Healthy Coorong, Healthy Basin

Science Forum | Goolwa 2023

Nutrient Dynamics in the Coorong

Assoc. Prof. Luke Mosley | University of Adelaide

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The issue

- Coorong South Lagoon acknowledged to be in an undesirable state with poor water and sediment quality, and declining ecological health
- Widespread community concern
- While nutrients such as Nitrogen and Phosphorus are essential in aquatic systems, excess availability of these can lead to **eutrophication** (defined as an increase in the supply of organic matter to an ecosystem)
- Internationally, increased external loading of nutrients and/or reduced flushing have been found to be key drivers of eutrophication in estuaries

Nutrient Dynamics Project Overview

1.1 Existing data and knowledge collation
- Collate nutrient data from previous studies
- Assess and collate knowledge from relevant studies in Coorong and internationally

1.2 Nutrient sources and transport
- Characterisation of nutrient sources
- Tracing of water mixing and redox cycles
- Groundwater Investigations
- Nutrient budget

1.3 Nutrient cycling and fluxes
- Sediment quality survey
- Nutrient flux and cycling
- Resuspension influence
- Macroinvertebrate influences nutrient cycling

1.4 Nutrient removal options
- Desktop assessment of options
- Collate and incorporate findings and data from field trials and intervention projects involving nutrient removal

http://www.goyderinstitute.org/publications/technical-reports/
Snapshot of Key Science Findings

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Collation and Synthesis of Water Quality Data

Follow on scientific paper (Mosley et al 2023): [https://authors.elsevier.com/sd/article/S0025-326X(23)00079-6](https://authors.elsevier.com/sd/article/S0025-326X(23)00079-6)
Nature and drivers of eutrophication

- Total nutrient concentrations in freshwater sources much lower than Coorong lagoon concentrations
- Strong relationships of total nutrients and chlorophyll with salinity
- The evaporation of water and concentration of nutrients due to increased water residence time is a drive nutrient enrichment
- Isotope tracers showed River Murray influence very important in North Lagoon, and large River Murray flows important to flush South Lagoon
- Dissolved nutrients generally at low concentrations, most nutrients in organic form (e.g. algae, dead organic matter)
Sediment quality

- Coorong sediments increase in organic carbon and nutrients in a gradient away from Murray Mouth
- ~50 times more nutrients in top 5cm of sediment than water column
- Algal derived source of nutrients to sediment¹
- Anoxic black monosulfidic oozes (MBOs) dominant across much of South Lagoon and south of North Lagoon

Nutrient fluxes back to water

- Microbes breakdown organic matter, consuming oxygen and releasing dissolved nutrients
- High ammonium and low nitrate in South Lagoon sediment
- Low denitrification activity (i.e. lack of key nitrogen loss mechanism in healthy system)
- High flux of ammonium to surface water
- Low capacity to bind Phosphorus due to anoxic sediment
- Apparent influence of aquatic plants on nutrient cycles based on light-dark differences
Loss of burrowing benthic macrofauna in southern region of Coorong

North Lagoon oxic zones along burrows

South Lagoon anoxic with no burrows
Effect of loss of benthic macrofauna ‘ecosystem engineers’ on nutrients

- Lower nitrate but higher ammonium and organic matter in South Lagoon sediment\(^1\)
- All consistent with limited benthic organism related oxygenation of sediment in South Lagoon currently

Sediment restoration experiment

Nutrient removal options

• Improving lagoon flushing by coastal seawater input into the South Lagoon or increased River Murray or South East drainage inflow and improved connectivity

• Reduction in nutrient loads entering the Coorong from the Murray-Darling Basin and South East catchment

• Artificial oxygenation of water and sediment

• Macrophyte (e.g. Ruppia sp.) restoration

• Benthic macroinvertebrate restoration

• Macro-algal and/or filamentous algal mat harvesting

• Hostile sediment removal and capping

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Most feasible options

- Multicriteria Analysis found that *improved lagoon flushing and connectivity* (i.e. to export nutrients) is likely the most feasible option from the scientific evaluation conducted
- This option would address the primary driver of eutrophication in the Coorong water and sediment
- Complementary ecosystem restoration strategies involving macroinvertebrates (when salinity <60 psu) and the aquatic plant community would be beneficial
Effect of 2022-2023 floods

• On preliminary analysis, the 2022-2023 flood event has had a positive effect on the water quality of the Coorong, in particular the South Lagoon (30-43% reduction in TN and TP respectively)

• However the discharge of River Murray flood water has caused some increased nutrient and chlorophyll levels in the expanded low salinity regions of the North Lagoon.

• Improved flushing beneficial to lower nutrients, organic matter and salinity – more frequent medium and large floods on the River Murray likely served this purpose historically

• Important to recognise that the flushing effects of floods and large water for environment delivery are very infrequent, so there is still a rationale to pursue Coorong infrastructure investigations and full Basin Plan implementation critical
Acknowledgements

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**NSW Government** – Dr Angus Ferguson

**DEW** – Dr Matt Gibbs (now CSIRO), Claire Sims, Jody O’Connor

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Up Next

Coorong Aquatic Primary Producers

Professor Michelle Waycott | Chief Botanist | State Herbarium of South Australia

Dr. Tamar Jamieson | Flinders University
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The Ruppia Community of the southern Coorong

Professor Michelle Waycott | School of Biological Sciences | University of Adelaide
| Botanic Gardens and State Herbarium | Department for Environment and Water

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Component 2 project team

- Component lead: Michelle Waycott (UoA and BGSH–DEW)
- Activity leads
  - Jason Nicol (broadscale distribution)
  - Michelle Waycott (Ruppia restoration strategy)
  - Michelle Waycott/Ryan Lewis (Ruppia and filamentous algae responses to water quality including salinity and temperature)
  - Michelle Waycott/Ryan Lewis/Luke Mosley (System-scale responses of Ruppia populations)
  - Sophie Leterme (Microbial communities and associated environmental conditions)
  - Michelle Waycott (data systems, collation and synthesis for modelling and management)


With contributions from Catherine Collier, John Conran, Andrew Thornhill, Matt Hipsey, Mohsen Chitsaz, Harrison Tiver (DEW), Geoff Gallasch, Christina Asanopolous, Kate Frahn, Elise Culver, Jamie Simpson, Leif Currie, Phuong Chau, Ruadhan Hankinson-Elder, Tan Dang, Charlotte Miles, Elan Perez-Garcia, Laura Mazzone, Louis Ket, Andrew Bird, Luis Williamson, and Andrew McDougall

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Aquatic plants and algae
*a large and small scale question*

(image extracted from G. Gallasch Drone footage, with permission)
History of loss of the Ruppia Community

Coorong South Lagoon Ruppia Community prior to start of these studies

Data derived from TLM Monitoring (Paton, Bailey and Paton).
Composition of the Ruppia Community

- eDNA screening of samples collected during surveys 1.

Where does the Ruppia Community occur

Biomass

Plant Biomass of the Ruppia Community 2020–2021 over two reproductive seasons
Ruppia Community highly variable location and season/year
Environmental conditions ‘good’ for the Ruppia Community

**Month** (temperature)
Higher biomass in Summer before extreme salinities and temperatures occur

**Water Depth** (m AHD)
Presence of deeper plants associated with perennial populations and ongoing milder conditions
Environmental conditions ‘good’ for the Ruppia Community

Salinity differences between years – more turions in 2021!
Environmental conditions ‘good’ for the Ruppia Community

Automated data collection at Parnka Point (station A4260633)
Environmental conditions ‘good’ longer term
Where does the Ruppia Community occur

Sediment quality
Where does the Ruppia Community occur

*Seed banks*
The Ruppia Community – phenology
Phenology of the Ruppia Community
Nutrients in the littoral aquatic plant community

Significant difference between samples in 2016/17 and 2020/21
Sediment condition, nutrients and plant performance
Maintaining a healthy aquatic macrophyte community

Filamentous algae
A sign the system is unhealthy
Filamentous algae follows a seasonal development cycle
Light stress at sites significant for long periods where there are algal mats.
Current state versus a desired state

Ruppia community in the southern Coorong

South lagoon – current (2021)
Nutrient excess: accumulating in annual cycle forming localised black oozes
Seasonal salinity marine to hypersaline

South lagoon – best case
Primarily N-limited
Seasonal salinity marine to hypersaline

Depth range >1 m
Target for the Ruppia Community
Role of microbes on *Ruppia* seagrass in the Coorong

*Tamar Jamieson*, Mohsen Chitsaz, Angélique Gobet, Michelle Waycott, Sophie Leterme

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Seagrass in the Coorong
Seagrass communities

- Microbial communities indicate ecosystem health\textsuperscript{1-5}.

- Seagrasses and microbes form relationships which are mutually beneficial\textsuperscript{6-9}.

- The relationship between the seagrass and microbes is important for survival\textsuperscript{10-12}.
Study sites and environmental conditions

Five sampling sites:
- Wild Dog Islands
- Policeman Point
- Parnka Point
- North Magrath Flats
- Noonameena

Four sampling periods:
- October 2020
- December 2020
- March 2021
- June 2021
Impact of sample type

Each sample type has a specific microbial community.

Communities consist of dominant and rare organisms.
Sample type specific microbiota

Microbes that contribute to the differences in each sample community are largely independent of surrounding environment.

Blue = water samples
Brown = sediment samples
Green = *Ruppia* samples
Sediment specific microbiota

Microbes in the sediment that contribute significantly to the communities of the different life stages of the *Ruppia* plant are unique for each stage.

Blue = turion & rhizome present
Brown = roots present
Green = leaves and roots present
Ruppia root specific microbiota

Microbes associated with the root of the *Ruppia* plant that contribute significantly to the differences in each life stage of the *Ruppia* development are unique.

Blue = turion & rhizome present
Brown = roots present
Green = leaves and roots present
Ruppia specific microbe functions

Microbial functions are site and season independent.

The Ruppia plant provides chemicals which the microbes breakdown for energy.

Some of these process provide Ruppia with chemicals it requires to live.
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Sam Brooke
Woody Drummond

Michelle Waycott Lab
Emma O’Loughlin
References

11. Ugarelli, K., Laas, P. and Stingl, U., 2018. The microbial communities of leaves and roots associated with turtle grass (Thalassia testudinum) and manatee grass (Syringodium filliforme) are distinct from seawater and sediment communities, but are similar between species and sampling sites. Microorganisms, 7(1), p.4.
Up Next

Coorong Food Web Dynamics

Professor Sabine Dittmann | Flinders University
Associate Professor Qifeng Ye | SARDI Aquatic Sciences
Healthy Coorong, Healthy Basin

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Coorong food web dynamics

Qifeng Ye\(^1\), Sabine Dittmann\(^2\), George Giatas\(^1\), Ryan Baring\(^2\) and Simon Goldsworthy\(^1\)

\(^1\)SARDI; \(^2\)Flinders University

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Background

• A functioning and resilient food web is critical to the Coorong ecosystem.

• Decades of deteriorating ecological conditions have simplified the food web of the Coorong South Lagoon, which has adversely affected invertebrate, fish and waterbird communities.
Aim – To understand food web dynamics in the Coorong

Specific objectives

• To determine the major food sources and their relative contribution to the diet for key waterbird and fish species in the Coorong

• To investigate the food resources and conditions required to increase food availability and energy supply for key fish and waterbirds in the Coorong

• To develop an integrated quantitative food web model that can assess food web responses to various conditions

→ Inform management on restoring a functioning Coorong food web
Overview of Research Methods

Activity 3.1: Review, synthesis & conceptual models

Activity 3.2: Diet studies

Activity 3.3: Bioenergetics & key drivers for food resource
  • Zooplankton; Macroinvertebrates & Fish

Activity 3.4: Quantitative food web model development
## Activity 3.1

### Review & synthesis findings

- **Diets of fishes** in Coorong are well understood
  - variety of feeding modes
  - most have benthic invertebrates as main prey.

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Feeding Modes</th>
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<tbody>
<tr>
<td>Mulloway</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Australian salmon</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Congolli</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Greenback flounder</td>
<td><em>Australian herring</em></td>
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<tr>
<td><em>Bridled goby</em></td>
<td><em>Australian herring</em></td>
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<tr>
<td>Yellow-eye mullet</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Black bream</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Tamar goby</td>
<td><em>Australian herring</em></td>
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<tr>
<td>Smallmouth hardyhead</td>
<td><em>Australian herring</em></td>
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- Knowledge gaps for several species (e.g. lagoon goby).
Review & synthesis findings

• Understanding of bird diets is limited for the Coorong.

• Long-term ecological monitoring over past decades → foundational knowledge of key biota and effects of droughts and high flows/floods.

• Conceptual understanding of food web.
• Created diet matrix as input for the quantitative food web models.
• Identified knowledge gaps
Activity 3.2

Diet studies findings

• Filled knowledge gaps for lagoon goby and waterbirds.
• Traditional gut content and DNA metabarcoding of scats.

• Diet of lagoon goby in the Murray Estuary and North Lagoon was almost exclusively amphipods.
Shorebird and fish populations benefit from:

- Abundant and diverse prey assemblages
- Suitable foraging habitat

**Shorebird diets** (sharp-tailed sandpiper, red-necked stint and red-capped plover):
- South Lagoon: chironomid larvae
- North Lagoon: chironomid larvae, amphipods, worms
- Where choice of prey available, prey selectivity for amphipods

**Waterfowl diets** (chestnut and grey teals):
- Dominated by *Ruppia* and included a variety of other vegetation

**Shorebird and fish populations benefit from**

- Abundant and diverse prey assemblages
- Suitable foraging habitat
Activity 3.3

Food resource availability, bioenergetics & key environmental drivers

• Zooplankton, macroinvertebrates, fish – similar patterns

• Diversity, individual densities & biomass: Murray Estuary & North Lagoon > South Lagoon

• Greater diversity of prey in Murray Estuary for predators with different foraging strategies

• Prey choice in South Lagoon low

• Pattern affected by flow over barrages and from Salt Creek
• Flow $\rightarrow$ increased abundance of zooplankton, macroinvertebrates and fish

Macroinvertebrates

Fish

Survey
- **Salinity strongest environmental driver:**
  - \( > 50 \) → lower individual & biomass densities
  - \( < 40 \) → highest densities
- **Exceptions:**
  - Chironomid larvae
  - Smallmouth hardyhead
• Biomass of fish and macroinvertebrates along the salinity gradient of the Coorong
• Nutritional quality and energetic values of key food resources
Macroinvertebrates:
- Highest in Murray Estuary
- Benthic micro-molluscs: highest energy density & highest production

Fish:
- More similar across regions
- Smallmouth hardyhead: high energy density in South Lagoon
- Murray Estuary: high energy density by variety of trophic groups
Activity 3.4  Food web modelling

Ecopath with Ecosim (EwE)

Conceptual model

Quantitative ecosystem model

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• DEW HCHB managers.
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The Goyder Institute enhances the South Australian Government’s capacity to develop and deliver science-based policy solutions in water management. It brings together the best scientists to provide expert and independent research and scientific advice to inform Government water policy and identify future threats and opportunities to water.

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Questions