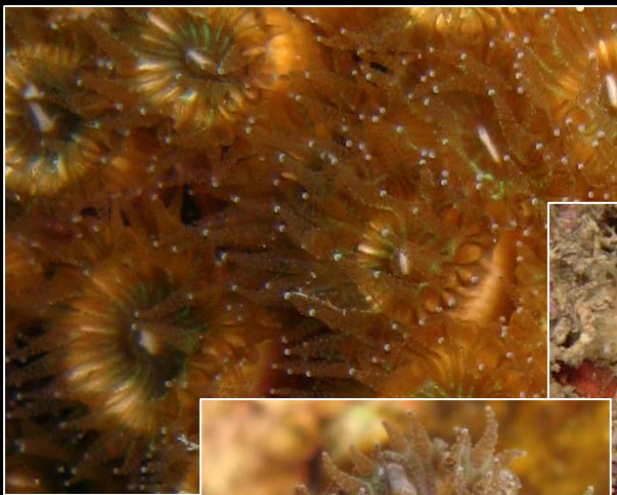




A survey of the corals within diving depths of Capo Rizzuto Marine Protected Area, Calabria, 2008



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# **A survey of the corals within diving depths of Capo Rizzuto Marine Protected Area, Calabria, southern Italy, 2008**

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## **Abstract**

In the first study ever made of the corals of Capo Rizzuto Marine Protected Area, 10 species of coral were found, seven that do not host symbiotic zooxanthellae algae, two that do, and one that can either host or not host zooxanthellae. One additional species that lacks zooxanthellae was identified from a photograph, for a total of 11 species. This is a relatively good number of species for a relatively short study, and represents 50% of all shallow-water coral species known from the entire Mediterranean. Two species, *Paracyathus pulchellus* and *Polycyathus muelleriae*, as well as a species identified from the photograph (*Astroides calycularis*) were not previously reported from the Ionian Sea. The two zooxanthellate species, *Balanophyllia europaea* and *Cladocora caespitosa* were found in areas exposed to light, and the first was most common in patches of a species of coralline algae. Fossils of *Cladocora caespitosa* were found in rocks near the seashore in the town of Le Castella. The azooxanthellate species were found in heavily shaded areas, on overhanging surfaces on the lower edges of boulders, in holes, and on overhanging surfaces of wrecks and vertical surfaces of deep wrecks. Over 20 species of sponges were photographed, as well as other invertebrates such as nudibranchs and bryozoans. Monitoring transects were set up and recorded for one zooxanthellate coral (*Balanophyllia europaea*) and other classes of organisms inhabiting the substrate, and sizes of another zooxanthellate coral (*Cladocora caespitosa*) were measured. Photographs of all coral species were taken and a field identification guide produced, including descriptions of the living coral species and their skeletons. The introduced and highly invasive alga *Caulerpa racemosa* var. *cylindracea* was found at most sites where it was common but not dominant. The quantitative monitoring transects set up will provide a way of monitoring the abundance of this invasive species.

## **Introduction**

Coral reefs are well known in the tropics, but corals in temperate waters are less well known to the public. Corals which host the unicellular dinoflagellate algae termed “zooxanthellae” are referred to as “zooxanthellate.” Corals which do not host these algae are referred to as “azooxanthellate” (Schuhmacher and Zibrowius, 1985). Most zooxanthellate corals are restricted to the relatively warm waters of the tropics and subtropics, generally about 30 degrees latitude or less, and generally above about 22<sup>0</sup> C winter minimum temperature. There are a few exceptions, such as *Astrangia poculata*

which survives as far north as Cape Cod, Massachusetts on the U.S. Atlantic coast where seawater can reach freezing temperatures in the winter and intertidal rocks are scoured by ice. But there is only that one species of zooxanthellate coral that can survive those extreme conditions. Also zooxanthellate corals are restricted to areas where there is sufficient illumination for the zooxanthellae to perform photosynthesis, and are thus restricted to relatively shallow water, almost always less than 100 m deep and most commonly in less than 30 m depth. Also, they are restricted to microhabitats exposed to light, and are not found in caves and on overhanging surfaces. The zooxanthellae provide a variety of compounds to their host corals, and can supply a large proportion of their energy requirements. As a result, zooxanthellate corals generally grow larger than the azooxanthellate corals, which lack this energy source, though there are some exceptions to this rule. Azooxanthellate corals are not restricted to warm water, with 17 species living in Antarctica (Cairns, 1982), nor are they restricted to shallow water, with some species possibly living as deep as 6,328 m (Cairns, 1981), but at least 5000 m (H. Zibrowius, personal comm.). Although azooxanthellate corals can live in illuminated microhabitats, most live in low-light habitats, in deep water or on cave roofs or overhanging surfaces. They prefer cave roofs and overhanging surfaces over floors of caves and overhangs probably because of the greatly reduced sedimentation on the upper surfaces. Most prefer the shaded microhabitats, probably because of the reduced competition with fast-growing algae and zooxanthellate corals (in the tropics). Because of the lack of the zooxanthellar energy source, most azooxanthellate corals grow slowly, and thus would be at a competitive disadvantage with fast growing algae and zooxanthellate corals in illuminated habitats. Most azooxanthellate corals are small and solitary (having a single polyp), while most zooxanthellate corals are larger and are colonial (having several to many polyps). There are exceptions, such as small and/or solitary zooxanthellate corals, and colonial azooxanthellate corals, including species which produce large bioherms (biologically produced structures) in deep water where it is dark, though generally the branching colonies of these species have relatively thin branches with a relatively small calcium buildup. Azooxanthellate corals in the genus *Tubastraea*, and a few corals in genera such as *Dendrophyllia* and *Balanophyllia*, are exceptional in that they are able to live in illuminated microhabitats and/or shaded microhabitats. *Tubastraea* species are colonial, and most are larger and grow faster than most azooxanthellate corals (Marshall, 1996) and are functionally more similar to zooxanthellate corals. Their ability to grow faster and larger likely makes them much more able to compete with fast growing algae in the light. The largest species, *Tubastraea micranthus*, can reach up to about 2 m height, with a base of about 20 cm diameter. *Tubastraea micranthus* actually has green algae which live within the skeleton instead of within its tissues, but which nevertheless provide nutrition to the animal tissue (Schlichter et al. 1995). Thus, they may be functionally similar to zooxanthellate corals, and found only in illuminated water in the tropics. However, green algae are also known to live in the skeletons of many other corals, and the algae may not be critical to the rapid growth and large size of *Tubastraea micranthus*.

The diversity of zooxanthellate corals decreases markedly with increasing latitude and decreasing temperatures, with none farther north in Europe than the Mediterranean. The Mediterranean, being temperate waters, hosts only four species of zooxanthellate corals, while Indonesia in the area of highest diversity, straddling the equator, has 581



known zooxanthellate coral species (Veron, 2002), plus an unknown number of unreported or unidentified species. It is actually amazing that the Mediterranean has any zooxanthellate corals at all, since it gets very cold in the winter; the Capo Rizzuto area surface water reaches temperatures as cold as 12°C at times (Vincenzo Nardi, diving instructor, personal comm.). The Mediterranean hosts 33 species of scleractinian corals, 29 of which never have zooxanthellae, two of which (*Cladocora caespitosa* and *Balanophyllia europaea*) always have zooxanthellae, and two (*Madracis pharensis* and *Oculina patagonica*) which can either have zooxanthellae or not (Appendix A). They live in a wide range of depths, from 0 to at least 1200 m (Galil and Zibrowius, 1998), though only azooxanthellate species live in deep water since zooxanthellate species require light, which is absent in deep water. Corals living in water deeper than about 50 m must be collected by methods other than scuba, such as dredging, tangling in nets, etc. One species that can have zooxanthellae or not (which thus could be called “facultative zooxanthellate”: *Oculina patagonica*) appears to be introduced (Zibrowius, 1974), first being found in Italy in 1960 and now found in Spain, France, Italy, Greece, Turkey, Lebanon, Israel, Egypt, Tunisia and Algeria (Sartoretto et al. 2008 and references therein). The Mediterranean does not have living coral reefs, where the calcium of dead corals builds up, but it does have a few places where one species (*Cladocora caespitosa*) builds fairly large living structures (up to 560 m<sup>2</sup> in area) that could be called fields, banks or bioherms (Kruzic and Pozar-Domac, 2003)(Figure 1).



**Figure 1.** *Cladocora caespitosa* bioherm in Croatia.

Azooxanthellate coral diversity also decreases with increasing latitude, with none known north of a point in Norway (Zibrowius, 1980; and only that far north because of warming of the Gulf Stream), though 17 species are known from Antarctica (Cairns, 1982). Of the 33 species known from the Mediterranean, 15 are found in caves (Zibrowius, 1980). Of the four species that can or do host zooxanthellae, three are colonial, and one (*Balanophyllia europaea*) is solitary. Thirty-two species are indigenous to the Mediterranean, and one (facultative zooxanthellate) species (*Oculina patagonica*) is introduced (Zibrowius, 1974; Fine et al. 2001; Sartoretto et al. 2008). The zooxanthellate corals are most common within diving depths, and the azooxanthellate corals are largely restricted to overhanging surfaces within diving depths. Twenty-two of the 33 species have been found in less than 30 m depth (Zibrowius, 1980). Of the shallow azooxanthellate species, 12 are solitary and 12 are colonial (Zibrowius, 1980). The closest sites where coral diversity has been studied are in the Naples area where 18 of the shallow-water species have been found, in Sicily where 14 shallow-water species were found (Zibrowius, 1980), and in Croatia where 18 shallow water species were found (Kruzic, 2002). Zibrowius (1980, Table 2) summarized available records from many studies for 12 areas of the Mediterranean, which had a mean of 15.6 species, with a range of 13-19 species. He reports (p. 212) that in the Ionian Sea (Corfou, Gulf of Corinthe, and Gulf of Taranto) eight shallow-water species have been reported: *Madracis pharensis*, *Caryophyllia inornata*, *Hoplangia durotrix*, *Phyllangia mouchezii*, *Leptopsammia pruvoti*, *Cladocora caespitosa*, *Balanophyllia europaea*, and *Cladopsammia rolandi*.

There have been quite a few studies of the ecology and biology of a few Mediterranean corals, primarily *Cladocora caespitosa*, *Balanophyllia europaea*, *Oculina patagonica*, and *Leptopsammia pruvoti*. *Cladocora caespitosa* is a colonial zooxanthellate coral that is probably the best studied Mediterranean coral. Studies include examinations of the ecology and ability of this species to build constructions (Peirano et al. 1998; Schiller, 2008). It is mostly found in turbid water and rarely found in clear water (Rodolfo-Metalpa et al. 2008). Morri et al. (2001) reviewed literature on *Cladocora caespitosa* and suggested that since its present distribution is smaller than the distribution of fossils of that species, climate change may have reduced its range. H. Zibrowius (personal comm.) states that its range has not decreased, it still ranges from the Alboral Sea to the Levant (Israel) and to Piran, Slovenia and the NE Aegean Sea. Colonies as old as 60 years have been found, which can provide records of colony growth and climate. Where this species is common, colonies growing separately as hemispheres can cover the entire bottom, producing a continuous, undulating coral surface of coral colonies up to 1 m thick (Figure 1), but this is rare. Kruzic and Benkovic (2008) describe some of the largest growths of this species known, in Croatia. Peirano et al. (1999) report that there are annual growth bands (like tree rings) in X rays taken of the skeleton like that of other corals, and that the skeletons show a high density band in the winter and a low density band in the summer. Such bands are well known in zooxanthellate reef corals, particularly *Porites*. The differences between the two bands is due to differences in the thickening of skeletal elements, not the size or speed of growth of the corallites. Colonies grow about 1-4 mm per year. Some colonies are found in water deep enough

that there is insufficient light for enough photosynthesis to produce significant energy that way. Colonies gain energy from feeding as well as from photosynthesis by zooxanthellae. Rodolfo-Metalpa et al. (2008) reported that light intensity over the range studied had no effect on the rate of growth and budding of *Cladocora caespitosa*, but higher temperature and more food supply increased the growth rate. Budding of new polyps was greater during the favorable conditions of high temperature and food. The effect of feeding was greater for corals kept at low temperature, indicating that the corals are more dependent on feeding at low temperatures than at higher temperatures when zooxanthellae can provide more energy. Schiller (1993a) reported that *Cladocora caespitosa* colonies harbor a rich but variable community of organisms hiding between their closely spaced branches. The community is dominated by sponges, though there are polychaetes, brittle stars, crustaceans, and others. Some sponges hold branches together, but others bore into the skeleton until the living tip of the branch breaks off. The fragment that is produced may be able to start a new colony. The parent colony, however, has difficulty recovering, as tissue in well developed colonies does not connect between the polyps (which are on long stalk-like branches) so tissue cannot cover the broken off stub and regenerate a new polyp. However, as other polyps grow they may divide and fill in some gaps. In the Bay of Piran, Slovenia where this work was done, juvenile colonies are encrusting, and larger colonies are often broken by storms in shallow water. Tissue does connect corallites on young colonies which are encrusting with short corallites. When many corallites are broken off of colonies and slide downward, this is called “slumping”, and some fragments probably start new colonies.

There have been several studies reporting the effects of high temperatures on *Cladocora arbuscula*. A study of polyp expulsion (Kruzic (2007) reported that at high temperatures (30°C, 4°C higher than the normal maximum summer temperature), *Cladocora caespitosa* showed polyp expulsion though only the polyp tissues were expelled instead of the tissues plus skeleton as has been reported in *Oculina patagonica* (Kramarsky-Winter et al. 2007). Living intact polyps without skeleton were found attached to the aquarium walls. This resembles “polyp bail-out” as described by Sammarco (1982) more closely than polyp expulsion. Both are produced by stress. Rodolfo-Metalpa et al. (2006a) reported that in Genoa and eastern Italy, where temperatures normally hit a summer maximum of 24°C, the zooxanthellae in *Cladocora caespitosa* and *Oculina patagonica* do not decrease in number or in function in short term tests until between 29 and 32°C. Temperatures of 1-2°C above the summer maximum can be of extended duration in that area, but temperatures of 3-4°C above only occur for a few days. Tests were carried out for 2 days. Rodolfo-Metalpa et al. (2006b) did long-term tests on the same two species. They tested corals for 48 days at 20 and 24°C, and 20 days at 26 and 28°C. All measurements were normal at 20°C, but most physiological parameters were affected after 2-5 weeks at 24°C. *Oculina patagonica* quickly bleached at all but the lowest temperatures, but showed little necrosis at the higher temperatures at the end of the experiment, while *Cladocora caespitosa* only bleached in the higher temperatures, and all colonies in high temperatures had stopped growing, and experienced tissue necrosis and death by the end of the experiment. Thus, the long term high temperatures proved lethal for the *Cladocora caespitosa*, while the short term high temperatures had not. Rodolfo Metalpa et al. (2000) reported that in La Spezia, NW Italy, in September 1997 and August 1998 there was mortality of both *Cladocora*



*caespitosa* and *Balanophyllia europaea*. In 1997-98 there was the strongest El Nino event on record, and there was mass coral bleaching and death on many tropical reefs around the world. In La Spezia, the coral tissues retracted but still had zooxanthellae, and then they disintegrated and died, a pattern that differs from bleaching in the tropics. Recent studies have found that skeletal isotopic analyses of *Cladocora caespitosa* could serve as a climate proxy for the Mediterranean Sea (Silenzi et al. 2005; Montagna et al. 2007). Schiller (1993b) found that some polyps on normal colonies are white, while other polyps are brown. Dark polyps have 50 times as many zooxanthellae as white polyps on the average, but in a few white polyps zooxanthellae were undetectable. Reports of zooxanthellae counts in corals usually report about 2.5 to 3.5 times as many zooxanthellae in unbleached than bleached colonies. Other papers have reported zooxanthellae densities in tropical corals of about 1-6 million per cm<sup>2</sup> and densities in bleached corals of about 10,000 per cm<sup>2</sup>. Although there are 10,000 per cm<sup>2</sup> in bleached corals that look very white, the zooxanthellae are microscopic and that number does not absorb enough light to be visible as color. In the *Cladocora caespitosa* study, chlorophyll was 3 times higher per zooxanthella in the white polyps than the dark, and chlorophyll c was 13 times higher. The zooxanthellae may have had more pigment because they were not shaded by other zooxanthellae. Rodolfo-Metalpa et al. (2008) reported that growth rates, zooxanthellae, and chlorophyll in *Cladocora caespitosa* and *Oculina patagonica* generally increased from winter to spring, and then decreased from early summer to autumn. *Oculina patagonica* behaved like a tropical coral, while *Cladocora caespitosa* acted more like a temperate coral, its growth being enhanced by temperature but not irradiance. Both species are under stress during the coldest and warmest parts of the year.

There are also reports on a variety of other aspects of the biology of *Cladocora caespitosa*. Kruzic et al. (2008b) reported that *Cladocora caespitosa* was observed spawning 4 days before full moon in June, and spawned on 5 nights. About 30% of the colonies spawned, each colony releasing eggs or sperm but not both. Since they are hermaphroditic, any one colony must release only one at a time, probably to decrease self-fertilization. The eggs stick to the outside of the colony. A tuna farm is located just 300 m from one of the three largest known banks of *Cladocora caespitosa* in the Mediterranean, in Croatia (Kruzic and Pozar-Domac, 2007). Masses of filamentous algae were stimulated by the nutrients from the farm, overgrowing the coral and killing it. Over 90% of the corals in the bank were killed by this alga between 2001 and 2005. Rodolfo-Metalpa et al. (2005) describe tissue necrosis in *Cladocora caespitosa*. Herndl and Velimirov (1986) reported that *Cladocora caespitosa* was an abundant coral at Piran, Slovenia. They reported that it had increased dramatically in the previous decade in the northern Adriatic. They found that mucus was equal to 44% of the respiratory carbon loss of the coral. They also reported that bacteria achieved a 20% conversion of the mucus carbon, indicating its high nutritional value. They report it is rich in energy in wax esters, triglycerides, fatty acids, etc.

*Balanophyllia europaea* is a solitary zooxanthellate coral which is probably the second most studied Mediterranean coral. Goffredo et al. (2002) found that *Balanophyllia europaea* is a simultaneous hermaphrodite which becomes sexually mature at about 3 years of age and 6-10 mm oral disc diameter. Spermaries tend to be near the mouth within the coelenteron, and ovaries tend to be near the polyp base in the

coelenteron. This may reduce the amount of self-fertilization by maximizing the number of sperm that swim out the mouth. Goffredo and Zaccanti (2004) reported that planulae are about 2 mm long and have zooxanthellae when they are released. They are neutrally buoyant and swim. Their longevity averages 10 days with a maximum of 53 days. The average age of metamorphosis is 7 days, with a maximum of 42 days. Half of the larvae settle as far from the parent as possible. Adults produce an average of 6.8 planulae, and all adults release them on the same day. Larval duration is longer in this species than in *Balanophyllia elegans*, a species on the west coast of North America, because the latter does not have zooxanthellae, which can provide most of the energy the larva needs. Goffredo et al. (2004a) found that the growth rate of *Balanophyllia europaea* decreased with increasing size. The average lifespan was 3.6 years, with a maximum lifespan of 20 years. At their site in NW Italy, they were found only between 5 and 10 m deep. Goffredo et al. (2004b) report that in genetic studies using protein electrophoresis, *Balanophyllia europaea* shows a deficit of heterozygotes that is consistent with the view that their simultaneous hermaphroditism leads to high levels of self-fertilization. They hypothesize that this is adaptive for this species, which settles in disturbed habitats at low densities. Populations of this species were genetically connected at small spatial scales of 8-40 m, but not at large spatial scales (36-1,941 km). Swimming larvae provide dispersal over the smaller scale, but inbreeding allows differentiation to develop between more distant populations.

Goffredo et al. (2007; 2007; 2008) studied *Balanophyllia europaea* along a latitudinal gradient in Italy and found that growth rates went down with increases in temperature, but the maximum size of individuals increased with increasing temperature. There were also fewer young individuals at the higher temperatures, indicating that at higher temperatures populations may have difficulty replenishing themselves. They predict that they will be close to their thermal limits by 2100 in the south where water temperatures are higher. Mediterranean corals host clade A zooxanthellae (Visram et al. 2006), which may have a lower thermal limit there than in the tropics. Goffredo et al. (2000) describe spermatogenesis in *Balanophyllia europaea*. Goffredo and Zaccanti (2004) report that *Balanophyllia europaea* can reach population densities of up to 100/m<sup>2</sup> at 5-10 m depth, and occurs down to a maximum of 50 m depth. Fertilization for this brooding simultaneous hermaphrodite occurs in April and May. Embryos are brooded for 4-5 months and larvae released in August to September. The larvae are about 2 mm long when released, and swim, unlike the one other species in the genus that has been studied. *Balanophyllia elegans*, an azooxanthellate coral on the west coast of North America, has crawling larvae. The larvae of *Balanophyllia europaea* settle on surfaces and metamorphose into polyps at an average of 7 days age. *Balanophyllia europaea* is the only zooxanthellate species of *Balanophyllia*. *Balanophyllia europaea* individuals are randomly spaced in the habitat, which fits with the swimming dispersal mode, unlike *Balanophyllia elegans*, which are clumped due to the short distances that the larvae crawl.

*Oculina patagonica* is a colonial facultative zooxanthellate coral that appears to have been introduced from the temperate zone of the Atlantic coast of South America near Buenos Aires and has spread in the Mediterranean (Zibrowius, 1974; Bitar and Zibrowius, 1997; Fine et al. 2001). It is now fairly common on the Mediterranean coast of Israel, where it has been found to bleach each summer. As noted previously, polyp

expulsion was discovered in this species (Kramarsky-Winter et al. 2007). Fine et al. (2001) have elucidated the basic biology of *Oculina patagonica*. It is a thin encrusting species. Although it was first reported from northwest Italy near Savona (near Genoa), it is now most common in Spain where it reaches densities of 30 colonies under a 10 m line in shallow water, and second most abundant in Israel where it reaches 10 per 10 m line. It was not found in several intensive surveys of Israel coastal marine life up through the late 70's. Those surveys reported several quite small coral species, so they were fully capable of finding this species. Fine et al. (2001) report it is rare in Italy even where it has been found, but it has also been known from four sites on the Ligurian Coast. Rodolfo-Meltalpa et al. (2008) reported collecting 135 fragments of *Oculina patagonica* at Albissola (44° 17'N, 8° 30' E), so it must not be rare there. Mortality and recruitment in Israel are low, but recruitment in Spain is high. It has separate sexes (it is gonochoric). Female gonads start developing in May, males in July, and both are mature in late August to early September. The sex ratio is 1:1. In addition to zooxanthellate colonies in the sun, there are many natural azooxanthellate colonies that inhabit small dark caves in Israel. Gonadal development in natural azooxanthellate colonies is the same as in zooxanthellate colonies. However, there are no gonads in colonies that are bleaching. Some have thought that the lack of zooxanthellae means bleached colonies don't have the energy to reproduce, but the fact that naturally azooxanthellate colonies have gonadal development shows that the lack of zooxanthellae is not why bleached colonies are unable to produce gonads. Perhaps the high temperature damages the coral tissue. On the other hand, azooxanthellate colonies in the shade are in water just as hot as zooxanthellate colonies in the sun- if high temperatures damage the coral tissue, the natural azooxanthellate colonies should not be able to produce gonads. The pattern is consistent with the hypothesis that at high temperature and light levels, zooxanthellae produce active oxygen which is damaging to both zooxanthellae and coral tissues (e.g., Downs et al. 2002). Active oxygen and damage should be produced only by zooxanthellae in the light. Colonies bleach in the summer in Israel, but not in Spain, which may explain why Israel has low recruitment but Spain has high recruitment (and now high populations). The water in Israel gets hotter in the summer than in Spain, which is in turn hotter than France. 80-90% of all colonies bleach on the Israeli coast, but 98% of colonies recover. In Israel, the depth range for this species is 0.5 -10 m deep, and some colonies are in tide pools. Some tide pools reach 40°C and can reach 50‰ salinity. The abundance of colonies decreases below 4 m depth. Colony size and abundance increase towards the south in Israel. In Israel, the growth rate of colonies is 0.6-0.75 cm/yr, with the faster rates on vertical surfaces. Colonies 2 cm in diameter are estimated to be 1-2 years old, and colonies over 2 cm diameter are fertile in the reproductive season. Colonies in aquaria spawn over just 2 nights in full moon in September. The eggs are released one at a time, and are negatively buoyant. The planulae (larvae) have zooxanthellae 8 hours after spawning. The authors propose that this species has several properties that increase its ability to be introduced and to spread fast. First it is able to reproduce both sexually and asexually (by polyp expulsion), second it has an early reproductive maturity, third it can survive extremes of temperature, salinity and light, and fourth it has a high growth rate. They suggest it might have arrived by fouling a ship hull, and then with polyp expulsion was able to colonize natural substrate.

Studies of the mechanism of bleaching have supported the hypothesis that a bacterium, *Vibrio shiloi*, causes bleaching in *Oculina patagonica* (e.g., Kushmaro et al. 1996; 1997; 1998; 2001; Rosenberg and Loya, 1999; Banin et al. 2000; Israeli et al. 2001; Rosenberg and Ben-Haim, 2002; Fine et al. 2002; Rosenberg and Falkowitz, 2004; Davidson, 2005; Koren and Rosenberg, 2006; Reshef et al. 2006; Rosenberg et al. 2007). The genus *Vibrio* contains various pathogenic species, including the one that causes cholera in humans. The bacterium sticks to a receptor in the normally protective coral mucus. The bacteria produce toxins that inhibit photosynthesis in the zooxanthellae and cause them to rupture. One of the toxins forms ammonia channels in the zooxanthella membrane, destroying the pH gradient and blocking the photosynthetic process. This all happens only at high temperatures, and the bacteria are required: if the coral is exposed to high temperatures without the bacterium, they do not bleach. The temperature dependence of the bacterial process is thought to depend on the fact that the bacterium can only produce the enzyme called superoxide dismutase (SOD) at high temperatures. SOD is required for the bacteria to survive in the oxygen-rich coral tissue (oxygen being produced by photosynthesis of the zooxanthellae). The bacteria survive the cold winter inside a segmented worm, the fireworm *Hermodice carunculata*. The fireworm feeds on the coral, thus inoculating them with the bacteria in the spring. Fine et al. (2002) reported that colony growth was dramatically reduced during bleaching. They studied the effects of injuries and found that while unbleached colonies can regenerate small injuries, partly bleached colonies regenerate less than unbleached colonies, and fully bleached colonies do not regenerate at all. Unbleached colonies move resources from healthy parts of the colony to damaged areas, such as the disc-shaped lesions where fireworms feed on tissues. Transport of organic compounds within coral colonies is already well-known. Fine et al. (2002) found that *Oculina patagonica* at 1-4 m depth in Israel show strong bleaching, but the same species at 0-80 cm depth show negligible bleaching even though they were about 2°C hotter. Corals transplanted from 4 m deep to shallow did not bleach, while corals transplanted from shallow to deep did. The bacterium *Vibrio shiloi* was abundant in the deeper bleached colonies but could not be detected in the shallow colonies. When colonies were infected with the bacteria in the laboratory, the bacteria multiplied and the colonies bleached. If such colonies were exposed to ultraviolet radiation, the bacteria died and the colonies did not bleach. Thus, it appears that naturally occurring ultraviolet radiation in the very shallow water keeps the bacterium from growing in the coral and causing bleaching. A recent study found bleaching of *Oculina patagonica* in Israel in 2005 occurred without bacterial infection. Some of the bleached corals died even though they were not infected. Although bleaching can be induced by experimental infection of the coral by *Vibrio shiloi*, natural bleaching occurred without it, demonstrating that the bacteria was not the cause of the 2005 bleaching (Ainsworth et al. 2007). Ainsworth and Hoegh-Guldberg (2008) reported that in *Oculina patagonica*, the loss of zooxanthellae during bleaching occurs by the zooxanthellae degrading in the coral tissue. They did not see coral cells dying. This supports the view that the damage in bleaching at least in this species is to the algae not the host coral. Shenkar et al. (2005) found that fewer small colonies bleached than large colonies. In bleached colonies, the percentage of the colony that was bleached was proportional to the temperature. Bleaching began at the outer edges of the colony and expanded inward with increasing temperatures. Some of the colonies experienced partial

mortality around the outer edges of the colony, and other colonies died completely. Colony mortality was most common in the largest colonies. The result was that the average colony size decreased after summer bleaching. A study of the effects of acidification on *Oculina patagonica* and *Madracis pharensis* found that at a pH predicted to be produced by future climate change, the skeletons dissolved, but the polyps survived as apparently healthy individual polyps without skeleton. Polyps retained zooxanthellae, elongated and tripled in biomass, and showed normal gonadal development. When the pH was returned to the present pH, the polyps began secreting skeleton again and fused back into colonies (Fine and Tchernov, 2007; Stanley, 2007).

*Leptopsammia pruvoti* is a solitary azooxanthellate coral that has received relatively little study. Goffredo et al. (2005) reported that *Leptopsammia pruvoti* lives on shaded surfaces from the surface to 70 m depth, and can reach densities of over 17,000/m<sup>2</sup>. They are gonochoric (separate sexes) brooders. Embryogenesis takes place in the coelenteron (central cavity), and the larvae swim. Goffredo et al. (2006) reported that there are equal numbers of the two sexes. Spermaries take 12 months to mature but oocytes take 24 months. Fertilization is from January to April and planulation from May to June. Individuals reach sexual maturity at 3 mm diameter.

*Astroides calycularis* is a colonial azooxanthellate coral that has also been the subject of a few studies. Zibrowius (1995) reported that it prefers strong water movement and lives from near sea level down to about 30 m, typically in shaded locations below overhangs or at entrances to caves. He reports that *Astroides calycularis* is not present in the northern Mediterranean, but it is present in fossil deposits in the northern Mediterranean area. Apparently, warmer periods in the past allowed it to live in the northern Mediterranean. Transplantation experiments showed that while it can survive for some time in the northern Mediterranean, it is unable to grow or reproduce. This is an azooxanthellate coral, so the reason it can't grow or reproduce in the northern Mediterranean is not because of the inability of the zooxanthellae to withstand the cold. The eastern limit of its reported distribution is the southeastern Adriatic (near Dubrovnik: Kruzic et al. 2002; Grubelic et al. 2004). The current northern limit is in the northeast Adriatic (Grubelic et al. 2004). It was reported from the Adriatic in 1899, 1904, 1945, and 1991-2001. These times all correspond to warmer than usual periods. The most recent report of Grubelic et al. (2004) is of three individual colonies, all about 2-4 cm in diameter, at three widely spaced locations, ranging from 1 meter deep to between 25 and 30 m deep. All three colonies were collected. The map in the paper indicates a fourth coral, so a fourth coral may have been seen but not collected. Zibrowius (1974, 1995) gives details of where the species has been found, primarily along North Africa from the Straits of Gibraltar to Tunisia, Pantellaria and Linosa, but also Spain from Gibraltar to Cape Palos, and Sicily, Malta, the Aeolian Islands, Ventotene of the Gulf of Gaeta, and Italy from the Straits of Messina to Naples. It is also on the Atlantic coasts of Spain and Morocco, not far from Gibraltar. Benedetti et al. (2006), studied survey methods in a large cave in southwestern Italy, where *Astroides calycularis* and *Leptopsammia pruvoti* were common on all hard surfaces.

There have been few studies of the deep-water corals of the Mediterranean, because of the difficulty of accessing such corals. In one study, Orejas et al. (2008) reported that two deep-water corals (*Lophelia pertusa* and *Madrepora oculata*) collected from 218 and



214 m depth in the Mediterranean grew 15-17 mm/yr and 3-18 mm/yr in aquaria, respectively.

Studies of fossils of Mediterranean corals include Bernasconi et al. (1997). Aguirre and Jimenez (1998) reported extensive Upper Pleistocene fossil banks of *Cladocora caespitosa* in southeastern Spain, while Bernasconi et al. (1997) describe a Pleistocene fossil bank of this species in Crati, Calabria. Diseases do not appear to have been described in Mediterranean corals or azooxanthellate corals yet.

The present study was conducted to document the biodiversity and some of the basic ecology of corals in Capo Rizzuto marine protected area in Calabria, southern Italy, and establish monitoring sites for corals and other benthic organisms.

## **Aim of the study**

The aim of this study was to assess Scleractinia corals diversity within the Capo Rizzuto Marine Protected Area and to start long term monitoring to survey over time their presence, abundance, distribution, association with other benthic communities, their status of health (presence of diseases, bleaching, competition with introduced species such as the algae *Caulerpa racemosa*, anthropic stressors). The final objective is to identify potential threats to the health of the MPA's ecosystems for better planning mitigating actions against them, and to enrich the scientific knowledge regarding Mediterranean Scleractinia corals that are still very limited.

## **Methods**

Searches for corals were conducted at 22 sites, using SCUBA, to a maximum depth of 30 m in October, 2008. Most sites had little slope, so the range of depths searched at any one site was limited. Site coordinates were recorded with a portable GPS unit. Information on sites is presented in Table 1 and a map in Figure 2.



Figure 2. Capo Rizzuto Marine Protected Area zoning and survey sites location

Dive#	Site Name	Date	Depth	LAT	LONG	Monitoring	# Visits	Samples	Species
1	Relittone	14-Sep-08	9.5	38.87602	17.02540	Clad./Quadrats	2	3	6
2	Atollo basso	15-Sep-08	10	38.89733	17.01640	No	1	0	1
3	Scogliera	16-Sep-08	14.2	38.90634	17.02533	No	1	1	1
4	Scogliera Cala Greca	17-Sep-08	5.8	38.91147	17.07565	No	1	0	2
5	Relittino	17-Sep-08	8.5	38.90870	17.00608	Cladocora	1	6	4
6	Bengala	18-Sep-08	27.6	38.910512	17.02656	Cladocora	2	5	7
7	Capo Bianco	18-Sep-08	6	38.90272	17.11002	No	1	3	2
8	Capo Cimiti	19-Sep-08	7-20	38.94963	17.16818	No	1	2	2
9	Gunny	22-Sep-08	14-23	38.91448	17.13337	Cladocora	1	5	7
10	East Castello	24-Sep-08	5-9	38.90607	17.02222	No	1	1	2
11	West Castello	24-Sep-08	5-9	38.90722	17.02105	No	1	0	1
12	Atollo Profondo	25-Sep-08	20-25	38.90525	17.05677	No	1	0	1
13	Ponente Basso	26-Sep-08	25-30	38.88623	16.99983	No	1	1	1
14	Palombaro	26-Sep-08	16-21	38.90545	17.00338	No	1	2	5
15	Sella	29-Sep-08	25-28	38.89045	17.00593	No	1	0	2
16	Paco 2	29-Sep-08	18-22	38.90428	17.00485	No	1	0	4
17	East Castello 2	30-Sep-08	7	38.90645	17.02042	Transect	1	0	1
18	Praialonga	01-Oct-08	7	38.92265	16.99857	Transect	1	0	0
19	Capo Colonna South 1	03-Oct-08	6	39.02906	17.20378	No	1	3	4
20	Capo Colonna South 2	03-Oct-08	8	39.03087	17.20503	Transect	1	0	2
21	Capo Colonna South 3	03-Oct-08	8	39.02952	17.20350	Transect	1	0	1
22	Panettoni	07-Oct-08	22	38.90280	17.13462	No	1	0	2
	Totals						24	32	

**Table 1. Information about the sites surveyed during this study.**

At sites without wrecks, searches were concentrated on the ceilings of overhanging hard surfaces, which are the preferred habitat of most azooxanthellate corals. At most sites, such habitats were found primarily under the edges of boulders, but formations in some areas appear as gullies or holes. Vertical and slightly overhanging surfaces were generally not searched as preliminary searches revealed no corals. Searches were concentrated on lower light level recesses where the chance of finding corals was greatest. Searching was aided by the use of underwater lights. Sponges and other invertebrates were also photographed. On wrecks, overhanging surfaces were also searched, primarily those with the lowest light levels. On the deepest wrecks, some near-vertical surfaces also had corals. In shallow water (~2-7 m depth) at some sites, illuminated surfaces were searched for the zooxanthellate coral, *Balanophyllia europaea*, and individuals counted.



**Figure 3. Surveying corals**

When corals were collected, a numbered container was photographed, and then the coral to be collected was photographed. Then the coral was collected and placed in the container. Tissue was removed from corals with bleach, and then they were photographed and examined under a dissecting microscope. Initial identification was by DF using Zibrowius (1980), and subsequently verified by H. Zibrowius from photos.



**Figure 4. Diver laying a point-intercept transect**

Population surveys were carried out to provide baseline data for future monitoring. Transects were used to collect benthic cover information at a number of sites. A 50-meter transect tape was placed parallel to the coast, at about 5 m depth. A point-intercept survey was conducted by recording the benthic cover or substrate at each 0.5 m point, producing 100 points. Categories recorded included algae, *Padina* sp., *Caulerpa racemosa* var *cylindracea*, other green alga, seagrass (*Posidonia oceanica*), sponge, sand and rock. On a return pass, two observers counted *Balanophyllia europaea* individuals in a 0.5 m wide belt, one observer on each side of the tape, for the same 50 m.

Colonies of *Cladocora caespitosa* were photographed, their location relative to wrecks recorded, and for two colonies their greatest horizontal length measured.

On one wreck (Relittino), quadrat frames of PVC pipe filled with air and 25 cm on a side were placed haphazardly on an overhanging structure that had azooxanthellate corals, and were photographed to survey corals.

## Results

### The Corals

A total of 10 species of coral were found in this study, two having zooxanthellae, seven without zooxanthellae, and one that usually was without but was also capable of having zooxanthellae. The species are listed in Table 2. None were previously known from the Capo Rizzuto area, and *Paracyathus pulchellus*, *Polycyathus muelleræ* and *Astroides calycularis* were not previously known from the Ionian Sea.

	Species Name	Abundance	Zooxanthellae	Sites
1.	<i>Balanophyllia europaea</i>	Common	Yes	1,2,3,4,7,8,10,11,19
2.	<i>Caryophyllia inornata</i>	Common	No	1,4,5,6,7,8,9,19,20,21
3.	<i>Cladocora caespitosa</i>	Rare	Yes	1,5,6,9
4.	<i>Cladopsammia rolandi</i>	Uncommon	No	10,14,15,16,19
5.	<i>Hoplangia durotrix</i>	Common	No	1,5,6,9,16
6.	<i>Leptopsammia pruvoti</i>	Rare	No	14, 19
7.	<i>Madracis pharensis</i>	Common	Sometimes	6,9,12,13,14,15,16
8.	<i>Paracyathus pulchellus</i>	Uncommon	No	1,6,8,9,14,16,22
9.	<i>Phyllangia mouchezii</i>	Rare	No	14
10.	<i>Polycyathus muelleræ</i>	Uncommon	No	6,9,19
11.	<i>Astroides calycularis</i>	Rare	No	Photograph

**Table 2.** List of coral species found during this study

Eight of the coral species were identified from skeletons using Zibrowius (1980) and verified by H. Zibrowius from photographs of the skeletons, and one species (*Cladopsammia rolandi*) was identified by H. Zibrowius from photos of skeletons. One species (*Phyllangia mouchezii*) was identified by H. Zibrowius from a photograph of the living coral, and one species (*Astroides calycularis*) was identified from a color photo on the Capo Rizzuto MPA website. The photographer reports that the photo was taken within the Capo Rizzuto MPA.

The 11 species of corals found here were less than the number that have previously been found in studies of coral in the nearest places that have been studied: Sicily (14: Zibrowius, 1980), Naples (18: Zibrowius, 1980), and Croatia (18: Kruzic, 2002). However, these other studies were all able to have greater effort spent searching, such as the study in Croatia which involved a number of people over 3 years studying 57 sites. The number of species found always increases with increasing effort, and so 11 species is a relatively high diversity to be found in the Mediterranean in a study with the modest effort possible in the present study. Just eight species are known from Lebanon so far, indicating lower coral diversity in the south-eastern Mediterranean (total: 10 species; Bitar and Zibrowius, 1997). A total of 50% of the 22 species of shallow-water (less than 30 m depth) corals known from the Mediterranean were found in this study. The number



of species found typically increases rapidly with effort at the beginning of searching, and then slows with continuing effort as seen in Figure 5.

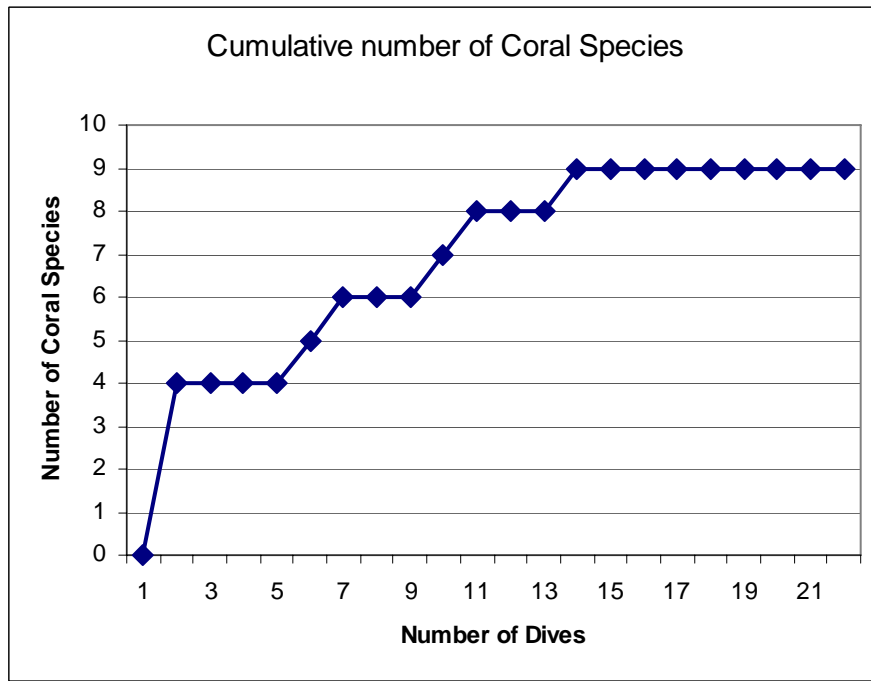


Figure 5. Cumulative number of coral species found over number of dives

The following information illustrates aspects of the biology of corals in the Mediterranean that live in shallow water (less than 30 meters deep). In Figure 6, it can be seen that nearly all tropical corals are zooxanthellate, but in the Mediterranean only about a fifth of all species are zooxanthellate.

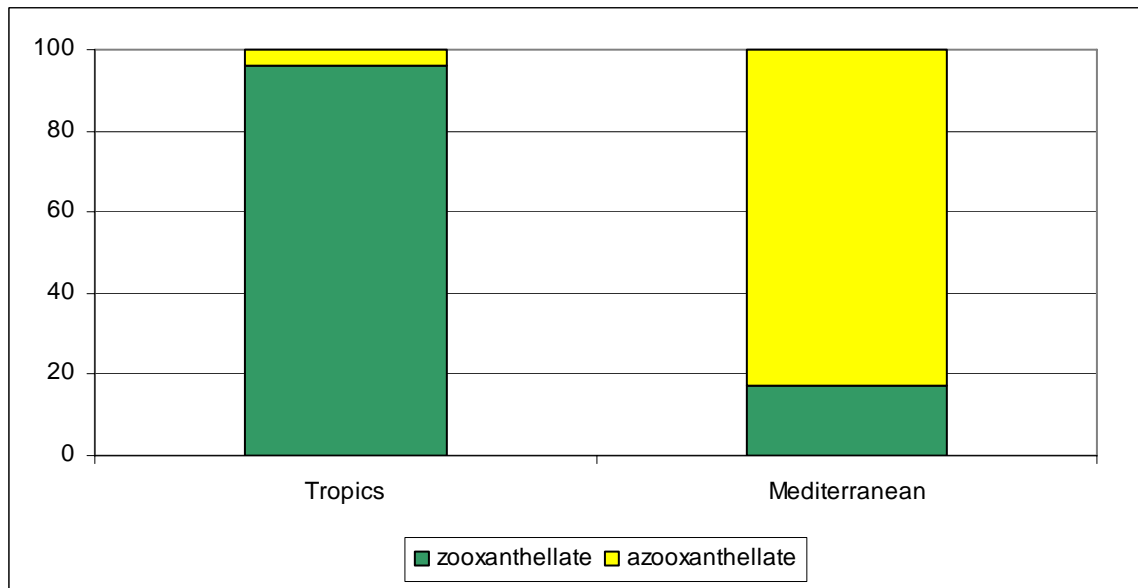


Figure 6. Percentage of zooxanthellate and azooxanthellate coral species found in the tropics and in the Mediterranean sea.

Zooxanthellate species in the shallow Mediterranean are on the average much larger than azooxanthellate species (4cm average width versus <5mm), though there is a wide range of sizes in both groups.

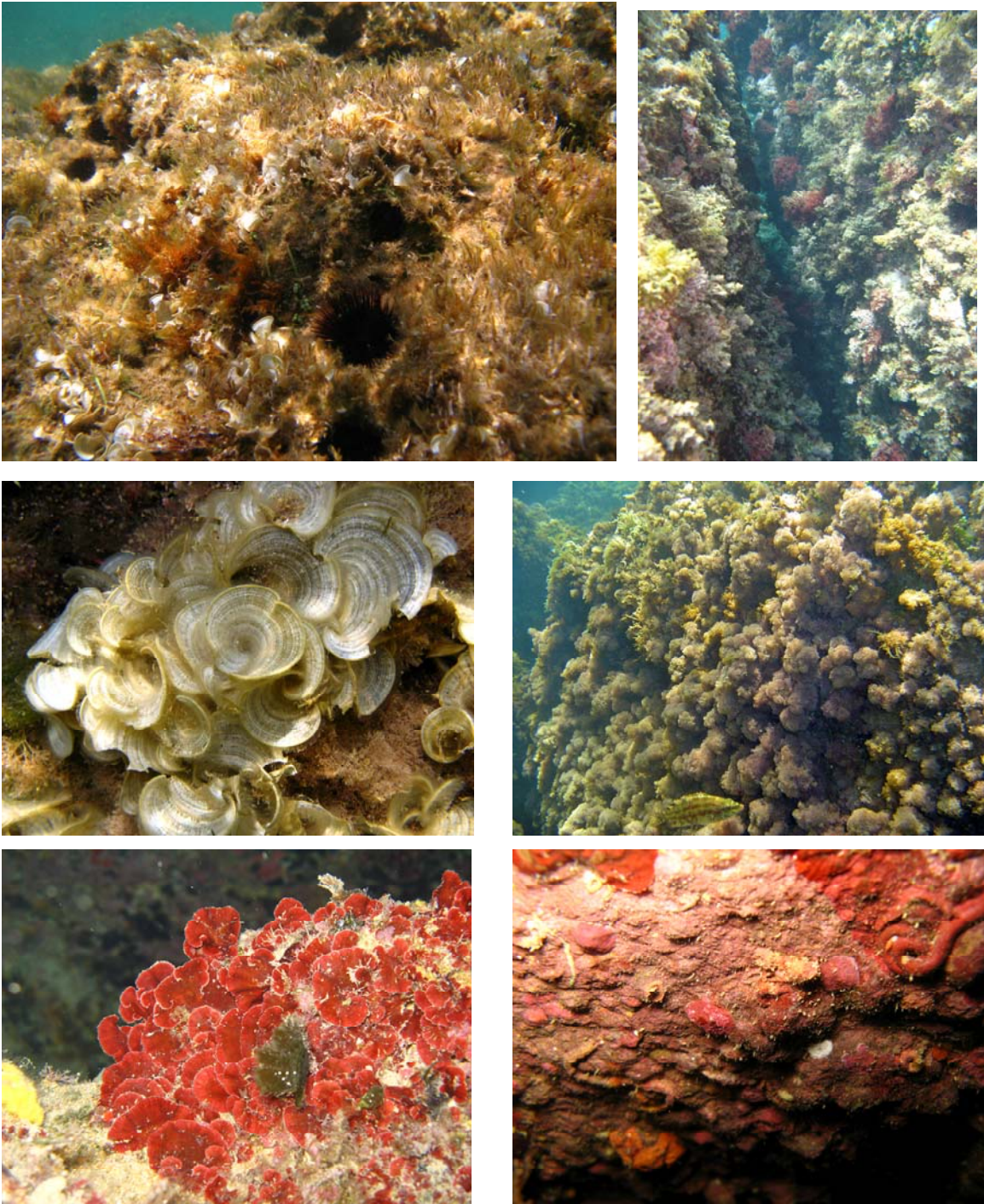
Most zooxanthellate corals in shallow Mediterranean waters are colonial (having more than one polyp), while just half of azooxanthellate corals are colonial.

All but one of the shallow water Mediterranean coral species are attached to the substrate.

Appendixes A and B present some characteristics of all the shallow-water corals in the Mediterranean. Appendix C presents which species were found at which site in this study. Appendix D presents data on the samples that were collected. Appendix E presents the quantitative data from the point-intercept monitoring transects. Appendix F gives site descriptions for each of the sites studied.

## **Ecology of the Corals**

Most hard surfaces exposed to light were found to be heavily dominated by algae, primarily the brown alga *Padina* sp. and turf algae that formed a dense layer several centimeters thick (**Figure 7**). Small areas most commonly about 10-20 cm diameter were clear of fleshy and turf algae, and were most commonly yellow, though some areas of pink coralline algae occurred. Patches occasionally had one or more sea urchins in a hole nearby. The solitary zooxanthellate coral *Balanophyllia europaea* was found most often in bare yellow patches, though some were found among fleshy algae. Most were found on sloping surfaces, and they appeared to be more common in shallow water than deeper. Vertical surfaces commonly were densely covered with turf algae. Sloping overhangs with less light were often dominated by foliose and encrusting red algae, probably including *Peysonellia* sp. (**Figure 7**) Sometimes the floors under overhangs were dominated by foliose red algae. Several areas in the Capo Rizzuto MPA are dominated by *Posidonia oceanica* (seagrass) but these sites were not selected for surveys in this study as they were unlikely to have favorable habitat for corals (**Figure 10**). Overhanging surfaces with still less light were dominated primarily by encrusting sponges, though several species of bryozoans were also common. Azooxanthellate corals were only found on the least well lit of ceilings dominated by encrusting sponges, and were in general rare, being found on only a small proportion of such surfaces. On wrecks, surfaces had similar communities depending on light levels. However, among the overhanging surfaces with the lowest light levels, some such surfaces had large populations of azooxanthellate corals.



**Figure 7. Habitats dominated by various types of algae and found in the Capo Rizzuto MPA area**

Even vertical surfaces on the deepest wrecks had some azooxanthellate corals. In general, dark overhanging surfaces on wrecks had much higher densities of azooxanthellate corals than similar surfaces under the edges of boulders. Thus, wrecks provide additional, preferred habitat for azooxanthellate corals and increase populations (Figure 8).

A slightly different habitat was encountered at deeper sites slightly south of Le Castella (Ponente Basso, Palombaro, Sella, and Paco 2). In these areas, there were edges of lumps and grooves. Instead of obvious boulders with spaces under their edges, there were horizontal holes on the sides of the lumps and grooves. On the lumps at the two shallower sites, some of the holes were part way up the side of the lump. Further, looking into the holes, instead of a smooth surface covered with encrusting sponges, surfaces were very



Figure 8. Relittone wreck

irregular, and had a variety of life on them. These sites had many *Madracis pharensis* colonies and *Cladopsammia rolandi* individuals, which the sites with boulders had few if any. Descriptions of individual sites is presented in Appendix A.

## Monitoring Results

### *Point-intercept transects*

Quantitative measures of the community exposed to light were made at four sites. Figure 9 shows the results. One site (Praialonga) was dominated by seagrass. The other three sites were dominated by algae, including algae of the genus *Padina*, which were recorded separately. Although the introduced and invasive alga *Caulerpa racemosa* var. *cylindracea* was present at most sites with algae and could easily be found, it was not dominant at any of the sites studied. Other sites within the MPA have been documented to be dominated by *Caulerpa racemosa* (Figure 10), thus monitoring its abundance at other sites is important. Sand and rock represented a portion of the substrate at most sites, and clay was found at one site (East Castello). Counts of *Balanophyllia europaea* in half meter belt transects on either side of the tape at East Castello produced 23 individuals in 50 m<sup>2</sup> or a density of 46/100 m<sup>2</sup>. Similar belt transects at the other two locations did not produce any *Balanophyllia europaea*.



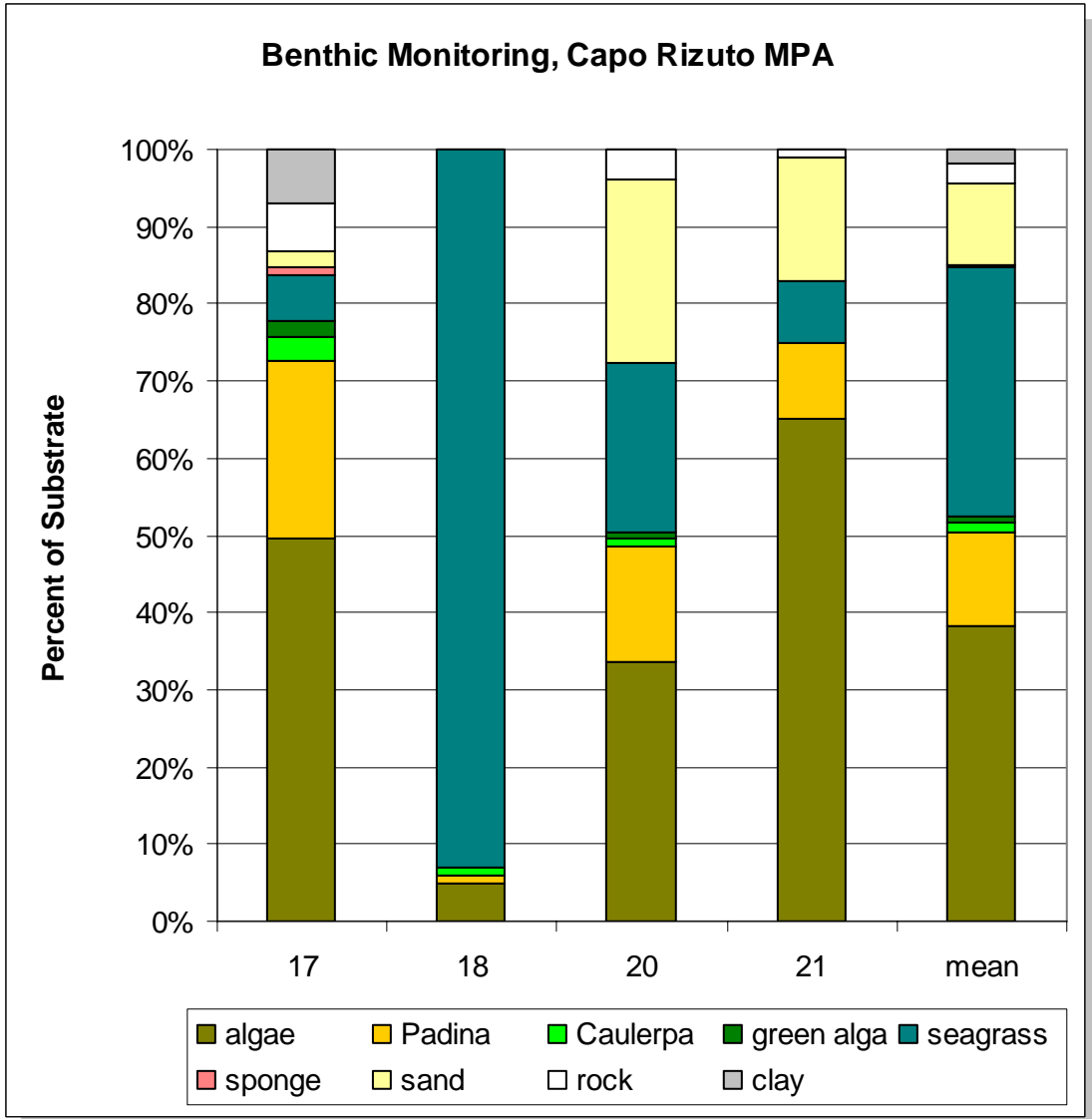


Figure 9. Quantitative monitoring results

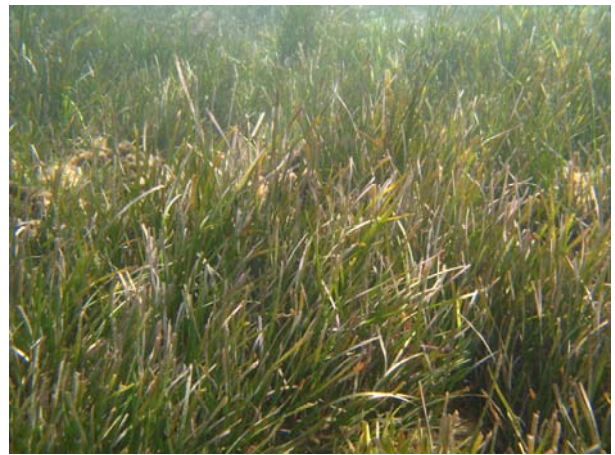


Figure 10. Area dominated by *Caulerpa racemosa* (left) and *Posidonia oceanica* (right)



### ***Cladocora caespitosa* colonies**

Four colonies of *Cladocora caespitosa* were found during the 22 dives. One colony was found on the wreck of the Relittone, one near the wreck of the Relittino, one on the Gunny, and one on the Bengala; all were photographed. A photo of the colony on the Relittone from 2006 is also available. The colony on the wreck of the Bengala was 8 cm in longest horizontal dimension, while the colony on the Relittone was 13 cm; the others were similar in size though not measured. A photograph of the colony near the wreck of the Relittino showed the introduced and invasive algae, *Caulerpa racemosa* var *cylindracea* next to the colony and perhaps starting to grow over it. This invasive alga has been observed to grow over this coral and could threaten it. Kruzic et al. (2008a) reported it was growing over the largest known bed of this species (in Croatia) and causing the coral tissues to retract and mucus to be secreted, indicating stress. Photographs of each colony are presented in Appendix D

### ***Balanophyllia europaea* counts:**

At Site 10, on the north side of the Castello, 45 individual *Balanophyllia europaea* were counted in the latter part of the dive after overhangs were searched for azooxanthellate corals. At Site 7, Capo Bianco 9 individuals were counted, and at Site 11 on the south side of the Castello, 65 were counted. All were within areas of a light yellow coralline algae with no other algae. Although none were found in the filamentous or fleshy algae at monitoring sites, some have been found among fleshy algae in other dives.

### ***Quadrats***

Photos were taken of 25 cm X 25 cm quadrats on the ceiling of a space in the wreck of the Relittone. There were a large number of azooxanthellate corals on that surface, with *Caryophyllia inornata* appearing to be the most common species. It turned out that the area photographed was too large, so the corals were too small in the photos to be reliably counted. One attempt produced a count of 72 corals in one quadrat. That would give a density of 1.15 corals per 10 cm<sup>2</sup>, or 1152 per m<sup>2</sup>. Although the area of available habitat in this space was not measured, it would appear to be on the order of one square meter. Thus, this habitat may provide space for around a thousand corals. A method was not devised for marking the location of the quadrats, so it will not be possible to return the quadrats to the same location in the future to monitor these populations. Smaller quadrats are required, and some method would need to be devised to mark the locations used. That will not be easy on the steel plate, underwater, working upside down, in fairly low light.

### **Bleaching and diseases**

No signs of either coral bleaching or coral disease were observed during this study. Bleaching has been reported in Mediterranean corals, but disease has not to our knowledge.

### **Fossils**

Fossils of *Cladocora caespitosa* were found in rocks just above sea level in the center of the town of Le Castella, opposite to the castle. H. Zibrowius confirmed the identity of the fossils from photographs. The fossil-bearing rocks were between

sandstone layers. Most of the fossils were individual scattered cylindrical corallites that could easily be removed from the matrix, but in one or two spots there were several corallites that appeared to still be in the form of the original colony. The age of the fossils is unknown to the authors.



Figure 11. Coral fossils found in rocks above the sea level near the centre of Le Castella.

### Species Descriptions

For more detailed descriptions of coral skeletons, see Zibrowius (1980).

### Family Astrocoeniidae

*Madracis pharensis* (Heller, 1868). Sites 6, 9, 12, 13, 14, 15, 16.

This colonial species forms groups of rounded lumps or knobs about 4-15 mm diameter, often on overhanging surfaces. Living colonies in the dark are white or light grey (one colony in a photograph was light green), and colonies in light are brown. Corallites are about 2 mm diameter, with a columella composed of a single tapering spine and two orders of 10 simple septa. First order septa connect with the columella in the shallow corallite, and are exert as spine-like points at the edge of the calice. Second order septa do not reach the columella, are often rudimentary, and may be incomplete. In the living coral, tentacles are often extended.

This species can be either zooxanthellate or azooxanthellate. It was most abundant by far at Site 13, Ponente Basso, at 25-30 m depths. At this site, small horizontal holes around 30-50 cm diameter were found inside larger grooves or vertical holes. Nearly every one of the horizontal holes had *Madracis pharensis* covering the entire ceiling of the hole. At a few holes, knobs of *Madracis pharensis* near the opening had brown color indicating zooxanthellae. At a couple holes, there were significant amounts of *Madracis pharensis* outside the hole. *Madracis pharensis* outside the hole was dark brown and had larger knobs than inside the holes, up to about 3 cm diameter. At Site 15, Sella, about

one quarter to one third of holes had *Madracis pharensis* on the ceiling, and a few knobs were close enough to the entrance to be brown.

This species was originally described from the Mediterranean, and has been reported from the Caribbean (e.g., Fenner, 1993; Veron, 2000), Galapagos (Wells, 1983) and Hawaii (Fenner, 2005). In the Caribbean and Hawaii, colonies grow on the ceilings of caves, form knobs, and can have orange or pink colors. Skeletal details do not differ from Mediterranean specimens, but the skeletons are simple and have few taxonomic characters, and given the geographic separation, genetics may reveal differences in the future. Genes that in other types of organisms show clear differences between species often show no differences between some coral species, making coral genetics difficult.



Figure 12. Living zooxanthellate colonies of *Madracis pharensis*.



*Madracis pharensis*. The white lumps are the living azooxanthellate colonies, and the smaller brown structures on them are the polyps which are about 2mm diameter. All photos were taken in Capo Rizzuto Marine Protected Area.

Figure 13. Living azooxanthellate colonies of *Madracis pharensis*.



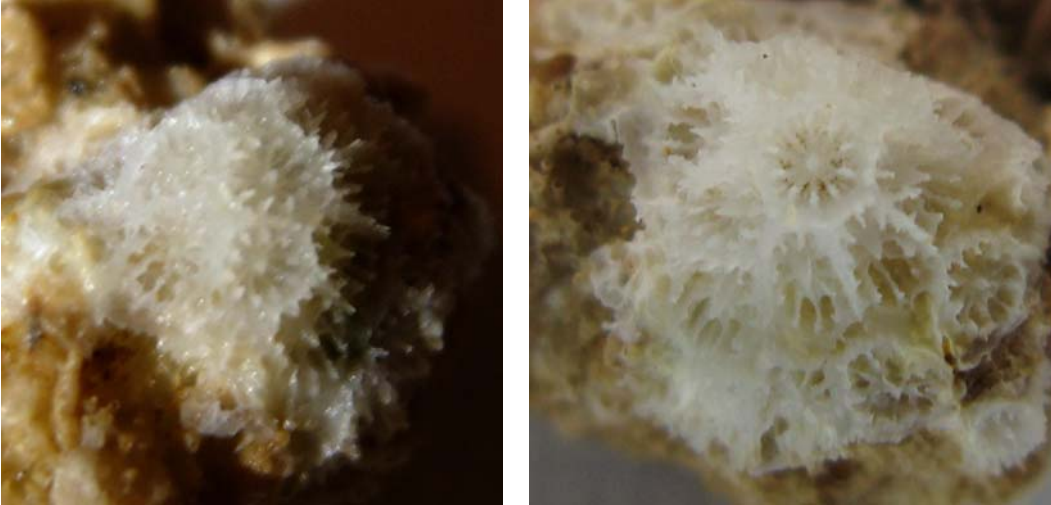


Figure 14. *Madracis pharensis*, skeleton.

### Family Faviidae

*Cladocora caespitosa* (Linneus, 1767). Sites 1, 5, 6 and 9.

This colonial, zooxanthellate coral forms the largest colonies found in the Mediterranean, which can be as large as a meter or more in diameter, or rarely colonies may fuse to form wide undulating fields (Kruzic and Pozar-Domac, 2003). Corallites are about 8 mm



Figure 15. Corallites of *Cladocora caespitosa*.

diameter, circular, and are on the tips of parallel branches, so that the colony forms what is formally called a “phaceloid” colony. Branches are separated by just 2-3 mm, and all end at the same level, forming a surface so that the colony almost looks solid instead of being composed of branches. This shape is often called “sub-massive” as it appears to be a solid mass but actually has deep separations between branches. Colonies can have more open branching as seen in Zibrowius (1980), but

such colonies were not observed. Two orders of septa can usually be distinguished, with the first order extending to the columella, and the second order not. First order septa in our sample each had a single palus, second order septa did not. The columella is usually large and papillose. Costae extend down the exterior surface of the corallite.

All colonies found were on the order of 6-10 cm diameter, in sunlit areas. Three of the four colonies were growing directly on wrecks, and one was near a wreck. This species certainly does not require wreck surfaces and hasn’t been reported to be more

common on wrecks. It is the least common of the three species found that can host zooxanthellae. It is brown or yellow.



Figure 16. *Cladocora caespitosa*, living colony.



Figure 17. *Cladocora caespitosa*, skeletons of two corallites.



## Family Caryophyllidae

*Caryophyllia inornata* (Duncan, 1878). Sites 1, 4, 5, 6, 7, 8, and 9, 19, 20, 21.

This solitary, azooxanthellate coral is very common on some overhanging surfaces of natural formations and wrecks. It is small, about 3-7 mm diameter at most, circular, and white or pink. It was most common on the underside of a domed section of the wreck of the Relittone, and second most common on the wreck of the Bengala. There are three orders of septa, and first order septa are quite exert (projecting). There are pali. The columella is a tangle, which shows different degrees of development in different individuals.



Figure 18. Living *Caryophyllia inornata* (center of the photo). Each corallite is about 3 mm diameter.



Figure 19. Skeleton of *Caryophyllia inornata*.

*Paracyathus pulchellus* (Philippi, 1842). Sites 1, 6, 8, 9, 14, and 16, 22.

This solitary, azooxanthellate coral is uncommon on overhanging and vertical surfaces of



Figure 20. Living *Paracyathus pulchellus*

natural formations and wrecks. It is small, about 6-10 mm diameter maximum size, oval, and usually brown. Some of the septa are more exert (raised higher) than other septa enough to be seen projecting in the living coral. In photographs of living corals, a ring of projections called pali may be seen just inside the septa. The adults of this species seem to be scattered, though photos sometimes reveal smaller individuals in the area of the adult. They are easily distinguished by being larger than the other solitary azooxanthellate corals. Two or three orders of septa can be distinguished, with the first order being

much more exert than the other orders.

There are pali in front of many of the septa

including all the first order septa and most other septa. There may be more than one palus in front of some septa. The pali are often oval but some may be round.





Figure 21. Living *Paracyathus pulchellus*



Figure 22. Skeletons of *Paracyathus pulchellus*.

*Polycyathus muelleriae* (Abel, 1959). Sites 6, 9, and 19.



**Figure 23.** Living corallites of *Polycyathus muelleriae*

This colonial, azooxanthellate coral is uncommon to rare in some places but fairly common in some areas such as wrecks. It may be visible as a cluster of corallites all the same size with other organisms such as sponges between them, or there may be bare colony surface between corallites. For those with other organisms growing between the corallites, it is likely that there is skeleton underneath those organisms uniting the corallites physically, though coral tissue is unlikely to be connecting them. Colonies are around 5 – 10 cm diameter, with individual corallites about 4-6 mm

diameter, separated from each other by about 1-5 mm. For a few colonies, the bare surface of the colony shows a low branching formation. Most corallites are circular but a few are oval. Corallites have a thinner outer rim of septa and larger depression in the center than other species. Ridges called costae running down the sides of corallites can be seen in photos of live colonies. In the cleaned skeleton, at least two orders of septa can be seen with the first order slightly more exert than other septa and projecting farther into the center. Most septa have rounded pali in front of them. The columella in the center consists of similar but smaller and shorter projections than the pali.



**Figure 24.** Living colonies of *Polycyathus muelleriae*.





Figure 25. Living colonies of *Polycyathus muellerae*.



Figure 26. The skeleton of a single corallite of *Polycyathus muellerae*.

*Hoplangia durotrix* Goss 1860. Sites 1, 5, 6,9 and 16.



Figure 27. Living *Hoplangia durotrix*

This colonial, azooxanthellate coral was recorded at five sites and was very common in and reached high densities on some wreck overhanging surfaces (Figure 30). It was identified from one specimen and various photographs. Individual corallites are circular and about 3-4 mm in diameter. It is easily distinguished from *Caryophyllia inornata* in living individuals when it forms a colony, because *Caryophyllia inornata* is solitary. Solitary individuals differ by having a deeper hole in the

center of the corallite. In the skeleton, first order septa are more exert than the second and third order septa. The center is very deep and there are no pali and a very rudimentary columella if any.

center of the corallite. In the skeleton, first order septa are more

exert than the second and third order septa. The center is very deep and there are no pali and a very rudimentary columella if any.

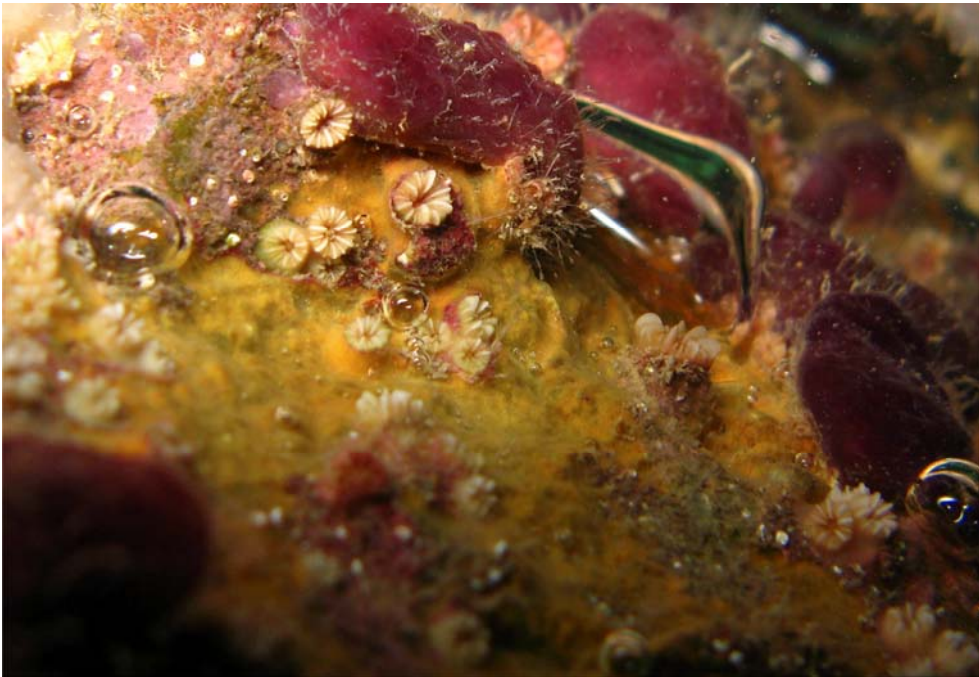


Figure 28. Living *Hoplangia durotrix*





Figure 29. Skeleton of *Hoplangia durotrix*.

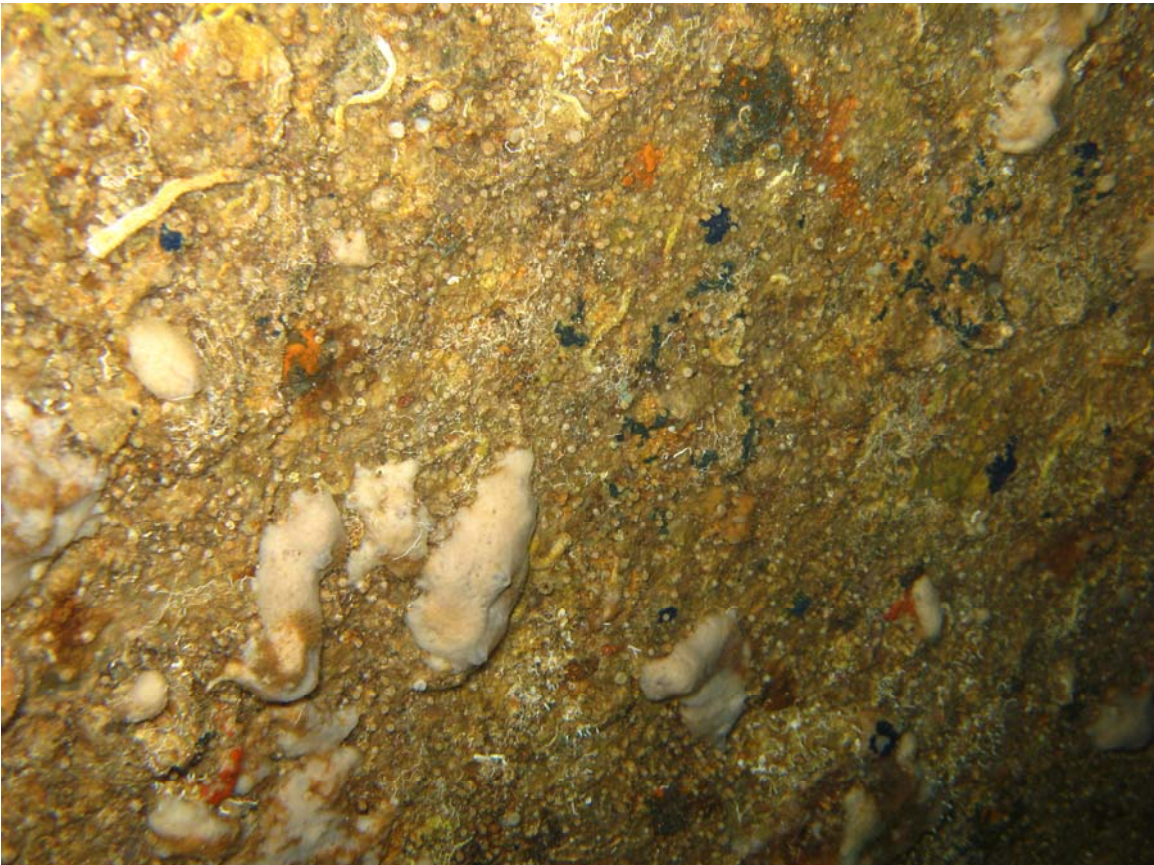


Figure 30. Overhang with high numbers and density of *Hoplangia durotrix*.

*Phyllangia mouchezii* (Lacaze-Duthiers, 1897). Site 14.

This colonial, azooxanthellate coral was identified by H. Zibrowius from one photograph of live corals, and so would appear to be rare in the study area. This species can form clusters of short corallites, or can form branching colonies, with a corallite at the end of each branch. In the illustration, it appears that it has four or five corallites joined at the base. Zibrowius (1980) shows the septa to be in at least 3 cycles of greatly different length but the first order septa are not very exert.



Figure 31. A photo of living *Phyllangia mouchezii*.

### **Family Dendrophylliidae**

*Cladopsammia rolandi* Lacaze-Duthiers, 1897. Sites 10, 14, 15 and 16.

This colonial azooxanthellate coral was quite common at two medium-depth sites at the western end of the MPA, Sella and Paco 2, being most common at Paco 2. Individuals



are circular and small, about 3 mm in diameter. Living individuals appear bright yellow and thus are relatively easy to distinguish. In photographs, some individuals appear yellow and others appear orange. It is not known whether the color difference can be used to distinguish it from *Leptopsammia pruvoti*, which was collected from the same groups of corals. Corallites are round or slightly oval. The septa are arranged in a Pourtales Plan which means that they fuse, and larger septa are commonly surrounded by other large septa on both sides of them that diverge from them near the center of the corallite and fuse with their counterparts from another first-order septum. This distinctive pattern is a common signature of the family. It is less obvious in at least some individuals of the otherwise very similar looking *Leptopsammia pruvoti* as shown in Zibrowius (1980). The columella is variable in size, and the outside has small granulated costae with pores between.



Figure 32. Living *Cladopsammia rolandi*.





Figure 33. Skeleton of *Cladopsammia rolandi*.

*Balanophyllia europaea* (Risso, 1826). Sites 1, 2, 3, 4, 7, 8, 10, 11, 17 and 19.



Figure 35. Living *Balanophyllia europaea*

This solitary zooxanthellate coral was quite common at sites 3, 10, and 11. Corallites are up to about 2 cm diameter and a similar height. Young individuals are circular, while larger individuals are oval and the largest individuals can be rectangular or be concave on one or both of the longer sides. They appeared to be most common in patches of a yellow encrusting coralline algae, and appeared to be more common on slopes than on flat surfaces. Septa show a Pourtales Plan of curving and fusing much like *Cladopsammia*. The columella is papillose or spongy. The outer surface has small costae with granules forming rows and pores between the granules. Individuals appear brown.

Individuals appear brown.



Figure 34. A cluster of *Balanophyllia europaea* corallites



Figure 36. Living individuals of *Balanophyllia europaea*.



Figure 37. Skeletons of *Balanophyllia europaea*.



*Leptopsammia pruvoti* Laze-Duthiers, 1897. Site 14, 19.

This solitary azooxanthellate coral was identified from one specimen at one site and photographed at two sites. It is well known for being a bright yellow (e.g., Aguilar, 200?). It is about 3 mm diameter and circular. It is not known what distinguishes it in the field from *Cladopsammia rolandi* though there might be some color differentiation. In some corallites septa can show little evidence of Pourtales Plan, or it can be quite obvious. The columella can be so small it is almost non-existent, or it can be very large (Zibrowius, 1980). The costae are small, granulated and have pores between them.



Figure 38. Skeleton of *Leptopsammia pruvoti*.

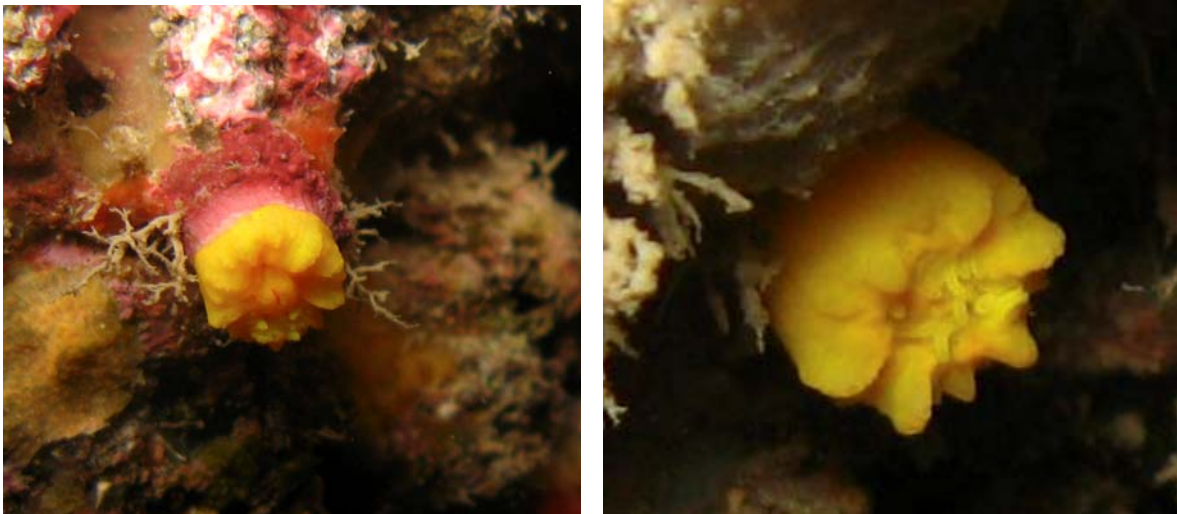


Figure 39. Living *Leptopsammia pruvoti*.

*Astroides calycularis* (Pallas, 1766).

This colonial, azooxanthellate coral appears to be rare in the Capo Rizzuto MPA, as it was not sighted in this study. However, a photograph of it appears on the Capo Rizzuto website (<http://www.riservamarinacaporizzuto.it/galleria/galleria.php?cod=12#>), and the photographer (G. Felicetti) confirmed that the photo was taken within the reserve. This coral is bright orange and forms encrusting colonies with short projecting corallites.

## Discussion

The present, relatively brief study was able to find 10 species of coral in Capo Rizzuto Marine Protected Area, plus an additional species identified on a photograph available on the Capo Rizzuto MPA website. This 11 species is 50% of all the coral species known in shallow water (less than 30 meters depth) in the entire Mediterranean. Additional effort and larger areas both increase the number of species found, so this is a good number of coral species to have found in the Capo Rizzuto reserve in a relatively brief study of a relatively small area. Two of the species host zooxanthellae algae and are thus found in light. One of these is solitary (*Balanophyllia europaea*) and the other colonial (*Cladocora caespitosa*). The former is relatively common in some areas, but small, reaching only about 2 cm in diameter. It was found most often in patches of a light yellow coralline algae. This aspect of its ecology may not have been previously known, and makes it much easier to find than by random searching. The larvae of this species swim (Goffredo and Zaccanti, 2004) and may be attracted by a chemical released from the coralline algae, much as larvae of the Caribbean coral *Agaricia agaricites* are attracted by a chemical produced by bacteria on coralline algae (Morse and Morse, 1996; Haywood and Negri, 1999). Further study will be needed to verify that the *Balanophyllia europaea* is more common in yellow patches than in algae; macroalgae cover would make it more difficult to find.

*Cladocora caespitosa* was relatively rare in the reserve, although fossils were found near the shoreline. Fossils of this species are known from the Crati valley of Calabria (Bernasconi et al. 1997) and are common in the Mediterranean area (Aguirre and Jimenez, 1998; Peirano et al. 1998). Populations of *Cladocora caespitosa* are said to be primarily controlled by competition with soft frondose algae (Peirano et al. 1998; Morri et al. 2000). Urchins are strong grazers on algae (Hereu, 2006). Beds of *Cladocora caespitosa* develop only on rock cleared by sea urchin grazing (Herndl and Velimirov, 1986; Morri et al. 2000). Areas cleared by urchins were quite small and uncommon in the study area, as the abundance of sea urchins was relatively low. *Oculina patagonica* was not found in this study, which fits with the report that it is abundant and increasing in abundance in Spain but may be less common in Italy, known from only a few colonies near Savona (Bitar and Zibrowius, 1997; Fine and Zibrowius, 2001) and four sites on the Ligurian Coast (H. Zibrowius, personal comm.), though at Albissola it is fairly common.

Most of the coral species present in Capo Rizzuto Marine Protected Area are quite small, azooxanthellate species which were found in dark locations, on the roofs of dark overhangs and ceiling surfaces on wrecks. Typical sizes were about 3 mm diameter. They inhabit the ceilings of these spaces and never the sides or floors, as the ceilings are not subject to the deposit of sediment. They were abundant at one site on the wreck of

the Relittone, fairly common on some surfaces of other wrecks, and uncommon to rare on the overhanging surfaces of the undersides of boulders. There were two main exceptions to this. First, *Madracis pharensis* was abundant at some deeper sites characterized by softer substrate with holes instead of overhanging edges of boulders. At one such site *Madracis pharensis* was present in nearly every hole searched. This coral is colonial, and closely related to zooxanthellate species found on tropical coral reefs. Where parts of the colony extended out near the mouth of the hole or even outside the hole, the colony had a brown color which indicated the presence of zooxanthellae, and the colony formed larger lumps or knobs. The larger knobs of the zooxanthellate portion of the colony probably indicate that the zooxanthellae provided the colony with additional energy to form a larger skeleton. In other sites directly shoreward from the sites with high populations of *Madracis pharensis*, *Cladopsammia rolandi* was abundant on many overhanging surfaces.

Monitoring stations were set up and baseline surveys made of benthic organisms on illuminated surfaces, and quantitative counts of zooxanthellate species taken. The introduced and invasive alga *Caulerpa racemosa* var. *cylindracea* was present at most sites but not dominant. The monitoring stations provide a baseline to monitor the abundance of this potentially harmful alga.

Several additional things would be good to study in the future. The areas where *Cladopsammia rolandi* were common had living corals that appeared yellow, but some photographed partly orange. At least one skeleton proved to be *Leptopsammia pruvoti*. This area should be searched in more detail and more corals collected with photographs in which the collected coral is pointed out, so that distinctive features of these two species can be determined and the relative populations of the two species determined. In addition, if more *Phyllangia mouchezii* can be found, one should be collected to verify that the identification is correct. A member of the Aquarium staff is said to remember locations near the Le Castella harbor where another species, *Astroides calycularis*, had been seen. A photo of a living colony of *Astroides calycularis* is also shown on the Capo Rizzuto website, though the location where the photo was taken is not presently known. Also, the Aquarium staff person is said to know where larger colonies of *Cladocora caespitosa* live. Unfortunately, this person was not available to show the investigators these corals before the end of the study. Both of these should be investigated in future studies. A more formal study of the possible association between the yellow coralline algae patches and *Balanophyllia europaea* should be carried out to see if it is more abundant in those patches than in a similar area of algae. Also, the abundance of sea urchins should be recorded, since they may be a keystone species controlling the abundance of algae and thus of zooxanthellate corals like *Cladocora caespitosa*.

A variety of other organisms were found in this study and photographed. Sponges were particularly abundant and diverse on the shaded overhanging surfaces searched for coral. Well over 20 species could be distinguished in the photographs, and additional species were being found right up to the end of the study, indicating that more species remain to be found and a high diversity of species is present. Living sponges are often quite distinctive, but identification of species requires a sponge taxonomist. Often, the identities of living sponges are not known because species descriptions were originally done on preserved or dead sponges, with all color gone, no information on habitat was recorded, and often no tissue is left. In future studies, samples of photographed sponges



should be collected and provided to sponge taxonomists for identification. It is likely such a study will result in a field guide that will make it possible to identify many living sponges for the first time, and it is quite possible that new sponge species may be found. The photographs of sponges taken in the present study provide a good basis for a future sponge study. In addition, disease was seen on a very small number of sponges in two species. Since diseases have caused the death of many sponges in the Mediterranean (e.g., Cerrano et al. 2000; 2001), these diseases need to be quantified and monitored.

A significant storm runoff event of sediment was observed, and such events likely impact the marine community negatively. In the future, climate change may have significant impacts, since research has shown that *Cladocora caespitosa* and *Balanophyllia europaea* may be negatively affected.

The aims of this study were fulfilled by the discovery of 11 species of corals in the Capo Rizzuto MPA, with baseline information gathered on the abundance, distribution, and association of the corals with other organisms. It is hoped that the information gained from this study may provide the reserve management with information that is useful for the reserve management, though much more information is needed.

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**Appendix A.** Shallow-water Scleractinian corals of the Mediterranean.

Presented in taxonomic order. Information from Zibrowius (1980).

Species	Zooxanth.	Azooxanth.	colonial	solitary	attached	free living	Introd.
<i>Madracis pharensis</i>	X	X	X		X		
<i>Oculina patagonica</i>	X	X	X		X		X
<i>Cladocora caespitosa</i>	X		X		X		
<i>Cladocora debilis</i>		X	X		X		
<i>Caryophyllia smithii</i>		X	X	X	X		
<i>Caryophyllia inornata</i>		X		X	X		
<i>Coenocyathus cylindricus</i>		X	X?	X?	X		
<i>Ceratotrochus magnaghii</i>		X		X	X		
<i>Paracyathus pulchellus</i>		X		X	X		
<i>Polycyathus muelleræ</i>		X	X	?	X		
<i>Sphenotrochus andrewianus</i>		X		X		X	
<i>Thalamophyllia gastii</i>		X	X		X		
<i>Hoplangia durotrix</i>		X		X	X		
<i>Phyllangia mouchezii</i>		X	X		X		
<i>Monomyces pygmaea</i>		X		X	X?		
<i>Guynia annulata</i>		X		X	X?		
<i>Dendrophyllia ramea</i>		X	X		X		
<i>Cladopsammia rolandi</i>		X	X		X		
<i>Balanophyllia europaea</i>	X			X	X		
<i>Balanophyllia regia</i>		X		X	X?		
<i>Leptopsammia pruvoti</i>		X		X	X		
<i>Astroides calycularis</i>		X	X		X		



**Appendix B.** Comparison of results from different coral surveys in the Mediterranean.

Maximum sizes, depth range, and locations reported. For the Capo Rizzuto, Croatia, and Zibrowius columns, the numbers indicated are the number of sites each species was found at, out of the number of sites indicated at the top of the column. Zibrowius refers to Zibrowius (1980), and the 12 regions those reported in his Table 2. Four sites in this study had corals that were either *Cladopsammia rolandi* or *Leptopsammia pruvoti*, but since extensive collections were not made at each of these sites and they were not distinguished underwater, it is not known how many sites each species was present at.

Species	max size	Depth	Rizzuto 16	Naples	Sicily	Croatia 57	Zibrowius 12
<i>Madracis pharensis</i>	20 cm	8-150 m	6	X		9	10
<i>Oculina patagonica</i>	40 cm	0-10					2?
<i>Cladocora caespitosa</i>	1 m	0-60	3	X	X	6	12
<i>Cladocora debilis</i>	5 cm	28-100		X			5
<i>Caryophyllia smithii</i>	2 cm	20-300		X	X	23	12
<i>Caryophyllia inornata</i>	1 cm	0-160	5	X	X	36	12
<i>Coenocyathus cylindricus</i>	1 cm	20-600			X	3	2
<i>Ceratotrochus magnaghii</i>	6 mm	7-400			X	4	6
<i>Paracyathus pulchellus</i>	2 cm	6-400	6	X	X	2	12
<i>Polycyathus muelleriae</i>	10 cm	0-300	2	X		8	11
<i>Sphenotrochus andrewianus</i>	4 mm	15-				1	3
<i>Thalamophyllia gastii</i>	5 cm	13-		X		1	7
<i>Hoplangia durotrix</i>	2 cm	2 to 35	2	X	X	14	12
<i>Phyllangia mouchezii</i>	8 cm	3-100		X	X	6	12
<i>Monomyces pygmaea</i>	3 cm	18-		X		3	9
<i>Guynia annulata</i>	2 mm	15-		X		2	8
<i>Dendrophyllia ramea</i>	20 cm	6 to 40		X	X	1	11
<i>Cladopsammia rolandi</i>	7 cm	12-	4?	X	X		5
<i>Balanophyllia europaea</i>	3 cm	0-114	8	X	X	39	12
<i>Balanophyllia regia</i>	15 mm	2 to 25		X	X	2	9
<i>Leptopsammia pruvoti</i>	2.5 cm	6 to 45	4?	X	X	24	12
<i>Astroides calycularis</i>	5 cm	0-85		X	X		6
totals			9	18	14	18	

**Appendix C.** Coral species found at each site.

Site	Wreck	Balanophyllia europaea	Cladocora caespitosa	Madracis pharensis	Caryophyllia inornata	Paracyathus pulchellus	Polycyathus muelleriae	Hoplangia durotrix	Leptopsammia pruvoti	Cladopsammia rolandi	Phylangia mouchezii
1 Relittone	X	X	X		XX	X		XX			
2 Atollo Basso		X									
3. Scogliera		XX									
4. Scogliera Cala Greca		X			X						
5 Rellitino	X		X		X			X			
6 Bengala	X		X	X	XX	X	X	X			
7 Capo Bianco		X			X						
8 Capo Cimiti		X			X	X?					
9 Gunny	X		X	X	X	X	X	X			
10 East Castello		XX								X	
11 West Castello		XX									
12 Atollo Profondo				X							
13 Ponente Basso				XX							
14 Palombaro				X		X			X	X	X
15 Sella				X						X	
16 Paco 2				X		X		X		XX	
17 East Castello 2		X									
18 Praialonga											
19 Capo Colonna South 1		X			X		X		X		
20 Capo Colonna South 2				X	X						
21 Capo Colonna South 3					X						
22 Panettoni				X		X					




X= found at the site; XX=common



**Appendix D: Monitoring Results**

Results of point-intercept monitoring transects, given in percent of the substrate covered by each category.

	East Castello 2 (17)	Praialonga (18)	Capo Colonna S. 2 (20)	Capo Colonna S. 3 (21)	mean
<i>Padina</i>	23	1	15	10	12.25
<i>Caulerpa</i>	3	1	1		1.25
Green alga	2		1		0.75
Other algae	49	5	34	65	38.25
Seagrass	6	93	22	8	32.25
Sponge	1				0.25
Sand	2		24	16	10.5
Rock	6		4	1	2.75
Clay	7				1.75

*Cladocora caespitosa* monitored colonies:

Site	Size	Location	Colony picture 2006	Colony picture 2008
Relittino				
Relittone	8			

Bengala	13			
Gunny				



## Appendix E. Site descriptions, Capo Rizzuto MPA, Calabria, Italia

Site 1: Relittone. 9/14/08 West of Le Castella, at buoy. Wreck site. Wreck is steel, collapsed, with scattered pieces. One piece has azooxanthellate corals, this is a sheet of metal that is somewhat dome-shaped, with enough space on one side for a diver to easily access the underside. As with all azooxanthellate corals, the corals are on the ceiling of the overhanging surface. The surface has encrusting sponges and encrusting coralline algae. There is a very large population of tiny azooxanthellate corals here, probably in the low thousands but perhaps in the high hundreds. They are spread over a large area, most are 2-3 mm diameter and white, a few larger. On the floor under the space is one colony of *Cladocora caespitosa*, in a hemispherical shape, about 10-15 cm diameter, healthy but with a couple corallites broken out of it in a couple places. The upper surfaces of the wreck and rocks are covered with a thick layer of algae, primarily *Padina* and large turf-like species. Max depth was 10 m.

Site 2: Atollo basso. 9/14/08 East of Le Castella, near to but west of Capo Piccolo. No wreck. Large amounts of dense seagrass beds, particularly shallow. Large rocks, most about 2 m tall, with variable spaces between. Upper surfaces of rocks are heavily covered with the same community of algae as everywhere, sides are also heavily covered with it. There are a few spaces under the edges of the large rocks where there are overhanging surfaces. These surfaces had high coralline algae and sponge cover. Most had no azooxanthellate corals, but at least one at the end of the dive did have. One *Balanophyllia europaea* sighted. Max depth 10.5m. Short dive (16 minutes).

Site 3: Scogliera. 9/16/08 La Castella, just west of the harbor. No wreck. Shore dive. Park on sloping driveway next to elongated brown low building on slope. Enter on west-facing shelf at water level, very slick surface due to algae. About 3-4 m deep there, swim out of the little bay, begin observation, swimming first out to about 40 feet deep where it appears that rocks end and sand/seagrass begins. From the start to end, large rocks dominate, with typical algal cover on upper and side surfaces. Most rocks were 2-3 m tall, but the largest were 4 m or more. A few spaces under the lower edges of boulders provide overhangs. Overhangs are almost completely covered with CCA (encrusting coralline algae), with some encrusting sponges. No azooxanthellate corals were found in 67 minutes. However, in shallow water, on upper and some side surfaces, several *Balanophyllia europaea* were found.

Site 4: Scogliera Cala Greca. 9/17/08 Near Capo Piccolo, east of La Castella. Lots of large rocks, sand between some, a few spaces under edges of rocks with overhangs, CCA and sponges on overhanging surfaces, only one individual of azooxanthellae coral sighted and some *B. europaea*. Some seagrass, especially at anchoring site. Dive just 23 minutes.

Site 5: Relittino. 9/17/08 Well west of La Castella, at buoy on wreck. Steel wreck, large, in pieces that are difficult to recognize because wreck and rocks are covered with the usual algae. One piece is table-shaped, with a central column and large flat plate like a table top. The underside has many sponges, particularly a purple species that forms

small rounded ridges and lumps in a reticulate pattern. CCA also. No azooxanthellates found, perhaps because the light level is too high. Azooxanthellates found it at least two other places. One is a large rectangular object, might be a motor, which has much internal spaces. Interior spaces are heavily encrusted with sponges and coralline algae much like the table. Much of the surfaces do not have azooxanthellate corals, but some areas do. Another space is a vertically narrow space under an object level with the rest of the surfaces (bottom) exposed to light. This space is almost entirely covered with CCA, but in a tight space to the right there are a few scattered azooxanthellate corals. Other overhanging wreck surfaces, laying near the bottom had high numbers of azooxanthellate corals. Large rocks with sand between them had small spaces under their edges which were searched and had high CCA cover but no azooxanthellate corals were found.

Site 6: Bengala. Steel wreck near buoy in 27+ m of water. A section of one side of the hull remains standing. Both sides are covered with a dense cover of a variety of sponges. There are azooxanthellate corals on both sides, including a *Madracis pharensis* colony on the outside on the port side back several meters from the bow and fairly high. This wreck is particularly rich in *Polycyathus muelleriae* colonies. Inside the bow, on a cross bar perhaps 1-2 m below the upper rim of the hull, on the starboard side, is a colony of *Cladocora caespitosa*, which is in perfect condition. Near the standing piece of hull on the port side there is a section of ribs curving upward topped by a crossbar. All of it is covered by sponges, but the underside of the crossbar has some azooxanthellate corals. Two structures rise perhaps 10 m high to around 20 m depth.

Site 7: Capo Bianco. 22 feet max on dive. Lots of boulders 1-4 m tall. Searched under edges of boulders. Sponges similar to underside of table at Relittino, azooxanthellate corals were sighted but hard to find. Counted 9 *Balanophyllia europaea* in the 58 minute dive. Most are circular, ~1cm diameter, brown or light orange. Most on edge or side of rock.

Site 8: Capo Cimiti. Lots of seagrass. Dive started at 9 m deep, cracks and holes between boulders searched. Seagrass must be on boulder tops, cracks and holes appear between seagrass. Some areas of normal *Padina* and other algae, but more seagrass than algae. One hole-overhang near the start of the dive had a few azooxanthellate corals. Four *Balanophyllia europaea* were photographed among algae.

Site 9: Gunny. Steel wreck near buoy in about 24 m of water. This is a large wreck, in pieces, with the bow still intact. There are several good overhanging surfaces plus some large vertical surfaces. The vertical surfaces are covered with algae, only one coral seen. One colony of *Cladocora caespitosa* was found, about 10 cm diameter. It was on the inside of the bow section on the port (lefthand facing the bow), where a second inner layer came to a forward end, at the bottom. The colony had algae growing over it, which was removed as well as possible, but the colony appeared to be OK. One colony of *Madracis pharensis* was found on a ceiling that was up in a section of hull. It appeared light brown but was white in photos. It was a patch about 15 cm diameter of small round lumps.

Site 10: North side of the Castello. Shore dive. Large boulders 1-3 m tall. Mostly rocks and algae, some seagrass. Lots of small overhangs at base of boulders. Corals found in only one. *Balanophyllia europaea* was found in clear yellow patches, with 45 individuals counted.

Site 11: South side of the Castello. Shore dive. Smaller boulders, some patches of grey clay that have nothing growing on them, but have rounded edges and holes of boring organisms. To the left are more boulders, lots of seagrass, cracks, overhangs, holes. Overhangs have usual sponges, no corals seen. About 65 *Balanophyllia europaea* were counted in yellow patches.

Site 12: Atollo Profondo. Boat dive starting at buoy, max depth 24 m. Seagrass, with grooves and holes. Sides of grooves and holes are nearly vertical, only a few tiny overhangs, not big enough to have corals. Does not appear to be boulders. Only one coral seen, *Madracis pharensis*.

Site 13: Ponente Basso. Boat dive starting at buoy, max depth 30 m. Algae with grooves and holes. Topographic relief greater, deeper than buoy anchor. Holes small, but nearly every one has its roof covered with *Madracis pharensis* small white knobs. Some *Madracis pharensis* near mouth of holes have brown color, a few are outside and have larger knobs, encrusting areas, and brown color, are obviously zooxanthellate. Nearly flat topography above the buoy anchor.

Site 14: Palombaro. Boat dive. Flat sandy bottom with algae-covered lumps rising from it. Lumps are presumably rock. Small holes in sides and at bottoms of a large rock, several on side facing away from sandy area have small yellow azooxanthellate corals (*Leptopsammia pruvoti*) on their roofs, in one area the yellow corals are outside the hole in a shaded area. A few other corals present.

Site 15: Sella. Boat dive from buoy. Low relief lumps and cracks and edges. Upper surfaces of lumps covered with algae, cracks and lower spaces between lumps sandy-bottomed. Edges and cracks have small holes, often circular. About 1/4-1/3 of holes have *Madracis pharensis* on the roof.

Site 16: Paco 2, Boat dive. Sand bottom with large lumps up to about 3 m tall. Overhangs large, can be over 1 m wide, and over 50 cm tall. Lots of *Cladopsammia rolandi*, most yellow but some slightly orange which may have been *Leptopsammia pruvoti*. Photo shows two *Hoplangia durotrix*.

Site 17: East Castello 2. Primarily algae-covered hard surfaces, with a few patches of seagrass. Transect line goes parallel to shore. About 5 m deep.

Site 18: Praialonga 2. Almost entirely seagrass. Transect line goes parallel to shore. About 5 m deep.

Site 19: Capo Colonna South 1. About 5 m deep, lots of boulders, some very large, lots of overhanging edges of boulders. Most have sponges but no corals, *Polycyathus muelleriae* found in a narrow crack, also found *Leptopsammia pruvoti* and more *Caryophyllia inornata*. Sun-lit surfaces had relatively few yellow patches, which were small, one *Balanophyllia europaea* was seen. Clear cold water. We were trying to swim toward the buoy from a spot towards shore, ended up near the point of the capo.





Site 20: Capo Colonna South 2. Transect starts at the buoy (tie tape to buoy chain), and goes south parallel to the overall coast. 17m deep at buoy chain, rises from that to perhaps 10 m depth. Fair bit of seagrass. Area around buoy is bare rock, appears to be scraped clean by buoy chain. Search after transect found rounded lumps, edges, and grooves, and mostly holes, not boulders with overhang-cracks. A couple of larger overhangs. Two *Madracis pharensis*, one hole had *Caryophyllia inornata*.







Site 21: Capo Colonna South 1. Cement weight with small buoys set in seagrass area. Ran tape outward parallel to shore of cape. Boulders obvious, mostly algae on hard surfaces. Overhangs and cracks between boulders. Very few yellow patches, most small. Similar to Site 19.







Site 22: Panettoni. Flat sand at 26 m, slopes up to 20 or 22 m with rounded lumps and grooves, edges, and holes. Seagrass mostly up near top. Two *Madracis pharensis*, two *Paracyathus pulchellus*, sponges.

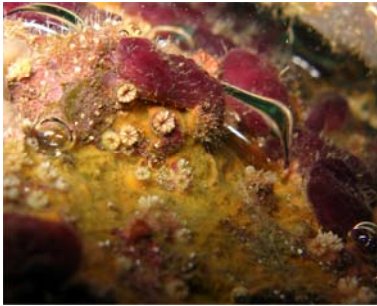






**Appendix E.** Sample data, with site ID, sample ID , diameter of the sample corallite and live and skeleton photographs.







Site ID	Sample ID	Identification	mm	Photo live	Skeleton
1	1	<i>Caryophyllia inornata</i>	7		
1	2	<i>Paracyathus pulchellus</i>	10.5		

1	3	<i>Caryophyllia inornata</i>	6.5		
3	8	<i>Balanophyllia europaea</i>	15.5		
5	4	<i>Caryophyllia inornata</i>	5		






5	6	<i>Cladocora caespitosa</i>	8		
5	5	<i>Caryophyllia inornata</i>	7		
5	10A	<i>Caryophyllia inornata</i>	4.5		





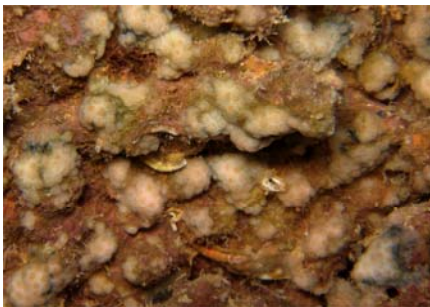

5	10B	<i>Hoplangia durotrix</i>	2.5		
6	12	<i>Caryophyllia inornata</i>	6		
6	11	<i>Paracyathus pulchellus</i>	6		



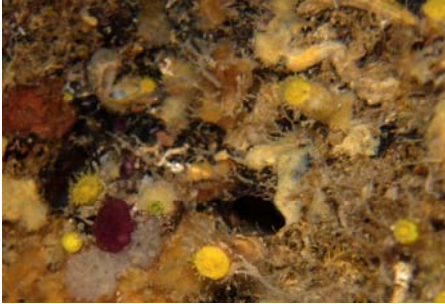





6	16	<i>Paracyathus pulchellus</i>			
6	18	<i>Polycyathus muelleriae</i>	5.5		
6	15	<i>Paracyathus pulchellus</i>	6		

7	20	<i>Caryophyllia inornata</i>	6.5		
7	19	<i>Caryophyllia inornata</i>	4.5		
7	13	<i>Caryophyllia inornata</i>	4.5		


8	24	<i>Paracyathus pulchellus</i>	8		
9	17	<i>Paracyathus pulchellus</i>	5.5		
9	21	<i>Caryophyllia inornata</i>	7 x 5		

9	25	<i>Caryophyllia inornata</i>	5.5		
9	27	<i>Polycyathus muelleriae</i>	5		
9	28	<i>Madracis pharensis</i>	1.5-2		



10	30 (=68)	<i>Leptosammia pruvoti</i>	2.5		
13	37	<i>Madracis pharensis</i>			
14	9, 26	<i>Leptosammia pruvoti</i>			



19	36	<i>Polycyathus muelleræ</i>	4		
19	38	<i>Caryophyllia inornata</i>	3		