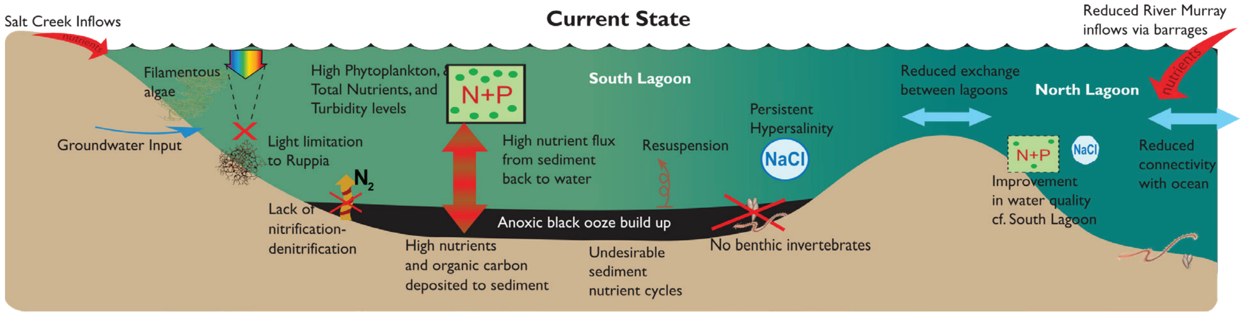
Southern Coorong Factsheet

December 2021

Nutrient cycling in the Southern Coorong



Conceptual understanding of the current state of nutrient cycling in the Coorong Southern Lagoon

Plants and animals of the Coorong need nutrients to thrive. Some nutrients, principally nitrogen, phosphorus, and carbon, are essential to plant and animal growth. The presence of these nutrients also affect water and sediment quality, which influences the overall health of ecosystems. Nutrients enter the Coorong ecosystem through water that flows into the system from multiple sources. These nutrients are incorporated into the Coorong's ecological cycle through interactions between water, sediment, plants, animals and microbes. Healthy Coorong nutrient cycles should be supported by functional foodweb cycling, for example, where high levels of productivity enable recycling of organic matter and the capacity to sequester and store carbon.

It's important to understand how nutrients move between the water and sediments into living organisms and are then recycled back to the environment. This is the nutrient cycle, which is out of balance in the Southern Coorong due to long-term environmental change. We now know that nutrient levels and cycling processes in the Southern Coorong are in an unhealthy, hyper-eutrophic state (i.e. contain high nutrient and organic matter loads).

Nutrients remain trapped within the South Lagoon because there is insufficient 'flushing' of water and nutrients out to the North Lagoon and ocean via the Murray Mouth. Narrow constrictions and expansive shallow areas (particularly in spring-summer) reduce connectivity and water flow between the north and south lagoons. Excess nutrients accumulate and promote the growth of phytoplankton and filamentous algal blooms, which disrupt healthy nutrient cycling.

The sediment plays an important role in nutrient cycling. In the Southern Coorong, filamentous algae and phytoplankton break down on the sediment surface, increasing sediment nutrient and organic carbon loads. Organic matter is decomposed by bacteria that consume oxygen to fuel rapid growth and create anoxic (no oxygen) sediments. In anoxic sediments, only anaerobic (without oxygen) respiration occurs, which increases the release of nitrogen and phosphorus into the water and promotes enhanced algal growth. These conditions further exacerbate the hyper-eutrophic state in the Southern Coorong.

Organic-rich sediments called 'monosulfidic black oozes' can also form when the sediment becomes anoxic. Oxygen-rich zones in the sediment prevent this from occurring and promote nutrient cycling into more beneficial nutrient forms.

Anoxic sediments and hypersaline (high salinity) conditions are also toxic to macroinvertebrates and aquatic plants. In healthy systems, sediments are oxygenated by macroinvertebrates (e.g. via burrowing by worms and bivalves) and aquatic plants (via roots). As these important parts of the natural ecosystem currently occur in low amounts or are in poor health in the Southern Coorong, sediments can't be oxygenated sufficiently, which further fuels negative impacts to the nutrient cycle.

The Southern Coorong can be restored to its desired state by understanding and addressing what has led to the hyper-eutrophic state including changes to the nutrient cycle.

Further reading:

Mosley, L., S. Priestley, J. Brookes, S. Dittmann, J. Farkas, M. Farrell, A. J. P. Ferguson, M. Gibbs, M. Hipsey, J. Huang, O. Lam-Gordillo, S. Simpson, P. Teasdale, J. Tyler, M. Waycott, and D. Welsh. 2020. Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research, Adelaide.

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December 2021

The role of sediments in the eutrophication of the Southern Coorong

Image: Anoxic sediments impair healthy nutrient cycling in the Coorong (Photo: Luke Mosley)

Sediments have an important role to play in the nutrient cycle of the Southern Coorong. But sediment quality has been degraded and this is fuelling eutrophication.

Healthy nutrient cycling in the sediment and at the sediment-water interface requires an oxic (oxygen containing) zone to be present. In the Southern Coorong, sediments have become anoxic because bacteria use oxygen to decompose organic matter faster than it can be resupplied. Dead filamentous algae and phytoplankton settle on the sediment surface, providing high loads of organic matter to fuel this process.

In anoxic sediments, anaerobic (without oxygen) respiration occurs, which impairs nutrient cycling by:

1. *Preventing nitrification-denitrification processes* - Nitrification is the biological process in which dissolved nitrogen as ammonium, is oxidised into nitrite and nitrate. Denitrification is the process by which nitrate is converted to nitrogen gas. If the sediment is anoxic, then nitrification-denitrification cannot occur. Nitrogen remains in the nutrient cycle instead of being released as a gas and removed from the Coorong. The nitrogen remains as ammonium, which fuels excessive phytoplankton and filamentous algal growth.
2. *Enhancing the flux (release) of phosphate from the sediment to the water column* - In well-oxygenated sediments (near the interface with the water) the oxidation of iron forms an iron oxide compound (the yellow-brown 'rusty' colour) that binds phosphate. This prevents or limits its release into the water where algae can use it to grow. When sediments become anoxic, phosphate is instead released to the water column, and it also fuels excessive phytoplankton and filamentous algal growth.
3. *Forming monosulfidic black oozes (MBOs)* - MBOs are formed in anoxic sediments via sulfate reduction, a process where dissolved sulfate in the water is converted by bacteria to sulfide (which gives the sediment its characteristic black colour). The sulfate reducing bacteria that form thick layers of MBOs in the Coorong are fuelled by high organic matter loads to the sediment.

Macroinvertebrates build burrows and bioturbate (mix) the sediment enabling the oxygen-rich surface water and sediments to mix into deeper layers. Filter feeding macroinvertebrates (e.g. clams) also remove nutrients from the water column. Aquatic plants such as *Ruppia* also pump oxygen from the water to their roots, which is released into the sediment. Therefore, aquatic plants and macroinvertebrates have an important role to play in sediment-water nutrient cycling through oxygenation. Macroinvertebrates that burrow and filter feed do not tolerate hyper-salinity greater than approximately 60g/L (1.7 times seawater salinity). The loss of benthic (bottom-dwelling) invertebrates from the Southern Coorong caused by hyper-salinity and the slow rates of recovery of aquatic plants following the Millennium Drought is likely fuelling increased eutrophication (excessive nutrient and algal production).

These processes perpetuate the "negative feedback loop" that maintains a hyper-eutrophic state in the Southern Coorong. To return the Coorong to a desired state, strategies are needed to improve sediment quality.

Further reading:

Mosley, L., S. Priestley, J. Brookes, S. Dittmann, J. Farkas, M. Farrell, A. J. P. Ferguson, M. Gibbs, M. Hipsey, J. Huang, O. Lam-Gordillo, S. Simpson, P. Teasdale, J. Tyler, M. Waycott, and D. Welsh. 2020. Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research, Adelaide.

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845916

December 2021

Monosulfidic black oozes are anoxic and alter nutrient cycles

Image - Left: Monosulfidic black ooze in a sediment core sample from the Coorong South Lagoon (Photo: Luke Mosley)
Right: Unhealthy Monosulfidic black ooze sediments in the Coorong (Photo: Luke Mosley)

Monosulfidic black oozes are black, organic and sulfide rich sediments. They have formed over large areas of the Southern Coorong under anoxic sediment conditions that are created when thick algal mats and dead phytoplankton decompose.

Decomposing algal mats have very high levels of organic carbon and nitrogen. Bacteria use all the oxygen to decompose the organic matter and so the sediments become anoxic. Monosulfidic black oozes (MBOs) form when there is no oxygen for aerobic bacteria to break down organic matter and instead anaerobic bacteria convert iron oxide and sulfate in the sediment and water to hydrogen sulfide and iron monosulfide. Hydrogen sulfide is a foul-smelling gas, often referred to as “rotten egg gas” and is often smelled when sediment in the Southern Coorong is disturbed.

When monosulfidic black oozes form, the sediments can become completely uninhabitable for aquatic plants and macroinvertebrates. The high sulfide concentrations can cause sulfide intrusion into the roots of aquatic plants, reducing plant growth rates and contributing to die-off events. Low dissolved oxygen and high hydrogen sulfide levels also make conditions inhospitable for most benthic (bottom-dwelling) macroinvertebrates. Aquatic plants and macroinvertebrates can help to oxygenate sediment, but because they cannot inhabit monosulfidic black oozes, the impacts to the nutrient cycle are further fuelled by their absence.

Monosulfidic black oozes have formed in large quantities because the Southern Coorong has persisted in a hyper-eutrophic state. Excessive organic matter and anoxic conditions, coupled with very high salinity, impair nutrient cycling and make the sediment uninhabitable for many organisms, which further fuels eutrophication. Project Coorong is investigating the ways in which export of nutrients, algae and salt can be increased to restore a desired healthier state.

Further reading:

Mosley, L., S. Priestley, J. Brookes, S. Dittmann, J. Farkas, M. Farrell, A. J. P. Ferguson, M. Gibbs, M. Hipsey, J. Huang, O. Lam-Gordillo, S. Simpson, P. Teasdale, J. Tyler, M. Waycott, and D. Welsh. 2020. Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research, Adelaide.

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Southern Coorong Factsheet

December 2021

Pathways to reversing the hyper-eutrophic nutrient state of the Coorong

Restoring the nutrient cycle of the Southern Coorong and achieving a 'mesotrophic' (moderate nutrient) state requires an integrated management approach to improve its current hyper-eutrophic state. Detailed research investigation and a nutrient mass balance of the Coorong is being undertaken to identify where nutrients are and what processes influence them so that they can be targeted for removal. While immediate solutions to remove nutrients are needed, direct actions need to be carefully investigated, in consultation with the community and considering environmental, cultural and socio-economic factors. The following strategies are currently under consideration:

1. Strengthening flushing and connectivity to export excess nutrients and algae. This can be achieved by increasing:
    - inflows and/or outflows
    - channel depth to improve connectivity between and within lagoons.

    Under the climate change projections for 2050, the flows from the water recovered under the Basin Plan are expected to maintain flows across the barrages into the Coorong. Sea levels along the South Australian coast are also not expected to increase to the point where there is a greater connection between the Coorong lagoons (0.24 m AHD) until 2050.

2. Remediating sediments that are in poor condition is critical to restoring the Southern Coorong to health. Restoration of aquatic plants and the re-colonisation of sediments by macroinvertebrates can create oxygen-rich zones in the sediment. Oxygen-rich sediment will promote nitrifying and denitrifying bacteria and biologically-mediated nutrient removal. Most burrowing and filter feeding macroinvertebrates require salinities below 60 g/L (approx. 1.7 seawater salinity), which is often exceeded in the Southern Coorong under current conditions. Improving connectivity and flushing will remove salt and reduce salinity so that there are only short periods of time exceeding this threshold, enabling the ecosystem to help reduce nutrient levels.

3. Reducing external nutrient load to the Coorong could help, but would require whole of catchment nutrient reduction programs which would be costly and very difficult to implement, particularly for the Murray-Darling Basin catchment.

Image: Healthy sediment sample with aquatic plants (Photo: Luke Mosley)

4. Algal harvesting or removal/capping of hostile (hypersaline, sulfide-rich) sediments could also reduce nutrient enrichment at local scales, though both options involve significant practical issues to avoid disturbing aquatic plants and safe disposal of waste materials.

Addressing eutrophication and repairing the nutrient cycle will help improve the health of the Coorong and restore the needs of each component of the food web.

Further reading:

Mosley, L., S. Priestley, J. Brookes, S. Dittmann, J. Farkas, M. Farrell, A. J. P. Ferguson, M. Gibbs, M. Hipsey, J. Huang, O. Lam-Gordillo, S. Simpson, P. Teasdale, J. Tyler, M. Waycott, and D. Welsh. 2020. Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research, Adelaide.

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Australian Government

Government of South Australia
Department for Environment and Water

Connectivity and flushing

The Coorong is a unique and complex estuary with features that have made it prone to reaching its current degraded state.

Flow of water into and through the Coorong (ie. connectivity) is generally low because:

- it is in a semi-arid region with low rainfall
- there is a regulated supply of freshwater through barrages from the River Murray and to a lesser extent, from the South East Drainage Network. Both of these sources have been impacted by anthropogenic water extractions and diversions over the last century
- tidal flushing from the sea through the River Murray mouth is more restricted now due to reduced River Murray flow and reliance on dredging to maintain an open system
- the Coorong has very shallow areas and a narrow channel at Parnka Point that restrict how well the Southern Coorong is connected to the northern Coorong and the sea.

Water stays in the Southern Coorong for long periods of time, so that water evaporates but salt does not, meaning that during periods of low flow the water becomes saltier over time. This process of evapo-concentration occurs every year in spring and summer as the weather becomes hotter and drier. During a drought, there is less freshwater entering the Coorong to exchange the saltier water, so the Southern Coorong becomes more hyper-saline. The Southern Coorong was persistently extremely hyper-saline during the Millennium Drought, which was catastrophic for the plants and animals that live there.

Like salt, nutrients are affected by evapo-concentration. Several other processes have led to the Southern Coorong becoming hyper-eutrophic. For example, nitrogen can be locked away in aquatic plants or released as gas by biological processes, however, the high salt levels stop these natural pathways.
Therefore, low connectivity and hyper-salinity has increased the process of eutrophication.

When the Southern Coorong is well connected, animals and plankton can move freely. Zooplankton, which enters the Coorong in freshwater from the River Murray and South East Flows, forms the base of food webs. There is a low supply of these as food for fish and birds during periods of low flow and connectivity.

Fish can freely move into and out of the Southern Lagoon when it is well connected and the salinity is not too high. Sandy sprat and Congolli are medium and large-sized fish that are an important part of the diet of Mulloway. In years that water levels have been high, both prey fish are found in the Southern Coorong, but they are absent in drier, and hence higher salinity, years.

The Coorong is a naturally variable system, but the desired state for the Southern Coorong includes only short periods of low connectivity and high salinity. During periods when connectivity is improved, salt and nutrients can be flushed out and animals can move freely. Options to improve connectivity are being investigated through Project Coorong.

Further reading

Asanopoulos, C. and Waycott, M. (2020) The growth of aquatic macrophytes (Ruppia tuberosa spp. and Althenia cylindrocarpa) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research Technical Report Series No. 20/13, Adelaide, South Australia. ISSN: 1839-2725

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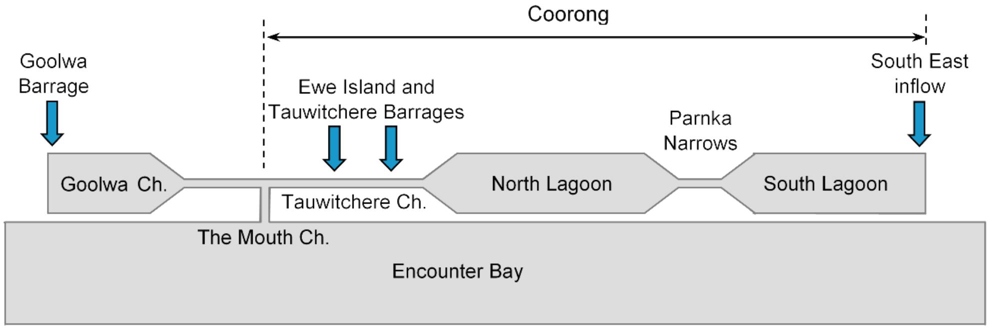

Schematic view of the Coorong (from Gibbs et al., 2018).

Southern Coorong Factsheet

December 2021

The aquatic plants of the Southern Coorong

Image: Ruppia megacarpa (Photo: Ryan Lewis)

The submerged aquatic plants of the Southern Coorong are recognised as a keystone resource to the Coorong ecosystem. The plants themselves are used as food, shelter and act to stabilise and oxygenate sediments supporting the life cycle of animals such as fish and birds, as well habitat for invertebrates and algae.

There are three species of submerged aquatic plants currently found in the southern Coorong. These include *Ruppia tuberosa*, *Ruppia megacarpa* and *Althenia cylindrocarpa*. These aquatic plants live their whole life cycle under the water and tolerate a range of salinities. These features of their life history mean that they are also sometimes known as seagrasses. In the past, other species of seagrass have been recorded in parts of the Coorong including *Zostera muelleri*, which is now absent from the system. In fact, the species of aquatic plants known to grow in the Coorong over the past 30 years are those that tolerate the very high salinities that occur each year, sometimes more than three times saltier than sea water.

Coorong water levels rise and fall each year during the winter to summer seasonal cycle. This creates large areas of aquatic plant habitat during the wetter months that dries up and becomes unsuitable as aquatic plant habitat during the drier summer months.

Over the last five years the aquatic plants that have been observed in the southern sections of the Coorong are *Ruppia tuberosa*, most obviously from Noonameena to Salt Creek, and *Althenia cylindrocarpa* again from Noonameena to Jacks Point. The presence of *Ruppia megacarpa* has been detected in adjacent ponds or streams and by the presence of seeds in the main lagoon.

It is very difficult to discriminate between the main aquatic plant species in Coorong, as they look almost identical unless flowering. The flowering of *Ruppia* includes the formation of long fragile stems with the flowers/seeds forming in a cluster at the end. In contrast, *Althenia* forms branching stems with many separate points where small numbers of flower/seeds form sequentially sometimes up to 1 m in length.

Some species of *Ruppia* can form small persistent vegetative structures at the base of shoots called turions. In *Ruppia* these turions are flask or sickle shaped and they allow the plants to survive for a few months when water levels drop. They are also rich in carbohydrates making them choice food for herbivores.

Further reading:

Asanopoulos, C., and M. Waycott. 2020. The growth of aquatic macrophytes (*Ruppia tuberosa* spp and *Althenia cylindrocarpa*) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research, Adelaide.

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Why aquatic plants are important

Aquatic plants of the Southern Coorong include *Ruppia tuberosa*, *Althenia cylindrocarpa* and *Ruppia megacarpa*. They are grouped together as a community of aquatic plants because it's difficult to distinguish these species when they are not flowering, All three species are small, submerged aquatic plants with very fine leaves. This aquatic plant community is often referred to simply as 'Ruppia'.

Aquatic plants are essential for a range of animals and the health of the Coorong. The formation of a dense canopy of aquatic plants creates a habitat for small and juvenile fish and invertebrates. These are in turn eaten by medium and large-sized fish such as Congolli and Mulloway. Herbivores and detritivores eat all parts of aquatic plants, including leaves, roots and even seeds.

Aquatic plants have other important but hidden roles to play in the Southern Coorong. The plants photosynthesise during the day, producing oxygen. The plant's vascular system carries oxygen from the leaves to plant roots where it is released into the sand or mud. This creates a layer of oxygen-rich sediment around the plant roots where bacteria and other microbes use oxygen to turn ammonium into nitrate. Nitrate can then be converted into a nitrogen gas and released into the atmosphere; reducing the levels of nitrogen in the water and sediment.

The leaves of aquatic plants are rich in nitrogen. As the leaves grow, nitrogen is taken up from the water and sediment to supply the leaves. These nutrients are stored in the leaves until the plant leaves are eaten, or they become detritus and break down over longer periods of time. Nutrients stored in plant leaves are locked away so that they are not available to nuisance filamentous or planktonic algae, reducing nutrients available for algal growth. This is another reason that aquatic plants are good for the eutrophication status of the Coorong.

The extent and amount of aquatic plant communities have been low in the Southern Coorong since the Millennium Drought. The extent of aquatic plants has shown some slow recovery in recent years, though the plants remain in poor condition, which exacerbates current poor sediment and water quality conditions. Given plants are key primary producers within the Coorong foodweb, improving their current condition will benefit food and habitat availability for native invertebrates, fish and birds.

Image: Aquatic plants provide important food and habitat in the Coorong

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Asanopoulos, C., and M. Waycott. 2020. The growth of aquatic macrophytes (*Ruppia tuberosa* spp and *Althenia cylindrocarpa*) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research, Adelaide.

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Ye, Q., G. Giatus, S. Dittmann, R. Baring, L. Bucater, D. Deane, D. Furst, J. Brookes, D. J. Rogers, and S. Goldsworthy. 2020. A synthesis of current knowledge of the food web and food resources for waterbird and fish populations in the Coorong. Goyder Institute for Water Research, Adelaide.

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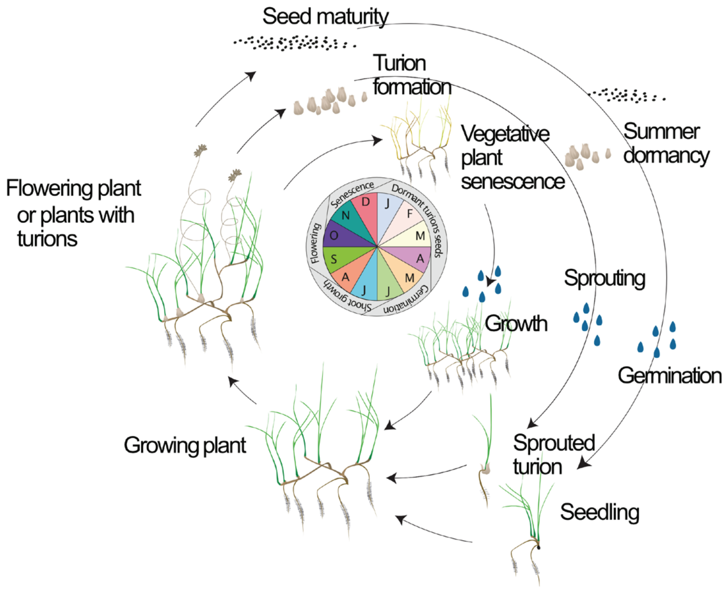
Aquatic plant lifecycles in the Southern Coorong

Image: Flowering 'Ruppia tuberosa' plants in the Coorong (Photo: Michelle Waycott)



Aquatic plants, including *Ruppia tuberosa,* can grow by producing new shoots on runners like grass. They are also flowering plants and produce seeds that fall into the sand and germinate when the conditions are right.

Aquatic plants persist as adult plants throughout the year in some areas of the Southern Coorong where the conditions allow it. In other areas, the seeds or turions (shoot base) sprout in autumn, they grow in winter and the plant life cycle is completed by late spring.

Aquatic plants need just the right environmental conditions to thrive. Clear water allows sunlight to reach the leaves of aquatic plants so that the plants can photosynthesise and grow. This is needed throughout the growing and adult stages of the life cycle. Clear water and good water quality is therefore required most of the time.

Many of the needs change over the life cycle of the plants as they grow, spread and reproduce. Water is essential to support the growing and adult stage of the life cycle, but seeds and turions can survive in the sand in shallow areas that dry out. Therefore, it is important that the water level is high enough for plants to thrive in shallow areas over winter and spring but the water level can drop in late spring and summer.

The seedbank needs to be replenished each year so that this life cycle can continue. Seeds mature on long stalks after flowers reach the water surface where they are fertilised. Mature seeds can't form if the water level drops too early in spring or if the water becomes too salty. Seeds germinate when the water level rises in spring if the water is not too salty.

The extent of aquatic plants in the Coorong was reduced during the Millennium Drought (2001–2010) because of persistently low water levels and extremely high salt concentrations. It hasn't recovered to historical levels. Eutrophication and algal blooms are hampering the long-term recovery of the Coorong despite initial successful aquatic plant translocation efforts.

Salt and nutrient levels need to be reduced to return thriving aquatic plant communities to the Southern Coorong. This can be achieved by increasing water levels and connectivity and reducing how long water stays in the lagoon.

Further reading:

Asanopoulos, C., and M. Waycott. 2020. The growth of aquatic macrophytes (*Ruppia tuberosa* spp and *Althenia cylindrocarpa*) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research, Adelaide.

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Algae affects recovery of aquatic plants

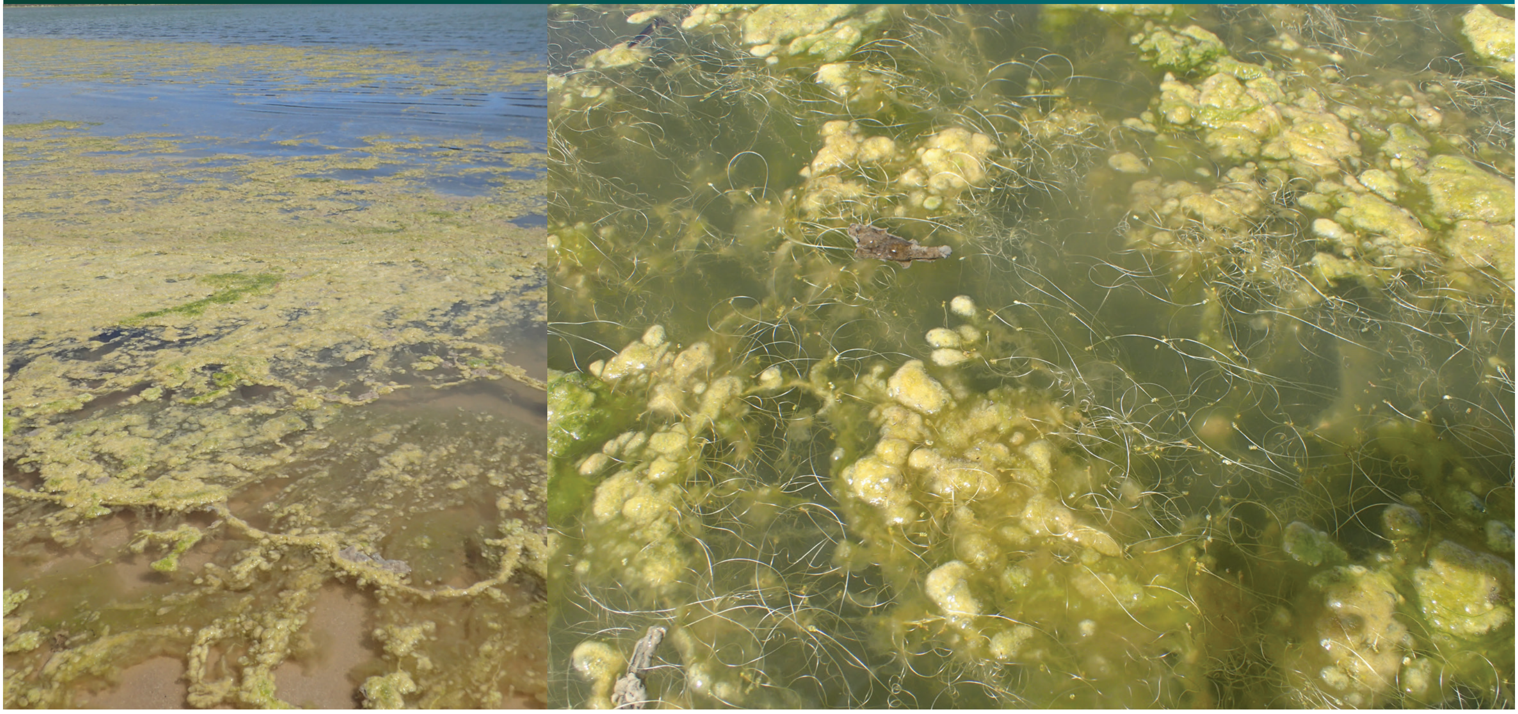

Image - Left: Filamentous algal mats in the Coorong (Photo: Michelle Waycott)
Right: Filamentous algae attaches to aquatic plants in the Coorong (Photo: Michelle Waycott)

Algal blooms can interrupt the life-cycle of aquatic plants in the Southern Coorong.

Filamentous algae forming dense blooms has become a common occurrence in the Southern Coorong. In the late stages of the algal bloom, it forms rafts at the water surface. These algal rafts entangle and damage long flowering stalks, which prevents seeds from maturing. Mature seeds are needed to form a seed bank so that aquatic plant seedlings can germinate and grow the following year.

Rafts of algae also shade the aquatic plant communities. Sunlight is needed by aquatic plants for photosynthesis and growth, but when shaded by algae they cannot get enough light. As a result, they grow and spread more slowly.

The organic-rich deposits that form when the algal blooms decay lead to the formation of monosulfidic black oozes. Aquatic plant communities and seedlings cannot survive in these anoxic (no oxygen) and sulfide-rich sediments. Therefore, algal blooms are making some areas of the Southern Coorong unsuitable for aquatic plants.

Algal blooms have formed in the Southern Coorong because it has reached a high nutrient state and is hyper-eutrophic. Nutrients remain trapped in the Southern Coorong because there are limited inflows and 'flushing' of nutrients out of it to the North Lagoon. The excess nutrients promote the growth of filamentous algal blooms.

The extent of aquatic plants declined during the Millennium Drought, affecting the animals that depend on them in the Southern Coorong. That loss was caused by very low water levels and high salt levels. Recovery of aquatic plants is being hampered by the hyper-eutrophic conditions and filamentous algae.

It is anticipated that aquatic plants will naturally recover in the Southern Coorong if water level is maintained through spring with low amounts of algae.

Further reading:

Asanopoulos, C., and M. Waycott. 2020. The growth of aquatic macrophytes (*Ruppia tuberosa* spp and *Althenia cylindrocarpa*) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research, Adelaide.

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845916

Glossary

Ammonium — A dissolved form of nitrogen readily taken up by algae and aquatic plants.

Anoxic — Lacking oxygen.

Aquatic plants — A phrase used to describe the mixed submerged aquatic plant community that includes *Ruppia tuberosa, Ruppia megacarpa* and *Althenia cylindrocarpa*. Where otherwise stated, the phrasing will be referring to either species independently or the genus.

Bacteria — A unicellular microorganism with simple internal structures.

Bioturbation — The reworking of sediments by animal activities including burrowing, ingestion, and defecation of sediment grains. It has a profound effect on sediment condition and the environment.

Connectivity — A mechanism that allows for the movement of water, materials and animals between areas, including between the north and south lagoons of the Coorong, between the sea and the Coorong through the Murray Mouth, and from the River Murray or south east flows to the Coorong (but not typically vice versa). It is an important element of hydrodynamics, has a strong influence on water quality (through exchange of salt and nutrients) and is essential for some ecological processes, such as migration of fish at different times of year and for the transport of zooplankton from freshwater inflows to support food webs of the Coorong.

Detritivore — An animal that feeds on dead material, especially plant parts.

Denitrification — The process by which nitrate is converted to nitrogen gas bubbles, which are released to the atmosphere. If the sediment is anoxic, then nitrification-denitrification cannot occur and the nitrogen remains in the nutrient cycle.

Eutrophication — The process of nutrient enrichment and the increase in the supply of organic matter. Eutrophic systems typically have excessive plant and algal growth, which become internally produced organic matter loads as they decay. They grow excessively in response to nutrient enrichment such as nitrogen and phosphorus inputs. Eutrophication has cascading effects for the entire ecosystem. The hyper-eutrophic state in the Southern Coorong is characterised by high concentrations of chlorophyll-a (>50 mg/L), total nitrogen (>4 mg/L) and total phosphorus (>0.2 mg/L) in the water.

Evapo-concentration — The concentration of solutes such as salt and contaminants as water evaporates. The effects of evapo-concentration increase with increasing water residence time, and at higher temperatures in summer.

Filamentous algae — The green filamentous algal community which occurs in the Coorong, consisting of *Ulva paradoxa, Rhizoclonium sp.* and *Cladophora sp.*.

Herbivore — An animal that eats plants.

Hyper-eutrophic — An extremely high-nutrient state due to eutrophication.

Hyper-saline — Salinities that are greater than that of normal seawater.

Macroinvertebrate — Invertebrate fauna that are greater than 0.5 mm.

Mesotrophic — Intermediate levels of nutrients, common in healthy estuaries. A mesotrophic Coorong would be fairly productive (with plant and animal life), but could be at risk of having water quality problems.

Millennium Drought — An Australian drought which impacted the Murray-Darling Basin over the period 1996–2010, and substantially impacted the Coorong over the period 2001–2010. The period from 2007–2010 was particularly extreme with extended periods of no flow through the barrages to the Coorong.

Monosulfidic black oozes — Monosulfidic black oozes (MBOs) form when there is an excess of organic matter, and sediments become anoxic as the bacteria consume all the oxygen to decompose the organic matter. Iron (III) and sulfate are converted by bacteria to iron (II) and hydrogen sulfide, because there is no oxygen. The iron typically comes from iron oxide minerals in the sediment that are reduced, whereas sulfate comes from water (it is plentiful in seawater and saline groundwaters)

Nitrogen — A nutrient that is essential to plants and animals and forms compounds such as amino acids and proteins. Nitrogen can be found in aquatic environments in dissolved, particulate, inorganic, organic and gaseous forms. Too much nitrogen can be associated with eutrophication.

Nitrate — A dissolved form of nitrogen.

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Glossary

Nitrification — Nitrification is the process by which ammonium is converted to nitrite and then nitrate. It can also take place in the sediment and requires oxygen. Denitrification is the process by which nitrate is converted to nitrogen gas bubbles, which are released to the atmosphere. If the sediment is anoxic, then nitrification-denitrification cannot occur and the nitrogen remains in the nutrient cycle.

Nutrient cycle — The movement or exchange of nutrients, such as nitrogen, from inorganic and organic forms into organic matter, including plants and animals, and back again.

Oxygenate — Supply or enrich with oxygen. Sediments in aquatic systems need to be oxygenated in order for healthy nutrient cycling and nutrient exchange from sediment to water and to the atmosphere to occur. Oxygenation of sediments can occur through biological processes (e.g. animal movement, pumping through plant roots), or physical processes such as water turbulence and currents moving sediments around.

Phosphorus — A nutrient essential to life and strongly influencing water and sediment quality in the Coorong. Phosphate is the dissolved form of phosphorus, which is uptaken by plants and algae.

Photosynthesis(e) — The conversion of light energy to organic compounds, can be referred to as carbon fixation.

Phytoplankton — Small plankton algae that is essential to aquatic food webs.

Respiration — Respiration is a chemical reaction which takes place in all livings cells and releases energy from glucose. Anaerobic respiration occurs without oxygen and releases less energy but more quickly than aerobic respiration.

Ruppia — A genus of aquatic plant, referring to the species *Ruppia tuberosa* in the Southern Coorong.

Salinity — Salinity can be defined as the concentration of dissolved mineral salts present in waters and soils on a unit volume or weight basis.

Southern Coorong - The Southern Coorong is defined here as the area ranging from Parnka Point in the north and south to 42 Mile Crossing, approximately 65 to 105 km from the Murray Mouth that connects the estuary to the sea.

Turion — Reproductive structure of *Ruppia tuberosa* (Type I and Type II) and *R. polycarpa* (Type I) produced underground that is capable of forming into a new plant

Water quality — The condition of water or some water-related resource as measured by biological surveys, habitat-quality assessments, chemical-specific analyses of pollutants in water bodies, and toxicity tests.

Zooplankton — Animals (often microscopic) that either move by water currents or are weak swimmers in the water column.

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