Georg Glaeser
Daniel Abed-Navandi

Ecosystems of the Mediterranean Sea

A Photographic Dive

Springer

Dolphins in the Mediterranean
A pod of common bottlenose dolphins *Tursiops truncatus* is swimming towards the photographer in the open sea off the Croatian coast. Fortunately, sightings of these dolphins in the Mediterranean have been increasing in recent years. The greatest threat to dolphins is their accidental capture in fishing nets (also known as bycatch), ship traffic, and drifting plastic waste (p. 184f.).

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Close-up of the head of a common prawn *Palaemon*

Prawns have, like crayfish, common lobsters, and spiny lobsters, compound eyes with "mirror optics" – as opposed to the "lens optics" that are more common in most other crustaceans and in insects. With mirror optics, light rays are reflected on surfaces in the individual eyes, rather than being refracted by lenses. In a flash photograph of such an eye, this is clearly visible from the rectangular "pseudopupil".

The long process between the eyes is equipped with a row of pointed spines that protect the prawn against frontal attacks by larger fish. Tiny sensory hairs are visible between these spines. Especially the eyes of the prawn are visible to fish and therefore require greater protection. Similar, forward-pointing spines can be found on the front of many crustaceans – their escape route is usually backwards (p. 37).

Vogt, K. **Die Spiegeloptik des Flußkrebsauges**
Journal of comparative physiology, 135: 1-19 (1980)
https://www.degruyter.com/document/doi/10.1515/znc-1975-9-1027/pdf

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A rockpool prawn *Palaemon* takes an unusual pose: After escaping into the open water, it sinks back to the protective rocky ground with its antennae spread wide. Its two pairs of antennae probably serve both as feelers – to detect attacks in time – and as rudders to control the sinking.

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Relying on its camouflage pattern, the red scorpionfish *Scorpaena scrofa* remains motionless in front of the camera (p. 81).

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Body details of a feather star: The feather star *Antedon*, which is related to starfish, sea urchins, and sea cucumbers, anchors itself with its feet to the solid seafloor and filters plankton from the water that passes through the feathers of its arms (p. 158f.).

A fried egg jellyfish *Cotylorhiza tuberculata* floats in the open sea and is reflected on the water surface (p. 172f.).

Preface

Humans as observers in the sea

The sea as an environment is actually hostile to human life. We have to adapt to the sea's properties if we want to visit it: In the water, we quickly suffer from the cold temperatures. Due to reduced weight and water resistance, we cannot use our bodily strength as effectively. We cannot breathe underwater. Our eyesight is narrowed by goggles and the refractive index of the water. And we often encounter living beings that are unknown to us. But with practice, we can grow more familiar with this strange underwater world and spend some time there as curious, exploring observers. No other habitats of Earth illustrate the principles of life as strikingly as the oldest, most primordial habitats in the sea – the habitats from which all life forms have ultimately evolved.

Greater abundance of organisms than on land

It is thus unsurprising that marine habitats often host a greater variety of species, even in the smallest spaces, than similar habitats on land, and even the best trained specialists regularly encounter unknown animals or plants during their trips into the underwater world.

Yet, even creatures that are well familiar to us can harbour surprises: For instance, when you discover that a female warty crab carries thousands of eggs on its abdomen (p. 41), when a trusting rock shrimp starts "cleaning" a finger that is stuck out towards it, when a swarm of tiny fish "dances" as if by choreography (p. 178f.), or when an ocellated wrasse grabs a bunch of algae from your hand to build its nest (p. 44). The Mediterranean, so often declared to be dying, clearly still has the power to astonish us.

Snorkelling and diving

While snorkelling with mask and fins, humans are mostly restricted to a depth of five to ten metres from the surface, and even after extensive training, they will already reach their bodily limits after holding their breath for one or two minutes. Scuba diving may be technically and financially more elaborate, but it will unlock new possibilities. Ideally, you will not dive greater distances, but spend more time "going into detail" and trying to observe the underwater world more intensively.

This book is a habitat guide…

…and not a classification book. It is therefore divided by habitats, rather than by animal or plant groups.

So, you will not find, as is usually the case, a chapter on algae, then one on crustaceans, then another on fish, and so on, but instead we will dive with each chapter into eight different habitats – for instance, into a rocky or sandy coast, or into the open sea. What awaits us there are the different plants and animals that are typical of the respective habitat.

It is not possible to provide an exhaustive survey of the incredible biodiversity in the Mediterranean, where over 17 000 species of organisms have already been discovered. We will, therefore, limit ourselves to the most common species that can be found there.

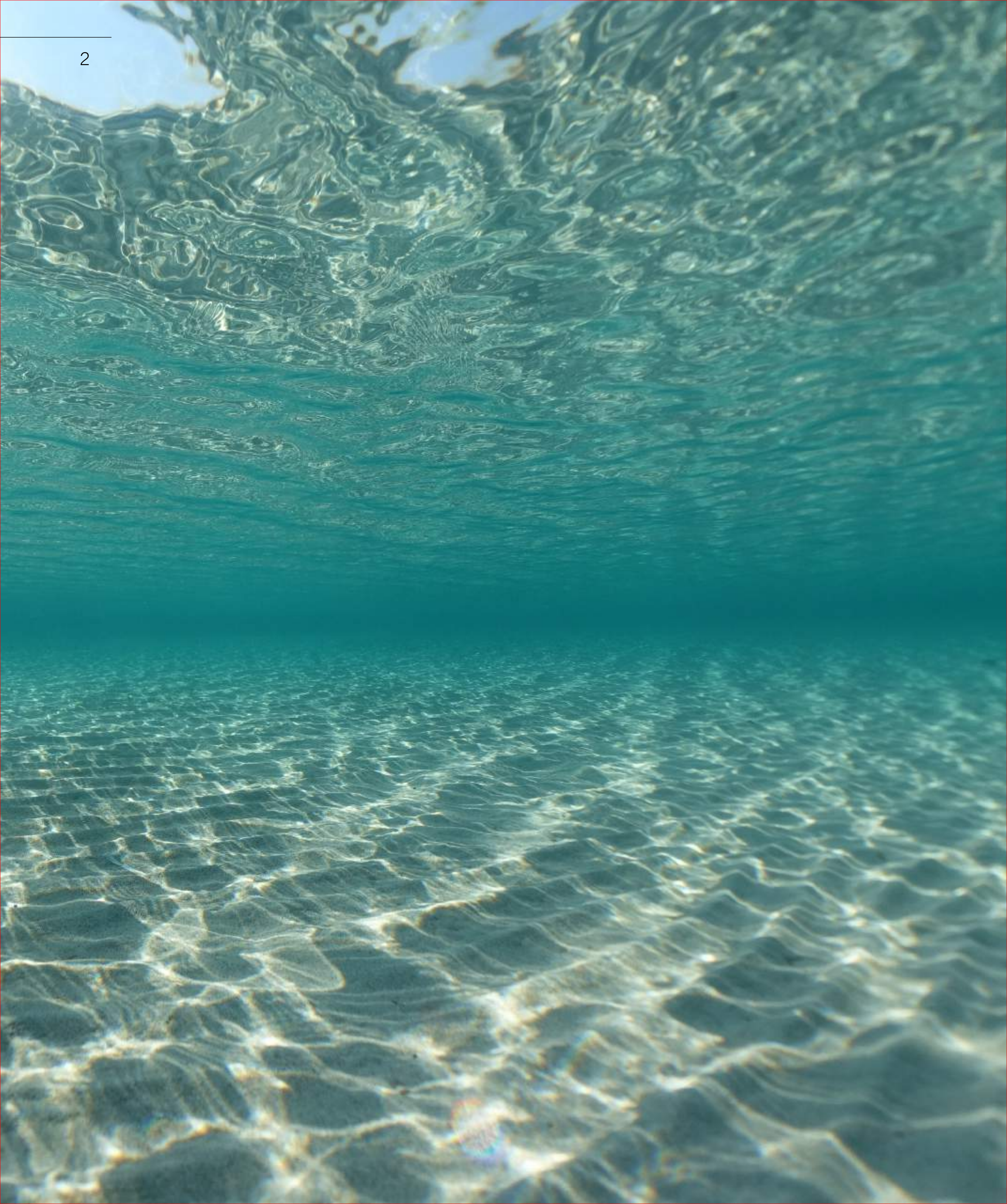
A few words about the authors

Daniel Abed-Navandi is a scientific expert in the field of marine ecology and works at the "Haus des Meeres – Aqua-Terra-Zoo", a public aquarium in Vienna. Since 1990, he has been teaching practical courses on marine habitats at the University of Vienna, which have led him from the Mediterranean to the eastern Pacific and even further to Australia. His vivid and science-based texts are wrapped around the photographs of Georg Glaeser. He has been a Professor of Geometry at the University of Applied Arts Vienna since 1998 and is also an experienced diver in whose eyes no organism is too tiny or too insignificant to be "put in the proper light". What matters to him is not only the documentation of the typical features of his "photographic models" but also an empathic mediation of his admiration and respect for all living beings.

Every time we put on fins and goggles…

…a new adventure begins: What will I see today? This book is meant to help recognise and better understand underwater habitats

We hope you enjoy it!



Habitat-Defining Parameters

In the sea, just as on dry land, very different habitats exist
Compared to life on land, however, marine habitats are more closely connected by the medium of water – cold deep-sea floors are connected with warm and bright water surfaces, rugged rocky shores with offshore seagrass meadows, and sandy beaches washed by waves with deep muddy bottoms.

Substances can travel very far
In the constantly moving sea water, substances can dissolve very well and be transported over long distances. Plant-fertilising substances derived from organisms decaying in the dark deep sea can thus travel to other habitats. And chemical messengers produced by animals at one coast can exert their effect at a different coast. Marine life can also move in a more energy-efficient manner than animals moving through the medium of air.

Geological, geographical, and climatic parameters
Why is it then that seacoasts often look so different and form diverse habitats despite this close connection between marine habitats?
Whether there is a sandy beach at one place or a rocky shore at another place is determined by the interplay between geological, geographical, and climatic parameters. The most important geological factor is the rock type: It makes a big difference whether the sea bottom is made of erodible lime, sandstone, or sturdy granite. The question of how long a surface has been covered by sea water – for centuries or for millennia – also plays a crucial role.

Impact of oceanic forces
Equally significant is a surface's exposure to the forces of the sea. For the formation of a habitat, it makes a difference how large the angle of inclination of the seafloor is – whether it is a steep or flat coast – and how large the coastal opening angle is. A coast with a rocky cape that extends far out into the sea enables the development of different organisms than a shallow, calm bay.

Proximity to river mouths
A habitat's proximity to river mouths is another significant factor, because salinity fluctuations, fertiliser pollution, and sediment deposits caused by rivers can pose physiological challenges to certain animals and plants and inhibit their growth.

Tropical or temperate
The characteristics of a habitat are also affected by the climate zone in which a coastal area is located. Limestone sediments in tropical climates host different vegetation than the same sediments in temperate climates, even if their exposure to the sea is similar. We expect coral reefs to grow on such coasts in tropical seas, whereas limestone coasts in temperate climates are more likely to grow forests of brown algae. A region's temperature and irradiance over the seasons determines which animal and plant species can thrive there.

"Keystone species"
In each habitat there are so-called keystone species, which play a crucial role in determining that habitat's features. Some organisms worth highlighting here are sea urchins, which are the most important grazers of algae forests; sea sponges, which can cover the entire sea bottom in dark, rocky regions; and seagrasses, which stabilise sandy grounds with their dense root systems, preventing the sand from being swept away by waves and thus turning it into a new, permanently stable habitat.
The following pages will introduce you to a variety of animals and plants in their marine habitats, along with their *scientific* and common names. These animals and plants are commonly found in the Mediterranean and can easily be spotted by divers and snorkelers. We invite you to join us on this journey to discover the different habitats in the Mediterranean, as we travel from one seabed to the next.

A journey along the path of solar energy
The order in which the various habitats are presented in this book largely follows the path of the one energy source that creates and sustains all life on Earth – the path of sunlight: Strongly sunlit habitats are thus described before darker ones, and the plants of a specific habitat (if there is any noteworthy plant growth) are always described before its animals.

Habitats in the Mediterranean Sea

1 Bright, sun-exposed rocky ground

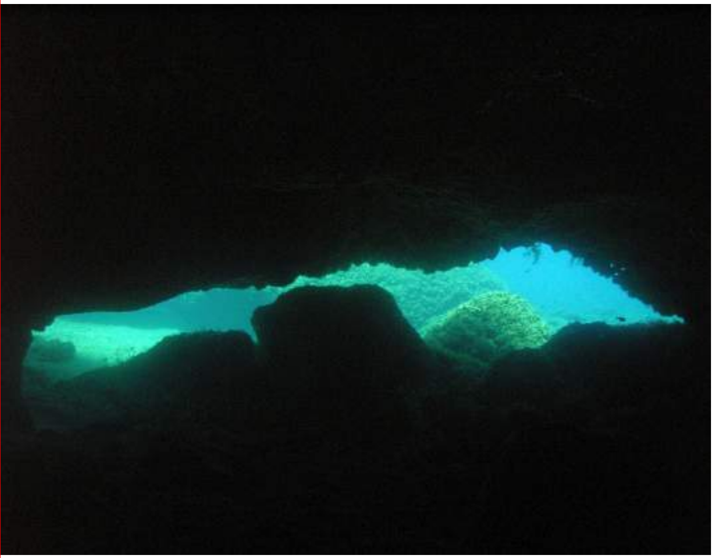
Hard bottom habitat

Brown and green algae, anemones, sun-loving sponges, tubeworms, sea urchins, crabs, shrimps, cuttlefish, sea breams, wrasses, combers.

2 Dark, shady rocky ground

Hard bottom habitat

Green and red algae, zoanthids, corals, serpulids, sea squirts, aeolidid slugs, crustaceans, scorpionfish, gobies, blennies.



3 Sea caves

Hard bottom habitat

Corals, anemones, bryozoans, sponges, spiny lobsters, squat lobsters, octopuses, moray eels, eels.

4 Intertidal zone

Hard bottom habitat

Crabs, beadlet anemones, sea snails, mussels, barnacles, blennies, seabirds.

5 Sandy ground

Soft bottom habitat

Anemones, predatory snails, echinoderms, red and grey mullets, gurnards, weevers.

6 Seagrass

Soft bottom habitat

Seagrasses, pen shells, gilthead seabreams, seahorses, hermit crabs.

7 Deep muddy ground

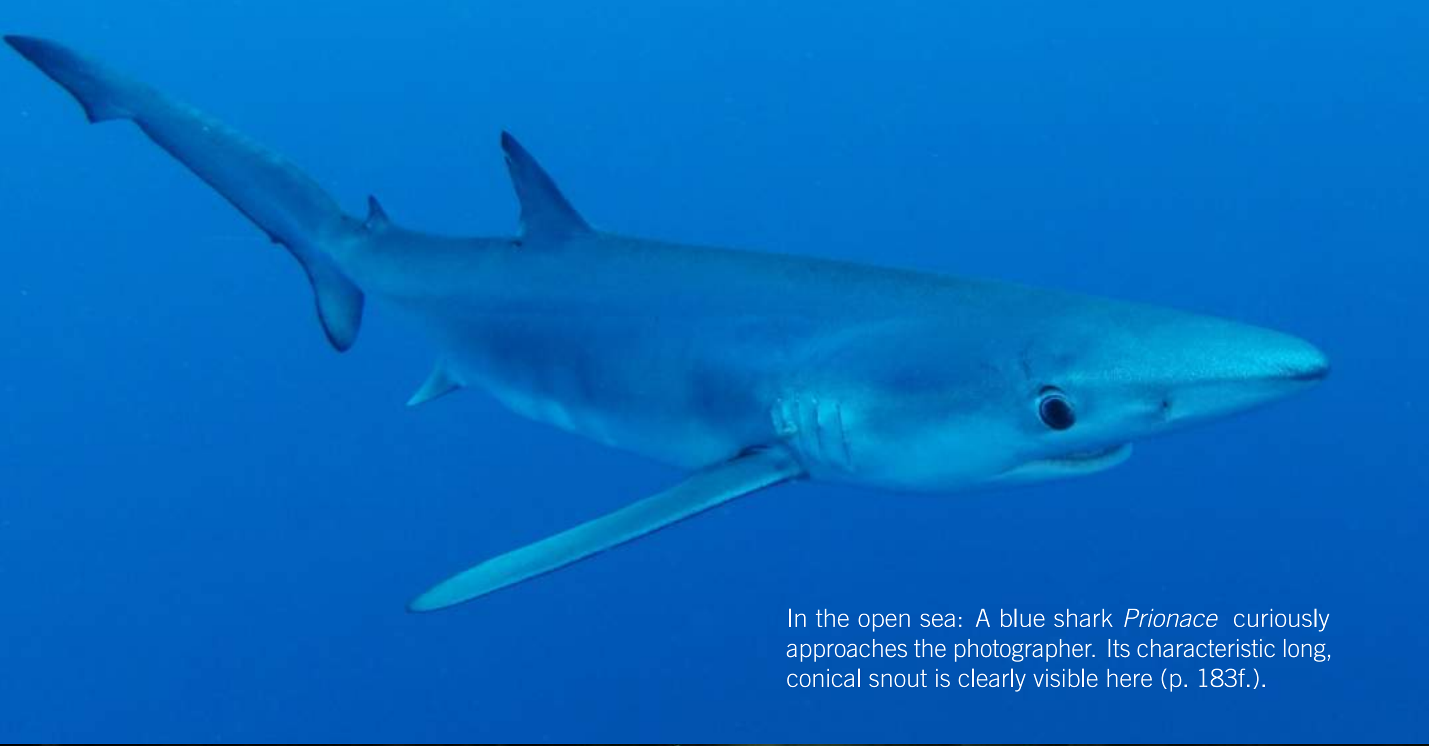
Soft bottom habitat

Sponges, Tethys sea slugs, hermit crabs, brittle stars, sea squirts, rays.

8 Open water

Jellyfish, copepods, sand smelts, damselfish, blue runners, tuna fish, sharks.

Impressive Photo Models in their Habitats



In the open sea: A blue shark *Prionace* curiously approaches the photographer. Its characteristic long, conical snout is clearly visible here (p. 183f.).

Sun-exposed rocky ground: A red-black triplefin male *Tripterygion tripteronotus* observes the photographer (p. 104f.).

Sandy soft ground: The piper gurnard *Trigla* feels threatened and expands the posterior part of its pectoral fins so that their undersides face up and dark eye spots appear (also p. 134).

Habitat: Sunlit Rocky Ground

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_1

Durable subtrate

Solid rocks provide a surface that – as opposed to gravel, sand, and mud – remains in place for years, even with strong water movements. Such rocky sea floors are often the foundation for durable, species-rich ecosystems.

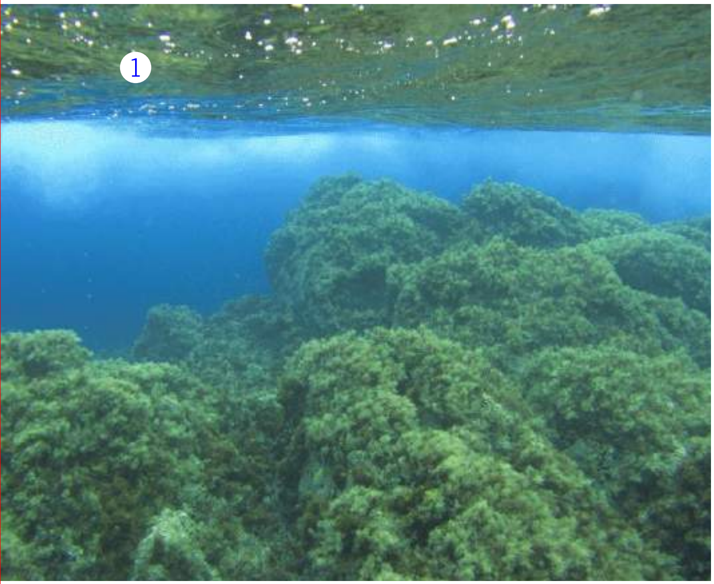
Distinction based on solar irradiance

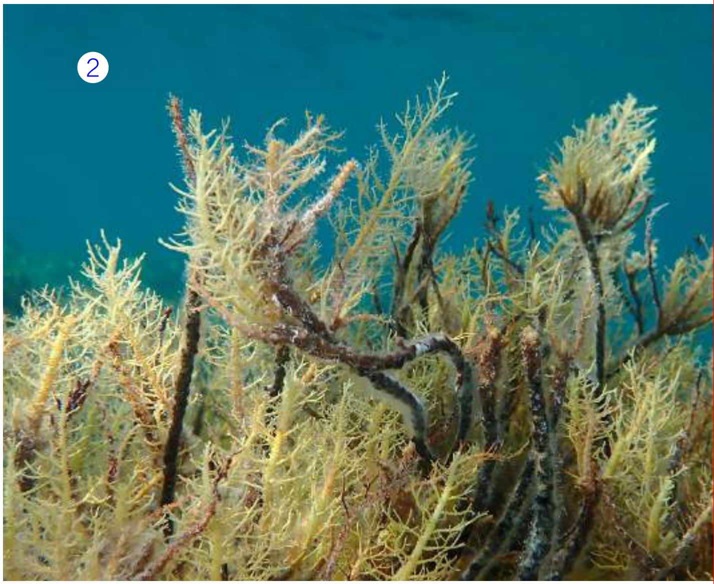
Depending on the amount of sunlight that hits these solid grounds, we distinguish between the following three habitats, each of which show different features:

● sunny surfaces ● shady surfaces ● caves

A Sphinx blenny *Aidablennius sphynx* in courtship coloration

Sun-loving Brown Algae





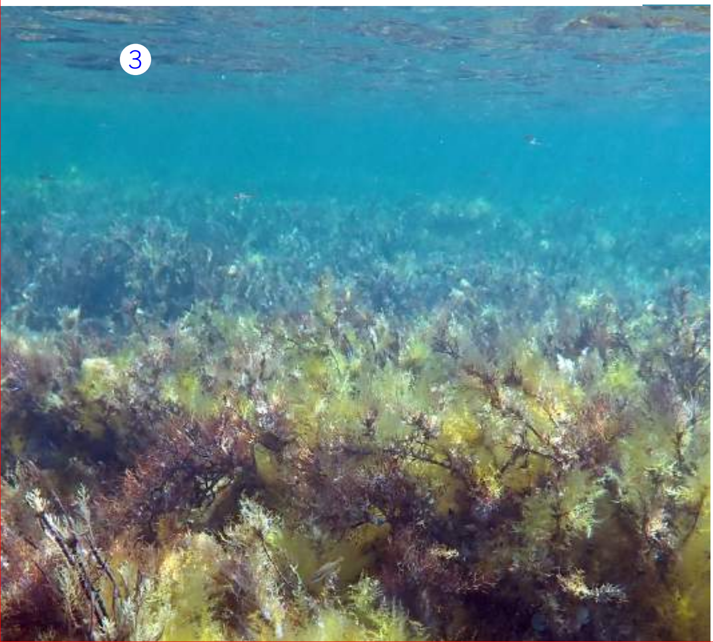
The blanket-forming growth of *Cystoseira* kelp

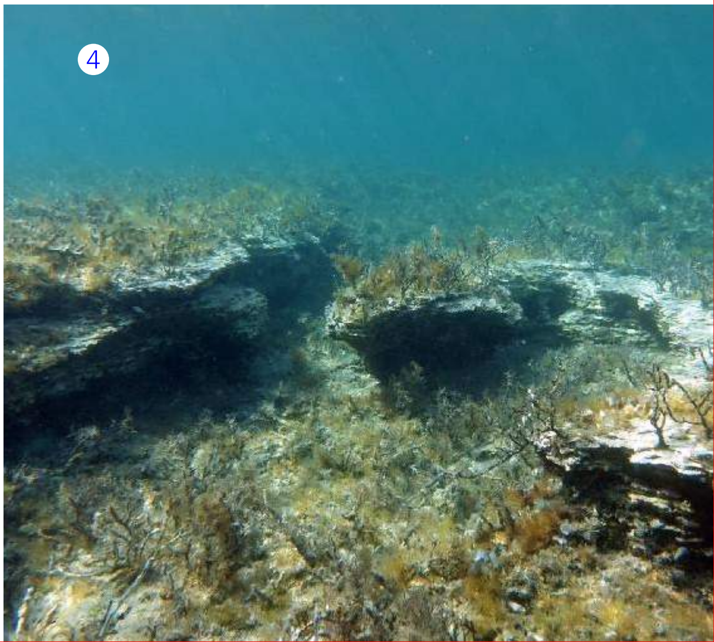
Strongly sunlit rock surfaces are densely covered in a forest of kelp, which can sometimes grow several metres tall (1). Solid, immovable rock surfaces allow for the colonisation of brown algae that grow over several years – in the Mediterranean these are usually kelps of the genus *Cystoseira*.

Seasonal changes

New kelp sprouts every spring, and in late summer they already start shedding those parts that are heavily overgrown with other algae or animals. Only small parts of the kelp – depending on the species, either the dark brown stipe or merely its holdfast on the sea bottom – remain during the poorly lit and stormy winters.

(2): Young *Cystoseira* kelp in spring, with barely any overgrowth. The bright brown shoots growing out of the dark brown stipe are only a few weeks old. (3) - (5): A kelp forest during summer. The *Cystoseira* "trees"





are up to one and a half metres tall and already overgrown with more shortlived algae species.

The thin annual shoots have mostly been shed by this point (4).

Living off carbohydrate reserves until spring

By late summer the *Cystoseira* stipes are so heavily overgrown (5) that no light can reach the algae. In this condition brown algae overwinter and survive until spring by living off carbohydrate reserves that are stored in their stems and holdfasts. In the meantime, other, smaller-growing algae will form between the kelps' stipes.

A chance for peacock's tail and forkweed algae

More short-lived and fast-growing brown algae, like the peacock's tail *Padina* (bottom left image) or forkweed *Dictyota* (bottom right image), now grow between kelps. On the leaf margins of the peacock's tail pictured below, the semi-circular feeding traces (6) of a salema porgy *Sarpa* (p. 38f.) are visible.

Other Algae in Shallow Seas

A forest of umbrella algae blanketing the bottom

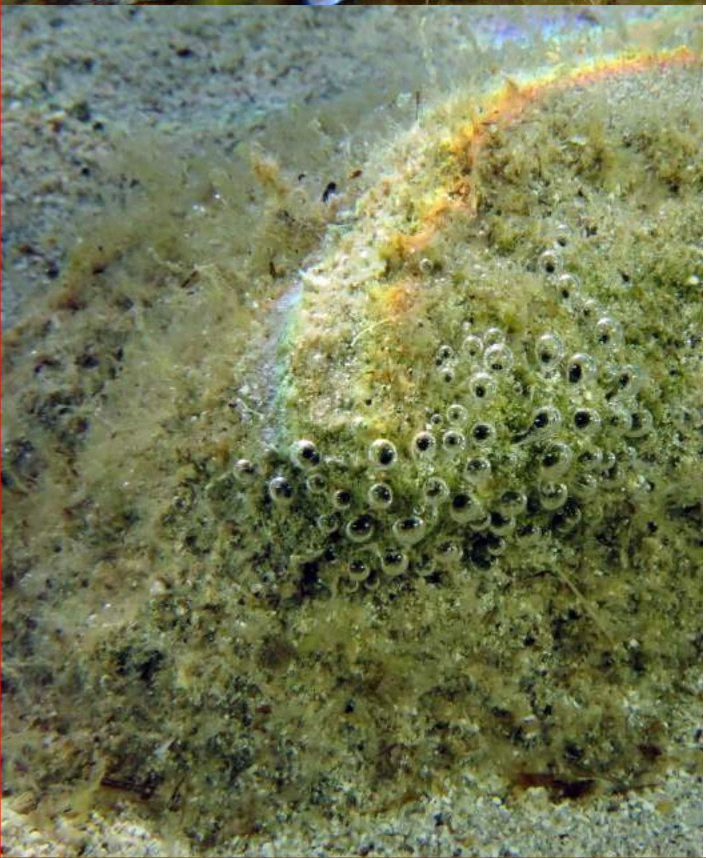
Aside from the notoriously sun-loving brown algae, there are also species of green algae that can be found growing on bright rocky grounds. On the rock pictured above, the umbrella alga *Acetabularia*, which grows only a few centimetres high, has formed a dense forest.

Giant cell with nucleus at the base of the stalk

The tiny umbrellas of *Acetabularia* algae are attached to a rock via flexible stalks, which are merely a millimetre thin. These algae consist of a single giant cell with a nucleus that is located at the bottom end of the stalk.

A ground-breaking discovery

These algae once contributed to a major scientific milestone: A simple and hence elegant transplantation-regeneration experiment with umbrella algae served to demonstrate that a cell's construction manual is contained in the nucleus: When the circular cap of one algae species is transplanted onto the cap-less stalk of another species that usually forms jagged caps, then the circular cap will gradually change its form and become jagged over the course of a few days. The logical conclusion is: The alga's genetic information must be contained in its cell nucleus.



Fertilised sea lettuce

The photo below shows a very sunny, rocky sea bottom that is covered with *Ulva* sea lettuce. This green algae can be found as blankets on seashores where plant nutrients are washed from the land to the sea. The source of these nutrients could be either groundwater that emerges from a cracks in the rock and is contaminated with fertiliser, or nearby river mouths or sewage treatment plants. We can often determine the most likely source by looking at an accurate map of the area.

Every illuminated rock on the sea floor…

…will be overgrown with algae within a few days. The rock in the left photograph is covered with green algae that form a thin felt-like turf. Trapped in it are silvery bubbles of oxygen that are produced by the algae – a clear sign of photosynthesis in progress. The next wave that washes over the algae will carry their waste product away.

Sessile Animals – Anemones

Sea anemones: underwater gardeners

On brightly sunlit rocks, you might find a peculiar family of marine animals growing between brown algae: Sea anemones host a symbiotic microalgae garden as a nutrient source inside their body. Algae endosymbiosis is quite common with cnidarians, but also with sponges. Such gardening sea anemones and corals typically have a brownish-yellow colour due to zooxanthellae-algae cells inside their tissues.

Sponges growing in bright locations, on the other hand, grow microscopic blue algae, so-called zoocyanellae, inside their bodies. These algae are responsible for the sponges' dark colour.

Mediterranean snakelocks sea anemones form a "dinoflagellate garden"

Pictured on the right, a bed of *Anemonia viridis* sea anemones. These animals, which are also known as Mediterranean snakelocks sea anemones, use a "pedal disc" to attach their soft, flexible bodies to a stone (large image on the right-hand page). They have hundreds of tentacles protruding into the sunlit sea, moving with the motion of the water. Inside these tentacles, they grow their garden of dinoflagellate-zooxanthellae.

Two colour morphs with identical clone colonies

There are two colour morphs of *Anemonia viridis*: The ones with uniformly brown tentacles belong to the *rustica* variant, and those with greenish tentacles and violet tentacle tips are knowns as the *smaragdina* variant (two images on the next double page). The *rustica* variant, which is pictured on the left, often forms large colonies of genetically identical clones that extend over many square metres. The nutritional needs of Mediterranean snakelocks sea anemones are partially met by their zooxanthellae gardens, but they are also capable of catching zooplankton with their sticky, stinging tentacles.

What is usually hidden under the tentacles of sea anemones: their fragile stem, also known as a peduncle. Here the peduncle of a trumpet anemone *Aiptasia* is briefly exposed for a photo.

Protection in the Poisonous Tentacle Forest

Swarms of tiny, silvery opossum shrimps of the genus *Leptomysis*sometimes hover directly above the poisonous tentacles. The tentacles provide the swarm with protection against predators that stay away from sea anemones due to their stinging tentacles. The shrimps themselves feed on even smaller plankton animals, which they snatch from the water with their feet. Yet, since they, too, are not immune to the anemones' toxins, they must skilfully manoeuvre between the tentacles, which sway with the waves.

Leptomysis shrimps grow almost a centimetre long. Their big eyes and the clearly visible, bright stripe along their backs help the swarm to stick together.

Inside the greenish brood chamber on the underside of the females' abdomen, the embryos mature for several weeks.

Coral Polyps

Coral colonies in the Mediterranean

Left: A hand-sized colony of the Mediterranean pillow coral *Cladocora* has grown on a rocky surface that is exposed to the sun.

Large image: The polyps of the pillow corals are just a few millimetres wide. They regularly divide into two and thus grow, building a new coral colony. After a few years, the new colony will have grown several centimetres from the rocky surface and be made up of hundreds of polyps. Pillow corals can sometimes form "mini coral reefs" that extend over many decimetres (explanation on the right-hand page).

Pillow corals have their own microalgae garden

The white limestone skeleton of the pillow coral is covered by a thin tissue membrane. Inside this membrane, a garden of microalgae – recognisable by their light brown colour – grows. Very similar to the Mediterranean snakelocks sea anemone, these microalgae are the corals' main nutrient source. In addition to this, each polyp extends its sticky tentacles into the water to prey on animals floating by in the passing current. Plankton that has been caught in this way is then moved by the tentacles to the bright, elongated mouth at the middle of the polyp, where the food is swallowed whole. This plankton serves as supplementary nutrition in addition to the microalgae.

Corals with only one polyp

Image below: A solitary coral of the genus *Balanophyllia* has grown on a sunlit stone, stretching out its tentacles, which are ready to catch prey. Solitary corals consist of a single polyp. Each of these polyps is one to two centimetres long. Very similar to the reef-building pillow corals, they feed on an algae garden and plankton.

What are reefs?

In navigation, a reef is any more or less solid object that rises from the sea bottom and blocks a ship's passage. This could be a rocky reef made of solid rocks (cliff), a sand reef made of sand that has been formed by waves (sand banks), or "biogenic" reefs. Coral reefs are well-known examples of such biogenic reefs, but also oyster reefs and tubeworm reefs.

Biogenic reefs...

...are fixed structures created by marine animals that form limestone skeletons, grow on top of each other, and thus build a massive limestone body over time. Animal skeletons provide most of the mass of a biogenic reef. Only a thin layer of a reef – no more than a few centimetres thick – is inhabited by living animals.

Sun-loving Sponges

Left image: The bright yellow tube sponge *Aplysina* is a real eye-catcher with its cylindrical tubes, which have an excurrent opening, a so-called osculum, at the top. Images below: Frequently, the equally yellow umbrella slug *Tylodina* can be found in the immediate vicinity of a yellow tube sponge. It feeds exclusively on this rather poisonous sponge. The sponge's alkaloid poisons are rendered harmless by special metabolic processes in the slug and are even used as protection against predators.

Out of the many hundred sponge species, only very few can grow in direct sunlight and rival brown algae in the competition for space.

Sponges are sessile animals...

...that are attached to rock substrate. Their bodies can grow into different shapes, depending on their respective habitat. They feed mainly on microscopic plankton, which they filter from the water.

The body of a sponge...

...is composed of a mesh of tough organic fibres and hard needles, which are called spicules. Together with the fibres, they form a skeleton, which is overgrown and fused with the sponge's cells, giving the sponge its shape. The inside of a sponge is riddled with canals, which form chambers in some sections. The walls of these chambers are lined with collar cells (choanocytes).

Sponges constantly absorb water

The beating of choanocyte flagella draws plankton- and oxygen-rich water into the sponge through thousands of tiny pores, the so-called ostia, which cover its entire surface. The water is filtered by the choanocyte's sticky collars, loaded with waste products, and then ejected again through a larger excurrent opening called osculum.

Symbiotic blue-green algae

The few sponge species that succeed in colonising sunlit rocky grounds form, much like corals, gardens of symbiotic blue-green algae in their tissue. These algae serve as an additional nutrient source.

The yellow tube sponge *Aplysina*...

...is often found on a bright rocky substrate. Its intense colour is due to the uranine dye synthesised by these sponges. The purpose of this dye is not known, but it could be toxic and act as a repellent against predators.

Excurrent and incurrent openings

Their characteristically cylindrical, chimney-like tubes have a slightly raised excurrent opening, known as osculum. Image on the left: Even the tiny ostia, which line the sponge's body wall and inhale water, are visible in this photograph. Only the area around the osculum has no ostia, probably to avoid a short circuit between the incurrent and excurrent water.

Kidney Sponge, Chicken Liver Sponge, Bath Sponge

Kidney sponges, chicken liver sponges, and bath sponges belong to the group of horny sponges.

Kidney sponge: cushion-shaped and slippery smooth

Bottom left: A kidney sponge *Chondrosia* is growing in competition with a tubeworm (bottom left image). Kidney sponges often have the shape of a cushion, and their surface is even, of a mottled greyish brown colour, and noticeably smooth due to an outer mucous layer.

Chicken liver sponge: reproduction through "abseiling"

Bottom right: The chicken liver sponge *Chondrila*, which is related to the kidney sponge but has a rounder shape, can lower itself down, as if on a rope, through its slow, downward growth aided by gravity, which allows this sponge species to reach and colonise distant surfaces. At first glance the sponge may look like an octopus tentacle. The horny sponge *Ircinia* that grows below can be recognised by its dark grey surface with its characteristic conical elevations and the large excurrent openings.

Bath sponges

Bath sponges *Spongia* are also assigned to the horny sponges and found on sunny rocks. They grow at regular intervals and become several decimetres tall. Their skeleton, with its intricately ramified network of channels and chambers made of spongin fibres, has been popular as a soft, absorbent cosmetic tool for several millennia.

Complex cleaning process

The skeleton is derived through a lengthy, multi-step chemical process where the living cells and mineral deposits of the sponge are removed, so that only the soft spongin fibers remain. In this close-up of a bath sponge skeleton, the ostia channels that are formed by the fibre network and lead to the sponge's interior are clearly visible.

Tubeworms

Plankton feeders growing among algae

Many sessile animals feed exclusively on plankton, which is obtained from the water through various methods. The tubeworm *Sabella* uses an umbrella-shaped fan crown to sieve algae and bacteria from the water that passes through the fans. Through the worm's flexible living tube, several decimetres long, this sieve apparatus protrudes above the algae forest into the plankton-rich water, which is moved by waves and tides.

A complex feeding system

The sieve apparatus is composed of a multitude of rays, the so-called radioles, which are each lined with a row of fine branching feathers known as pinnules (upper right photo). The surface of each pinnule is covered with hair-like cilia that are only a few thousandths of a millimetre long. These cilia filter the plankton out of the water as it flows through the pinnules and trap it in sticky slime. Via food groves on the upper side of each radiole, the concentrated plankton slime is transported to the tubeworm's mouth opening, which is located at the centre of the fan crown.

Riisgård, H. U., Larsen, P. S. **Particle capture mechanisms in suspension-feeding invertebrates** *Marine Ecology Progress Series, 418: 255-293 (2010)*

The position of the radioles is optimised

Depending on the prevailing current velocity and plankton concentration, tubeworms will place their radioles into the optimal position to filter the microscopic plankton from the water as efficiently as possible. If the water flows too fast through the fan crown, then the filter apparatus will be quickly overloaded and can no longer retain and process most passing plankton particles. However, if the water is slowed down too much, then the worm might not catch enough food.

Hydropolyps – waiting for food

Several stems of the Christmas tree hydroid *Pennaria*, a few centimetres in size, grow out of the algae turf (bottom right photo).

The individual polyp heads of this cnidarian, barely a millimetre in size, can be seen on their side branches.

Their thread-like tentacles are covered with microscopic stinging cells that serve to catch drifting plankton – but can also painfully nettle human skin.

Marine Grazers

Mobile animals

Among the mobile animals of the sunny rocky bottom are many grazers that feed on fast-growing micro- and macroalgae.

The sea hare *Aplysia*...

...is a marine gastropod that has no shell and can grow up to 30 cm long. Even amid a thick algae forest, these peculiar animals cannot be missed (left).

The twisted, spoon-shaped "ears" on the head are actually nostrils. Below the nostrils they have two tiny, light grey eyes (1). At the front of their heads are their bright-rimmed oral tentacles, which they use to examine their food. Like all herbivores, sea hares must eat great amounts of food. Therefore, they spend a lot of time grazing algae on the seafloor.

As a result, they produce a lot of faeces (2) consisting mainly of the polysaccharides cellulose and alginate, which are found in abundance in algae. Nitrogen and phosphorus compounds, which are essential for grazing animals in particular, are extracted completely during the digestion of the algae.

Reproduction of sea hares

Top right: Spotting two sea hares side by side is a rare occasion. This usually happens during the courtship that precedes their mating.

Bottom right: Sea hares are hermaphrodites – before mating they "negotiate" which partner will contribute egg cells and which partner will contribute sperm cells towards sexual reproduction.

Below: Shortly afterwards spaghetti-shaped egg strings wrapped around algae are visible. Hundreds of eggs develop inside these strings, and after a few weeks, the microscopic sea hare larvae will hatch. They float as plankton in the sea for several months, before they settle down again in algae forests as tiny millimetre-long sea hares. Besides, sea hares are among the few snails that can swim: The next page shows a "flying" sea hare (on p. 162 another swimming sea slug is described).

Plaut, I., A. Borut, Spira, M.E. **Growth and metamorphosis of *Aplysia oculifera* larvae in laboratory culture**
Marine Biology, 122: 425-430 (1995)

When Mantel Flaps Become Wings

Sea hares are one of the few gastropods that can swim. They have a pair of so-called parapodia, which they flap like bird wings.

Purple poison

When sea hares feel threatened, they excrete a toxic purple aplysiatoxin, which they produce from the algae they eat (below).

Cropped Down to the Bare Rock

Sea urchins are among the most important grazers living on rocky grounds overgrown with algae. If the sea urchin population in an area is dense, they can change the ground from kelp forests into a barren rock surface within just a few years.

Purple Sea Urchin and Black Sea Urchin

Light, waves, and warm water

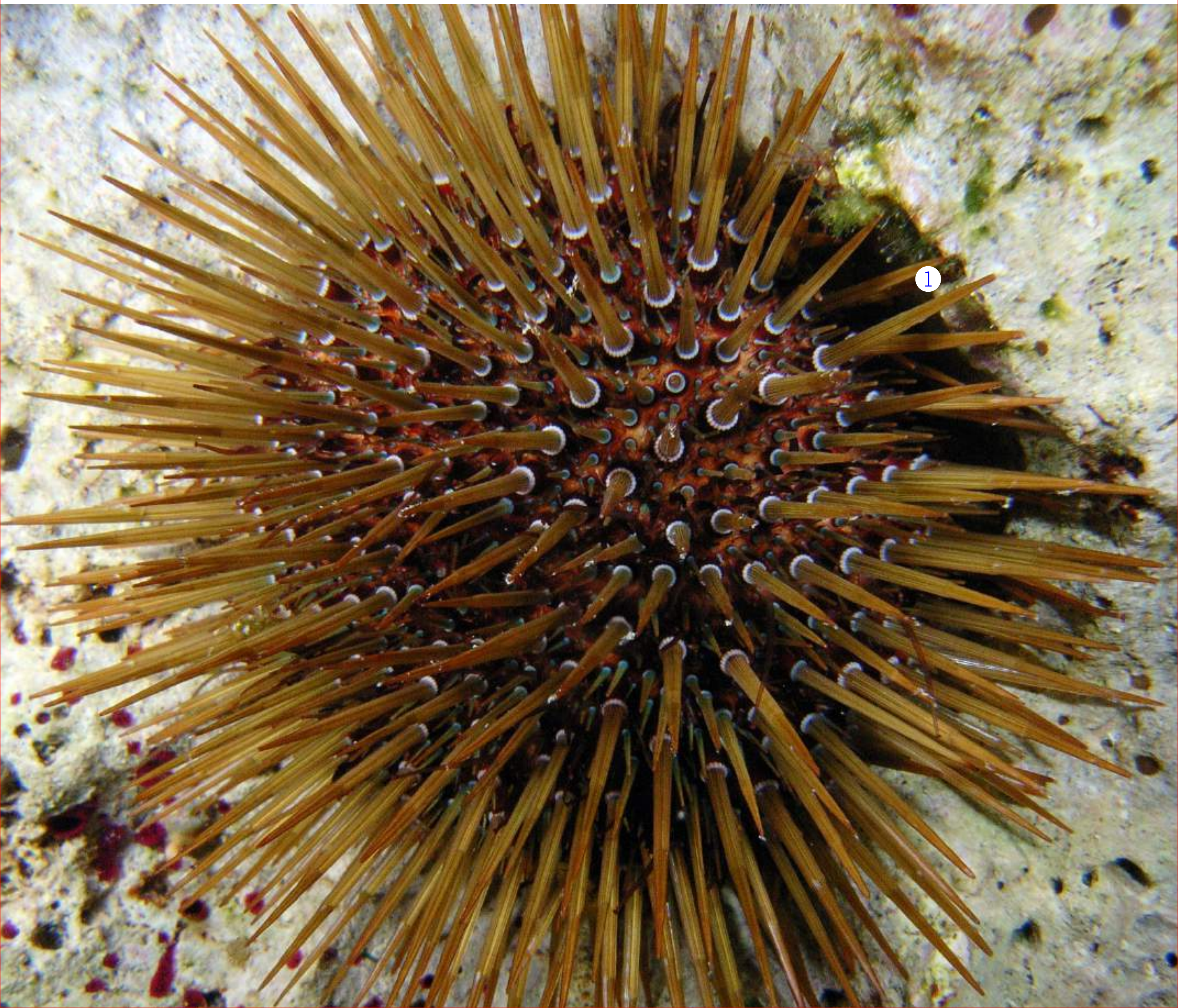
Two sea urchin species are commonly found on rocky grounds at a depth of only a few metres. Such shallow waters provide the ideal conditions for the growth of the algae on which these sea urchins feed - a lot of light, high water temperature, and the movement of waves, which promotes the gas exchange around the plants. Both species have very pointed, fragile spines and can, for the most part, be distinguished solely by their distinctive colours.

Purple sea urchin (1)

The spines of the purple sea urchin *Paracentrotus* are brown or dark purple. The rocky ground that surrounds the urchin on this photo has already been stripped bare.

Typical back decoration

With their numerous thread-like tube feet, purple sea urchins often pick up objects lying on the sea bottom and attach these to their backs. These objects are usually algae leaves, animal shells, or small stones, but occasionally

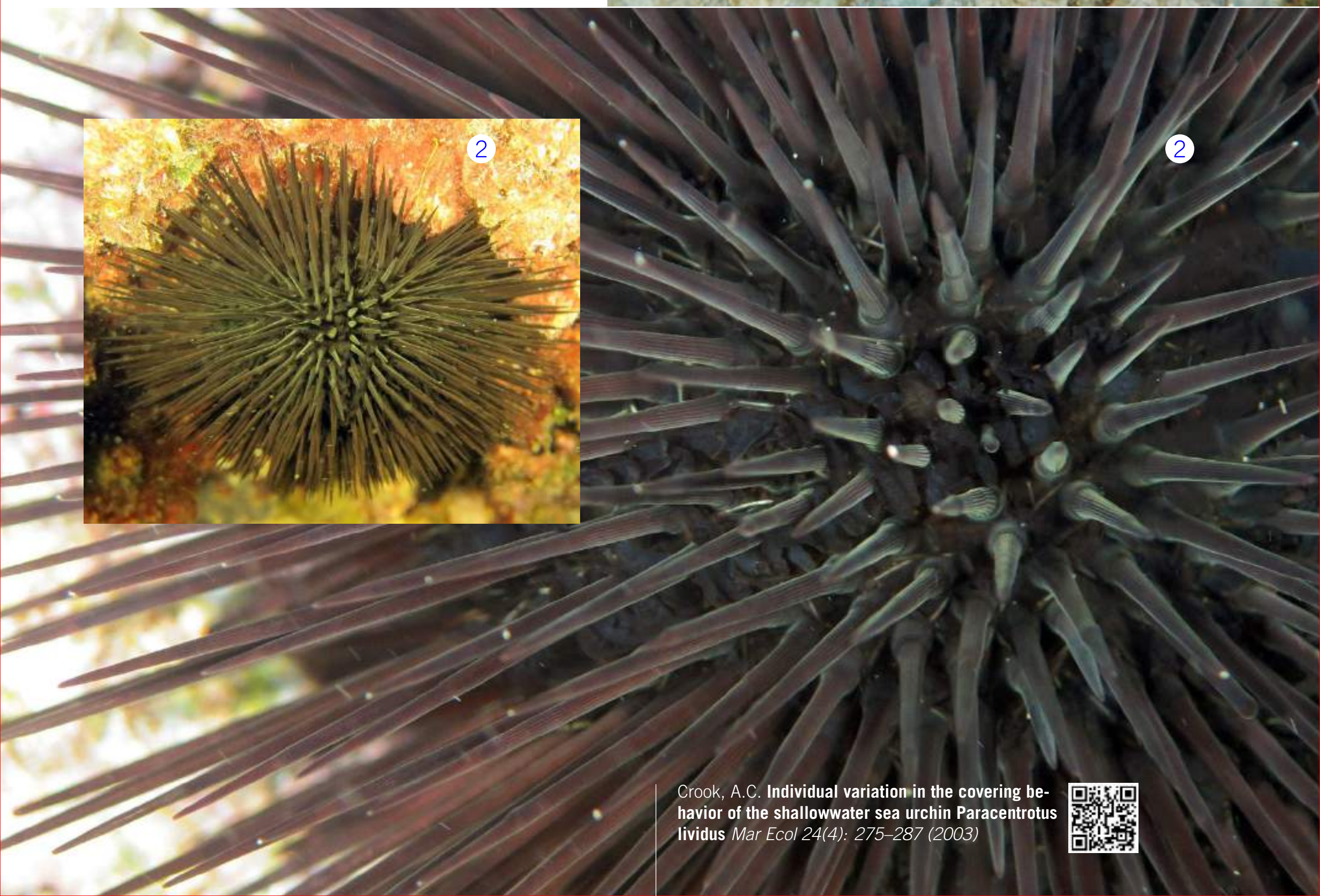


some urchins wear garbage as decoration (pictured on the right).

The reasons for this peculiar behaviour are not known. Some have speculated that it might serve as protection against sediment showers or ultraviolet rays, as a food gathering mechanism, as camouflage, as mechanical defence against predators, or that it might simply be the result of an indiscriminate clasping reflex.

The black sea urchin (2) never picks up objects

The other sea urchin species with long spines, the black sea urchin *Arbacia* (pictured below), is never covered by other objects because this species does not have tube feet on its back, which would be necessary for this behaviour. Furthermore, opposed to the purple sea urchin, the black sea urchin's spiky dress is always arranged in a strikingly regular pattern and has a velvety black colour.



Crook, A.C. **Individual variation in the covering behavior of the shallowwater sea urchin Paracentrotus lividus** *Mar Ecol 24(4): 275–287 (2003)*

The Violet Sea Urchin

Renewable teeth
With their five teeth, the jaws of rock-dwelling sea urchins are perfect for removing algae from hard surfaces. Similar to the teeth of terrestrial grazers from the families of rodents and even-toed ungulates, the teeth of sea urchins are self-sharpening and continuously regenerate the material that is lost through abrasion while feeding. The characteristic feeding traces in five rays can be seen on page 47 in the bottom photograph.

The violet sea urchin *Sphaerechinus* (3)...
...lives on rocky surfaces at greater depths, where they are less exposed to strong wave motions. This sea urchin species is larger and more ball-shaped than the purple sea urchin (1) and the black sea urchin (2) (p. 31). Its violet spines have bright tips and are noticeably blunt. Page 80 shows a peculiar defence mechanism that is used by *Sphaerechinus* urchins to protect themselves against their main predators.

Not every violet sea urchin is a *Sphaerechinus*
It is at this point that one realises that body colour characteristics are not always helpful when categorising species: The brown-violet spines of the violet sea urchin have white tips, the spines of the purple sea urchin can be light or dark brown, but also greenish and unfortunately also violet. The spines of the black sea urchin always have a velvety shimmer, but their colour ranges from dark brown to black. The purple sea urchin *Paracentrotus* pictured below on the left is not a violet sea urchin *Sphaerechinus*, despite its colour.

Easier to distinguish by their shell skeletons
Below on the right: The skeleton – called test – of the three most common sea urchin species is fragile but quite commonly found. Green: *Paracentrotus* (purple sea urchin), violet: *Sphaerechinus* (violet sea urchin), reddish: *Arbacia* (black sea urchin). The radial rows of knobs are the joints to which the spines are connected. The small holes that appear in a similar formation are the podial pores from which the tube feet emerge.

Abalones are crepuscular

Abalones *Haliotis* are probably the shyest snails living on strongly sunlit rock surfaces. During bright daylight, they prefer to hide underneath stone blocks (1). Only at dusk they crawl onto the top of the stones to graze the algae there under the cover of darkness (below on the left). This behaviour enables them to avoid mollusc-feeding predators that are active during the day, such as seabreams.

Leftovers

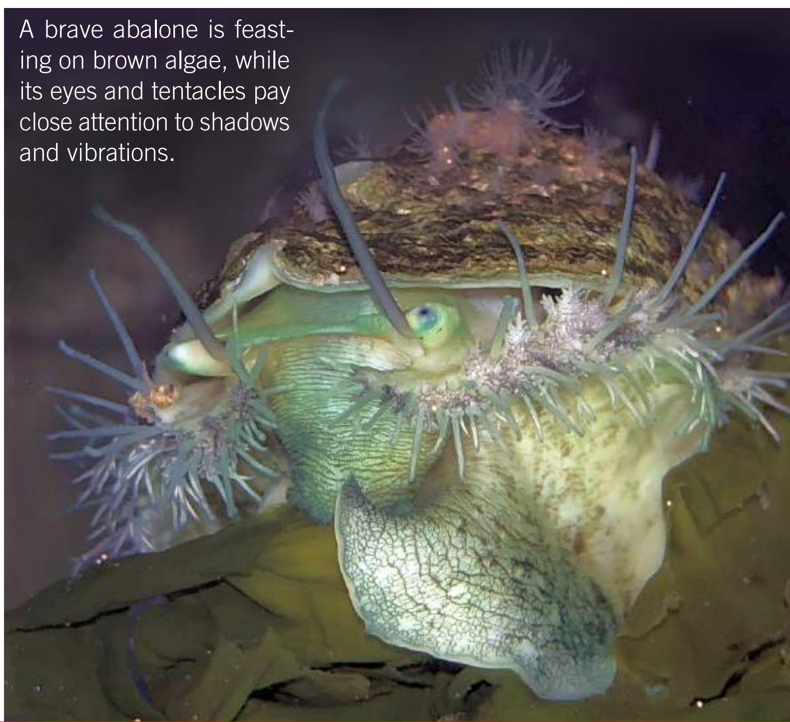
This does not always work! Photograph (2) shows an abalone shell – the leftovers of a fish's meal. If the shell of a devoured abalone, which can be up to seven centimetres long, ends up lying with the reflective mother-of-pearl layer facing up, then its silvery sheen might already be visible from the sea surface.

Chestnut turban snails also graze during the day

Another snail that feeds on the richly laid table of algae, but also does so during the day, is the chestnut turban snail *Bolma.* It is protected by its thick-walled shell against fish teeth and crab pincers, but it is usually hard to find under a dense overgrowth of algae (3).

Protective lid in striking colours

Chestnut turbans can also seal off their shell with a bright orange lid (4). It provides protection against octopus and sea stars, which use toxic saliva to subdue prey. The purpose of the lid's bright orange colour is unclear, but it often proves to be their undoing, because divers like to collect the pretty lids, which can be used to create jewellery.



A brave abalone is feasting on brown algae, while its eyes and tentacles pay close attention to shadows and vibrations.

Algae Grazers

The hermit crab…

…*Clibanarius* prefers to dwell in the less densely grown glades of kelp forests. With its brownish pincers, which are ideal for grabbing objects with great precision (pictured below), it grazes on low-growing algae meadows. Its orange-red antennae and silver speckled eyes make it easy to distinguish it from the four other hermit crab species, which inhabit other habitats (72 and 148).

Protecting its soft body with a well-fitted snail shell

Like all hermit crabs, *Clibanarius* hide their soft, worm-shaped abdomen in a snail shell that will only fit them for a limited time. Shells of the snail species *Truncularíopsis*, *Cerithium*, and *Phorcus* are most frequently inhabited by hermit crabs. Occasionally, you see groups of *Clibanarius* hermit crabs exchanging shells for an optimal fit.

***Maja* the spider crab…**

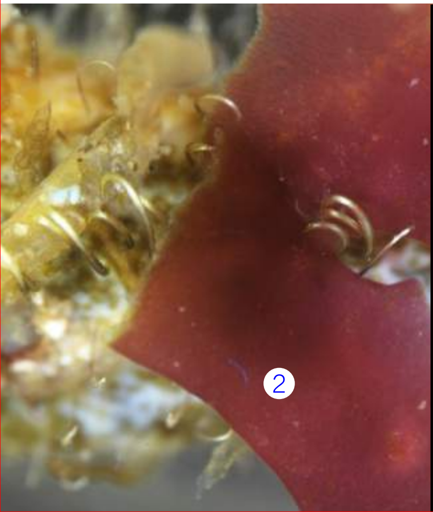
…(next page) stalks on its long legs like a spider through the thicket of algae (1). There, the sea spider is hard to see as its body is almost completely covered by algae. If the animal does not move, it is practically invisible.

Tricarico, E. et al. **Shell recruitment in the Mediterranean hermit crab *Clibanarius erythropus***
J. Exp. Mar.Biol.Ecol. 381(1): 42-46 (2009)

A well-kept dorsal garden with Velcro-like mechanism

When looking closely at the carapace of a sea spider (2), you will discover that it is covered with specialised hook-shaped bristles, which function like the tiny hooks of a Velcro fastener, holding firmly onto pieces of algae.

Sea spiders actually attach algae to these bristles and maintain the resulting back garden, providing them with a camouflage that is perfectly adapted to their particular surroundings. As gardening tools, sea spiders use their pincers, which have thin tips that can grab slippery algae leaves with precision and attach them to the hook bristles. The eyes, pincers, front and sides of the carapace do not have hooked bristles and are therefore not covered (4).



Mysterious Colour Pattern

Blue-yellow and yet almost invisible shrimp?

Palaemon shrimps pluck food out of algae meadows in shallow waters using their fine, tweezer-shaped pincers. Their transparent bodies have dark stripes between the segments and blue-yellow ringed legs, which creates a colour paradox: While their body contours are made less recognisable by the dark stripes across their carapace, the contrasting colour rings on their legs are very striking. What could be the purpose of this contradictory pattern?

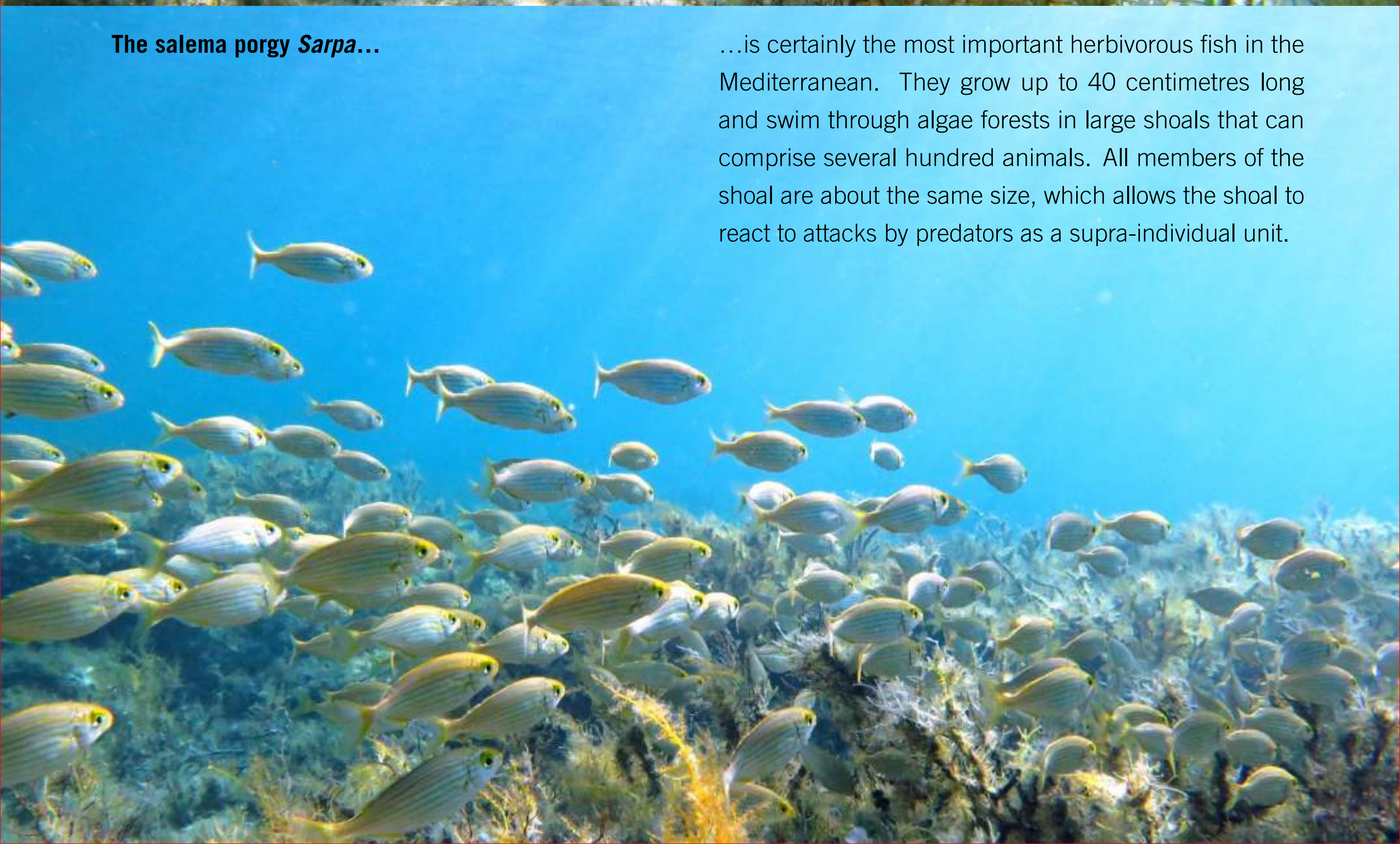
Pregnant *Palaemon* females…

…carry green eggs on the underside of their abdomen (image below). After maturing for a few weeks, the young shrimps are released into the water. They then float as millimetre-sized plankton larvae through the sea until they reach a suitable rocky shore, where they sink to the bottom again.

Shoaling Fishes on their Pasture

The salema porgy *Sarpa*...

...is certainly the most important herbivorous fish in the Mediterranean. They grow up to 40 centimetres long and swim through algae forests in large shoals that can comprise several hundred animals. All members of the shoal are about the same size, which allows the shoal to react to attacks by predators as a supra-individual unit.



Occasionally, a shoal of salema porgies will stop and graze on a chosen patch of algae for several minutes (1). On the leaf margins of the peacock's tail *Padina*, the semi-circular bite marks of their incisor teeth (2) are visible.

Migration through the Suez Canal: Rabbitfishes are displacing salema porgies

For several years, another shoaling fish has been acting as the main grazer of the Mediterranean Sea: the rabbitfish *Siganus* (3). This species has migrated through the Suez Canal from the Red Sea to the Mediterranean and is now expanding towards the west along the Levantine coast.

In some parts of the coast, the salema porgy has already been completely displaced by the rabbitfish, probably because the jaws of the latter allow for a more efficient grazing of algae, taking deeper bites. This higher efficiency might be due to the jaw's original adaptation to the harder algae that grow in tropical reefs.

Sala, E., Kizilkaya, Z., Yildirim, D., Ballesteros, E.
Alien marine fishes deplete algal biomass in the Eastern Mediterranean *PloS one, 6(2), e17356 https://doi.org/10.1371/journal.pone.0017356 (2011)*

Grazers and Predators

Among blennies, there are several species that prefer to feed on algae.

Image above: The “mystery blenny” *Parablennius incognitus* , which grows only a few centimetres long, prefers to graze the short algae turf that sits between taller-growing algae. Male mystery blennies use the abandoned burrows of *Lithophaga* date mussels as a spawning place. Frequently, their heads with the characteristically branched tentacles over each eye are peeking through these holes.

Image below: The sphinx blenny *Aidablennius sphynx* also feeds on algae, which it bites off strongly sunlit, level rock surfaces. The lappets of the males are short and unbranched. Behind their eyes they have a blue, red-rimmed spot.

Asymmetrical claws

Left: A warty crab has caught a cerith snail *Cerithium*. Now, it gradually breaks the shell open with its claws to get to the soft body. The two claws are differently shaped: The stronger claw on the right has blunt teeth on the inside edges and is used like pliers to crack hard-shelled food. The left claw, however, has sharp edges and a tip that is used to grab soft animals with precision and chop them into smaller pieces.

Predatory crabs

In the thicket of algae forests, numerous predators can find both hiding places and prey. The warty crab *Eriphia* is the largest crab that divers and snorkellers will encounter in the Mediterranean Sea. Its carapace can be up to ten centimetres wide, and its claws are thus also relatively large and powerful.

Image below: A disturbed female warty crab has retreated into a cave and has taken a defensive position. Its legs, ready to snap, are spread wide apart, showing a contrasting blue and yellow warning colouration.

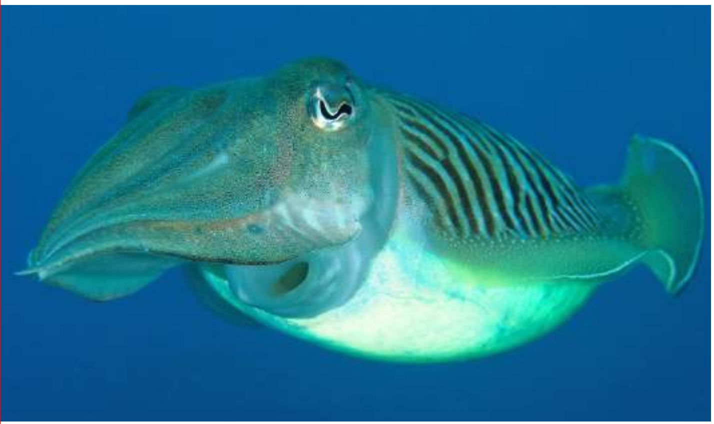
The brown mass attached to the crab's abdomen (1)...

...are its soon-to-hatch embryos: Thousands of zoea larvae will be spawned during the night and then float as millimeter-sized zooplankton for several weeks in the open sea.

Camouflaged Predators with Jet Propulsion

Efficient preying in algae forests

The common cuttlefish *Sepia officinalis* preys on crabs and fishes in algae forests. The cuttlefish pictured above has adopted a camouflage position to hide from the photographer. It is pointing four of its ten arms upward to match its body with the vertical algae stems and make it less visible to predators.



Good eyes, jet propulsion, and harpoon tentacles

High-definition vision allows cuttlefish to spot prey from a great distance. Using camouflage, they slowly sneak up and then quickly latch onto prey through jet propulsion, which they produce by expelling water from their respiratory cavities (bottom left image). They grab their prey with their short arms and quickly kill it with a toxic bite from the beak, which is located at the centre of the arms.

Cuttlefish can also grab their prey from a long distance – more than twice their body length. While crouched and immovable, they then strike their prey with two extendable feeding tentacles, which have suckers on their tips. These tentacles are eventually thrust out at great speed towards the prey and pulled back in, ladden with fish – like a harpoon attached to a rope.

The four images on the right-hand page illustrate how efficient a cuttlefish's camouflage can be.

Barbosa , A., Allen, J., Mäthger, L., Hanlon, R. **Cuttlefish use visual cues to determine arm postures for camouflage** *Proc Biol Sci. 2012 Jan 7; 279(1726): 84–90 (2012)*

Colourful Shrimp Eaters

Ocellated wrasse

Wrasses of the genus *Symphodus* feed mainly on small crustaceans, which they pick out from algae tufts. The ocellated wrasse *Symphodus ocellatus* (pictured above) has on its gill covers a greenish eye spot ringed in red. The spot of male specimens can be especially colourful during the mating season in early summer. The two images below show an interesting mating behaviour:

Nests made of algae threads

The colourful male is using algae threads, which are sometimes collected from a greater distance, to build several palm-sized nests (bottom left). Females that are ready to mate will circle these nests in loose swarms and lay their eggs. The male pictured in the bottom right photograph is carrying seaweed pieces to the nest. It will also accept suitable nest building materials from the hands of snorkellers!

Xanthochromic colour mutation

Among the many brown females, you might occasionally see a strikingly orange-coloured specimen. They are the result of a colour mutation known as "xanthochroism". There is still limited research on whether this unusual characteristic is an inheritable condition and whether it is associated with higher reproductive success or higher mortality due to increased visibility.

Splendid Wrasses

The rainbow wrasse *Coris*...

...is another predatory wrasse species. Its mouth can be opened wide and is equipped with canine teeth to catch shrimps and snails. Sometimes they even smash their prey against stones to break its shells. The males are strikingly colourful with their green hue and the orange zig-zag band (left).

Protogynous hermaphrodites

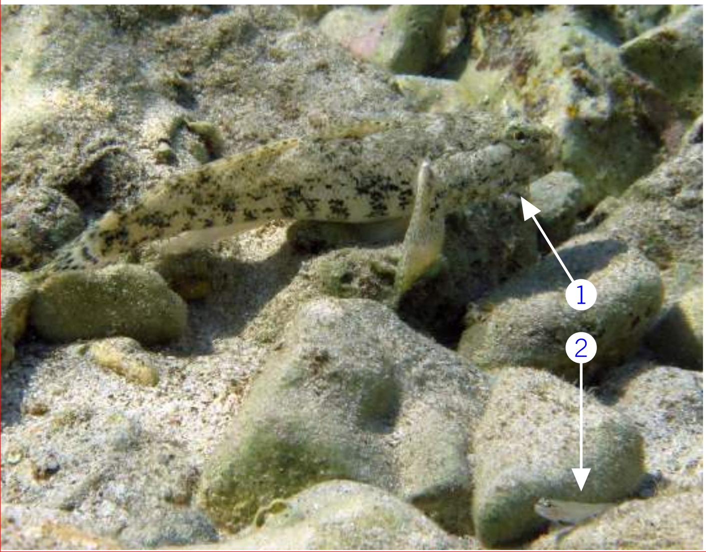
The females (bottom left) are brownish white. Like all wrasse species, rainbow wrasses are protogynous hermaphrodites: They are born as small females, and then after a few years develop into larger males (the bottom-left image shows an "intermediate stage" during the rainbow wrasse's sex change). That is why there are more females than males among wrasses.

The ornate wrasse *Thalassoma* …

…is closely related to the rainbow wrasse. The photo above shows a female specimen. The swarm pictured on the right is sifting through the brown seaweed for small fish and invertebrates.

The males (below) are larger and more brightly coloured than the females. They undergo the same protogynous sex change as the rainbow wrasse.

Mixed Diet



The sharpsnout bream *Diplodus puntazzo*...

...feeds on algae, snails, worms, and shrimps, which they find growing on algae and rocks. They have a pointy snout and a concave forehead, which distinguish the sharp-snout bream from other bream species often seen in algae forests, such as *D. sargus*, *D. vulgaris*, and *D. annularis*.

The common two-banded sea bream *Diplodus vulgaris*...

...is easily identified by its two black stripes. They sometimes form shoals of several hundred, whereby individuals are sorted according to body size.

The giant goby *Gobius cobitis*...

...hides from prey by camouflaging itself among rocks (bottom left, (1)). They are the largest goby species in the Mediterranean and can be found in shallow water of only a few centimetres depth, just below the intertidal zone. There is also a tiny incognito goby *Gobius incognitus* (2) at the bottom right of the photograph, on which giant gobies may prey. In the bottom right image an incognito goby is looking straight into the camera-lens.

The tripplefin blenny *Tripterygion*...
...preys on small crustaceans in algae meadows. Males are larger and more brightly coloured than females.

The well-camouflaged female pictured below rests motionless in the turf algae. Small peacock's tail algae *Padina* surround the animal.

The painted comber *Serranus scriba*...

...can easily be distinguished from other fish species by the bluish blotch on its belly and its yellow fins. If you look closely, you can see the intricate markings on its gill covers from which the fish got its name.

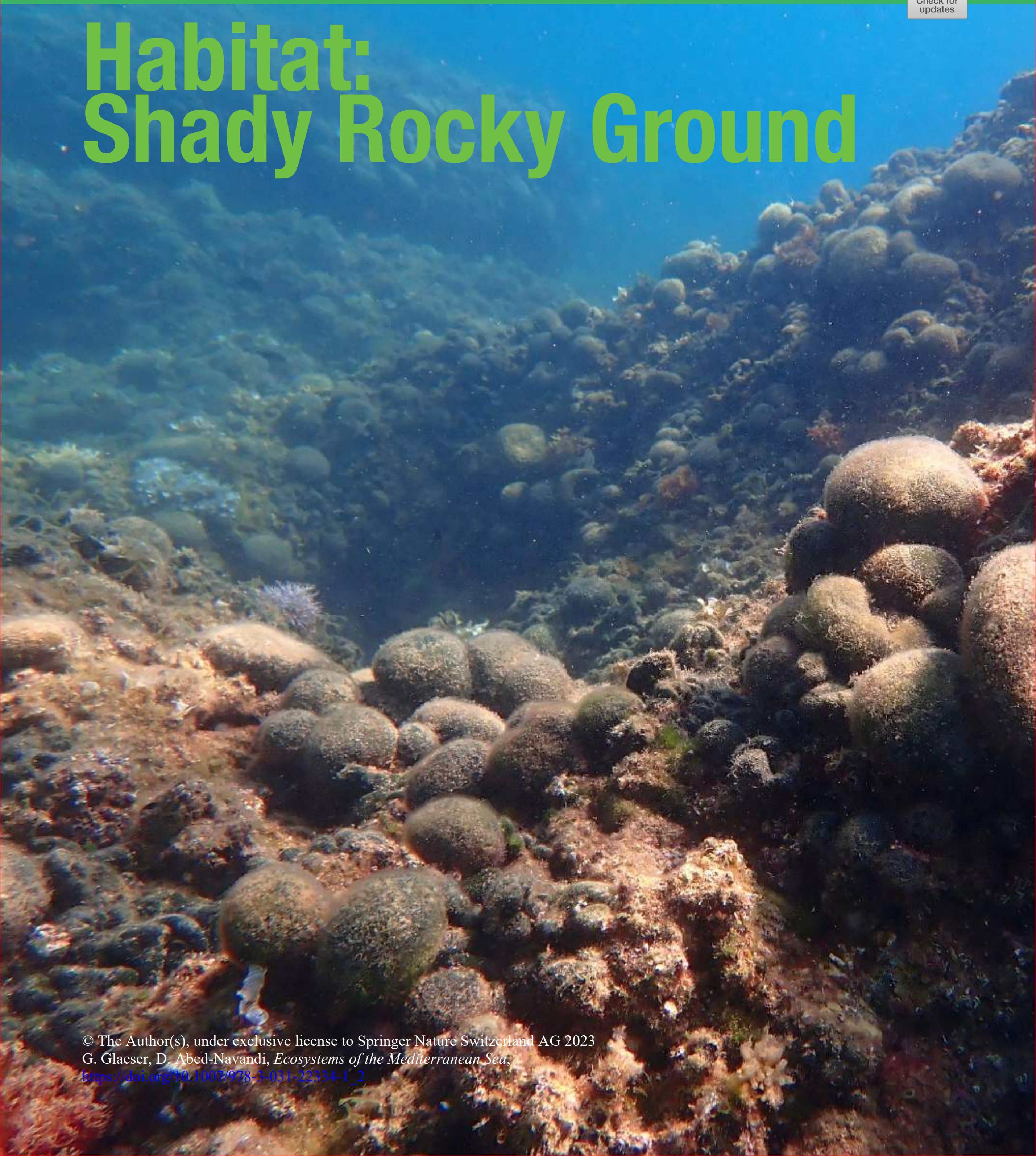
The painted comber is a prominent predatory fish in algae forests, where it ambushes other fish and shrimps with sudden, rapid sprints before swallowing them whole. They draw in their prey through their overly large mouths, which can be opened wide. This is illustrated by their long mouth clefts, which reach almost behind the eyes.

Simultaneous hermaphroditism

Painted combers are both male and female at the same time: Before mating, they must agree on who will provide eggs and who will provide sperm. The mating event takes place at dusk and can be observed with a bit of luck (courtship sequence on the right hand page).

Tuset V.M., Garcia-Diaz M.M., Gonzalez J.A., Lorente M.J., Lozano I.J.
Reproduction and growth of the painted comber *Serranus scriba* (*Serranidae*) of the Marine Reserve of Lanzarote Island (central-eastern Atlantic)
PloS one, 6(2), e17356 https://doi.org/10.1016/j.ecss.2005.02.026
Est Coast Shelf Sci 64:335-346 (2005)

Habitat: Shady Rocky Ground



G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_2

Green and red algae on poorly lit grounds

Depending on their orientation, two types of rocky grounds can be distinguished in shallow water: sun-facing zones that are dominated by brown algae, and more shady zones that are covered less densely by algae. Mainly green algae and red algae grow on these poorly lit grounds.

Since the amount of light decreases at greater depths and is thus similar to that in the shady areas of shallow water, deeper rocky bottoms also contain almost exclusively green and red algae.

More plankton-eating animals in darker regions

Depending on the average turbidity of the water, these poorly lit areas in the Mediterranean where few algae still grow extend over a depth range of 5 m to 100 m.

As light levels decrease, however, these rocky habitats are more frequently colonised by sessile, plankton-feeding animals.

Tubeworm *Protula*

Experts at Living in the Shade

High amounts of chlorophyll turn algae dark green

Shade-tolerant green algae are a striking shade of dark green because their cells contain a lot of leaf pigment. These algae need high amounts of chlorophyll to make the most of the limited light they receive.

Green sponge ball and green sea fingers

The green sponge ball *Codium bursa* (top) is one of the largest and most peculiar algae species in the Mediterranean. Its body is formed like a flattened sphere and can reach a diametre of up to 20 cm.

The closely related green sea fingers *Codium fragile* (bottom right) are also dark green.

Stronger waves make them sway in a characteristic manner. Their bodies are made of numerous, interwoven filamentous cells known as hyphae. The light green leaves that are growing next to the fingers are the cactus algae *Halimeda*.

Calcium carbonate crystals as support and protection against grazing

Left: Older *Halimeda* plants have numerous, round leaves that are connected to one another and form chains. *Halimeda* algae can thus grow several centimetres high. Calcium carbonate crystals are deposited in its tissue, making the plant sturdier and inedible to fishes.

Mermaid's fan

Top left: A bed of dark green mermaid's fan algae *Udotea* is partially overgrown by the light green blade algae *Caulerpa prolifera*. The mermaid's fan consists of a short stem that widens into a fan-shaped leaf.

Top right: Older leaves are already covered by whitish algae. Their margins have been frayed by animal bites and the motions of the water. Younger leaves, on the other hand, are still uniformly dark green and have straight margins.

The realm of red algae begins further down the sea

Red algae thrive in darker zones. The bottom left image shows a barren rocky surface that has been heavily grazed by sea urchins.

Shadow pigments for light processing

In addition to the green chlorophyll pigments present in all plant groups, red algae also possess special red photosynthetic pigments called phycoerythrins and phycobilins. With these "shadow pigments" they can make optimal use of the blue-green light that is increasingly reaching deeper into the water and reach their surroundings. Since red algae absorb primarily blue-green wavelengths, they appear distinctly red.

Red Algae


1


2

Slimy surface

The majority of red algae have soft, cartilaginous leaves with a slimy surface (1). The slime protects the algae from being overgrown by other organisms.

Coralline algae

The dark red *Gelidium* that grows up a shady, vertical rock wall (2) also has soft, slightly slimy leaves. However, a special group of red algae stores high amounts of calcium carbonate in their bodies and are correspondingly hard. They are grouped as "coralline red algae".

In (2) most of the rock's surface is covered by the coral-pink coralline alga *Lithophyllon*, which has grown in a characteristically planar manner around the soft-leaved *Gelidium*. The coral weed *Corallina* (3), another coralline alga, grows upright with branching fronds.

Extensive algae beds

Since the calcium carbonate in their leaves makes them very robust and effectively prevents animal predation, beds of coralline algae are quite long-lived. Some shady rock walls are eventually covered by an extensive, monospecific bed of coralline algae after several years of growth (4).


3

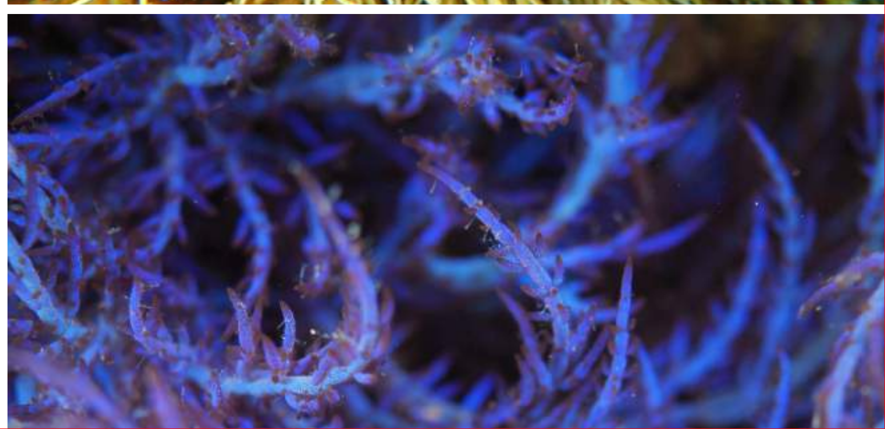

4

Without artificial light…

…red algae growing at greater depth do not look very colourful. At sea depths greater than ten metres, red becomes a camouflage colour – especially for animals. The two photographs on this page show a cuttlefish swimming in an algae forest. To hide from predators, the cuttlefish has shaped its tentacles to look like algae. Even the tips of the tentacles appear to be white, like the tips of the surrounding red algae (p. 42f.).

Blue Red Algae?

Some red algae – like this *Lomentaria clavellosa* – surprisingly sport bluish iridescent colours, which outshine the red that is common in this group of algae. This interplay of colours, however, does not result from colouring agents but is rather caused by the interference of nanostructures on the surface of the algae in the size range of 100 nm – they might protect the algae from damage by light radiation.



Chandler, Chris J., et al.
Structural color in marine algae
Advanced Optical Materials 5.5 : 1600646. (2017)
https://doi.org/10.1002/adom.201600646

Sessile Animals on Shady Surfaces

Animals that remind us of plants

Shady rocks are often inhabited by sessile animals. In terms of growth and body form, these animals are often more likely to remind us of plants than of the land-dwelling animals that we are familiar with.

The typical traits of land-dwelling animals

The life characteristics we perceive in land animals are motility (the ability to move), mobility (the ability to change location) and the presence of a head, eyes, and limbs. However, these traits are not obligatory characteristics of animals.

Animals and plants differ in their metabolism

The fundamental difference between animals and plants lies solely in the way their metabolism works. Plants use sunlight as an energy resource and carbon dioxide and mineral nutrients as material resources, while animals use other organisms both as energy and material resources.

Sessile animals feed on plankton

Many sessile animals resemble plants with their branching and widening upward-growth only because they are both optimised towards collecting vital resources that are finely dispersed and primarily found above the ground. For plants, it is the sunlight shining from above, from which they gain vital energy through photosynthesis. For sessile animals, it is finely dispersed plankton that has been transported by water currents and becomes a vital food resource only after it is concentrated by means of specialized filtering organs.

Zoanthids

Right: A meadow of egg yolk-yellow zoanthids *Parazoanthus* dominates a colony of organisms covering a vertical, shady rock wall. Between its yellow polyps, there are also scattered tufts of red and green algae.

Tentacles around mouth opening

Left and also bottom of the left-hand page: A closer inspection of the polyps reveals the slit-shaped mouth at the centre of their oral disc. At the margins of the disc, there are many tentacles, which are extended outward in a radial arrangement due to the pressure inside the zoanthid's body and are thus ready to catch food. The whitish particles in the body wall of the polyps are deposits of sands, which act as a skeleton of foreign material and provide protection.

Only small nodules after disturbance

Right: A zoanthid colony has overgrown a green sponge ball *Codium.* Long offshoots are clasping the ball. The polyps have contracted after a disturbance and are now only visible as small nodules. After a few hours, they will once again fill themselves with water and be ready to catch food.

Octocorals

Left: Several polyps of the cornucopic coral *Cornularia* form a small colony between leafy red algae. They reproduce through a network of thin, tubular runners, or stolons, and can thus overgrow other organisms.

Octocorals and hexacorals

A magnified image (below) shows that the polyps of cornucopic corals have eight feathery tentacles – hence their classification as "octocorals". This feature makes them easily distinguishable, even underwater, from representatives of their big sister group within the *Anthozoa* which always carry multiples of six unfeathered tentacles and are accordingly known as "hexacorals". The most prominent members of the hexacorals are sea anemones, zoanthids, and stony corals (p. 58f.).

Below: A carmine-red leathery coral *Alcyonium* is growing almost horizontally on a rock wall.

Leathery corals are also octocorals, which can be deduced by counting the tentacles of the white polyps growing out of this finger-shaped colony.

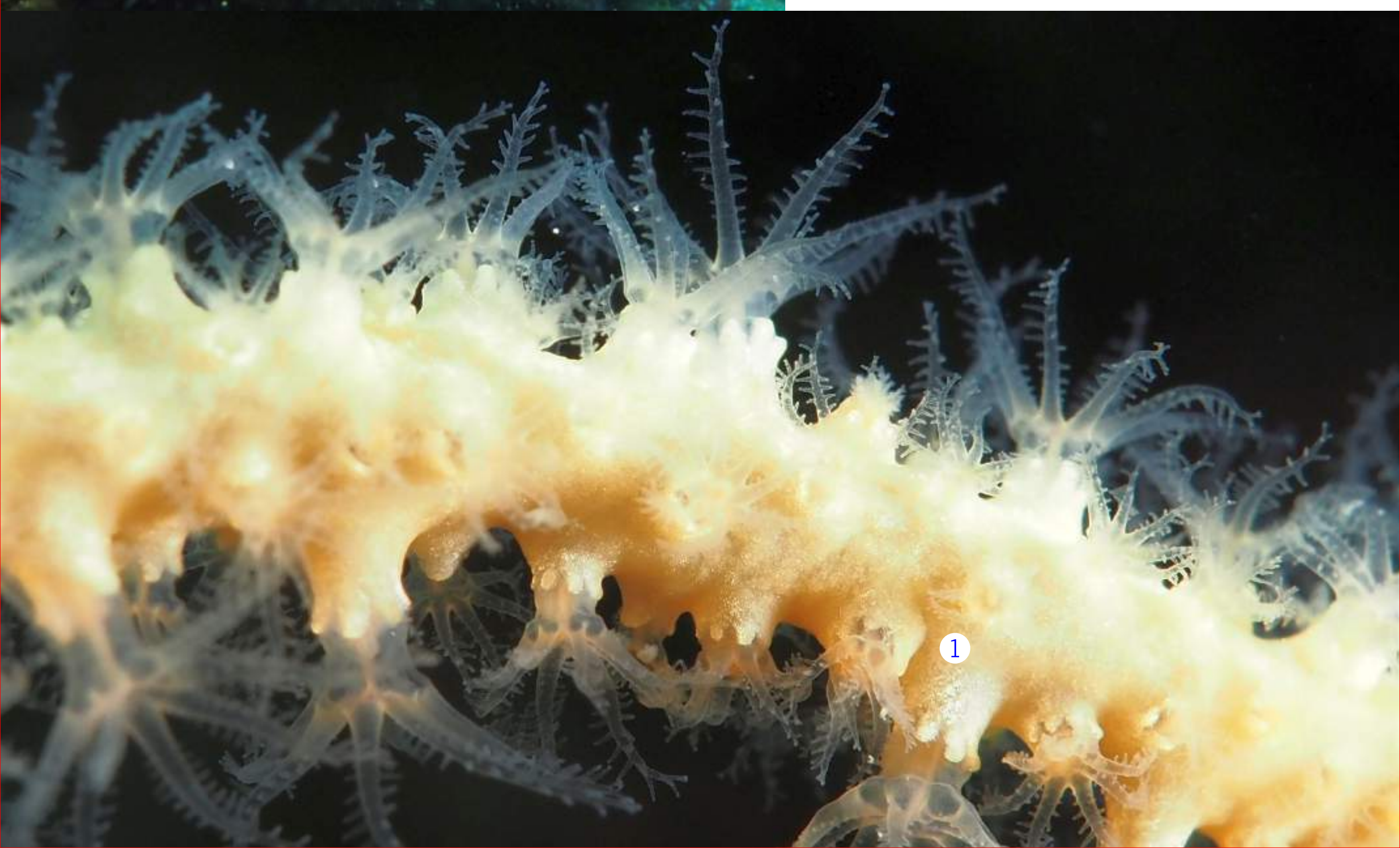
Sea Fans or Gorgonians

Masters in plankton filtration

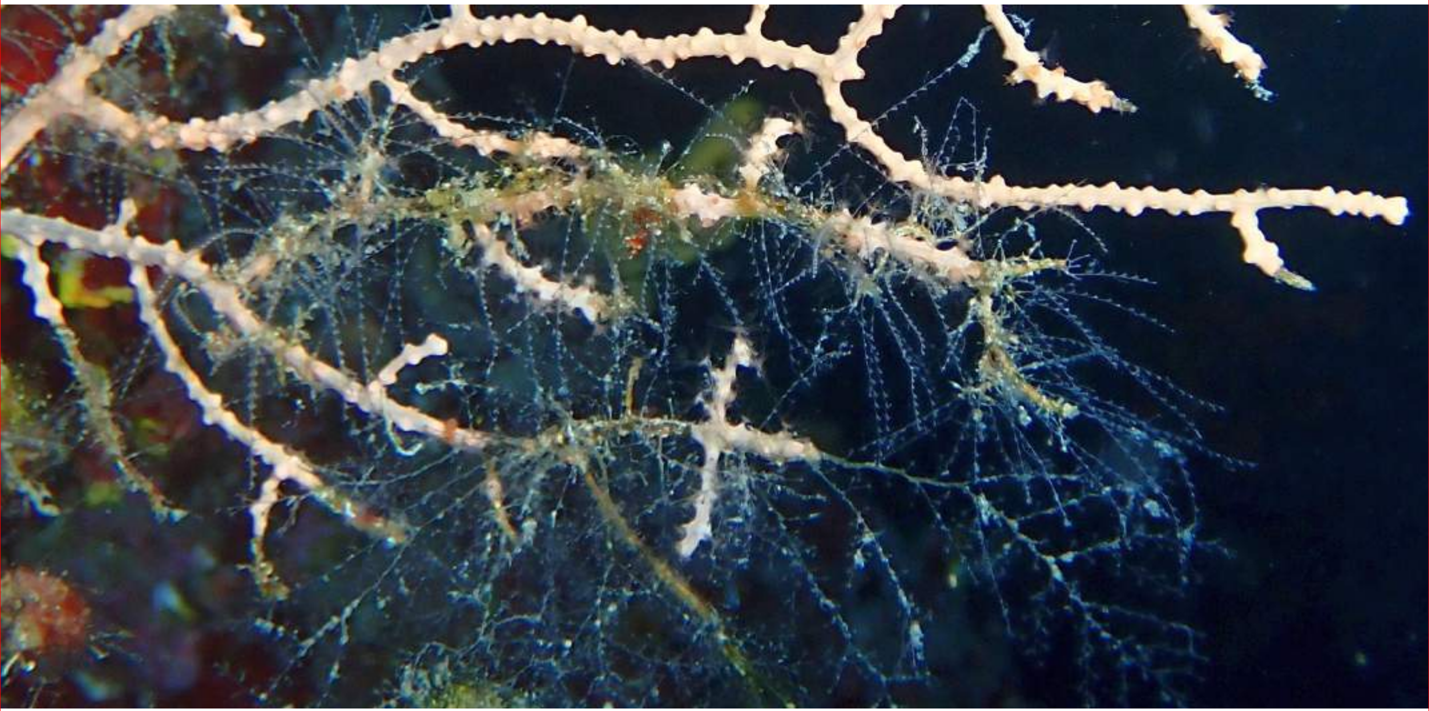
The sea fan *Eunicella* grows on steep rock walls below the zone dominated by shade-loving algae. Their fans branch evenly in one plane and grow vertically to the most frequent direction of the water flow. This makes them ideally suited for filtering plankton from passing water.

Sea fan corals have flexible horny skeletons

Depending on the species, the skeleton is covered by an orange, white, or purple bark, which contains calcareous particles for protection. Upon disturbance, the polyps retract into the bark. The remaining opening is closed by eight flaps – visible at the basis of the extended polyp pictured below (1).

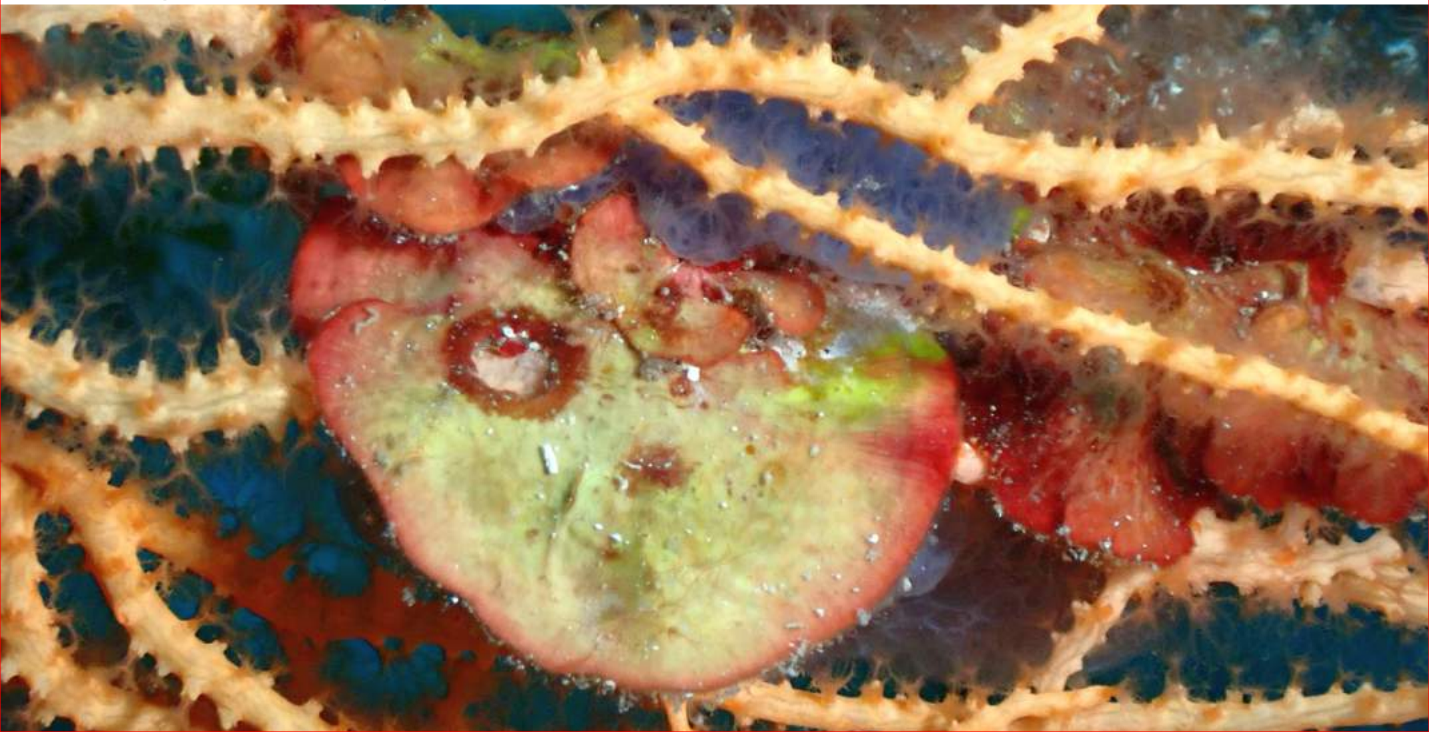


Competition for Space to Grow



Shortage of space

Occasionally red algae (image below) or other animals, such as hydrozoan colonies (image above), manage to overgrow the fans of horny corals. This form of growth illustrates the intense competition for optimal locations among all sessile organisms.



Colder than twenty degrees

Far below the algae zone, at depths of 20 m and more, grows the cold loving purple gorgonian *Paramuricea* which can reach up to one metre in size. It cannot exist in shallower water layers due to summer temperatures that sometimes climb above 20°C in these locations.

Animal and plant remains as nutrition

The filtration apparatus of sessile animals, which rely on the transport of food by water currents, capture not only plankton organisms but also animal and plant remains that have already agglutinated and been colonised by bacteria. In the photograph below, such remains are visible as white flecks hanging from the tentacles of a purple gorgonian – they also provide nutrition to the polyps.

Serpulids

Serpulids

The tubeworm *Protula* (top right) uses its feathery tentacle crown to catch microplankton from the water, which is flowing from left to right in the image. If the tubeworm is disturbed, it will quickly retreat into its hard tube made of calcium carbonate.

A lid to close the tube

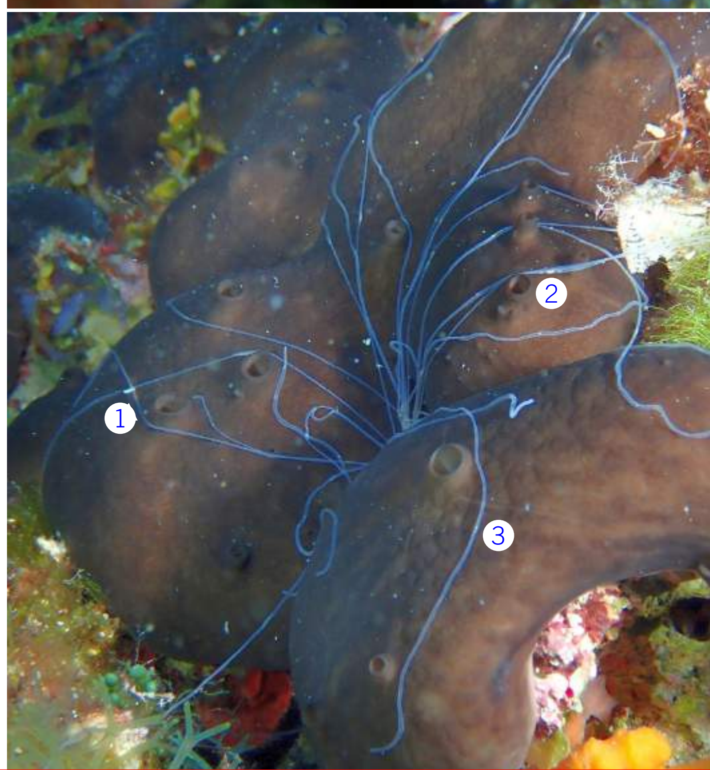
Another serpulid genus that thrives on rocky grounds in the shade is known as *Serpula* (large image on the left-hand page). Unlike the aforementioned species, *Serpula* tubeworms have a tentacle crown with a funnel-shaped lid, which can close the entrance to their tube.

Tube extension

Serpula has a red collar membrane with which they can envelope the tip of their white tube. They secrete calcium carbonate through glands beneath the collar and thus keep extending their tube throughout their lives.

Spaghetti worms

The blue-white threads that seem to grow out of the kidney sponge (bottom right image) are the tentacles of a spaghetti worm of the family *Terebellidae* . Its body is hidden between the sponge cushions. The mobile, sticky tentacles are collection organs to capture sinking food particles. As the particles are transported by hair-like cilia towards the spaghetti worm's body, they grow into larger balls of food (1,2,3).



Ascidians, Oysters, and Bryozoans

Ascidians are related to all vertebrates

Ascidians thrive especially in darker areas, where they are not displaced by faster-growing algae in the competition for space. They are attached to rocks and feed on microplankton, which they filter from their breathing water: They continually suck in fresh water through a tube-shaped appendage located at the end of their body. After filtering plankton and oxygen out of the water through the fine-meshed gills, they discard the wastewater through another tube on the side of their body.

A body structure similar to that of corals

Some ascidians have a body organisation that resembles that of colonial corals, one of them being the sea strawberry *Aplidium* (bottom image): Hundreds of animals have merged here into a dense colony. They share a large common exhalant siphon but have individual, smaller inhalant siphons.

Above: Brown algae grow on the bright upside of a highly weathered rock. In a shady nook underneath, a red sea squirt *Halocynthia*, and further down two oysters are visible.

Oysters

Similar to ascidians, oysters feed on microplankton that they filter from their breathing water. Top-right image: When an oyster is undisturbed and in the process of pumping water, the soft body between its two open shells is visible. This photograph clearly shows the grey filtering gills and short, dark sensory tentacles at the edge of the shell, which trigger the oyster's closing reflex upon being touched. (Compare with pen shells, which can be found on sandy grounds, p. 146.) The reddish crust on the shell is a bryozoan colony.

Bryozoans…

…are colonial animals – the individual specimens are microscopically small. They resemble a calcified box with a U-shaped crown of plankton-gathering tentacles poking out of it. In this image the tentacles are visible as bright, velvety fuzz. Bryozoans colonise dark rocky grounds almost exclusively, because – like ascidians – on brighter surfaces they cannot keep up with algae in the competition for space. Higher up in the sea, they would be quickly

overgrown by algae, which would then prevent them from getting fresh water with nutrients and oxygen. The black-violet crust in the right image is a bryozoan colony of the genus *Reptadeonella*. Next to it there is a colony of an orange-coloured species.

Bryozoan species with bag-shaped colony margins

The majority of bryozoan species grow in a planar form. Some species, however, grow upright from the bottom and have thus better access to fresh water with more nutrients and oxygen – such as the species of the genus *Schizobrachiella*, which are commonly found in the Mediterranean and have characteristically bag-shaped and upright colony margins that break easily (also p. 86 on animals living in dark caves).

Mobile Animals on Shady Surfaces

Predators due to lack of plant food

Since algae barely grow on shady rocky grounds, there are hardly herbivore grazers among the mobile animals found in these habitats. Most mobile animals there are predators. Some animal groups, such as sea slugs, have very restricted, single-species diets.

The pilgrim hervia *Cratena*...

...feeds exclusively on one cnidarian species, the colonial hydrozoan *Eudendrium* (left and bottom images). Not far from the tree-shaped colonies, this brightly coloured sea slug, which can grow up to five centimetres long, can be found.

The pilgrim hervia prefers eating those polyp heads that have just caught plankton with their poisonous stinging capsules. To avoid harming themselves, they "defuse" the poisonous cells with a mechanism that is not fully understood yet, and they also store these cells in the colourful cerata on their backs, where they serve over longer periods of time as protective weapons against predators like wrasses or seabreams.

After weeks of grazing on the orange heads of the polyps, the sea slug deposits strings of eggs on the horny remains of the hydrozoan colony.

Willis, T.J., Berglöf, K.T.L., McGill, R.A.R., Musco, L., Piraino, S., Rumsey, C.M., Fernandez, T.V., Badalamenti, F.
Kleptopredation: a mechanism to facilitate planktivory in a benthic mollusc
Biol. Lett. 13: 04-47 (2017)
http://dx.doi.org/10.1098/rsbl.2017.0447

Greenwood, P.G. **Acquisition and use of nematocysts by cnidarian predators**
Toxicon 54, 8: 1065-1070 (2009)
https://doi.org/10.1016/j.toxicon.2009.02.029

Fireworm

Amongst the hundreds of species of bristleworm…

…in the Mediterranean, the fireworm *Hermodice* is the only one that fearlessly crawls around during the day. It grows up to 30 cm long, feeds mainly on carcasses, and resembles a centipede.

Gills branched like trees

Every segment on the fireworm's body has a pair of stubby legs, called parapodia, and – even more strikingly – red, tree-like branched gills with strong blood flow and white, fragile bunches of bristles. On the back of its head, it sports a soft, light red growth called caruncle. Its purpose is not yet known, but it may serve as an organ of smell that helps the fireworm to quickly and precisely locate its food.

The white bristles are poisonous

The purpose of the white bristles, which are made of calcium carbonate, however, is obvious: When touched, they break easily and release a neurotoxin into the skin of the attacker which causes painful inflammation. Other than that, it has no dangerous effects.

If the bristles get stuck in a human's skin, they can be carefully removed with adhesive tape. The skin should then be cleaned with diluted vinegar and warm water at a temperature of 45°C.

Simonini, R. et al. **Synergy between mechanical injury and toxins triggers the urticating system of marine fireworms** *Journal of Experimental Marine Biology and Ecology 534: 148-157 (2021)* http://dx.doi.org/10.1016/j.jembe.2020.151487

A mysterious cluster of fireworms was pictured by the photographer at dusk. Either it is a rare mass mating or the worms are in the process of vanquishing a sessile prey animal in a pack.

A fireworm passes a hermit crab *Calcinus* that lives in calcium carbonate tubes

Unlike all other hermit crabs, the females of *Calcinus* are often found in tubes of calcium carbonate that are fixed to the sea bottom and have been abandoned by tubeworms (p. 65f.) or worm snails. Only a small number of them live mobile in snail shells. Due to this immobile way of living, *Calcinus* females rely on things that float or crawl within its reach for nourishment. If a diver notices a *Calcinus* hermit crab that waits for prey, they can try to feed it with small pieces of algae. Usually, the hermit crab will reach for the pieces very quickly with its pincers and bring the food to the mouthparts located between the pincers. It is not clear why the females of this genus prefer this kind of immobile living – compared to other hermit crab genera, the small *Calcinus* crab females might be at a disadvantage in the competition for fitting, empty snail shells and therefore settle for the fixed tubes to avoid homelessness.

Busato, P. et al. **Competitive dynamics of a Mediterranean hermit crab assemblage: the role of interference and exploitative competition for shells** *Journal of natural history 32: 1447-1451 (1998)* https://doi.org/10.1080/00222939800770981

A competitor for empty snail shells…

…could be the striped hermit crab *Pagurus anachoretus.* It is frequently found in shadowy areas. The purple stripes on its legs and antennae as well as the turquoise eyes make it easy to identify.

As with with all animals, a close look at the mouthparts allows for conclusions regarding its food (pictured below on the right side).

The predatory hairy crab *Pilumnus*...

...has moved into a cove in a shadowy rocky habitat. Hairy crabs are skittish and therefore photos like this are rare. They could be mistaken for the warty crab that lives on very sunny rocky ground, although they can be distinguished by the bristles and granules on the first pincer as well as their size (p. 41f.).

Specialised "cutlery"

Below: The striped hermit crab has pointy tubercles ("teeth") along the cutting edge of its bigger pincer on the right-hand side. It uses this pincer to chop up small hard-shelled animals like snails or other crustaceans.

Mediterranean Red Sea Star

Echinaster

A red sea star climbs along the border between bright and shadowy rocky ground. Below four metres its lively red colour changes to a dull blue-green, since the red parts of the sunlight that are necessary for correct colour recognition are absorbed when passing through the water (p. 104f.).

Food consisting of tiny particles

If you turn over a feeding red sea star, you can only see the reddish gastric membrane – but no food that is being ingested by it, since red sea stars only feed on tiny particles on the sea floor which they pump into their stomachs.

Breathing through gill rakes

A closer inspection reveals a great number of outstretched, dark-red gill appendages on the red sea star's body – you could almost say he is panting. Red sea stars push out these delicate excrescences of their skin especially during digestion, when there is a high demand for oxygen.

Additionally, two more similar species of red sea star live in the Mediterranean. They are less common and can only be found in warmer regions of the Mediterranean. The three species can be easily distinguished by the proportions of their arms and the markings on their backs.

Hacelia...

...(pictured at the top) has arms that taper off, forming a pointy end, similar to *Echinaster*. The markings on the back, however, consist of several tidy rows of dark spots.

Ophidiaster...

...(pictured on the right) – the third species of red sea star – has circular arms that are, for the most part, of a constant thickness. Only right at the ends and the base, the arms taper off slightly.

Predatory Sea Star

Flexible arms and tube feet

Predatory sea stars have developed a different way of feeding: With their flexible arms and powerful tube feet, they defeat larger, sessile animals, such as a mussel.

Patent-worthy glue

Surprisingly, the discs at the tips of the sea star's feet are not suction cups but sticky discs secreting a protein that is reliably adhesive in a wet environment and can immediately be peeled off again.

Algrain M et al.
In the footsteps of sea stars: deciphering the catalogue of proteins involved in underwater temporary adhesion
Open Biol. 12: 220103 (2022)
http://doi.org/10.1098/rsob.220103

More than Five Arms

Agile predator

Coscinasterias is an agile predator that is rather fast when compared to other sea stars and can feed on bigger animals, such as this date mussel (image below).

The *Coscinasterias* sea star has a six to ten arms…

…and thus differs from the more common pentamerous appearance of other echinoderms. Most species of sea stars have five arms, which is also true for the sister group, the sea urchins, which have alternating groups of five regions covered by spines and five regions covered by little feet (p. 32 and p. 200).

Digestion happens outside of the body

If you quickly remove a *Coscinasterias* from a rock (image on the left), you can sometimes clearly see its everted stomach. As with most sea stars, digestion takes place outside the body. In this photograph the sea star has tried to digest a living mussel, which can only be recognised by its white breathing tubes.


1


2

The spiny starfish *Marthasterias* with its five arms…

…resembles, at first glance, the many-armed *Coscinasterias* sea star. However, they can be distinguished by features such as the number of arms, size, and especially the spines on the back: The spiny starfish has less spines, which are also surrounded by pale green rather than reddish rings of pincers (1).

Hungry predator

The large specimen (2) has been turned on its back quickly, which has revealed strong yellowish tube feet clasping seven hermit crabs! The spiny starfish has obviously crashed a "shell swapping party" held by hermit crabs (p. 34f.) and was already preparing to digest the crabs.

Five light-sensitive sensors on the ends of the arms

The red spots on each arm tip (3) are the starfish's eyes (inside the red circle). They do not have any light-focusing lenses and can, therefore, only produce crude images to differentiate between dark and light objects. Still, these five blurred environmental images can help the starfish to navigate its surroundings, for example, when it is looking for dark hiding places or determining the time of day.

Gill for breathing

Additionally, the spiny starfish extends thin-skinned, whitish gills from the back side of its arms into the oxygen-rich water (4). Spiny starfish love the cold and are only found in shallow water during the colder half of the year. As soon as water temperatures climb high enough for humans to swim, it is already too warm for the spiny starfish. They retreat to deep rocky grounds, since their upper temperature limit lies at around 23°C.


3


4

A Toxic Counter-attack

Sea urchin vs. spiny starfish

Another inhabitant of deeper rocky grounds, which are less affected by light and the force of the waves, is the violet sea urchin *Sphaerechinus.* It is larger and more spherical than the two most common sea urchin species living on sunlit rocky grounds. Its violet spines are short, have bright ends, and are conspicuously blunt.

As protection from its main predator, the spiny starfish, the violet sea urchin uses tiny venomous pincers to great effect. These pincers are called pedicellariae, sit between the blunt spines, and bite the attacker.

When a spiny starfish approaches...

...a specific stimulus, possibly an odorant, is absorbed and triggers a reflex-like reaction in the violet sea urchin: The spines tilt to the side, making room for the venomous pincers underneath to move. Then, the pincers open their three movable valves around the bright centre and are thus ready to defend against the attacking starfish's tube feet (1,2,3).

Injection of paralysing toxin

As soon as the tube feet touch the pincers, the valves close and inject a paralysing toxin through tiny fangs into the soft skin of the feet. On many occasions, this causes the spiny starfish to retreat, which leaves the slower sea urchin sufficient time to escape.

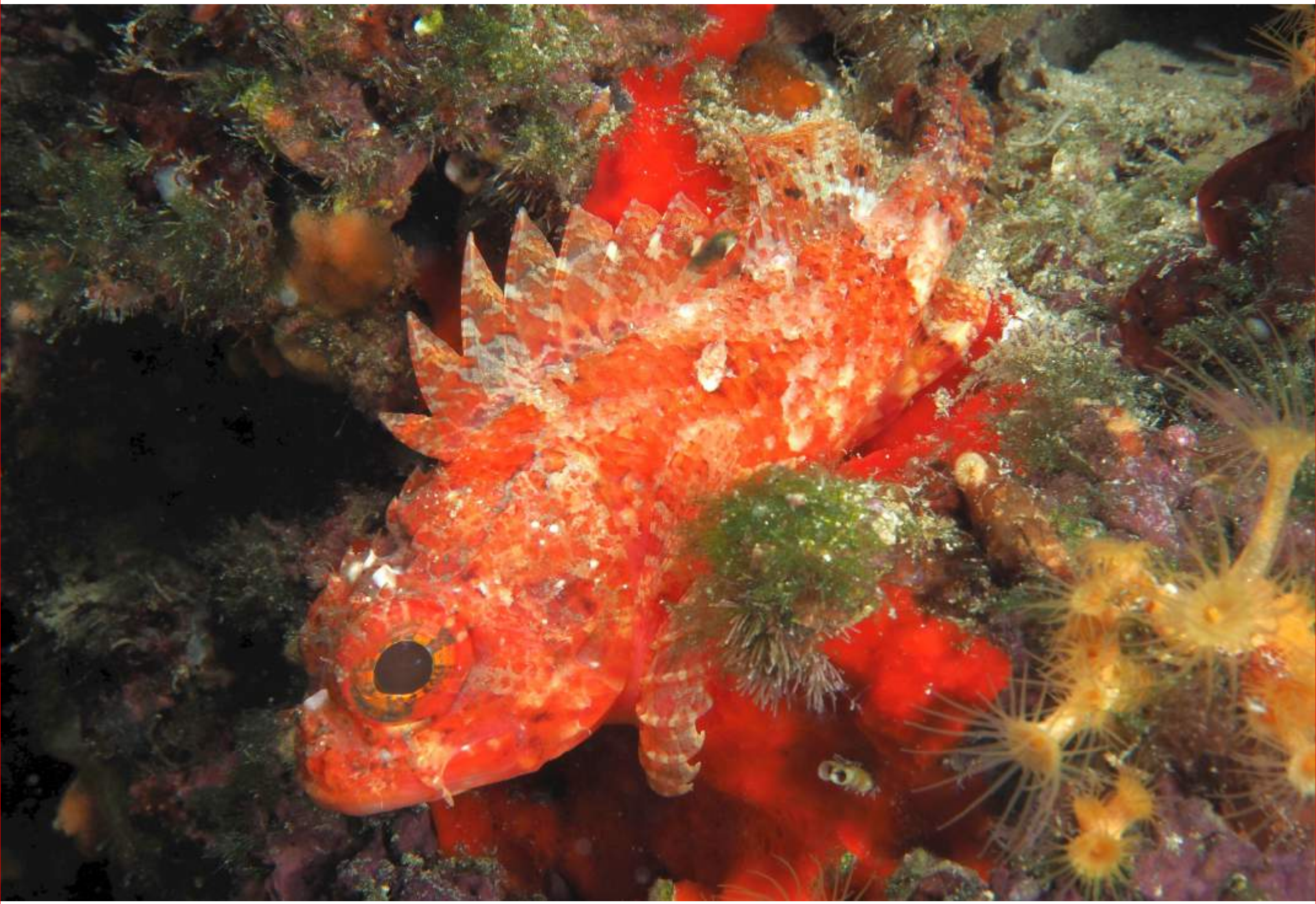
Ghyoot, M., Dubois, P., Jangoux, M.
The venom apparatus of the globiferous pedicellariae of the toxopneustid *Sphaerechinus granularis* (Echinodermata, Echinoida): Fine structure and mechanism of venom discharge
Zoomorphology 114: 73-82 (1994)
https://doi.org/10.1007/BF00396641

The small red scorpionfish *Scorpaena notata*…

…is a common ambush predator in the shady rock habitat. Perched between similarly coloured growth on a slightly elevated rock, it lies in wait for hours, looking to catch prey such as fish or crabs. Its relatively large eyes help the red scorpionfish to see well enough during the hunt, even in low light conditions.

Hungry fish take more risks

Surprisingly, almost half of the scorpionfish that were caught in gillnets in a study during summer had empty stomachs. However, this could be due to a systematic error in the study design, since hungry fish may be active and, therefore, are caught in a disproportionately higher number?



Venomous stingers with eye spot

When disturbed, the red scorpionfish raises its venomous dorsal fins, as can be seen in the above photo. It thus reveals a dark eye spot, which is typical of this species. Both signals are intended to scare off an attacker. If you are unfortunate enough to be stung by the spines of a scorpionfish, you should apply the same first aid measures as described for the sting from a weever fish (p. 140).

Morte, S. et al. **Diet of *Scorpaena porcus* and *Scorpaena notata* (Pisces: Scorpaenidae) in the western Mediterranea** *Cah. Biol. Mar. 42 : 333-344 (2001)*

The red-mouthed goby

Like the red scorpionfish, the red-mouthed goby *Gobius cruentatus* (upper image) is another ambush predator that lives on shady rocky grounds. It grows up to 18 centimetres long and usually inhabits a territory under a rock that sits on gravel. It can be easily distinguished from other goby species by the typical colouration of the mouth and the characteristic elongated dorsal fin.

Zvonimir's blenny

Parablennius zvonimiri lower image) is a blenny that is found almost exclusively in the shady rocky zone. It is quite shy but, due to its dark-red colouration and row of white spots in the middle of its back, easily distinguishable from all other 20 blenny species that live in the Mediterranean. During the warm seasons, the male, which can grow up to ten centimetres in length, occupies the abandoned burrows of date mussels in order to mate and breed there.

The tompot blenny *Parablennius gattorugine*...

...is the second blenny that can occasionally be found on shady rocky grounds. However, it grows more than twice as long as Zvonimir's blenny, has a characteristic banding pattern and tufted tentacles above its eyes. Its colour can vary with its environment. At the top left – between the red algae – the tompot blenny sports a brownish colour, on the upper right – in an area with brown algae, it develops an olive green colour.

The long-striped blenny *Parablennius rouxi*...

...can be found sitting very still on deeper rocky grounds. Its precise "address": moderately shady, horizontal rock surfaces covered with light-coloured debris in areas with little water movement, mostly below three metres and beyond the impact of average waves. It feeds on small crustaceans and algae, and is smaller than the aforementioned blennies, only growing up to seven centimetres long. It can be easily distinguished from the other blennies of the Mediterranean by its light, uniform colour and the dark longitudinal stripe running from the eye to the caudal fin.

Habitat: Dark Caves

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_3

No noteworthy plant growth

Sea caves are hollow spaces bounded by rocks that are almost entirely cut off from sunlight. Due to this lack of light energy, photosynthesis cannot take place. So, there is no significant plant growth in sea caves, which could serve as the basis for a food chain.

Primarily sessile, plankton-eating animals

However, sea caves are connected to adjacent sunlit habitats by the moving water and are thus supplied with a selection of plankton and suspended particles. So it is unsurprising that these dark habitats are primarily inhabited by sessile, plankton-eating animals. If beneficial, plankton-rich water currents prevail, then the cave walls might even be completely overgrown.

Typical succession of inhabitants

From the cave entrance to the end, a characteristic succession of colonisers can be observed: First and foremost, various cnidarian species settle. They specialise in catching larger plankton, which is even more abundant at the cave entrance. There they also find the stronger water movement generated by waves and tidal currents, which is necessary for catching plankton. Further back at the "dead end" on the other hand, bryozoans and sponges grow more abundantly. They feed mainly on very small plankton, which they can only filter out of the water in this low current zone by means of a self-generated water movement.

Mobile animals use the cave in different ways

Among the mobile animals that inhabit sea caves, there are those that use this habitat either as day-time or night-time hiding places, but also those that continuously inhabit caves.

A club-tipped anemone at the entrance

Club-tipped anemones *Telmatactis* occasionally grow at the entrance of sea caves. They can be easily distinguished from other sea anemone species by their tentacles with club-like tips. They use these strong tentacles to catch relatively large animals like shrimps and young fish.

A sunset cup coral on the walls

The lemon-yellow sunset cup coral *Leptopsammia* often grows on cave walls and ceilings. Even with stretched tentacles, they hardly measure two centimetres in diameter. Their main prey are planktonic crustaceans that are transported by currents and waves to their tentacles.

A rare sight: precious corals

Bottom image: Several thriving colonies of precious corals *Corallium* are growing inside a crevice in a vertical cave wall, where they are well-protected. Like a fan, the colonies are branched in a plane. The white polyps are clearly visible against the coral's red skeleton; they have extended their eight tentacles into the water, ready to catch plankton and other floating particles. For millennia, the fragile, red calcium carbonate skeleton of the precious coral has been a highly coveted material used for jewellery making. That is why this slow-growing coral species has become quite rare – the 10-centimetre-high colonies pictured on this page have been growing for well over 50 years! Nowadays, such colonies can only be found in very secluded crevices or at depths below 100 metres, which cannot be reached by divers.

Gallmetzer, I. et al.
Slow growth and early sexual maturity: Bane and boon for the red coral *Corallium rubrum*
Estuar. Coast. Shelf Sci. 90, 1–10 (2010)
https://doi.org/10.1016/j.ecss.2010.04.018

False corals

Much more common than the precious coral nowadays is the orange-red false coral *Myriapora*, which looks similar to the precious coral and can also be found growing in sea caves. However, the false coral is actually not a cnidarian but a bryozoan colony (also p. 160). As opposed to the branches of the precious coral, the fragile twigs of a false coral branch like a bush in all directions, rather than just in one plane. In the photograph on this page, the extended, plankton-gathering tentacles, which are only a millimetre long, are visible as bright fuzz that covers the round, blunt-tipped twigs entirely.

Schizoretepora bryozoans

Colonies of salmon-pink bryozoans of the genus *Schizoretepora* are also commonly found in dark, secluded areas inside sea caves. Its branches are ribbon-like, but as with the false coral, the growth habit of the colony is bushy-branched in all directions.

Plankton-gathering apparatus with a flow-optimised shape

The bush-like growth of sessile, plankton-filtering animals is considered to be an indication of the fact that their location is swept by nutrient-carrying currents from all directions. Species with fan-shaped colonies, on the other hand, grow in areas where the current flows in one or two main directions. Their flat plankton-gathering apparatus is hit by nutrient-carrying water at a perpendicular angle, which makes them more efficient at catching particles.

Varyingly constant current directions

The first "random" water movement patterns prevails in shallow shore regions, down to a depth of about ten metres – this pattern is created by the interaction of different ocean waves. The second pattern with a predictable current direction is found at depths below. It is generated by the force of tidal currents and large-scale ocean currents.

Riedl, R. **Biologie der Meereshöhlen. Topographie, Faunistik und Ökologie eines unterseeischen Lebensraumes. Eine Monographie.** *Verlag Paul Parey. Hamburg und Berlin, 636 p. (1966)*

Sponges in Caves

Sponge communities

The left image shows the sort of sponge community that is typically found in Mediterranean sea caves. The sponge with the characteristic apricot colour is known as *Agelas*. The water around the sponges is remarkably clear – an indication of the animals' filtering activities (the mechanism of their filtration system is described on p. 21).

Sea sponges are the oldest multicellular animals

They exist today almost the same way they did 600 million years ago. This evolutionary long-term success could mainly be due to their toxins. Upon first glance, you can already tell from their many colours that sea sponges have a manifold "menu" of chemical substances on offer.

Two "good inventions"

Their main purpose is protection against infections by microorganisms and against predators. If you carefully detach a small piece from a sponge and then smell it when you are back up in the air, you will catch a whiff of that protective mechanism – each sponge has its own, characteristic smell, which, in most cases, we would consider to be quite unpleasant.

A second "good invention" that can be observed in sea sponges are their microscopically small, variously shaped skeleton needles with which the bodies of many species are armed. They are made of calcium carbonate or silicate crystals and have different shapes. Like their spongin fibres (p. 21), these needles serve as support for their bodies and as a spacer keeping away organisms that might overgrow the sponge.

The horny sponge *Ircinia*…

…grows on walls inside sea caves (right). It might be a variation of the same species that can be found growing on sunny rocky grounds with a dark-grey colour (p. 22f.), but the cave-dwelling sponges have adapted to their location. In lightless caves, these sponges cannot cultivate blue-green algae and are, therefore, white in colour. Its sole nutrient source in these caves is microplankton that is filtered from the water.

Growth form depends on the current

At locations where there is hardly any water current, sponges often grow in an upright, branching manner, turning away from the ground to reach fresh, unused water more easily. Where stronger water currents are predominant, they tend to grow in a flat or cushion-like shape.

Race to the current

The top image shows a pale-yellow crumpled duster sponge *Axinella damicornis* growing in competition with an orange-coloured bryozoan *Smittina*. The grey channels through which the sponge pumps out its filtered waste water are also clearly visible in this image.

Not the suction cup marks of an octopus

The middle image shows the carmine-red surface of the sponge *Phorbas topsenti*, which is characteristically pockmarked with craters. At the bottom of these craters, there are sieve plates with tiny pores known as ostia, through which water is sucked into the sponge. The purpose of the craters is not known. There may be a local pressure difference as the water flows past the craters, making it easier to pump the water out.

Blue sponges are rare

Very few sponge species in the Mediterranean are coloured blue, which makes their classification quite easy: On the right-hand picture, taken at the entrance of a sea cave, one of them, the blue encrusting sponge *Phorbas tenacior*, and a yellow staghorn sponge *Axinella verrucosa* crowd each other. The two representatives of the genus *Phorbas* are not exclusively found in dark caves; they also grow on shady rocky grounds, as long as the shade-loving algae there leave them enough space.

More Cave Animals

In the darkest corners…

…of sea caves, the encrusting orange sponge *Spirastrella* can be found, growing mostly on the walls and ceilings. As can be seen in the right half of the picture, several of its outflow channels radiate into a shared, elongated outflow duct. The yellow threads are the particle-collecting tentacles of a spaghetti worm (p. 65).

A sea squirt colony

Upon closer inspection of the cave walls, surprising things can be seen growing in between the sponges that dominate these surfaces – a colony of sea squirts *Clavellina* has been discovered here. The individual specimens, which can grow between one and two centimetres large, are completely transparent except for the white line at their mouth opening. Even their pharynx is visible glowing in an iridescent blue colour. The pharynx pumps plankton-rich water into the animal. The water then enters their bodies through a round opening at one end, flowing through the pharyngeal gill slits, which catch nutrient particles with a mucus-covered net before the water exits the animal through a second opening on the side of their bodies.

The stony sponge *Petrosia*…

…grows at the entrance of sea caves. It can easily be recognized by its characteristic cushion shape and reddish-brown colour. As opposed to most sponge species, its body feels surprisingly hard to touch.

The dotted sea slug *Peltodoris*

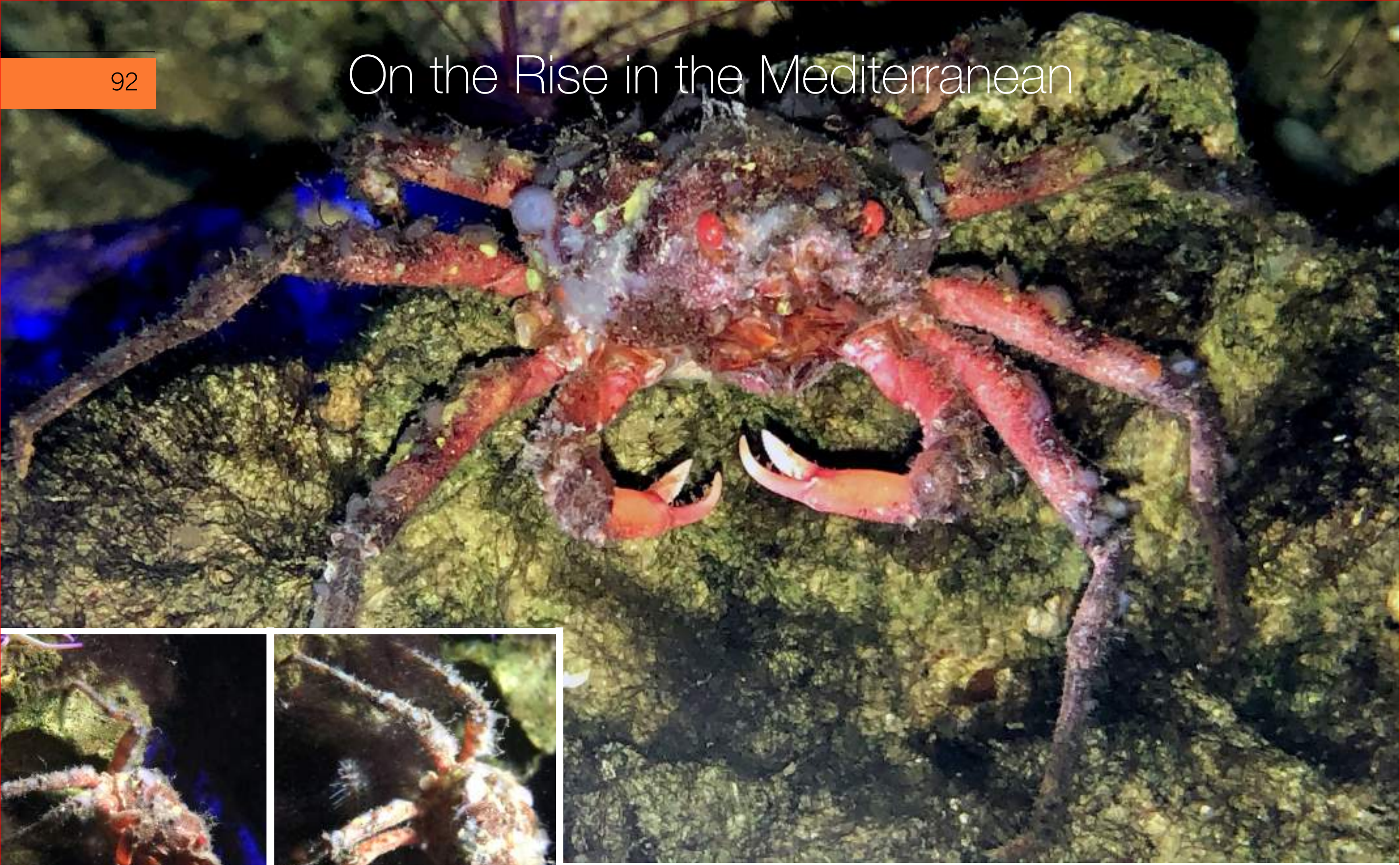
This strikingly patterned nudibranch is often found feeding on a stony sponge (top right) – it has obvioulsy developed a metabolic pathway by which it can render the sponge's toxins harmless. The sponge is not only the slug's food base but also, quite conveniently, its spawning site. Until hatching in a few weeks' time, thousands of embryos mature inside a characteristic, yellow spawning spiral that sticks to the partially eaten sponge.

A spiny lobster in a niche…

…on the cave's wall has found a daytime shelter (bottom left). Its body is almost completely hidden inside the niche; only its two pairs of antennae, the first pairs of legs, and its two eyes are visible. Its many strong spines are pointing forward to protect the lobster's head against frontal attacks by larger predators.

In the niches of sea caves, cleaner shrimps…

…of the genus *Lysmata* also often wait for resting fishes – in the bottom right image, it is the tompot blenny's turn. Behind the focus plane the slightly blurry shrimp is visible. When it is approached by such a "client", the shrimp will first touch one of the pectoral fins of the fish with its antennae. If the fish tolerates this and remains calm, then the shrimp will start to clean the blenny's skin from parasites with its tiny pincers. It will spend several minutes working its way forward to the blenny's head, where it will eventually clean its mouth, throat, and even the sensitive gills under the gill covers, which are readily opened by the fish. Once the fish has had enough of this, it will twitch a few times, and the shrimp will then walk back into its cave niche. However, cleaner shrimps are not solely dependent on this type of food resource; they also feed on other small animals and even sea anemones of the genus *Aiptasia*, as has been observed with specimens kept in aquariums.



The wrinkled spider crab *Herbstia*...

...has obviously been on the rise in the Mediterranean for several decades. It was once a rare species – in the 1950s Rupert Riedl, a pioneer renowned for his research on Mediterranean sea caves, most likely did not encounter any of these crabs during his numerous sea cave expeditions yet. Nowadays, they are quite common and can also be found in great numbers, especially as they crawl on the ceilings of sea caves.

"Sublethal predation"

An interesting feeding behaviour is documented here in this photo series: A wrinkled spider crab preys on a brittle star, which manages to escape. The brittle star "only" loses two arms, which will regenerate after a few weeks – this can be compared to "grazing", which is common in plant stands. Science calls such feeding relationships between animals "sublethal predation".

Lipej, L. et al. **The northernmost record of the Brachyurian *Herbstia* (Fabricius, 1787) and its distribution in the Adriatic sea (*Decapoda, Brachyura, Epilatidae*)** *Annales Ser.Hist.Nat.Vol.2, no.20, p.151–156 (2010)*
https://zdjp.si/wp-content/uploads/2015/12/LIPEJ.pdf

Within a few decades

The devil firefish *Pterois miles* is also widening its territory. Within a few decades, you will most likely encounter it regularly on shady rocky grounds and near sea caves all over in the Mediterranean. A few decades ago, this predatory fish from the coral reefs of the Red Sea, which can grow up to 35 centimetres long, arrived to the eastern Mediterranean Sea via the Suez Canal and expanded from there rapidly towards the west. After about ten years of expansion, it had already colonised the central Adriatic Sea. The northernmost sighting occurred off the Croatian island Vis in the year 2021.

Only in the northern Adriatic Sea…

…a stable population of these fish is most unlikely to develop, because during winter the water temperature there drops below 10°C over several weeks, which is far below the cold tolerance levels of tropical sea fish. The prey of the devil firefish is similar to that of the native painted combers, scorpionfish, and groupers. The devil firefish competes with them for bottom-dwelling fish, such as breams, wrasses, damselfish, gobies, and blennies – but crabs and shrimps have also been found in their stomachs.

The sweeping invasion success of the devil firefish seems to be due to a combination of factors, including its early sexual maturity, defence against predators with several, surprisingly long venomous spines, and its ecological versatility in connection with naive prey and the overfishing of larger native predatory fish like groupers and sharks.

Kletou, D. et al. **A lionfish (*Pterois miles*) invasion has begun in the Mediterranean Sea** *Mar Biodivers Rec 9, 46 (2016)* https://doi.org/10.1186/s41200-016-0065-y

Dragicevic B et al. **New record of *Pterois cf. miles* (Actinopterygii: Scorpaeniformes: Scorpaenidae) from the eastern middle Adriatic Sea (Croatian waters): Northward expansion** *Acta Ichthyologica et Piscatoria 51(4): 379-383 (2021)* https://doi.org/10.3897/aiep.51.75811

Phillips E, Kotrschal A **Where are they now? Tracking the Mediterranean lionfish invasion via local dive centers** *Journal of Environmental Management, 298 (2021)* https://doi.org/10.1016/j.jenvman.2021.113354

Slipper and Squat Lobsters

Crevices in cave walls...

...and even in cave ceilings are used as a habitat by the Mediterranean slipper lobster *Scyllarides*. It is a nocturnal animal and feeds mainly on bivalves and snails.

Antennae with slightly different functions

Slipper lobsters are closely related to spiny lobsters (which are pictured on p. 91), but as opposed to the latter, slipper lobsters possess second antennae which are much shorter and widen into a shield. The bent, rod-shaped appendages in between are the first antennae.

With most decapods (which includes shrimps, spiny lobsters, common lobsters, and crabs), the first antennae serve to perceive chemical stimuli such as odorous and messenger substances or to measure the water's salt content, while the second antennae fulfil mechanical functions as feelers and, as in the case of the slipper lobster, as levers.

Rocks that lie on cave floors…

…and thus contribute to the accumulation of fine sediments are the ideal small habitat for the blue striped squat lobster *Galathea strigosa* (image above) and the black squat lobster *Galathea squamata* (image below). Both feed on these sediment particles, which they sweep from the sea bottom with their brush-shaped foot jaws.

Pincer legs can regenerate themselves

On both sides of the mouth opening of the black squat lobster, his blue-orange coloured jaw feet can be seen folded into the opening. Its missing right pincer leg was probably sacrificed during a fight against a predator, but will be regenerated within a few months, over the course of the lobster's next moulting period.

Octopus

In rock niches with narrow entrances

The predator of the squat lobster's claw on the previous page could have been a specimen of the genus *Octopus*. These shell-less molluscs often use spacious rock niches with narrow entrances as protective dens where they eat, rest, and hatch their eggs. These dens are frequently closed by shell remains or rocks that octopuses hold from inside with their suction-cup-covered tentacles in order to keep predators like congers and moray eels from entering.

Leftover food lying outside the octopus's den

Octopuses leave their cave dens for hunting during the day, sometimes travelling several metres to other habitats like sunny rocky grounds and even sandy grounds in their search for prey. In these habitats they mainly catch crustaceans, snails, and mussels – the extent of this habitat-connecting feeding relationship can be elegantly estimated from the accumulations of the empty shells of non-habitat-specific animals in front of an octopus den.

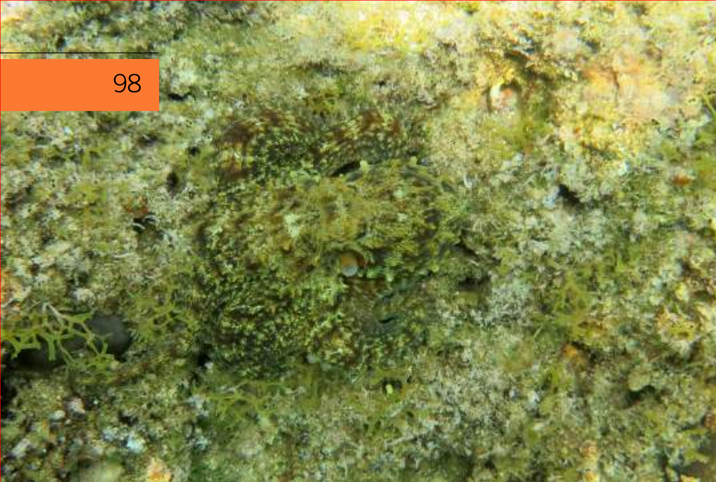
Extremely efficient predator

With their boneless and malleable bodies, their high-resolution eyes, and their eight strong but highly sensitive tentacles, which they can use simultaneously, octopuses are powerful predators that are highly efficient in detecting, outwitting, and catching their prey. They have a high demand for food – over the course of their 1.5-year lifespan, they reach a maximum weight of several kilograms, at a length of 1.3 metres. If they had a motto to live by, it would probably be something like "Live fast and die young"…

Almost ready to go

Right-hand side: A large octopus stretches its bell membrane wider and wider and is ready to shoot away at lightning speed (also photo on the next double page at the bottom right).

Cuccu, D., et al. **Reproductive development versus estimated age in a wild population of *Octopus vulgaris* (Cephalopoda: Octopodidae)** *Journal of Experimental Marine Biology and Ecology 93(3): 843-849 (2013)* DOI:10.1017/S0025315412000203



Camouflage and Surprises

Change of colour within seconds

The skin of octopuses can change its shape and colour within seconds. This mechanism is used as camouflage, as an optical form of communication with other octopuses, and as a scare tactic against predators (top and bottom image).

Octopuses' ability to learn and intelligence…

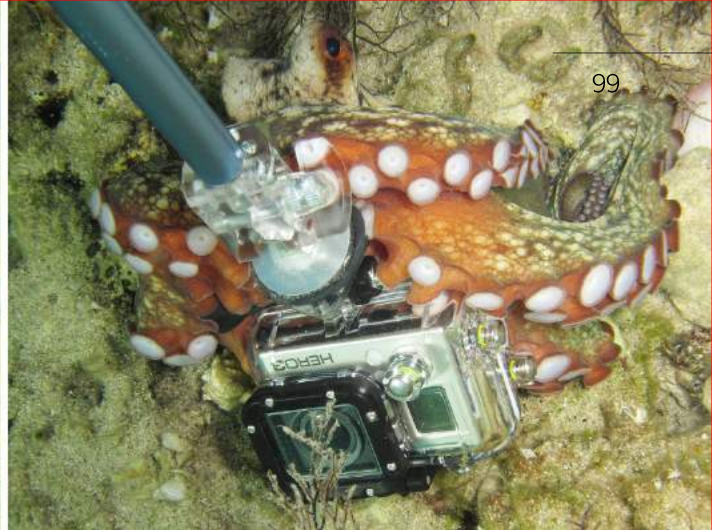
…has been marvelled at and researched for a long time. It is known for certain that these animals are capable of learning by observing each other – even though they are solitary animals for almost their entire lives – and that they thoroughly examine unknown, harmless objects, which is considered to be a form of curiosity and play behaviour. They are also able to solve puzzles where food is hidden in geometric forms and will do so quicker after a few repetitions.

The Greek scientist Aristotle, however, stated that octopuses are clearly not intelligent enough to escape the contraptions and deceits of fishermen – for instance, they will accept empty jars that humans offer them as den substitute and are then caught quite easily.

Unscrewing a camera

The photo on top of the right-hand page shows a scene that could only be captured photographically because the author had two cameras with him: To film the octopus up close, he used an "action camera" and held it close to the animal with an extension stick. As soon as the unkown, shiny object was close enogh, the eight tantacles clutched the camera. However, the photographer did not want to give up his camera without a fight and so he held onto the stick. After they were locked in a stalemate for quite some time, the octopus started to unscrew the camera, quite to the surprise of the photographer. It was only much later, after the animal had calmed down, that the author was able to retrieve his camera from the cave.

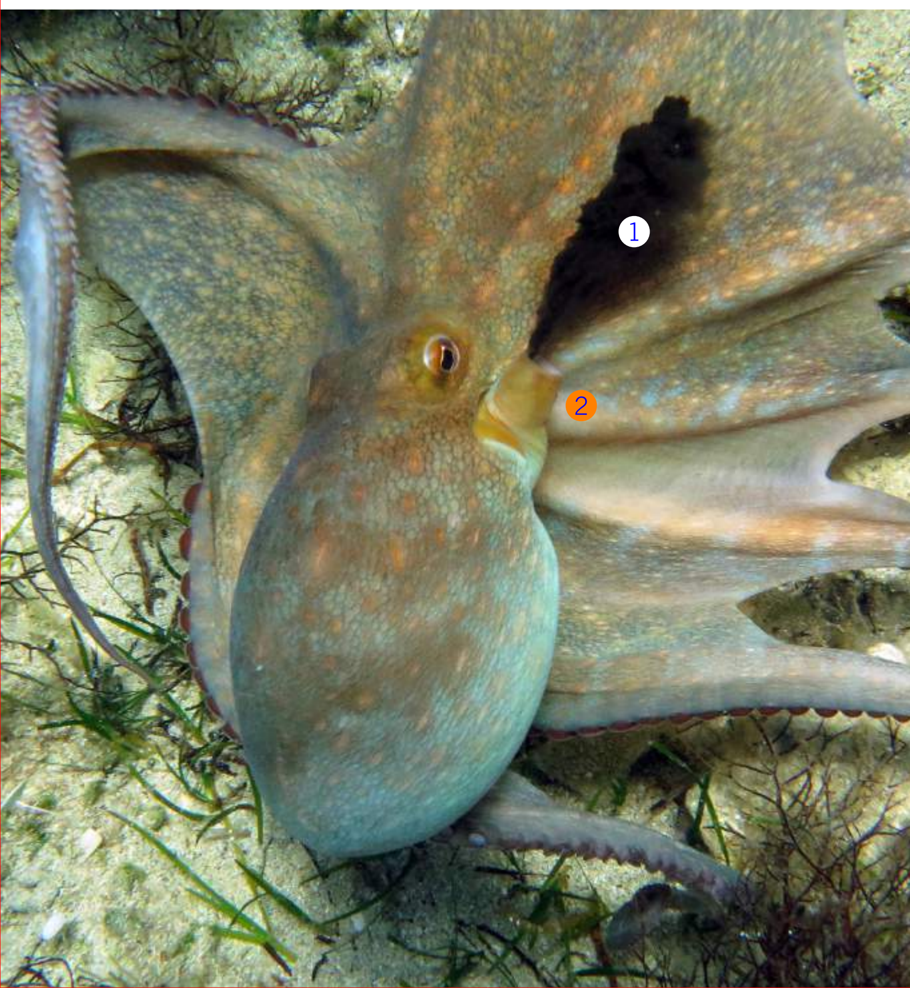
Aristoteles *Book IX, Part 37 (around 350 b.c.)*
http://classics.mit.edu//Aristotle/history_anim.html



Images above (refering to the event described on the left): Octopuses might be skilled at screwing motions, because they use the same motions to detach mussels sticking to rocks.

Black-brown ink cloud

Below image: When threatend, the octopus ejects a dark cloud of ink (1) from its orange funnel (2). When it flees, the cloud will linger between the attacker and the fleeing animal (bottom right).



Hunters and Hunted

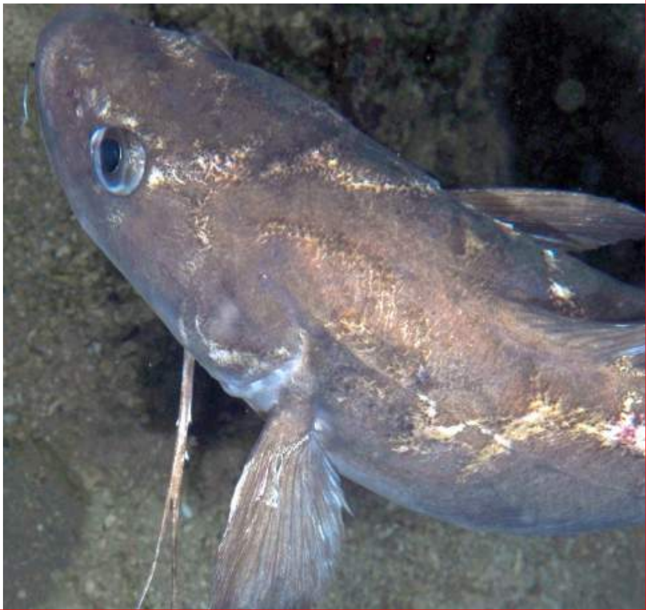
Octopuses also have enemies

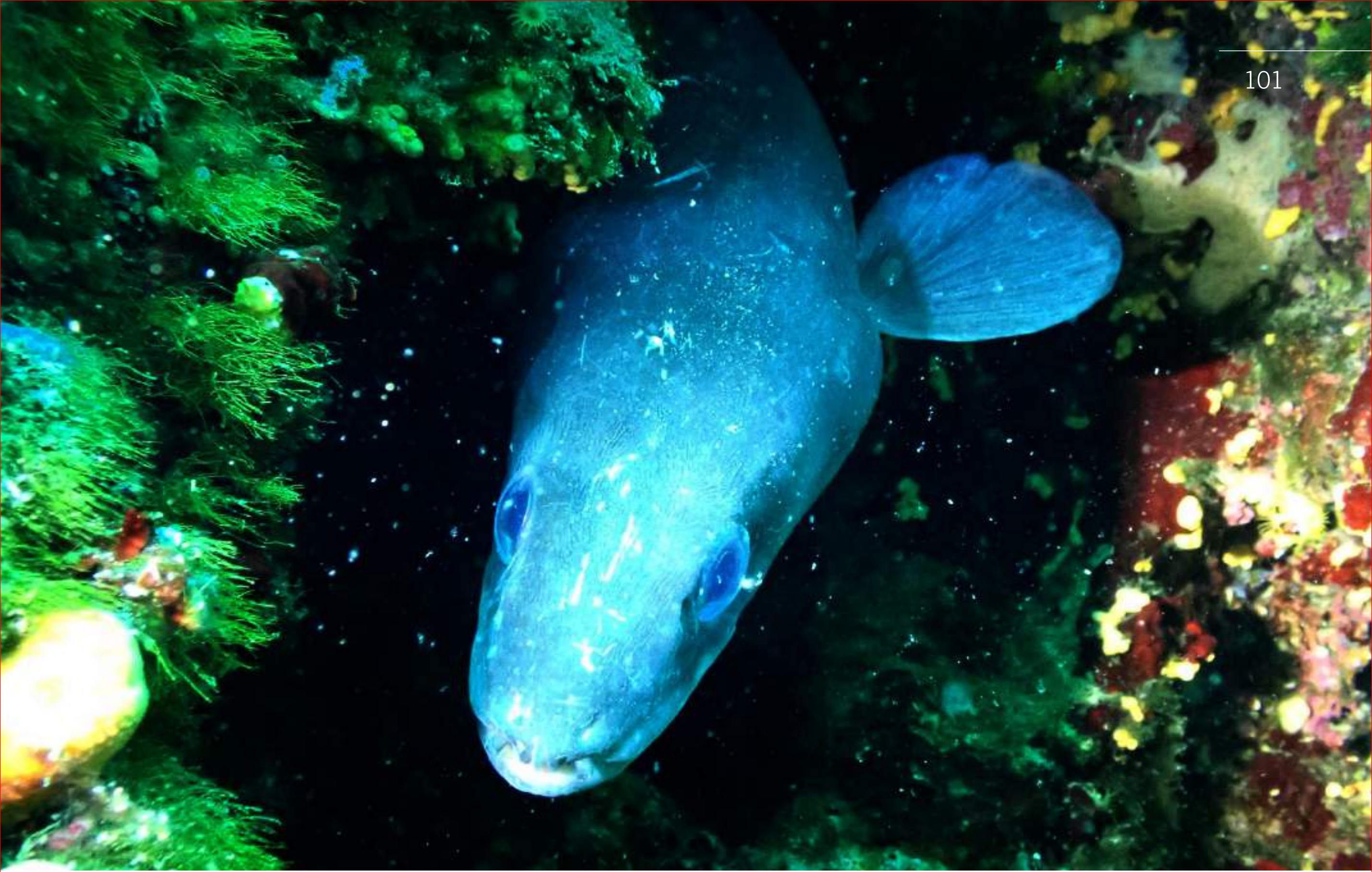
Image on the left: A moray eel in its daytime hiding place. They are nocturnal, and, in some places, the main predators of octopuses. Their slim jaws with pointy fangs and their extraordinary olfactory sense provide them with the best conditions for a successful octopus hunt.

Larger prey

Photographs below:

A badly injured forkbeard *Phycis* on the ground of a sea cave. These images show their thread-like pelvic fins and two bite marks – a preying eel might have failed to catch the forkbeard due to its slimy skin.





Conger eel

Conger eels also hide inside crevices in sea caves and leave their hiding places in the dark for hunting sleeping fishes and octopuses, while being guided by their sense of smell – but also their big eyes. Unlike moray eels, however, they do not have pointed fangs, but many small teeth that, nevertheless, bite very effectively. The females reach a length of over two metres.

The Dusky Grouper

One of the largest fish in the Mediterranean

The dusky grouper *Epinephelus marginatus* grows to 1.5 m in length and 60 kg in weight. With its broad, thick-lipped mouth and its brown body with bright stains, the dusky grouper can be easily distinguished from other grouper species (p. 134f.).

Prey is sucked in

The dusky grouper lives as a solitary and territorial animal and uses sea caves and rock crevices as hiding places. Close to these spaces, it hunts crabs, squids, and fish that are sucked in whole by the grouper's big mouth.

Difficult to swallow

When threatened, the dusky grouper erects its dorsal fin, revealing the fin's strong spines. The gill covers are also armed with spines. All these spines make it quite difficult for predators to grab and swallow the grouper.

In need of protection

In coastal areas where dusky groupers are not fished, you can already encounter these fish just below the intertidal zone. However, in many areas, they have been decimated by spearfishing within a few decades and are now only found in depths below 50 metres. The creation of additional marine protected areas where fishing is prohibited would be the best measure to enable a return of the dusky grouper.

The closer you look, the more living beings...

...you will recognise: For example, a closer look (1) reveals several shield-shaped sea lice *Caligus*, barely two millimetres long, in the region behind the eye of the large grouper. They belong to the otherwise free-living group of copepods (p. 168).

Bodilis P. et al. **Recruitment of the dusky grouper (*Epinephelus marginatus*) in the North-Western Mediterranean Sea** *Cybium , 27 (2): 123-129 (2003)*
https://doi.org/10.26028/cybium/2004-272-005

With their antennae and mandibles, they attach themselves to their host to feed parasitically on their bodily fluids. The thread-like appendages on their abdomen are egg strings, in which many hundreds of their larvae mature (enlargement in the top right image, (2)).

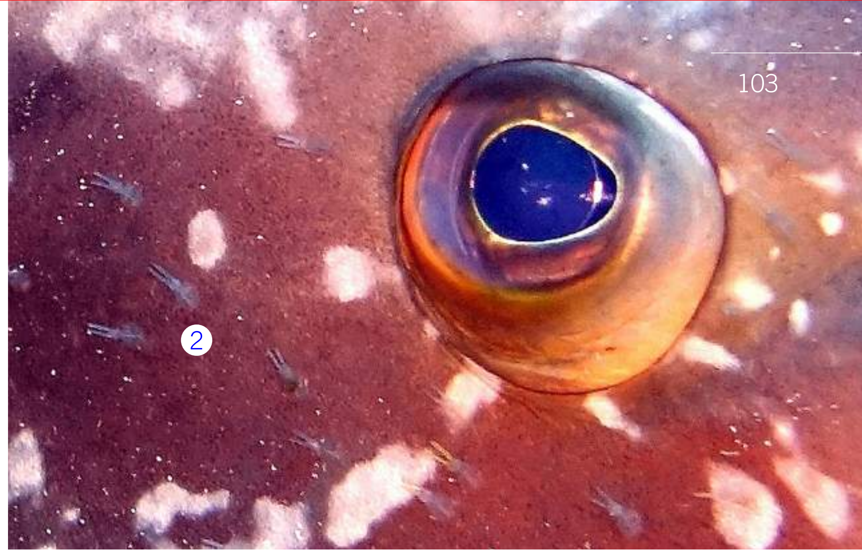
Only five millimetres long…

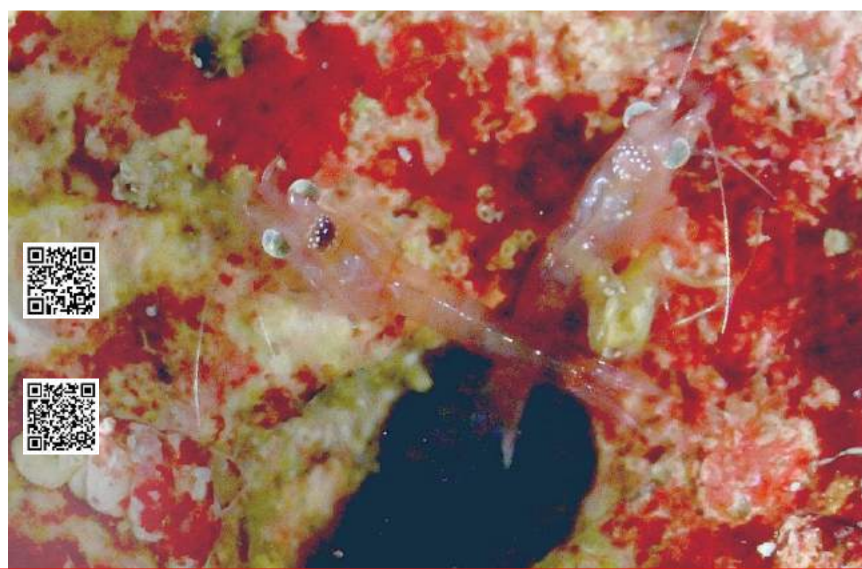
…is the opossum shrimp *Heteromysis* (middle and bottom image to the right), which inhabits the crevices of cave rocks in small groups and catches one's eye with its characteristic back-and-forth swimming style (opossum shrimps are only half the size of their relatives on sunny rocky grounds, p. 168).

The smaller, the more difficult to find

The closer you look, the more living beings you will discover. This applies on the one hand to scale – the microscopic world remains hidden to our human eyes unless we use an optical instrument.

On the other hand, this also applies to our precision when we examine living beings: Through a very close analysis of opossum shrimps that appeared in aquaria, two Viennese marine biologists were able to discover nine new *Heteromysis* species within a period of two years.

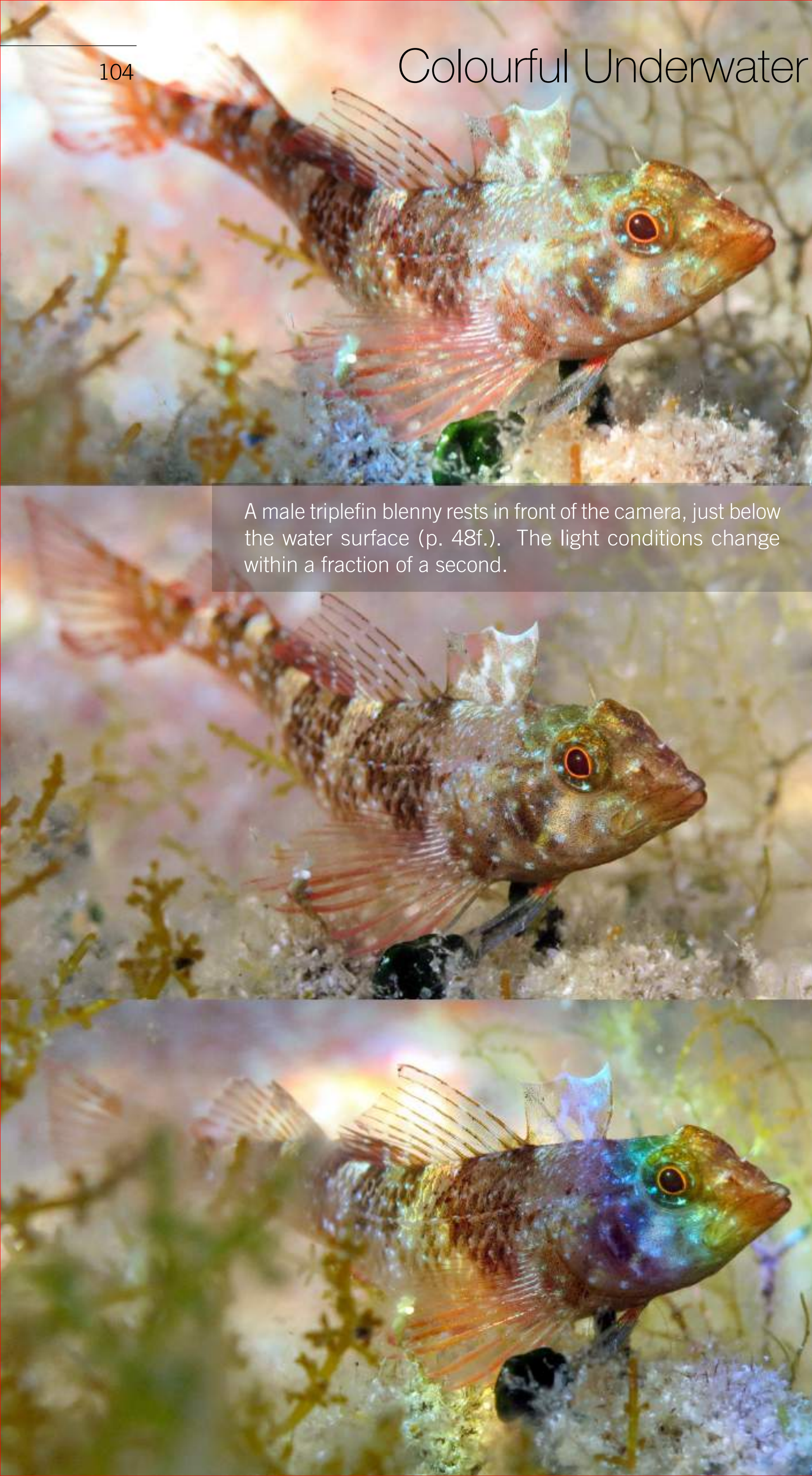




Wittmann, K.J. et Abed-Navandi, D. **Four new species of *Heteromysis* (Crustacea: Mysida) from public aquaria in Hawaii, Florida, and Western to Central Europe** *European Journal of Taxonomy, 735(1), 133-175 (2021)* https://doi.org/10.5852/ejt.2021.735.1247

World Register of Marine Species (WoRMS): Bemerkenswerte neue Meeresspezies von 2021
https://www.marinespecies.org/news.php?p=show&id=8993
https://lifewatch.be/en/worms-top10-2021#Heteromysis_hornimani

Colourful Underwater World?



A male triplefin blenny rests in front of the camera, just below the water surface (p. 48f.). The light conditions change within a fraction of a second.

The full colour spectrum

Underwater photobooks are – like this one – usually very colourful, even much more colourful than books about nature on land. To a certain degree, this may contradict the subjective impression that divers and snorkelers have underwater: In reality, blue, green, and grey shades are predominant.

Sunlight and flashlight

Photography literally means "drawing with light". However, light is actually quite relative: When we talk about light, we usually mean the sunlight that is available to us on land – or the kind of light simulated by photoflash devices.

Which colour is the "real" one?

Underwater – with increasing depth and/or increasing distance – the long-wavelength components of light are absorbed. For instance, if you are swimming on the water surface and you photograph a snorkeler on the surface from a distance of four metres, then the snorkeler's skin will have a strong blue tinge because the sunlight – reflected from the skin – must travel four metres in the water until it reaches the camera.

The total distance matters

The same effect can be observed if the snorkeler dives below the photographer at a depth of two metres: The light must travel two metres to reach the snorkeler and then, as reflected light, it must travel back another two metres to the camera lens.

If the photographer dives down two metres and swims within a metre of the snorkeler, then the skin will look almost as it would on land because now the light only has to travel three metres to reach the lens.

Even at a minimal distance

Let's look at the photo series of the triplefin blenny on the left-hand page, which was taken at a very close distance from the fish at a depth of only a few centimetres. So, the total distance that the light had to travel was less than 30 cm. The three shots were taken at an interval of one tenth of a second. Due to the wave motions on the surface, different parts of the fish appear illuminated in the shots. In the image at the bottom, even rainbow colours are visible – due to the different refraction indices of the prismatic colours (also photograph on p. 7).

Flash or daylight lamps

At medium to great sea depths, you only get stable colours at a close distance while using artificial light. Mostly you will end up with coloured images like the photograph on the right, because sponges, zoanthids, corals, sea stars, etc. often have red, orange or yellow colours. When diving without additional artificial light, you will not see these colours, or only to a limited extent.

At a distance greater than, for instance, one metre (i.e. a total journey of two metres for the light travelling to the lens and back), even the strongest flashlight cannot prevent this colour distortion.

A painted comber *Serranus scriba* in a small cave. The artificial light does not correspond to the natural light.

Colour Riddle

Red as camouflage colour

A pygmy black-faced triplefin blenny *Tripterygion melanurus* (right) at the edge of a shady rock crevice. Its photo was taken with flashlight; it appears strikingly red in this image. We can only perceive this red colour if the animal is illuminated by light with the same wavelength quality as on the water surface. However, this blenny spends most of its life in shady caves at a depth of several metres, in an area that is not reached by the long-wavelength, red components of sunlight. Without artificial light, the fish appears deep brown and is thus camouflaged.

The same mysterious colour pattern...

...(black fish head and red fish body when exposed to water-surface light quality) can be found as a peculiar parallelism with two other fish species: the black-headed blenny *Lipophrys nigriceps* (below), which shares the same, shady cave habitat with the pygmy black-faced blenny, and the males of the red-black triplefin blenny (left), which prefer, however, the bright algae meadows of sunny rocky grounds (p. 104f.). There its red colouring is clearly recognisable as a signal colour, at least for our eyes.

Two lines of thought to interpret colours:

1. Colours that we perceive may not always have a function – think of the vivid red of the haemoglobin in our blood or the bright green of our bile pigment biliverdin.
2. Truly relevant animals – that is, animals of the same species, symbionts, and predators – perceive colours differently than our own eyes due to unknown fluorescence and filter phenomena in these eyes. More recent research suggests that this might be the case.

Meadows, MG, et al. **Red fluorescence increases with depth in reef fishes, supporting a visual function, not UV protection** *Proc.R.Soc.B 281: 20141211* *http:// dx.doi.org/ 10.1098/ rspb.2014.1211* *(2014)*
Sparks, JS, et al. **The covert world of fish biofluorescence: A phyllgenetically widespread and phenotpically variable phenomenon** *PLOS One. 9(1): e832259 Doi:10.1371/journal.pone.0083259 (2014,*

Mouthbrooder

The bright red cardinalfish *Apogon imberbis* inhabits caves that it uses as daytime hiding places. At night they swim freely outside their caves. As opposed to most other bony fish species, the cardinalfish is neither an open-water spawning fish nor a substrate spawning fish but a mouth-brooder – the males carry a clutch of eggs inside their mouths for several weeks, until they hatch.

The image below shows – illustrating what has been discussed on the previous pages – how the colours of the red fish appear brownish without flashlight.

Habitat: Intertidal Zone

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_4

Challenging environment

When we enter the sea to go snorkelling or scuba diving, we pass through a remarkable habitat: the intertidal zone. If it is located along a rocky coast, this habitat provides its inhabitants with particularly harsh living conditions. The force of the waves is particularly strong in this zone.

Half of the time the area is dry

Moreover, the sea level oscillates due to the tides – in the Mediterranean by a few decimetres approximately every six hours. The organisms here are alternately either covered by water for half a day and exposed to the strong forces of the waves, or they fall dry and have to endure desiccation and temperature fluctuations of up to 30°C.

Coping with extreme conditions

To withstand these extremes, they must either be of a very robust build or they must be able to react quickly. By promptly responding to the changes, they can leave this rapidly changing environment as fast as the changes occur.

Beadlet Anemone and Gastropods

Waiting for better tides

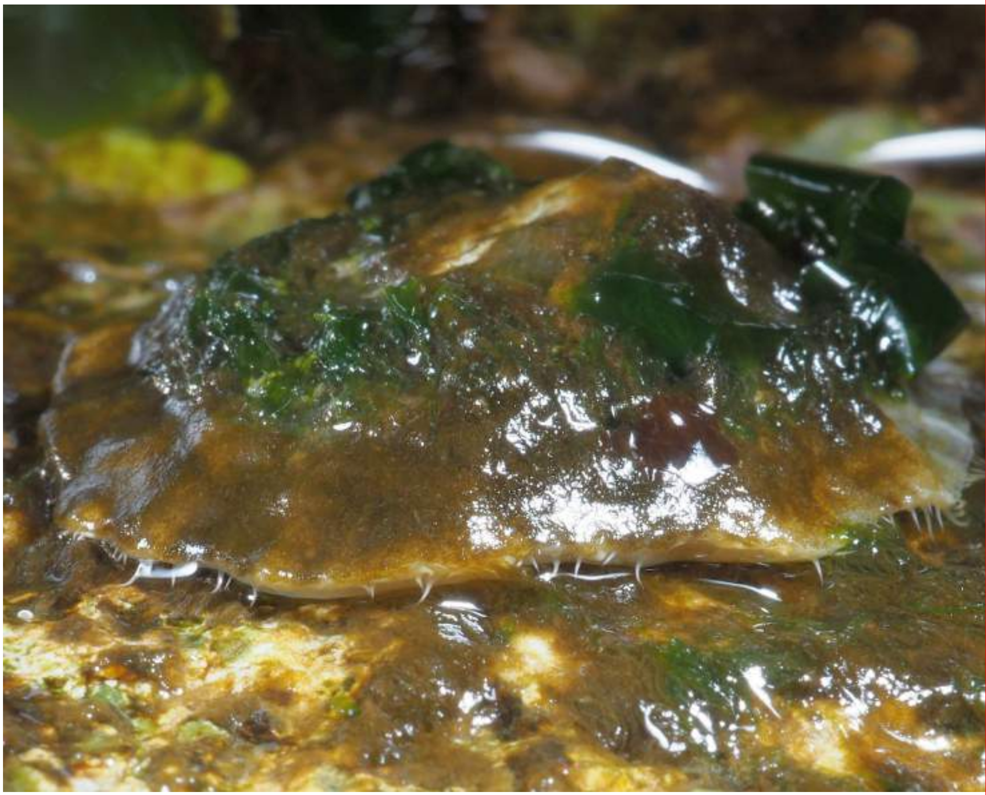
While taking a walk along a rocky coast, you will discover a red, rubbery hemisphere sticking to a dry rock just above the water (image above). This is the beadlet anemone *Actinia* in its dormant form, waiting for the water to return. After a few hours, the time has come – the water rises again. Once the animal is submerged, it pumps itself up with water and extends its short, strong tentacles into the waves in order to catch plankton and breathe (image below) – and so the sea anemone's half-life continues, always directed by the rhythm of the tides.

Hard and waterproof shell

Some snails have adapted to the constantly changing conditions in the intertidal zone by using a hard and waterproof shell. As soon as they are covered with water, the common limpet *Patella* (right), the sea cradle *Chiton* (bottom right), and the turban snail *Phorcus* (bottom left) graze on the turf algae, which grow particularly fast in this zone.

Heavy algae growth

The strong water movement, which promotes gas exchange, the bright light, and the fertilisers from bird droppings and humus from land are responsible for the strong growth of algae in the intertidal zone.



Mussels and Crustaceans

Plankton-eating mussels

Besides the beadlet anemone, there are other plankton feeders in the intertidal zone that can also cope with the physical extremes there: The black-blue mussels *Mytilus* live in dense clusters and tie their bodies to rocks using elastic filaments which can withstand even the strongest breaking waves. During the hours of the day in which they are covered by water, they breathe and feed with their gills which pump many litres of water past them. Small plankton algae, bacteria, and suspended matter are separated from the water.

Incurrent openings, gills, and faecal strands

Water pumping mussels can be recognised by their shell valves, which are opened only a few millimetres wide – the image below also shows the white gills through the light brown fringes surrounding the incurrent openings (1). Additionally, recently excreted, bright faecal strands (2) can be seen. To a large extent, they consist of fine sediment, which the animals cannot utilise.

Where there is even less water

The rocky zone above the beadlet anemones and mussels is even less often covered by water. Yet, there are countless sessile crustaceans living in this habitat.

Only very few hours per month to live

The barnacle *Chthamalus* grows here in dense clusters. Its calcareous shells form a sharp-edged surface on the already dangerously jagged rocks – its colonies can be found up to one meter above the average sea level.

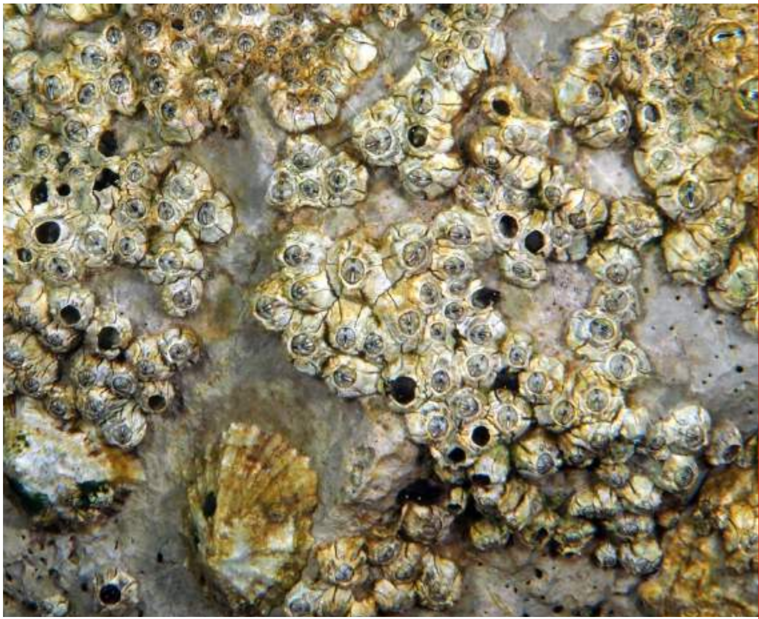
At this extreme altitude, the barnacles only have a few hours to live each month. They use these short phases, during which the water level or waves reach them, to breathe, mate, and catch plankton (in this order).

Some animals change their location quickly

Not all animals in the intertidal zone are sessile and wait for the water to return. There are also very fast animals like the sea slater *Ligia*, which is just one centimetre long. With its large eyes and long legs, it is perfectly equipped to flee from waves and predators. It avoids the water and feeds on the algae growth on rocks.

Keeping the gills moist

A similar way of life can be observed in the marbled rock crab *Pachygrapsus* (image below). It can also survive on land, as long as its gills under the dorsal shell are kept moist. When it senses movements in its surroundings with its eyes, it flees at lightning speed into the nearest crevice. Its food are again algae, which are scraped off rocks with the tips of its claws (3) (left picture below show the scars on a dry rock).



Insects in the Sea or Crustaceans on Land?

Insects on land are equivalent to crustaceans

There are only very few insects that have chosen the sea as a suitable habitat. They almost completely surrender this habitat to their close relatives, the crustaceans. There are, however, a few points of contact in the intertidal zone – for example, two specimens of a mosquito species (perhaps lake flies of the genus *Clunio* or *Telmatogeton*) are mating here at the "shore" of a tidal pool.

Insects and crustaceans both belong to the Pancrustacea

Insects and crustaceans are now one: According to recent findings in molecular biology, insects are no longer a clade in opposition to crustaceans, but both are united in the group Pancrustacea, i.e. they are merely "land-dwelling, air-breathing crustaceans with six legs".

Territories in the Intertidal Zone

Several blenny species have chosen the intertidal zone as their permanent habitat. They grow only a few centimetres in length and form territories in which they find sufficient hiding spots, food, and spawning grounds. They only swim for short distances just above the rocky ground – which is actually more reminiscent of hopping than swimming.

Heavier than water

They also do not have a swim bladder, which would allow them to float in the water. Usually, they lean on their large pectoral fins and observe their surroundings with their eyes, which are situated high on their head. This allows for a timely reaction to waves breaking above them or to approaching predators.

Just below the water line…

…is the stare-eyed blenny's (*Lipophrys trigloides*) preferred habitat (image above). It can even endure a few seconds above the water if a wave trough is particularly deep. Unlike most other blennies, it does not feed on vegetation growing on rocks but on animals like young mussels, small crustaceans, or other blennies that have just started their lives on the sea bottom.

Yellow cheeks blenny

Microlipophrys canevae, also known as Caneva's blenny, lives in a habitat in the deeper regions of the intertidal zone. From there it undertakes foraging excursions to the algae meadows of the deeper rocky habitats, where it may already encounter different blenny species like the mystery blenny (p. 40). Just like this cousin, it lives in abandoned bore holes left by date mussels and uses them as spawning burrows. Often a courting male specimen sporting yellow cheeks can be spotted peering out of its hole while waiting for a female ready to spawn (image in the middle).

As soon as the Caneva's blenny has left its burrow, its cheeks change colour almost instantly to a brown-spottet camouflage pattern, which is also sported by female individuals (image below, also p. 117).

Between Two Media

While snorkelling, you will spend most of your time in the intertidal zone. When entering the water, you will start swimming in knee-deep water and use diving goggles from this point to look at the sea bottom. This not only prevents unnecessary injuries (sea urchins, jellyfish, fire worms, fish with spines, nettling anemones, rough rocks, etc.), it is also gentle on fauna and flora: The more you discover in this zone over time, the more you come to respect this sensitive habitat.

A cormorant is drying its plumage (next double page).

Prolonged observation is easy and exciting

Blennies are best suited to being studied by snorkelers – like the Caneva's blenny *Microlipophrys canevae*, also on p. 115. They soon get used to being observed and then present their full behavioural repertoire, not just their startle and flight behaviour. When the sea is calm and the tide is right, blennies in the intertidal zone can even be observed from the shore through the water surface.

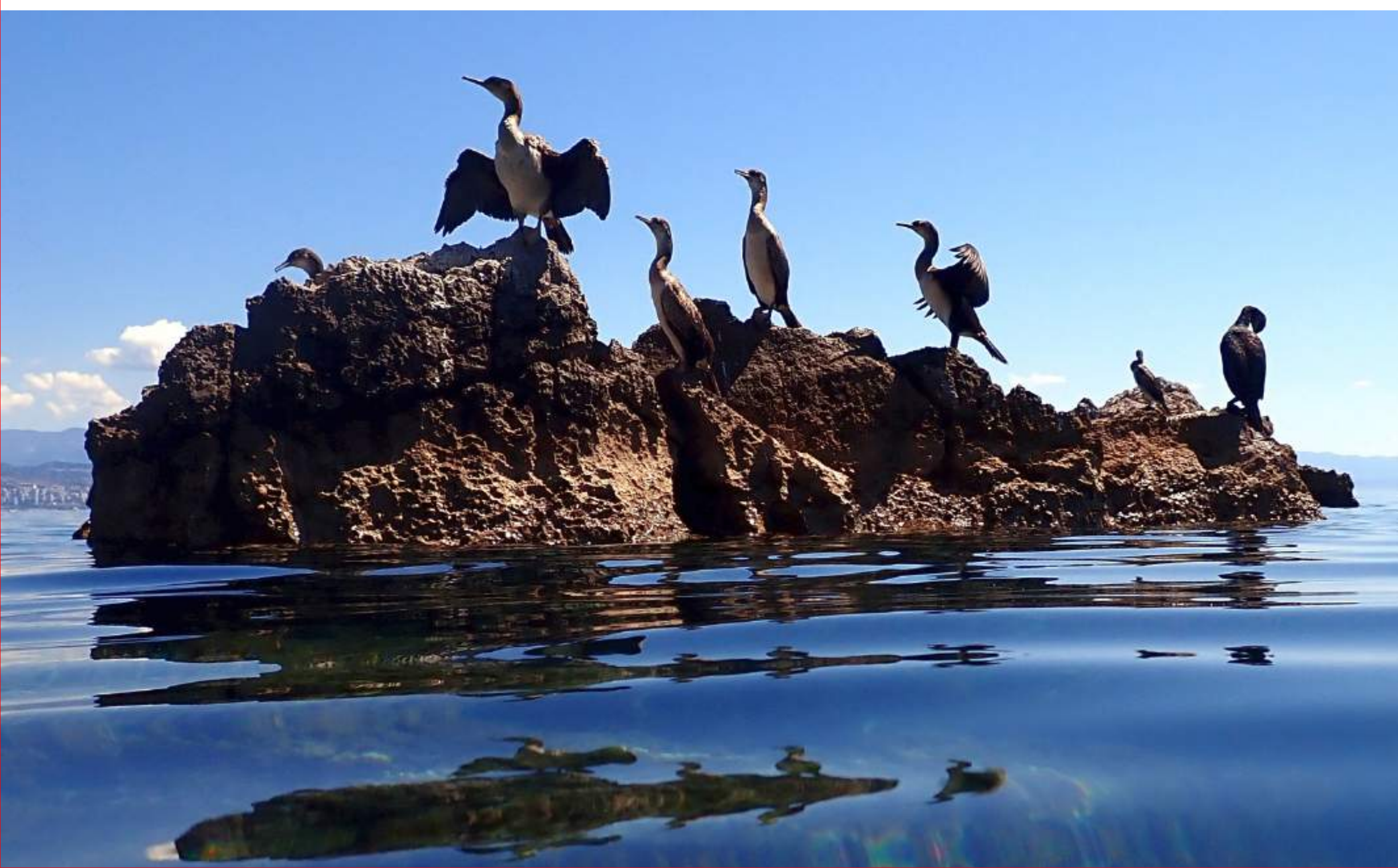
Resting and Breeding in the Intertidal Zone

Dive-hunting and keeping the plumage dry

The intertidal zone is the place where many seabirds come to rest and breed. In the photo below, several cormorants *Phalacrocorax* are resting after dive-hunting and drying their water-soaked plumage in a characteristic pose.

Excellent divers

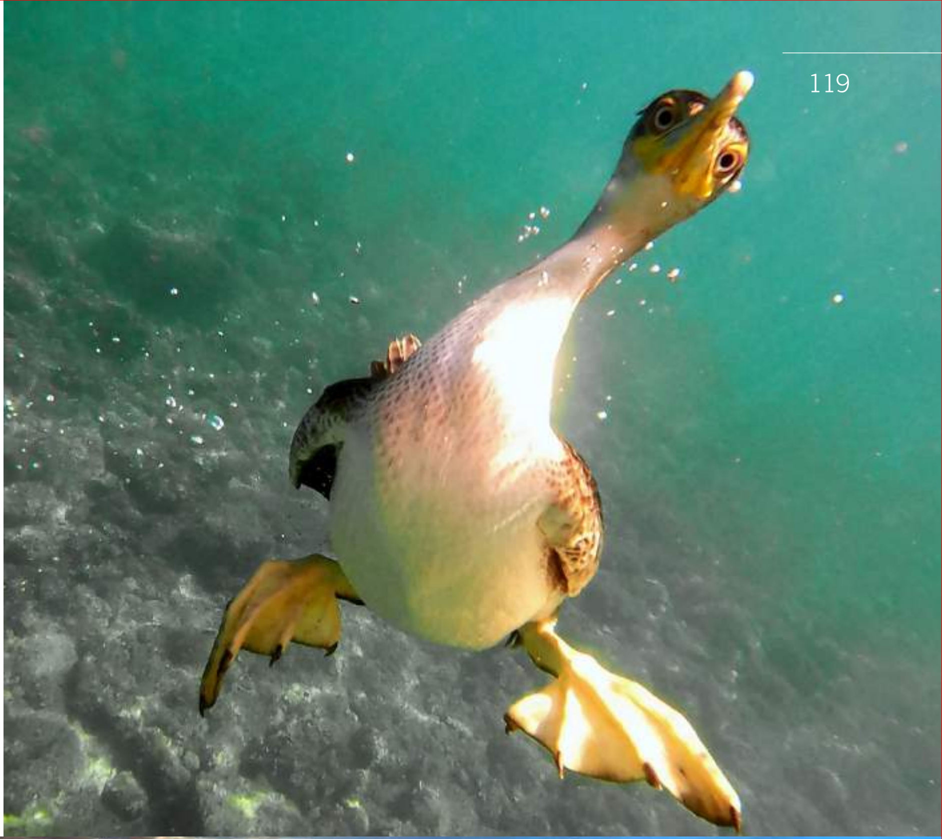
Cormorants are skilled divers – for up to a minute and several metres deep they pursue schools of fish (image above). Their bodies have adapted to this in many ways: In order to reduce the buoyancy that would slow them down when diving, their bones are comparatively heavier



than those of birds living on land. Their plumage is water-repellent and air-retaining only close to the skin, to ensure that they do not cool down too much; the rest of the plumage immediately loses its debilitating air as soon as it touches water.

Sculptured lenses facilitate vision under and above water

The cormorant's eyes are equipped with unusually flexible lenses, whose refractive power is constantly adapted to the respective location by deformation. This results in acceptable underwater images.

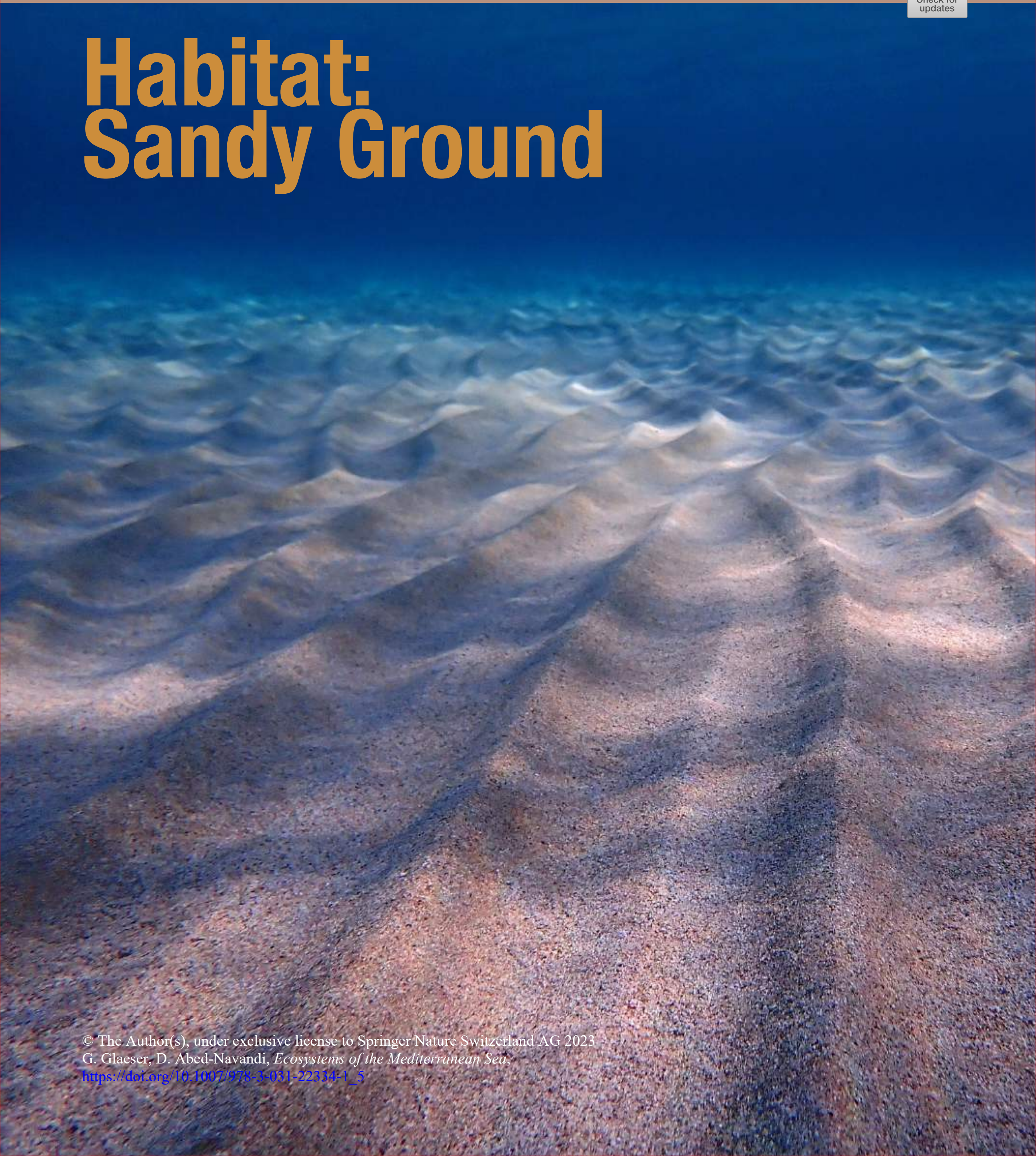


Snatch Your Prey

The European herring gull *Larus*…

…uses, like the great cormorant, the intertidal zone as a resting and breeding site. However, as opposed to the cormorant, the gull also derives its food from this habitat. Gulls are masters of stealing food, and they are often also the first scavengers to arrive. The photographs on this double page show adult herring gulls with a European conger, a crab, and a bone fragment in their mouths.

Habitat: Sandy Ground



G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_5

Sand bottoms appear barren and monotonous

Compared to other habitats that are home to a great abundance of different life forms, such as rocky grounds, sandy sea bottoms appear like a "desert". Why is that?

The birth of a sand bottom

Sandy sea bottoms appear on stretches of the coastline where grains of sand (diameter between 0.1 and 2 mm) can accumulate and remain on the ground due to an appropriate steepness (or slope) of the terrain. On a steeper and more agitated coastline, grains of sand will be carried off by the water – thus, the solid rocky ground is immediately exposed there. Conversely, on a coast that is less steep and much calmer, there is sticky muddy sediment on the sea floor in which not only grains of sand but especially the finest grains (up to a diameter of 0.02 mm) will remain.

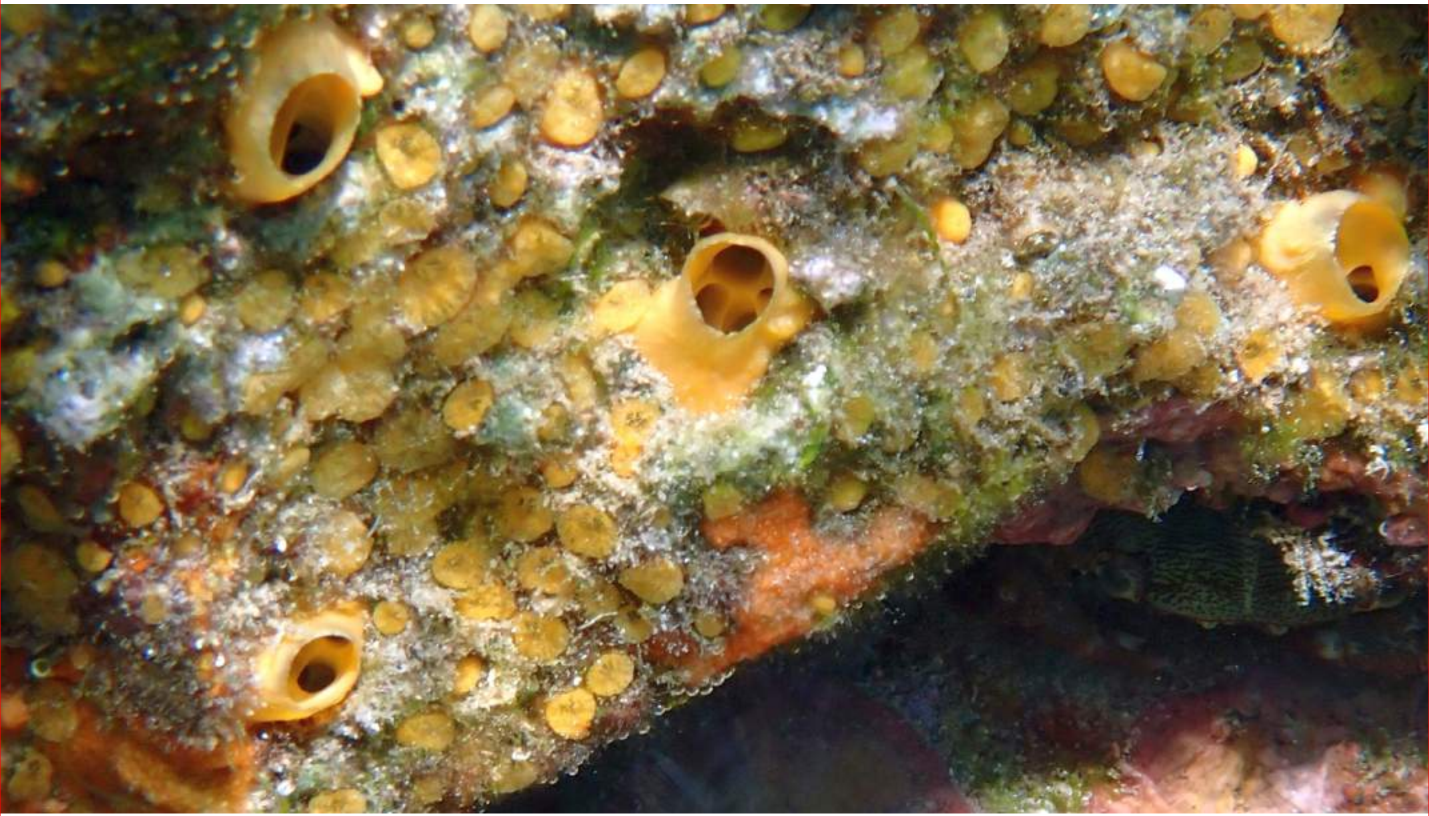
The top layer of a sand bottom…

…is stirred up by stronger swells on a regular basis. The parallel, sharply ridged ripple marks that are visible in the photograph on the left are an indication of such a rearrangement of each individual grain of sand during the last few days. Due to these regularly occurring "microcatastrophes", there are no permanent structures on sandy bottoms which could serve as the basis of a biocoenosis.

Only those who can dig survive

Despite these adverse conditions, some animals have managed to adapt to the living conditions on sand bottoms. The most important prerequisite is certainly the ability to dig into the sand in order to find prey, to avoid becoming prey themselves, and to survive the adverse phases of grain rearrangement on the sand's surface by "digging in".

Where Does All the Sand Come From?



Sand is created mainly by the erosion of solid rocks

When rocks are rolled around during heavy storms, they are ground down and sorted on the sea bottom by size into gravel, sand, and clay. In some regions, rivers too are carrying considerable amounts of sediment to the coast.

Animals can also grind solid stones

Snails in the intertidal zone that graze layers of algae also contribute to the formation of sand (p. 111f.). In the rocky habitats in the deeper parts of the sea, rocks are also weathered by animals.

The boring sponge *Cliona* growing on limestone...

...is certainly the most striking example of this. It appears as yellow, orange, and violet spots on the surfaces of rocks (top image). These spots are the in- and excurrent pores of the sponge, which uses acids to erode a network of well-protected living chambers inside limestone. Through the activity of boring sponges, fist sized rocks can be entirely broken down and transformed into sand grains after only a few years. The left image shows an eroded rock with the uncovered, empty living chambers of the boring sponge.

Sand from the continents

In addition to this sand originating from the oceans themselves, large rivers also add sediments to the build-up of sandy bottoms.

When Threatened, Retreat Quickly into the Sand

Preying on small animals

The body of the golden anemone *Condylactis* is almost entirely buried in the sand; only its tentacles rest on the sand's surface, waiting to catch small animals that are close to the ground.

As with the rock-dwelling Mediterranean snakelocks sea anemone (p. 14f.), the tips of its tentacles are purple. However, they are shorter and somewhat thicker. When disturbed, the golden anemone contracts and disappears entirely in the sand bed.

Living in tubes

Above: The tube-dwelling anemone *Cerianthus* catches plankton in the moving water with its long, thin tentacles. It lives in a soft, self-made tube that sits deep inside the sand bed. The photograph only shows a short section of the tube below the purple tentacles. Similar to the golden anemone, it can retreat quickly.

Filtering with a sieve apparatus

The tubeworm *Acromegalomma* also lives in a tube that is deeply anchored in the sand bed. Similar to the tubeworms on the rocky bottom (p. 24f. and 65), it filters microplankton from the water with the feather-like rays of its sieve apparatus. Each ray has a small dark eye at the end. When the eyes perceive a shadow, the worm disappears into its tube in a flash.

Predatory Snails

Slow crawling predatory snails

The spiny dye murex snail *Bolinus* (top image) and the banded dye murex snail *Truncalariopsis* (middle image) can often be found crawling slowly on sandy bottoms. They are predators and follow scent trails originating from their prey, which consists of carrion and live animals. In antiquity, a valuable purple dyewas extracted from both species.

Spawn clump resulting from mating in masses

Occasionally, one can see sponge-like formations lying on the sandy ground, stuck to a hard object (image below). Those are the spawn clumps left behind after a mass mating of the rock snails *Bolinus* and *Truncalariopsis*. They consist of hundreds of horny egg capsules, each containing hundreds of fertilised eggs waiting to ripen. After several weeks, countless snail larvae hatch and begin their months-long life as plankton.

Peculiar tracks

If the sand has not been stirred up by waves for several days, the traces of animals that live in the sand can be seen on the ground, and the two circular breathing holes of certain clams are visible even from the water surface. Top four pictures: The rosy razor clam *Solecurtus*. In this video you can see how the clam buries itself: https://tethys.uni-ak.ac.at/solecurtus.mp4

Shell communities

Much more often, however, only empty shells on the sand's surface bear witness to the bivalve-life hidden underneath. (Picture below: shells of the smooth clam *Callista*). The lifespan of the clams themselves is only a few decades; their shells, however, are preserved. Embedded in sedimentary layers for many millennia, they are easily identified by scientists. Investigating the size of clam and snail communities and the species they are made up of can be used to draw conclusions about living conditions of the habitat during preceding periods. For instance, human activities on land such as mining, deforestation, harbour construction, and road building are reflected in the shell community, since large amounts of disruptive sediments are mobilised by these activities and enter the sea.

Gallmetzer, I. et al. **Tracing origin and collapse of holocene benthic baseline communities in the Northern Adriatic Sea** *Palaios 34: 121-145. DOI:102110/palo.2018.068 (2019)*

Echinoderms in the Sand

The common heart urchin *Echinocardium*...

...(image at the top) shares the sand bed with many bivalve species. It can be found at a sand depth of several centimetres, but as opposed to most bivalves, the common heart urchin is more mobile and takes daily feeding walks to reach places with fresh sand that is rich in microorganisms. During these subterranean walks, it uses its soft, flattened spines to shovel sand grains from front to back, similar to the arm movements of humans during breaststrokes. Urchins that have been dug out of the sand can dig themselves in again within a few minutes, but they do so by sinking into the sand vertically.

The red comb star *Astropecten aranciacus*...

...can reach a diameter of up to 60 cm! On some sandy grounds, it is the most significant predator preying on digging animals. It feeds mainly on bivalves but also preys on common heart urchins and other sea stars. It probably tracks its prey by following their scent across the sand. When it detects a clam, it will dig itself deep into the sand, suck the clam into its stomach, and digest it as a whole over several days. Such digesting red comb stars remain buried in the sand. However, their domed central disc that protrudes from the sand bed still gives them away.

The dorsal surface of comb stars...

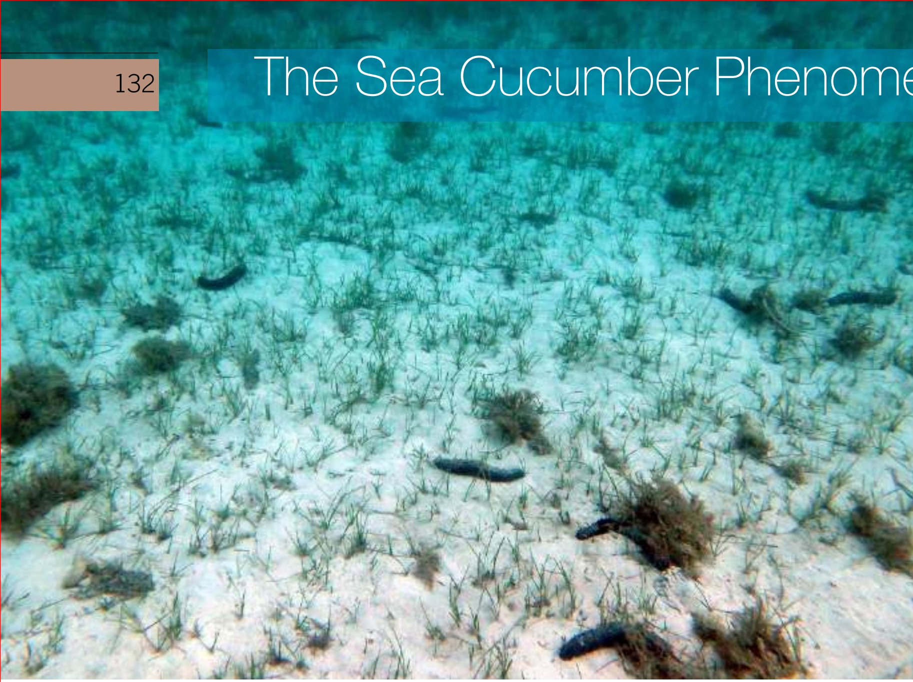
...(bottom left) is covered by mobile, umbrella-shaped ossicles that keep sand grains at a distance. In the millimetre-wide, sand-free hollow layer beneath the ossicles, there is enough space for the wedge-shaped gills to breathe, even when the sea star is completely covered by sand.

It takes a comb star only a few seconds to disappear in the sand bed (bottom right image). As opposed to the sea star species living on rocky grounds (p. 76f.), comb stars have tube feet that are pointed rather than having widened adhesive discs at the tips.

Brittle stars are the closest relatives…

…of sea stars. Yet, the former, as opposed to the latter, do not move by using their short tube feet, but they "walk" over the sea bottom at night with their flexible arms, always using two opposite arms to push themselves from the ground. The brown-grey *Ophioderma* (above) rests during the day in hollows underneath rocks lying on the sand. The pale, scaled serpent star *Ophiura* (bottom), on the other hand, occasionally disappears completely into the sand. Both brittle stars feed on small animals that they grab with their arms and then pass to the mouth on their underside.

The Sea Cucumber Phenomenon



Sea cucumbers wherever you look

The sea cucumber *Holothuria* is one of the most common animals on sandy and deep muddy grounds. In some places of these habitats, there are up to one animal per square metre. In addition, they can reach a length of up to 30 cm. The biomass of all sea cucumbers is, thus, enormous.

Defensive, even if they do not look like it

The sea cucumber is one of the few marine animals that does not possess a protective shell and is also not capable of fleeing from danger and burying itself in the sand. Nonetheless, sea cucumbers can act in a defensive way: On the one hand, they can extrude sticky defensive threads called Cuvierian tubules. On the other hand, their bodies contain saponin and terpene venoms.

Featured on humans' menus despite venoms

Nonetheless, the sea cucumber often ends up on the plates of *Homo sapiens*: The recipe requires the removal of the venoms by soaking the sea cucumber in milk for several hours and then destroying any remaining venoms through long cooking.

The food of sea cucumbers...

...is composed of bacteria and organisms that have fallen to the grounds and have been covered by sand.
To get hold of this finely dispersed food, sea cucumbers swallow large amounts of sand unselectively. The nutritious components inside the sand are digested, and the majority of the sand – which often amounts to over 99 weight percentage – is excreted again. Large amounts of faeces are thus defecated like strings of pearls (left-hand page at the bottom). Similar amounts of faeces are produced by sea hares (p. 26f.) due to the low nutritional value of its algae food.

Spawning pedestal

Although sea cucumbers inhabit sandy grounds, they often look for rocks (left-hand page, top right) in order to release their reproductive cells from there into the water. They spawn through an opening called the gonopore, with the anterior part of their bodies raised and stretched away from the ground. These spawning pedestals enable a widespread dispersal and thus a greater mixing of the sperm and egg cells of a sea cucumber community on a sandy ground.

Stonik, V., Stonik, I.
Toxins Produced by Marine Invertebrate and Vertebrate Animals: A Short Review.
In: Marine and Freshwater Toxins, (pp. 1-13). Springer Science doi:10.1007/978-94-007-6650-1_5-1 (2014)

Feeling the Prey

The goatfish *Mullus*…

…swims in small groups right above the sandy ground and looks for traces of buried worms or crustaceans in the sand with its sensitive barbels (top image).

When it feels out one of these animals, the goatfish rapidly digs deeper to swallow its prey (middle image). By stirring up the sand, goatfish often attract other fish like breams and wrasses to join a feeding community.

The piper gurnard *Trigla*…

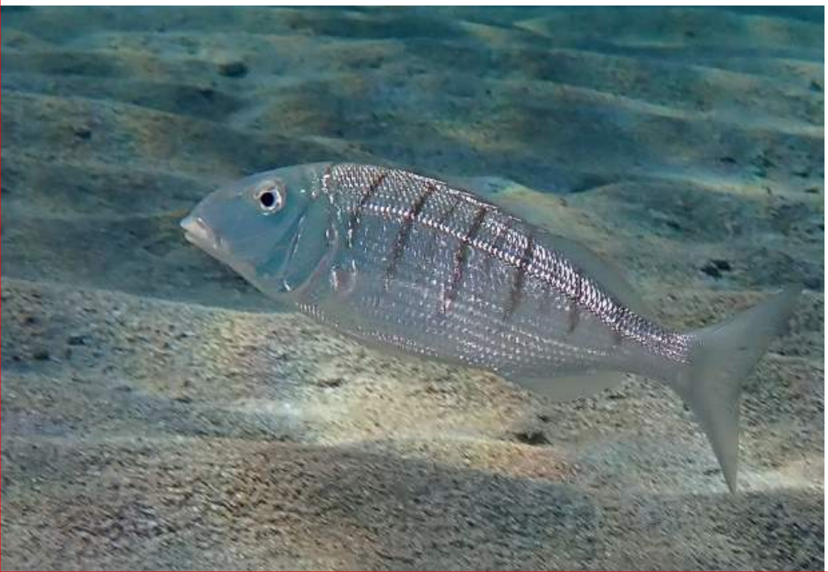
…(bottom image, p. 7, and right-hand page at the top) also relies on tactile cues while looking for food on the sandy ground – however, it does not use barbels on the lower jaw for this purpose but the six free rays of its pelvic fins, which carry taste buds. Piper gurnards walk on these finger-shaped rays, which are angled towards the ground, like on spider legs, to feel out prey.

Defence strategy

When a piper gurnard feels threatened, it will open the back part of its pelvic fins so that its brightly coloured underside faces up (next page), and some species even show large, shining eye spots (p. 7f.). The piper gurnard will take advantage of its followers' brief shock reaction to escape.

Growling noise

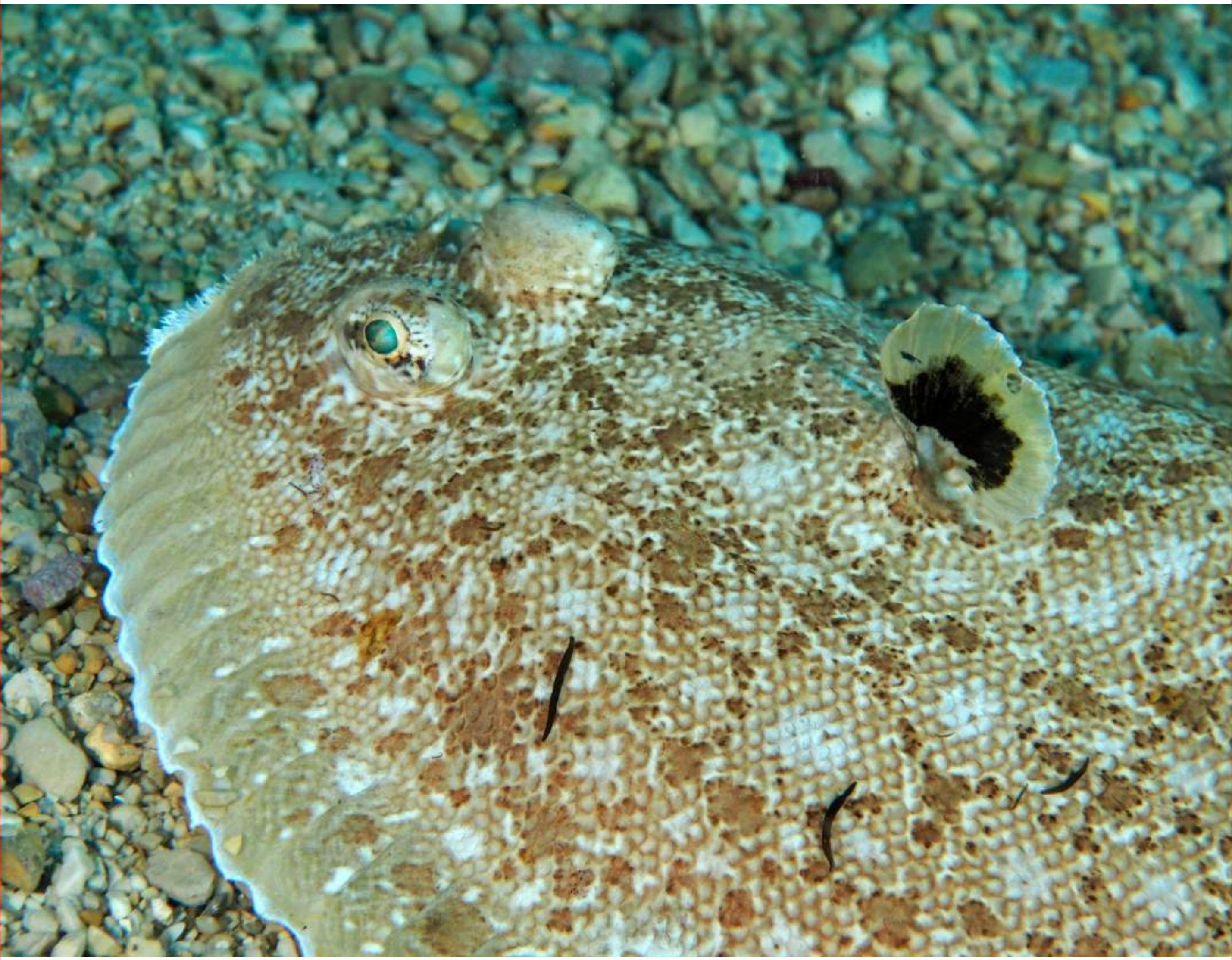
With its swim bladder and special muscles, the piper gurnard is capable of producing growling sounds, which give the species its name.



The sand steenbras *Lithognathus*...

...(left) feeds, like the goatfish and the piper gurnard, mainly on small animals digging in the sand, such as worms, crustaceans, and clams. However, the sand steenbras has not evolved any special tactile organs to scan the sandy surface. Instead, it takes entire loads of sand into its big mouth, where digestible food animals are separated out. The sand is then spat out again.

Camouflage in the Sand

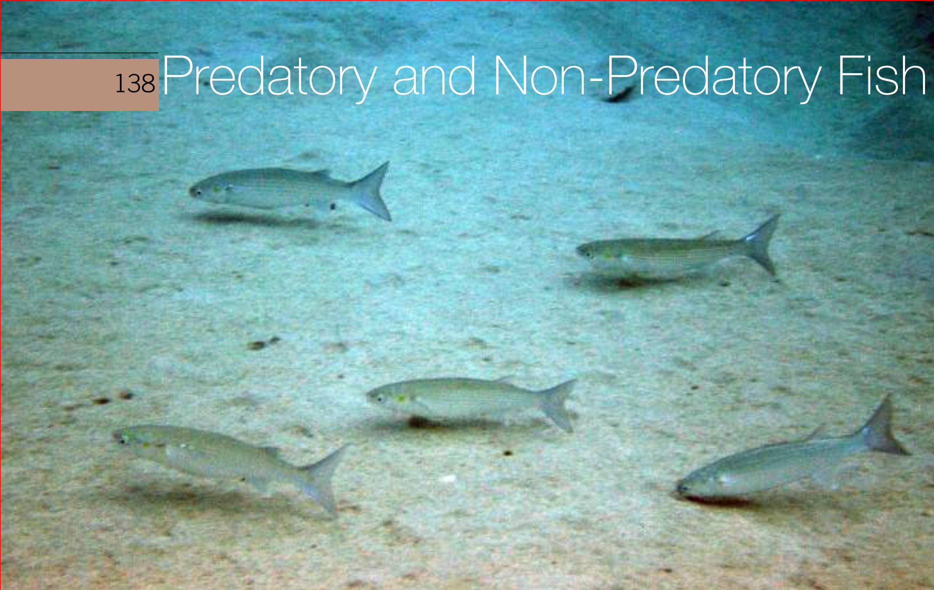


Too close for comfort!

A common sole *Solea* (pictured on the left-hand page) notices that it has been found and strikes a threatening pose by lifting its pectoral fin. The black spot that becomes visible under the pectoral fin might be a case of mimicry that imitates the dark dorsal fin of the venomous weever (p. 140f.). The three black threads on the body of the common sole are parasitic fish leeches feeding on the body fluids of its host.

Sensory papillae detect pressure fluctuations

Image to the right: Head of a slender goby *Gobius geniporus* whose colouring and pattern has perfectly adapted to the sandy ground. The sensory papillae that are arranged in rows on their front body serve to detect pressure fluctuations caused by predators and prey. The slender goby grows up to 16 centimetres long and can only be found in the Mediterranean.



The mullet *Mugil*…

…can be found in almost all the habitats of the Mediterranean – here it can be seen grazing the upper layer of a sandy ground. The sand has obviously not been moved by waves for quite a while. As a result, suspended matter has deposited on the ground and is now eaten by fish. Middle left image: From up close, the golden spot on the gill cover that is characteristic of the golden grey mullet *Mugil auratus* is clearly visible.

Camouflage in daytime hiding place

The trail of an electric ray *Torpedo* (bottom left) in his daytime hiding place on the sandy ground. Only experts know that a 50 cm-long ray is hiding beneath the sand. Without the sand, the pan-shape of the animal is clearly visible. On both sides of their head, electric rays possess an electric organ made of modi-

fied muscle tissue with which it can emit strong electric discharges.

Hunting with electric shocks

Electric rays use electric shocks for defence against predators on the one hand but mainly to capture fish sleeping on the ground, like mullets, during the night.

Fringes around the spiracles

The bottom left photograph shows the electric ray's small eyes and the fringed breathing holes known as spiracles. The fringes around the spiracles probably protect the ray from sand entering its breathing chambre while it is buried in the ground.

An electrifying encounter

Bottom right: The snorkeler (Daniel Abed-Navandi) is approaching the not quite harmless fish and simulates receiving an electric shock (60 to 230 volt and over 30 ampere)…

Buried Predators

Luring and sucking in prey

The stargazer *Uranoscopus* in a rare swimming pose (top image) – it is usually buried up to its eyes in the sandy ground. It thus preys on fish that look for food on the sandy surface. To lure fish near its mouth, it snakes a worm-shaped fleshy lobe, which is attached to its lower jaw, in front of it. If a curious fish approaches the bait for a closer look, it will be swallowed by the stargazer's powerful suction mouth.

Middle image: After a brief disturbance, the stargazer has buried itself in the sand again, but its oral lure is not active yet.

The dreaded weever

Much more common than the stargazer, the weever *Trachinus draco* is found on all sandy bottoms (images below and at the top of the next page). It also uses sand beds as the only available hiding place to lie in wait for other animals (top left image on the next page). Unlike the stargazer, however, it emerges from its hiding place in a flash to seize the prey that it has discovered nearby.

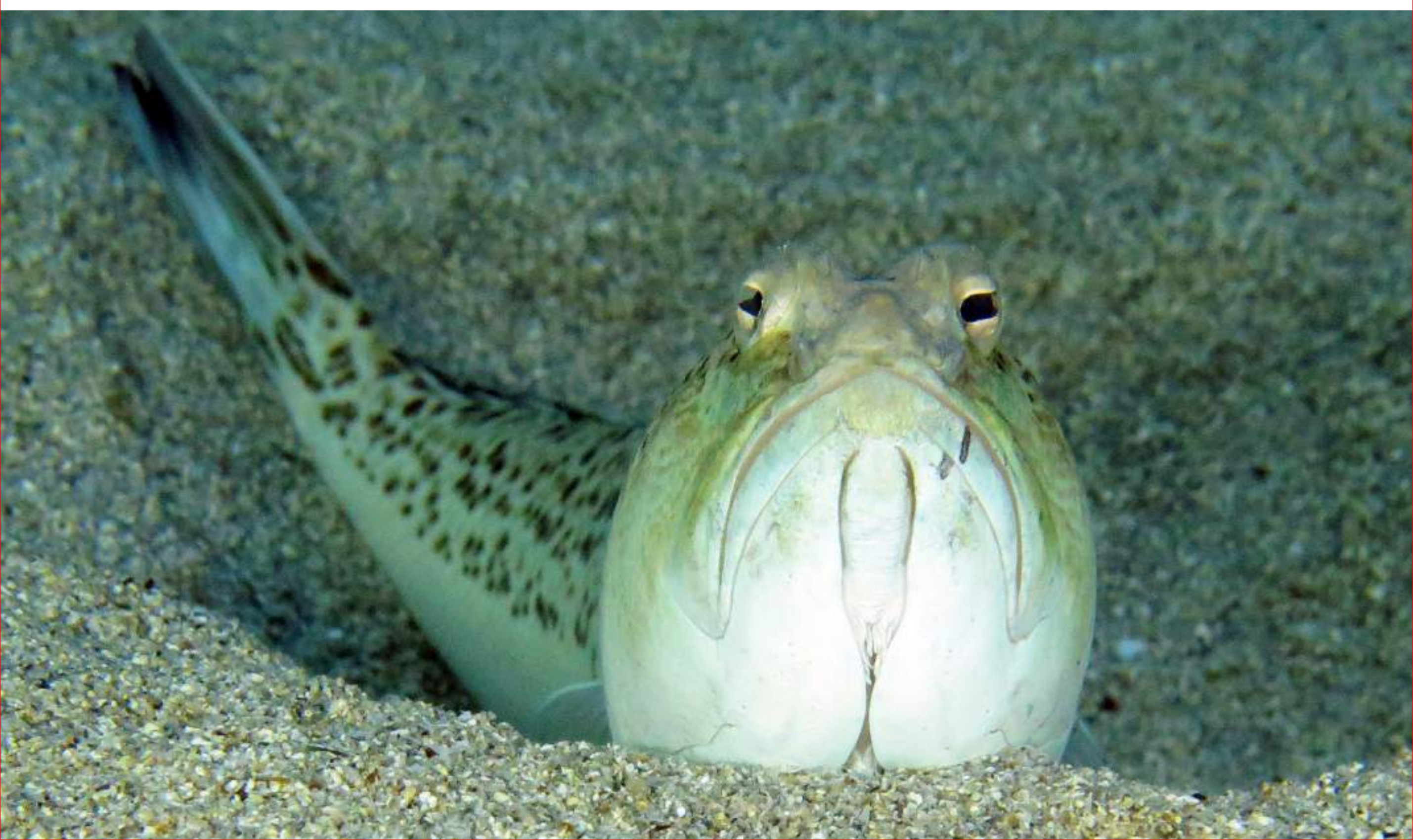
Dangerous venomous spines

Similar to the scorpionfish found on shady rocky grounds, weevers are equipped with venomous spines on their first dorsal fin and on their gill covers. You should, therefore, refrain from walking on sandy grounds in the sea, as much as you might enjoy the feeling of the sand under your bare feet. Weevers let divers come very close, and there have been cases where weevers rapidly swam towards the faces of divers and made targeted use of their venomous spines! The twitching of their black dorsal fin upon agitation is considered to be a warning signal (top right). Like the bite of a venomous snake, their sting can have different effects, but it often causes sharp pains and strong swelling.

First aid

If you are stung by a weever, you should certainly seek medical attention. In the meantime, placing a hot flannel (40-50°C) on the affected area is recommended as a first aid measure, because the heat will deactivate heat-labile protein toxins.

Below: A rare frontal shot of an uncovered starry weever *Trachinus radiatus*. Its big mouth, which is used to swallow other sandy-ground fish, is clearly recognisable. The venomous spines are not visible here.



Habitat: Seagrass

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_6

Seagrasses are descendants of terrestrial plants

As opposed to algae, the other marine plants, seagrasses are vascular plants. They are descendants of terrestrial plants that wandered back into the sea over millions of years ago. They share this unusual evolutionary trajectory with marine mammals.

Conveyor belt

The growth of seagrasses resembles that of terrestrial grasses: Each plant consists of several long, green leaves that reach from the ground vertically to a height of up to 50 centimetres and keep growing continuously as long as they live. The individual plants are connected by horizontal runners, which in turn fix themselves in the sand with roots. A seagrass meadow is thus like an elastic net that is firmly anchored to the sand.

Conditions for seagrass

Seagrass meadows can grow many thousand years old. Their emergence is particularly dependent on the exposure of the respective seashore: The coast must not be too steep, it must be covered by sand, and it must be protected from strong water movements (p. 3).

Sand self-suppliers

Due to the consolidation of the soil by the roots and the water-breaking property of the leaf-forest, a unique situation is created in which erosion is reduced and even sediments are trapped. Above a certain size, seagrasses are thus the engineers of their own sand bottom and under suitable conditions, a new, permanent habitat may emerge, which, due to its three-dimensional structure, provides shelter to many specialised animals.

Several Millennia Old

Slow growth

The image at the top shows an emerging meadow of little Neptune grass *Cymodocea.*

After years of undisturbed growth, the original sandy ground is completely covered by seagrass. The narrow leaves have reached a length of up to 50 centimetres (image in the middle).

Metre-thick mat

The Neptune grass *Posidonia* (below) grows even longer and denser. The mats that are formed by its rootstocks and the sand trapped in them can be thousands of years old and several metres thick.

Carelessness with consequences

Anchors that are carelessly thrown into seagrass meadows tear into the stabilising root network. Such wounds make seagrass meadows susceptible to more damage, even from weak storms.

The photograph on the right of the left page shows the damage to a seagrass meadow caused by a single anchor manoeuvre.

Repeated destruction

The top right photograph shows a seagrass meadow after repeated disturbances: What is left between the ripped-out runners is only the original sandy ground.

Nursery

In the leafy thickets of seagrass meadows, many young fish like this Mediterranean parrotfish find shelter, while the adults live in other habitats.

Aufwuchs organisms

For many aufwuchs organisms, the centimetre-wide leaves of Neptune grass provide an ideal surface for growth. The right image shows the pink coralline algae *Hydrolithon*; the white, dot-shaped polychaete worms *Spirorbis*; and the pinnate stems of the hydropolyps *Aglaophenia*.

Anchored in the Sand

The pen shell *Pinna*...

...anchors itself in the sand. It is equipped with a large, robust shell protecting it well during stormy periods, so that it does not have to disappear into the sand.

A closer look between the shell valves of the pen shell reveals its inhale and exhale openings, which are separate from each other: The inhalant opening is protected against intruders by a row of sensory tips. In the opening, the two lobes of its filtering gill are visible. The groove-shaped protective scales on the shell surface, which are more pronounced with smaller specimens, are probably there to protect the shell against the lethal embraces of octopuses and sea stars.

The gilt-head bream *Sparus*…

…reaches a length of up to 60 centimetres and can be found in all coastal habitats of the Mediterranean. Their food consists mainly of clams and snails. Here, the photographer captured a not very timid specimen that was digging up a purple dye murex from a sandy patch between seegras.

An edible fish that is also farmed

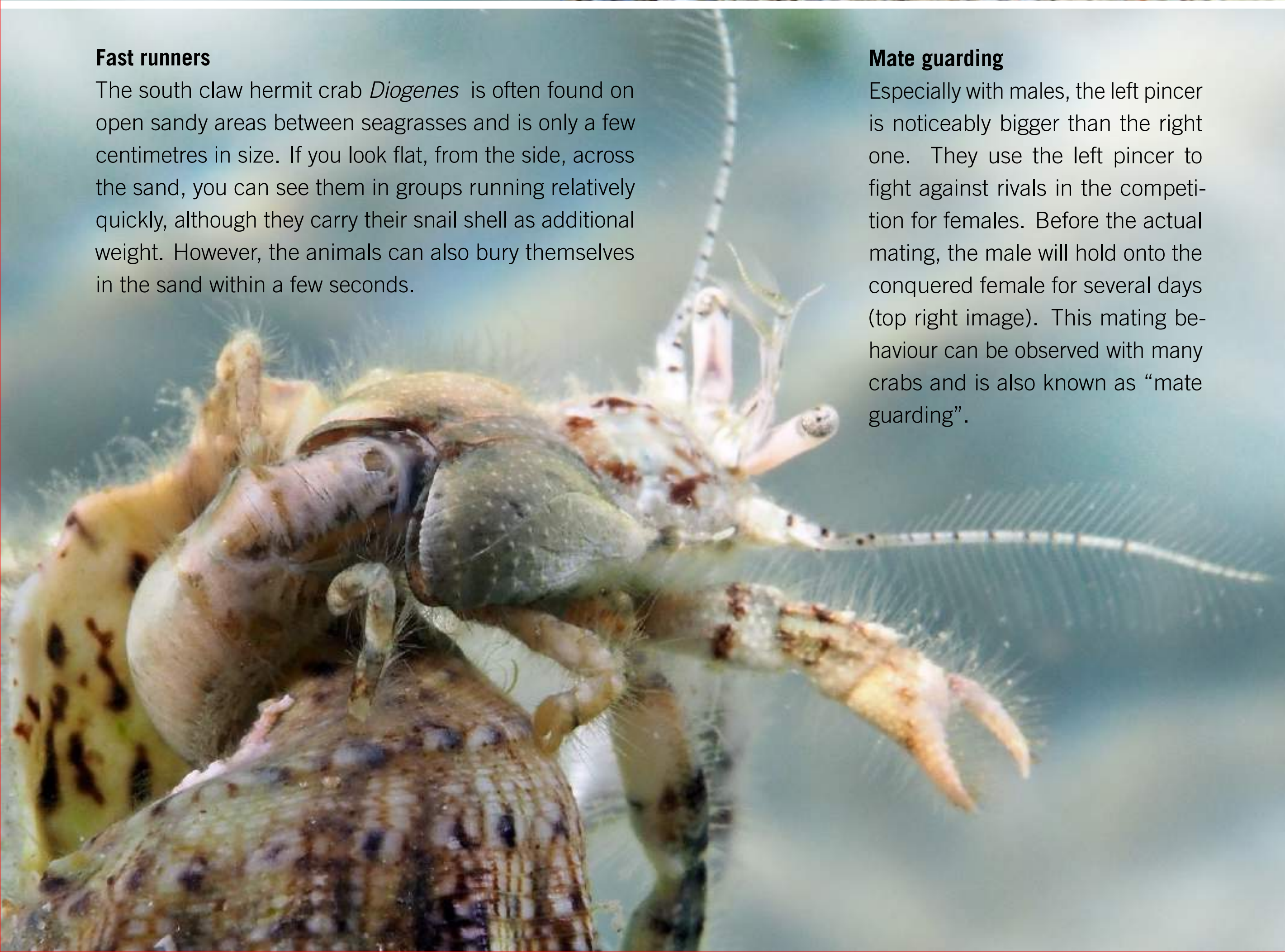
Gilt-head breams are commercially bred for food. When they are two years old – the size of a plate – they are sold in Mediterranean countries as "dorada" or "orata". They can be distinguished from other Mediterranean bream species by their black mark at the upper corner of the gill slit and by the golden stripe on their forehead, between the eyes.

Their population seems to have grown again over the last years – this might be a positive side effect of fish farming, because occasionally, fish that have been bred there manage to escape from their net cages.

Glamuzina, B. et al. **Observations on the increase of wild gilthead seabream, *Sparus aurata* abundance, in the eastern Adriatic Sea: problems and opportunities** *Int Aquat Res 6: 127–134 (2014)* https://doi.org/10.1007/s40071-014-0073-7

Dempster, T. et al. **Recapturing escaped fish from marine aquaculture is largely unsuccessful: alternatives to reduce the number of escapees in the wild** *Reviews in Aquaculture 10: 153-167 (2018)* https://doi.org/10.1111/raq.12153

On the Sand between the Seagrass



Fast runners

The south claw hermit crab *Diogenes* is often found on open sandy areas between seagrasses and is only a few centimetres in size. If you look flat, from the side, across the sand, you can see them in groups running relatively quickly, although they carry their snail shell as additional weight. However, the animals can also bury themselves in the sand within a few seconds.

Mate guarding

Especially with males, the left pincer is noticeably bigger than the right one. They use the left pincer to fight against rivals in the competition for females. Before the actual mating, the male will hold onto the conquered female for several days (top right image). This mating behaviour can be observed with many crabs and is also known as "mate guarding".

The black goby *Gobius niger*…

…is the most common goby species that can be found on the sandy grounds of the Mediterranean. It can easily be distinguished from the hundreds of other goby species by its size, the dark colour of the males, and the long dorsal fin. The males dig out breeding caves under flat shells or stones and will guard the eggs that females spawn there for several weeks. The large image shows one such spawning nest under a stone, which has been uncovered by the photographer. The maturing embryos are already visible as silvery glints in front of the pectoral fins and under the head of the male that stands guard. After taking his picture, the photographer restored the nest to its original condition, and the goby continued to guard its offspring.

Living in the Grass

Long-snouted seahorse *Hippocampus guttulatus*
Unfortunately, a rare sight! A male seahorse, recognisable by its filled brood pouch, uses its prehensile tail as an anchor by wrapping it around a tuft of little Neptune grass and spends several hours thus preying on small crustaceans.

Previously not classified as a fish
With the head of a horse, the prehensile tail of a monkey, the independently moving eyes of a chameleon, and a body covered with armoured plates, seahorses are one of the most peculiar fish in the sea. Early zoologists initially classified seahorses as insects and not as fish, and they named the genus *Hippocampus*, which is derived from Greek “hippos” for horse and “kampos” for sea monster.

Living in the seagrass

Top left: A large male spider crab on the edge of a seagrass meadow no longer relies on the camouflaging growth on its back and instead strikes a threatening pose. The claw shape typical of mature males is clearly visible in this photograph (p. 34f.). Top right: The grey wrasse *Symphodus cinereus* has adapted to life in loose seagrass meadows. It can easily be recognised by its bright colour and its dark spot at the bottom of the tail base. Its spawning nests are made of seagrass and algae leaves that are strengthened

with sand grains (not visible in the image).

Middle images: Dusk marks the beginning of snake blenny *Ophidion*'s active period in the seagrass meadow. It will leave its hiding place in the sand and look for buried crustaceans with its barbels. At first glance, the snake blenny could be mistaken for a young conger eel (p. 101), but the latter are comparatively longer and do not have barbels on the lower jaw. Images below: A painted comber and a slender goby are following the movements of the photographer, paying particular attention to the light-reflecting body and lens of the underwater camera.

Interlocking Habitats

The giant doris *Felimare picta*...

...is one of the largest sea slugs in the Mediterranean, reaching a length of up to 20 cm. The image above shows its typical antennae on the head, which are used for smelling, and the star-shaped gills at the rear end of the body. As with many of their relatives, their food spectrum is very narrow – the giant doris feeds exclusively on the horny sponge *Ircinia*, which grows on rocky grounds (p. 23f.).

Scent trails leading to another habitat

Nonetheless, the giant doris can also be found on other types of ground. The doris in the top image is even crawling on a sandy ground, which is an unusual terrain for them. It was probably lead there by a scent trail that was emitted by a sexual partner living on a neighbouring rocky ground.

Different habitats are often close to each other

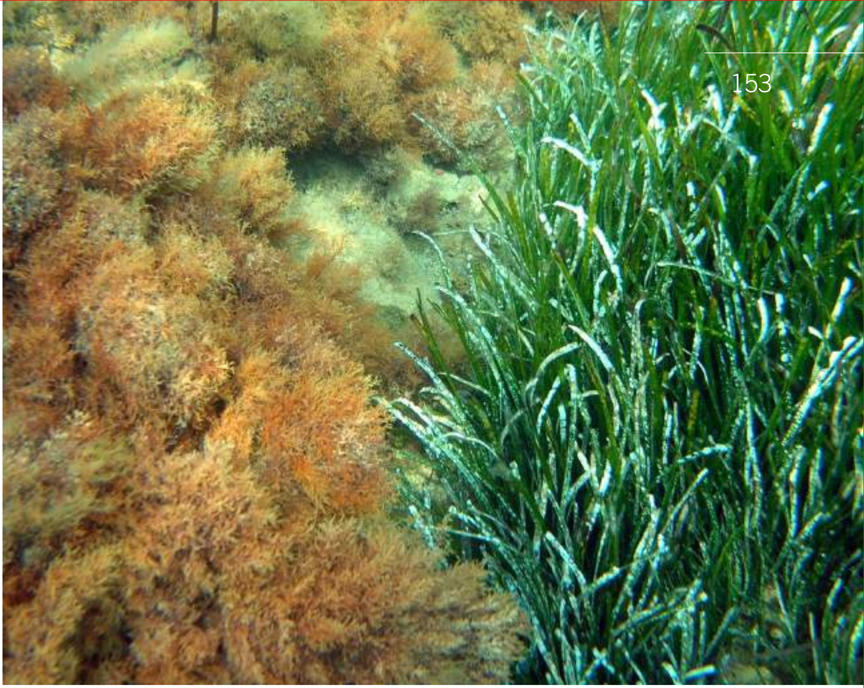
Since the different habitats are often closely interlocked, such short-term crossovers into foreign habitats can happen occasionally, especially if an animal is guided by scent trails.

Neighbouring habitats

Another example of interlocking habitats can be found in the image to the right: A kelp forest growing on a rocky ground borders a Neptune grass meadow on a sandy ground. The substrate determines which habitat will emerge there over time (p. 3f.).

A flounder buried in the sand…

…has been unmasked by the photographer and escapes by crossing different habitats (images below). The left side of its body is patterned in a way that blends with the sandy ground and carries both eyes. The right side is facing the ground and blind.



Habitat: Muddy Grounds

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_7

The majority of the ocean floor is muddy

Deep muddy grounds are the biggest marine habitats in terms of surface area. They cover 90% of the oceans' floors and start where steep rocky habitats level off to flat sea bottoms – at depths where water motion is so minimal that the finest sediments remain on the ground and form thick mud layers over the course of time. In the Mediterranean, depending on the exposition of the coast, the emergence of such habitats is possible from a water depth of about 20 m.

Barely any plants

Similar to sea caves, muddy grounds are exposed to hardly any sunlight, which is why there is no noteworthy plant growth in these habitats. For food supply, muddy grounds thus also depend on food particles transported by water currents and gravitation, and on migrating animals.

Sessile animals

Many animals inhabiting muddy grounds are sessile plankton feeders. To avoid sinking into the soft sea bottom, they have a widened base or are anchored into the ground with fine roots.

Sponge Islands

Substrate for many other animal groups

Most muddy grounds are dominated by sea sponges, which simultaneously provide a colonisable substrate for many other animal groups. In the top left image, an orange-coloured and a pale-yellow sponge have formed an island on the mud that is used as a base by several scallops of the genus *Chlamys*. Their shells are, in turn, overgrown by the orange-coloured sponge (1). At the centre of the image, there is another typical inhabitant of such "sponge islands": the predatory hairy crab (2). Next to it, to the right, the pincers of a squat lobster (3) are visible.

Brittle star on a pedestal

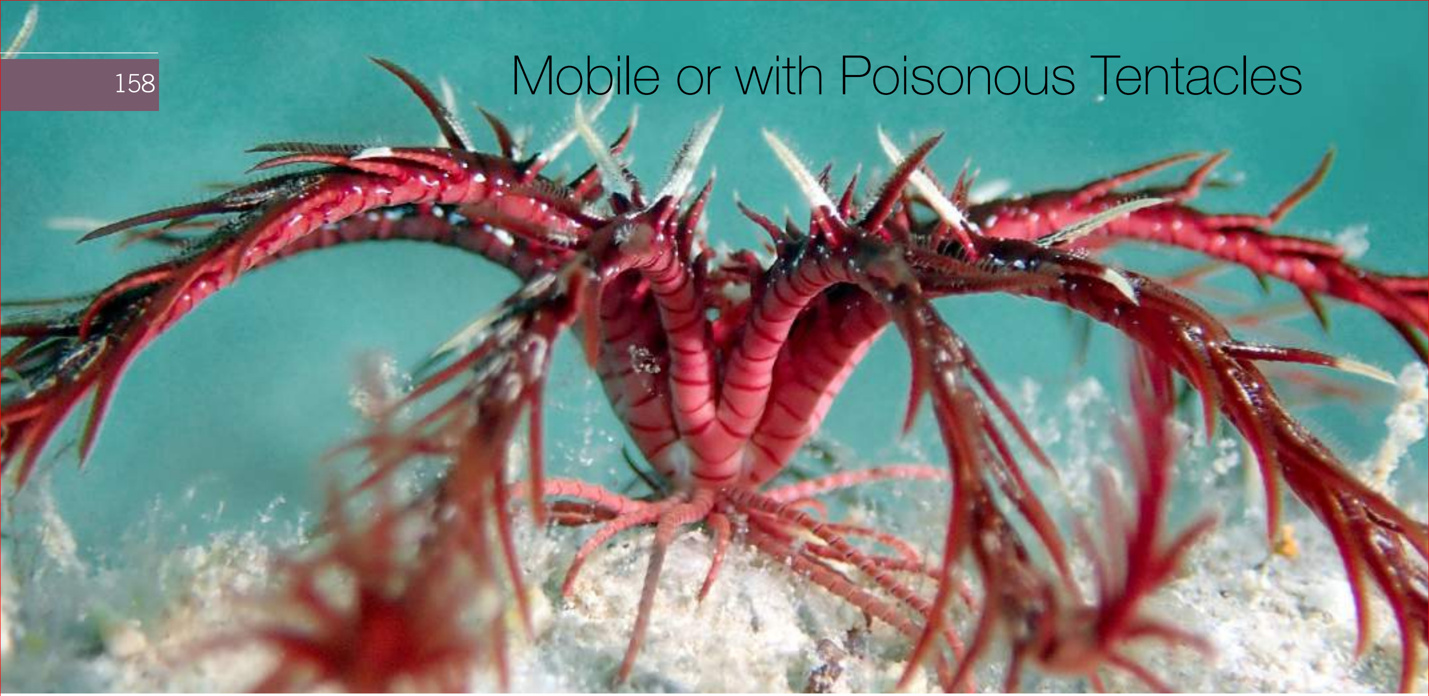
(small image to the right and large image on the previous double page)
The brittle star *Ophiotrix* also uses sponges that are several centimetres high as a pedestal. In order to reach further into the nutrient-rich water to collect food, brittle stars raise their central discs and also hold up their spiny filter arms. The particles captured by the arms are then passed to the central mouth by the brittle star's many short tube feet.

Ten tentacles for plankton collection

Bottom left: A brown sea cucumber *Ocnus* has attached the side of its body to a sea sponge and – as brittle stars also do – is dangling its ten sticky mouth tentacles in the water current to catch plankton. It transports the food to the mouth opening by alternately stuffing each tentacle into the mouth.

Aside from sponges, ascidians like this *Phallusia* can be found as sessile inhabitants of the muddy grounds. Moving plankton eaters like this brittle star use them as a pedestal to reach into the more nutrient-rich layers of the water.

Mobile or with Poisonous Tentacles



The feather star *Antedon*…

…is also an echinoderm and attaches itself to the ground with specialised appendages called cirri to remain in an optimal position for plankton feeding.

Versatile arms

Each arm is lined with a multitude of plankton-filtering, feathery projections called pinnules – a similar trapping mechanism can be observed with the fan crown of tube worms (p. 24f.).

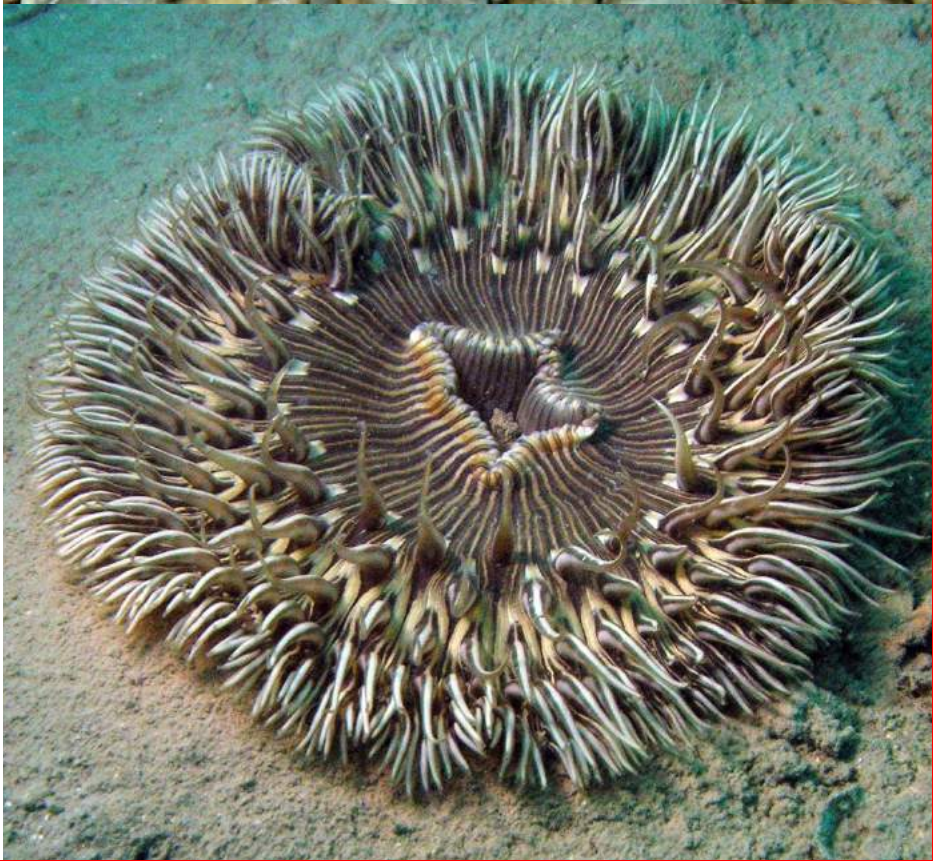
By alternately beating their arms up and down, feather stars can swim at a relatively fast speed, though not for long stretches of time.

The scallop *Pecten*…

…reaches a shell diameter of up to 15 cm. They are mostly found on deep muddy grounds, but sandy and gravelly grounds of only a few metres depth are sometimes also inhabited by scallops (as in the image on the right).

This bivalve can jump

To escape predators, like sea stars and crabs, scallops jump up to a metre by rapidly snapping their shell valves. However, with this trick they cannot escape the bottom trawling nets – large amounts of scallops, which are sold as delicacies, are caught every year by fishing fleets ploughing up the seafloor and all its inhabitants.



Seven hundred tentacles

The daisy anemone *Cereus* can also occasionally be found on muddy grounds (image at the bottom). Its pedal disc is buried in the ground; only their oral disk with the central mouth opening and the over 700 short tentacles, which are arranged in several concentric circles, can be seen. If an animal on the ground carelessly touches one of the poisonous tentacles, the anemone rapidly contracts to clutch its prey firmly with as many tentacles as possible.

Hermit Crabs in the Mud

The eye spot hermit crab *Paguristes*...

...is the most common hermit crab living on muddy grounds. In the top image (1), the two purple eye spots on the inner side of the chelipeds to which this hermit crab owes its name are clearly visible – they are probably a signal to other animals.

Overgrown beyond recognition

The snail shell of the eye spot hermit crab is often entirely overgrown by other animals, which sometimes even live in a symbiotic relationship with the crab.

The shell pictured in photograph (2) has been colonised by a dark purple bryozoan colony (p. 86f.), a pink-coloured sponge, and the parasitic sea anemone *Calliactis.* The latter's posture is unusual for most sea anemones: Its tentacle crown does not point upward, towards the plankton, but down to the ground.

A useful broom

The anemone sweeps up – like a broom – nutrient particles that have already sedimentated. The sweeping motions that are necessary for this process are generated by the hermit crab as it walks about. A sessile animal is thus rendered mobile by the movements of another mobile animal, gaining access to new nutrient sources. Despite the anemone's name, its relationship to the hermit crab does not seem to be of a parasitic nature, because the anemone's poisonous stinging capsules offer the hermit crab protection against predators like sea stars, octopuses, and larger fish. This hypothesis is well supported by the fact that the hermit crab takes its sea anemone with it when it moves into a new shell.

Another example of a symbiosis

Some snail shells are coated by the orange-coloured sponge *Suberites* (3) and can thus grow to an almost grotesque size. The eye spot hermit crab does not seem bothered by this – once again, we could hypothesise that there is a mutual benefit for the two animals: The sponge is freed from pore-clogging fine sediments by the hermit crab's movements, and the crab does not have to look for a new snail shell because the sponge keeps growing in the direction of the shell's spiral.

2

3

A second hermit crab species living on deep muddy grounds is *Pagurus cuanensis* (image blow). Different from the eye spot hermit crab, this species has claws that are covered with many fine bristles on the upper side (4).

4

Predators on and above Muddy Grounds

A rare sight

One of the largest sea slugs of the Mediterranean – the predatory *Tethys* – is crawling over a muddy sand bottom. It reaches a length of over twenty centimetres. To catch prey, it pulls its black lined oral hood over echinoderms, crustaceans, other molluscs, and even small groundfish!

Tethys slugs can swim short distances close to the ground by alternately contracting its body and by beating their dorsal appendages, known as cerata (image below).

Right-hand page:

The grey triggerfish *Balistes*...

...is also a rare inhabitant of muddy grounds. It can grow up to thirty centimetres in length and feeds on crustaceans, mussels, and snails, which it rinses out of the mud by spraying a water jet through its mouth into the sediment.

The common pandora *Pagellus*...

...is the most common fish on some muddy grounds. It can grow up to sixty centimetres long. Its food is similar to that of the triggerfish, consisting mainly of crustaceans, mussels, and snails.

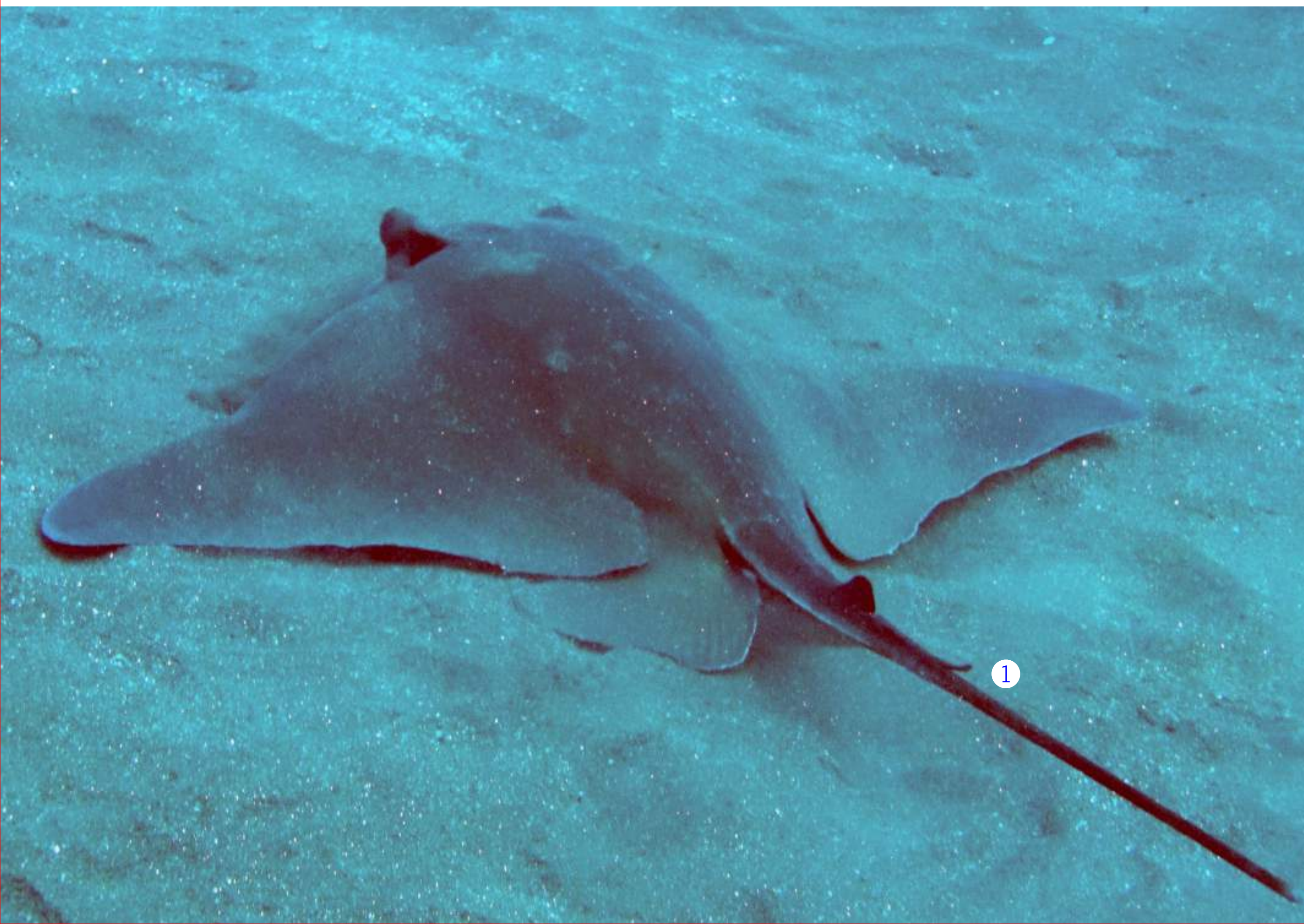
Eagle Ray

An eagle ray *Myliobatis*...

...has been startled by a diver and takes off. A reason for caution is its venomous, barbed sting, which is several centimetres long and located in the middle of its flexible tail (1).

The venomous sting of sea rays...

...is deployed when a larger fish holds a ray's body in its mouth, or when a human steps on the animal while walking on the sand bottom.

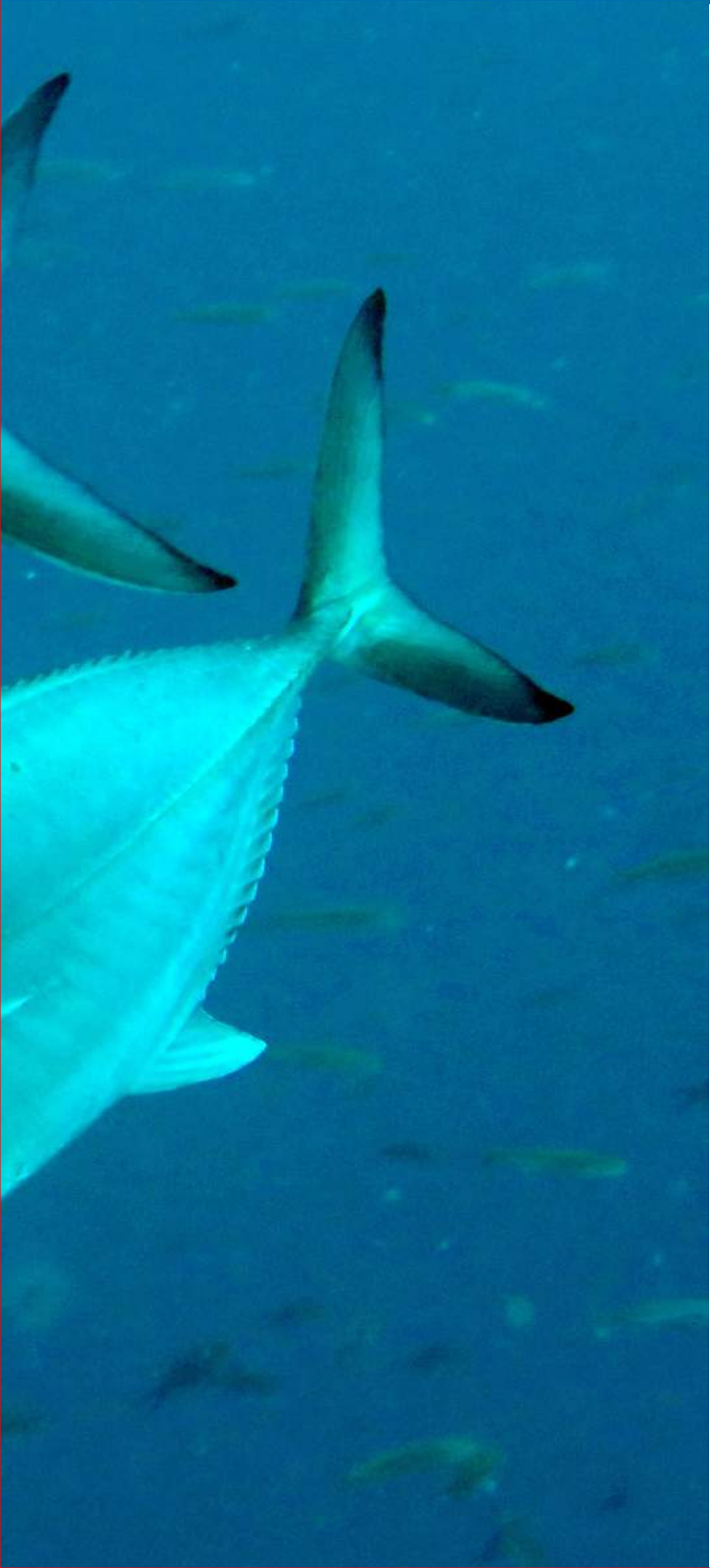


A Hard Floor Island in Muddy Ground

Small rock islands at the margins of muddy grounds are the preferred territory of the brown comber *Serranellus hepatus.* With its length of 10 centimetres, the brown comber only reaches half the size of the closely related painted comber (p. 50). On top of that, it can be identified by its dark pelvic fins and green eyes.

Habitat: Open Water

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_8



The largest habitat on our planet

The open water of the oceans not only spans the largest area, but its enormous depths – 3.8 km on the global average and still more than 1.4 km in the the Mediterranean – make even the highest forests of the continents appear as a comparatively thin covering of our Earth.

Plants of the open waters…

…are microscopically tiny, often single-celled algae, which can only grow in the uppermost layer, where they are reached by enough sunlight. Depending on the water transparency, this productive layer can be up to one hundred metres thick.

Nutrient supply in deeper layers

Below that, the largest area of the open sea is too dark to enable algae growth. Therefore, the nutrient supply in this dark zone is, similar to that in sea caves and deep sediment grounds, dependent on whatever is transported down from brighter habitats – either through downward migration, through the mixing of water, or through the slow sinking of dead organisms.

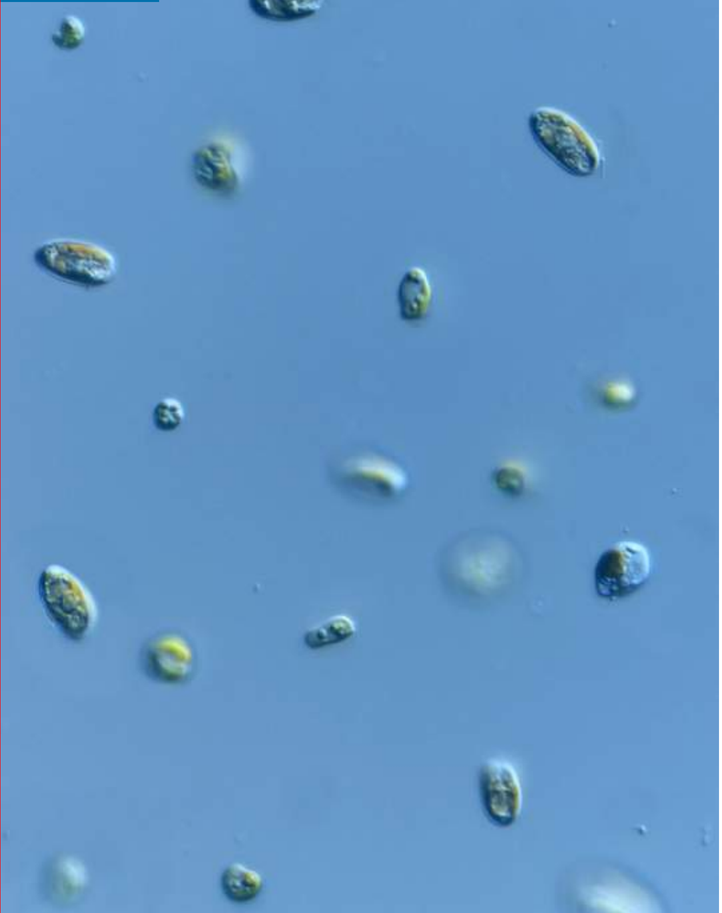
Tiny zooplankton

On the "shoulders" of tiny planktonic algae lies the far-reaching open-sea food web: They are food for the tiniest zooplankton – above all crustacean zooplankton – which are, in turn, eaten by jellyfish and open-water fish. The seabeds are also nourished by the food floating in the open waters. Sessile animals that are attached to the ground like sponges, cnidarians, tube worms, and bivalves filter these nutrients from the water by using different techniques that are described in previous parts of this book.

Little biomass in open seas

The population density in the open sea, however, is comparatively low. Most of the time, a cubic metre of seawater contains only a few grams of organisms - billions of animals and plants, which are usually not visible to the naked eye when diving. After they have multiplied en masse, they become noticeable as turbidity that impairs underwater visibility. To actually see them, we must use concentration procedures like filtration and have a microscope at hand. Spotting larger animals like the jack mackerels pictured here is down to your luck.

Planktonic Algae and Tiny Crustaceans



Planktonic algae

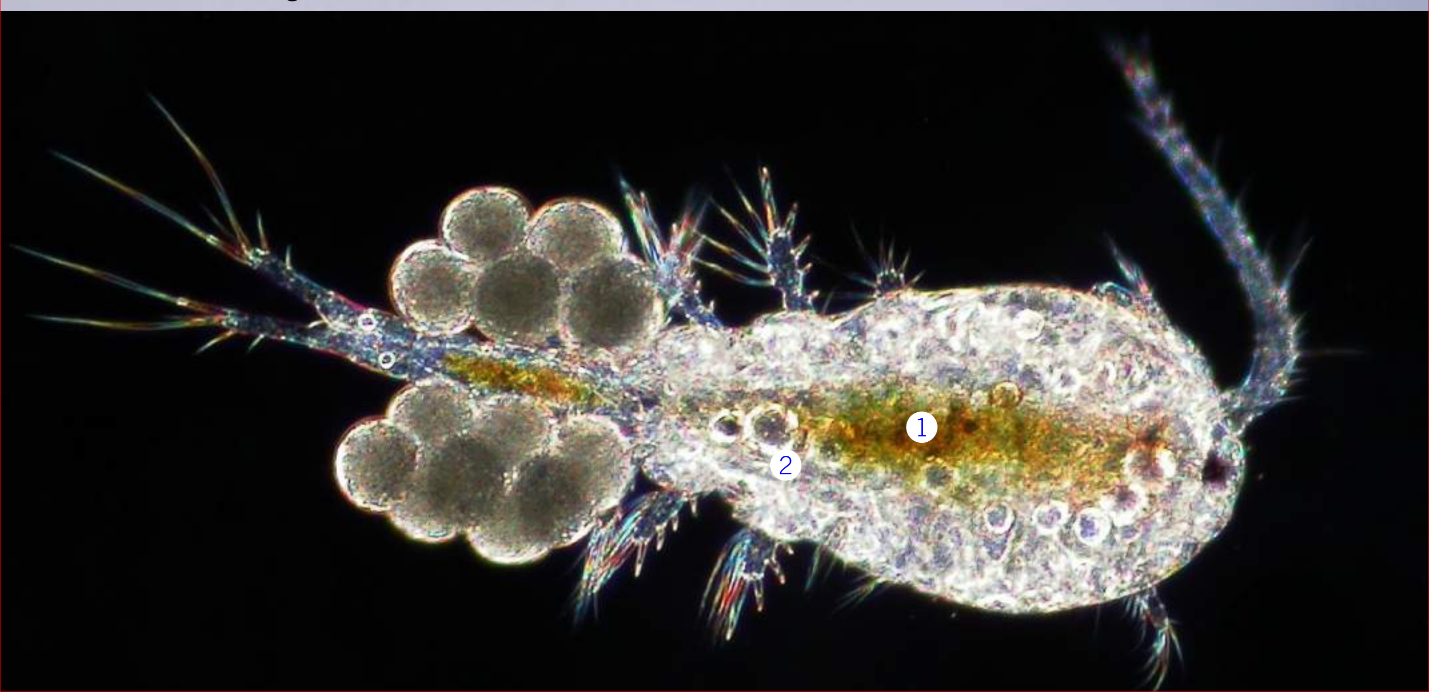
To the left there is an extremely enlarged image of concentrated planktonic algae. 150 of these reddish, oval cells stringed together would measure only one millimetre. Like most microorganisms, planktonic algae can divide several times a day under suitable conditions. Crucial factors are especially the amount of light and nutrient salts as well as the water temperature. The lifespan of planktonic algae, however, is only a few days. Some planktonic algae species have flagella with which they can swim short distances, but they are mainly moved by water currents and gravity.

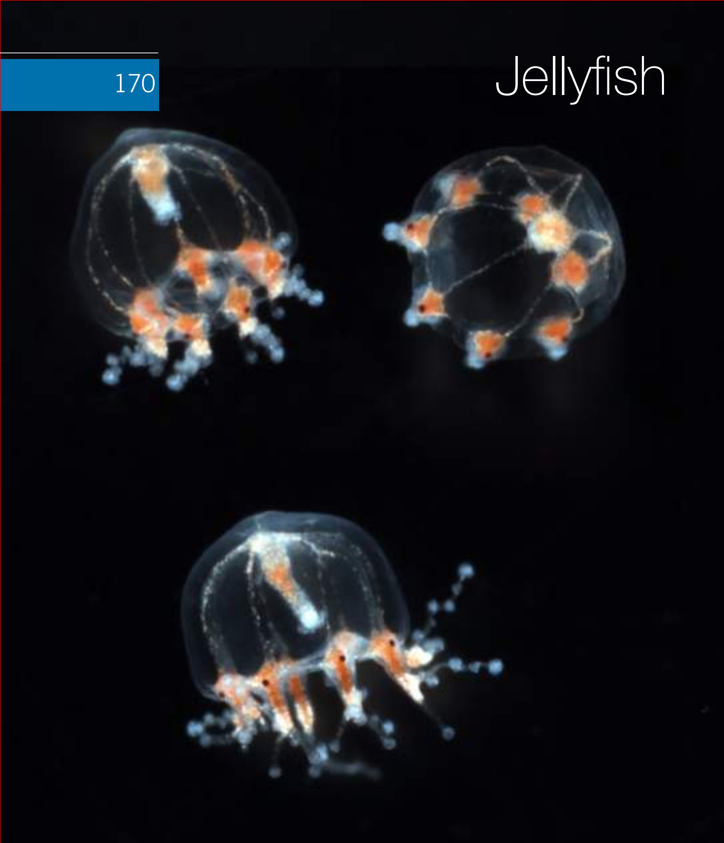
Planktonic crustaceans

Different planktonic crustaceans feed on the abundant menu of planktonic algae: Water fleas (top right) and copepods (two images at the bottom) use thin bristles on their legs to filter the finely dispersed algae from the water so that a thick, brownish pulp of algae forms in their stomachs (1). Their filtering capacity is quite considerable. In many of the plankton-filtering crustaceans of the open water, the movement made to obtain food also conveniently serves to propel them – with a mostly hopping motion.

Enrichment of fats in the food chain

Inside the bodies of the three planktonic crustaceans pictured here, transparent spheres along their intestines (2) are visible. These spheres are droplets of fat that stem from the consumed planktonic algae and serve as storage and float for the crustaceans. They are composed of a high proportion of long-chain, polyunsaturated omega-3 fatty acids, which are enriched in the course of the entire food chain up to the largest fish and possess – even for us humans – a high nutritional value.





Only a few millimetres in size

Several groups of cnidarians produce medusae: Those of the hydrozoa are called hydromedusae. Their typically umbrella-shaped bell is almost completely transparent. Occasionally, their food mass, consisting mainly of planktonic crustaceans, can be seen in the branched conduits of the stomach.

Eyes or equilibrium organs and tentacles

Some species of hydromedusae have evolved dark eyes at the margin of the bell that can sense light gradients. Other species have bright equilibrium organs at the same spot that also serve for orientation. What all hydromedusae have in common are tentacles with stinging cells that trail from the margin of the bell. The stinging cells, also known as nematocysts, are often concentrated in bright nematocyst batteries that are arranged like strings of pearls. Their concentrated effect can even be felt upon contact with the relatively thick human skin.

The biggest jellyfish in the Mediterranean…

…is the barrel jellyfish *Rhizostoma* . It can grow up to 30 cm in length, and with a calm sea, they might even be visible from the shore.

Barrel jellyfish belong to the class of true jellyfish, and inside this group, they are attributed to the order of Rhizostomae. They have eight long mouth tentacles that branch like cauliflower and serve to catch microplankton. Young jack mackerels often linger in the immediate proximity of barrel jellyfish and even seek protection between their mouth tentacles when they sense danger.

Short mouth tentacles

The Mediterranean jellyfish or fried egg jellyfish *Cotylorhiza* (top left, also left of p. 1) can reach a diameter of up to 20 cm and is also a Rhizostomae. Its eight mouth tentacles, however, are very short. Between the tentacles, they have many appendages with tiny, characteristically white and violet warts. The greenish-brown colour of their bell is caused by their symbiotic algae garden. Similar gardens are formed in other cnidarian groups, such as sea anemones and corals (p. 62f. and p. 14).

Doomed to die after stranding

A jellyfish that has been carried by the water current to the breaker zone of a sandy beach is doomed to die (image at the top right, probably the remains of a crown jellyfish *Cephea*). In the breaker zone, the jellyfish is battered by the turbulent waters, its bell fills with air bubbles, and its soft body is ground by the sand – eventually, only the gelatinous mesoglea, which serves as an internal skeleton, is left behind. These remains might then, of course, be washed back into the sea (bottom left).

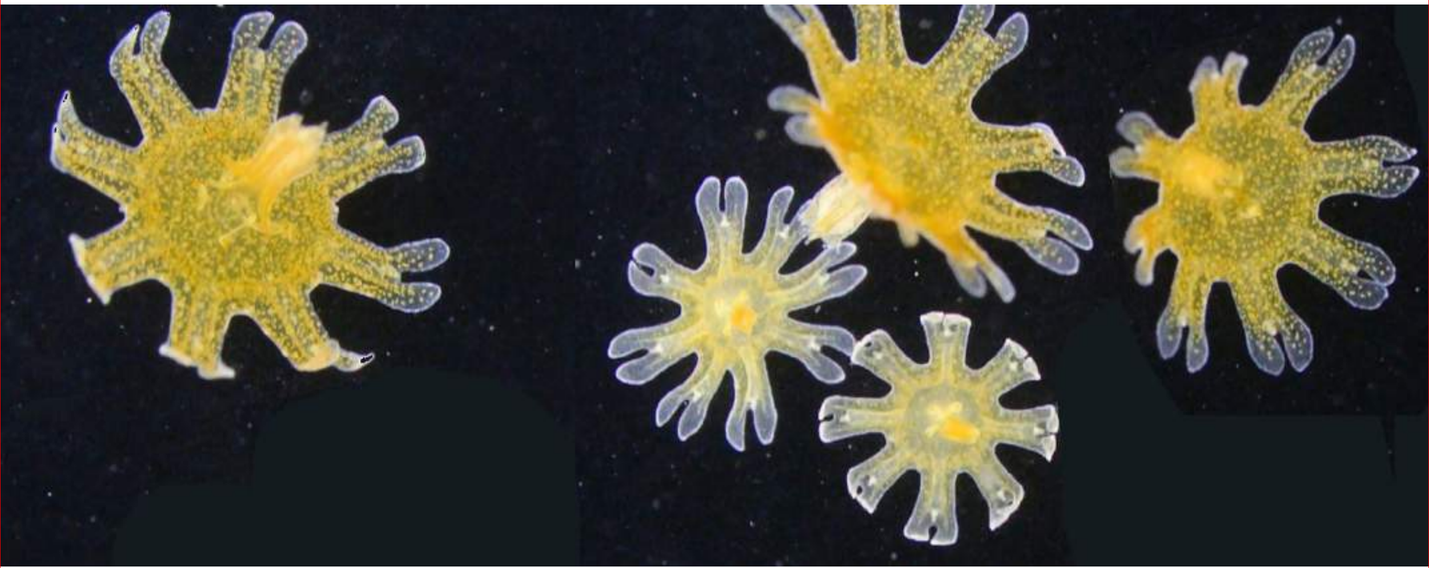
Dangerous stinging cells

The mauve stinger *Pelagia* (top image and also on the left page bottom right image) can reach a bell diameter of up to 12 cm. Its eight tentacles can grow up to 40 cm in length. It is also a true jellyfish, but inside this group, it is categorised within the order Semaeostomeae. As opposed to Rhizostomae, Semaeostomeae jellyfish feed on larger plankton and even small fish. They have evolved hunting tools that are adapted to their prey: on the one hand their characteristic tentacles, which can quickly pull in, and on the other hand the rapidly acting venom inside their stinging capsules.

These capsules can also penetrate our human skin. Especially mauve stingers cause many skin injuries to people swimming in the Mediterranean every year. If large areas of the body or the face are affected by a jellyfish injury, you should seek medical assistance. The best measure to avoid being stung by a jellyfish is to wear goggles – also while swimming and bathing, because with goggles you can spot thin tentacles and other threats lurking in the sea on time.

Bezio N. et al. **Effects of capture surface morphology on feeding success of scyphomedusae: a comparative study** *Mar Ecol Prog Ser 596:83-93 doi:10.1046/j.1365-2419.1998.00080.x (2018)*
https://doi.org/10.3354/meps12549

Polyp and Jellyfish



Two lifeforms of true jellyfish

Most jellyfish species can appear in two lifeforms: One lifeform is called "polyp"(right image). They measure only a few millimetres in size, look like small trees, and grow hidden in dark, overhanging rock crevices at the bottom of the sea (right image). If a polyp's living conditions are very good, then it will generate the second lifeform: young jellyfish that only measure a few millimetres and are known as "ephyra"(top image). They grow as zooplankton in the open sea until they become adult jellyfish. The mauve stringer, however, is a big exception among the jellyfish, because they skip life as a polyp and the change of habitat that accompanies the process: They only exist in the jellyfish form and propagate by directly giving birth to tiny jellyfish.

Only for a few decades...

...the warty comb jelly or sea walnut *Mnemiopsis* has been present in the Mediterranean (right-hand page at the top). They originated in the West Atlantic Ocean, but in the 1980s cargo ships accidentally carried them to the Black Sea, where they quickly became the dominant plankton species and turned into a threat to the anchovy populations there, because both animal species feed on the same nutrient resources. The sea walnut population has since spread from the Black Sea and is now increasing significantly in the Northern Adriatic Sea.

No Stinging Cells but Still a Threat?

Sea walnuts are sometimes strongly concentrated by onshore water currents and are then visible as pink-coloured swarms (top right). Luckily, like all other comb jellies, they do not possess any stinging capsules. Instead, they catch their plankton food with their sticky tentacles.

Unlike true jellyfish...

...comb jellies do not swim through contraction and repulsion but through the synchronic beating of their fine lashes known as cilia, which are arranged in comb-like rows along the surface of their bodies.

The cilia combs glow...

...in fantastically iridescent rainbow colours. As with some red algae ("blue red algae", p. 57), this play of colours is caused by light interferences on the structures of the cilia at a scale of only a few nanometres.

Shiganova, T.A. **Invasion of the Black Sea by the ctenophore *Mnemiopsis leidyi* and recent changes in pelagic community structure** *Fisheries Oceanography 7: 305–310 doi:10.1046/j.1365-2419.1998.00080.x (1998)*
Welch V. et al. **The cause of colouration in the ctenophore Beroë cucumis** *Current Biology 15: 24 985– 986 doi:10.101)* 2005

A large compass jellyfish *Chrysaora*...
...swims through the water. As is common for other Semaeostomeae jellyfish, the tentacles attached to its umbrella are pulled through the water in a typical wave motion caused by repeated pumping contractions.
In the photo, which was taken in a specialised jellyfish aquarium, the beginning of this regular waveform of the tentacles can be seen just below the edge of the bell. When the tentacles touch something – this could be a planktonic crustacean but also our skin – they contract. The contact area is thereby increased, and at the same time, the many nematocysts discharge their toxins. Eventually, the four mouth arms also come into contact and absorb the prey into the stomach cavity.

Ocean Sunfish

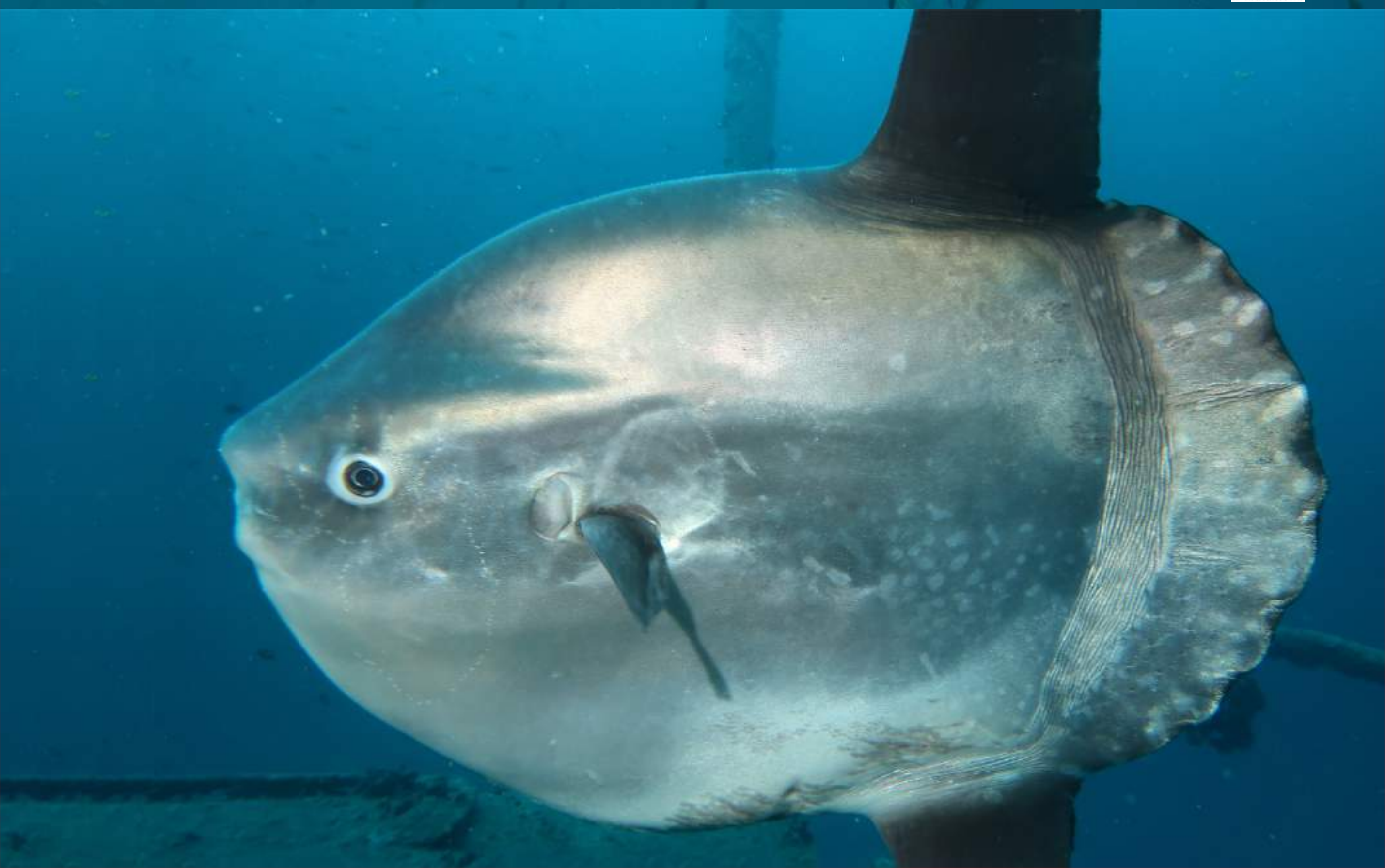
Giant planktivore

A giant ocean sunfish *Mola* drifts idly through the open water around a wreck. It feeds mainly on equally idle zooplankters like jellyfish. Its disc-shaped, silvery-brown body can reach a length of up to two metres.

Why do these animals sometimes lie flat on the surface?

Sunfishes have sometimes been spotted lying on their sides at the surface of the sea. This has been interpreted as a form of resting behaviour, but it might also be an invitation for seabirds to clean parasitic crustaceans off their bodies – this cleaning behaviour was observed at least with albatrosses that pulled parasites from sunfish bodies lying flat on the water surface.

Takuzo Abe, Keiko Sekiguchi
Why does the ocean sunfish bask?
Communicative and Integrative Biology, 5:4, 395-398
DOI:10.4161/cib.20376 (2012)



"Small Fish"

No anchovy and yet in huge swarms

Top left image: The grey-green, silver-striped sand smelt *Atherina* reaches a length of 14 cm and forms dense swarms in the open water near the shoreline. The fish in these swarms are strictly sorted by size. Their uniformity probably confuses the predators that follow the swarm and makes it harder for the attacker to track and catch a single animal (p. 199).

Loose swarms

The open sea close to the shore, many metres above the bottom, is also the habitat of the Mediterranean damselfish *Chromis* (left-hand images and in the middle). It can grow up to 12 cm in length, and its tail fin has a forked appearance due to the two black stripes on the top and bottom edges. Like the sand smelt, the damselfish feeds on zooplankton that floats by and also forms large swarms, but these are looser. The bigger gaps between the damselfish probably allow the swarm to manoeuvre more quickly and thus catch plankton with greater efficiency.

Daily habitat change of the masses

Although damselfish come to the open water to feed at dusk, like most coastal fish, they retreat into gaps between the rocks where they spend the night. These rocks are also their spawning sites. In early summer, they form large breeding colonies where they lay hundreds of eggs on previously cleared rock surfaces, fertilise the eggs, and then guard them until they hatch a week later.

The juvenile stage of Mediterranean damselfish…

…is bright cobalt blue. These tiny, but eye-catching blue fish spend the summer next to overhanging rocks and rock crevices until they reach a size of two centimetres (bottom left image).

The picarel *Spicara*…

…(top right image) is another longish, silvery fish that swarms in the open water and feeds on plankton animals, which it swallows whole with its suction mouth. It is clearly recognizable by its characteristic rectangular black spot on the sides.

Similar bodies shapes determined by their habitat

The bogue *Boops* (centre-right image) is the spitting image of the picarel. It lives in the same habitat, forms swarms, but has no spots on the sides. It also feeds mainly on zooplankters, but with its rows of rasping teeth, it can also shred soft pieces of food. Occasionally, bogues rasping on jellyfish can be observed.

Many open-water fishes have similar physical characteristics

They have silvery bodies shaped like an elongated spindle, big eyes, and relatively small tail fins with a narrow peduncle. The reasons for this are probably, on the one hand, the consistent physical parameters of the open-sea habitat, which have generated the same physical characteristics several times:

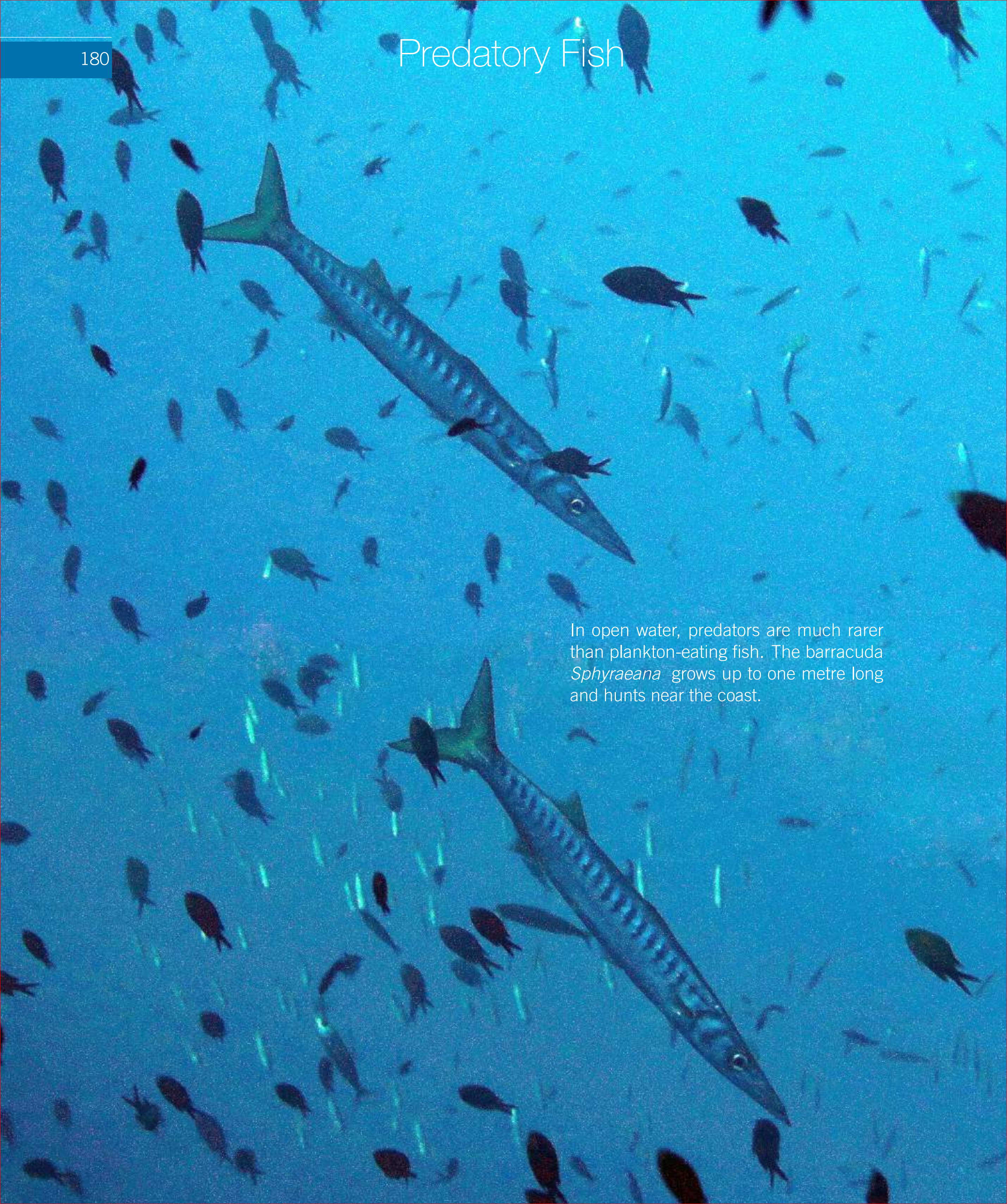
1. The silvery fish bodies reflect their surroundings and thus serve as camouflage (fish are thus discovered relatively late).
2. Feeding and fleeing movements in the open water tend to be straightforward and at the same time very fast. Manoeuvrability is not as important in this structureless environment, which is why the fish bodies in open water are often spindle-shaped and not laterally compressed and high-backed, as with the bottom-dwelling bream or wrasses.
3. The eyes of open-sea fish are noticeably bigger than those of their groundfish relatives, which enables them to spot the often microscopically tiny zooplankters quickly.

On the other hand, the various fish species that share these physical characteristics are often found in mixed swarms – the different species thus additionally benefit from this standardisation of physical characteristics. From an evolutionary perspective, selection may thus drive a sort of "signal convergence", similar to Müllerian mimicry.

Saddled seabream

In the below right image, hundreds of the saddled seabream *Oblada* are swimming in the open water, many metres above the bottom. The saddled seabream grows up to 30 cm long and is another silvery open-water seabream, sharing its habitat with the bogue and the picarel. It is easily distinguished from the other two by its black and white markings on the base of its tail.

Predatory Fish



In open water, predators are much rarer than plankton-eating fish. The barracuda *Sphyraeana* grows up to one metre long and hunts near the coast.

“Encounters out of the blue”

A group of blue runners *Caranx chrysos* suddenly approaches the photographer with curiosity. After several synchronous swimming manoeuvres, they disappear again…

…into the deep blue. Most predatory fish in this unstructured habitat use a similar strategy to hunt: The appearance and seizure of mouth-sized prey takes place in a matter of seconds.

Endangered Predators

Very fast swimming open-sea fish…

…like mackerels and tuna rarely dwell right next to the coast or the sea bottom and are, therefore, rarely spotted by snorkelers and divers. However, they are also a coveted catch for fishers: A young tunny *Euthynnus* has fallen prey here to its own curiosity, as it took the artificial bait trolled by a fishing boat (left image). Evidently, the jerky moving hook was not taken into the fish's mouth at all, but has pierced the upper jaw from outside.

Sharp fall in population density

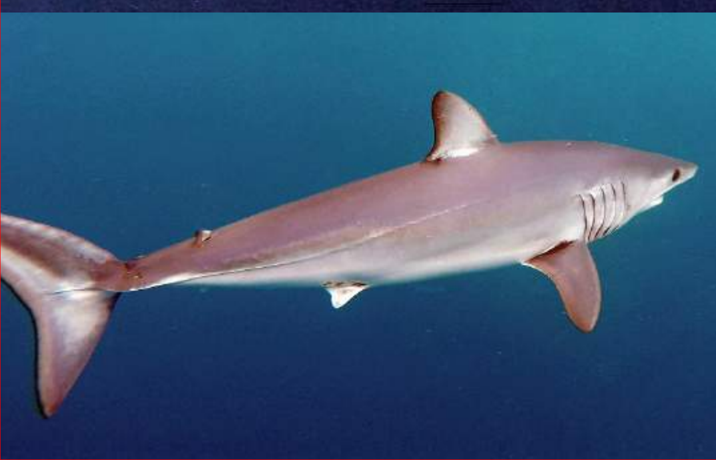
Image below: An Atlantic bluefin tuna *Thunnus* is gutted and carved in an Adriatic harbour – this has become an extremely rare sight! Tuna cross the entire Mediterranean in spawning migrations of several thousand kilometres, during which they have been intensively fished for centuries – absurdly with ever increasing technical effort, but at the same time with declining yields. In 2008 their population density fell to a third of its level in the year 1950. Luckily, and mainly thanks to an improved monitoring of fishing activities, bluefin tuna stocks seem to be recovering. In recent years there has also been a rise of "tuna ranching", where young tuna that have been caught in the wild and are not yet market-ready are fattened in net cages close to the coast over several years. Since bluefin tuna can thus be fished according to the current demand, market supply has increased, but this has not reduced the fishing pressure on wild stocks.

Taylor, N. et al. **Atlantic Bluefin Tuna: A Novel Multistock Spatial Model for Assessing Population Biomass** *PloS ONE. 6.12.e27693, DOI: 10.1371/journal.pone.0027693 (2011)*
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3235089/

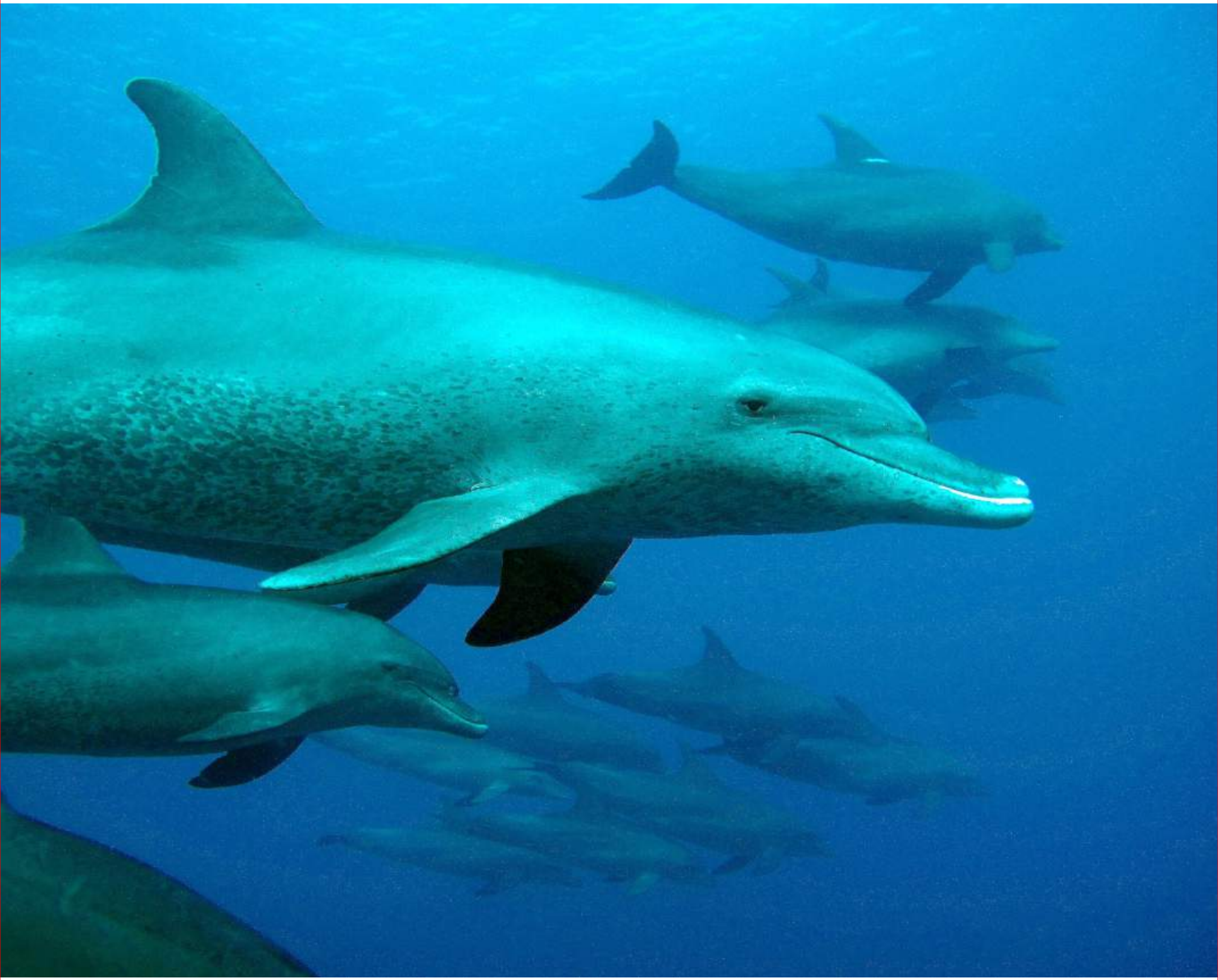
Almost fifty shark species live in the Mediterranean

Most of them, however, inhabit sea bottoms, far below our diving depths. Among the few shark species that inhabit the open sea, the blue shark *Prionace* is one of the most common (images above, also p. 6). With its long snout, its slender body, and its highly asymmetrical tail fin, it can be distinguished from the much rarer mako shark *Isurus* (centre-left and bottom images). The bottom right photograph was taken at a sandy beach on the island of Crete; the underwater photographs on this page were taken in the Atlantic.

The primary prey of both shark species are the fast swimming open-sea fish from the mackerel and tuna family as well as squids.



Dolphins



The most common whales in the Mediterranean

The open waters of the Mediterranean are also the habitat of different species of whales. Among them, dolphins are certainly the most common. It still takes a lot of patience and luck to spot these skilful and rapid swimmers underwater.

Bottlenose dolphin and the common dolphin

But which of the eight species is it? The bottlenose dolphin *Tursiops* (image on the left) has a short snout that dips slightly downward, and its lower jaw extends beyond the upper jaw. The slightly shorter common dolphin *Delphinus* (image on the right), on the other hand, has a long, narrow beak, and their lower jaw is as long as the upper jaw.

In pairs or small schools

Both species live in pairs or in small schools and come to the surface for breathing, jumping in little arcs, but only rarely entirely out of the water. After breathing in several times, they dive for a few minutes into the deeper water layers to hunt there for fish.

High energy needs

Due to their constant movements and high inner body temperature of 37°C, dolphins have a particularly high energy demand: At a water temperature of 20°C, a 150-kg-heavy, 2.3-metre-long bottlenose dolphin will need about six kilograms of fish on a daily basis to sustain its basal metabolism.

Ridgway, S. H., Fenner, C. A. **Weight-length relationships of wild-caught and captive Atlantic bottlenose dolphins** *Journal of the American Veterinary Medical Association, 181(11),1310-1315 (1982)*

Perez, M. A., et al. **Estimated feeding rate relationship for marine mammals based on captive animal data** *JNOAA Technical Memorandum NMFS F/NWC-184 (1990)*
https://repository.library.noaa.gov/view/noaa/5928/noaa_5928_DS1.pdf

Rare – and sometimes confused with other sharks

The great white shark *Carcharodon carcharias* is certainly the rarest shark species out of the 47 that are home to the Mediterranean (the photographs on this double page were taken in South Africa). The more common mako shark (p. 183) and the basking shark, which belong, like the great white shark, to the family of mackerel sharks, are sometimes mistaken for it. The great white shark is clearly recognisable by its big, triangular teeth that have serrated edges and by the length of its gill slits (which do not reach the back of the shark).

Descended from Australia!

Great white sharks have long been present in the Mediterranean. However, surprisingly, the origin of these Mediterranean animals does not lie in the adjacent Atlantic (via the Strait of Gibraltar) or in the Indian Ocean (via the Suez Canal), but their closest relation are actually the great whites that live in far away Australia. According to calculations based on the rate of change of a similar gene sequence in both populations, the settling of Australian great white sharks in the Mediterranean occurred as early as 3.5 million years ago.

A great white shark that measured 5 m in length and


Das interessante Blatt

Nr. 35. Wien, 2. September 1926. XLV. Jahrg.

Ein Haifisch in der Adria.

[illegible]

Ein Haifisch in der Adria: Das jüngst bei Porto Ré gefangene und in der Fischhalle von Fiume ausgestellte Riesentier, in dessen Magen Teller, Staffette usw. gefunden wurden.

weighed 1 200 kg was caught with a tuna fishing net in the Northern Adriatic in 1926 and was exhibited in the fish market of Rijeka (newspaper extract above). Newspapers of that time falsely assumed that the shark had migrated from the Red Sea. Reliable reports of great white shark sightings in the Mediterranean, however, date as far back as the 17th century – long before the construction of the Suez Canal (see link "Antibes" on the right page).

Nursery in the Aegean Sea?

In the Aegean Sea, east of the island of Lesbos, there seems to be a significant nursery of great white sharks. In this area, several young specimens that were only a few months of age have been caught by fishing nets.

The number of great white shark specimens…

…has been decreasing steadily for centuries. According to cautious estimates, the number of specimens living in the entire Mediterranean today ranges between only ten and one hundred specimens. Without human interference, its population density would be around hundreds or even several thousand specimens. The main reason for this dramatic decrease is their overfishing – be it intentional or unintentional – and the simultaneous decrease in its main prey, consisting of tuna fish and sea mammals like whales and seals.

Shark attacks

In the 19th and 20th century, there were several lethal incidents where swimmers in the Mediterranean were attacked by great white sharks, especially in coastal areas where tunas were regularly fished from the shore. The last such incident occurred in the year 1989, in the Tyrrhenian Sea near the Italian port town Piombino (see link "Constanzo" on the right page).

Leone, A., et al. **Pliocene colonization of the Mediterranean by Great White Shark inferred from fossil records, historical jaws, phylogeographic and divergence time analyses** *Journal of Biogeography 47.5: 1119-1129 (2020)* http://dx.doi.org/10.1111/jbi.13794

Boldrocchi, G. et al. **Distribution, ecology, and status of the white shark, *Carcharodon carcharias*, in the Mediterranean Sea** *Reviews in fish biology and fisheries 27.3: 515-534 (2017)* DOI:10.1007/s11160-017-9470-5

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Kabasakal, H. **Exploring a possible nursery ground of white shark (*Carcharodon carcharias*) in Edremit Bay (northeastern Aegean Sea, Turkey)** *J Black Sea/Medit Environ, 26.2, 176-189 (2020)*

https://www.sharkattackfile.net/spreadsheets/pdf_directory/1989.02.02-Constanzo.pdf
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Humans and the Sea

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*,
https://doi.org/10.1007/978-3-031-22334-1_9

Anthropocene

No other organism ever known to have existed has had such a lasting impact on the Earth within such a short period of time as human beings. Our impact has been considered substantial enough to justify the naming of a new geochronological epoch: the Anthropocene. Not only the terrestrial habitats inhabited by humans but basically all areas of the biosphere have been influenced by human activities.

Even the deep sea is affected

Traces of disturbing human activities can already be found in the deep sea: Even a newly discovered amphipod shrimp on the slope of the Mariana Trench at a depth of 7 000 metres already had crushed PET plastic waste in its stomach. However, not all types of plastic accumulate on the sea bottom: Among the robust plastics which are not degraded by microorganisms, it is mainly the non-floating plastics PET, PVC, and polyester that are increasingly found on the bottom of the ocean.

Giant trash vortex

However, plastics that float in the sea water, such as PE and PP, travel a different route: They are either carried by waves to beaches, where they form a wash margin that is not only optically disturbing, or they gradually become concentrated in one of the giant trash vortices that have emerged in the middle of all oceans over the past decades.

Large image: The sea bottom has sometimes highly explosive trash surprises in store: A drifting mine that has not (yet?) detonated lies on the bottom of the sea. The small ball at the front is a several-decade-old *Geodia* sea sponge.

Stachowitsch, M. **The Beachcomber's Guide to Marine Debris**
Springer (2018)
Weston, J. et al. **New species of *Eurythenes* from hadal depths of the Mariana Trench, Pacific Ocean (Crustacea: Amphipoda)**
Zootaxa Vol. 4748 No. 1: 5 (2020)
https://doi.org/10.11646/zootaxa.4748.1.9

Fishing and Hunting of Marine Mammals

Humans have been fishing since time immemorial

For as long as humans have existed, marine animals have appeared on their food menu. Already 20 000 years ago – in the Upper Palaeolithic – humans ventured into the sea for fishing. Findings of bone harpoons and fishing hooks dating from that time, as well as remains of fish species that can only be found in the open sea, represent the earliest indications of marine fishing activities.

A famous mosaic from Pompeii

An ancient Roman mosaic that was created more than 2 000 years ago shows a very realistic representation of twenty-two fish and mollusc species of the Mediterranean that are still of economic importance today. It features the following animals, which are arranged in rows, from top to bottom and left to right (large image) as follows:

https://commons.wikimedia.org/wiki/Category:Fish_Catalogue_mosaic,_MANN_120177_(from_Pompeii)#cite_note-1

1. goatfish, shrimp, gilt-head bream
2. mullet, electric ray, scorpionfish
3. wrasse, catshark
4. kingfisher, spiny lobster, octopus, purple dye murex, squid
5. Mediterranean rainbow wrasse, moray eel, painted comber, rainbow wrasse (?)
6. catshark, sea bass
7. saddled seabream, gurnards, brown comber (?)

Soon on the verge of extinction

The first marine animals to be caught from the almost infinitely rich sea pantry were certainly those that could easily be reached from the shore.

In most cases, humans were the faster learners in this hunting relationship, often pushing the population of their prey to the verge of extinction.

The Mediterranean monk seal *Monachus*

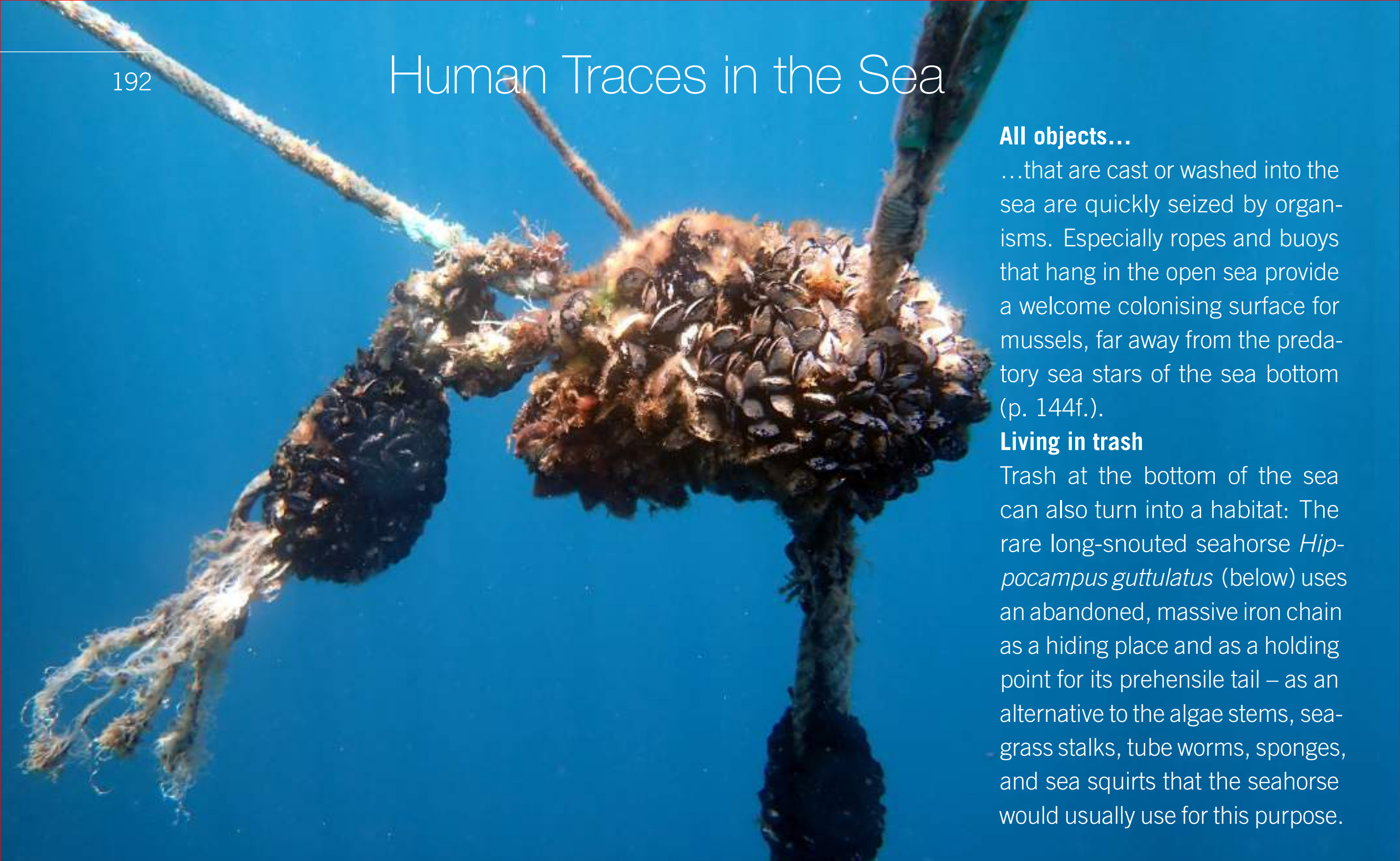
This is starkly illustrated by the gradual disappearance of the Mediterranean monk seal *Monachus* (images below): Among all marine mammals around the world, this seal is now among the species that are most at risk of extinction. At this point only a few hundred animals exist at secluded cliff coasts that are difficult to access, for animals and humans alike. Most likely, before the beginning of human hunting, the monk seal was once widely spread on most Mediterranean beaches and not just limited to a few places of refuge. Humans first used monk seals in the Upper Palaeolithic about 20 000 years ago, and the persistent exploitation of these animals has allowed only those colonies to survive that live in the least accessible areas.

Saved at the last minute?

Fortunately, the extinction of the Mediterranean monk seal seems to have slowed – reports of sightings in the Adriatic Sea have increased over the last few years. The seal pictured here, a single individual, has been spotted in a bay in southern Istria over several years. However, monk seals reproduce very slowly: After a gestation period of almost a year, females give birth to only one cub, which is then nursed with nutrient-rich milk in a hiding place on land over several months. Monk seals live to be about 25 years old and are sexually mature from the age of four years.

Fioravanti, T et al. **A Mediterranean Monk Seal Pup on the Apulian Coast (Southern Italy): Sign of an Ongoing Recolonisation?** *Diversity, 12, 258 (2020)* https://doi.org/10.3390/d12060258

Morales-Pérez, J et al. **Mediterranean monk seal hunting in the regional Epipalaeolithic of Southern Iberia. A study of the Nerja Cavesite (Málaga, Spain)** *Quaternary International, 515, 80-91 (2019)* https://doi.org/10.1016/j.quaint.2017.11.050



All objects...

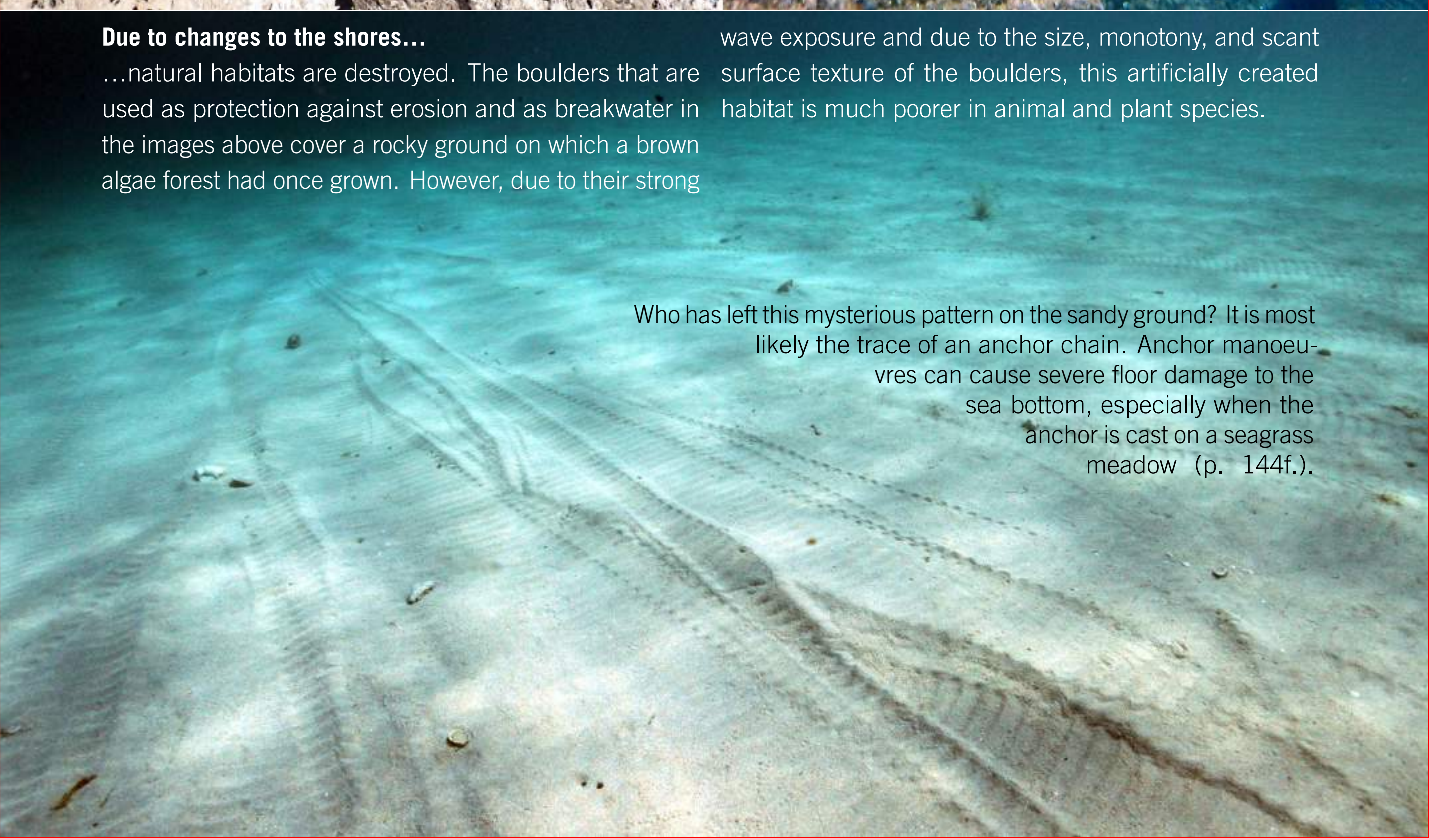
...that are cast or washed into the sea are quickly seized by organisms. Especially ropes and buoys that hang in the open sea provide a welcome colonising surface for mussels, far away from the predatory sea stars of the sea bottom (p. 144f.).

Living in trash

Trash at the bottom of the sea can also turn into a habitat: The rare long-snouted seahorse *Hippocampus guttulatus* (below) uses an abandoned, massive iron chain as a hiding place and as a holding point for its prehensile tail – as an alternative to the algae stems, seagrass stalks, tube worms, sponges, and sea squirts that the seahorse would usually use for this purpose.

Due to changes to the shores...

...natural habitats are destroyed. The boulders that are used as protection against erosion and as breakwater in the images above cover a rocky ground on which a brown algae forest had once grown. However, due to their strong wave exposure and due to the size, monotony, and scant surface texture of the boulders, this artificially created habitat is much poorer in animal and plant species.



Who has left this mysterious pattern on the sandy ground? It is most likely the trace of an anchor chain. Anchor manoeuvres can cause severe floor damage to the sea bottom, especially when the anchor is cast on a seagrass meadow (p. 144f.).

Endangered Species – Captive Breeding?

Trophy hunt

The existence of some species is on the line. The photograph above documents a rare sighting of a Triton's trumpet *Charonia*. Due to their shells, these sea snails have long been collected as decorative objects and as trumpets. The snail's antennae with two black bands and the small dot-shaped eyes at the base of the antennae are clearly visible in this photo. The shell of a Triton's trumpet can reach a length of over 40 centimetres.

Seahorse populations in the Mediterranean…

…(right-hand side) have been declining for years. They are still considered to be highly sought-after collectibles, even though they usually end up in a display case as a shriveled-up, smelly souvenir. Furthermore, the destruction of their coastal habitats by tourism and shipping facilities contribute to their decline.

Captive breeding to save some fish species from extinction?

Edible fish are raised in giant aquaculture cages (pictured below) over several years. Ideally, aquaculture enterprises should not use other fish for feeding, and young fish should not be taken from nature but instead be obtained from breeding.

G. Glaeser, D. Abed-Navandi, *Ecosystems of the Mediterranean Sea*, https://doi.org/10.1007/978-3-031-22334-1

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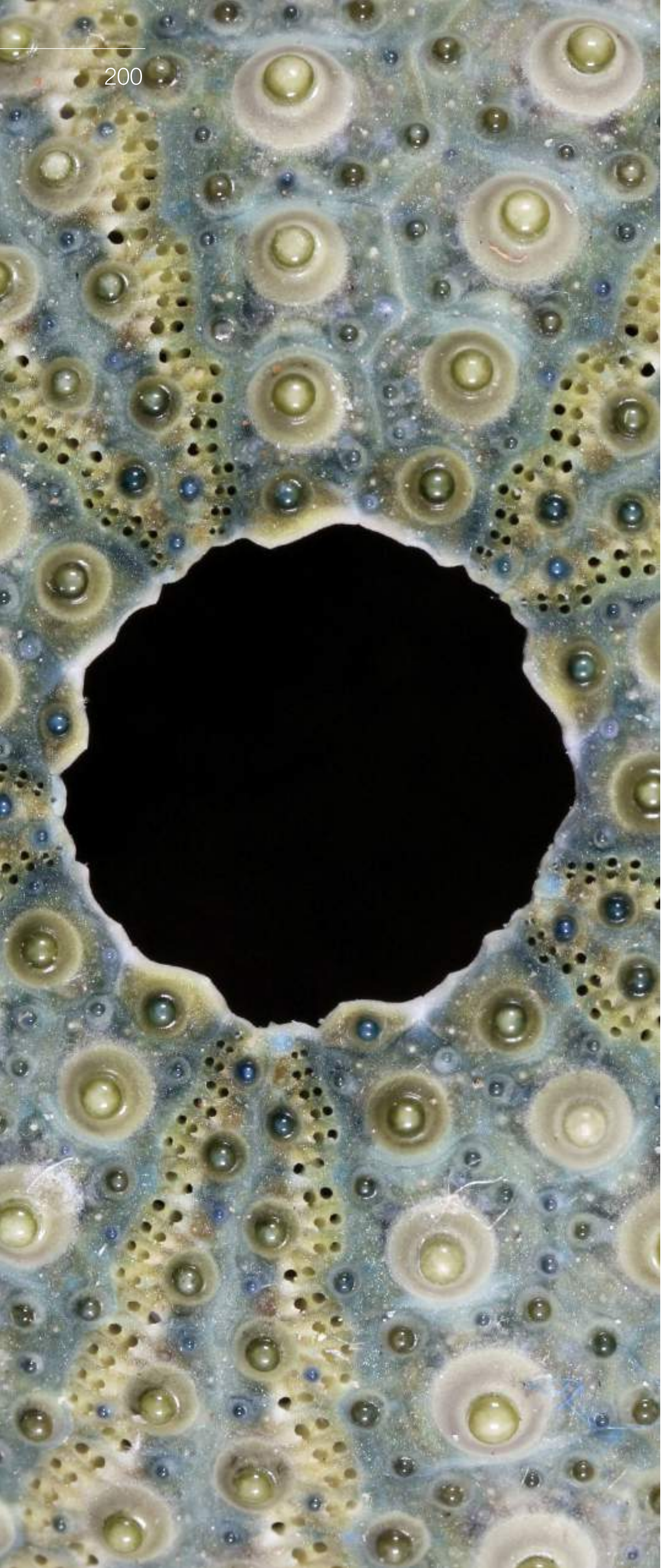
Left: Young saddled seabreams *Oblada* sometimes hide under shady rocks to avoid predatory fish that attack from the open waters (p. 179).

Right: A male black-headed blenny *Microlipophrys nigriceps* in its shady cave habitat. Only during mating season the cheeks sport this striking lemon-yellow colour. (p. 106).

Left: The brown algae *Sargassum* has buoyancy bodies filled with gas and therefore does not need other structures to support its body – much like the giant brown algae that live in colder oceans.

Right: Huddled together – sea smelts sometimes seek shelter above sand bottoms to avoid predatory fish from the open water (p. 178).



Additional Scources

The book is structured in such a way that primary sources are cited on the respective pages, while supplementary basic literature on the biology of the Mediterranean Sea is listed here. The scientific names are valid at the time of printing and have been taken from the **World Register of Marine Species** marinespecies.org.

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Recommended: A French website about marine organisms maintained by scientists:
https://doris.ffessm.fr/

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Left: Close-up of a shell skeleton of a purple sea urchin *Paracentrotus* (p. 32f.).