Marine heatwaves in the Archipelago Sea – coping mechanisms

Citizen science project:

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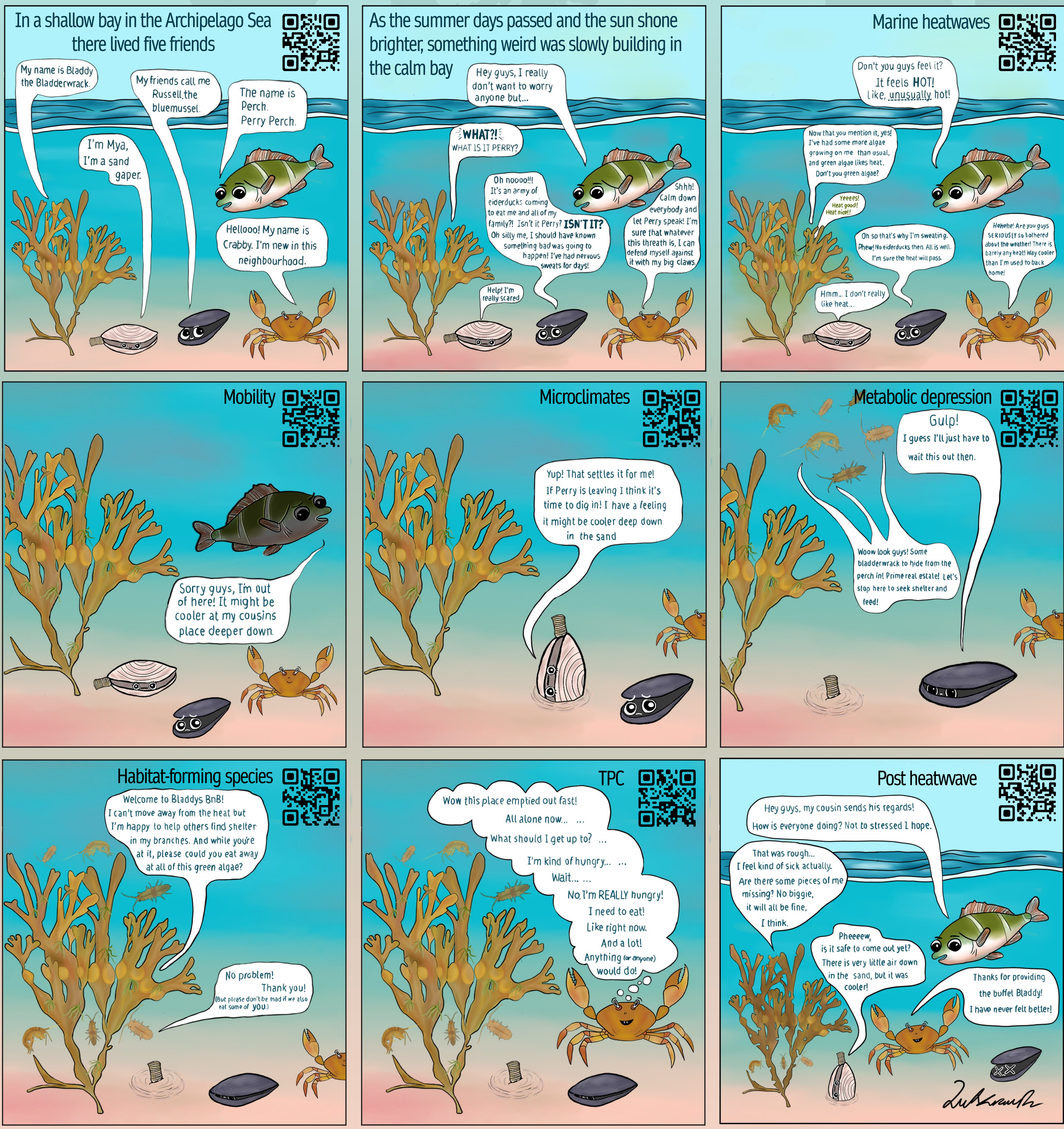

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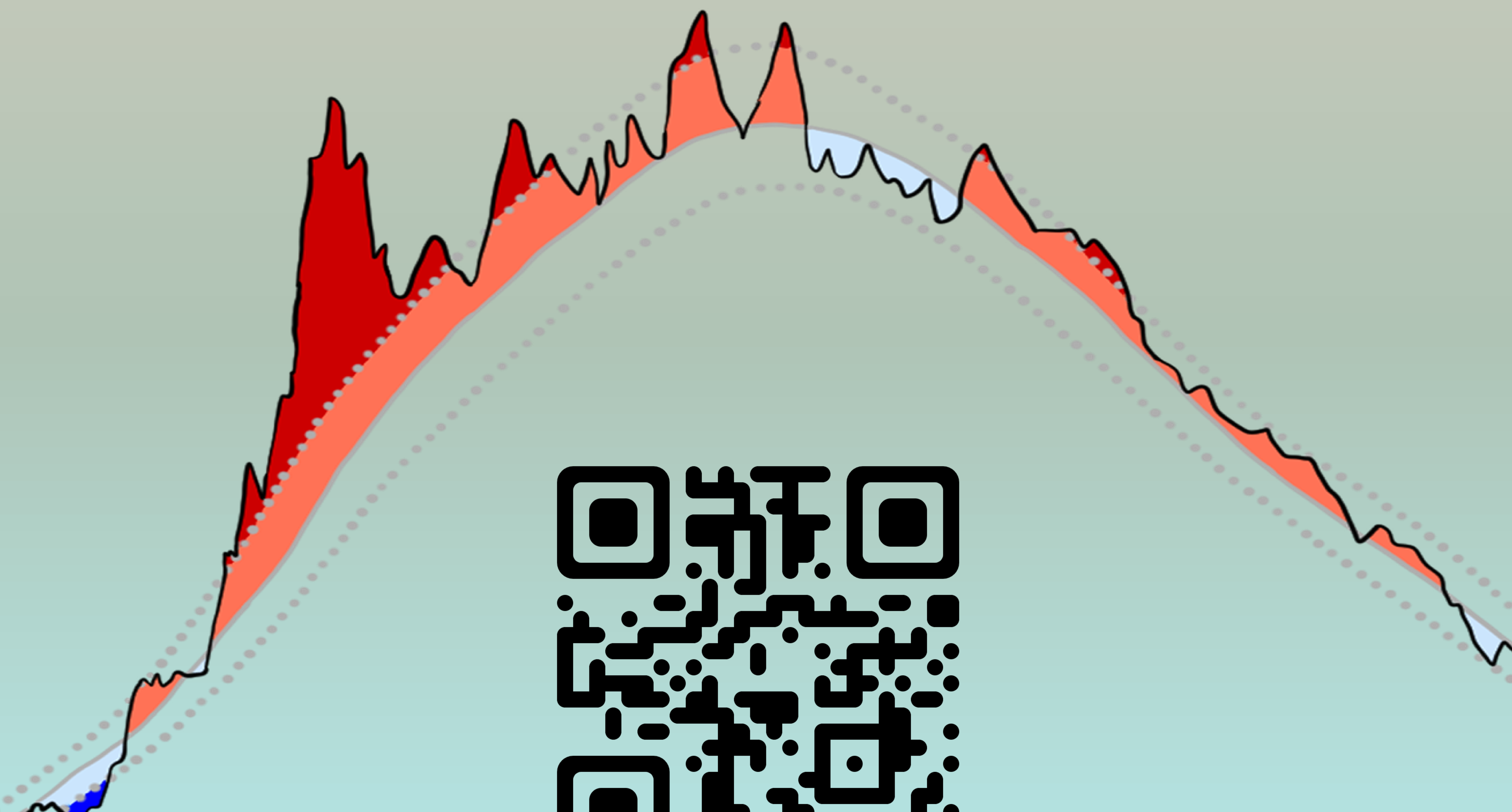
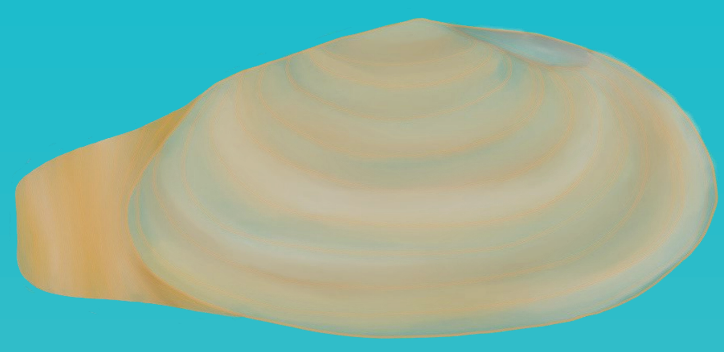
Or visit:

https://github.com/lukraufv/cit_sci_25

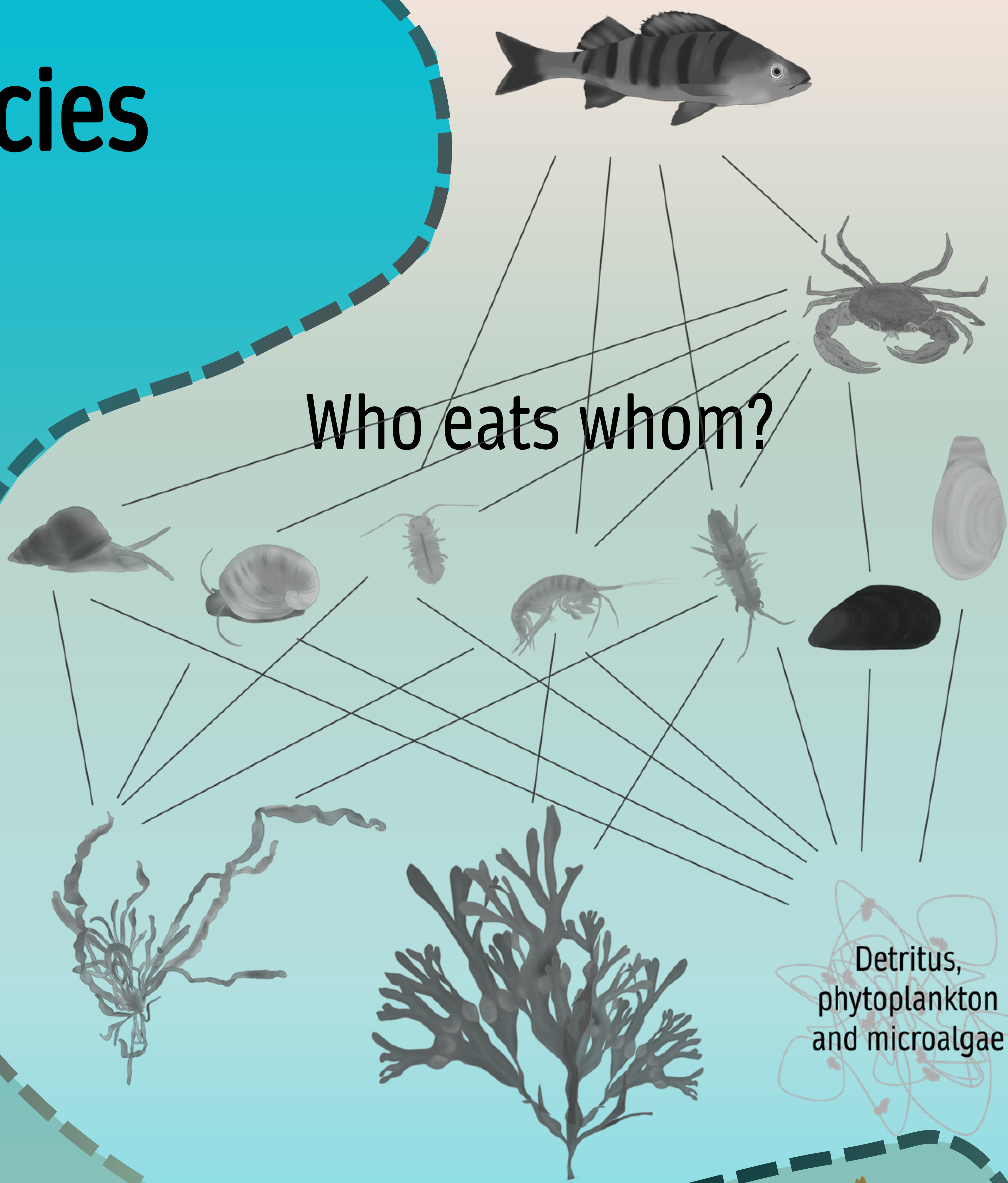


Archipelago Sea species

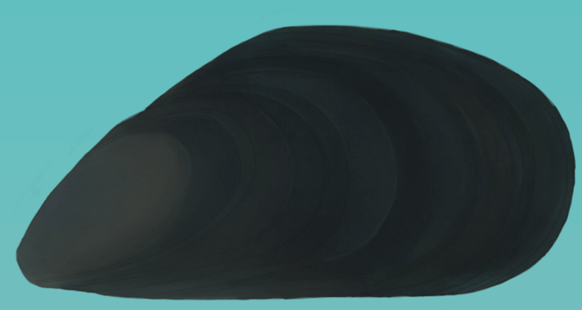
Sand gaper
(Mya arenaria)



Sand gapers are suspension feeders that live buried in the sand or sediment
Eats: Plankton, diatoms and suspended particles
Lifespan: 10 – 12 years. Maximum 28 years
Temperature tolerance: Up to 29 °C
Size: Up to 5 cm



Bluemussel
(Mytilus trossulus)



A bivalve that attaches to hard surfaces and filters food from the water
Eats: Plankton and microalgae
Lifespan: Lives for up to 10–12 years
Temperature tolerance: Around 25-28 °C
Size: 1-4 cm

Perch
(Perca fluviatilis)

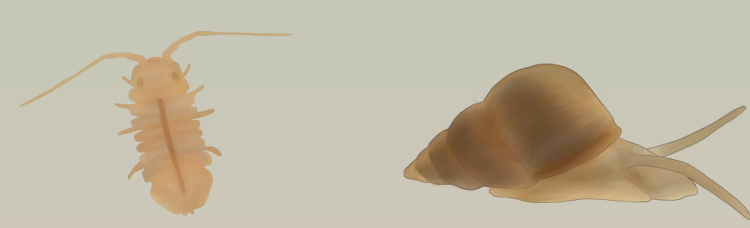
This fish lives in both fresh and brackish waters and is known for its striped appearance.
Eats: Mainly crustaceans and smaller fish.
Lifespan: Lives for 10-12 years
Temperature tolerance: Up to 31 °C
Size: Up to 50 cm

Bladderwrack
(Fucus vesiculosus)

A seaweed, providing shelter for many species.
Lives on rocky substrates
Eats sunlight
Lifespan for 2-5 years at depths of up to 6 meters
Temperature tolerance: Around 25-27 °C

Harris mudcrab
(Rhithropanopeus harrisii)

Native to North America; now invasive in parts of Europe including the Baltic Sea.
Eats: Omnivorous – feeds on mussels, clams, amphipods isopods and detritus.
Lives for 1-3 years
Temperature tolerance: Up to 36 °C
Size: Up to 2 cm



Snails, amphipods and isopods
Hydrobia, Idotea, Gammarus, Jaera...

Some of the species that live in bladderwrack
Eats green, red and brown algae
Lives for 1-2 years
Temperature tolerance: Varies – some are more sensitive than others
Size: 0.1 – 1 cm

Drawings:

What are marine heatwaves?

A marine heatwave is when sea surface temperatures stay unusually high—above the 90th percentile for that time and place—**for five or more days** (Hobday et al., 2016).

These events can be triggered by weak winds, increased solar radiation, persistent high-pressure systems, or shifts in ocean currents. While often seen in open oceans, they also occur in smaller seas like the Baltic Sea, where their impact can be just as intense.

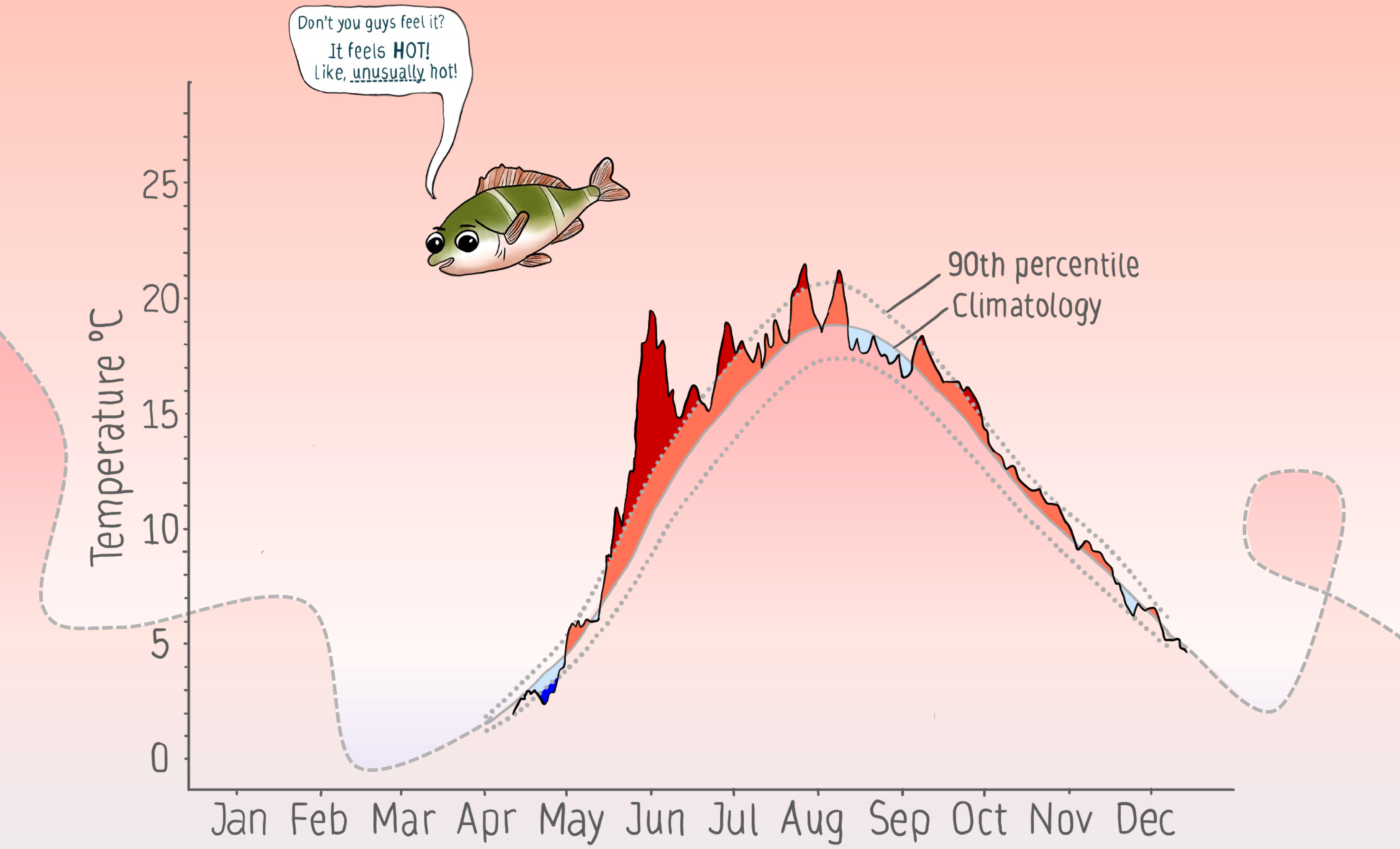


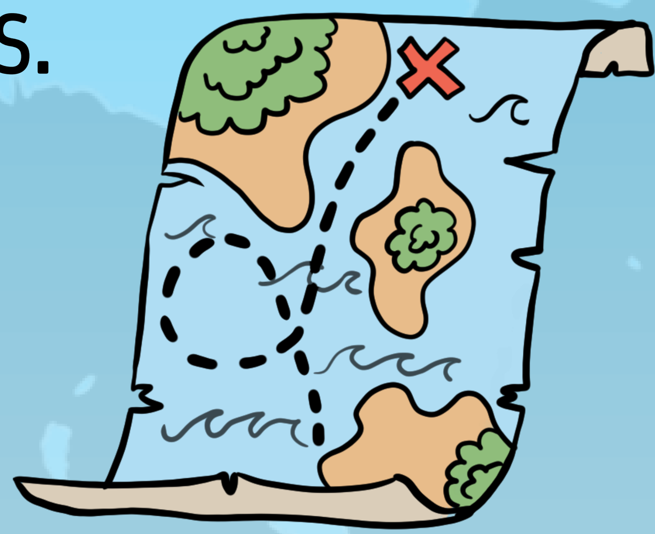
Figure 1. Temperature data collected at Korpoström, Finland, 2024. The data are shown together with a climatology (grey line), which is a long-term average based on many years of seawater temperature records from Seili, Finland. By comparing current temperatures to this average, we can see when the water temperature shifts from normal (orange/light blue) to heatwave conditions (red) or cold spells (blue). If temperatures stay above or below the dotted lines for more than five days, it signals a heatwave or cold spell, respectively.

Hobday, Alistair J., Lisa V. Alexander, Sarah E. Perkins, Dan A. Smale, Sandra C. Straub, Eric C. J. Oliver, Jessica A. Benthuysen, et al. 'A Hierarchical Approach to Defining Marine Heatwaves'. *Progress in Oceanography* 141 (1 February 2016): 227–38. https://doi.org/10.1016/j.pocean.2015.12.014.

Drawings:

Migration

Migration is a natural response many species use to avoid extreme temperatures, including marine heatwaves. It involves moving from one habitat to another—temporarily or permanently—to find more favorable conditions.



Who can and can't migrate?

Mobile species like fish, and some marine invertebrates

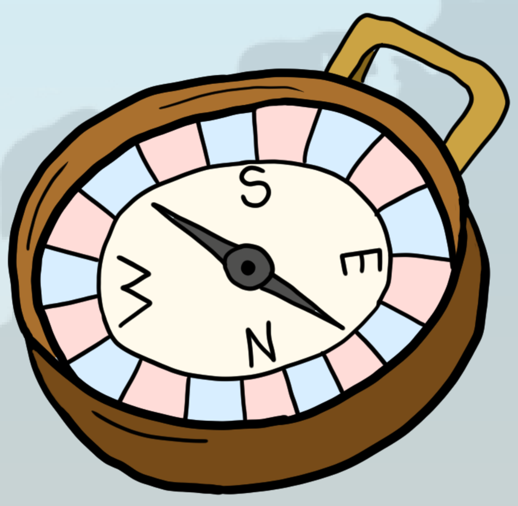
Sessile or slow-moving species (e.g. corals, mussels, plants) cannot migrate, making them more vulnerable to heat stress.

Types of Migration:

Latitudinal migration: Moving north or south to cooler regions.

Vertical migration: Moving deeper in the water column or underground.

Microhabitat shifts: Seeking shaded, sheltered, or cooler spots within the same area.



In the **Baltic Sea**, the **European perch** (Perca fluviatilis) can adapt to changing temperature conditions. Perch are **trophic generalists** and can live in a wide range of habitats.

While perch are not known for long-distance migrations like salmon, they can **shift locally**—meaning they have the capacity to move to **deeper or shaded waters** during heatwaves to escape elevated surface temperatures. This kind of **short-range migration** can help them avoid thermal stress and maintain access to food and oxygen. But as heatwaves grow more intense, cool refuges may grow more scarce.

Ning, Nathan, Chris Barlow, Lee J. Baumgartner, Joachim B. Bretzel, Katherine E. Doyle, Deanna Duffy, Amina Price, and An V. Vu. 'A Global Review of the Biology and Ecology of the European Perch, Perca Fluviatilis'. *Reviews in Fish Biology and Fisheries* 35, no. 2 (1 June 2025): 587–618. https://doi.org/10.1007/s11160-025-09924-z.

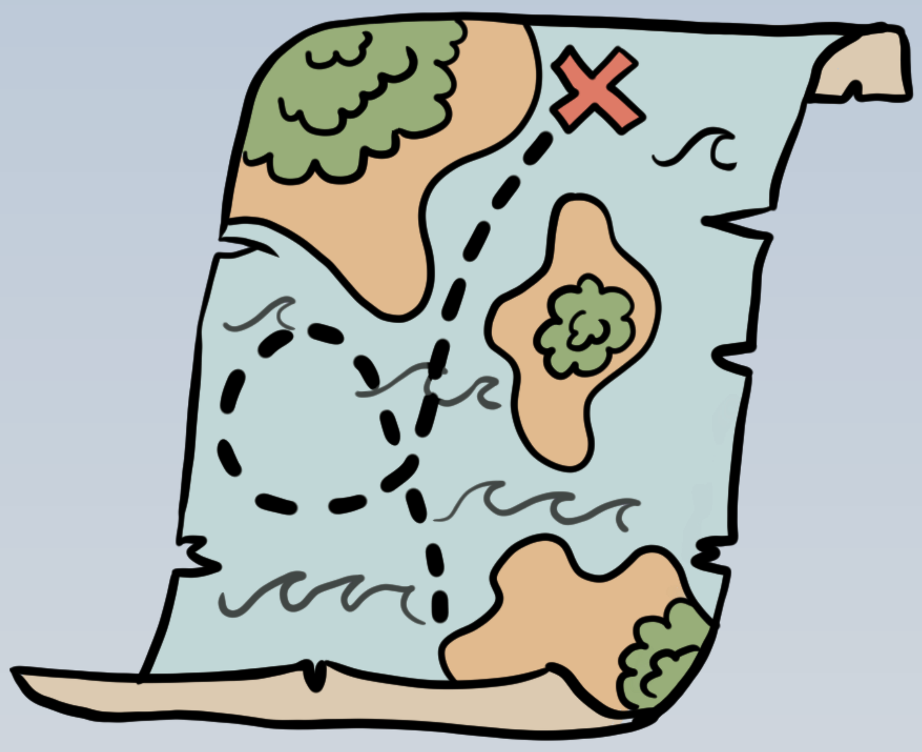
Drawings:

Microhabitats

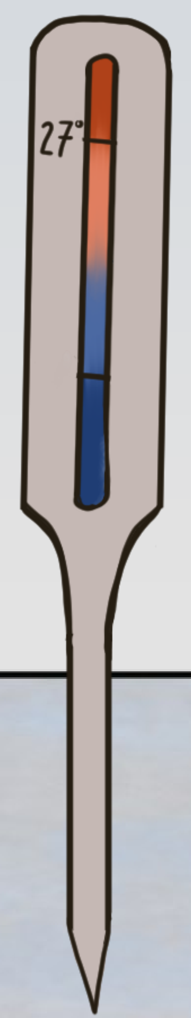
Just like on land, the ocean has microclimates—small areas where conditions differ from the surrounding water. These can be cooler, more shaded, or better oxygenated, offering refuge for marine life during extreme events like marine heatwaves.

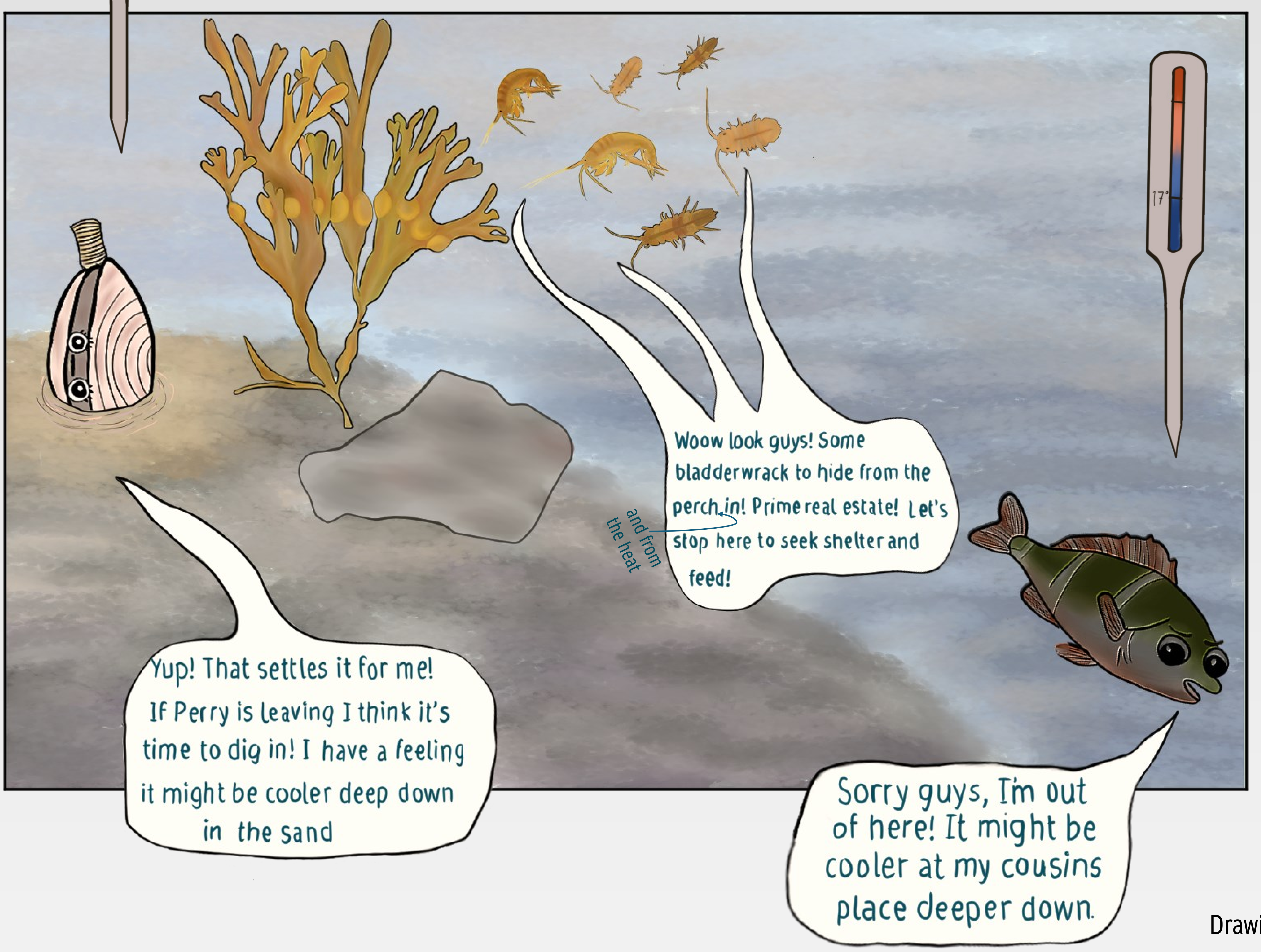
Microhabitats can form:

- Under seaweed canopies (like Fucus vesiculosus)
- In crevices or shaded rocky areas
- At greater depths, where water warms more slowly
- Near freshwater inflows, which can cool surface layers



For species with limited mobility, these microhabitats can mean the difference between survival and stress. But as heatwaves become more intense, even these safe spots may become less effective.

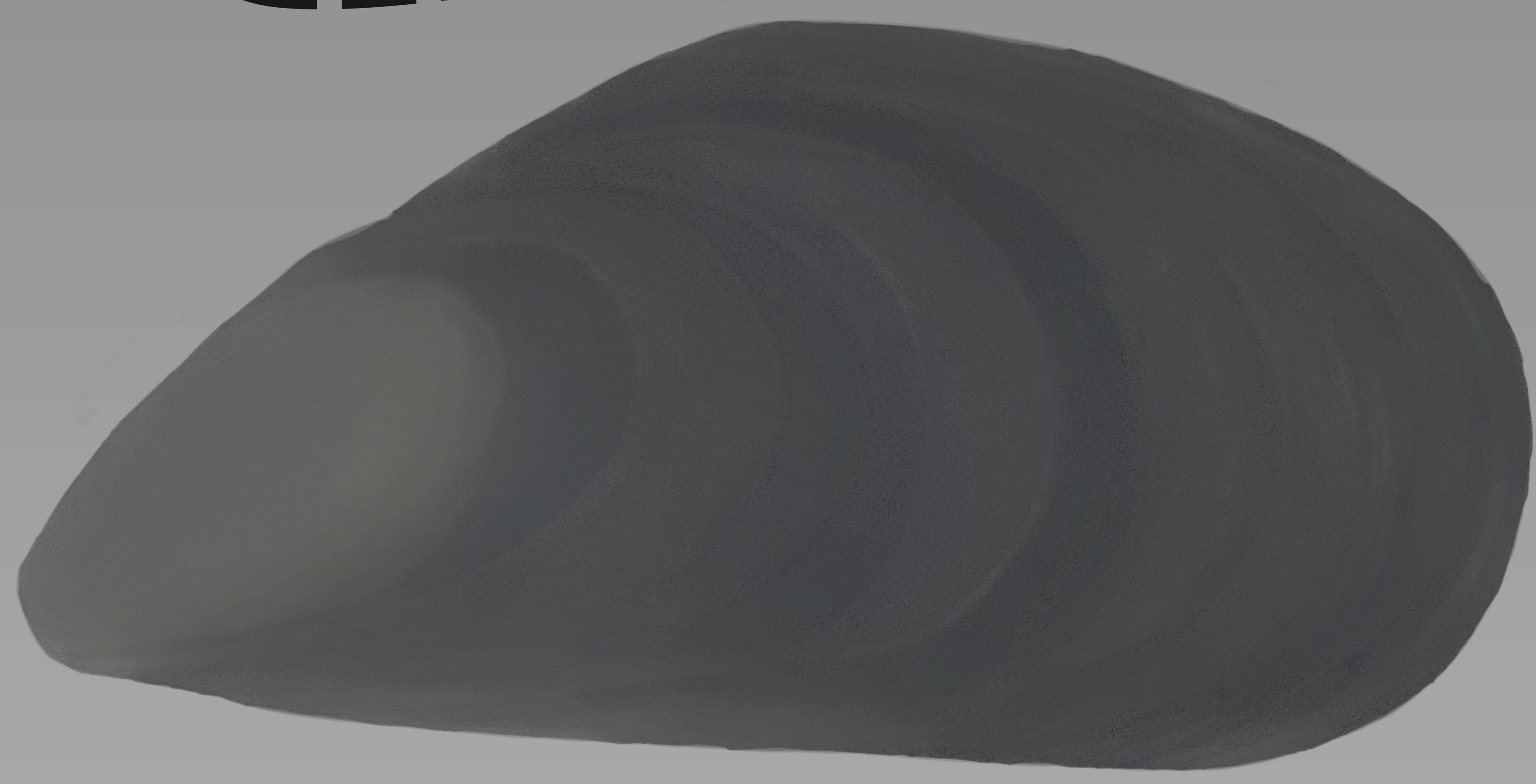




Drawings:

Metabolic depression

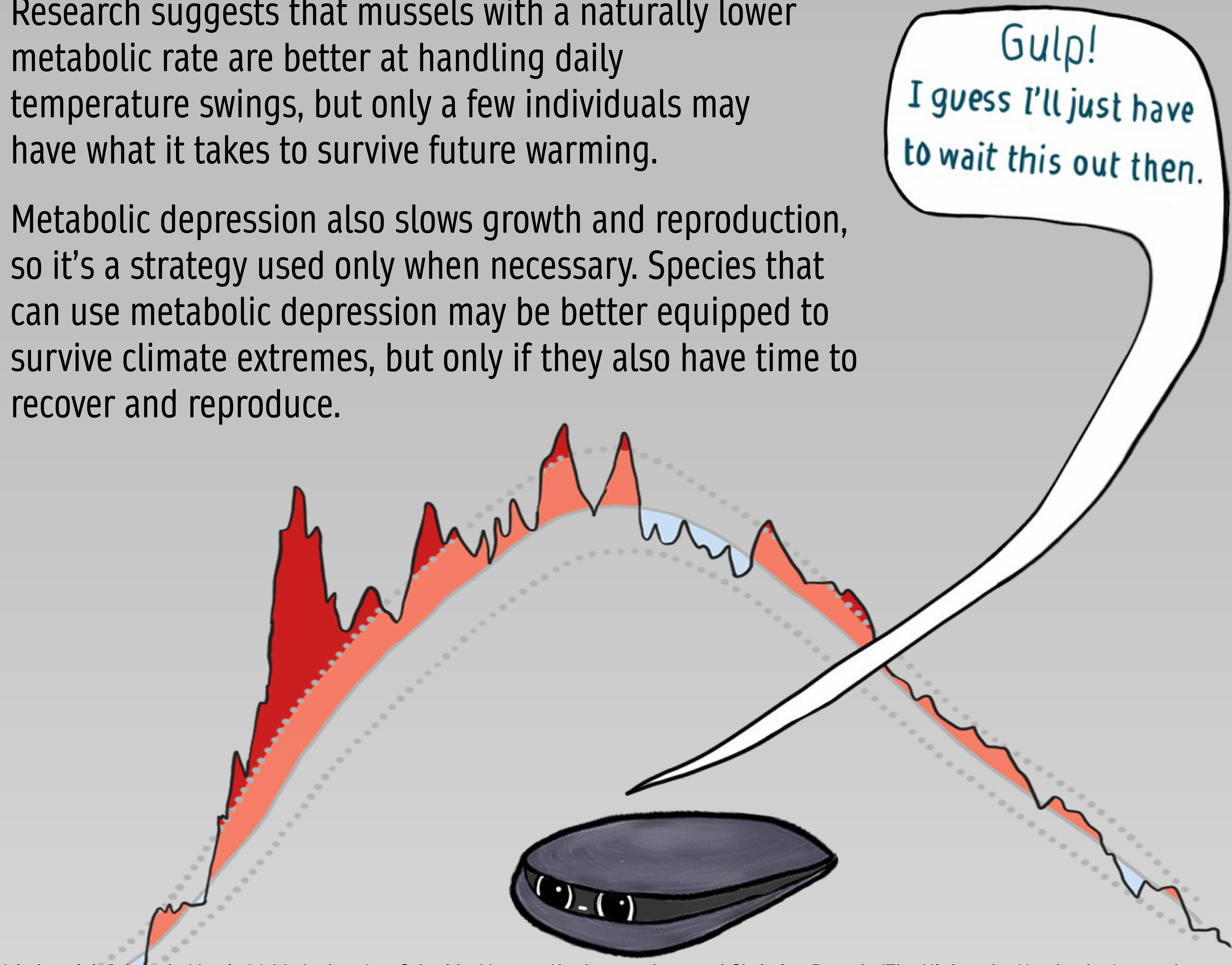
Metabolic depression is when an organism intentionally lowers its metabolic rate—reducing energy use, oxygen consumption, and activity levels. It's like putting the body into "low-power mode" to survive tough conditions.



Some young blue mussels ***(Mytilus spp.)*** may survive extreme heat by slowing their metabolism—reducing how much they eat and breathe. This strategy, called metabolic depression, helps them avoid a dangerous mismatch between energy supply and demand during heatwaves.

Research suggests that mussels with a naturally lower metabolic rate are better at handling daily temperature swings, but only a few individuals may have what it takes to survive future warming.

Metabolic depression also slows growth and reproduction, so it's a strategy used only when necessary. Species that can use metabolic depression may be better equipped to survive climate extremes, but only if they also have time to recover and reproduce.

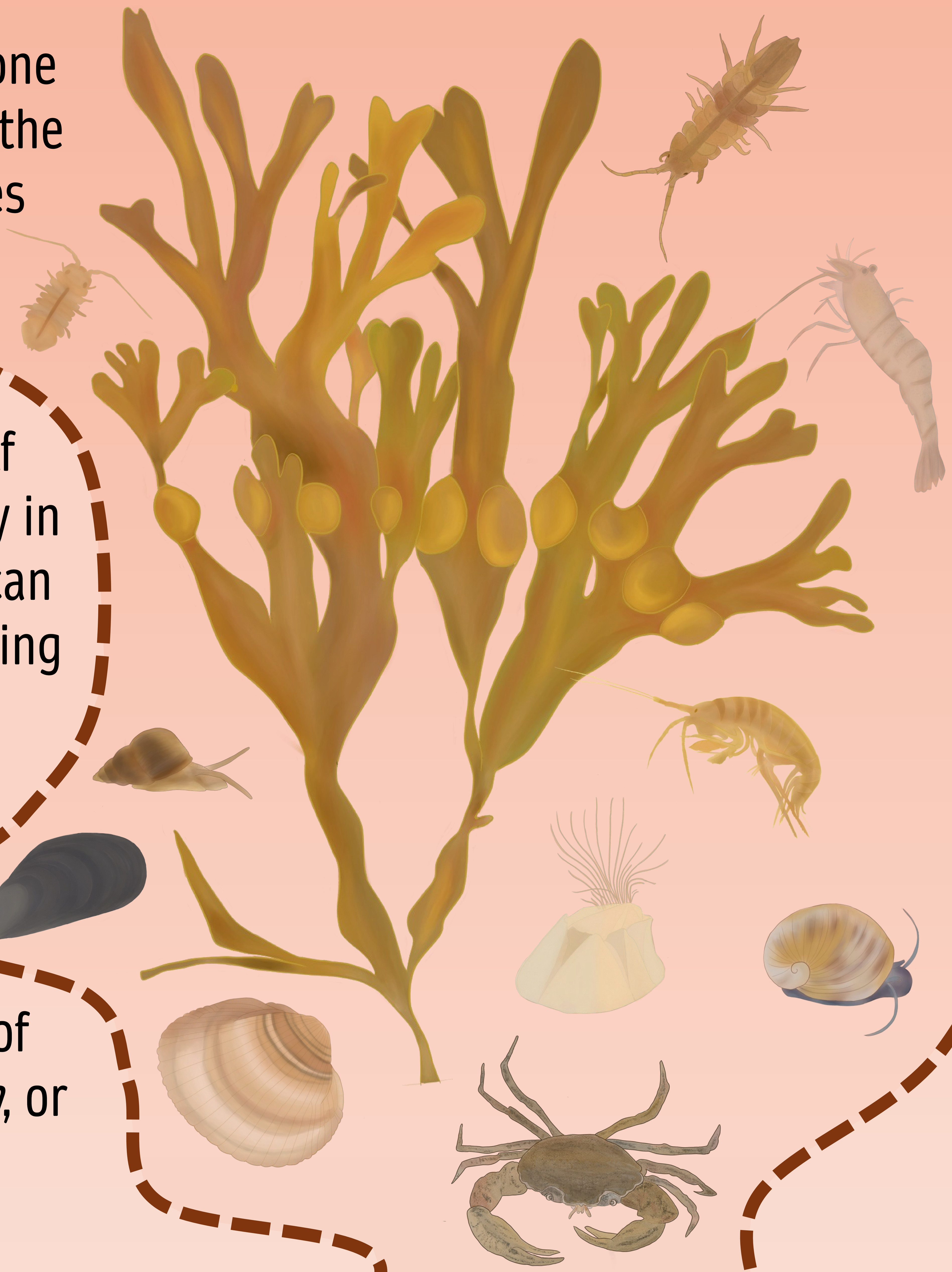


Vajedsamiei, Jahangir, Martin Wahl, Andrea Lee Schmidt, Maryam Yazdanpanahan, and Christian Pansch. 'The Higher the Needs, the Lower the Tolerance: Extreme Events May Select Ectotherm Recruits With Lower Metabolic Demand and Heat Sensitivity'. *Frontiers in Marine Science* 8 (2021). https://www.frontiersin.org/articles/10.3389/fmars.2021.660427.

Drawings:

Habitat forming species

Some species don't just survive in their environment—they shape it and make up the foundation of the habitat. These are called habitat-forming species.



Fucus vesiculosus (bladderwrack) is one of them, found along rocky shores of the Baltic Sea, this brown seaweed creates underwater forests that shelter fish, invertebrates, and algae.

During marine heatwaves, Fucus itself can suffer from heat stress, especially in shallow waters. But when healthy, it can buffer temperature extremes by shading the seafloor and slowing water movement. This creates cooler microhabitats that may help other species survive the heat.

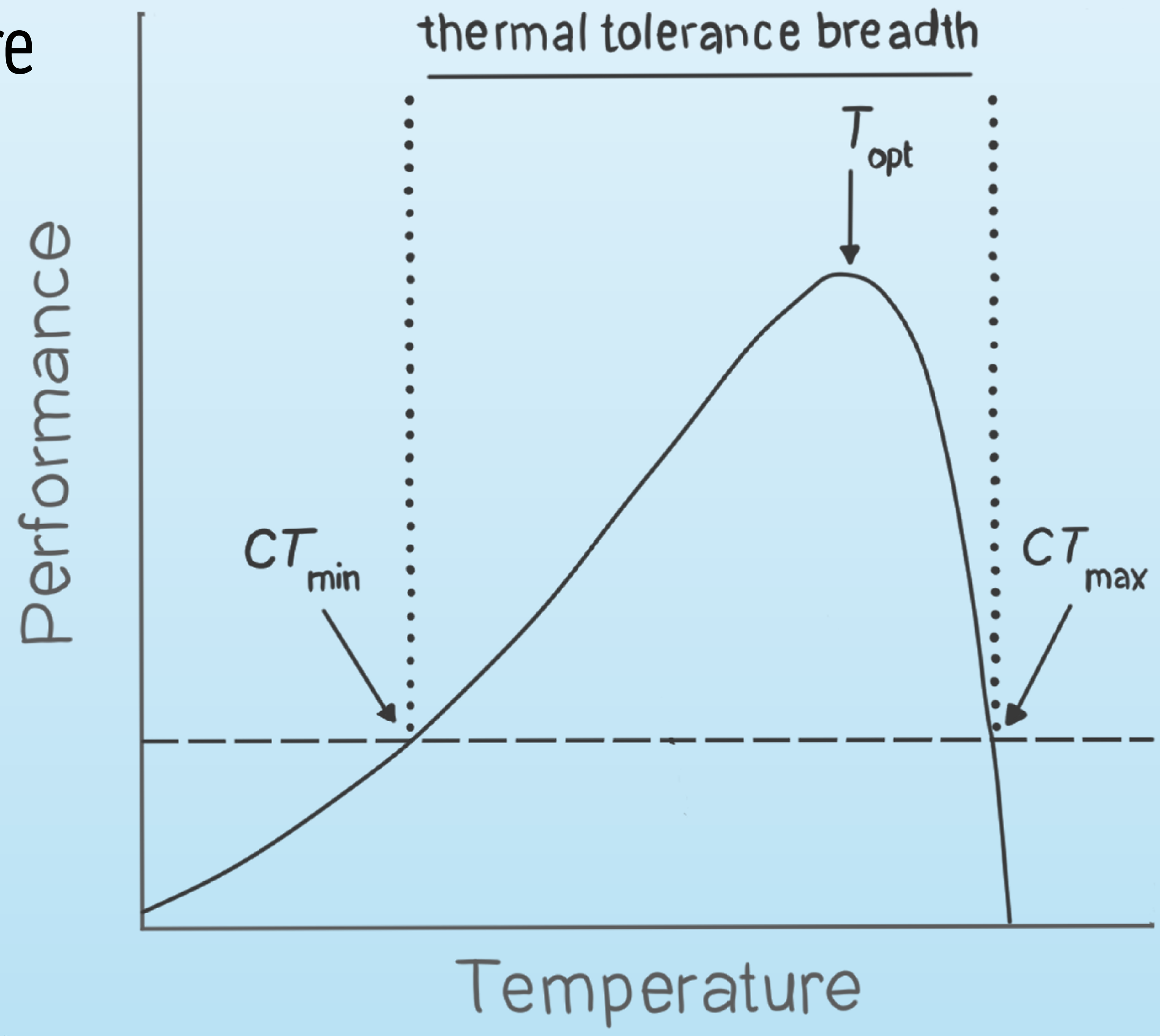
Warmer waters often lead to blooms of green algae like *Ulva* and *Cladophora*, or brown algae like *Pylaiella* which can smother Fucus, blocking light and reducing its ability to photosynthesize and grow.

If heatwaves become too intense or frequent, even these ecosystem engineers may struggle—putting entire communities at risk.

Drawings:

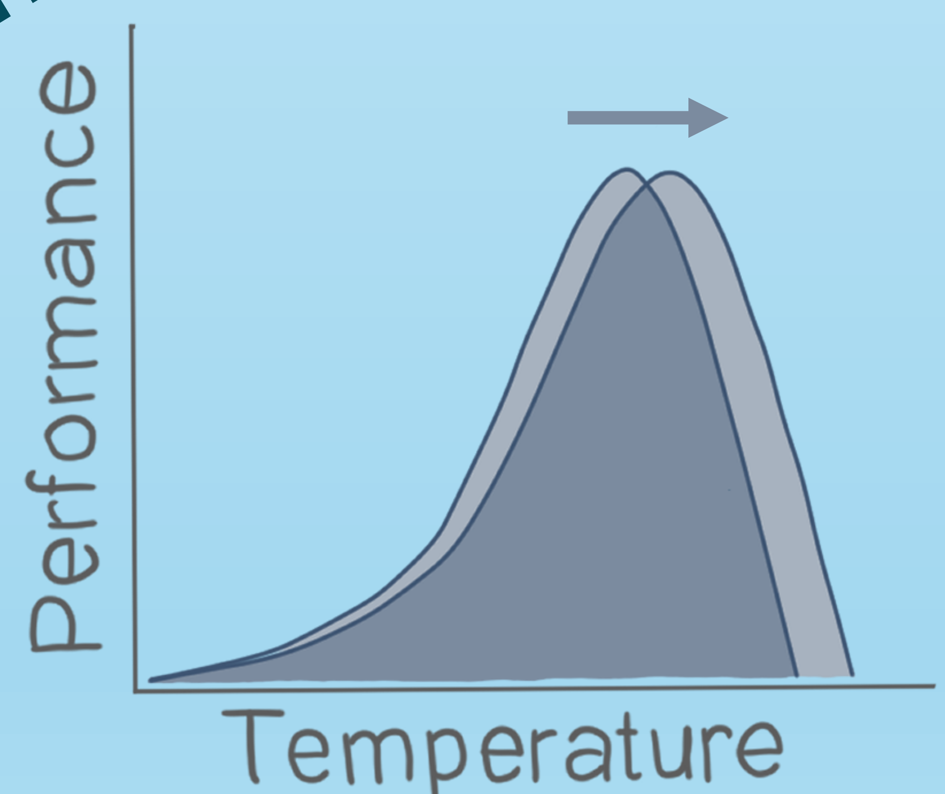
Temperature performance curves

Every species has a temperature range where it performs best—this is shown by a Temperature Performance Curve (TPC). The curve usually looks like a hill:

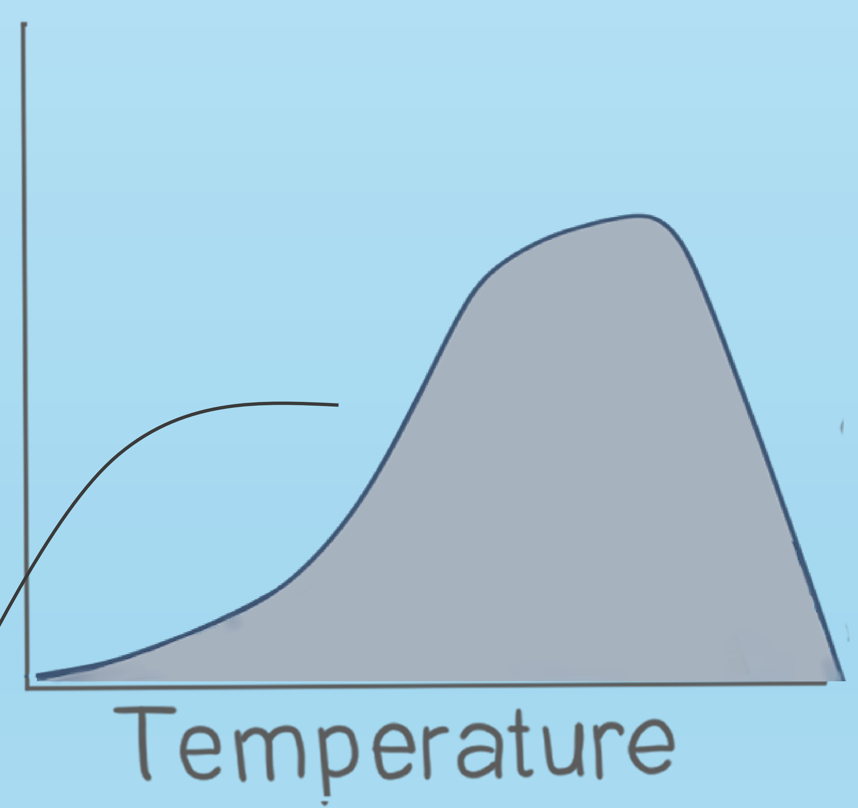


Rising slope: Performance improves as temperature increases.
Peak: The optimal temperature (T_{opt})
Falling slope: Performance drops as temperatures get too hot.
Critical thermal limits (CT): Beyond these, survival is at risk.

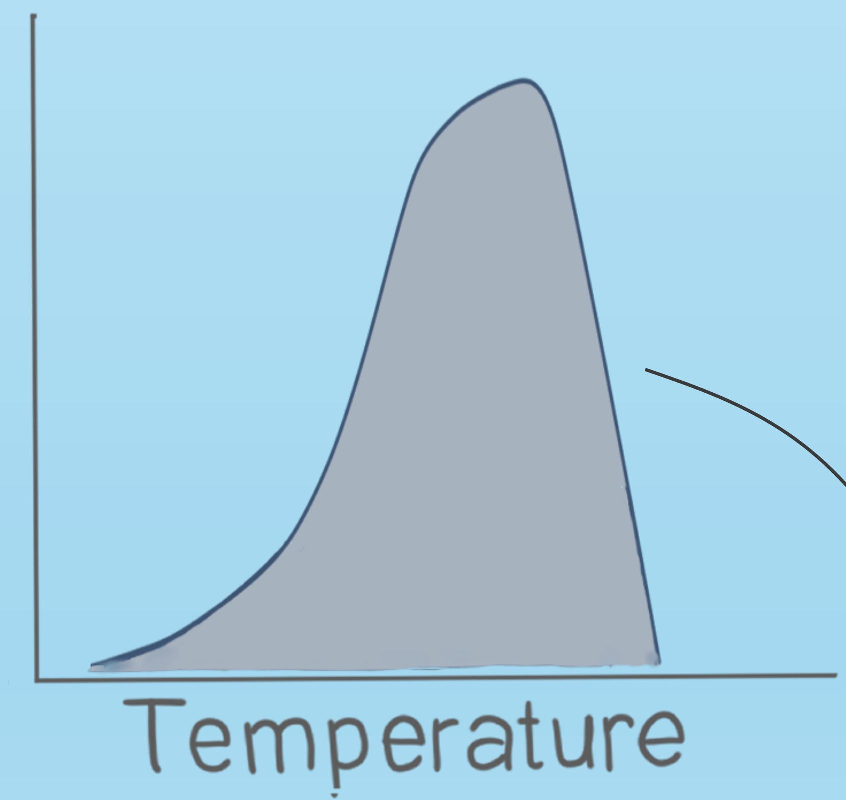
TPCs can shift with acclimation or evolution



1. The peak might move to a higher temperature.



2. The curve might flatten, allowing broader tolerance.



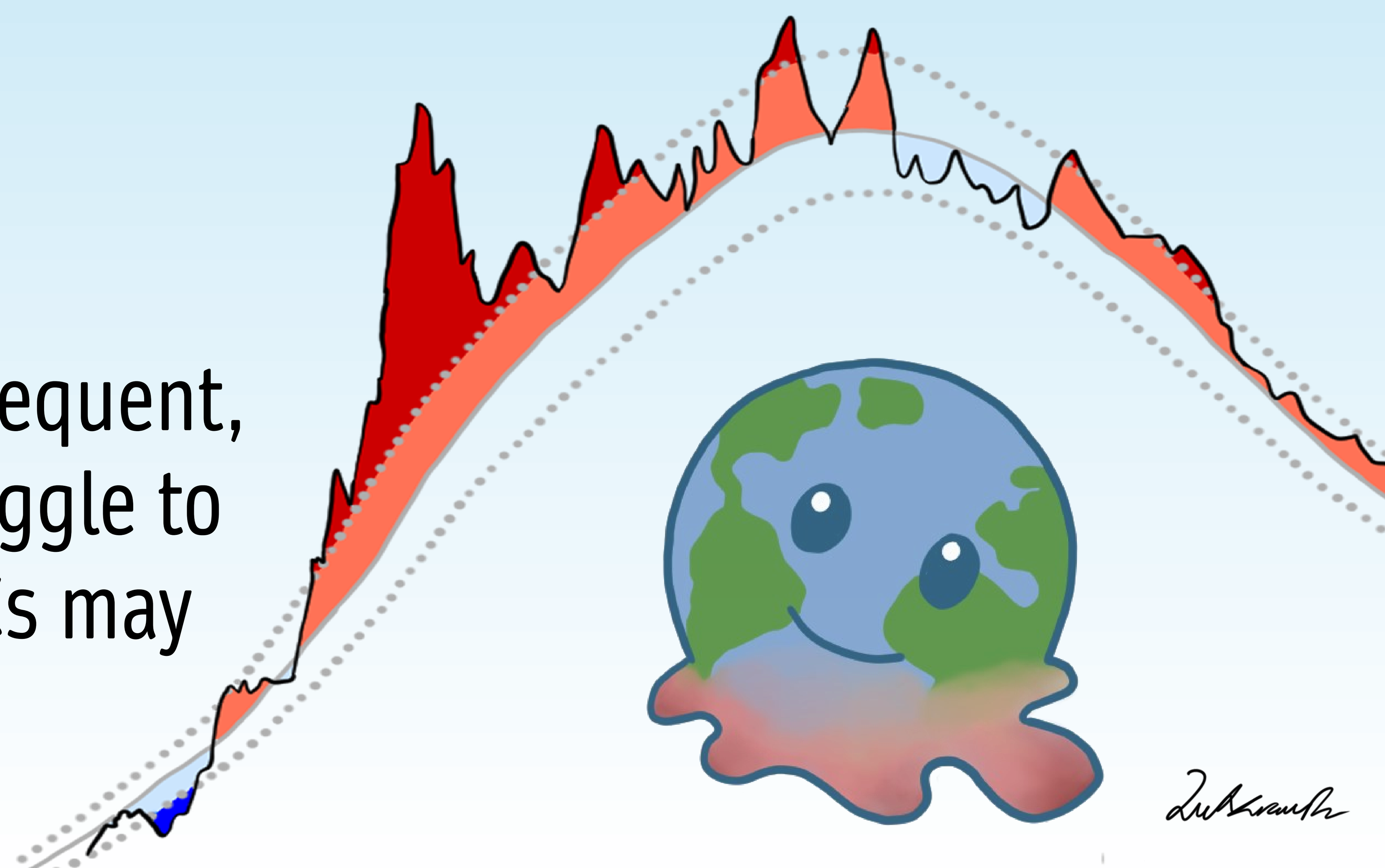
3. Or the curve might narrow, making a species more vulnerable.

Generalists have broad TPCs—can handle a wide range of temperatures.

Specialists have narrow TPCs—thrive in stable conditions but are more sensitive to heatwaves.

Why It Matters

As oceans warm and heatwaves become more frequent, species with narrow thermal tolerance may struggle to survive, while those with flexible or shifting TPCs may adapt or expand their range.



After the heatwave

What can happen in Baltic Sea coastal habitats after a marine heatwave?

Blue mussels & clams
Mussels may survive if they can close their shells and reduce metabolism, but prolonged heat can cause mass mortality, especially in juveniles. Clams may burrow deeper to escape heat, but oxygen depletion in sediments can be fatal.

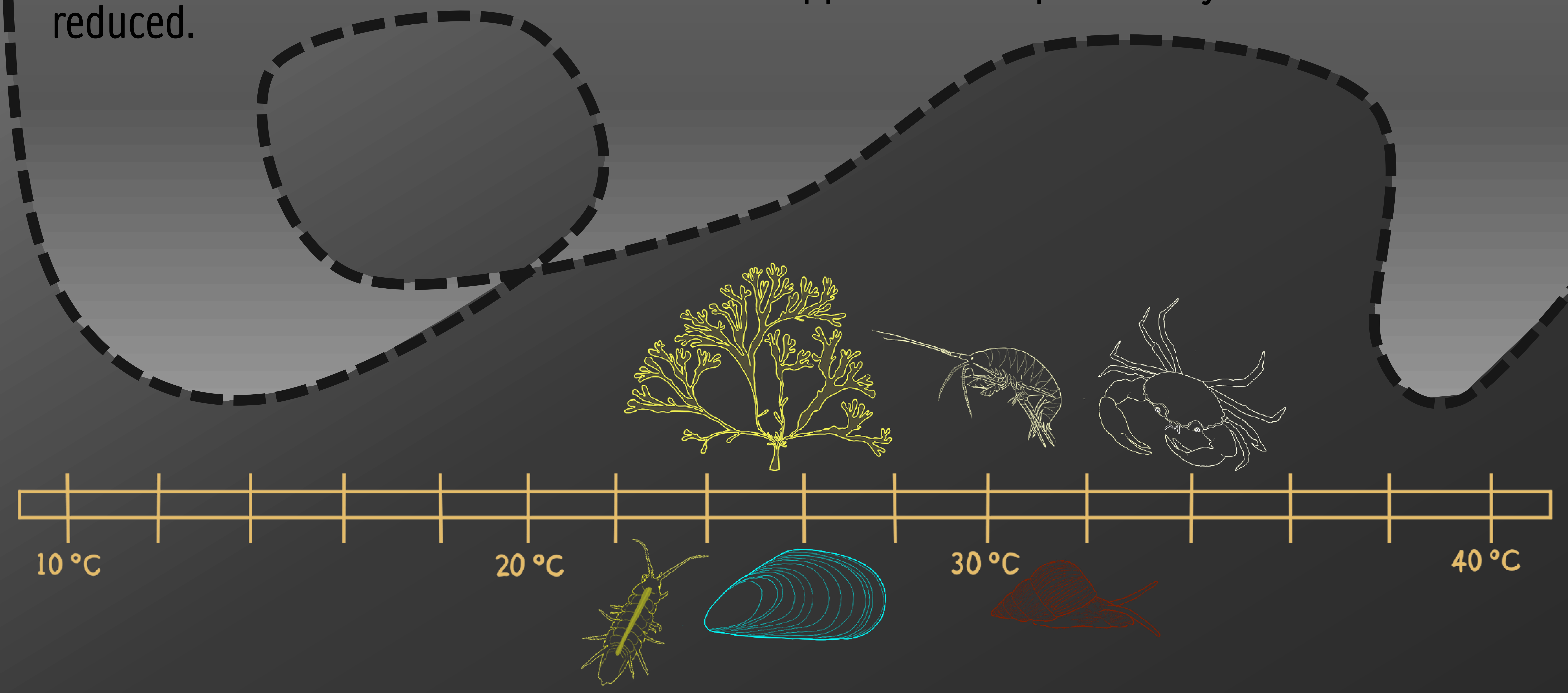
Amphipods & isopods
Some species may die off due to heat or oxygen stress. Others may recolonize quickly if conditions stabilize, especially if predators are reduced.

Perch (Perca fluviatilis)
Likely to move to deeper or cooler waters during the heatwave. May return post-event, but prey availability and habitat structure (e.g., Fucus cover) may be reduced.

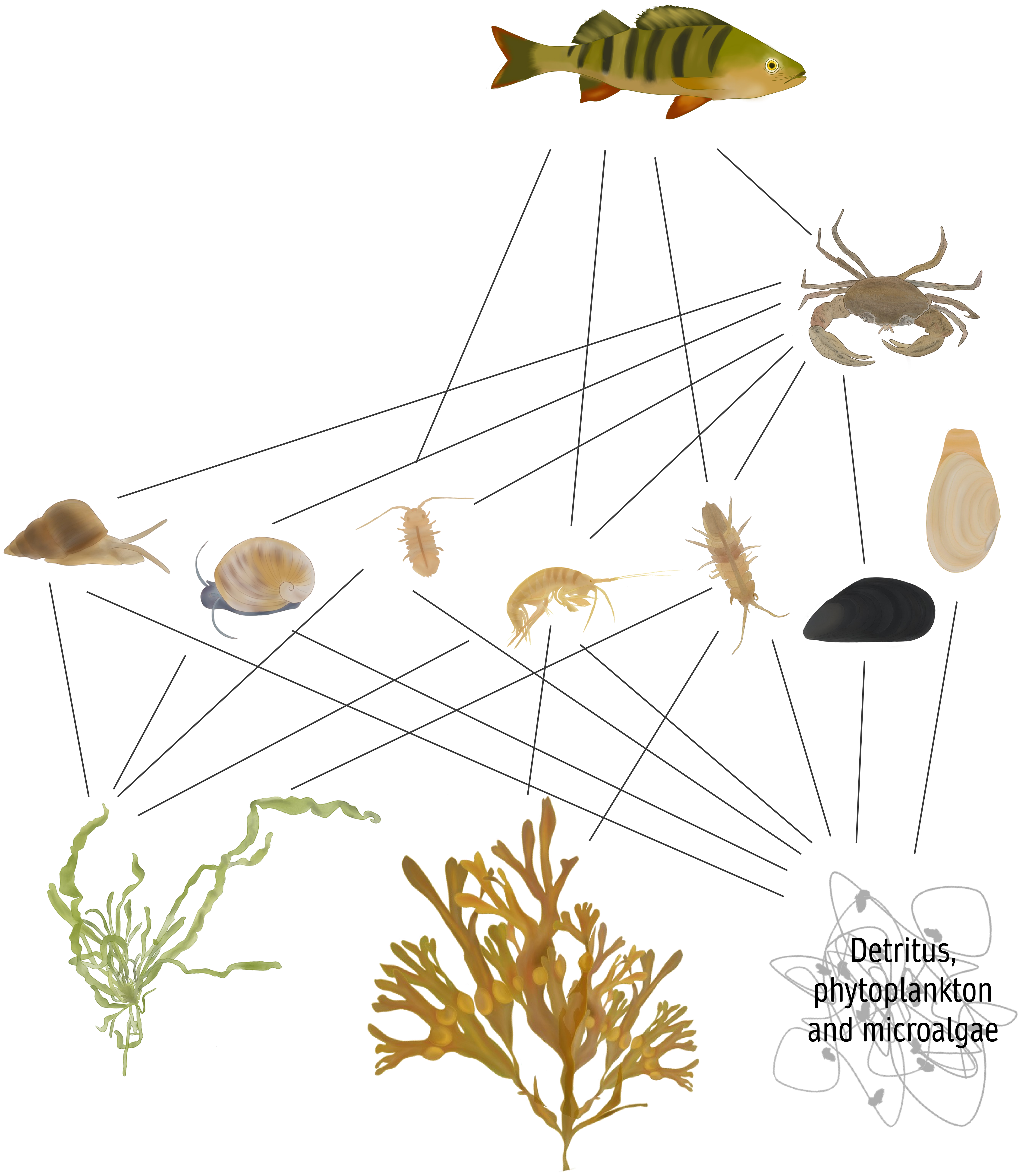
Fucus vesiculosus (bladderwrack)
May suffer tissue damage or dieback, especially in shallow areas. If weakened, it becomes more vulnerable to epiphytic algae. Loss of canopy reduces shade and shelter, impacting the entire community.

Non-indigenous mud crabs
Often more heat-tolerant than native species. May gain a competitive edge post-heatwave, especially if predators or competitors decline.

Ecosystem-Level Effects
Loss of structure: If Fucus is damaged, the habitat becomes less stable.
Algal blooms: Heat and nutrient release can trigger blooms of algae – smothering fucus
Community shifts: More heat-tolerant or opportunistic species may dominate.



Drawings:


Detritus,
phytoplankton
and microalgae