and La Canna. Interestingly enough, this lizard has maintained autotomy (self-amputation of its tail to distract predators), a phenomenon which usually disappears in populations living in small islands where the numbers of predators are restricted.

The Pelagie Islands and Malta host Maltese wall lizard (*Podarcis filfolensis*) which, in Italy, is only found on Linosa and Lampione. Recent study has shown that the Maltese populations are genetically similar to those of the Pelagie Islands, which must therefore have been colonized only recently by lizards, probably following accidental introduction by man.

It is interesting to observe the successful reproduction of these lizards on the tiny islands around Lampedusa, where the absence of predators enables them to become more numerous than on the larger island. According to some scientists, Maltese and Pelagian lizards do not hibernate because of the warm climate of these islands, but only stop activity during rainy days in winter. The chronic lack of food on these small, arid islands has led the Maltese lizard to adopt a generalist diet, often resulting in cannibalism of adults on their young. In captivity, females even eat the eggs they laid themselves.

Plunging cliffs near Trieste house Dalmatian algyroid (*Algyroides nigropunctatus*), a common inhabitant of these areas.

Dalmatian algyroid (*Algyroides nigropunctatus*)

Birds. Birds are the largest faunal group on rocky shores, and spectacular colonies of marine species choose high-gradient rocky flanks as ideal nesting sites. The inaccessibility of cliffs offers a certain degree of protection to the nests of these birds, which avoid predation from other species and from man. Mediterranean coasts do not host large colonies and numerous species like those of the Atlantic, especially in northern Europe. There are only a few nesting species and colonies along rocky Italian coasts. However, they are worthy of notice and are an important attraction to tourists from the viewpoint of faunal conservation.

Bird species nesting on rocky coasts belong to various orders: Procellariiformes, Pelecaniformes, Charadriiformes, Falconiformes, Columbiformes, Apodiformes and Passeriformes.

Procellariiformes are true seabirds which are never seen inland. They have two typical tubular projecting nostrils on the upper part of their hooked bills, through which they eliminate excessive salt. Their wings are long and narrow, and these superlative flyers often skim the water only an inch or two above the waves. They continually change their angle of flight, and may join groups converging in food-rich areas. According to species, they feed on small fish or marine invertebrates carried by the current, such as small jellyfish, plankton

Herring gull (*Larus cachinnans*)

Mediterranean shearwater (*Calonectris diomedea*)

molluscs, small squid and shrimps. They often follow ships and large cetaceans. They usually sleep floating on the surface of the sea, and only during their reproductive period do they visit the mainland to nest in colonies on rocky coasts, where the female lays a single egg. During this period, they become nocturnal in habit and emit peculiar hoarse, guttural sounds.

Species nesting on Italian rocky shores are Mediterranean shearwater (*Calonectris diomedea*), Manx shearwater (*Puffinus puffinus*) and stormy petrel (*Hydrobates pelagicus*).

The first is recognizable by its large size, a pale brown back (a slight difference between back and front feathers) and its slow flight, 3-4 slow wingbeats followed by 6-7 seconds' glide. It is the only Mediterranean representative of the order to fly high, like herring gull and albatross.

As regards Manx shearwater, according to some ornithologists, populations nesting in the Mediterranean belong to a different species (*Puffinus yelkouan*), recognizable by both morphological features and sounds.

Nesting colonies of shearwaters may be found on all Tyrrhenian islands (Tuscan Archipelago, Ponza group, Aeolian and Egadi Islands, Sardinia, and surrounding small islands), in the Canale di Sicilia (Pelagie Islands) and Adriatic (Tremiti Islands).

Manx shearwater (*Puffinus puffinus*)

In the Tuscan Archipelago, Mediterranean shearwater forms colonies on five small islands, with 300-600 nesting pairs. Manx shearwater has large colonies on Capraia, Montecristo and Giannutri, of between 200 and 1000 pairs. The islands round Sicily host Mediterranean shearwater in 12 sites (15,000 individuals on Linosa), whereas there are only a few pairs of Manx shearwater in nine sites. The Tremiti Islands host both species.

The clearly smaller stormy petrel nests in Sardinia and the Egadi Islands. This species, little bigger than a sparrow, may be distinguished from shearwater by its darker feathers, which contrast with the white streaks on the wings and rump as far as the rectrices. Stormy petrel flutters irregularly, skimming the water and keeping its legs straight. This is why it sometimes seems to be walking on the water, supported by its wings. When the sea is rough, petrels are particularly active because they feed on debris and small sea organisms brought to the surface by water turbulence. They nest on rocks on isolated and inaccessible coastal stretches. Their nests are built in hollows almost at sea level. Nesting is often asynchronous, i.e., pairs do not nest all together at the same time, but take turns in occupying sites. For instance, on Marettimo (Egadi Islands), a colony of about 1000 pairs nests inside a complex series of grottoes with a single point of access to the sea, although the reproductive period of the

Cormorant (*Phalacrocorax carbo*)

species may last for six months each year. This situation was caused by the fact that these birds abandoned their original breeding grounds due to disturbance by tourists and particularly motorboats. This shows to what extent this species is affected by the presence of humans.

Among the Pelecaniformes are two species of cormorants which also nest in Italy, cormorant (*Phalacrocorax carbo*) and shag (*Phalacrocorax aristotelis*). Cormorants often winter in Italy, but nest only seldom and locally. In the past century, this species nested only on rocky Sardinian shores. However, since the 1980s, it has started nesting in trees (willows and poplars) in river environments in Emilia Romagna, Lombardy, Piedmont and Sicily (near Lentini).

Between January and April, cormorants lay 3-4 eggs, which hatch after one month. Individuals living near coasts use rocks as points for takeoff on diving sessions, hunting for fish.

Today, cormorants winter throughout Italy: large numbers even colonize lakes and rivers very far from the sea. In freshwaters, this fish-eating bird finds a large quantity of food, because eutrophic rivers contain grey mullet and other fish species introduced by man for commercial or fishing purposes.

The dark silhouette of cormorants, with their elongated necks and slightly hooked bills, has now become a common sight in Rome and other cities

Shag (*Phalacrocorax aristotelis*)

crossed by large rivers. There, cormorants roost on trees, bridges and quays. In the city sky, their slow and regular flight can easily be distinguished from that of the soaring herring gull, the heavy wingbeat of grey heron, and the swift gliding of pigeons.

Shags are a sedentary, localized species, regularly nesting on the rocky shores of the Tyrrhenian islands, particularly along isolated stretches not visited by man. Colonies may be found in Sardinia (over 1000 pairs), Lampedusa (about 40 pairs) and on the Tuscan Archipelago (Gorgona, Capraia, Pianosa, Montecristo, and a few small islands around Elba). The Tuscan Archipelago hosts about 50 pairs in all.

Sahgs are distinguishable from ordinary cormorants because they are totally black with a green iridescent sheen, except for a small yellow patch on the skin at the base of their bills and the typical tuft on their heads. The tuft is made up of forward-curving feathers, which are exhibited by adults during the mating season.

Shags live along coasts throughout the year, although young may wander to inland waters. Between December and March, they lay three pale blue eggs which hatch one month later. In cormorant and shag, both parents carry out incubation and rearing of the young, which learn to fly at around 7 weeks. It is worth noting that the two species do not compete for food, as shag feeds on smaller fish which live in deeper water.

The Charadriiformes living along Italian rocky shores are a few species of seagull (two of which nest) and two species of great auk.

Although most people consider seagulls as symbols of uncontaminated nature oblivious of human impact (and sources of inspiration for writers and poets), some of these birds may actually embody environmental degradation and are an example of invasion enhanced by man, unaware that this is to the detriment of other wild animals.

This is particularly true of herring gulls which, like crows and ravens, are shrewd, bold birds, the social behaviour of which facilitates their learning and cultural adaptation to changes in their environment. Other non-synanthropic species, described later, avoid humans, and their numbers are shrinking, partly owing to the omnipresent invasion of herring gull. This is probably why herring gull and raven starred in the film The Birds (1963) by the well-known film director Alfred Hitchcock. In that film, set against the Californian rocky shores, these birds over-reproduced and invaded towns, attacking humans. These flights of fancy occasionally turn to reality, since many people have been attacked by herring gulls while adjusting their television antennas on the roof.

Herring gull (*Larus cachinnans*) in the nest

Mediterranean herring gull (*Larus cachinnans*) is the most common species in Italy, where its population has grown to staggering numbers, invading city, river and lake environments alike. This is due to the large quantity of garbage which humans generate and which is an inexhaustible source of food readily available for this species. In the mornings, herring gulls are often seen flying from the sea inland and in the evenings in the opposite direction. They head for rubbish dumps, which are the feeding areas for these social groups. Other birds have even settled near dumps, especially those near water and rocks where they can roost and nest.

Adult herring gull (*Larus cachinnans*)

Young herring gull (*Larus cachinnans*)

In April, herring gulls generally lay three eggs, which are sat on by both parents and hatch after one month. The young fly after 35-40 days. Most pairs nest along rocky shores on islands (large and small), and along a few Tyrrhenian and Adriatic stretches.

Together with nesting pairs, the number of breeding grounds is also increasing: in Sicily and surrounding islands, between 1979 and 1983, according to data gathered by Bruno Massa, herring gulls nested in 16 areas; between 1984 and 1992 the number had reached 32, extending to inland reservoirs and silos in Porto Empedocle (Agrigento). Nesting colonies are also found on buildings in cities, and small colonies even nest on buildings and monuments in the centres of Rome and Trieste. According to Bonaparte and Alexander, naturalists of the early 19th and 20th centuries, herring gulls were a rare species in Rome and surrounding areas. The number of individuals flying up the Tiber into the capital in search of food has grown progressively, especially since the 1950s. The first certain nesting dates back to 1971 and, in 1996, there were already 40-50 permanent pairs, and their numbers are still growing.

Herring gulls, more than cormorants, have become a usual sight also in other Italian cities. Large numbers live in towns by the sea, those crossed by large rivers or built on lake shores.

Much can be said about herring gulls and their innate or acquired behaviour, which determines their relationship with man and other animals. City lights have influenced the biorhythms of this species, which can be seen flying even at night. They have adapted to life in dim light, like those of clear summer nights or misty, winter days in the Arctic. Thus, in the centre of Rome, even around midnight, the white silhouettes of herring gulls may be seen flying from building to building, making some people think for a moment that they have spotted barn owls!

So far, there is nothing to worry about, but problems arise when we examine other aspects of these animals' behaviour. Besides the large quantity of excrement, which is added to that of pigeons in damaging buildings (especially ones of historical and archaeological interest), and the possible transmission of parasites and diseases (which must still be proven), these invasive birds often attack rubber and plastic tubing in modern buildings: they actually continually attack and torment them, for yet unknown reasons, until they damage them, causing leakages and short circuits. However, the worst damage they cause is

Kittiwake (*Rissa tridactyla*)

to other wild animals, which they eliminate both through food competition and diet interference.

Just like crows, seagulls behave aggressively towards individuals of the same or different species - the phenomenon known as mobbing -especially predators. This behaviour may be explained as their defence against potential predators which could endanger their young. But, given the large number of herring gull in Italy today, and its abnormal distribution, this behaviour endangers predators. Peregrine, kestrel, kite, buzzard, and all other day predators are greatly disturbed in their hunting, and this may affect their survival and successful reproduction. Moreover, episodes of mobbing leading to the death of the predator have been observed. Also, the predation of eggs and nests of many birds (including predators) by herring gull must be taken into account in the management of fauna and biological diversity.

Herring gull also mobs Audouin's gull (*Larus audouinii*) - in this case, not a predator, but a congener, with which herring gull competes. Very little is known about the relationship between these two species, but mobbing undoubtedly aims at competitive elimination of species which use similar resources or occupy the same, limited reproductive areas. Audouin's gull is a rare, localized species, endemic to the Mediterranean; among all the seagull species in the

Kestrel (*Falco tinnunculus*)

world, it occupies the smallest area. It nests in small colonies along rocky coasts on islands. Today, it breeds in Sardinia, Corsica, the Tuscan islands, Spain, North Africa and Greece, with about 4000 pairs in all, 350 of which are in Italy. It is a pelagic species, i.e., more closely associated with the sea than herring gull, as it normally feeds in the open sea and visits coasts during reproductive periods.

Competition between the two species operates by means of interference. On the Tuscan islands, the numbers of Audouin's gull have fallen whereas those of herring gull have risen, both because the latter actively excludes the former from breeding grounds, and because it preys on its eggs and chicks. The two species are distinguishable not only for their size, but also for the colour pattern of the bill: herring gull has a yellow bill with a pink spot in the front part of the jaw, in Audouin's gull, the spot is red with a black band crossing it near the tip.

In non-reproductive periods, other gull species may be seen along Italian rocky coasts, such as lesser black-backed gull (*Larus fuscus*), common gull (*Larus canus*) and kittiwake (*Rissa tridactyla*). Lesser black-backed gull is similar to herring gull, although its back is darker. Common gull is similar to a small herring gull, with a thin, completely yellow bill. Kittiwake is even smaller, with

Audouin's gull (*Larus audouinii*)

short, black legs; a pelagic species throughout the year, it nests on plunging rocks in the North Sea.

There are also other species not associated with rocky shores, which visit lakes and rivers, such as black-headed gull (*Larus ridibundus*), Mediterranean gull (*Larus melanocephalus*), slender-billed gull (*Larus genei*) and little gull (*Larus minutus*).

Other representatives of the Charadriiformes are auks. They generally live in the cold waters of the northern hemisphere, and typically nest in large colonies on promontories and cliffs of the North Sea, Arctic Sea and northern Atlantic. The plumage of most species is similar to that of penguins, black above and white below. Auks are actually the ecological equivalent of penguins in the Arctic Circle, where penguins are absent (they only inhabit the southern hemisphere).

Just like penguins, auks swim underwater in search of fish and other marine organisms on which they feed, using their front wings as fins and their tails as rudders. Until the early 20th century, northern Europe hosted great auk (*Alca impennis*), a species which had adapted to this ecological role so well that it had lost the ability to fly. This caused its easy extinction by man. Today, surviving species can all fly, and they skim the water swiftly, with strong, rapid

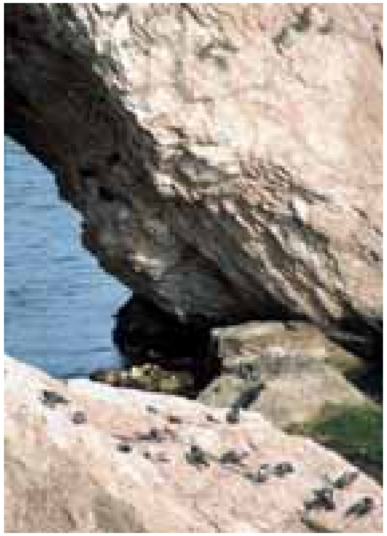
Lesser black-backed gull (*Larus fuscus*)

wingbeats. Only two species move to the Mediterranean to winter: puffin (*Fratercula arctica*) and razorbill (*Alca torda*).
Puffins are pretty birds that vaguely resemble parrots, with their large, colourful bills, flattened at the sides, which make them unmistakable and attractive. Actually, bill colouring shows sexual maturity and reproductive capacity, because during the rest of the year, the superficial horny plates of their bills are shed, making them smaller and less colourful. Their bills are very capacious and enable them to carry a large quantity of prey (up to a dozen sardines) to the nest, which is a great advantage, since they have to fly long distances to the open sea to find food for their young. Like other alcids, they lay only one egg at a time. Puffins may also nest in hollows in the ground, into which they burrow, or lairs which have been deserted by shearwater or wild rabbit, usually under rocks. In Italy, puffin lives in the lower Tyrrhenian, where it may even pass the summer.
Razorbill also has a typical bill, which is black, flattened laterally, angled below and crossed by a thin, pale band. It only nests on cliffs, and flies to the Mediterranean (Ligurian and Tyrrhenian) to winter and occasionally, to summer.
Several birds of other orders choose rocky shores to nest, or breed along rocky coasts and inland cliffs alike. Here, the determining ecological factor is neither closeness to the sea nor altitude, but the availability of inaccessible cliffs. This

Puffin (*Fratercula arctica*)

is the case of Falconiformes such as peregrine (*Falco peregrinus*), kestrel (*Falco tinnunculus*), lesser kestrel (*Falco naumanni*) and Bonelli's eagle (*Hieraaetus fasciatus*), and a few Apodiformes such as Alpine swift (*Apus melba*). Bonelli's eagle lives on rocky cliffs, and over 150 pairs breed in these environments on the Aeolian and Pelagic Islands. Alpine swift, which often lives on cliffs in the mountains, is distinguished from synanthropic swift species because it has a white breast and belly. It is clearly larger than common swift and pallid swift, which are usually seen in towns.
Rock dove (*Columba livia*) is a member of the Columbiformes which nests in cliff environments, often on rocky shores, where it is regularly preyed on by peregrine. However, its feeding areas are inland, in cultivated areas or near towns.
Rocky coasts or mountain cliffs are nesting places for a few species of song birds (Passeriformes), such as blue rock-thrush (*Monticola solitarius*), black redstart (*Phoenicurus ochruros*), sand-martin (*Ptyonoprogne rupestris*), rock sparrow (*Petronia petronia*), raven (*Corvus corax*) and jackdaw (*Corvus monedula*). As regards raven, this large corvid can now only be seen in Alpine environments (where it was re-introduced) and in southern Italy, where it has miraculously survived and its nesting pairs live both in the mountains and on rocky shores. The large eagle owl (*Bubo bubo*) also visits rocky coasts, where it

Peregrine (*Falco peregrinus*)



Rock dove (*Columba livia*)

preys on seagulls. Cities - particularly old ones with great buildings and complex architectural structures full of ornamental patterns, ideal hollows for the nests of birds - have become home to many cliff species. Cities represent shelters and sources of food for many bird species, such as rock dove and swift. The former is aided by the great amount of garbage available and the tendency of people to overfeed them. Swift, which is an insectivorous species, owes its abundance to the numerous flies and beetles it catches on the wing. Italy hosts two species of swifts, common swift (*Apus apus*) and pallid swift (*Apus pallidus*), hardly distinguishable in flight.

There are also other cliff species which live in towns in small numbers. This may depend on the fact they are territorial and solitary species, or that they cannot find sufficient food, even though cities offer many shelters. Among these are blue rock-thrush, black redstart, and others.

Griffon vulture (*Gyps fulvus*) is another bird which lives both on shore and mountain cliffs. Extinct in Sicily since 1965, this large vulture still lives in Sardinia with two nesting populations (Bosa and Punta Cristallo). In the last decade, the species has been re-introduced in the central Apennines and north-eastern Italy (lake of Cornino, Udine).

Eleonora's falcon (*Falco eleonorae*) owes its name to a medieval princess, Eleonora d'Arborea, who passed laws defending diurnal raptors in Sardinia. At that time, such birds were largely used in falconry. Eleonora's falcon is a migrant species which nests exclusively on rocky coasts, particularly on Mediterranean islands and the Canary Islands. Most of them leave the Mediterranean in November and winter in Madagascar, although some remain in the eastern Mediterranean. There are about 4000 pairs in all, 480 of which live in the ten registered Italian colonies (especially in Sardinia, and the Tuscan, Aeolian and Pelagie islands). This shows how important Italy is for the conservation of this species which, in April-May, sets out to explore the Mediterranean sky, catching migrant birds in flight. In July-August, Eleonora's falcon lays 2-4 eggs in small rock hollows or the nests of other species, such

Eagle owl (*Bubo bubo*)

as shag. The mother bird, in particular, sits on her eggs for 28 days. The young learn to fly after 28-35 days.

White-tailed eagle (*Haliaeetus albicilla*) used to nest in Italy along rocky shores, both on rocks and in trees. Its last definitely ascertained nesting dates back to 1956, in Sardinia. The species no longer nests in the western Mediterranean. In Italy today, members of this species, generally wandering juveniles, can only be seen flying erratically in winter or during migration. White-tailed eagle is an eclectic predator which feeds on fish, birds, mammals and carrion. It often attacks other predators such as falcons and seagulls, making them drop their prey.

Golden eagle (*Aquila chrysaetos*) may also nest on rocky shores, like the pair living on the Island of Tavolara, in north-eastern Sardinia. As its prey includes herring gull, eagle plays an important ecological role in keeping the rising numbers of gulls under control.

Other birds which often visit rocky shores, where they do not nest, belong to the order Ciconiiformes. Herons are frequent on cliffs, where they search both for prey trapped in pools after storms, and amphibians living in burrows filled by rainwater. In these environments, the most common species are grey heron (*Ardea cinerea*), little egret (*Egretta garzetta*) and squacco heron (*Ardeola ralloides*).

Griffon vulture (*Gyps fulvus*)

Eleonora's falcon (*Falco eleonorae*)

Black rat (*Rattus rattus*)

Mammals. Sandy and rocky coasts are frequently visited by fox (*Vulpes vulpes*).

This eclectic carnivore, which tends to become omnivorous, explores coasts methodically, wandering at night in search of any kind of waste. Stranded sea animals, rejected remains of fish, human food waste, wounded or tired migrant birds, nests, or any kind of animal or vegetal product may fall within the fox's diet. This occurs particularly in those coastal stretches that contain Mediterranean maquis, pine woodland and cultivated areas. Stray or wild dogs are more and more frequent on many Italian coasts. Their growing number is due to many factors, such as abandon, food offered by summer tourists, and the great amount of garbage near both towns and tourist areas.

Among small mammals in these exposed environments is black rat (*Rattus rattus*) and garden dormouse (*Elyomis quercinus*), a common sight on Mediterranean cliffs. Along high Adriatic cliffs and rocky shores (Duino-Aurisina, Trieste, Friuli Venezia Giulia), snow vole (*Chionomys nivalis*) wanders as far as the shoreline.

Garden dormouse (*Eliomys quercinus*)

Snow vole (*Chionomys nivalis*)

Mouflon (*Ovis orientalis*), an ancestor of the domestic sheep, is a Middle East species, which was introduced in Italy in protohistoric times. Today, this artiodactyl may be seen along rocky shores in northern and eastern Sardinia and various small islands, such as Marettimo (Egadi), Zannone (Ponza group) and Capraia (Tuscan islands). This herbivore has a limited impact on cliff vegetation, as poachers and stray dogs keep its populations low, much lower than those of sheep. However, on a few islands, like Capraia and Zannone, where mouflon reaches large numbers, vegetation may be severely damaged. The absence of predators on mouflon on small islands should be replaced by control over mouflon density, thus preventing vegetation from undergoing periodical stress, but also saving these herbivores from starvation.

Monk seal (*Monachus monachus*) is a secondary consumer in marine food

Mouflon (*Ovis orientalis*)

Monk seal (*Monachus monachus*), photograph taken in a Sardinian grotto

chains. However, this species cannot survive far from the mainland, which is an essential refuge for resting, thermoregulation, and rearing of the pups.

Today, the very few surviving individuals of this species live in Sardinian waters and shelter in grottoes along rocky coasts. Here, on small beaches or platforms of emerging rock, the last monk seals retreat from the eternal presence of humans, especially in summer. The beaches, quiet, isolated inlets between rocks where these animals basked in the sun, gave birth and reared their young until the 1850s, are now occupied by tourists who reach them in motorboats. This constant interference has made monk seals change their lifestyle, turning them into a species associated with rocky shores and grottoes.

This pinniped is the only Mediterranean seal. It may reach nearly 3 metres in length, and weigh up to 350 kg. When born, the pups are about one metre long and weigh 20 kg. They are black all over and covered with woolly underfur, which is totally absent in adults.

Monk seals feed on fish (moray, dentex, bass, white bream, grey mullet, eel, red mullet, etc.), large crustaceans (prawn, lobster) and molluscs (octopus, squid, bivalves). Their search for food is aided by their many long whiskers, with which they detect animals in the sand and rocks on the seabed. Adult seals catch an average of four preys each day, eating about 10 kg of food.

In past centuries, monk seals lived in areas stretching from the Atlantic and North African shores (where most individuals live now), as far as the Black Sea. In the Mediterranean, large groups of 200-300 individuals survive in the Aegean Sea between Greece and Turkey. Some of these live on the Greek islands of the Ionian Sea. Probably, the seal seen in the summer of 2001 near the beach of Policoro (Basilicata) came from these islands. This is not surprising, because young seals sometimes wander during periods of exploration in which they colonize new areas and maintain the gene flow. When adults, they become sedentary and territorial.

In the last decade, there have been only a few other definite sightings, all in Sardinia (Gulf of Orosei, Tavolara, Capo Caccia). The survival of this species here is due to the presence of grottoes, where seals may still breed. In the past, monk seals were undoubtedly more frequent, as shown by place names which refer to the dialect names fishermen used to call these animals: sea bulls and sea cows.

Today, monk seals are certainly the most seriously threatened mammals of Italian fauna. Besides being disturbed by tourists and their motorboats, seals are often killed by fishermen, who claim they steal fish from their nets, damaging them. Although it is a protected species in all countries, populations of monk seals are falling in all their areas of distribution.

Submerged communities

C. NIKE BIANCHI · FERDINANDO BOERO · SIMONETTA FRASCHETTI · CARLA MORRI

Organisms living in sandy, silty seabeds generally burrow into the sediment, so as to be invisible. Instead, a living seascape of clearly visible organisms covers rocky seabeds: the elements of this seascape are not only vegetal, as submerged rocks host sessile animals (those which attach themselves to the substrate). Algae, just like plants on land, live by exploiting solar energy through photosynthesis. Sessile animals can do the same, thanks to microscopic photosynthetic symbiont organisms but, more frequently, they capture particles of organic matter or small organisms floating in the water. The possibilities of nourishment for living creatures therefore depend both on available light (essential for photosynthesis) and on food supplies provided by moving water (essential for animals). The relative importance of these two factors determines the distribution of organisms. The intensity of light peaks near the surface and decreases with depth, and eventually it becomes so dim that it prevents photosynthesis. Water turbidity determines how much light can penetrate: clear waters enable photosynthesis at higher depths than turbid ones. Water movement depends on waves (on the surface) and currents.

The availability of light enables algae to dominate life on superficial rocky seabeds. Their physiological efficiency is such that they overpower any other form of life in the struggle for substrate occupation. As depth increases, light intensity decreases, and algae lose their efficiency and are replaced by sessile fauna: zoning of populations occurs.

Starting from the surface, various levels can be identified, i.e., vertical divisions of the sea environment with homogeneous conditions, or ones which gradually dissolve to a critical threshold which constitutes their limit. Transitional areas between levels reveal great changes in flora and fauna. These areas are defined in biological, not bathymetrical terms. Biological zoning, however, is not a simple succession of populations in depth. When the steepness of the rocks diminishes the amount of light penetrating the water, even at only a few centimetres, algae are immediately replaced by animals, especially sponges. Spatial heterogeneity is therefore the characteristic of rocky seabeds.

Algae are divided into three main groups: green, brown, and red. These colours depend on the pigments which come with chlorophyll. Theoretically, green

An extraordinary seascape: a cliff covered with large colonies of *Paramuricea clavata* (Tremiti islands, Apulia) algae, the chlorophyll of which is similar to that of terrestrial plants, should live nearer the surface, where light is more intense. As light grows dim, brown algae should dominate, followed by red. However, this sequence does not correspond to reality. A few green algae abound on the surface, such as the well-known sea lettuce *Ulva rigida*. But their development is associated with the supply of nutrient-rich fresh water. Brown algae, instead, dominate shallow water. Other green algae, such as *Halimeda* and *Codium*, live in deeper water, where light is less intense. And red algae contradict all the rules of distribution: although most prefer life in dim light, many species live immediately under or near the surface.

Sponges, cnidarians (sea anemones), bryozoans (moss animals) and tunicates (sea squirts) are sessile animals which, together with algae, contribute to the seascape on submerged cliffs. They are often colonial, and their asexual reproduction enables them to develop rapidly and compete for substrate occupation. There are also serpulids (tubiculous polychaetes), cirripede crustaceans and sessile molluscs such as vermetids, mussels, oysters and spondyls. In these forests of plants and animals are also organisms which better correspond to the common concept of animal, i.e., moving and floating fauna: fish and crustaceans, such as lobster, prawn, crab and many others, gastropod molluscs, worms and echinoderms, sea urchin and starfish sea cucumber, brittle star and feather star.

When light grows dim, even in shallow water, algae are replaced by animals. In addition to orange sponges, there are colonies of hydroids (*Eudendrium racemosum*) which are similar to algae

Critical depths

Ferdinando Boero · Simonetta Fraschetti

Just as the distribution of photophilous and sciaphilous algal populations speaks for light conditions, so the colonies of some animals (hydroids, sea fans) speak for average hydrodynamic conditions.
Shady, infralittoral overhanging rocks host red algae mixed with feathery hydroids of the genus *Aglaophenia*.
Surface water is turbulent and *Aglaophenia*, to catch food exploiting the water flow, must move its “feathers” in all directions, because food comes from everywhere.
As depth increases, hydrodynamism changes from turbulent to oscillatory, and *Aglaophenia* arrange themselves parallel to the surface, in order to be crossed vertically by moving water.
The passage from turbulent to oscillatory movement indicates a first critical depth, and is of great importance for the identification of food and mechanical stress.
Sea fans also arrange themselves perpendicularly to the water flow, to capture as much food as possible.
The orientation of their fans shows the direction of moving water. Below the first critical depth, sea fans are parallel to the surface, just like *Aglaophenia*.
As depth increases, however, the oscillatory movement becomes linear.
The passage between the two indicates the second critical depth, and is clearly visible in the orientation of sea fans, which changes from parallel to perpendicular to the surface.
The deeper the critical depths, the more exposed coasts are to storms.
The arrangement of these feathery colonies indicates the mean environmental conditions affecting organisms over sometimes long periods of time.

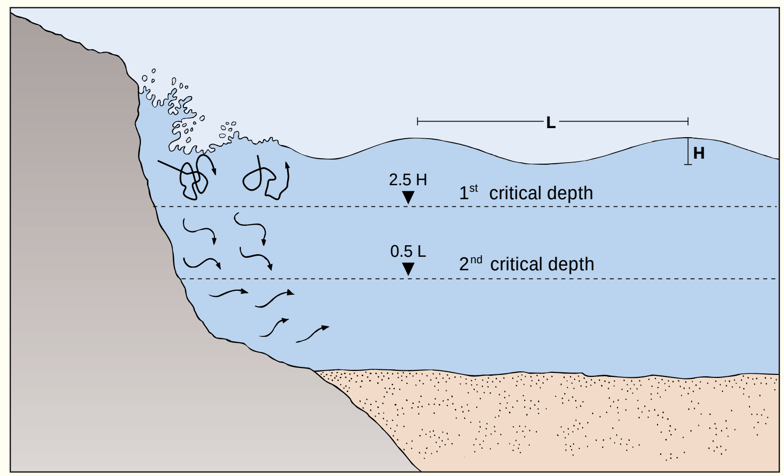


Chart showing how depth produces changes in water movement on a submerged cliff. Critical depths depend on wave parameters (L = wavelength, H = wave amplitude)

Abrasion platform 1-2 m above sea level with coalescent pools; the diameter/depth ratio is high (5 to 10). Corrosion of limestone is favoured by sea-grass in the pools (Gulf of Orosei, Sardinia)

■ Splash zones

Supralittoral zones are emerged stretches sprayed by seawater, ecotones between land and sea, transitional environments colonized by only a few specialized organisms, with both terrestrial and marine affinities. In the upper supralittoral zone, near the terrestrial world, are black lichen (*Verrucaria adriatica* on limestone and *V. amphibia* on siliceous rock), like tar spots. Algae, except for a few microscopic forms, are absent, because of salty aerosol sprayed by waves, which is sufficient to hinder terrestrial plants and too weak to enable colonization by marine vegetation. There is, however, a strip of blackish micro-organisms, called blue-green algae, myxophyceans or cyanobacteria.

A typical supralittoral animal is *Fucelia maritima*, a dipteran similar to flies, from which it differs because its wings, at rest, fold over each other, instead of remaining apart. The isopod crustacean *Ligia italica* (see photo on page 73), which walks on completely dry rocks, is more similar to its terrestrial brothers (woodlice) than to marine ones.

The first sea animals on supralittorals are periwinkles *Littorina* (*Melaraphe*) *neritoides*, small gastropods with blackish-brown shells, which throng near cracks in rocks, where humidity is retained.

Cyanobacteria, incorrectly called “blue algae”, form a blackish belt on supralittoral rock

Rock pools

Rock pools are peculiar environments in supralittoral zones, i.e., seawater pools disconnected from the sea and only filled by storm waves or rainwater. They undergo extreme variations in saltiness and temperature and, in summer, may dry up completely.
Here live a few, specialized populations, either similar to terrestrial ones, such as some hydraenid coleopterans (beetles) of the genus *Ochthebius*, or similar to sea ones, like harpacticoid copepods (crustaceans) of the genus *Tigriopus*.
The culicid dipteran *Aedes mariae* spends part of its biological cycle in rock pools. Thousands of its larvae crowd in elevated pools, where saltiness and temperature are very high. In early summer, before the pools dry up, they metamorphose into annoying stinging mosquitoes.
Rock pools are short-lived and, when they dry up, the organisms living in them must be able to move to other habitats (as insects do), or become quiescent by encysting themselves (like copepods). When rain and storms recreate these habitats, life begins once again.

Between waves and tides

The midlittoral zone is alternately washed by waves and tides and is also influenced by variations in pressure. Its populations have marine affinity and tolerate prolonged emersion.
This is the favourite environment of experimental ecologists, especially if tidal variations are conspicuous. At low tide, natural situations can be manipulated to verify hypotheses regarding, for example, the importance of limpet grazing in influencing the development of algal felts.
The simplicity of populations and their accessibility facilitate research, and many models in modern ecology derive from experiments carried out on midlittoral zones.
As always, there is the other side of the coin. Midlittoral organisms are highly specialized and therefore differ from those which are always submerged. For instance, midlittorals contain rare colonial animals, which dominate submerged environments. General hypotheses deriving from midlittoral ecology may therefore result from extremely particular and specialized conditions.
These zones are divided into upper midlittoral, definitively above sea level, and lower midlittoral, mainly below sea level.

Barnacle belts

The upper midlittoral is covered with barnacles: sessile cirripede crustaceans, also called acorn barnacles, which are protected by calcareous shells like molluscs. The first ones - *Euraphia depressa* - appear along the lower limit of the supralittoral fringe. The two midlittoral species, *Chthamalus stellatus* and *C. montagui*, may be abundant enough to form large belts (due to their gregarious habit: larvae settle where there are adults). These three barnacle species are distinguished by slightly differing shells (mantles), which are always whitish-grey or pale brown. Like all cirripedes, their legs transformed into cirri to capture plankton, and may stretch out of the shell openings.
The distribution of barnacles indicates the average exposure of shores to storms, even when the sea is calm. If barnacles move far away from the shoreline, the area is subjected to storms; if they keep near the shoreline, the area is protected.

Acorn barnacles of genus *Chthamalus* are typical of madolittoral belts

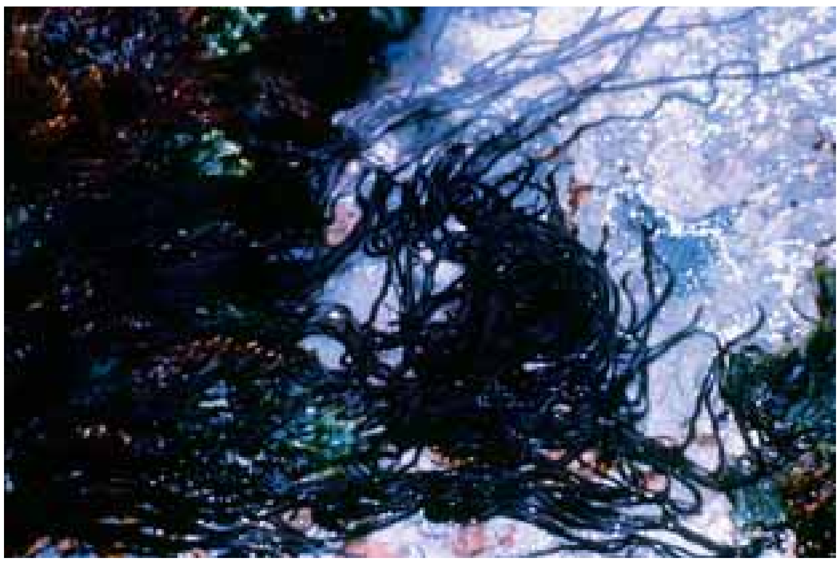
■ The first algal belts

Particular conditions (variable saltiness, eutrophy) on upper midlittorals give rise to large numbers of algae, with filamentous forms like *Bangia* (red alga) and *Enteromorpha* (green alga); but it is particularly in the lower midlittorals that these algae develop, especially mucilaginous species. Mucilage is a defence against drying out.

One of the most common species in lower midlittoral zones is the red alga *Nemalion helminthoides*, which arranges itself in typical, regular belts, parallel to the shoreline.

Rissoella verruculosa, a leafy red alga, also forms a characteristic belt, followed by another one with *Ralfsia verrucosa*, encrusting brown algae. The development of midlittoral algal populations peaks in spring. When summer sets in, higher temperatures and the drier climate hinder their expansion, and they shrink until they almost die out. In early summer, the belt with *Rissoella verruculosa* is already dehydrated and faded, and the rocks underneath look bare.

In the lower midlittoral zone are encrustations of *Lythophyllum byssoides*, a red alga of the corallinaceae family. In favourable conditions, the calcified thalli of these algae may form large frameworks which support the weight of a person



Red alga *Nemalion helminthoides*, sometimes called “sea spaghetti”

and are called “floors”. Concretions of *L. byssoides* host large numbers of minute fauna, among which is the typical bivalve *Lasaea rubra*, with a deep red shell, and the polychaete *Spirorbis infundibulum*, which lives inside irregularly spiralling calcareous tubes.

In the North Adriatic, lower midlittorals may host belts of the rockweed *Fucus virsoides*, an endemic species - a fact which emphasizes the affinity between this area and the North Atlantic. *F. virsoides* is found in the Marine Natural Park of Miramare (Trieste) and is the most endangered species.

Lower midlittoral zones contain essentially mobile animals, such as gastropod molluscs of the genus *Patella*, which obtain nutrients by scraping the algal layers covering rocks. This rock-grazing controls the early stages of algal communities and determines their development. Each species of *Patella* prefers different belts. *Patella rustica* lives high up, even as far as the supralittoral fringe. *Patella ulyssiponensis*, the shell of which is greenish-white and flattened, lives only on midlittorals. The large *Patella ferruginea*, the shells of which have wide ridges and notched edges, is rare and lives on shores of the central Tyrrhenian islands. *Patella caerulea* lives in the infralittoral fringe, has a circular or pentagonal greyish-brown shell, usually covered by algal felts. Species of the genus *Diodora* are similar to limpets, but have a slit at the apex of their shells.

Red sponge (*Crambe crambe*) and hydroids (*Aglaophenia octodonta*) with reproductive structures (corbulae)

Other gastropods, besides limpets and *Diodora*, live on midlittorals, such as those of the genera *Osilinus* and *Gibbula* and, among molluscs, a few chitons, with shells made up of articulating dorsal plates, to which they owe their name: polyplacophorans.

Midlittoral zones also host two crabs: marbled rock crab (*Pachygrapsus marmoratus*) has a square carapace, generally greenish or violet-brown, with irregular yellow spots. It wanders in search of food as far as the supralittoral zones, staying out of the water for sometimes lengthy periods. The warty crab *Eriphia verrucosa* is orange or greenish-brown, with black tips to its pincers. It is less common than marbled rock crab in dry areas.

Among sessile invertebrates in lower midlittoral zones is the red sea anemone *Actinia equina*, which contracts during the day, becoming a round, red or purple

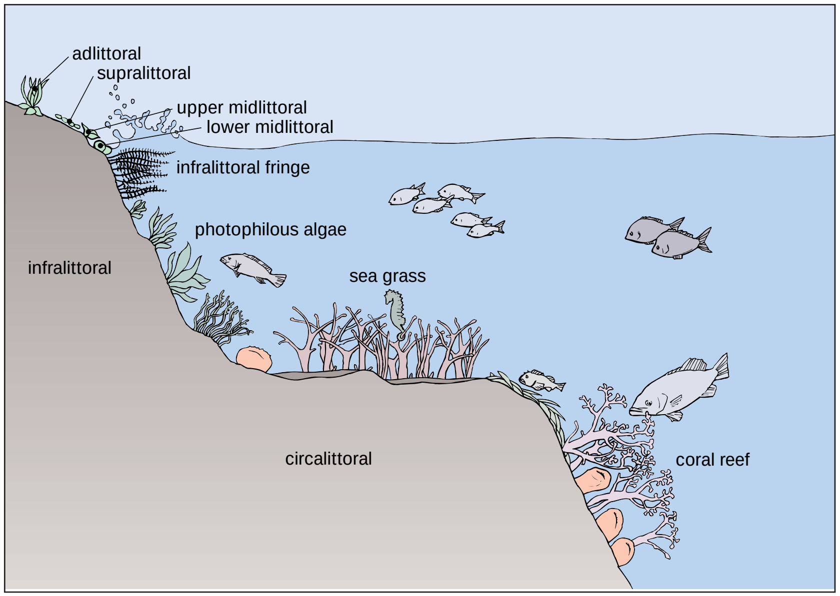


Chart showing vertical zoning of populations on Mediterranean rocky shores

blob. It is common in Italian seas, and particularly abundant in the Adriatic. The congener *A. cari*, which lives higher on coasts, is dark green with concentric brown lines. When it contracts, it becomes conical. *Paracoryne huvei* are hydroids which form encrusting, water-resistant colonies. In winter, they create large pink spots on sea-splashed rocks, but in summer they disappear, becoming cysts which may remain quiescent for several years.

Tide pools

Tide pools are found between midlittoral rocks and, unlike supralittoral pools, they are permanent. Their saltiness and temperature may change with low tide, rainfall, or protracted sunlight. Although they inhabit midlittoral areas, organisms living in tide pools do not undergo alternating emersion and submersion.

Flora and fauna are similar to those on infralittorals, but they can tolerate great environmental changes. Here are several small molluscs (e.g., *Columbella rustica*), shrimps of the genus *Palaemon*, and small fish, especially blenny. Tide pools may be covered with algal felts or sea lettuce (*Ulva*), if the sea is very close and its influence strong.

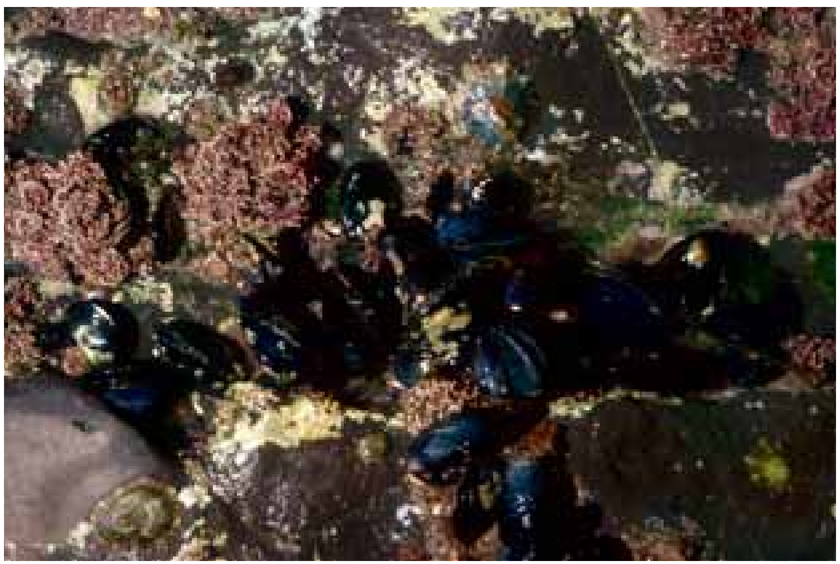
Periclimenes sagittifer, a minute shrimp

■ A transitional fringe

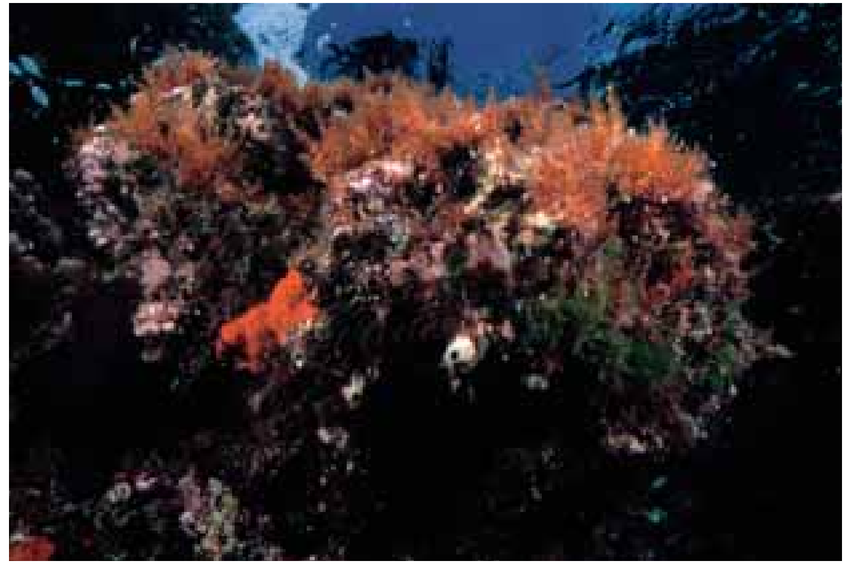
Immediately below the midlittoral zone is the infralittoral fringe, with exclusively marine populations. The lower limit is conventionally set at the lower limit of photophytic algae (living in intense light). This environment is influenced by the penetration of light which, in clear waters, may go down to 40 m but, in turbid waters, is even less than 20 m.

The infralittoral fringe, i.e., the upper part of this belt, occasionally emerges and therefore has transitional characteristics. The fringe may extend in depth for a couple of metres, and may be colonized by midlittoral organisms. The limit between midlittoral and infralittoral zones is not determined by depth (e.g., zero tide), but by biological factors.

Biological zero is the highest level where infralittoral algae, such as *Cystoseira*, live. Other species in this fringe are *C. amentacea*, *C. compressa* and *C. barbata*, with differing but not significant sessile and mobile fauna. *Cystoseira* are defined as species constructing habitats, i.e., capable of influencing the characteristics of the substrate by modifying light intensity, hydro-dynamism and essiccation. Therefore, under their leaves is a varied community composed of algae (*Corallina*, *Amphiroa*, *Valonia*, *Peyssonelia*) and animals (the anthozoan *Corynactis viridis*, the ascidian *Diplosoma listerianum*, several



Limpets, mussels and red alga *Corallina elongata* establish limit between midlittoral and infralittoral zones



Just below the surface, in full light, are the fronds of the red alga *Laurencia*. Cliffs then plunge vertically and, in a few centimetres, the physiognomy of communities changes: there are mostly red algae (*Amphiroa, Jania*), green algae (*Cladophora*) with shorter thalli, and orange sponges, barnacles and fan-shaped hydroids (*Aglaophenia*)

hydroids and bryozoans). If the *Cystoseira* fringe shrinks, due to its sensitivity to human influence, this varied community dies out and is replaced by filamentous algae.

Of the animals living in this fringe, the most important is the mussel *Mytilus galloprovincialis*. In slightly eutrophic environments, it lives in lower midlittorals, where the abundance of food enables it to survive without filtering (rather, with completely shut valves, to prevent dehydration) during periods outside the water. In favourable conditions, it may form large bands of closely attached individuals, with which a particular small fauna is associated.

The cirripede *Balanus perforatus* forms dense populations in the infralittoral fringe or just a few metres deep in the water. Its strong shells may remain attached to rocks even when they are empty, forming concretions. The hydroid *Halocordyle disticha* also develops in shallow water, in large pinnate colonies with long white tentacles. Hydroids are rare or absent in cold areas of the Mediterranean, but are typical of the Peninsula of Sorrento. There are only a few species of fish in this fringe, where the danger of remaining out of the water is very high. Among these are blenny, scaled blenny (clinids) and three-fin blenny (tripterygiids).

■ Seabeds with photophilous algae

Infralittoral rocky seabeds are often densely carpeted with algal populations. Although all the main macro-algal groups are part of photophilous (light-loving) algae, these are normally characterized by large, straight brown algae, belonging to the genera *Cystoseira* and *Sargassum* (gulfweed). There are many Mediterranean species of *Cystoseira*, and their rigorous division gives rise to the definition of submerged vegetational belts.
Among the most significant species, besides those already-mentioned in the infralittoral fringe, are *C. crinita*, which loves isolated areas a few metres deep; *C. foeniculacea*, at intermediate depths; *C. spinosa*, on relatively deep seaweed-covered rocks; and *C. zosteroides*, a species found in deeper waters, where populations have circalittoral affinities. Gulfweed has thallous expansions resembling leaves and berry-like floating organs. Of these species, *Sargassum vulgare* is the most common in shallow water. Other typical photophilous algae belong to the brown algae, such as *Padina pavonica*, similar to a small, whitish funnel, *Stypocaulon scoparium*, like a brown, bristly broom, and *Dictyota dichotoma*, with V-branching tufts, flattened twigs and sometimes iridescent tips. Among green algae are the chandelier-like *Codium vermilara*; rosette-shaped *Anadyomene stellata*, found only in southern seas; and the "mermaid's wine-glass", *Acetabularia acetabulum*, made up of a slender stalk at the top of which is a ring of branchlets. Among photophilous red algae are the curious tufts of *Jania rubens* and the large fronds of *Sphaerococcus coronopifolius*.
Many, less significant animals live among seaweeds. Most of them are epiphytic, such as many hydroids and moss animals, or cavitary, i.e., living in cavities at the base of algae.
The hydroid with tropical affinity, *Eudendrium racemosum*, has colonies which look like algae in shape and colour, except for the orange tentacles at the tip of its branches.
Besides epiphytic and cavitary species, animal species living among algal populations may also be vagile (mobile), such as the opossum shrimp *Leptomysis mediterranea*, which swarms between the fronds of *Dictyopteris membranacea* and other algae.
Mobile animals living among algae may be large, like gastropod molluscs, both prosobranchs (marine snails) and opisthobranchs (sea slugs), and cephalopods, like the octopus *Octopus vulgaris*.

Rock blenny *Parablennius gattorugine*

Sargassum vulgare, a large, erect brown alga

Red alga *Sphaerococcus coronopifolius* in a mixed population of photophilous algae

Green alga *Codium vermilara* and brown alga *Stypocaulon scoparium*

Padina pavonica with fan-shaped thalli; brown algae *Dictyota* and *Liagora* with pink branchlets

Two-banded bream (*Diplodus vulgaris*)

Madrepore *Balanophyllia europaea* and vermilion sponge *Cliona rhodensis*

Sponge *Chondrilla nucula* with zoocyanellae

Brown algae (*Dictyota*), olive sponges (*Chondrilla nucula*), sea urchins (*Arbacia lixula*) and a fireworm (*Hermodice carunculata*)

Among starfish are *Coscinasterias tenuispina*, unmistakable with its more than 5 rays (6-9), and *Marthasterias glacialis*.

Fish living among algal populations include wrasse (Labridae): green wrasse (*Labrus viridis*) and East Atlantic peacock wrasse (*Sympodus tinca*) are the most important. Rainbow wrasse (*Coris julis*) and Mediterranean rainbow wrasse (*Thalassoma pavo*), found especially in southern Italy, are extremely colourful and quick-moving.

Other typical inhabitants are the serranids, such as painted comber (*Serranus scriba*) and gaper (*S. cabrilla*); several sparids, like sea bream (*Diplodus sargus*, *D. vulgaris*, *D. puntazzo*) and saddled bream (*Oblada melanura*). Salpa (*Sarpa salpa*) is one of the few herbivorous fish in the Mediterranean, and photophilous algae and *Posidonia* meadows are their favourite environments. *Sparisoma cretense*, the only Mediterranean parrot fish, lives in Sicilian and Apulian waters.

Significant animals in algal populations are not all vagile. A few sessile animals contend with algae for the occupation of substrates. Most of these are sponges and sea anemones with symbiontic photoautotrophic micro-organisms. Sponges live in symbiosis with cyanobacteria called zoocyanellae, of which the best-known are *Petrosia ficiformis* and *Chondrilla nucula*. Zooxanthellae endow sponges with brown-violet colours. Sea anemones also live in symbiosis with zooxanthellae, which live in the sea anemone *Anemonia viridis* and in a few madrepores, both colonial (e.g., *Cladocora caespitosa*) and solitary (*Balanophyllia europaea*).

■ Underwater deserts

Excessive grazing by sea urchin *Arbacia lixula* exterminates leafy algae, leaving only encrusting calcareous algae (*Lithophyllum incrustans*)

Sea urchins play an important role in the development of photophilous algae. Many sea urchins, like the black *Arbacia lixula* with compressed shell, are grazers, and their nibbling hinders the development of algae, giving rise to real deserts.

The greenish, purplish or brown sea urchin *Paracentrotus lividus* with its round shell, also grazes among photophilous algae.

When grazing pressure is extensive, erect algae disappear, leaving only a few encrusting rhodophytes with calcareous thalli, such as *Lithophyllum incrustans*.

In addition to sea urchins and the thin layers of calcareous algae, there are other encrusting organisms protected by calcified structures (e.g., bryozoans, such as *Reptadeonella violacea* and *Schizoporella longirostris*) or spicules (e.g., sponges like *Crambe crambe*).

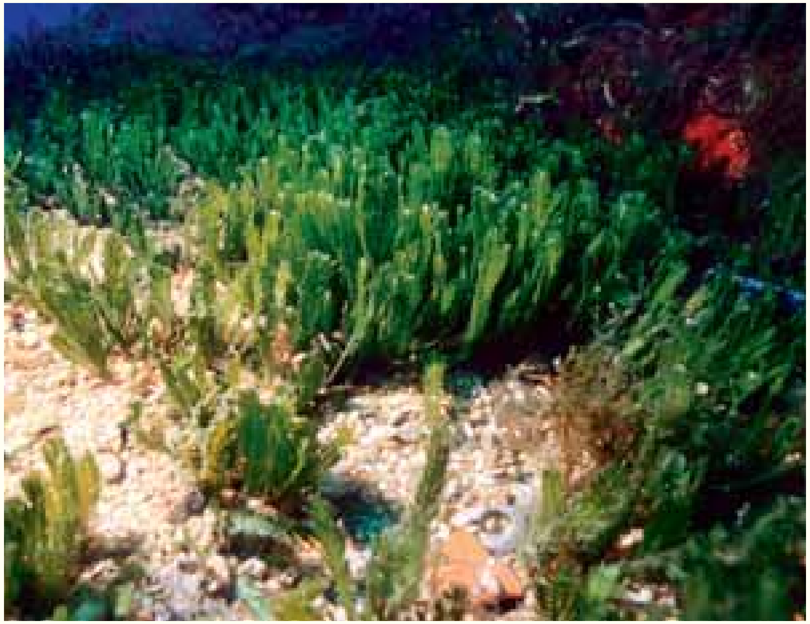
Man also contributes to underwater desertification. Collecting of date mussels (the bivalve *Lithophaga lithophaga*) from the surface as far down as 10-15 m, is changing the structure of coastlines subjected to this criminally destructive practice. Destruction of the rock using underwater explosive charges simply to obtain date mussels, delicious though they may be, implies the eradication of all life forms and allows the immediate establishment of dense populations of *Arbacia* and *Paracentrotus*.

Grazing by sea urchins protracts desertification, as they feed on animal and algal propagules which enable substrate re-colonization. Proliferation of sea urchins is often associated with extensive coastal fishing, which eliminates the fish preying on them. Underwater deserts are signs of environmental degradation and depression of biodiversity.

Exotic marine species

Carlo Nike Bianchi · Carla Morri

Submerged rocky seabeds, just like emerging coasts, host several species native to various seas. It was man who voluntarily or involuntarily brought them to the Mediterranean.
One modern peculiarity of the Mediterranean Sea is the existence of the Suez Canal, which reconnected two bodies of water which had remained separate for millions of years. Hundreds of species native to the Red Sea were able to enter the Mediterranean (for hydrological and ecological reasons, migration in the reverse direction is negligible). This type of penetration of species is called “Lessepsian migration”, from the name of the engineer and diplomat Ferdinand de Lesseps, the Frenchman who promoted the building of the Suez Canal. Almost every day, a new Lessepsian species is known to enter the Mediterranean, to such an extent that the flora and fauna of the eastern Mediterranean are becoming more and more tropical, and many Lessepsian species have even reached Italian coasts.
In addition to Lessepsian migrants, many other marine species have been, and still are, intentionally or accidentally introduced by man: by means of organisms growing on ship bottoms and fouling them, water used as ballast, aquaculture, the trade in live bait, packing of sea food with live algae, and fish exported from exotic locations for sale to aquariums.
Just as on land, exotic species may settle, become naturalized, even replace indigenous species, and deeply modify original ecosystems by altering food chains and interspecific relationships. As far as we know, most introductions occurred over the last few decades. However, we do not know how important past introductions were. Before the Christian epoch, the Greeks travelled perhaps as far as Iceland, the Phoenicians circumnavigated Africa, and the Carthaginians probably reached the Atlantic islands, Brazil and the Maldives. After the Americas were discovered, thousands of Spanish galleons regularly crossed the Atlantic. Those ancient vessels had wooden keels and did not of course use anti-fouling varnish. They anchored in bays containing rich, diversified marine life, and not in polluted ports like today. How many marine species did those vessels carry along? How many exotic species were accidentally introduced into the Mediterranean at that time and became naturalized later? We are fully aware of this phenomenon on land (many plant and animal species living in Italy today are actually exotic), but we tend to underestimate the potential of the same phenomenon in the sea.
Italian coasts now host many exotic marine species, of almost all plant and animal types. One example is the alga *Caulerpa*. A few years ago, the Mediterranean only hosted a couple of species, one of which was *C. prolifera*. Since the 1980s, *C. taxifolia*, a tropical species that escaped from the Aquarium of Montecarlo, began to invade French and Ligurian coasts, covering seabeds, replacing many other species and altering food chains. It caused such severe damage that it was nicknamed “killer alga”. It now flourishes in various areas of the western Mediterranean, from the Balearic Islands to Sicily. In the meantime, another *Caulerpa*, native to the Red Sea, had crossed the Suez Canal: *C. racemosa*. While the media focused attention on the “killer alga”, its Lessepsian sibling surreptitiously invaded the entire eastern Mediterranean. Today, it is common along many Italian shores, even in the west. In the Ligurian Sea, the two exotic *Caulerpa* have made contact and are now competing against each other. However, *C. racemosa* seems to be even more aggressive than the so-called “killer alga”!
Among exotic marine animals, the strange case of *Oculina patagonica* is worth quoting. This is a colonial, bioconstructing madrepore with symbiontic zooxanthellae, i.e., very similar to species forming coral reefs and, at first sight, it resembles the Italian *Cladocora caespitosa*. Nobody would ever have thought that a coral could be passively carried on the fouled bottom of a ship! And yet, in 1966, a large colony of this species was casually discovered near the port of Savona. Later, this species was found in other places in the Ligurian Sea and the Mediterranean, and is now abundant in southern Spain and Israel. Remarkably, before its discovery near Savona, *Oculina patagonica* had never been seen alive. It had been described in 1908 from sub-fossil specimens collected in Argentina but, since then, nobody had ever found it on Argentinean seabeds. It would be a paradox for a species to be abundant in the Mediterranean and yet disappear in its native country.



Caulerpa taxifolia, an invasive green alga

Flabellina affinis (foreground) and *F. ischitana*, two colourful species of nudibranchiate molluscs

Desertification of coasts can also have side effects. The hydra *Clytia hummelincki* has recently appeared in the Mediterranean, along coasts in Calabria and Apulia, in the very deserts created by sea urchins. The jellyfish stage of *Clytia hummelincki* is an extremely large animal. Jellyfish prey on larvae and fish eggs, and their proliferation may affect fishing negatively.

■ Shady areas, hiding-places and grottoes

A tiny rocky ridge or a small gully are enough, when moving from light to shade, to cause a dramatic change in the greenish-brown colour of habitats with photophilous algae, in only a few centimetres. Colours become intense: the yellow of the anthozoan *Parazoanthus axinellae* or the sponge C*lathrina clathrus*; the red of the sponge *Spirastrella cunctatrix*; the orange of the bryozoan *Reteporella*; the black of the horny sponges *Spongia* and *Ircinia*; or the blue of the sponge *Forbas tenacior*. There are also many hydroids, such as *Eudendrium armatum*, which looks like a small, upside-down tree. Gullies host many fish, from white bream to grouper, and decapod crustaceans like hermit crabs (*Scyllarides latus*) and slipper lobster (*Scyllarus arctus*).
Opposite sunny, gently sloping underwater cliffs hosting photophilous algae are grottoes populated by organisms preferring less well-lit places. Although each

The bryozoan *Reteporella septentrionalis*, also called “sea lace” or “Neptune’s lace” grotto is a unique and unrepeatable microcosm, cavernicolous biocenoses are typical and occupy characteristic horizontal zones.

In just a few metres, grottoes reproduce effects of light penetration which, on the seabed outside, fade over tens or even hundreds of metres. According to their shape, one can move from shady entrances to the complete darkness of internal chambers. Among plants, there are a few red algae and the green alga *Palmophyllum crassum*, which are both found only a few metres from grotto entrances - after that, there are only animals. As there is no light, energy is carried into grottoes by the movement of water, in the form of plankton and particle-sized or dissolved organic matter. Sessile filterers cover the walls of grottoes. Hydroids live on the vaults of their entrances, where light is dim and water movement stronger. Colonies of *Eudendrium armatum* look like tiny oaks, with branches extending horizontally, moving water passing through them. Red coral (*Corallium rubrum*) is also found in grotto entrances and gullies. Its small colonies now yield inadequate commercial profit. Italy is one of the world's most important countries in the working of coral and all the "deposits" of this precious anthozoan were amply exploited in the past, so that today scuba divers cannot find red coral at accessible depths.

Internal areas in grottoes host other anthozoans, such as madrepores (*Caryophylla smithi* and *Leptopsammia pruvoti*), which use their cnidocysts to

Detail of branches of red coral (*Corallium rubrum*) with spreading tentacles

Bioconstructors

Carlo Nike Bianchi · Carla Morri

Bioconstructors build solid formations which raise seabeds. They build when "alive", although their constructions are alive only at the tips. Bioconstructions begin when a group of sessile, colonial or gregarious individuals settle and produce mass skeletons, generally made up of calcium carbonate. When the first layer of organisms dies, a second layer settles on their skeletons. When this layer also dies and is superimposed on the first, a third layer starts to settle. And a fourth, a fifth … and the construction continues for hundreds or thousands of years. Other species living in the tiny spaces between skeletons cement the framework.

The best-known bioconstructions are tropical coral barriers. In the Mediterranean, similar formations are only produced deep in the sea by the white corals *Lophelia pertusa* and *Madrepora oculata*. Fishermen using trawl nets know their reefs very well, because they can ruin their nets. In northern seas, white coral reefs may be up to 80 metres high!

Other bioconstructing organisms are found among coralline algae, such as vermetid molluscs, bryozoans, cirripede crustaceans and serpulid polychaetes. Mediterranean bioconstructions are usually mono- or oligospecific as regards the species responsible for their construction.

From this viewpoint, the Mediterranean follows the empirical law by which diversity of bioconstructors decreases from the intertropical belt to higher latitudes.

The main bioconstructions on Mediterranean rocky seabeds are:

1. Midlittoral pavements, formed by the coralline alga *Lithophyllum byssoides*.
2. Calcareous platforms of the vermetid mollusc *Dendropoma petraeum*, spreading in the infralittoral fringe, especially in southern Italy.
3. Infralittoral framework of the cirripede *Balanus perforatus*.
4. Infralittoral encrustations of the coralline algae *Corallina elongata* and *Lithophyllum incrustans*.
5. Formations of three Mediterranean coral species with symbiontic zooxanthellae: *Cladocora caespitosa*, *Madracis pharensis* and *Oculina patagonica*. *C. caespitosa* has calcification rates similar to those of many tropical bioconstructors and may thus form very large banks.
6. There are two types of coralline formations in circalittorals, generally constructed by coralline algae (*Mesophyllum lichenoides*, *Lithophyllum stictaeforme*, *Neogoniolithon brassica-florida*): cliff coral reefs, which grow on deep rocky walls, and platform coral reefs, which develop on horizontal substrates.

Shallow bed with prevalence of red coralline algae

Biodestructors

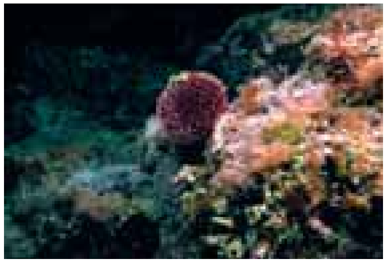
Ferdinando Boero · Simonetta Fraschetti

Many marine animals erode bioconstructions mechanically and a few may corrode limestone chemically by emitting acids.
The most important biodestructors burrow hollows in carbonatic rock and are called “borers”. Probably, they do not compete well for the occupation of the substrate and cannot proliferate on rock surfaces. To avoid competition, they behave like animals in soft seabeds, except that, instead of digging in sand or silt, they burrow in rock. They make rock and bioconstructions less resistent to the destructive action of waves, and may facilitate marine erosion of coasts.
The most important boring animals are sponges (especially clionids), polychaetes (spionids and others), and molluscs (particularly bivalves of the genera *Lithophaga*, *Gastrochaena*, etc.).
Date mussel (*Lithophaga lithophaga*) bores into vertical and plunging cliffs and *Gastrochaena dubia* into gentle slopes. Piddock (*Pholas dactylus*), widespread in the high Adriatic, pierces soft rock.
Clionids include several brightly coloured species (greenish, brown, yellow, orange, red, lilac) which combine mechanical and chemical boring.
The role of clionids in the delicate balance between the construction and demolition of coral reefs is very important and is not only limited to destruction - it sometimes contributes to construction.
For instance, *Cliona nigricans*, a large greyish-yellow to dark green species, is one of the few sponges covered with zooxanthellae (most sponges host zoocyanellae). It lives as deep as 50 m and is also active on biodetrital seabeds, where it attacks rock fragments and clumps of coralline algae.
From the actively boring form, growing inside a calcareous mass and thus invisible from the outside, *C. nigricans*, like many other species of the same genus, may evolve into another form, which partly emerges outside, forming large papillae, and may eventually evolve into yet another form, with which it incorporates calcareous fragments dissolved in its own body, thus creating stabler and thicker biogenic substrates for many other sessile animals. When growing in large numbers, it produces a long, hard, secondary substrate which recreates coralline seabeds: the worst of all biodestructors turns into a bioconstructor!

Boring sponges (*Cliona celata*), encrusting red algae (*Lithophyllum*), erect red algae (*Laurencia*) and sea urchins (*Arbacia lixula*), 1 metre below the surface

catch prey carried by currents. They are therefore passive filterers and require ample water exchange around their colonies to obtain sufficient food. This is why they are numerous around grotto entrances, where even minimal movements of water are amplified. Hydroids lurk deeper inside, and the limit of their penetration indicates the limit of food efficiently transported by currents. Other anthozoans, with larger tentacles, can penetrate further. If water movement decreases as we proceed inside grottoes, how can large anthozoans survive? The answer is: by feeding on mysids (opossum shrimps). Some of these, such as *Siriella* and *Hemimysis*, are often found in grottoes and carry out daily migration, i.e., they swarm into grottoes by day and swarm out by night, searching for food. Therefore, they gather energy outside and bring it inside, where they become prey to large passive filterers like sea anemones and *Cerianthus*. Besides being prey, opossum shrimps are also a source of nutrients. Their excrement is important for active filterers which feed on dissolved or particle-sized organic matter. Cnidarians wait for food to reach their tentacles, whereas active filterers create micro-currents by beating the water with cilia or flagellae on their filtering systems.
Active filterers are, for example, bryozoans like *Myriapora truncata* or false coral, the red, tree-like colonies of which resemble red coral. Active filterers par excellence, the most typical inhabitants of grottoes, are sponges. *Petrosia ficiformis*, which is very compact, lives in all areas of grottoes, dark or light. If light is sufficient for photosynthesis, *Petrosia* is purplish, due to the zoocyanellae living on it in symbiosis. When light is dim or absent, it is white. In the exploration of grottoes, sponges belonging to groups previously considered to be extinct have been found. They are living fossils, such as *Petrobiona massiliana*, found in grottoes along the French Mediterranean coast and later discovered in many other grottoes, also in Italy. When observing grotto walls, we may often see small red tree-like shapes, which are neither coral nor bryozoans. They are the foraminiferous protozoans *Miniacina miniacea*, only a few millimetres high. As regards vagile fauna, grottoes typically host prawns such as *Plesionika narval* and *Stenopus spinosus* and crab like *Dromia personata* and *Herbstia condylata*, although fish are the most conspicuous and vulnerable fauna.
Many grottoes are called “black”, because they used to host large specimens of *Sciaena umbra*. Unfortunately, in present-day Italian grottoes, the presence of black umbra, but also of greater forkbeard (*Phycis blennoides*) and conger eel (*Conger conger*) is only a memory. However, large fish soon colonize grottoes if they are adequately protected. Typical small fish found in grottoes are cardinal fish (*Apogon imberbis*), leopard-spotted goby (*Thorogobius ephippiatus*) and black brotula (*Oligopus ater*).

A forest of the candelabra-shaped sea fan *Eunicella singularis*



Purple sea urchin (*Sphaerechinus granularis*) on an algal bed (*Laurencia, Amphiroa*)

Colonies of the hydroid *Sertularella crassicaulis* on tips of the sea fan *Eunicella singularis*

Green alga *Codium bursa*

■ Seabeds with sciaphilous (shade-loving) algae

Where light is insufficient for the life of photophilous algae, the circalittoral zone starts, and extends on the continental platform as far as depths inaccessible to scuba divers. The only algae which colonize circalittoral seabeds are sciaphilous, i.e., thriving in dim, diffused light.

The first circalittoral populations living on hard seabeds are those found in fringing reefs. Fringing reefs are distinguished from coral reefs (which, according to some scientists, are a richer version of fringing reefs) because they lack significant bioconcretions and a few important species. But perhaps it would be better to identify communities by the presence rather than the absence of particular characteristics.

Fringing reefs typically host sciaphilous algae, the thalli of which are slightly calcified or leathery. Among these are the green algae *Halimeda tuna*, *Flabellia petiolata* and the red alga *Peyssonnelia squamaria*. The globose-depressed green alga *Codium bursa* also abounds in hemiphotophilous communities leading to fringing reefs. The upper layer of the fringing reef typically hosts animals such as the anthozoan *Alcyonium acaule* or the sponge *Axinella verrucosa*, which looks like a small tree. The zoantharia *Parazoanthus axinellae* owes its name to the fact it is often epibiotic on *Axinella*. Epibiosis is due to acrophilia (love of high places), a lifestyle adopted to prevent sedimentation and to extend further in water. The chandelier-shaped gorgonian *Eunicella singularis* is the only Mediterranean gorgonian, or sea fan, which lives in symbiosis with zooxanthellae, which give it an off-white colour. Typical of this shady habitat are also the large hydroids of the genus *Eudendrium*, such as *E. glomeratum* and *E. ramosum* which, like the photophilous *E. racemosum* and the troglophilous *E. armatum*, may be mistaken for brown algae.

Many algae die out during winter and are replaced by large hydroids: in addition to *Eudendrium*, there are species of *Halecium*, *Sertularella* and *Bougainvillia*. Among the numerous vagile fauna found in fringing reef communities is lobster (*Palinurus elephas*), purple sea urchin (*Sphaerechinus granularis*) and moray (*Muraena helena*), which shelter in rock gullies; large swarms of ray's bream (*Chromis chromis*) float in the water.

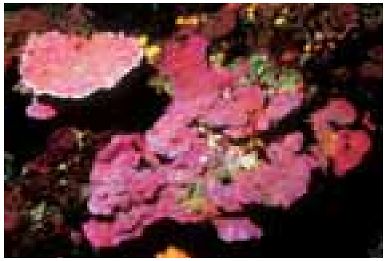
■ Coral reefs

Coral reefs are the typical biocenosis of hard circalittoral seabeds. They are characterized by bioconstructions formed of calcareous coralline algae (not true corals). One of the main reef-building coral algae is *Mesophyllum lichenoides*, which is already found in infralittorals (it is also called infralittoral coral alga). Other constructing coral algae are *Lithophyllum stictaeforme* and *Neogoniolithon brassica-florida*.

Animals share in bioconcretion both as constructors (bryozoans, serpulids, madrepores) and as coral borers (clionid sponges, bivalves, boring sipunculid worms) but, above all, they characterize the upper coral reef. Large gorgonian forests are a common sight.

Gorgonians (sea fans) and other important animals in coral reefs are sessile and filterers, and feed on organic particles floating in the water. They bring energy from the water column, exploiting its primary (phytoplankton) and paraprimary (debris) production and thus creating a link between benthos and the pelagic environment.

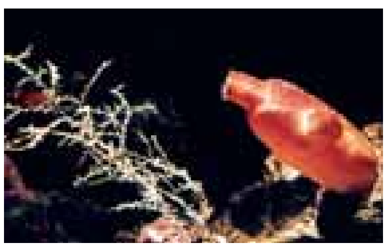
Paramuricea clavata is the most typical sea fan, with ruby colonies that turn yellow in certain areas. Its tree-like tentacles host epibionts such as bryozoans, hydroids, the alcyonarian *Parerythropodium coralloides* and the bivalve mollusc *Pteria hirundo*. *Eunicella cavolinii* is another sea fan which may be found in coral reefs. False black coral (*Gerardia savaglia*) is similar to the sea fan and used to be collected in spite of its fibrous skeleton, which is difficult to work.



Calcareous red alga *Lithophyllum stictaeforme* taking part in coralline bioconcretion

Small gastropod *Neosimnia spelta* preying on sea fan *Eunicella singularis*

Sponge, alga and madrepore bioconstructions, with *Sabella spallanzani* and its branchial tufts



Hydroid *Eudendrium racemosum* and sea squirt *Halocynthia papillosa*

The bottom of coral reefs, under sea fans, hosts many other animals, like the sponges *Spongia agaricina* or *Cacospongia scalaris* and many ascidians (sea squirts). The most typical sea squirt in coral reefs is the red “sea potato” *Halocynthia papillosa*. The thick, horny tunic of the large sea squirt *Microcosmus sabatieri* is encrusted with other organisms (the name of the genus actually means “small world”) and looks like a stone covered by algae and animals: only the vertical, purplish bands of the two siphons show us it is a sea squirt. Other typical sea squirts in coral reefs are didemnids, which are colonial and resemble sponges, and some colonial madrepores such as *Phyllangia mouchezi* and *Polycyathus muellerae*. Several species of bryozoans are important for coral bioconcretion, among which is stag-antler bryozoan (*Smittina cervicornis*).

Also serpulids - sedentary polychaetes living in calcareous tubes - contribute to bioconcretion, and *Serpula vermicularis* is among the most typical in coral reefs. Although the upper layer of coral reefs is typically made up of sea fans, the latter may sometimes cohabit with or be replaced by large sponges, such as *Siphonocalina coriacea*, similar to long tubes, or the large tree-like *Axinella*: *A. cannabina* and *A. polypoides*.

Large, erect bryozoans also compose the upper layer of coral reefs, e.g., elk-antler bryozoan (*Pentapora fascialis*), the colonies of which may be over 50 cm wide. The base of coral reefs, between rock and silt, or even biodetrital seabeds, host the rare sea fan *Eunicella verrucosa*, which is brilliant white (sometimes rosy) and bristly.

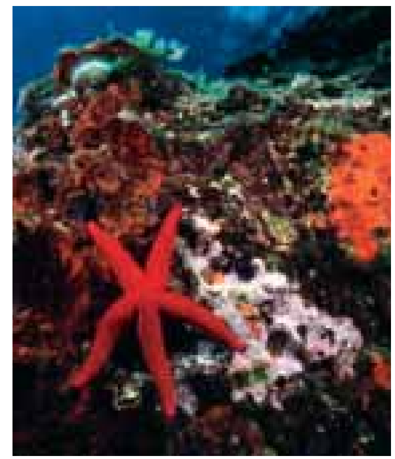
In turbid waters, highly sedimentary coral reefs house another sea fan, *Leptogorgia sarmentosa*, the thin colonies of which have different colours - yellow, orange, brick red, violet, and even white. Its colonies frequently host the feather star *Antedon mediterranea*, another case of acrophilia.

Among vagile invertebrates in coral reefs are the red starfish of the Mediterranean: the rough *Echinaster sepositus* is the most common; *Hacelia attenuata*, with polygonal rays, and *Ophidiaster ophidianus* with cylindrical rays, live in warm areas. Melon sea urchin (*Echinus melo*) and diademe sea urchin (*Centrostephanus longispinus*) are also conspicuous and have tropical affinity.

Coral reefs are home to many fish. Red ray’s bream (*Anthias anthias*) is almost exclusive to this habitat. Large-scaled scorpion fish (*Scorpaena scrofa*), with its dreadful sting, is also frequent. Nursehound (*Scyliorhinus stellaris*), a small shark commonly found on these seabeds, uses its cirri to attach its eggs to the branchlets of sea fans.

The most important fish in coral reefs is grouper (*Epinephelus marginatus*), now rare and localized. Large specimens may only be found in protected marine areas.

A colony of false black coral (*Gerardia savaglia*) encircled by swarming red ray’s bream (*Anthias anthias*)



Starfish *Echinaster sepositus* moving slowly on a plunging cliff wall two metres below the surface. Clearly visible are encrusting colonies of bryozoan (*Schizobrachiella sanguinea*), tree-like (*Amphiroa*), and fan-shaped (*Padina pavonica*) algae, encrusting coralline algae and sponges, both boring (*Cliona*) and encrusting (*Crambe crambe*)

Conservation and management

C. NIKE BIANCHI · FERDINANDO BOERO · LUIGI CAROBENE · GIUSEPPE CARPANETO · SIMONETTA FRASCHETTI · CARLA MORRI · SIMONETTA PECCENINI

Vegetation on rocky coasts is usually in better condition than that on sandy shores, because its inaccessibility provides for its self-defence. However, buildings have obliterated kilometres of cliffs along Italian coasts. In the last century, many cliff locations were effaced by urban construction, especially near cities by the sea, such as Genoa and Naples. The growth of towns, development of tourist and industrial centres, roads and railways have destroyed cliff vegetation. But even isolated areas were not spared human intervention. Only where cliffs are too steep to allow easy access do we find almost intact environments, as on the promontories of Portofino, Circeo, Cilento, Gargano, Conero, etc.. As these habitats are gene reservoirs, green, uncontaminated areas, and good examples for teaching purposes, they must be protected against any kind of intervention, by the establishment - if they have not yet been created - of sanctuaries and natural parks.

At present, there are various kinds and degrees of anthropic pressure on coastlines. Drastic interventions are those which revolutionize cliff environments completely, covering them with asphalt and cement. In other cases, cliffs are covered with soil from dumps, which negatively affects life on the seabed.

Seabirds are seriously threatened by marine pollution, which affects these fish predators more than any other animal. Toxic substances (e.g., mercury and chlorine derivates) in the bodies of their prey become highly concentrated in the tissues of predators (shearwaters, predators, swifts, etc.), giving rise to physiological unbalance, sterility, and death. Toxins often accumulate in eggs, hindering embryo development. One study of Audouin’s gull on the island of Capraia showed that the concentration of mercury in this species is so high that it alters their nervous systems and interferes with their reproductive cycles.

Herring gull and crow have become infesting species that hinder the survival of other birds like Audouin’s gull and predators. In Sicily, the growing numbers of herring gull have practically arrested the successful reproduction of little tern (*Sterna albifrons*), black-winged stilt (*Himantopus himantopus*) and avocet (*Recurvirostra avosetta*). Demographic control is necessary, particularly in areas

The rock called Pizzomunno, and the village of Vieste sheer above the sea in the background (Apulia) containing breeding grounds of rare or vulnerable animals, the populations of which could be endangered. Collecting eggs from nests at the beginning of the reproductive season may help curb herring gull.

Black rat is the only mammal capable of climbing on plunging cliffs where seabirds and raptors nest. On islands where this pest was introduced by man, black rat has become so numerous that it preys extensively on nests.

Other factors which threaten cliff fauna and vegetation are human sports like climbing, either with or without supporting or security equipment. Disturbance caused by people scrambling up and down cliffs - especially during the reproductive season of birds - may cause nests to be abandoned. This is particularly dangerous for those species, of which only a few hundred pairs nest in Italy, such as shag, Audouin's gull, shearwater and peregrine. Maps with the breeding grounds of these species and their nesting periods must be required to authorize people to go climbing at the best time and place.

Motorboats may also disturb bird species which are particularly sensitive to man's presence (e.g., stormy petrel) but above all that rare mammal, monk seal. Motorboats are especially harmful when they are anchored inside grottoes with paths for tourists, as is the case of the famous Grotta del Bue

An abandoned pumice quarry along the coast on Aeolian island of Lipari (Sicily)

Marino in the Gulf of Orosei (Sardinia). If these disturbing factors should persist, the tiny numbers of monk seal will decline still further. One solution would be ex-situ conservation, i.e., reproduction in captivity and freeing of specimens (which, however, do not fear man). In this way, species would be more resistent to man's disturbance and populations be composed of less fearful animals, which could be viewed by the public, with positive effects on eco-tourism.

Many other anthropic impacts affect fauna on rocky coasts. The young of some diurnal predators (especially Eleonora's falcon and peregrine) are caught to be illegally sold to collectors and falconry enthusiasts, particularly in Germany and other European countries. Exaggerated interest in these animals is often dangerous, and irresponsible naturalist photographers draw too close to the nests of birds, exceeding their natural escape distance. Some species, like falcon, abandon their nests and are no longer confident in sites which were once favourable for their reproduction.

Packs of stray dogs may jeopardize the reproduction of some species. This phenomenon occurs more and more frequently near tourist areas and especially in the evenings, and is associated with public and private disregard of the territory.

Rocky coast near Otranto (Apulia)

A rock “window” along coast of peninsula of Capo Palinuro (Campania)

Other disturbing factors are fire, which burns pine woodland and maquis along the coast, and air, river and sea pollution that fill the marine aerosol with contaminating elements such as oxides of sulphur, nitrogen and hydrocarbons, which damage pine woodland and coastal maquis.

Human activities also favour the diffusion of parasites such as scale insect *Matsucoccus feytaudi*, which destroys cluster pine woodland.

Human colonization by eastern Mediterranean populations (Phocians, Phoenicians, Etruscans, Greeks, etc.) came from the sea. Rocky coasts were often chosen as permanent or temporary settlements because of their elevated position, which enabled these primitive peoples to defend themselves against possible aggressors. Ancient sighting towers on rocky tops can still be seen along all Italian shores. The building of coastal settlements had a powerful impact on the pre-existing vegetation, from which large quantities of wood were collected to build houses and ships, and for household use.

Even the steepest cliffs have been terraced for cultivation. Beautiful examples of this type of agriculture are the vineyards in the five villages of Cinque Terre (Liguria), where proper and continued care for the dry walls supporting the terraces was favoured by the transformation of this area into a National Park. Elsewhere, abandoned, cultivated land in difficult areas is re-colonized by spontaneous vegetation that exploits terraces.

In Italy, “*Aree Marine Protette*” (Protected Marine Areas) almost always include rocky coasts. Rocky seabeds are not very extensive (most seabeds are sandy or silty) and organisms occupying them are long-lived, can be very large, and some of them can build massive bioconstructions. Therefore, the renovation rate is very slow and, when destroyed, it takes a long time to regenerate.

What principles must be considered when selecting areas that need specific conservation measures?

The first one is the beauty of seascapes. Aesthetic perception is not only associated with spectacular seabeds and plunging cliffs, but also with the conspicuousness of marine communities, which are often just as spectacular, like sea-fan forests, one of the favourite haunts of grouper.

The second is the presence of significant bioconstructions, such as the formations of *Cladocora caespitosa* found in Protected Marine Areas in Porto Cesareo (Apulia) and Isola Capo Rizzuto (Calabria).

The third is the presence of rare, threatened species or ones living in fragile, unique habitats like grottoes. Grottoes are the main feature of the Protected Marine Area of Punta Campanella (Campania).

The fourth is the co-existence of large numbers of benthic species and

communities, symbols of high biodiversity: most Italian Protected Marine Areas meet this requirement.
Another principle, unfortunately crucial, is proper identification of areas which were rich in biodiversity in the past and which are now depleted. Protection, in this case, would not aim at the conservation of natural conditions, but at the reconstruction of what was treacherously destroyed. In Apulia and Campania, for instance, illegal fishing of date mussel (*Lithophaga lithophaga*) has extensively depleted large stretches of the Protected Marine Areas of Porto Cesareo and Punta Campanella. In order to collect date mussel, entire benthic biocenoses must be blasted out of the rock by explosives, and this gives rise to desertification of seabeds. The fishing, possession and consumption of date mussel are illegal but, unfortunately, coastal destruction continues unabated.
Generally speaking, the most pressing conservation and management issues regarding rocky seabeds are their exploitation as anchorages and for underwater fishing and tourism. In summer, isolated, hidden inlets along rocky coasts are favourite destinations for people in all kinds of motorboats converging in large numbers. Mechanical damage caused by mooring has been reported, for example, near the Island of Gallinara, off Albenga (Liguria). Each year, anchors and their chains destroy about one-tenth of the seabed near the island.
Diving in late summer shows how several organisms are killed in upper coral reefs, especially the large, tree-like sponge *Axinella polypoides*. Small fishing-lines and trammel nets collect animals selectively, and generally have a minor environmental impact. However, nets and lines dragging along the seabed scrape and wound sessile animals. When fish are caught and try to escape, lines get entangled around sponges and sea fans, tearing them from their points of anchorage. Equipment lost in the sea later has long-term deadly effects: currents make fishing-lines and nets scrape the seabed and furthers injure sessile animals. Research in Portofino showed that the worst damaged are sea fans - to such an extent that 30% of their colonies are trapped in nets and fishing-lines - which are the main cause of death in *Paramuricea clavata*.
The beauty of rocky seabeds, certified by the “seal of quality” conferred by the establishment of Protected Marine Areas, offers an alternative to fishing. Instead of using their tools to deprive the sea of its resources, fishermen must be converted into guides who take tourists on tours aimed at appreciating the beauty of seascapes. This is a real possibility. Tourist diving accounts for 60,000 dives a year along the five kilometres of the Portofino promontory! However, experience in other Mediterranean Protected Marine Areas, particularly in Spain, shows that tourist diving can seriously threaten the integrity of habitats that must be preserved and safeguarded. Unfortunately, many scuba divers cling to sea fans, bump into bioconstructions, raise sediment with their flippers, and produce air bubbles that remain trapped on the vaults of gullies. This supposedly insignificant behaviour, if repeated thousands of times in the same place, has a severe impact. The fragile colonies of large calcified bryozoans, such as *Pentapora fascialis*, are the first organisms to be affected. In this case, paradoxically, protection increases the number of visitors and gives rise to environmental depletion. This issue has been solved by managers of protected areas in the tropics, the economic development of which depends on flourishing coralline formations.
Eco-tourists who wish to dive and admire seascapes must prove their ability to do so without damaging corals and other organisms. This does not only preserve the integrity of sites, but also arouses the sensitivity of scuba divers towards the environment and leads to correct behaviour even in non-protected areas.

Horizontally-layered calcarenite on a cliff. Recession of high flanks is facilitated by softness of rock and powerful storms (which also caused the ship to run aground)

Suggestions for teaching

MARGHERITA SOLARI

■ Cliff-living animals

- Aims: to promote capacity for analysis and comparison of the various factors which characterize natural environments; to promote the ability to recognize the typical species of high coasts.
- Level: elementary school (8-10 years) and junior high school pupils (11-13 years).
- Material: literature, slides and/or films, suitable clothing and equipment for excursions (cameras, binoculars, manuals for bird identification, etc.).
- Collaboration: possible collaboration with naturalist guides or experts, both in class and during excursions.

STAGES OF WORK

1. Analyse cliff environments through class discussions, particularly the elements (and restricting factors) which characterize them: gradient, exposure to sunlight, saltiness in areas sprayed by seawater (aerosol), difficulties of access for man and animals.
2. Collect data on cliff environments: slides, documentaries, CD ROMs, etc..
3. Study and analyse photographs (preferably groups of students).
4. Identify an easily accessible high coastal stretch for the excursion (preferably in spring).
5. Aided by naturalists, continue work in class by analysing the main species (especially amphibians, reptiles and birds) which typically live on high coasts, permanently or temporarily.
6. Focus work on birds, analysing the ecological requirements of the main species living in the chosen environment; draw charts – with pictures and drawings taken from the relevant literature - with morphological characteristics essential for bird identification (colour of feathers, shape and colour of bills, shape of wings, type of flight, etc.), and living habits (type of food, nesting sites, use of nests for reproductive and also resting purposes, territoriality, etc.). Analyse predation and competition relationships among birds as related to their feeding habits; analyse lifestyles and food of seagulls and study the synanthropic behaviour of herring gull, a species whose large numbers highlight environmental depletion.

Punta Troia (island of Marettimo, Sicily)

7. Excursion to chosen site: study animals (reptiles, amphibians) or their footprints; study birds' nests and identify species.
8. Follow-up in class: discuss data collected during the excursion.
9. Discuss the ecological peculiarities of high coast environments and the need to minimize environmental impact and human presence, also to prevent disturbance of nesting species.

■ Morphology of rocky shores

- Aims: to understand the morphogenetic processes of high coasts and the main factors involved; to create awareness of the evolution of the landscape; to develop the capacity for recognizing various forms of coastal morphology.
- Level: junior high school pupils (11-13 years).
- Equipment: maps preferably those of the IGM (Italian Military Geographical Institute), scale 1:25,000; photographs taken from the literature; DIY material (polystyrene, paints, plywood boards) to construct models.

STAGES OF WORK

1. Identify on maps stretches of high coast along the Italian shoreline, for comparison purposes.
2. Discuss the main processes and results of coastal morphogenesis, its evolution, and typical forms for each evolutionary stage (initial morphogenetic stage: small scarp and reduced debris at the foot; lack of beaches; intermediate stage: high cliffs, promontories, grottoes, arches, uneven coastline; last stage: extensive abrasion platforms, usually with large beaches).
3. Study photographs of various high coasts and their main forms.
4. Study symbols used in maps, particularly those related to reliefs (contours, cross-hatching, scarp wedges, dotted lines, etc.).
5. Divide class into groups, each one of which should analyse a coastal stretch and particularly its gradient (cross-hatching for steepest stretches), caves and grottoes (wedge symbols), beaches (dotted lines), bays (contours in inlets), rocks and arches (explain names like rock, arch, headland, high rocky formation, inlet, cape, grotto, etc.), roads and towns. Possible study of bathymetric curves.
6. Construct three small polystyrene models showing the evolutionary stages of rocky coasts, and closely examine the model that best reproduces the stretches studied on maps.
7. Analyse the main environments of rocky coasts, the most important living creatures and their relationship with their environment.
8. Discuss the peculiarities of high coastal environments and conservation issues.

Rocky coastline of Carloforte (Sardinia)

Rare coast vegetation, Cala Spalmatore (island of Marettimo, Sicily)

Collecting invertebrates in coastal pools

■ Rock pools

- Aims: to elicit analysis and comparison of restricting factors in “extreme” environments; to understand the importance of preserving both biodiversity and peculiar microhabitats.
- Level: elementary school pupils (7-10 years).
- Equipment: literature, pictures and films; suitable clothing and equipment for excursions (camera, plastic bags to collect stranded material, magnifying glasses).
- Collaboration of naturalist guides who may help during excursions.

STAGES OF WORK

1. Preliminary activities: analyse ecosystems (including terrestrial) which are familiar to children, focusing on the relationship between various species in the different trophic levels (primary producers; primary, secondary, tertiary consumers; decomposers).
2. Examine the limiting factors along coasts: lack of freshwater, salty water, marine aerosol, wave erosion (mechanical action of the water mass, pressure on trapped gases, abrasion caused by rocky fragments carried by water, etc.).
3. Analyse the limiting factors in pool environments: variations in temperature and salinity, exposure to predators, limited water turnover, etc.).
4. Examine the mutual relationships between animals colonizing pools even temporarily, focusing on the ecological role of encrusting and leafy algae, which transform solar energy into organic matter used by primary consumers (gastropods, echinoderms, crustaceans); analyse the various types of secondary consumers (predators such as fish, echinoderms, etc.) and decomposers (crabs and prawns) which feed on animal and vegetal remains.
5. Analyse the feeding habits of animals (e.g., variously specialized molluscs which may be filterers; grazers which scrape algae with their radulae; or others which suck their prey from their shells, etc.); show pictures and films treating this environment, especially if children are not familiar with it.
6. Study strategies adopted by animals in these environments: morphological adaptations (suckers, mimetic colours, lack of scales) and behaviour (burrowing holes and lairs in seabed sediments).
7. Possible excursion to easily accessible stretches of rocky coast containing rock pools to study the environment and its organisms, collect data (study material through magnifying glasses), make out a list of living creatures present (general identification, if precise is impossible); measure the main chemico-physical parameters of pools at varying distances from the sea (temperature, pH, saltiness) and compare data: some pools (those near the high-tide mark) have parameters which are similar to those of the sea, due to continual water

Rocky coastline of Marches

turnover; others, although with differing parameters, may host very similar organisms.

8. Discuss the need to preserve these ecosystems for their biodiversity.

■ Sessile organisms

- Aims: to develop the capacity for observation, analysis and comparison of different phyla and classes of organisms; to develop the ability to recognize the main sessile specimens along Italian coasts.
- Level: junior high school pupils (11-13 years).
- Equipment: literature, pictures and films; suitable equipment and clothing for excursions (cameras, plastic bags to collect stranded material, magnifying glasses).

STAGES OF WORK

1. Discuss the characteristics of subaerial and submerged environments from the viewpoint of plant requirements (constant light exposure, or limited by depth; great temperature variations or due to steepness, viscosity, presence of nutrients only in seabeds or dissolved in water, etc.).
2. Analyse the main morphological characteristics of higher plants with regard to their functions (roots for absorption, stalks with mechanical, supporting or

A small inlet along coast of Gargano (Apulia): waves facilitate accumulation of algae

transporting functions, leaves with photosynthetic functions); compare with algal morphology and functions (rhizomes to adhere to the substrate, thalli to absorb water and dissolved elements). Quote examples of morphological changes to suit the different environments: robust rhizomes in environments rich in energy, aerial vesicles for thallus flotation, etc.
3. Analyse the main algal colours (green, brown, red) and their relationships with depth and light.
4. Identify an easily accessible coastal stretch for the excursion (preferably in spring).
5. Make out a list of the main algal species in the chosen area, perhaps with the help of an expert.
6. Excursion: collect data, make observations and take photographs, and collect possible stranded remains.
7. Write notes (presence of symbionts, commensal animals, etc.); identify species and their morphology.
8. Compare structures of algae with those of sessile animals (sea anemones, annelids, corals, jellyfish) and consider similarities and differences in their lifestyles.
9. Discuss the variety of submerged populations, the characteristics of coastal environments, particularly those with rocky coasts which host several sessile species, and conservation issues.

Feather star (*Antedon mediterranea*) on sea fan (*Paramuricea clavata*): typical organisms on Italian rocky coasts

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Glossary

> Acrophilia: love of high places.
> Aerosol: liquid (generally water) diffused through gaseous means.
> Chasmophyte: a plant adapted to living in cliff cracks.
> Ecotone: transitional environment between two well-defined habitats.
> Endemic: species the distribution of which is geographically restricted.
> Epibiont: an animal settling on other animals or plants.
> Euryecious: an organism which tolerates great variations in key parameters of the environments in which it lives.
> Eustatism: slow movement of the sea level.
> Halophilous: an organism living in environments rich in dissolved or crystallized salt (mainly sodium chloride) in soils, usually found near sea shores or coastal brackish lagoons.
> Heliophilous: an organism which loves direct sunlight.
> Holocene: the present geological epoch, which started with the recent post-glacial period (about 10,000 years ago).
> Hygrophilous: an organism which lives in very damp environments, but is not aquatic.
> Mesophilous: an organism which avoids extreme climatic and environmental conditions.
> Photophilous: a light-loving organism.
> Phytophagous: an organism feeding on plants.
> Propagule: reproductive organ in lower plants.
> Sciaphilous: an organism which loves dim, shady places.
> Seiche: a variation in sea (but also lake) level, associated with atmospheric phenomena.
> Sessile: an animal living with a wide base attached to a surface; in botany, a leaf without petiole.
> Soliflux: slow movement of sloping substrate, which generally affects only the vegetation on the bottom, and is associated with freeze/thaw cycles in subterranean water.
> Steno-Mediterranean: an organism living only in the Mediterranean area.
> Synanthropic: an organism the life of which depends on man.
> Thallus: vegetative structure the segments of which do not belong to roots, stalks or leaves.
> Vagile: an organism moving freely.
> Xerophilous: an organism loving very arid conditions.

List of species

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