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The role of sediments in the eutrophication of the Southern Coorong

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).

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

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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The Goyder Institute for Water Research is the delivery partner for research components of Healthy Coorong, Healthy Basin, providing independent research to inform future management decisions for the region.

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.

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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