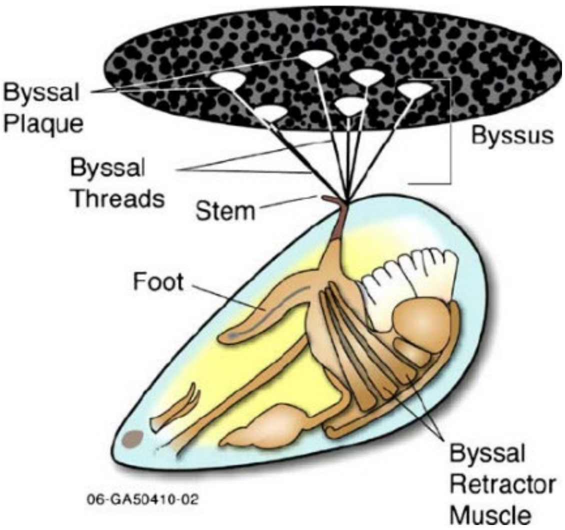
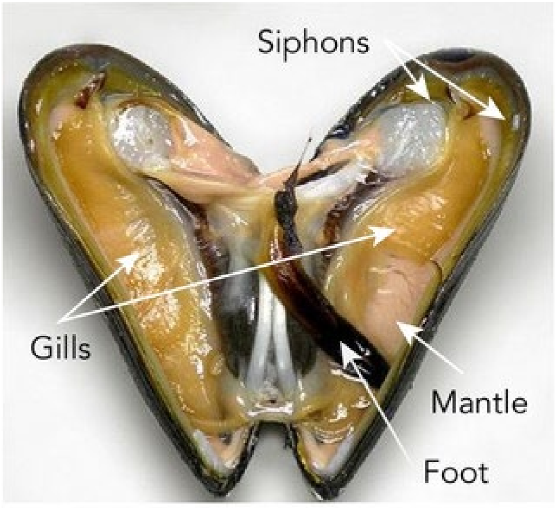
The Mighty Mussel

The green-lipped mussel, *Perna canaliculus* or kūtai, is economically and ecologically important to New Zealand. It is a bivalve - a soft-bodied marine animal that has two shells, called valves, that they can open and close. Oysters, clams, and scallops are also bivalves. In New Zealand, Greenshell™ mussels is the trade-marked name of New Zealand farmed green-lipped mussels.





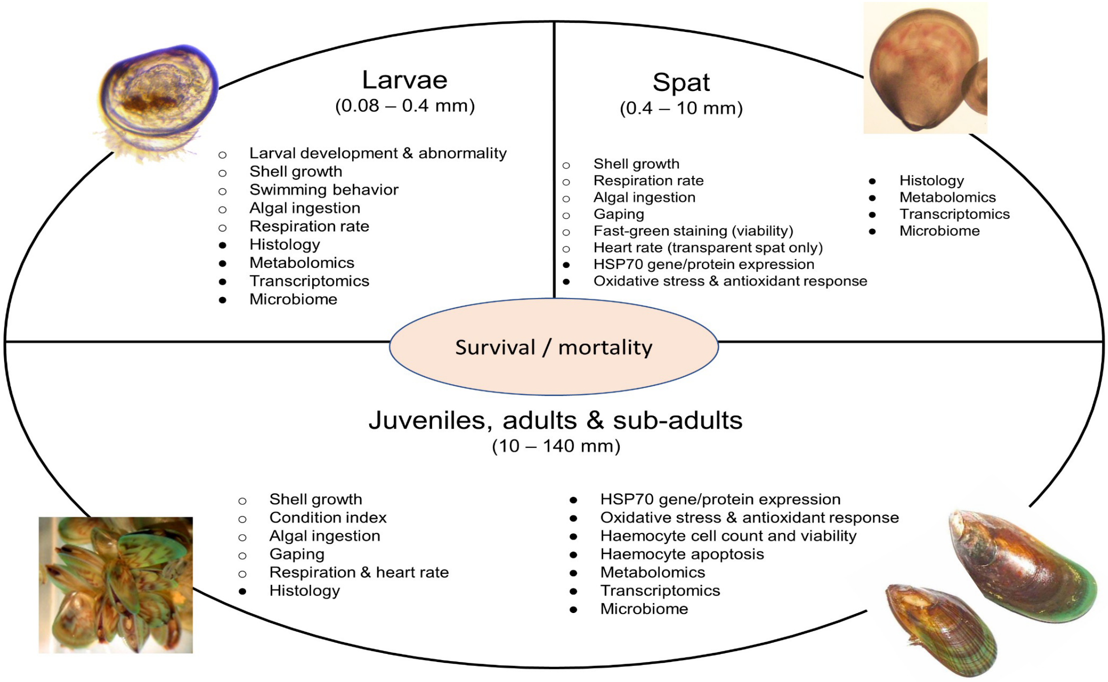
The byssus (pronounced 'bis sis'), often called the 'beard', is how mussels attach themselves to surfaces.

Mussels are filter feeders meaning they suck water in one siphon, pass it through their gills, and squirt it out the other siphon, the gills collect small phytoplankton and other food as well as performing gas exchange - oxygen in and carbon dioxide out.

Images Sourced From:
https://www.fishing.net.nz/fishing-advice/how-to/fishing-the-mussel-farms/
https://fs.fish.govt.nz/page.aspx?pk=122

Images Sourced From:
https://www.researchgate.net/figure/Anatomy-of-M-edulis-mussel-and-byssus-structures_fig2_5856719
https://www.pearlfarming.net/post/anatomy-of-mussels

Life Cycle of a Mussel



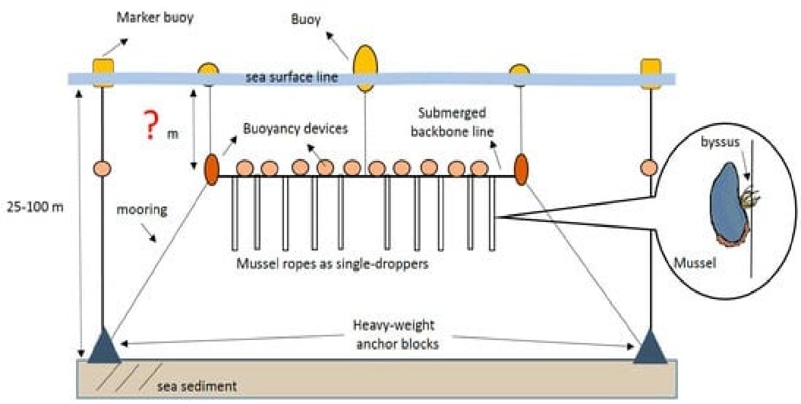
Historically (and still today) spat has been harvested off seaweed that washes up on Te Oneroa-a-Tōhe (Ninety Mile Beach) when the top column of water is pushed into shore by a combination of the bottom current and west winds, this pushes the spat covered seaweed onto the shore to be harvested.

Spat harvest rates at:

Year	2021	2022	2023	2024
Amount	116T	135T	127T	85T
Year	2021	2022	2023	2024
Amount	116T	135T	127T	85T

Wild harvest of spat is variable and unreliable so spat hatcheries on land are being developed. Research has shown heat tolerance is inheritable, so Cawthron is developing spat strains through selective breeding that are more resilient to ocean heat waves. Furthermore, spat reared in land-based hatcheries tend to be more resilient to ocean temperatures and other stressors.

How Mussels are Farmed in NZ



The mussels grow on lines below the surface attached to backbone ropes from 3,000 to 4,200 metres in length that are kept afloat by large oval buoys. The mussels feed on plankton and other microscopic sea creatures filtered out of the water as it flows past the dangling lines. The time from spat to harvest varies by growing area - 26 months in the Coromandel to 48 months in Stewart Island, but mussels are harvested in from September to December.

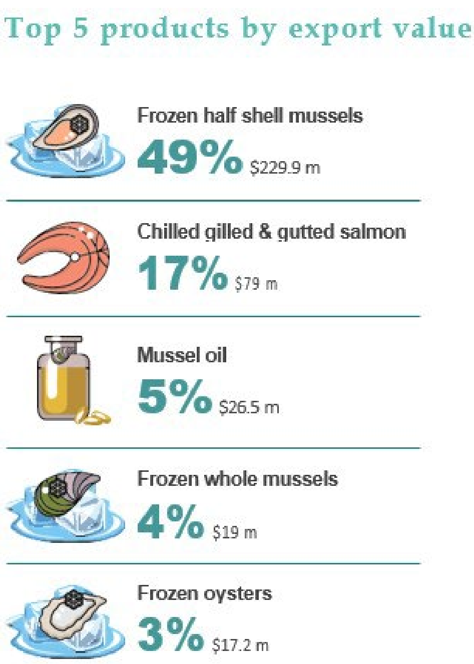
https://www.sciencelearn.org.nz/image_maps/17-how-mussels-are-farmed-in-new-zealand

Ocean growing muscles has challenges as swells above 2.5 metres can pull muscles off the ropes. (Also see images on Pg 1)

Aquaculture Industries in New Zealand

Comparison of the approximate annual value per 10 farmed hectares for different primary products	
Salmon	$140,000,000
Mussels	$850,000
Oysters	$800,000
Kiwifruit	$800,000
Dairy	$77,000
Sheep and beef	$8,500

Source: The New Zealand Government Aquaculture Strategy 2024
https://www.mpi.govt.nz/dmsdocument/15895-The-Governments-Aquaculture-Strategy-to-2025



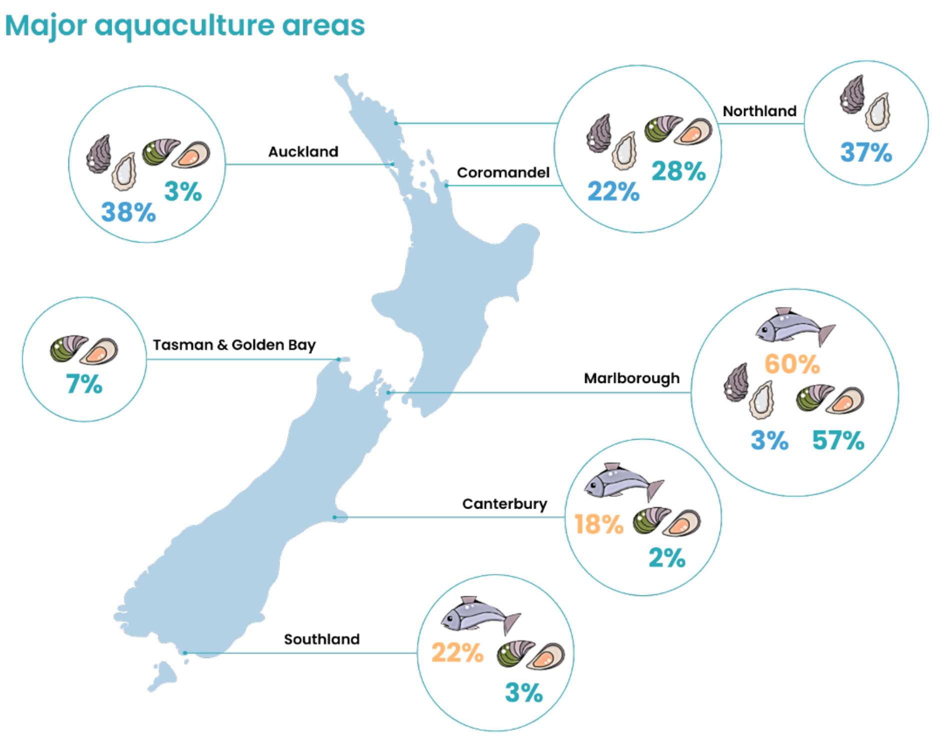


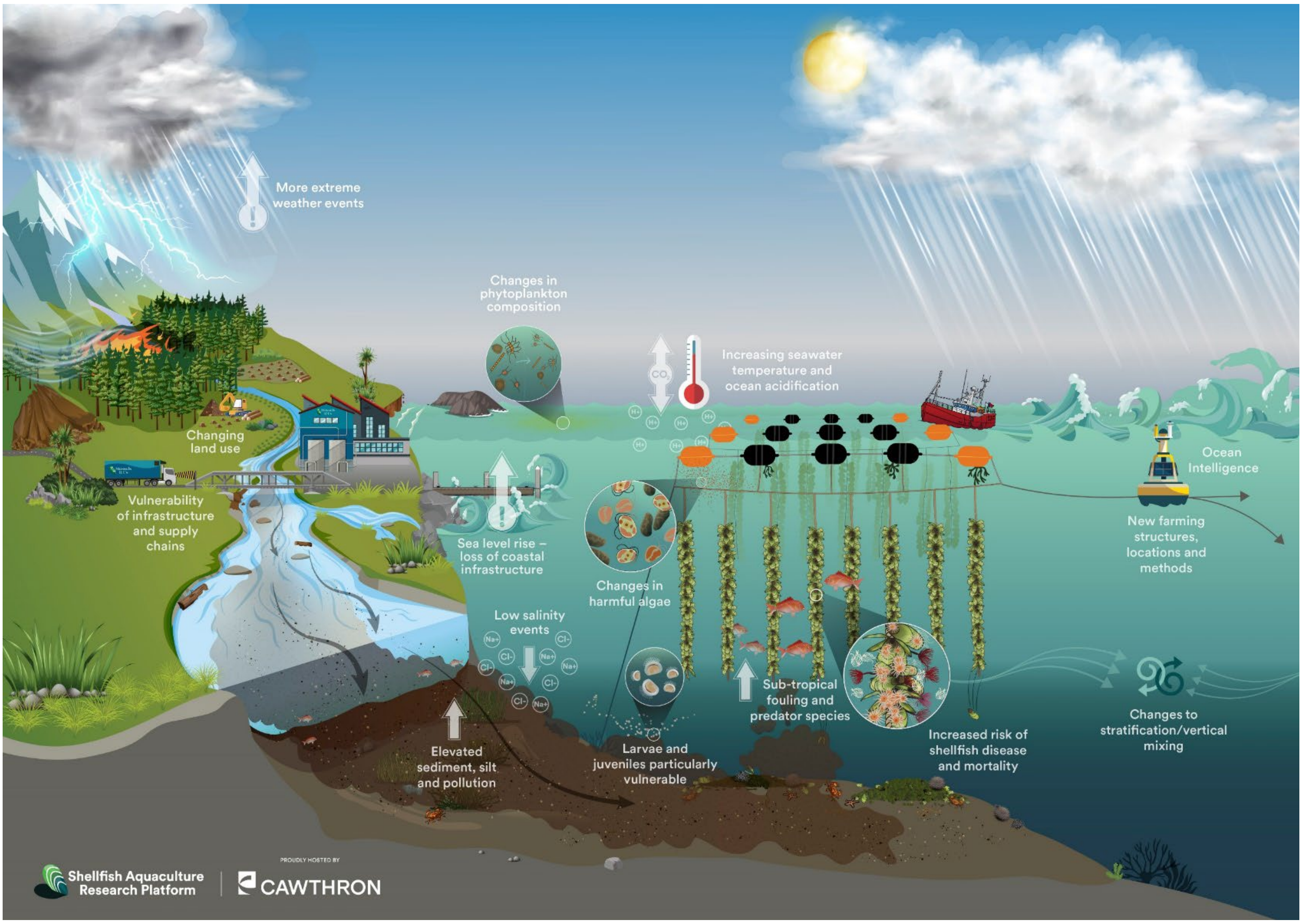
Image Taken From *The New Zealand Government // Aquaculture Strategy 2024*

The aquaculture industry faces climate change related challengers such as increased ocean warming and ocean acidification. Warmer oceans are a real threat to aquaculture, particularly the mussel industry. For example, during the 2018 summer, up to 20% of farmed mussels in the Firth of Thames dropped off their mussel lines when seawater temperatures reached 25 °C for over a week.

Management strategies to meet challenges of climate change as well as selective breeding of thermotolerant shellfish will be essential to ensuring mussel aquaculture as CO_2 levels rise.

Because one adult mussel can filter 250 litres of water per day mussels could have a place in bioremediation, for example in estuaries and filtering farm run-off. There are 28,000 mussels in the Port of Nelson filtering 5 million litres per day - mostly filtering heavy metals. These 28,000 mussels are on only two or three frames so cover a very small space.

Summary of the Effects of Climate Change on Mussel Farming



Some Issues Affecting Mussel Farming in New Zealand

Warmer Oceans

The ideal temperature for growing mussels is usually between 16°C and 18°C. Warmer oceans can cause stress and even death to mussels. Stress can cause mussel growth and bodily functions to slow. They also tend to stop feeding when ocean temperatures are at 26°C and above and susceptibility to disease and pathogens, pollutants and microplastics is increased. Prolonged periods of stress will eventually kill the mussels.

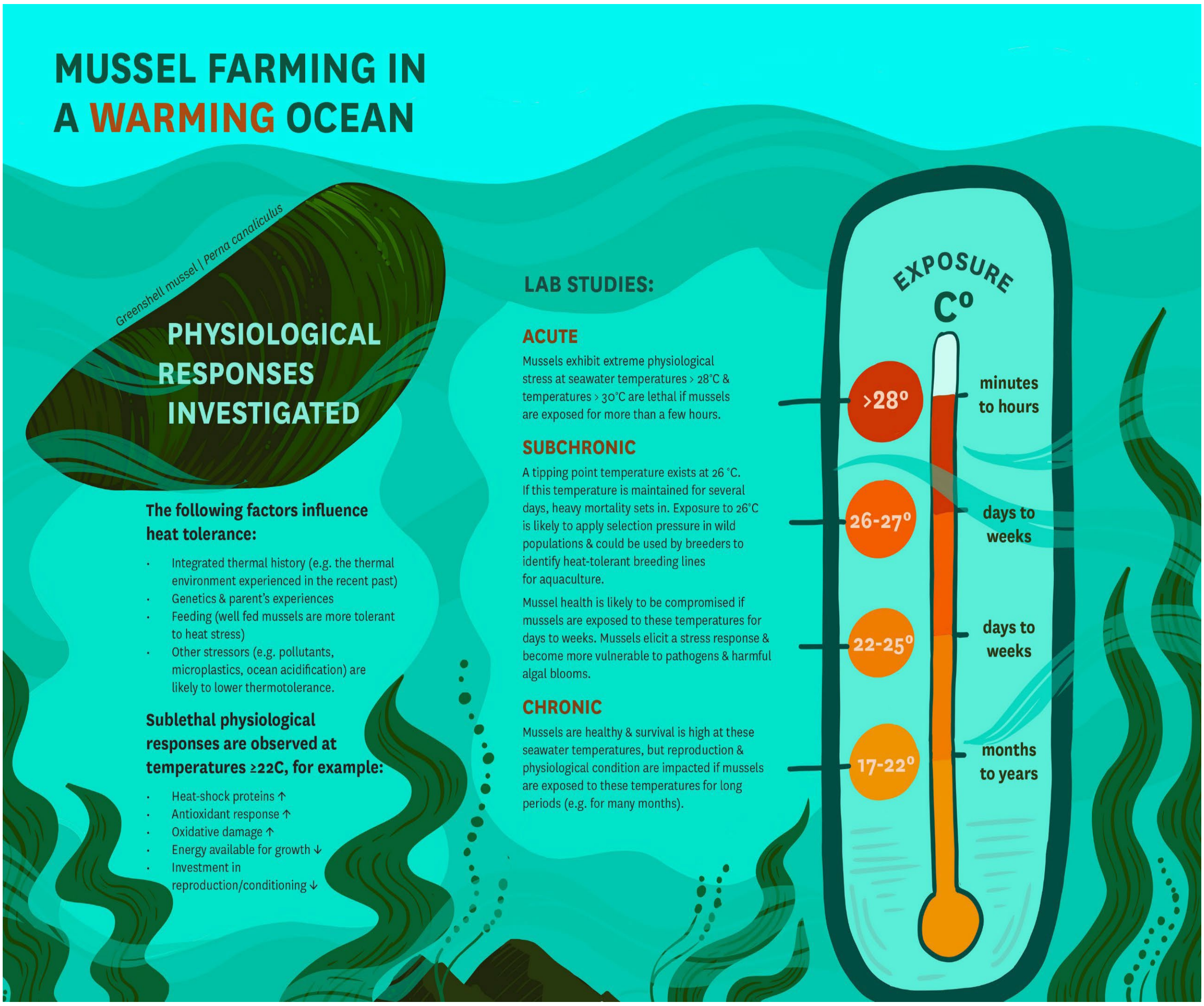
Stress can be measured by Gapping Behaviour and Heart Rates monitoring. The higher the heart rate the more stressed the mussel is and the slower their body functions so the less they grow which causes a loss of production/condition. Mussel heart rate is approximately 22 beats per minute at 16°C but can increase to 40 beats per minute at 24°C.

Gapping behaviour refers to the mussels opening and closing which they naturally do as they feed. The presence of predators and water quality will affect gaping behaviour. For example, if all the mussels in an area suddenly close that indicates either the presence of a predator or toxin they are trying to shut out. Likewise, if all the mussels in a region are gaping, they are likely under extreme stress and probably dying.

Mortality and deteriorating health of farmed mussels is increasing in summer on marine farms. Laboratory studies have shown that mussels are healthy and survive in seawater temperatures of 17 to 22°C but if they are exposed to these temperatures for long periods eg several months, or temperatures increase, physiological conditions and reproduction is negatively impacted. Exposure to temperatures 22 to 25 for days or weeks has the same effect and temperatures over 26C and higher for only a few days causes high mortality rates.

Higher ocean temperatures also weakens the byssus, causing mussels to drop off the rope. Studies have also show that successive exposure to heat waves limits the ability of mussels to recover and 'bounce back' and causes further stock losses.

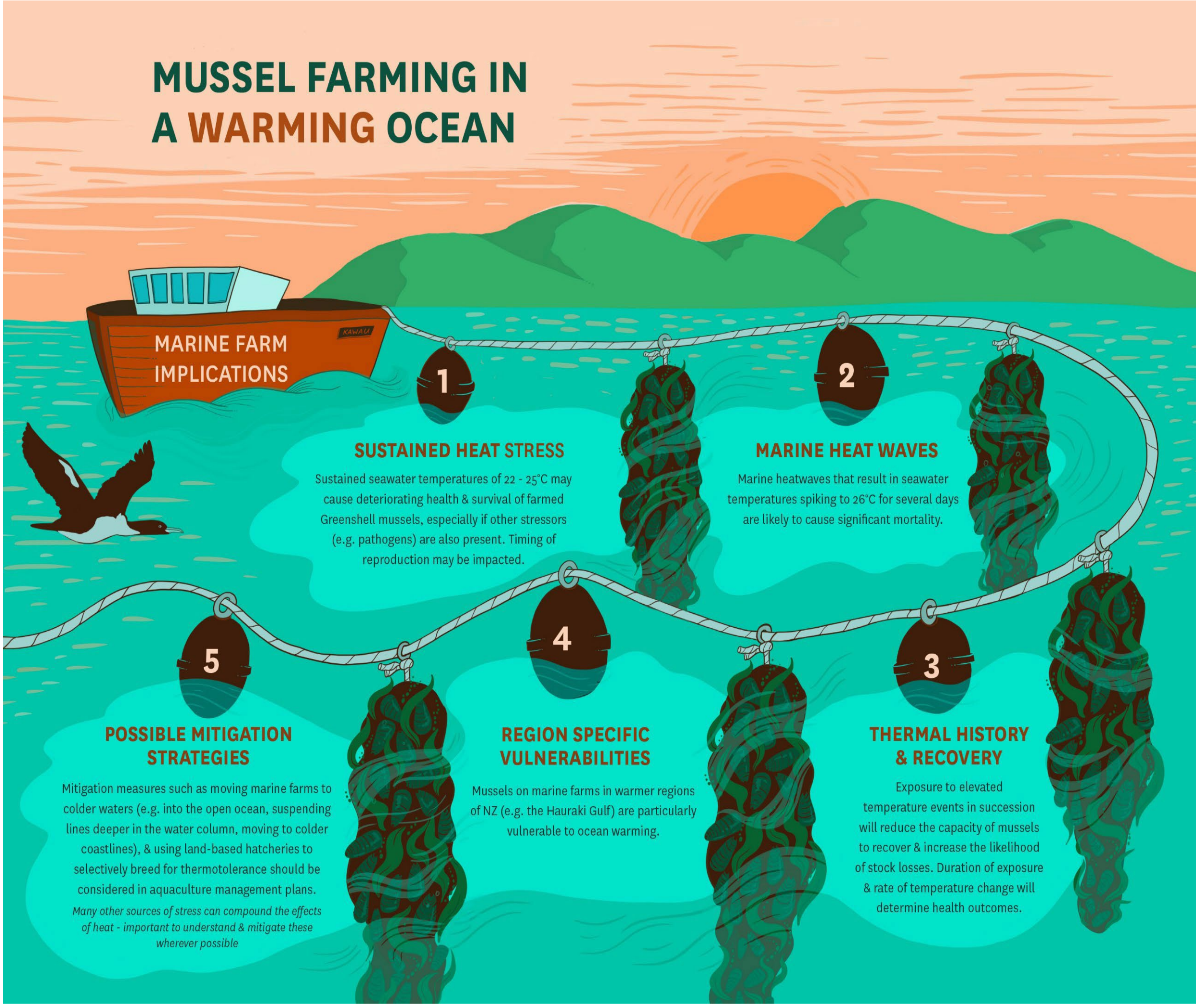
Another issue with farming muscles is that they need to be in calm waters so that they are not pulled off their ropes. However, calmer waters are usually shallower waters, and these are the waters that are most affected by rising sea temperatures. Taking the farms out to deeper, and therefore cooler waters means they are exposed to stronger currents and greater variations and strength of swells, which increases the chance of mussels being pulled off their ropes. Harvest is also more difficult because of the variable conditions the harvest boats have to be in.



Summary of laboratory studies investigating the effects of different seawater temperatures on the survival and physiology of Greenshell™ mussels. Image provided by and copywrite of Cawthorne Institute © ShARP/Cawthron

Thermotolerance in mussels is influenced by genetics which means that mussels can be selectively bred to be more resilient to heat stress, therefore providing increased resilience to marine heatwaves. Current laboratory research is focused on the responses of different mussel life stages to a range of seawater temperatures.

Other strategies could be to stop mussel farming in the Northern regions where the ocean is warmer and more prone to rising sea temperatures, lengthen the lines that they are attached to so that they are deeper where the water is cooler, selectively breed for thermotolerance, using land-based hatcheries, and farming them on land.



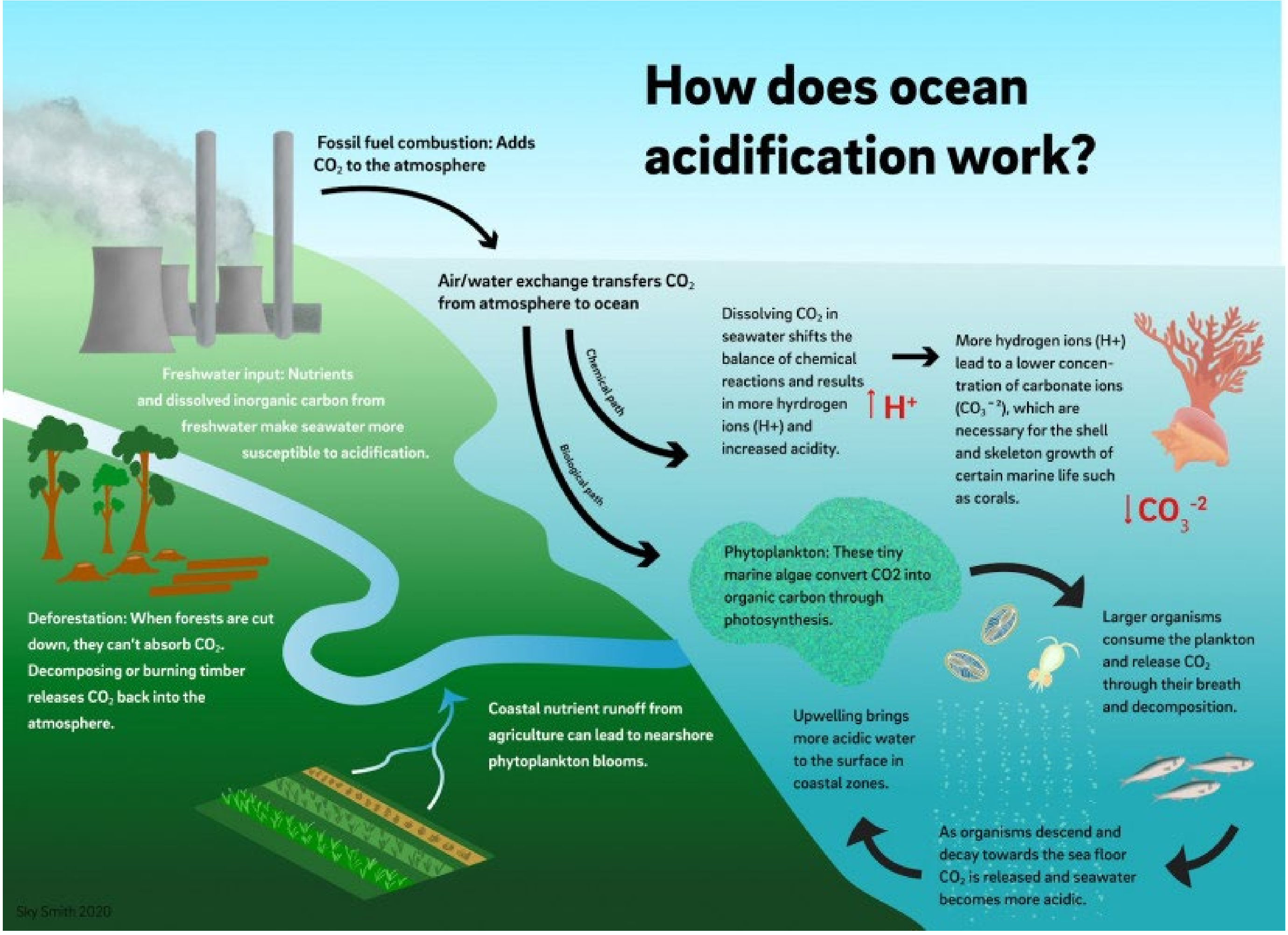
Summary of the potential effects of ocean warming on Greenshell™ mussel aquaculture. Image provided by and copywrite of Cawthorne Institute © ShARP/Cawthron

Warmer oceans can also affect the reproductive timing of wild mussels, this will also affect the amount of spat that will be washed up and harvested.

<u>Ocean Acidification</u>

Ocean acidification is a worldwide issue for bivalves including oysters, scallops as the lower pH creates conditions that eat away at the mineral deposits used by crayfish, shrimp, coral reefs and any other marine life that build their shells and exoskeletons.

Ocean acidification is caused by seawater absorbing large amounts of carbon dioxide (CO2) from the atmosphere which makes the water become more acidic. Basically, when CO2 and water combine, they produce carbonic acid, which releases hydrogen and bicarbonate ions. The more hydrogen ions there are, the more acidic the water becomes – hence ocean acidification.

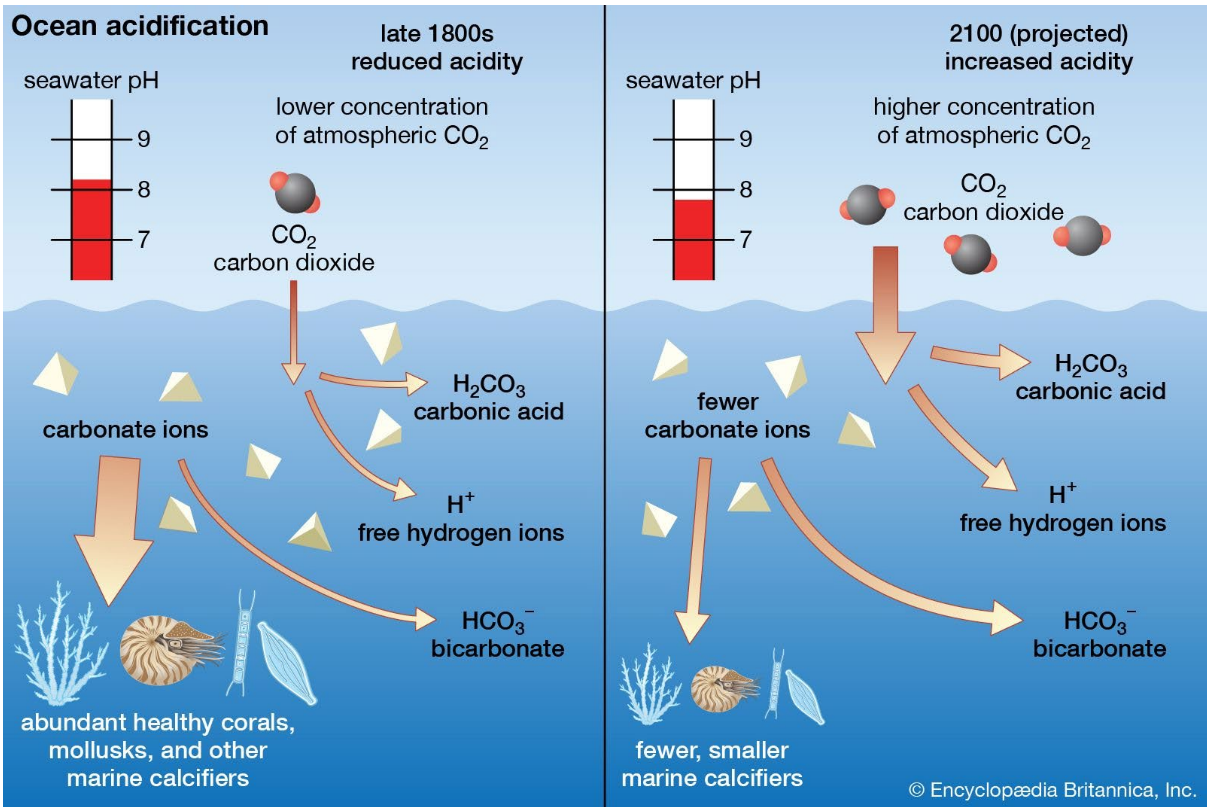


https://scripps.ucsd.edu/research/climate-change-resources/faq-ocean-acidification

The higher acid (lower pH) causes the concentration of carbonate ions that mussels need to form their shells to decrease therefore making it harder for muscles to build and maintain shells and leaving them more vulnerable to predators, environmental stresses and diseases. This slower or weaker shell growth means it takes longer for them to reach harvestable size. This can delay harvest timing which could disrupt supply and cause financial losses.

Spat are particularly vulnerable to ocean acidification. If the water becomes too acidic, juvenile mussels struggle to form their shells leading to high mortality rates. Spat tend to settle out of the water column onto a surface at three to four weeks of age. With a lower pH it can take up to another week for them to settle. As only 1% of larvae normally survive in the water column an extra week means more spat are vulnerable to predation for a longer time.

Acidification can also affect phytoplankton and zoo plankton populations which is what the mussel filter feed on. Geographically some places around New Zealand such as the Marlborough Sounds are more sensitive to ocean acidification as up welling causes the deeper more acidic waters to be bought to the surface. Deep ocean water is typically more acidic because they naturally contain higher levels of CO_2 due to the decay of organic matter and respiration of marine organisms and not mixing with surface water which allow CO_2 to be absorbed at the water. This naturally occur link caring acidity is exacerbated by additional carbon dioxide absorbs from the atmosphere due to human activities.



https://www.britannica.com/science/ocean-acidification