MUSSEL-FARMING
in the Gulf of Trieste

EDUCATIONAL NOTEBOOK 01

WHO WE ARE

Miramare Marine Protected Area is the only marine reserve in the Friuli Venezia Giulia Region, the smallest in the system of Italian marine protected areas, established in 1986 by decree of the Ministry of the Environment, which entrusted its management to **WWF Italia ONLUS**.
But Miramare is also at the heart of a **Biosphere Reserve recognised by UNESCO** as part of the MaB - Man and Biosphere programme for the harmonious coexistence of Man and the Environment: in this area, **the protection of biodiversity** goes hand in hand with **the development of sustainable production activities**, as they are capable of using natural resources without compromising them for future generations. One such example is mussel farming, the focus of this notebook.

It is our duty to promote and share these efforts, and we invite you to enjoy your reading!

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INTRODUCTION

Among the **sustainability education proposals** presented by the WWF staff of the Miramare Protected Marine Area, activities dedicated to the discovery and promotion of a traditional system for the use of sea resources have stood out for several years: the extensive mussel farms dotting Trieste's coastline.

The educational modules offered in conjunction with this educational notebook aim to teach students about the marine **ecological footprint** of the catch as well as fishing and aquaculture, and focus attention on mussel farming, a traditional type of farming in the Gulf of Trieste that meets the prerequisite of sustainability, describing its origins, how facilities work and product features. Furthermore, they highlight the remarkable richness of species hidden in this man-made **biodiversity hotspot**.

MARINE BIODIVERSITY AND SUSTAINABLE FOOD

Biodiversity is the fundamental pillar of food production, but the diversity of ecosystems and species is increasingly under pressure from a rapidly increasing population, consuming more and more, altering and degrading the environment. Many wild species are threatened with extinction due to unsustainable management of agriculture, livestock and fisheries.

Since the 1990s, more fish have been caught than the reproductive potential of fish populations, causing **fish stocks to decline** worldwide. Paradoxically, the efficiency achieved by technologically advanced systems for tracking fish stocks has been the cause of their depletion. Hence the need to change course and aim to develop sustainable forms of **exploitation of sea resources**. Among these it is worth mentioning:

- **fishing valleys aquaculture system**, extensive farming that takes advantage of the natural morphological characteristics of the Adriatic coastal brackish wetlands, practised in this region in the Grado and Marano lagoons;
- **fish farming**, an intensive farming activity carried out in floating cages located near the coast (in this region, in front of Duino), with companies managing the entire production cycle, from hatchery to marketing;
- **mussel farming**, a traditional type of cultivation in the Gulf of Trieste, which we will specifically describe in the following pages.

FISHING IN THE GULF OF TRIESTE

Historically, and until the 1950s, **tuna** (*Thunnus thinnus*) **fishing** was a common practice along Trieste's coastline, with the help of watchmen standing on the Karst ridge looking out for schools of fish. Once spotted, these were encircled with a 500-metre-long net that was cast from the tuna boats and then hauled ashore by the fishermen, assisted by the inhabitants of Contovello, Santa Croce and Aurisina, who rushed to the sea, alerted by the cries of the watchmen.

Tuna fishing in the 1940s below Santa Croce

Fishing with traps

Today, as tuna fishing in the Adriatic has almost disappeared, **traditional** fishing practices in the Gulf of Trieste include pot fishing to catch mantis shrimp (*Squilla mantis*) and cuttlefish (*Sepia officinalis*); **encircling nets** to catch bluefish such as anchovies (*Engraulis encrasicolus*) and sardines (*Sardina pilchardus*), and **nearshore mussel farming** (*Mytilus galloprovincialis*), with annual production reaching 70 tonnes. Compared to just twenty years ago, fishing activities in the Gulf have declined dramatically. Suffice it to say that Trieste's fish market, once housed at the Pescheria Grande on the city's waterfront, drew around 100 tonnes of local catch in 2022 compared to 900 tonnes recorded in 2004.

Fishing with lampara (fishing light) and encircling nets

Fish unloaded at the pier in Trieste

MUSSEL-FARMING

Mussel farming in the Gulf of Trieste is a **sustainable activity** that does not damage ecosystems, as it relies on renewable resources, consuming them at a rate compatible with the production and regeneration capacity of the environment.

However, mussel farming does have some environmental impacts, which are studied and documented to ensure they are kept under control. Let's look at the main pros and cons of this farming system.

Pros

1. Mussel farming represents a fair compromise between the human needs to exploit the resources of the sea and the urgency of not compromising their productivity in the short and long term, while ensuring their protection and conservation;
2. it allows for the preservation of areas designated for mussel farming from more impactful forms of fishing;
3. it represents an artificial micro-habitat consisting of floating and submerged inert structures that contribute to the expansion of the available surface where a rich microflora and microfauna find refuge and nourishment. These serve as food source for the subsequent levels of the food web.

Cons

1. The development and growth of the mussel community result in a continuous supply of organic or organogenic debris that can settle on the seabed (sometimes several cm/year depending on the hydrodynamics of the area) or be carried by tides and currents and end up stranded elsewhere.
2. The processing may lead to the abandonment or accidental loss of residual items (non-biodegradable plastic socks, PVC pipes and other plastic material present in the facilities), which may persist in the environment by settling on the seabed, getting entangled in fishing gear, or be washed ashore even at great distances from the farms.

ORIGINS AND DEVELOPMENT OF SHELLFISH FARMING IN TRIESTE

The term 'aquaculture' refers to **cultivation or farming** of aquatic organisms, both animal and plant, in fresh, brackish and marine waters, with human intervention on a part or on the entire biological cycle of the organisms.

Mussel farming is a branch of aquaculture dedicated to the cultivation of bivalve molluscs of the species Mytilus galloprovincialis, primarily for food production.

Shellfish farming has been practised along the coast of the Gulf of Trieste since the **mid-1800s**. Initially and until the 1960s, it involved facilities built on poles driven into the seabed, then on submerged lines supported by floats.

Images of mussel farming in the early 20th century

< Weighing mussels at the fish market in Trieste

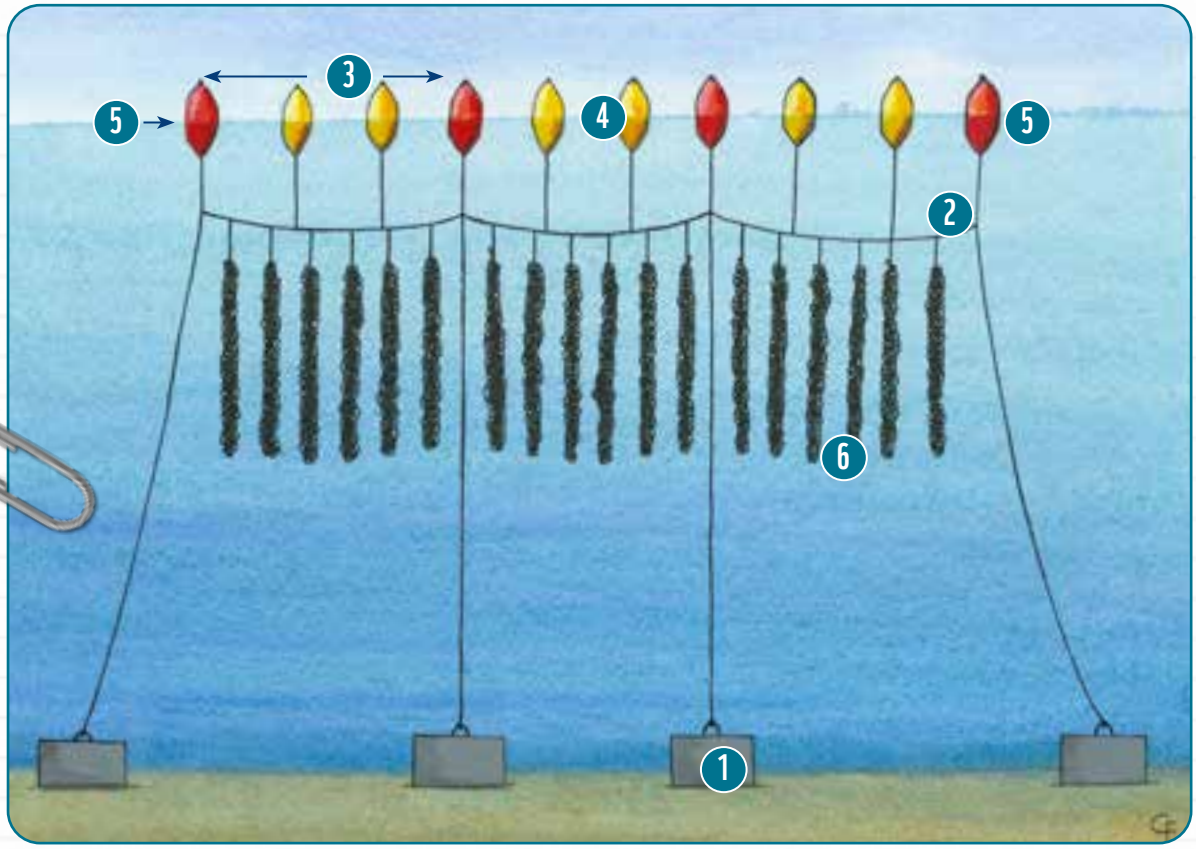
FARMS IN THE GULF

Modern floating mussel farms, known locally as "*pedocere*", are regulated by maritime concessions covering approximately 200 hectares of the nearshore waters in the Gulf of Trieste. They are distributed across three main areas: the south-eastern part of the Gulf along the coast near Muggia, the central coastal strip Grignano – Sistiana Bay, and Panzano Bay located in the north-western part of the Gulf.

GULF OF TRIESTE

MUSSEL FARM STRUCTURE

The typical offshore mussel farm is a suspended long-line canopy. Each farm typically consists of a series of submerged long-lines arranged in parallel at a depth of 3-5 m. Each row is anchored to the seabed with concrete **blocks** ❶, connected to the **headlines** ❷. The **headlines segments** ❸ are suspended at the desired depth using special polyester **floats** ❹. The floats that mark the perimeter of the farm are typically larger and heavier than the intermediate ones and are known as '**head floats**' ❺. The **droppers** ❻ , consisting of tubular polypropylene nets called 'socks', are attached to the headline, spaced 50 cm apart from each other and hang vertically into the water.



PRODUCTION PROCESS

The phases of the production process are:

1. Capturing and seeding

The mussel farmer sets up submerged seed collectors (e.g. old ropes) to facilitate the natural settlement of the larvae at the planktonic stage on the rope's surface and their growth to a length of 2 cm.

2. Socking and dropping

The spats are manually stuffed into plastic mesh sleeves called socks using plastic tubes or mechanical fillers. At this point the seeded mussel socks are tied onto a headline and dropped into the sea until the mussels start growing, which typically lasts for about 2 or 3 months.

3. Hauling and reseeding

After 2-3 months, the mussel farmer hauls up the dropper ropes using a winch and, after checking the size of the mussels, he separates them from the sock with a stripping machine and seeds them back onto new socks with a larger mesh size to allow for maximum growth.

4. Harvesting and selection

When mussels have reached harvest size, the socks are hauled on board, the mussels declumped and sorted in similar sizes using a mussel grader.

5. Packaging

After being washed and placed in bags, the mussels are sent to authorized mussel shipping centres where they are further selected and packed in plastic mesh of 1 or 2 kg.

In order to monitor the growth and ripening of mussels to harvest them, the mussel farmer goes out to sea daily with his work boat, specifically equipped with a winch, a declumper and grader to measure sizes.

Il Mytilus galloprovincialis

The species farmed in the aquaculture facilities in the Gulf of Trieste is the *Mytilus galloprovincialis*, commonly known as mussel.

Mussels are filter-feeding lamellibranch molluscs, located at the base of the food chain: they feed by filtering plankton and organic particulate suspended in the water (0.5 to 5 litres of filtered water per hour) and to do so they need adequate hydrodynamics, usually present near river mouths.

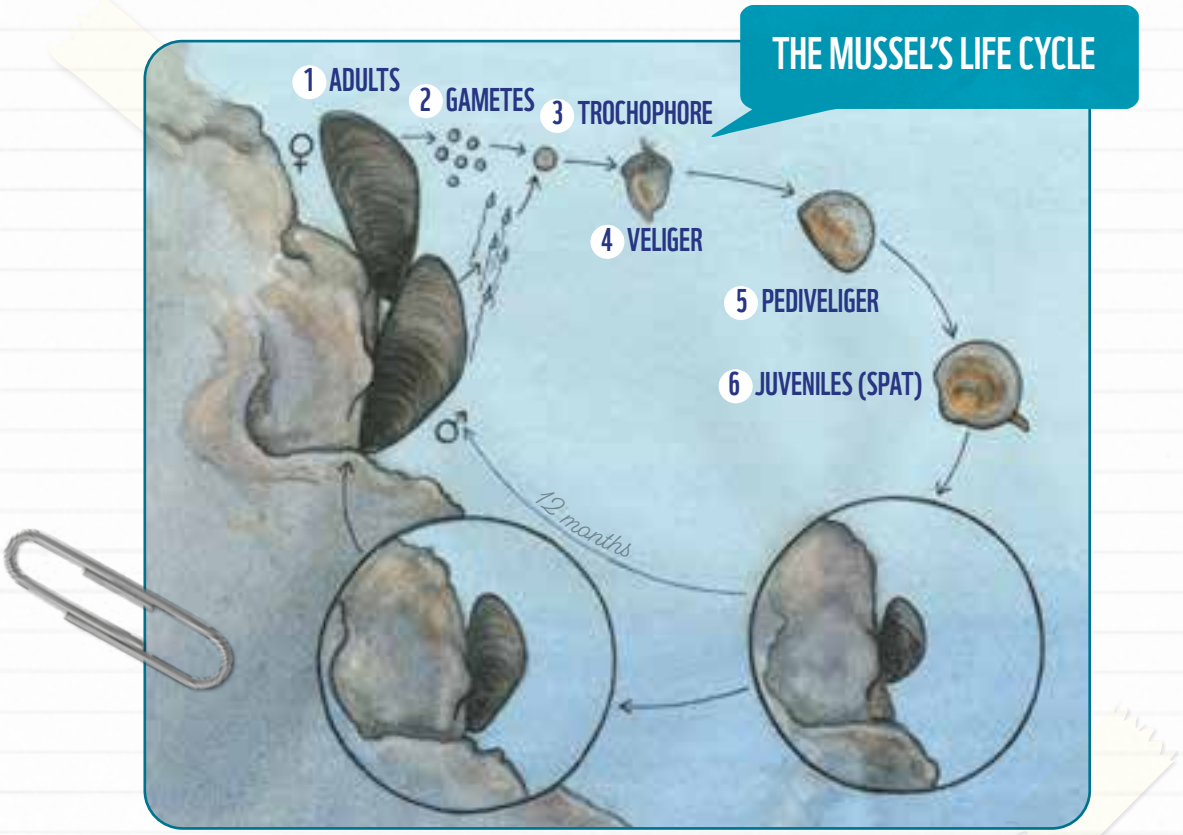
The **valve**, composed mainly of calcium carbonate, is black or black-purple on the outside, with thin radial and concentric growth circles towards the pointed end; the inside of the shell is smooth and pearly. The two valves are held together by a hinge with three or four denticles.

Once opened, the mollusc shows the mantle that contains all the internal organs, including the reproductive ones. The distinction between the **two sexes** can be made by observing the **colour of the mantle itself**: once they reach full sexual maturity, the males of the species are pale, white or yellowish in colour, while the females are a beautiful orange colour, sometimes very intense.

For reproduction, in spring and summer the females release **millions of eggs** into the water and the males **their sperm**. The eggs move like plankton into the open sea and from the fertilised ones **tiny larvae** are formed, which develop into young mussels, called spats of about three millimetres in the space of four weeks. Once they reach the adult stage, they are able **to cling onto rocks** or hard supports thanks to the byssus, a brown filament secreted by the mussels that solidifies upon contact with water and is known for its extraordinary tensile strength.

The average lifespan of the mussel is about four years and its sexual activity lasts a lifetime.

Its main predators are a few carnivorous Gastropods, some species of starfish and a few fish species, especially large Sparidae such as the Gilthead seabream, whose powerful jaws are able to overcome the protection provided by the mussel's calcareous shells.



OTHER MUSSEL SPECIES

But how can we distinguish locally farmed mussels from other products available on our markets? Let's try to compare some common species:

Mytilus edulis – Blue Mussel

Size: up to 7-8 cm

Distribution: Western Mediterranean and Atlantic. Not present in the Adriatic

Description: elongated shell very similar to *M. galloprovincialis* but more squared, dark brown in colour and not black-purple. The species shows a considerable variability of shapes

Features: the nutritional and organoleptic features are similar to those of *M. galloprovincialis*

Modiolus barbatus – Bearded Horse Mussel

Size: up to 6 cm

Distribution: entire Mediterranean and Atlantic

Description: characterised by the presence of bristles, variable colour (brown, yellowish, purplish and sometimes with light bands); variable shell shape and length of bristles

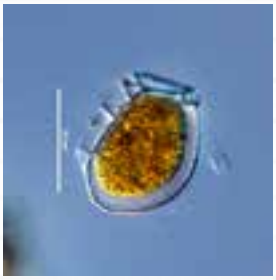
Features: it is not yet farmed and is therefore one of the few wild mussel species on the market, but breeding is being tested. It belongs to the same family (*Mytilidae*) but not to the genus *Mytilus*, the flavour is more intense and the cost higher than other mussels

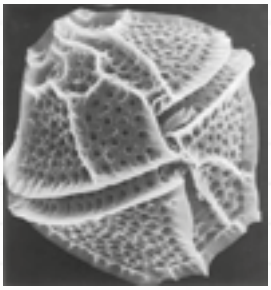
BIOTOXINES AND NUTRITION

The Adriatic Sea is also periodically, and with growing frequency, affected by the natural proliferation of **marine microalgae** that carry toxins that are particularly harmful to humans. By filtering large quantities of seawater, mussels can take on these algae and therefore contain high values of **biotoxins** that make them temporarily unmarketable: in these cases, mussel harvesting is forcibly blocked by the Health Authority until the parameters return to normal.

Unlike these biotoxins that cannot be removed by cooking and freezing, there are viruses and bacteria in shellfish that can be harmful to humans, but can be safely **eliminated by cooking**.

That's why it is crucial to avoid eating raw mussels.





Microalgae that carry toxins are accumulated by mussels and can cause serious infections in humans

NUTRITIONAL FEATURES

From a nutritional point of view, mussels have:

- ✓ a high protein content, only slightly lower than that of meat and fish, comparable to that of eggs;
- ✓ very high concentrations of iron;
- ✓ abundant concentrations of selenium (antioxidant) and zinc (important for growth and the immune system); presence of other minerals such as phosphorus, potassium and sodium;
- ✓ vitamins A, C, B, thiamine, riboflavin and calcium.

THE MAN-MADE ECOSYSTEM

As **concession areas**, where fishing and access are prohibited to any means except for the boats of mussel farmers, mussel farms are **true oases** for many species that find food and nutrients among the submerged lines. This is the case for large **pelagic animals** such as bottlenose dolphins and turtles and countless **seabirds**, several of them of community importance. They use mussel farm floats as perches to rest or launch themselves into acrobatic 'underwater hunts'. The best known is the European shag,

a skilled diver capable of very long apnoea. Among the floats you can also find eiders, sandwich terns, loons, grebes and many others.

Some of the species that can be found in the mussel farms between Grignano and Duino-Aurisina.
On the left: female eider with ducklings. Below: common dolphin.
On the opposite page, from the top-left photo clockwise: sandwich terns; barrel jellyfish; European shag.

All of them are, of course, attracted by the **great abundance of food** offered by the farms, including fish that, in turn, not only take advantage of mussels (such as giltheads, which are greedy for them), but also of the small crustaceans, molluscs, annelids and other organisms that colonise the farms. And it is precisely to this micro-world, its observation and discovery, that the practical workshop 'Biodiversity on mussel farms' is dedicated.

Are you ready? The microscope is waiting for you!

BIODIVERSITY ON MUSSEL FARMS

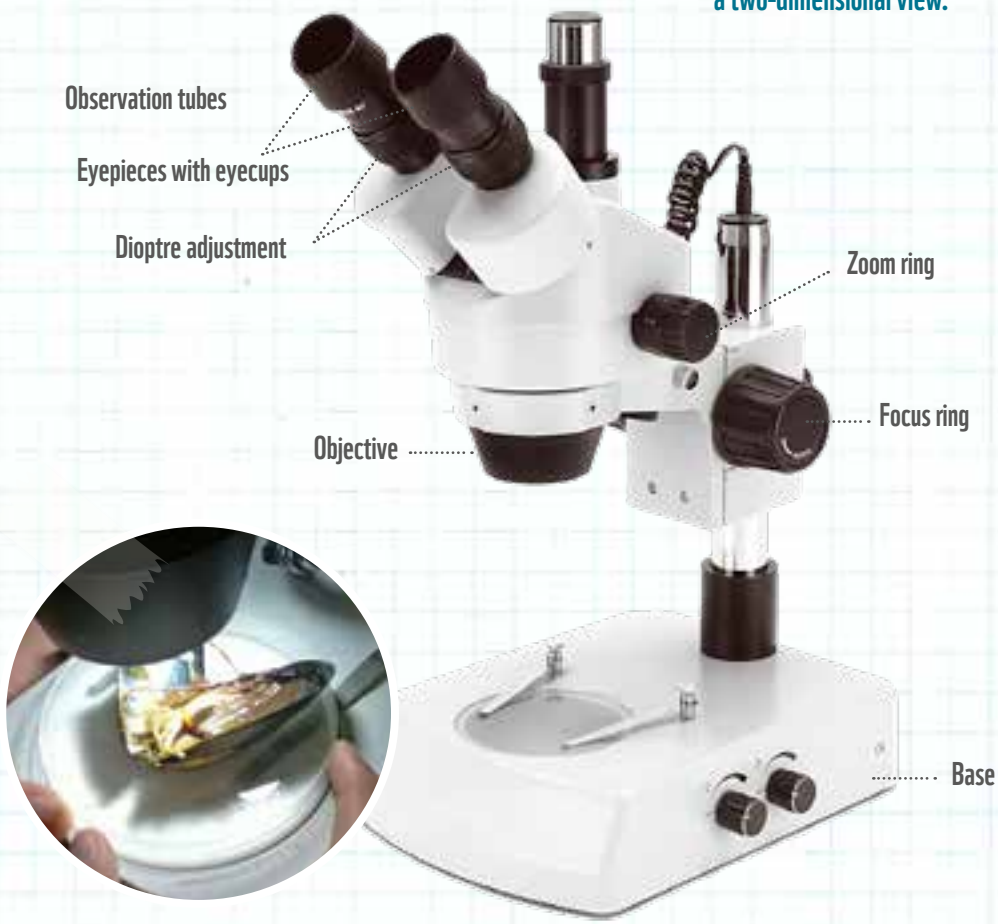
Observing a section of dropper lines under the microscope is a unique experience: it is like entering a miniature world, a treasure chest of marine biodiversity that reveals to the observer many species that have chosen this particular environment to settle, from algae to sponges, from anemones to annelids, from ascidians to the eggs of other species. If you are lucky, you may observe exceptional creatures such as brittle stars, nudibranchs and small crustaceans.

Some of the organisms found on the dropper lines that can be observed under the microscope

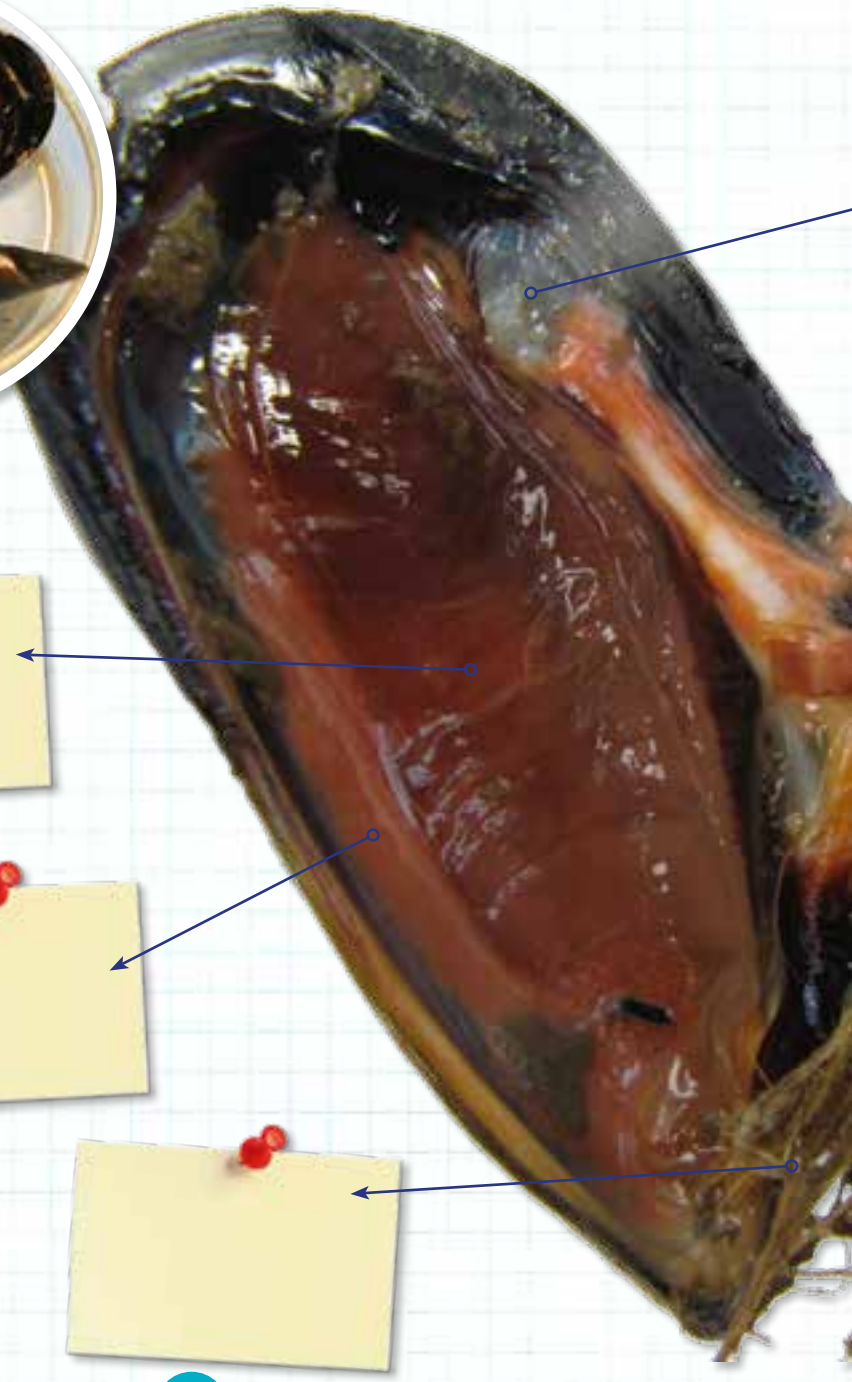
THE OBSERVATION TOOL

And here is the tool we are going to use to observe organisms hiding in a section of the dropper lines! It is a stereo microscope, with magnifications up to 80x, which allows us to see animals or plants that may be rather small in size and whose shapes we would not be able to recognise and appreciate with the naked eye.

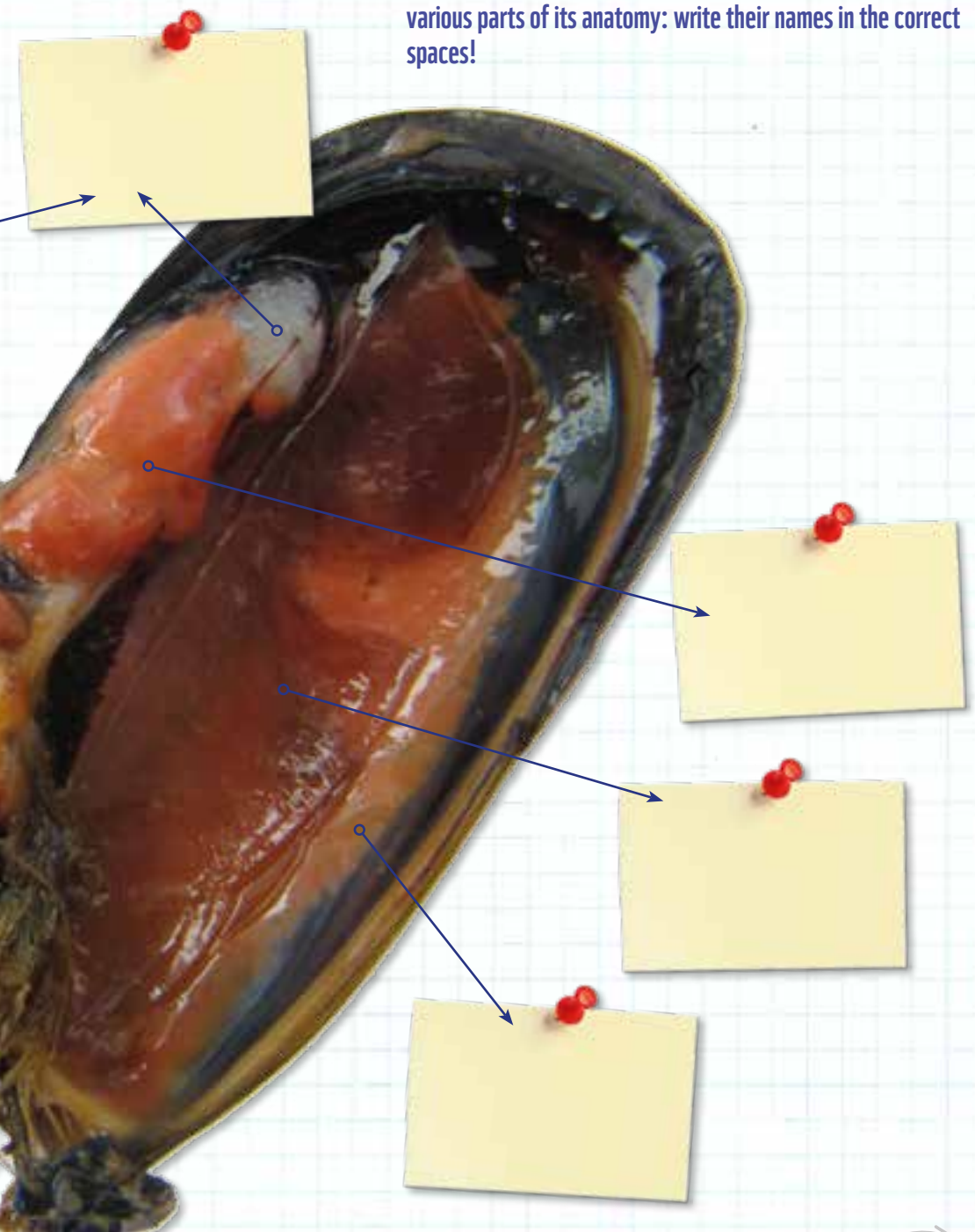
The stereo microscope allows a three-dimensional view of the objects observed and is more suitable for the analysis of opaque or thick samples, unlike the biological microscope which is more suitable for the observation of micro-organisms and provides a two-dimensional view.



THE SUBJECT UNDER OBSERVATION: THE MUSSEL



The first organism you will observe under the microscope is indeed the *Mytilus galloprovincialis*. If you have followed the trainer's explanation, then you will surly be able to identify the various parts of its anatomy: write their names in the correct spaces!



BENTHIC ORGANISMS

Droppers represent three-dimensional environments that serve as ideal habitats for many species, as they promote the settlement of sessile and interstitial invertebrates that in turn form the basis of various food webs. In this way, they increase the complexity of the existing sandy-mud environments and, as a result, the overall biodiversity.

Use these factsheets to recognise the key benthic organisms you observe under the microscope.

ALGAE

PLATYHELMINTHS (FLATWORMS)

SIPUNCULIDS

CNIDARIANS (SEA ANEMONES)

MOLLUSCS - GASTROPODS

MOLLUSCS - BIVALVES




MOLLUSCS - NUDIBRANCHES

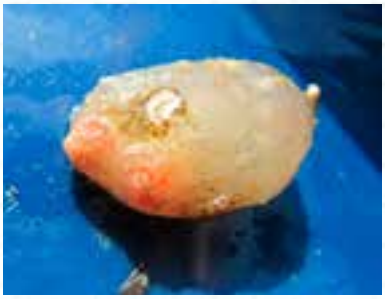



ANNELIDS - SEDENTARY POLYCHETES (TUBE WORMS)


ANNELIDS - WANDERING POLYCHETES

CRUSTACEANS

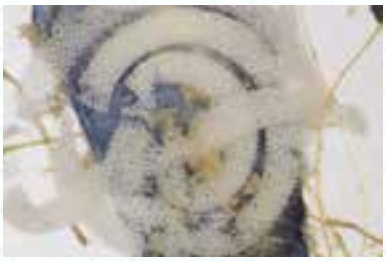
ASCIDS



ECHINODERMS

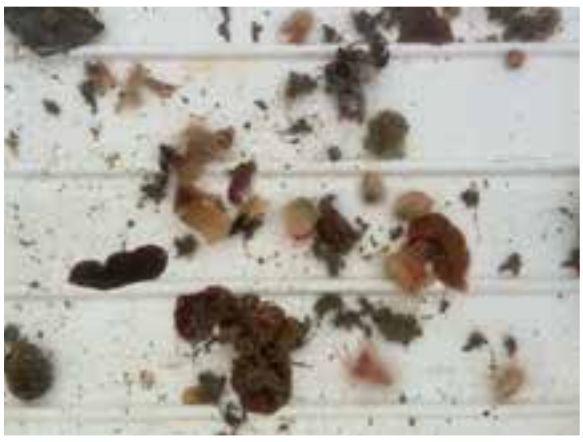
FISH

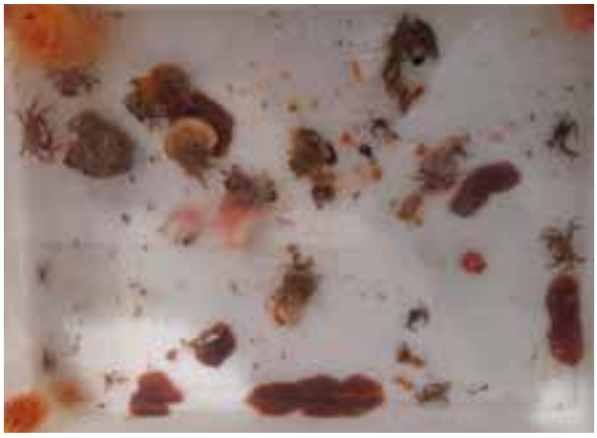
EGGS



KEEP YOUR EYES PEELED

Look at the pictures and try to identify the species present by using the factsheets on the previous pages.
Write the names of the benthic organisms you can spot and the number of individuals per species or *phylum* and then compare them with those reported by your classmates.





GLOSSARY

Adductor muscles: muscles, inserted on the inner face of the shells, which by contracting allow the shell to close and open.

Algae: plant organisms, mainly aquatic, without a differentiated structure in roots, stem, leaves and flowers.

Anchor block: concrete structure used to anchor the lines of mussel farms in place.

Annelids: worm-like organisms (e.g. earthworms and leeches) whose bodies are divided into segments called metameres or, more commonly, rings.

Aquaculture: farming of fish, molluscs, crustaceans in fresh or salt water.

Ascidians: Sea animals belonging to the chordates, sack-shaped, living solitary or in colonies, attached to the seabed or submerged objects.

Bacteria: simple, primitive single-celled organisms (consisting of a single cell).

Benthos: the community of all organisms, animal and plant, living close to the seabed.

Bivalves: molluscs with a shell consisting of 2 parts, called valves.

Byssus: commonly called byssal thread or beard, it is a filamentous structure used by bivalves to anchor themselves to a substrate.

Cell: the morphological and functional unit of all living organisms, which may consist of a single cell (unicellular or single-cell organisms, such as amoebas) or of a varied, mostly very large number of cells joined together to form tissues (multicellular organisms, such as man).

Chordates: animals with a dorsal cord (sketch of a spinal column) in the embryonic state, which may or may not be preserved in the adult state.

Cnidarians or coelenterates: invertebrates, mainly marine aquatic, of elementary structure and gelatinous consistency, equipped with stinging tentacles. Cnidarians include jellyfish and sea anemones.

Crustaceans: marine, freshwater and more rarely terrestrial or semi-terrestrial animals. They have a body divided into a head, thorax and abdomen, frequently covered by a hard shell (carapace), four antennae and ten or more legs, the first pair of which are transformed into pincers (chelae). This group includes, for example, lobsters and prawns.

Dropper line: nylon mesh line on which mussels are grown.

Echinoderms: exclusively marine and benthic invertebrates with a skin skeleton consisting of perforated calcareous plates arranged in a radial pattern. They include sea urchins, starfish, sea cucumbers and brittle stars.

Ecosystem: the combination of living organisms and non-living matter (such as sand, rock...) that interact with each other.

Extensive farming: these are forms of livestock farming practised over large areas, where the animals, with a low density of individuals, are left free and feeding is not dependent on humans.

Fishing gear: all the devices used for fishing.

Foot: muscular organ used by molluscs for crawling, burrowing or swimming.

Gastropods: a class of molluscs, including terrestrial, freshwater and primarily marine species. They are usually provided with a calcareous spiral dorsal shell, from which the foot for locomotion and the head with tentacled eyes emerge. This class includes snails, slugs and limpets.

Gills: a characteristic respiratory organ found in fish, molluscs and other aquatic animals; it consists mostly of a lamellar structure on the walls of which gas exchanges with oxygen dissolved in water occurs.

Grading machine: machine used to separate mussels according to their size .

Headlines: ropes onto which droppers are tied.

Intensive farming: these are forms of farming that use industrial and scientific techniques to obtain the maximum amount of product at the minimum cost. This is achieved with a high density of individuals in confined spaces (pens, cages, tanks), feeding them with feed and administering drugs.

Juveniles ("spat"): small mussels just a few days old (< 1 cm long).

Mantle: structure that produces the shell and protects the internal organs.

Molluscs: invertebrate animals, marine, freshwater or terrestrial, with a soft body, almost always provided with a shell.

Mussel farming: farming of mussels (*Mytilus galloprovincialis*).

Nudibranchs: small gastropod molluscs, without a shell and brightly coloured, mostly living on rocky seabed.

Parasite: any animal or plant organism that lives at the expense of another.

Platyhelminthes: flatworms, invertebrate worm-like organisms characterised by a flat, ribbon-like or leaf-like body. Some live freely in the sea, fresh water or damp land, while others are internal or external parasites of vertebrates, including humans, such as tapeworms.

Polychaetes: a class of aquatic annelids with a body provided with numerous bristles neatly arranged in tufts.

Porifera: simple-structured marine or freshwater animals with a sac-like body consisting of a set of holes and channels through which water circulates. Commonly known as sponges.

Re-seeding phase: involves placing groups of mussels, larger than the spat, into nylon nets with larger mesh and diameter.

Seeding phase: the introduction of small mussels, typically 1-3 cm in size, into the sock using tubes or similar tools.

Shellfish farming: farming of different species of molluscs (usually oysters, clams and mussels).

Sock: nylon or cotton net in which mussels are placed.

Sock stripper: stripping machine that separates mussels and socks.

Toxins: dangerous substances that may be present in the algae on which mussels feed.

Tube worms: particular group of annelids living inside tubes of calcium carbonate, sand or mud.

Virus: parasite that lives and multiplies at the expense of a living cell.

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