TEACHING RESOURCE | UNDERSTANDING AND MONITORING THE TASMANIAN MARINE ENVIRONMENT

Image credit: John Turnbull

RATIONALE

This resource aims to help students and teachers in secondary schools investigate and understand more about Tasmania's unique marine environment; how it supports the seafood industry and the scientific approach used for reporting on the current state of the local marine environment to make decisions about management of marine resources. In any ecosystem, there are biotic (living) and abiotic (non-living) factors affecting the system. This resource will examine the abiotic factors of marine ecosystems, and explain why people working in the fishing and aquaculture industry need to understand and monitor these factors.

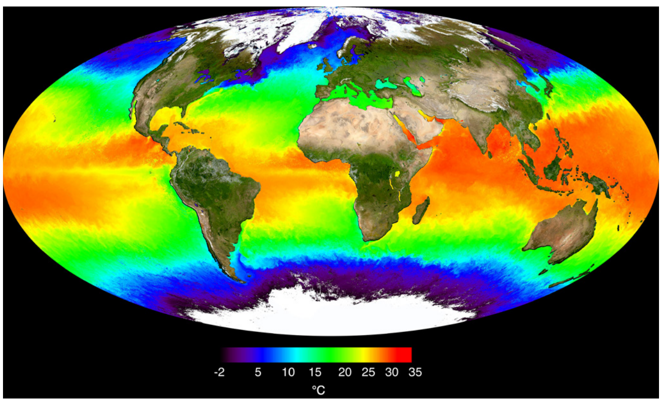
LEARNING OUTCOMES

- Understanding global and local ocean systems, and how these influence Tasmania's marine environment.
- Understanding about water quality and the different factors that are used to measure water quality in Tasmania.

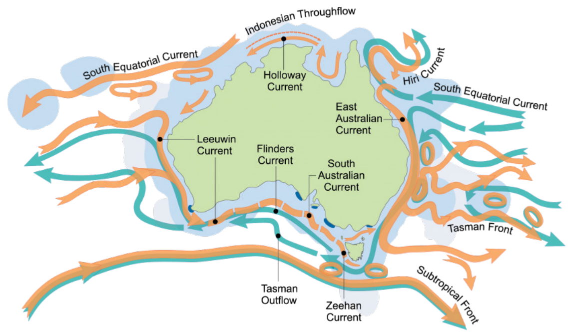
OCEAN SYSTEMS

The Southern Ocean is a dynamic and productive region. Tasmanian waters support a thriving seafood industry; from small scale shellfish farms to wild caught, high-value rock lobster and abalone, in-shore scalefish fisheries and finfish farming.

The marine environment can be influenced by multiple and cumulative factors, including local climates, currents and human activities. Scientists and marine resource managers monitor species and processes in the local marine environment to understand health and impacts, report on the current state of the local marine environment using a scientific approach and make recommendations and decisions for the management of human activities.



Tasmania's marine environment is classified as Cool Temperate (in contrast to Tropical and Polar marine environments). Source: NASA



Australian ocean currents. Source: CSIRO

Three main ocean current systems affect Tasmania. The Leeuwin and Zeehan currents come from the west and have a stronger effect during winter. The Antarctic Circumpolar Current runs around Antarctica and southerly storms bring cold upwellings to Tasmania.

The East Australian Current (EAC) runs along Australia's East Coast and brings warm (and relatively nutrient-poor) waters to Tasmania, with its strongest effect in summer. The EAC system has been strengthening in recent years and the southward extension is contributing to rising sea temperatures off Tasmania's East coast where water is warming faster than the global average.

In addition to broad scale ocean current effects, there are many localised factors that will influence Tasmania's marine and coastal waters. Local climate is impacted by topography and prevailing weather systems.

Water quality and how it relates to Tasmania's seafood industry

Healthy waterways are socially and ecologically important and have economic value. Tasmania's pristine waters support a seafood industry that produces and harvests high-quality seafood which is supplied to local and international markets. Water quality is closely monitored by seafood producers, typically at farm sites, and some aquaculture leases have real-time water quality monitoring stations that continuously transmit data to central locations in Hobart.

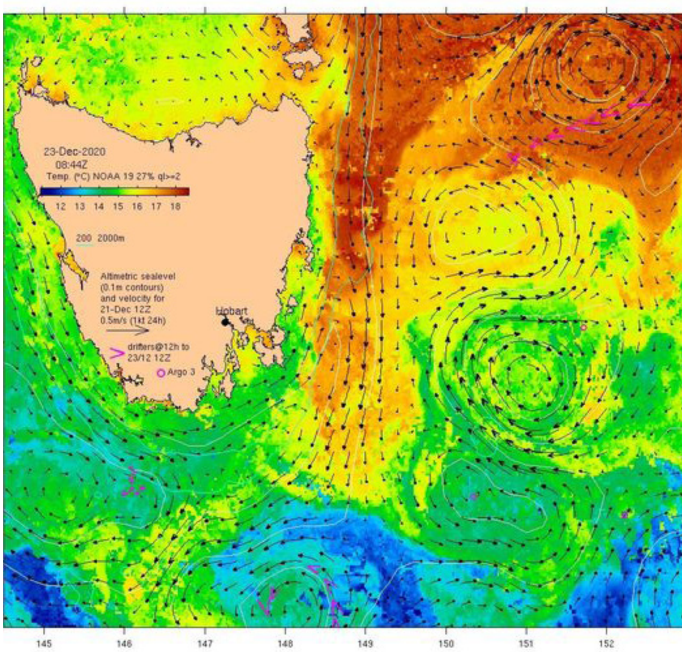
Examples of water quality variables

WATER TEMPERATURE

Water temperature naturally fluctuates on a diurnal and seasonal basis. There is an optimal temperature range for most species on earth. If aquatic species experience temperature out of their optimal range, they become stressed and more susceptible to disease; in extreme cases some may die from heat stress alone.

Changes in water temperature can also alter other abiotic factors. Two significant things to know about water temperature are:

- Cold water is more dense than warm water, so stratification layers can develop in waterways where there is little mixing from currents, wind and wave action.
- Cold water can carry higher concentrations of dissolved gasses (for example oxygen and carbon dioxide) than warm water.



Sea Surface Temperature Map, December 2020.
Source: IMOS

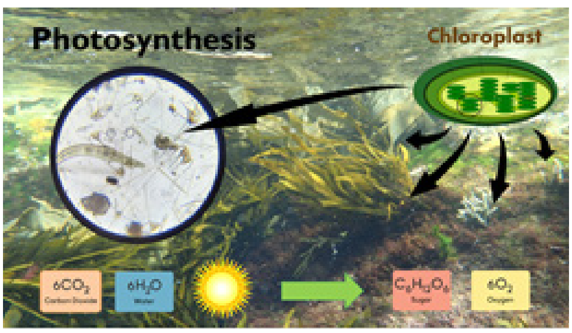
DISSOLVED OXYGEN

Dissolved oxygen (DO) is vital for most of marine plants and animals to survive, excluding marine mammals that breathe air. Ocean plants, phytoplankton and algae (seaweed) produce oxygen via photosynthesis, which increases the concentration of dissolved oxygen (DO) in our waterways.

Tasmanian aquaculture farms rely on DO to support healthy stock. DO can become limited if stocking densities are too high, if there is an abundance of organic decaying matter, if the water heats up too much, or if water movement through the farm is minimal.

- Cold water can hold more dissolved oxygen than warm water, so DO levels are usually lower over summer.
- Increased organic matter loads can reduce DO through aerobic bacterial decomposition. There can be a slight decrease in DO after rain, as runoff from land contributes organic matter (e.g. plant debris, animal bodies, and faeces).
- Oxygen can be measured in mg/L or as a percentage saturation. Water bodies are hypoxic at oxygen concentrations of less than 2 mg/L and anoxic at oxygen concentrations of near 0 mg/L.

Fish, shellfish and plants suffocate if DO concentration is too low. Aquaculture farms avoid this by maintaining clean equipment such as nets to support adequate water movement through the farm, minimising decaying organic matter, and calculating suitable stocking densities and reducing densities if DO becomes too low.



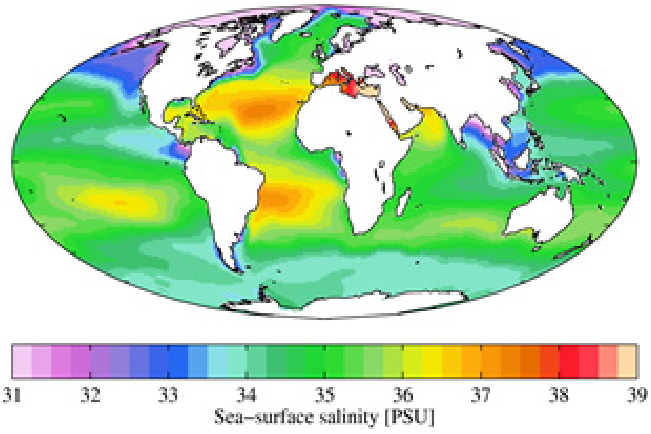
Photosynthesis by marine plants, algae and phytoplankton produce oxygen in the water. Image credit: Chloe Simons

SALINITY

Salinity is the amount of salt dissolved in water. The global average for salinity is 3.5% dissolved salts or about 35 ppt (parts per thousand). Salinity can vary significantly at a local scale depending on evaporation rates (affected by temperature and wind); precipitation (rainfall and snow) and freshwater river runoff (including snow melt).

As with other abiotic factors, each animal species has a range of salinity that can be tolerated, and outside this range, the animal will experience some degree of physiological stress or die.

- Salty water is more dense than fresh water, so fresh water will form a layer on top of salty water in areas where there is little mixing from ocean currents and wind and wave action.
- Some marine animals have a part of their life cycle that includes a fresh water stage for breeding.



Global Ocean Salinity map. Source: Wikimedia.

pH

The acidity or alkalinity of liquids/substances is referred to as pH (or potential of Hydrogen, due to the amount of free hydrogen ions in the given solution). Fresh water has a neutral pH of around 7. Sea water is more 'basic' at around 8.1. The pH of the ocean used to be around 8.2 (measured by examining ice cores). Extra carbon dioxide (CO_2) in the atmosphere dissolves into sea water forming a weak acid and therefore lowering the pH. As CO_2 emissions have increased since the industrial revolution, the pH of the ocean decreased.

- Ocean pH naturally varies over 24 hours. It tends to be lower overnight, when CO_2 is released by plants and animals, and higher over the day as CO_2 is absorbed via plants during photosynthesis.
- Fish become stressed and struggle to absorb oxygen when pH is too low, and the concentration of ammonia (toxic to fish) increases if pH is too high.

NUTRIENT WASTE (NITROGEN AND PHOSPHOROUS)

Nitrogen is cycled through the atmosphere, ocean and land through natural processes. It typically exists as ammonia (NH_3) or ammonium (NH_4^+) in the ocean. Ammonia is toxic to fish and ammonium is not.

Ammonia is a product of the breakdown of proteins. When a fish digests a protein-rich meal, ammonia is released via the gills and in urine/faeces. Ammonia can also enter the marine environment through non-consumed and high-nutrient inputs, such as fish food, and runoff from agricultural land (especially from fertiliser use).

In Tasmania, finfish farmers reduce the amount of non-consumed fish feed through remote monitoring and control of fish feeding operations. Various types of bacteria break down ammonia and ammonium in to forms of nitrogen that plants absorb to grow. Algal blooms occur when nitrogen concentrations are high. They can be problematic - blocking fish gills, in turn causing them to suffocate; and blocking light reaching other marine plants, preventing photosynthesis. Some algae contain toxins harmful to fish, which in extreme cases can cause mass death of fish species. This can lead to a lowered dissolved oxygen concentration as bacteria breakdown the flesh via aerobic decomposition (consuming oxygen).

Phosphates are another source of nutrients which promote algal blooms, and typically enter the water through excess fertiliser use.


Algal bloom. Image credit: CSIRO


Phytoplankton and zooplankton 100 x magnification.
Image credit: Chloe Simons

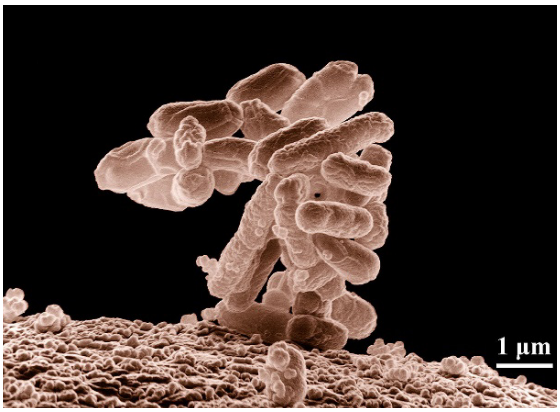
Other biological water quality indicators
Other biological indicators of water quality are the presence of different species and quantities of plankton and bacteria.

Plankton can bloom in large quantities in response to changes in water temperature and nutrient availability. Phytoplankton produces oxygen by photosynthesis, however large blooms of certain phytoplankton species can be problematic in the following ways:

- When large blooms of algae die, the decomposition releases CO_2 and uses up oxygen.
- Some species contain harmful toxins that can kill aquatic animals; or toxins can accumulate in fish (especially shellfish) and be harmful to humans.
- Large blooms can cause high turbidity of the water – lowering the transparency and therefore reducing the amount of sunlight to lower depths in the water. This can be harmful for benthic seaweed beds.

Out of the normal trends, algal blooms can indicate elevated nutrients. Chlorophyll a is the pigment that allows plants to absorb energy from the sun. A high chlorophyll a concentration in the marine environment is indicative of a recent algal bloom. Jellyfish blooms can also occasionally be problematic.

Coliform bacteria are bacteria found in faeces of warm-blooded mammals. Low levels of coliform bacteria are unlikely to cause serious illness, however large numbers can be detrimental to human health, and can sometimes signify the presence of other, more dangerous, forms of bacteria. Some bacteria strains enter freshwater and marine ecosystems via agricultural runoff and stormwater, especially if there is damage to sewage systems.



Coliform bacteria x10000 magnification. Source: Wikimedia

Introduced marine pest species are covered further in the teaching resources **Threats to Seafood Production in Tasmania, and Protecting the Marine Environment.**

More information about water quality parameters can be found on the DPIPWE website.

Reporting
Aquaculture industries operating in Tasmania have a legal requirement to test and report water quality parameters at various time intervals.

Reporting requirements can vary between aquaculture sites and are specified within Environmental Licences prior to farm establishment. Environmental reports are prepared by independent environmental contractors and licenced operators, and include water quality sampling results.

It is in industry's interest to support healthy marine ecosystems, as it sustains longevity of their operations, maximises the quality of their product and ensures stewardship of shared resources.

Specific salmon aquaculture licences and associated reports can be found on the Environmental Protection Authority (EPA) Tasmania website.

Examples of water quality results can be found online on the Tassal and Huon Aquaculture dashboards, and on the Shellfish Market Access Program (ShellMap) website.*

Various environmental data, including data on some of these indicators, can be found on:
- Land Information Systems Tasmania (LIST) website, under LISTdata; and
- CSIRO website, under Educational Datasets.

*ShellMap operates under a Partnership Agreement between the Tasmanian Government, Oysters Tasmania and the Tasmanian Seafood Industry Council, data is reported weekly and not publicly archived.

LEARNING ACTIVITIES

Water Quality Indicator Revision Questions

TEMPERATURE

- What are the main ocean currents that affect Tasmania and how do they influence the temperature of waters off Tasmania?
- What is temperature stratification in a waterbody and how does it form?

SALINITY

- Why does fresh water float on top of salt water?
- Would you expect to see higher or lower surface salinity after heavy rainfall?

DISSOLVED OXYGEN

- How do aquatic plants and algae contribute to the amount of dissolved oxygen in water?
- How does respiration by animals vary the amount of dissolved oxygen in water?
- Can cold water or warm water hold more dissolved oxygen?

pH

- Carbon Dioxide in water increases the water pH. How does the pH level vary over a 24 hour cycle?

NUTRIENTS (NITROGEN)

- Give two reasons why it is important to monitor and manage the fecal waste of farmed marine animals.

PLANKTON

- Plankton is an important part of the marine ecosystem. Give three reasons why scientists and people working in the aquaculture industry would want to monitor plankton samples regularly.

Design challenge

Make your own niskin bottle for collecting water samples:
https://www.instructables.com/id/Niskin-Bottle/

Extended Research Project

BACKGROUND:

Tasmania's location at the edge of the Southern Ocean means that it is well suited to aquaculture operations due to the cool and oxygenated water. However, the global changing climate, together with the southward extension of the East Australian Current, mean that the waters off Tasmania's east coast are warming.

SCENARIO:

Imagine you are working as a research officer specialising in water quality testing. An aquaculture company has contacted you, asking you to investigate how warming waters off Tasmania might have influence their operations in the future. The company is also especially concerned about the health and wellbeing of their fish and wants to ensure against low oxygen levels.

Prepare a report that details the following information:

- Describe to the client which ocean currents affect Tasmania and in what ways.
- Describe the relationship between water temperature and dissolved oxygen.
- Describe how photosynthesis and respiration affect oxygen levels in water.
- Investigate and suggest some possible ideas for your client, such as offshore marine farming, and integrated multitrophic aquaculture.

Suggested resources

OCEAN CURRENTS

Video resource https://www.youtube.com/watch?v=p4pWafuvdrY

THERMOHALINE CIRCULATION AND WATER DENSITY

Water density practical experiments: https://coolscienceexperimentshq.com/simple-experiments-to-learn-about-density/

WATER QUALITY INDICATORS

- Practical demonstration of photosynthesis producing oxygen https://www.youtube.com/watch?v=Uiuct-2yAxA
- Simulation of ocean acidification as carbon dioxide dissolves in sea water to increase the pH https://www.exploratorium.edu/snacks/ocean-acidification-in-cup