budget than large-scale fisheries, at ca. US$ 230 million - yr^{-1} [2]. In fact, GFCM red coral workshop participants often attend at their own cost, which might not lead to an ideal selection of participants. Clearly, an adequately funded group combining backgrounds from international policy, management, coral ecology, fishery, and even forestry is required to improve the fishery management of a species that provides structure to Mediterranean ecosystems [30].

6. Conclusions

Despite recent debates about how to achieve sustainable management of *Corallium rubrum* fisheries, to date few significant changes or improvements have been achieved, i.e., the stocks are currently harvested basically in the same way they were during the last decades. The harvest now concentrates at the depth limit of human SCUBA capability, as coral populations in shallower water are extirpated or consist of small individuals. Minimum size limits have still not been increased to levels indicated by fishery models, and most of all, illegal fishing has been proven to be out of control. Growing pressure to permit the use of ROV technology to harvest deep stocks threaten to rapidly overexploit the last intact populations by a highly efficient technology that removes all limitations of current SCUBA. Since uncontrolled harvesting of deep populations would lead to economic extinction of the species, it is advisable that this technology should remain on hold until local and international management address the extreme challenges in enforcing quotas and stopping illegal fishing.

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