Water for a Healthy Country

PROCEEDINGS OF
CLLAMM Ecology Research Cluster
CLLAMM Futures Workshop #1

December 5th and 6th 2006,
Flinders University

Rebecca Lester & Peter Fairweather

February 2007
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The Water for a Healthy Country Flagship is a research partnership between CSIRO, state and Australian governments, private and public industry and other research providers. The Flagship aims to achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.

The Australian Government, through the Collaboration Fund, provides $97M over seven years to the National Research Flagships to further enhance collaboration between CSIRO, Australian universities and other publicly funded research agencies, enabling the skills of the wider research community to be applied to the major national challenges targeted by the Flagships initiative.

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Foreword

The environmental assets of the Coorong, Lower Lakes and Murray Mouth (CLLAMM) region are currently under threat as a result of ongoing changes in the hydrological regime of the Murray-Darling River. While a number of initiatives are underway to halt or reverse this environmental decline, such as the Murray-Darling Basin Commission’s “Living Murray”, rehabilitation efforts are hampered by the lack of knowledge about the links between flows and ecological responses in the system.

The Coorong, Lower Lakes and Murray Mouth program is a collaborative research effort with the aim to produce a decision-support framework for environmental flow management for the CLLAMM region. This involves understanding the links between the key ecosystem drivers for the region (such as water level and salinity) and key ecological processes (maintenance and improvement of bird habitat, fish recruitment, etc). A second step will involve the development of tools to predict how ecological communities will respond to manipulations of the “management levers” for environmental flows in the region. These include flow releases from upstream reservoirs, the Lower Lakes barrages, and the Upper South-East Drainage scheme, and dredging of the Murray Mouth. The framework will attempt to evaluate the social, economic and environmental trade-offs for different scenarios of manipulation of management levers, as well as different future climate scenarios for the Murray-Darling Basin.

One of the most challenging tasks in the development of the framework will be how to predict the response of ecological communities to future changes in environmental conditions in the CLLAMM region. The CLLAMMecology Research Cluster is a partnership between CSIRO, the University of Adelaide, Flinders University and SARDI Aquatic Sciences that is supported through CSIRO’s Flagship Collaboration Fund. CLLAMMecology brings together a range of skills in theoretical and applied ecology with the aim to produce a new generation of ecological response models for the CLLAMM region.

This report is part of a series summarising the output from the CLLAMMecology Research Cluster. Previous reports and additional information about the program can be found at http://www.csiro.au/partnerships/CLLAMMecologyCluster.html
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1. Introduction and Overview

This document is a report on the CLLAMMecology Workshop held in December 2006 as a part of the CLLAMM Futures project.

CLLAMM Futures aims to integrate the knowledge of the other CLLAMMecology projects with that of past projects by developing a set of ecosystem-level models. These will be used to assess the effects of possible management options and to investigate the likelihood and distribution of a variety of alternative states occurring in the future. This information can then be passed on to the relevant organisations to inform future management of the region.

This workshop was the first of a planned three. Its purpose was to begin to integrate the existing CLLAMM ecologists, including new members to the team and orient participants. It was designed to specifically focus on existing knowledge and to identify repositories of that knowledge and begin to evaluate the current conceptual models used by managers of the region. It also provided an opportunity to share objectives and project plans across the CLLAMMecology program and to develop linkages between the CLLAMM Futures project team, those of other CLLAMMecology projects and relevant stakeholders from management organisations.

**Venue:** Lecture room 103 in Biology Building, Flinders University
2. Agenda

Day 1 = Tuesday March 4th

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Presenter/Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30</td>
<td>Welcome &amp; introduction to workshop</td>
<td>Peter Fairweather</td>
</tr>
<tr>
<td>9:40</td>
<td>Meeting everyone, incl. post-docs</td>
<td>All</td>
</tr>
<tr>
<td>10:00</td>
<td>Update reports on Cluster &amp; its Projects:</td>
<td>Mike Geddes</td>
</tr>
<tr>
<td></td>
<td>CLLAMMecology Research Cluster</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>MORNING TEA (in room 143)</td>
<td></td>
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<tr>
<td>11:00</td>
<td>Key Species Responses Project</td>
<td>Dan Rogers</td>
</tr>
<tr>
<td>11:30</td>
<td>Habitat Project</td>
<td>Jason Tanner</td>
</tr>
<tr>
<td>12:00</td>
<td>Productivity &amp; Trophodynamics Project</td>
<td>Justin Brookes</td>
</tr>
<tr>
<td>12:30</td>
<td>Futures Project</td>
<td>Peter Fairweather</td>
</tr>
<tr>
<td>1:00</td>
<td>LUNCH (in room 143)</td>
<td></td>
</tr>
<tr>
<td>2:00</td>
<td>Discussion re data being collected</td>
<td>Peter Fairweather + all</td>
</tr>
<tr>
<td>3:00</td>
<td>Making our plans more realistic?</td>
<td>All</td>
</tr>
<tr>
<td>4:00</td>
<td>AFTERNOON TEA (in room 143)</td>
<td></td>
</tr>
<tr>
<td>4:30</td>
<td>Introduction to the conceptual models being used by managers for CLLAMM</td>
<td>Peter Fairweather &amp; Nick</td>
</tr>
<tr>
<td></td>
<td>END</td>
<td>Souter</td>
</tr>
<tr>
<td>6:00</td>
<td>Dinner at local Asian restaurant (optional)</td>
<td></td>
</tr>
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Day 2 = Wednesday March 5th

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Presenter/Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Arrival &amp; welcome</td>
<td>Peter Fairweather</td>
</tr>
<tr>
<td>9:15</td>
<td>Workshopping the conceptual models &amp; continue discussion</td>
<td>Peter Fairweather</td>
</tr>
<tr>
<td>11:00</td>
<td>MORNING TEA (in room 143)</td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>CSIRO CLLAMM &amp; Water for a Healthy Country research + discussion of linkages</td>
<td>Barbara Robson + all</td>
</tr>
<tr>
<td>12:30</td>
<td>LUNCH (in room 143)</td>
<td></td>
</tr>
<tr>
<td>1:30</td>
<td>Management scenarios to be modelled</td>
<td>Peter Fairweather + all</td>
</tr>
<tr>
<td>3:00</td>
<td>END</td>
<td>All</td>
</tr>
</tbody>
</table>

Contacts:

Peter Fairweather (Flinders) 08 8201 5021
Rebecca Lester (Flinders) 08 8201 3436
Gillian Napier (Flinders) 08 8201 2193
3. Proceedings of the workshop

3.1. Day 1

3.1.1. Meeting the complete research teams in each Project, especially all the new post-docs

3.1.1.1. Overview of discussion:

The meeting provided the opportunity for the complete research teams to become familiar with one another, particularly the post-docs who had recently joined the team. Each person introduced themselves and where they fitted into the CLLAMMecology research cluster.

3.1.2. Presentations from Project leaders (or senior scientists) from each of the 4 Projects

- Outline of research plan, with examples of approaches, analyses & interpretation
- What sort of database (both past & new data) will we end up with?
- Schedules & fieldwork plans
- Sharing methods & SOPs for joint data-collection purposes
- Defining rules for co-operation & desired interactions over the next 12 months

3.1.2.1. Overview of discussion:

A presentation was given by each of the project leaders (or their representative) to outline the current status of each project and the plans for the coming year. A copy of each presentation is attached.

3.1.2.1.1. CLLAMMecology Overview

An overview to the CLLAMMecology project as a whole was given by Mike Geddes.

CLLAMMecology is a joint effort by the University of Adelaide, Flinders University, SARDI Aquatic Sciences, the Department of Environment and Heritage, AWQC, DWLBC and CSIRO Water for a Healthy Country. It consists of four projects: Key Species Responses, led by David Paton; Productivity and Trophodynamics, led by Justin Brookes; Dynamic Habitats, led by Jason Tanner; and CLLAMM Futures, led by Peter Fairweather.

The Cluster aims to develop knowledge at an ecosystem level, including key macrophyte species, macroinvertebrates, fish and birds. It contends that ecosystem response is a result of climate and management actions interacting with ecosystem drivers which affect key species response, productivity and trophodynamics to determine habitat availability. These can then be used to predict future outcomes under a range of conditions and to assess “water benefits” associated with a variety of management scenarios.

In this system, the ‘levers’ for management (that is, factors controlled by managers) include releases from reservoirs, the operation of barrages, dredging of the mouth, releases from the Upper South East drainage system, and other possible engineered solutions. These levers are constrained by a variety of factors. The current drought makes releases from reservoirs extremely unlikely in the foreseeable future and the barrages are likely to remain closed until at
least mid-2007. Water from the USE drainage system is feasible, but has a timeframe of more than two years. Dredging may be the lever that is most important at the moment, and perhaps the project should adjust its focus to reflect this, although changing the current management regime with respect to dredging may be difficult.

The Key Species Response project is focused on the ecology of identified key species of macrophytes, fish, invertebrates and birds. These species were chosen based on their conservation, ecological or economic values. Each taxonomic group will be studied along the salinity gradient in the region at 12 common sites. The project will involve field experiments and aims to gather information regarding distribution and abundance, reproduction and recruitment, behaviour, movement, and habitat requirements.

The Dynamic Habitat project will produce spatially and temporally explicit maps of habitat availability for those key species. The region is likely to be very sensitive to changes in depth given that it is usually very shallow. This project will enable the prediction of suitable habitat distribution under a range of possible conditions.

The Productivity and Trophodynamics project will investigate the role of the various functional groups of pelagic and benthic producers in primary production. These will form the basis of food webs describing the transfer of carbon up to birds and fish in the system.

3.1.2.1.2. Productivity and Trophodynamics Update

Justin Brookes gave an update on the status of the Productivity and Trophodynamics project and the challenges for CLLAMM Futures arising from the study.

Over the coming summer, the project team will be focused on three main areas. They will undertake a survey of the primary production in the Coorong, including benthic algal mats, pelagic phytoplankton and macrophytes; measure benthic and pelagic primary production using changes in dissolved oxygen levels; and construct food webs and carbon flow pathways using isotope and gut analyses. The food web study will identify the relative contribution of the various sources to carbon capture in the system.

Justin highlighted the need to develop a two-phase plan for the Coorong, initially focusing on a restoration phase, and then developing a long-term management regime, assuming that flow levels is the only lever available to alter the system. The restoration phase will need to be based on the preferred state for the system (e.g. algal- versus macrophyte-dominated primary production; c.f. Dutch work by Scheffer et al. (2001)), and the natural resilience in the system would need to be overcome to switch between states. One example of this need to overcome natural resilience and the hysteresis involved in switching between states is the work by Ibelings et al (in press). Decisions need to be taken regarding the preferred state, then the conditions making the system resistant to change need to be identified, and a time frame over which change could be expected be estimated.

Tools to assist in this process include the hydrodynamic model developed by the CSIRO, the 3-D model of the Lower Lakes, models developed by the MDBC, and our knowledge of the life cycle of macrophytes including *Ruppia* and the constraints on primary productivity (including nutrients, salinity, water clarity and water levels). The driver for changes in the system is most likely to be flow, so there would need to be a long term commitment to the ‘maintenance’ level of water, but possibly also a large flow to reset the system initially (i.e. more than one year with above average flow may be needed to reset the system). These models and data have various levels of detail. Some are quantitative, some semi-quantitative and others are probability-based or use preference curves. A major challenge for CLLAMM Futures is to integrate the variety of data available to identify how to move the system through state space to the desired point. Another key question is whether we can ever recover to the desired point. No participants were aware of species lost to the system, but will this continue to be the case over time, given that the current trajectory appears to be significant declines in the variety of taxa using the region?
The terminology used to describe the response of the system to change needs to be clarified. The differences between resistance, and a systems ability to resist change, and the resilience, or its ability to respond following disturbance, need to be teased out.

3.1.2.1.3. Key Species Response Update

The leader for the Key Species Response project was unable to attend the workshop, so an update on the *Ruppia* and bird sub-projects was provided by Daniel Rogers, for invertebrates by Alec Rolston and for fish by Qifeng Ye.

For the *Ruppia* spp. sub-project, the team includes David Paton, George Ganf, Jason Nicol and Daniel Rogers. The bird sub-project team includes David Paton, Daniel Rogers and Prija Wilson. Sabine Dittmann, Mike Geddes, Alec Rolston, Justine Keuning and Coby Matthews comprise the project team for invertebrates. The fish sub-project involves Bronwyn Gillanders, Qifeng Ye, Andrew Munro, Felicity McGovern and Elizabeth Bonner.

The presence and abundance of *Ruppia* will be surveyed at 10 sites approximately 5 km apart in the Southern Lagoon. It will not be surveyed at the 12 designated survey points, as it is unlikely to occur at most of these. Surveys include a visual assessment and 25 cores taken at each of three water depths (30 cm, shoreline and halfway between shoreline and high water mark). *Ruppia tuberosa* seeds, shoots, turions and any associated macroinvertebrates will be counted. Experiments are planned to investigate the effects of salinity and water depth to build on work conducted in the 1990’s. These may have to be *ex situ*, given limitations due to the drought. No bird exclusion experiments are expected to be possible. Preliminary results indicate low abundances of *Ruppia tuberosa*, with the plant absent from many historical locations. There was evidence of growth, especially at the northern end of the Southern Lagoon, and it is likely that water level, or, more precisely inappropriate seasonal shifts in water levels is driving performance, and ultimately distribution.

Invertebrates have been surveyed at 11 of the 12 sites using a sampling design stratified by depth and substrate type. Size frequency and evidence of reproduction will be recorded for several key species along with ash-free dry weight. The vertical distribution of invertebrate will be studied, along with their effects on bird foraging behaviour by Justine Keuning as a part of her PhD studies. Predator exclusion experiments and possible translocation or irrigation experiments are planned for the coming year. Preliminary results suggest that brine shrimp have a patchy distribution, but are most common at the southern end of the Coorong and that other zooplankton species are present, possibly in higher numbers than observed in previous years. Several questions were raised as to the survey methods for zooplankton and whether they were adequately covered.

Bird surveys were undertaken at 11 of the 12 designated sites in December. Birds were counted every 5 to 10 minutes from dawn to dusk over one day at each point. Behavioural attributes, time spent foraging, resting and flying were recorded. For target species, foraging depth and the prey items taken were recorded where possible. Preliminary results indicate that bird distributions are following historical trends, with higher diversity and abundances in the north and the south dominated by Banded Stilt, with few piscivores or teal. Sampling will be repeated in January, and collections of feathers and faeces will be made for isotope analysis by the trophodynamics project team. Additional work will focus on key groups: fishers, duck and waders. Central place foraging studies will be undertaken for cormorants, pelicans and Crested and Fairy terns. Comparison of duck foraging behaviour in brine shrimp-dominated versus *Ruppia*-dominated landscapes will be undertaken by Prija Wilson as her Honours project. Justine Keuning’s PhD work on wader foraging behaviour will also be extended. Foraging water depth is likely to be a key habitat constraint for many bird species.

The objectives of the fish key species response team include determining the distribution, abundance, size and age structures of selected key species and to relate these to habitat and environmental conditions. The reproductive biology and cues to spawning will also be investigated, along with the links between environmental conditions and recruitment. The final
objective was to assess the relationship between freshwater flows and recruitment success for commercial significant species.

Surveys involved a combination of seine and gill netting, and were conducted at all 12 designated sites. Surveys had been undertaken for October and November, with the December sampling imminent. At each site, all species were identified, counted and measured and a subsample collected. Water quality measurements were also taken at each fishing site.

Preliminary results indicated declining species richness from the estuary through the Northern Lagoon to the Southern Lagoon. Decreased abundances were also observed in November compared to October, and these seemed to be related to increasing salinity over time.

Members of the Key Species Response project reported land access problems at the Barkers Knoll site. As a result, surveys were not conducted for birds or invertebrates. The other 11 designated survey sites have been fine.

3.1.2.1.4. Dynamic Habitats Update

Jason Tanner gave a report on the progress of the Dynamic Habitat Project.

The project team consists of Jason Tanner, Simon Benger, Russell Seaman and Sunil Sharma, who will be joining the project team in January.

The project aims to quantify the available habitat in the CLLAMM region. It includes a digital elevation model of the area including both bathymetry and topography, a map of the subtidal and 'intertidal' (that is, habitats exposed periodically through the year) habitats surrounding both the Coorong and Lower Lakes and a model of light availability at various water depths. The project will incorporate information from the hydrological and biogeochemical models built by CSIRO, habitat requirements for key species and productivity data for the region. This will allow dynamic prediction of habitat availability, both in space and time and under a variety of different management regimes. One possible issue may be that the hydrodynamic model is a one dimensional model, which may make the accurate prediction of wader habitat (water depth and salinity) difficult. The hydrodynamic model will be able to predict both water levels and salinity distribution along the length of the Coorong, but will not be predictive across the breadth (i.e. discriminate across the estuary). It does include the effect of wind on that long axis, but at a relatively coarse level, given the nature of the current wind data available.

Sub-tidal habitats will be mapped using a combination of remote video sensing, sediment sampling and snorkeler observations. Substrate types and key physical habitat elements (including macrophytes) will be mapped. Sediment grain size, total organic matter and total nitrogen will be measured.

The project is progressing well with most fieldwork complete and laboratory analyses underway. There have been some access issue to part of the Southern Lagoon due to low water levels.

The digital elevation model will be based largely on existing data (primarily from SA Water), as well as bathymetry data collected and additional work focused on the ‘intertidal’ regions. The terrestrial habitat model will be based on remotely-sensed data and will initially cover the Coorong. It will possibly be extended to the Lower Lakes, depending on the availability of students. Historic imagery will also be included where possible to understand recent habitat changes.

3.1.2.1.5. CLLAMM Futures Update

An update on the CLLAMM Futures project was provided by Peter Fairweather.

The workshop was held as a part of the CLLAMM Futures project to understand the data collection being undertaken by the other project teams, identify historic data sources and to obtain guidance on the scenarios to be modelled as a part of the project. The project team
includes Peter Fairweather and Rebecca Lester, with inputs from Anthony Cheshire, Graham Harris and Peter Gell, as well as the other CLLAMM project teams as required.

This project aims to integrate the knowledge gained by the other projects at an ecosystem level and to investigate possible scenarios to inform future management of the region. It will also parameterise conceptual maps used by natural resource management organisations and construct a suite of indicators for use by managers.

This workshop is also intended to begin work on the parameterisation of the series of conceptual models for the CLLAMM system (sub-project 1). Further sessions will be held later in the workshop for this purpose. It is anticipated that these models will be available for use in a decision support system at some point in the future.

Five potential states have been suggested so far for the Coorong region (sub-project 2). These states are ‘brine shrimp paradise’, ‘wader’s delight’, ‘sea-grass meadows’, ‘bream dream’ and ‘the algal bowl’. It was agreed that several states could coexist in time across the spatial extent of the region. No additional states were suggested, but additional investigation will be required as to the frequency, occurrence, bounds and characteristics of each, and the possibility of others occurring, particularly previously unrecorded states with lower stable diversity. It is anticipated that each will be defined according to a matrix of physico-chemical parameters that indicate the switching points between each state. It is likely, however, that each state could exist over a range of conditions, and that there may not be sharp boundaries between each, with more than one state existing at any one point in time along the Coorong, or the system switching regularly between several. These switching points will be identified from historic data sets as far as possible. State and transition modelling will be used to determine the switching points between the models and techniques such as classification and regression trees and bifurcation plots show promise. Additional work will be undertaken over the coming months to determine the most useful combination of techniques. Further sessions later in the workshop address the list of useful scenarios to include in Futures modelling.

The final aspect of CLLAMM Futures is to determine a set of indicators for use by natural resource managers (sub-project 3). The key to this sub-project is to identify what is important in the ecology of the region. The needs and targets of regional, state and federal bodies will also inform this aspect of the project, and the final suite will be tested in situ.

The work plan for this project calls for two additional workshops; one in mid to late 2007 to finalise the various states and have the work to date evaluated by an international expert, Peter Petraitis, and one in late 2008 to integrate findings and collate final report content. Additional work will also proceed on the parameterisation of the conceptual models, including data mining and then modelling and conceptual testing of those models. Historic data will also be investigated for the state and transition modelling and in determining what states have existed in the past and what is possible in the future given a range of potential management options. The development of indicators for the region will be further down the track, and is likely to be undertaken by an Honours student under the supervision of Peter Fairweather and Rebecca Lester.

Potential issues for the project include uneven spread of available data. It is likely that there are areas we know little about, both in space and time. Another possible issue is the lack of environmental flow releases, which would disallow testing of hypothesised boundaries between states. A no-flow situation would also negate experimentation regarding the spatial impact of such environmental flows. Challenges include incorporating modelling undertaken by CSIRO (hydrodynamic and biogeochemical) and MDBC (historic flow versus ‘natural’ flow) and successful input into the social and economic evaluation.

3.1.2.2. Outcomes of Discussion

3.1.2.2.1. Key Species Response Project

- Decisions need to be made regarding what an ideal CLLAMM region would look like.
• Key challenges for CLLAMM Futures are to determine how to move the system through state space from ‘undesirable’ conditions to a more desirable dynamic condition. What is needed initially to make this happen and then, how can these conditions be maintained?
• Water depth is likely to be a key driver of habitat availability for birds and the accuracy of these predictions is important.
• Fish species richness and abundances appear to decline with increasing salinity. There also seem to be declines in the biomass of *Ruppia*, increases in brine shrimp abundance and a change in bird community possibly as a result of increased salinity in the Southern Lagoon.

3.1.2.2.2. Productivity and Trophodynamics Project

• There are likely to be two phases to the recovery of the region – a restoration phase and then an ongoing maintenance phase.
• The recommendations for flow inputs for these phases will differ.
• It will be a challenge to incorporate data of differing accuracy and scales to develop meaningful estimates of these two phases.

3.1.2.2.3. Dynamic Habitats Project

• A meta-database will be constructed and maintained by Jason Tanner. All projects will contribute relevant information to that database.
• Light meters will need to be regularly cleaned. Each project team to liaise with Jason Tanner to establish who will clean the meters and when.
• Projects that are using areas other than the 12 identified sites and would like to include these in the habitat modelling need to indicate this to Jason Tanner.
• A key output for the habitat project will be the production of lists of key species requirements for various life-stages.

3.1.2.2.4. CLLAMM Futures Project

• Various indicators are in use by the different project members at the moment, and by DWLBC. Rebecca Lester will compile a list of these.
• All project leaders should carbon copy Peter Fairweather on email traffic regarding the project to allow the CLLAMM Futures team to remain in the loop on each of the other projects.
• Rebecca Lester and Peter Fairweather will be visiting each project team in the coming weeks for further information regarding data collection, historic data sets and indicators.
• Rebecca Lester to determine the data format and platform used for CSIRO and MDBC models.

3.1.3. Deciding on what we can do now empirically, given that we are likely to have the absence of environmental flow releases during the life of this project:

- *Does it change our field plans?*
- *How do we optimise the information gained during these “no flow” conditions that we can measure collectively?*

3.1.3.1. Overview of discussion:

This session provided an opportunity to discuss the progress of the CLLAMMecology project to date and involved a range of topics.
3.1.3.1.1. Fieldwork logistics

There are some areas of the region for which site access requires contacting various parties. Mike Geddes and Daniel Rogers are good people to contact prior to leaving for fieldwork to ensure that the relevant authorities have been contacted. So far the sharing of vehicles and piggy-backing of field trips appears to be working well with no issues. Confirmation is needed, however, that the relevant collection permits have been obtained for each project.

3.1.3.1.2. Data-related issues

Given that much of the data collected will be used in the CLLAMM Futures project, there are advantages to ensuring that there is consistency in data collection procedures. Jason Tanner is going to create and maintain a meta-database for the Cluster. This will include information about what data is being collected and how. However, it will need to be populated by individual projects and information including things like the type of instrument would be useful. This and a list of variables can then be lodged on the Sharepoint.

Recording the location of measurements and sampling sites would also be useful. All spatial co-ordinates should be recorded using the GDA 94 (Zone 54) standard, or WGS 84 for devices that do not support the former.

Certain parameters including water quality parameters will be measured by more than one project team. It would be helpful if these could be measured to the same units and standards where possible. For example the measurement of both salinity and conductivity, along with temperature, would be preferable. pH will also be measured by the fish Key Species Response team, as it is crucial for interpreting the availability of ammonium (a toxicant). DEH also conducts bimonthly sampling that includes comprehensive water quality processing.

Rebecca Lester will undertake a review of the parameters measured by each group and the compatibility between groups. These parameters will be available on the Sharepoint.

3.1.3.1.3. Possible missing parameters

Several possible missing parameters were identified and proposals suggested for dealing with each.

Justin Brookes is to confirm whether zooplankton is being measured regularly and across all sites. If not, those project teams undertaking boat-based work will also need to take plankton tows and preserve the samples for the time being. There would then need to be discussion regarding the budget to sort and identify these samples.

Benthic grabs in deeper water may also be useful, as these are currently outside the scope of the Habitat project. There is the possibility that an Honours student may be able to undertake this work.

The polychaete mounds (the serpulid worm, *Ficopomatus enigmatus*) may have a substantial impact on the level of filtration occurring in the system. There is the possibility that the Habitat project could map the locations of these mounds using aerial photography, but ground truthing would be needed to determine which mounds were active and which were relics.

Seiche data may also be important to collect. Water depth is likely to be critical for determining the distribution of wader habitat, in particular, and seiche effects will influence this. There is the possibility that the bird team could record seiche effects while undertaking their day-long surveys, but protocols would need to be established to ensure that measurements were taken from the same location each time.
Recreational fishing catch data also represents a gap in the available data. No useful information has been collected, as recreational fishing surveys completed to date are not detailed enough. The possibility of undertaking another was raised, but the feasibility and timing of this was not determined.

There may also be a gap in the measurement of water levels and salinity prior to the installation of automated instruments by DWLBC. Also, DWLBC are not planning to include wind instruments in the initial installation, so the resolution of wind data may be poor, at least for the first year of data.

3.1.3.1.4. A Dose of Reality? Consequences of no flows

CLLAMMecology was originally designed as a combination of survey and experimentation in the CLLAMM regions for a baseline period, but also encompassing the environmental release of water. The current period of drought means that there is a low likelihood that there will be any water released from the Lower Lakes into the Coorong in the next few months, at least.

DWLBC confirm that that are currently managing the system to maintain lake levels above their failure rate. At the moment, they may be halfway to that point already.

As a result, there are portions of the project plan, and perhaps outcomes that are unlikely to be possible. This discussion focussed on minimising the risks and exploiting the opportunities associated with the lack of flows.

The majority of projects included a significant proportion of survey work to categorise the current conditions in the region. This work can still occur, but will be characteristic of low or no flow conditions, rather than average flow conditions. This information will be of significant use, as it will provide some information about one of the extremes for the system, and one that is likely to be increasingly common given the predicted changes to the local climate. For example, it is not known if fish will continue to breed in the absence of flow-related cues. This information can be supplemented by longer term data sources to place it in the context as a low/no flow sequence, thereby minimising the risks.

Some of the experimental work planned for the various projects may need to be altered if there are no environmental water releases. Transplantation experiments are still possible, but other experimentation into the effects of water level and salinity may need to occur ex situ. SARDI have some capacity to undertake mesocosm work in their pool farm, but details would need to be organised quickly so that Jason Tanner could organise for the use of these facilities.

Members of the relevant teams need to formulate a series of experiments and get these to Jason so that CLLAMM can make use of the available capacity.

Some possibilities for mesocosm experiments include determining the upper salinity tolerances of single species and the response of *Ruppia* spp. to changes in water level and salinity. Care will need to be used to design and specify what needs to go into the mesocosm. For example, local sources of water and sediment would be preferable to ensure that we maintain control over the conditions. The mesocosm experiments would necessarily assess the response of single (or a few) species, in the absence of normal competitive interactions.

Transplantation experiments may be useful for exploring the recovery dynamics of various species. For example sediment cores could be transplanted from the Southern to the Northern Lagoon. This will enable the recovery dynamics to be explored while maintaining usual competitive interactions. It may also be possible to determine the limits of recovery, i.e. under what extreme conditions will recovery be dampened, or fail to occur?

In addition to maximising the output that we can deliver given the current drought and low likelihood of environmental water releases, we should also develop a plan that is relevant should conditions change. Each project should develop a plan for additional experimental or survey work that it would undertake if environmental water releases occurred, or the drought broke. This should be done both for the lifetime of CLLAMMecology and for the future.
Another possibility is to make additional use of the dredging effect to measure the impact of flows through the mouth. In particular, the effects of water level fluctuation on the foraging area of birds or on wader numbers could be measured. This is likely to require the use of research students to undertake the work and is not currently part of the CLLAMMecology research plan.

Another possible strategy that was raised was to delay sections of fieldwork for 12 months in the hope that conditions would improve in this time. Three possible alternatives were highlighted: that fieldwork should be postponed; that fieldwork should continue as scheduled; and that fieldwork should be completed as scheduled, but additional funding sources identified for the repeat of this work should (when) conditions improve. It was felt that delaying fieldwork would only be of value if water was assured, and this issue was referred to the management committee meeting.

3.1.3.1.5. **CLLAMMecology position**

The current political climate means that it is possible or even likely that individuals within the CLLAMMecology research team will be asked for opinions regarding one or other of the proposals to maximise water availability for Adelaide. It was decided that it was not within the scope of the CLLAMMecology project to develop a project position on these projects, but that individuals were welcome to provide comment or opinion if they wished.

3.1.3.2. **Outcomes of discussion**

- Confirmation has since been obtained that the relevant collection permits have been obtained.
- Efforts will be made to maintain consistency of measurements between groups. A standard has been adopted for spatial co-ordinates and Rebecca Lester will review the measurements being taken by each project to review the compatibility between the projects.
- There was a suggestion that bird survey teams may be able to undertake seiche measurements given the length of time they are surveying in one place, although care would be needed to ensure that the method did not disturb the birds in the area. A protocol for surveying from the same points on different survey dates would need to be established. This is in addition to the water level recorders due to be installed by DWLBC. This would be the more rigorous measurement, but probably for fewer sites.
- Zooplankton sampling protocol to be reviewed. Is this being adequately covered by the trophodynamics group? If not, can those undertaking boat-based surveys take plankton tows and preserve the samples for the time being.
- Members of relevant project teams need to compile a list of mesocosm experiments quickly and pass these to Jason Tanner so that the facilities at SARDI can be utilised.
- Project teams should also develop plans for experimental and survey work to be undertaken if there is a change in conditions, either during the CLLAMMecology timeframe or in the future.
- Rebecca Lester is compiling a list of the datasets referred to during the workshop and will be contacting team members regarding these and other possible data sources.
- The management committee will discuss the alternatives regarding the postponement of aspects of the project in the hope that there is flow next year.
- CLLAMMecology will not be developing a position on issues including the possible weir at Wellington, but individuals are able to comment as they see fit.
3.2. Day 2

3.2.1. Exploring the management models of the Coorong & Lower Lakes:

- What do the relevant managers use them for currently?
- Uncovering the evidentiary basis for links shown in them
- Turning them into agreed mathematical expressions for further modelling development & use by CLLAMM Futures
- By specifying the direction, magnitudes & forms of mathematical relationships (flow-response curves), explore the sensitivity of them

3.2.1.1. Overview of discussion:

A series of conceptual models exist for the CLLAMM region that are intended for use by the natural resource managers. Nick Souter from DWLBC provided an overview of the models and their current and future use by managers.

The flow diagrams were commissioned by managers to assist in the design of monitoring programs for the various targets for the region under the Living Murray initiative. They were developed by a panel of experts, and attempt to identify key links in the system; specifically focussed on the management of freshwater inputs as a lever and on areas were little is known about the ecology of the system. The monitoring system has been developed in line with the Ministerial Council objectives, the identified Outcomes for the region and the Asset Plan. The three current, over-arching objectives for the region are to maintain an open mouth, to achieve successful fish spawning and recruitment, and to provide habitat for waders. Underpinning these objectives are approximately 20 targets that can be found in the Asset Environment Management Plan for 2005/2006 produced by MDBC. Nick Souter outlined some of these targets and indicated that water quality parameters were measured although there was not a specific target associated with these.

At this stage, the models are not used more extensively, and there is the possibility to refine them. There may also be the possibility to refine the targets themselves if a good case can be made regarding the significance of another link in the system, or the lack of importance of an existing target. It was agreed that the models were a useful starting point for the CLLAMM Futures modelling, and also that refining the models may be of value to those actively managing the region.

The various models are very similar for the most part, and a question was raised about whether they should be converted into a single type of model, with the strength of the relationships changing for each key species, or whether to keep them separate. It was decided that they should be parts of a larger model, but that each key species had some unique interactions, so it was worth looking at each separately. This also highlighted that each target group has a specific set of ‘ideal’ conditions.

There is some ambiguity in the existing models. It is not clear what the arrows represent. They may be material flows, rates of processes, drivers, ‘lever’ or state variables. There are arrows that do not seem to represent real relationships, and other likely relationships are not depicted. Some boxes are also ambiguous, with some representing conditions and some representing processes. This should be clarified, or preferably simplified prior to further use of the models. The models also make use of both dotted and solid lines. Dotted lines appear to represent transfer of material, while solid lines may demonstrate either direct or indirect control.

The most realistic manner in which natural resource managers can change the ecology of the CLLAMM region appears to be by varying marine and freshwater inputs. This will influence the habitat quality and quantity of the region and the models should be changed to an outcome
focus, rather than centring on processes like growth and recruitment. This will involve modelling habitat availability both temporally and spatially and techniques such as Monte Carlo simulation could be used to investigate patterns of likely species loss over a variety of conditions. In order for this to be achievable, the CLLAMM Futures project team will need access to the key species requirements, along with habitat availability and the trophodynamics of the region. It is recognised that there are external drivers (particularly for migratory birds) that managers in the CLLAMM region have no control over and these will be included in models as inputs.

Each model was discussed individually and comments and suggestions were made for each. Another iteration of the conceptual model was revised by Anne Walters and is available from the Environmental Flows Working Group.

Conceptual model for the Coorong:

- Move the ‘fish movement’ and ‘access to spawning habitat’ boxes to the conceptual model for fish.
- Change the ‘mouth open’ and ‘mouth closed’ boxes to be ‘mouth state’ and use dredging as one input.
- Scenarios can then be run with and without dredging to see what the benefits of each are.
- Remove the arrow between ‘wind’ and ‘dredging’.
- Adjust ‘water level’ so that it applies to more than just the Ruppia model. This also applies for freshwater inputs.
- The flow estimate for keeping the mouth open without dredging is 2GL per day, although this may be a little low.

Waders conceptual model

- The effect of macrophytes is not included in the model. Perhaps ‘filamentous algae’ should be replaced by ‘primary production’.
- Targets are not specified for sediment size in the Southern Lagoon, or for filamentous algal.
- The quantity of mudflat habitat is less important than the quality. Wetness, depth and frequency of inundation are all important.
- This means that we need suitable definitions of purpose. We need to ensure that the habitat is there and that it is capable of fulfilling its purpose (i.e. suitable habitat at the right point in time).
- There is a lack of ability to control wader biodiversity due to external factors like migratory habits.
- Different conceptual models would apply for non-wading birds. Ducks, pelicans, terns etc have slightly different requirements. Ruppia would need to be included for ducks and fish distribution is important for piscivores.
- Terrestrial inputs may also be important. What are the inputs of nutrients, organic material, insects etc?

Fish spawning, recruitment and survival conceptual model

- The model should be changed to be outcome driven, so it should include habitat availability.
- Timing of freshwater inputs, as well as amounts, is important.
- Climate forcing and marine inputs are missing from the model, as are pH and NH4 from the water quality parameters.
- Primary productivity, food webs and connectivity of physical habitat should all be included.
- The fish life cycle is important, but is not something that is easily influenced.
- There is no target for juvenile fish survival, which is a key factor in a sustainable population.
• Need to include the spatial context and quality of the physical habitat as specific connectivity is required to meet needs.

• Commercial fisheries mortality data should be incorporated as there is a consistent long-term data set.

• Macrophytes are again missing from the model, as are several arrows between boxes.

• Piscivorous birds and fish are included multiple times

• Food availability is likely to be affected by more than just nutrients.

*Ruppia* germination and growth conceptual model

• The model as it stands appears to apply for *R. tuberosa* only.

• As for the other models, habitat availability should be the focus of the model. This will make the model outcome focused, rather than process focused.

• Wind is not influenced by tides or mouth opening or water levels (although the relationship certainly operates in reverse, with wind affecting water levels, in particular, so a one-headed arrow would be appropriate).

• *Ruppia* is more likely to affect dissolved oxygen concentrations than the other way around (although this is still possible).

• Physico-chemical properties of the sediment are important as well as those for the water.

• Suitable substrate should be included in the model.

• *Ruppia* has complex dynamics involving seeds and turions. Sexual reproduction is an important component of the life cycle, so a sustainable population will include seeds, turions, adults and juveniles.

• Growth may not be an appropriate target, as the optimal conditions for growth may include low density of adult plants. Spatial extent of *Ruppia* may be a better aim, or perhaps standing biomass.

• Marine inputs are also likely to be important.

• Bird grazing will not only affect the live vegetation, but also the seeds and turions.

• During the rehabilitation phase for the Coorong, a viable source of seed will be important. There was a suggestion that this could come from the USE drainage water.

Invertebrate conceptual model

• The existing model is most suitable for benthic macroinvertebrates.

• Invertebrates have the most diverse life-history range of the target species, but perhaps also the least data and understanding.

• Additional models could also be developed for epibenthic, pelagic, macrophyte-dependent invertebrates and for those with winged adult dispersal (e.g. chironomids in the Southern Lagoon).

• Different models may also be relevant for the Northern and Southern Lagoons.

• Predation pressures, and suitable substrate should also be included in the model.

• The importance of the mouth being open was questioned. This is likely to have different impacts on different taxa.

• Primary production or particulate organic matter may be more useful than phytoplankton in the model, as this would also encompass detritivores.

• ‘Invertebrate emergence’ is an ambiguous term (c.f. insects and copepods for example).
- Separating polychaetes and bivalves from macroinvertebrates does not seem to be a useful division.
- Again, the model may be more useful for our purposes if it were expressed in terms of available suitable habitat.

Thus, key components for CLLAMM Futures conceptual model(s) include:
- Freshwater input
- Marine input
- Climate forcing
- Physico-chemical factors
- Spatial connectivity and opportunity
- Food relations
- Needs for each key species and their life stages
- Duration and timing of different aspects
- Availability of suitable habitat (this may be the key endpoint)

These may be described as is illustrated in the diagram below:

![Diagram showing the key components of the CLLAMM Futures conceptual model]

3.2.1.2. Outcomes of discussion

- Justin Brookes to confirm that marine inputs and freshwater inputs to the system in terms of nutrients are being measured by the Trophodynamics project.
- The models should be expressed in terms of habitat suitability, rather than purely availability. This is something that can be directly influenced locally and is outcome, not process, driven. This is particularly important for organisms that spend a significant portion of their lifecycle outside the Coorong (e.g. waders, some fish).
- Temporal connectivity, as well as spatial connectivity is important for key species success.
- Marine and terrestrial inputs are potentially as important as freshwater inputs, and marine inputs also have the potential to be managed.
• The habitat requirement matrices produced by the Key Species Response project should be explicit in terms of temporal components and timing to allow temporal connectivity to be included in the modelling.

• Key components to be included in the CLLAMM Futures conceptual model(s) were identified.

3.2.2. Deciding upon which management scenarios to be modelled by CLLAMMecology in the CLLAMM Futures Project, including aspects of:

- Releases for the environment (or not)
- Barrage operations
- Future weirs, doughnuts, channels from the SE or other possible extreme responses
- Climate change & weather extremes

3.2.2.1. Overview of discussion:

Various management scenarios that could be modelled by CLLAMMecology in the CLLAMM Futures project were identified. These can broadly be classified into three categories: current and possible management alternatives; effects of climate change; and ‘hard’ engineering options.

3.2.2.1.1. Current and possible management alternatives

• What would be the effect of catchment-wide management scenarios? For example, the Living Murray aims to create savings of 500 GL. What would returns of this nature achieve in the region? It is, at this stage, unclear what the ‘share’ of this water for the Coorong may be. Each icon site may be expected to bid for water. Feedback from each region about the benefits of the water would be useful in the decision-making process. For example, how much water is enough?

• Different flow scenarios, including the current operation, a ‘natural’ run and the Living Murray targets, should be included.

• The operation of the barrages could be modelled, including how to release the water for different purposes. For example, a large single volume may be needed to reset the system which may not be the most appropriate to provide cues for fish reproduction. It would be useful to be able to describe the benefits from releasing x litres of water from the barrages.

• USE drainage volumes could be modelled to supplement work done by Tong (1998). These are currently small and impact only a limited area of the Southern Lagoon, according to sampling undertaken by DWLBC, but there is the potential for approximately 400 GL to be available over ten years which should convert the southern lagoon into an estuarine environment according to the existing modelling. There may also be returns from the lower SE via the wetland system, which may also be subject to a bidding system. This may be in the order of 150 GL per year overall.

• Explore the connection between the Northern and Southern Lagoons. Should this connection be dredged? What are the effects of maintaining, severing or reconnecting the two lagoons?
3.2.2.1.2. **Effects of climate change**

- Explore the effects of reduced flow through the catchment to the Coorong. Reduced flows may result in pulsed releases, with lower peaks, being ‘smeared’ across the region.
- A variety of predictions for the severity of climate change could be included.
- Climate modelling suggests that there will be less water available for remediation purposes. Other sources of water (than the Murray) should be investigated.
- Perhaps a more positive scenario regarding the availability of water should be modelled, i.e. ‘divine intervention’ regarding rainfall.
- ‘Doom and gloom’ scenarios of response to climate change may be useful in adjusting our expectations of what is possible in the Coorong, including for the economic benefits of the region. For example, what would continued drought mean for the fishery or if the barrages were removed?
- What would be the effect of the two extremes? i.e. what would the effect of a large flood (c.f. 1956, 1974, early 1990s) be, or if the current drought continued for 5 years, or even 10 years (c.f. 2002 for example of 2+ years of low flow)?

3.2.2.1.3. **Hard engineering options**

- A variety of hard engineering options have been proposed for the region.
- These include cutting off the Southern Lagoon from the rest of the system to save the Northern Lagoon, turning the Lower Lakes into an estuary again, weirs, double dams and donuts.
- A sea canal from the Southern Lagoon to the sea is one suggestion (although it may contravene the EPBC Act), but may be difficult to model in this project as it requires further work on sediment dynamics and geomorphology.
- Another possibility is a drain from Lake Albert to the Northern Lagoon. CLLAMM Futures may also have limited availability to model this due to changes in geomorphology.

3.2.2.1.4. **Other options**

- Other options mentioned include radical shifts in the fishing regulations (although the effect of recreational fishing is unknown), enforcing fishing exclusion zones, or re-stocking of fish or *Ruppia* populations. This would rely on the dynamics of the system (i.e. trigger points versus spawning bottlenecks).
- Human exclusions may limit disturbance to bird foraging by lowering foraging to vigilance ratios. Banning jet skis may be useful, or limiting vehicle access. However, all of these options may be best suited for inclusion in the socio-economic study, rather than the CLLAMM Futures project.
- It may be possible to model past behaviour of the region based on palaeographic information.

3.2.2.1.5. **Other points raised**

- It may be important to define flows in terms of parameters other than volume. For example, nutrient content will vary from source to source.
- Exploring management alternatives for the region may not be sufficient. The modelling should be undertaken with a view to identifying an optimal scenario. This would require
definition of a ‘better’ solution. There are likely to be different optimal scenarios for initial rehabilitation and then for ongoing management.

- The timeframes over which the models are run needs to be considered, as does the form that the output will take. For example, the proportion of time particular thresholds are exceeded may be the indicator to report.
- There may be relevant obligations under the Ramsar treaty that stipulate targets for the convention area. These should be integrated with the targets set from the Asset Plan.
- The impact of groundwater into the system has not been accounted for and it may well be a significant water source for the region.

3.2.2.2. Outcomes of discussion

- Consideration is needed regarding the output of the models.
- It would be useful from a management perspective to be able to answer questions regarding the impact of certain volumes of water, or to provide an ‘optimal’ solution.
- There are three categories of scenarios to be modelled: current and possible management options; the effects of climate change; and hard engineering solutions.
- Some scenarios may not be possible to include as they would involve geomorphic and hydrologic changes to the system that cannot be included in the current model.

3.2.3. Exploring the range of socioeconomic & public interests in the CLLAMM region

- Hopefully at least one brief presentation from CSIRO re their modelling & other work?
- Considering what exactly might be included in the Water Benefits & social issues
- Possibly a role-play exercise to consider others’ viewpoints

3.2.3.1. Overview of discussion:

Barbara Robson was able to present an introduction to the modelling work being undertaken by CSIRO.

The aim for the CSIRO is to create a new decision support system for the Coorong. This involves the construction of a hydrodynamic model for the region and a linked biogeochemical model. These models will be supported by process-based research. Collaborations are occurring with Justin Brookes’s research group into the Lower Lakes region and with CLLAMMecology to extend the scope of the model from the physical and chemical to incorporate ecological factors. There is also the possibility of appending the hydrodynamic and biogeochemical models to the MDBC model, BIGMOD, which currently stops at the barrages.

CSIRO are focussed on providing information on the water balance, hydrodynamics, nutrient cycling and socio-economic aspects of the Coorong. At this stage, however, the socio-economic research is on hold due to change in personnel at CSIRO. The other research is proceeding as planned, and will be available to feed into CLLAMMecology and CLLAMM Futures over the next year or so. The CSIRO models will determine the effects of barrage operation, dredging and USED flows on the water levels, salinity and nutrient cycling within the system. These outputs can then be used as inputs for CLLAMM Futures modelling regarding habitat availability and changes over time in response to management actions.
The models will be spatially explicit, tailored specifically to the Coorong and will be capable of modelling long time frames (in the order of 10 to 20 years). Existing 3D models are often too processor intensive to operate over those time frames. The models treat the Coorong as a series of three ‘buckets’. These are the Murray Mouth estuary, the Northern Lagoon and the Southern Lagoon and interactions between the three are capable of being manipulated. Results from the hydrodynamic model show good representations of the salinity and water level data recorded for places like Tauwitcherie and Sandspit Point. In particular, the model performs well for time steps of more than 2 days, where seiche effects become less important. Outcomes of the model will include things like contour plots for salinity with varying flow duration and magnitudes. Stratification is not included in the model, which may be a limitation.

The hydrodynamic model will form the basis of the biogeochemical model. The biogeochemical model will also make use of rainfall, daily evaporation and wind data, daily inflows, solar radiation, nutrient loads and some biological characteristics. The model is expected to include information relating to primary production by benthic and planktonic macroalgae, macrophytes and phytoplankton.

Current knowledge gaps relevant to the biogeochemical model include the importance of internal nutrient cycling relative to external inputs, rates of nutrient processing and changes in nutrient processing relative to salinity and macrophyte cover. Subject to funding, these gaps should be explored over the coming 12 months, with measurements occurring at 5 sites in summer and in winter. Perran Cook is hoping to undertake work using benthic chambers, and is in contact with Sasi Nayar regarding his work.

Reviews of the hydrodynamics and biogeochemistry of the Coorong have been completed and the hydrodynamic model is expected to be released by the end of December 2006. A pilot version of the biogeochemical model is expected to be ready by June 2007 with the final model finished by June 2008.

CSIRO would like the assistance of CLLAMMecology through the contribution of data and understanding of ecological processes, especially relating to primary production, and in the development of scenarios for modelling. One of the key areas where CLLAMM researchers feel that they could have input is into how the characteristics of biota change over the different scenarios (e.g. with salinity increases). One comment highlighted that there were likely to be switches between primary producers within the system, and that the diversity of primary production may not be captured by the current conceptual model for the biogeochemical model. CLLAMM researchers were also interested in exploring the boundary between the physical and ecological models. It seems unlikely that top-down and bottom-up modelling approaches will meet precisely, and some estimation in the middle is anticipated.

The projects considering Water Benefits and social issues are currently on hold at the CSIRO, so these were not discussed in detail. The role-play exercise also did not go ahead due to time considerations.

3.2.3.2. Outcomes of discussion

- The hydrodynamic model will be ready for use soon.
- The biogeochemical model will predict nutrient cycling in the system, using information on the hydrology, chemistry and primary production of the Coorong.
- CLLAMM project members will need to provide information regarding the primary production of the region to ensure that the model is as accurate as possible in this respect.
- CLLAMM Futures team members will need to liaise closely with CSIRO regarding the use of the biogeochemical model in Futures modelling, and CSIRO modelling scenarios.
4. Conclusion

From the perspective of the CLLAMM Futures project team, the workshop was a success. It provided the opportunity for the Cluster members to liaise with one another and to begin developing working relationships, particularly for new members. It also provided the opportunity to clarify the objectives and plans of each project team, and to synchronise activities where necessary.

The discussion regarding the existing conceptual models and the possible scenarios to model highlighted many interesting and salient points. Potential shortcomings in the models were anticipated and explicitly addressed, and an approach was determined for the parameterisation of the models. The contribution of so many experienced researchers to the models and scenarios ensures that these will be as representative of the system as possible. The progress made on both the conceptual models and the scenarios were important introductory steps for the CLLAMM Futures project and should result in a more robust modelling outcome. Discussion and workshopping in future workshops will build on this foundation.

While the two days of the workshop illustrated the complexity of the CLLAMM region and the CLLAMMecology project, it also clarified the research objectives and how the various projects within the Cluster interconnect. The CLLAMM Futures project team gained a deeper understanding of the challenges involved in the Futures project, of potential pitfalls and of the concurrent work being undertaken that will feed into the modelling undertaken.
Acknowledgements

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We also acknowledge the contribution of several other funding agencies to the CLLAMM program and the CLLAMMecology Research Cluster, including Land & Water Australia, the Fisheries Research and Development Corporation, SA Water, the Murray Darling Basin Commission Living Murray program and the SA Murray-Darling Basin NRM Board. Other research partners include Geoscience Australia, the WA Centre for Water Research, and the Flinders Research Centre for Coastal and Catchment Environments. The objectives of this program have been endorsed by the SA Department of Environment and Heritage, SA Department of Water, Land and Biodiversity Conservation, SA Murray-Darling Basin NRM Board and Murray-Darling Basin Commission.

References


Appendix A: Participants

Attendees:
Kane Aldridge, Adelaide University
Simon Benger, Flinders University
Justin Brookes, Adelaide University
Anthony Cheshire, SMU
Joseph Davis, Murray Darling Basin Commission
Brian Deegan, Adelaide University
Sabine Dittman, Flinders University
Penny Everingham, DWLBC
Peter Fairweather, Flinders University
Mike Geddes, Adelaide University
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Rebecca Lester, Flinders University
Maylene Loo, SARDI
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Apologies:
Richard Brown, DWLBC
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Brenton Grear, DEH
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Andrew Munro, Adelaide University
Rod Oliver, CSIRO
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Russell Seaman, DEH
David Walker, Adelaide University
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Tim Wilson, DEH
Mike Young, Adelaide University
Appendix B: Presentations

CLLAMMecology Overview – Mike Geddes

Leader: Mike Geddes
Partners: UoA (host), Flinders, SARDI As Bc, DEH, JANOC (GWLRC)
Management: Anthony Chisholm, Mike Geddes
Projects: Key Species Responses: David Potter
Productivity and Trophic Dynamics: Jatrice Brookes
Dynamic Habit: Jason Turner
CLLAMM Futures: Peter Fairweather

The Estuarine Ecology – Invertebrates

The fish of the Coorong and Murray Mouth

The water birds of the Coorong and Murray Mouth

Ecological responses
**Key Species**

- Ecology of key fish, birds, plants and invertebrates
- Of conservation, economic or ecological significance
- Monitoring along salinity gradient: 12 sites
- Field experiments: translocations, flow events
- Responses: distribution & abundance, reproduction & recruitment, behaviour, movement.

**Habitat**

- Develop "dynamic" habitat models of the river
- Used to predict potential areas of habitat suitable for key species: salinity, depth, light
- Will be linked to hydrodynamic model: dynamic habitat
- Combination of using existing data, remote sensing and ground-truthing

**Trophic dynamics**

- Functional groups of primary production; pelagic, benthic, mats, Rapala
- Description of food-web: to birds and fish
- Will use stable isotopes and other techniques
Productivity and Trophodynamics Update – Justin Brookes

Futures

- Two phase plan for Coorong
  - Restoration phase
  - Long-term management plan
- CLLAMM must deliver on both
- Flow is the only tool available

Alternate states for Coorong

- Algae dominated vs macrophyte dominated
  - Typically driven by nutrients, in shallow lakes
  - Dutch examples (Stehffer et al.,...)
- There is intrinsic resilience in each alternate state which assists the transition to the alternate state
- Need to overcome this with the restoration plan

Restoration plan

- What is the preferred condition?
- What are the features that make the Coorong resilient to change?
- What time frame do we expect for change?
  - Life cycle of Ruppia vs time we can keep salinity at satisfactory level
  - Habitat plus seed source

Ibelings et al (Ecosystems in press)
Tools available to tackle this

- 3D hydraulic/habitat model
- 3D model of lower lakes
- Marine water monitoring system
- Modelling
- Life cycle of preferred macrophytes
- Understanding of what constrains primary productivity
  - Nutrient uptake
- Flow in the river
- Redesigning flow control structures
- How hard was flow to interroduce and overcome resilience of current "unhealthy state"

Futures model for trophodynamics

- Processed based model of productivity
  - Delivered by CSIRO
  - Validated within the program
- Semi-quantitative model of macrophytes and habitat
  - Preference curves for uptake
- Conceptual model of alternate states
  - Demonstration of macrophyte dominated state (hydrala)
  - Time frames, flow requirements, nutrient requirements
Key Species Response Update – Daniel Rogers and Qifeng Yi

Key Species Cluster
Group Leader: David Paton

Rupella spp.
- A genus of plants, related to seaweed, which is crucial to the ecosystem.
- The growth pattern is unique, allowing for optimal sunlight absorption.

Macroinvertebrates
- A diverse group of aquatic invertebrates, including clams and snails.
- Their survival depends on the pH level and temperature of the water.

Fish
- Important for the marine food chain.
- Vulnerable to pollution and overfishing.

Birds
- An indicator of the health of the ecosystem.
- Sensitive to changes in their environment.

Personnel
- Name, position, and contact information.
Flow Related Fish and Fisheries Ecology in the Coorong, South Australia

Dr. Qing Fei
SARDI Aquatic Sciences

**Objectives**
- To determine the distribution, habitat preferences and angentic activity of fish from different parts of the Coorong estuarine system.
- To determine how fish disperse downstream from the Coorong and where they subsequently concentrate.
- To examine aspects of fish habitat and influence of environmental conditions on spawning, larval development and survival of key species in the region.
- To investigate the influence of environmental conditions on key fish species in the region.
- To investigate the relationship between freshwater flow, climate and the observed density of key species in the region.

**Methodology**
- **Sampling Gear**
  - Beach seine (2 m wide, 22 m long and 0.3 m deep) with two nets
  - Resampling after 12 hours of backwatering

- **Sampling Procedure**
  - Sampling at 6 a.m. and 12 p.m. in the main river
  - Sampling at 6 p.m. in the river

- **Data Collection**
  - Water quality: temperature, salinity, pH and DO

**Time Table**

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Proceedings of CLLAMP Futures Workshop #1, December 6-7 2006, Page 29
Dynamic Habitats Update – Jason Tanner

Team members:
Jason Tanner (SARDI)
Simon Bergler (Nocton)
Russel Saman (IDRR)
Poslec (SARDI –酥琪 Sharma)
Tech staff

Components:
1. Map of subtidal habitats
2. Digital elevation model of the Coorong, Murray Mouth, and
surrounding waterbodies (bathymetry & topography) – derived from
existing data
3. Habitat map at 1 km surrounding the Coorong (in progress)
4. Habitat map at the area surrounding the lower Coorong
5. A statistical model that predicts habitat availability at a given depth for a
given time of year for the Coorong and Murray Mouth area
6. A GIS-based model linked to an existing water management model
that predicts changes in habitat distribution due to changes in water
management regime
7. A dynamic GIS-based model to predict habitat availability for
key species, each species will be studied, under different flow
scenarios

Subtidal habitat map:
Based on remote video and sediment sampling
Use snorkeler observations in low visibility areas
Document substrate type and key physical features including macrophytes and sessile invertebrates
Focus on the 12 key study sites (map a 1 km
swathe across the Coorong at each, with
supplementation at some sites)

Digital elevation model:
Primarily based on collation of existing data
(particularly from SA Water)
Supplement data with bathymetric data collected from a
recreational survey and other field trips
Use these data to conduct some surveying of “intertidal” areas
of each of the main sites

Logistics:
Field work mostly complete, except for problems
with accessing seaward side of South Lagoon
Laboratory analysis underway
Primary remote-sensing, with ground-truthing via in situ surveys
Focus on wetlands and "intertidal" areas (as those subject to wetting and drying as water levels change)
Priority will be area around Coombe, but may include Lower Lakes if a suitable student can be found
Will also use historical imagery to get an understanding of recent changes (last few decades)

**SARDI Light model**

Placed light loggers out at a subset of the sites.
Leave-in-place of 1+ year
Supplement with light profiles along a transect at each site (quarterly)
Use to develop a spatially & temporally resolved light budget

**SARDI SCS physical habitat model**

Integrate outputs from hydrodynamic model, DEM and habitat maps
Allow the extent of different physical habitats (based on substrate type, depth, salinity and light availability) under different flow regimes to be predicted
The CSIRO 3-D model will only predict average depth and salinity for each point along a lengthwise transect, so may be problematic for accurate predictions of water habitat

**SARDI Habitat availability model**

Link physical habitat model to key species habitat requirements to predict habitat availability
Also link to productivity data to estimate system-wide productivity
Use MODIS data to examine seasonal variation in system-wide productivity

Logistics:
- Collect existing imagery
- Conduct field surveys in late 2006, 1st half 2007
- Timing is flexible
- Requires 1 person for data collection, plus a backup

Logistics:
Light loggers will only collect useful data for 1-2 weeks before they need cleaning, so would be good if others can do this
Profiles will take ~2 days quarterly
CLLAMM Futures Update – Peter Fairweather

Ecosystem Responses to Future Scenarios
also
“CLLAMM Futures”
Peter Fairweather
5 December 2006

Overall objectives of CLLAMMecology
- translate water flows into ecological components of the Water Benefits
- focus on “what counts” not just “what is countable”
- because what matters most is what individual researchers are interested in
- intended targets = open mouth bird habitats, fish reproduction

List of relevant drivers
- Water levels
- Fluvial processes – excess & creation events
- Sediment
- Flow environment
- Wave action
- Sedimentation type
- [unintended]
- [plq]
- Resource
- Management actions
- Climate change regimes

The CLLAMM Futures team
Peter Fairweather 20%
Rebecca Lester 100%
plus inputs from Anthony Chestnutt, Graham Harris, Peter Gell
plus data/leads/insights from all other CLLAMMecology personnel
... hence this workshop

This Project
explicitly pitched at ecosystem level, to integrate other themes:
- long-term
- biophysical dynamics
- socio-economic
- technology

Deliverables include:
- modeling of ecosystem responses to likely future conditions — exploring alternative states as scenarios
- evaluate mangroves做梦 conceptual models & incorporate into above
- develop & trial indicator sets based on above

Alternative stable states
- History within ecology:
  - History in “[e]cology, forcing ecosystem state (of looking horizontally) for 100+ yrs
  - Resource regime shifts, esp. catastrophic ones
    e.g. PDO
  - Some theoretical concepts emerging
    - Some possible responses
    - Resilience, function, lack resilience, function, lack resilience, function, lack resilience
- Some conceptual work with assumption of “stability” inherent in this term
  - Some conceptual work with assumption of “stability” inherent in this term

Agreed to not use “stable” in CLLAMMecology
Alternative states in CLLAMM
- 5 suggested so far... any more? how plausible?
  - yes, they all exist temporarily - potential outcomes
  - spatial extent = habitat templates = BIOTIC-Biotic potential modeling
- temporal consistency = frequency of transitions = threshold of occurrence - sets of conditions that bound each state
- Need to work on these during workshops
  - brainstorm across different perspectives from Project team
  - agree upon the suite work on further state-S-transition modeling
- present data limitations need to be made explicit & used to guide further empirical work

Each of these states is a regime of multiple variables

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Focus potential 50 sample locations to do in a target-finding exercise

Sub-project #1 - conceptual models & scenario workshops
- Workshop series is a key integrating step
- Initially identify data gaps
  - construct conceptual models, agree on state-S-transition models, agree on state scenarios to be modeled
  - what outside input do we wish for (Beyond-Criteria)
  - forum to "test" data from models to input to forums
  - 1st workshop today/tomorrow

Sub-project #2 - Ecosystem Modelling
- Alternative states can be handled best using state-S-transition models
  - used in management, esp. rangecards
  - quantitative characterization of each state is a "nest"
  - e.g., CART approach to focus on conditions influencing transitions between them
  - explicitly probabilistic - links to mechanistic models
  - current attention upon what are the presumably variable conditions
  - model conditions as handy sets

Sub-project #3 - Indicators of ecosystem health
- Focus on developing protocols & triggering levels
  - e.g., about 5 key indicators have been suggested by colleagues
  - threshold work to be done
  - will also be an option to develop models for various indicators
  - What other areas exist for other Projects?
  - need to come these out of the system
  - Compile packages of biomonitor's protocols
  - to interpret for use by CLLAMM stakeholders
  - Need to demonstrate utility in situ
  - Back-up needs of regional, state & federal needs
How to integrate then?

- Run the 1st workshop in December 5-6, 2006
- Include post-docs on board
- Involve all project leaders to share their experiences and ideas
- Project leaders to meet in e-mail traffic to discuss
- Integrate other 3 Projects into the overall project
- Post-doc Rebecca Lester & I to visit other 3 Projects ASAP to set out details of work program

Way forward = 5 steps

1. Deliver 3 workshops & their reports
   - to build the team, ensure managerial relevance & link data/decision support via scenario development
   - a progressive focus:
     - site-specific, climate change model inputs & outputs, SCAT
     - drought management, climate change & SCAT, determine feedback mechanisms
     - NCCP climate change, hazards, climate change, hotspots, drought, water needs, SCAT

2. Work on conceptual models
   - A first step toward evidence-based approach with flow-chart models
     - identification, specify, develop & evaluate of relationships
     - site data: incorporate current monitoring & past records
     - climate data: incorporate current monitoring & past records
     - state-specific relationships on a series of response models
     - Indicate: link these or ongoing empirical researches
     - multi-disciplinary, involve under scenarios & management options
     - explore if & how to manage regions, landscape planning, decision making
     - link specific predictions with future releases

3. State-Transition Ecosystem Models
   - Focus on changes & what causes them
     - species distribution
     - environmental conditions
     - species interactions
     - species life cycle
     - species migration patterns
     - species behavior patterns
     - species interactions in ecosystems
     - species interactions with climate change
     - species interactions with human activities
     - species interactions with other species

4. Use S-T Models in Scenarios
   - To be workshoped first & then developed further:
     - Work on layer by layer
     - Start with layers with few variables (e.g., climate change)
     - Include climate change scenarios such as climate change, land use change, socio-economic change
     - Future = scenarios from management options
     - Consider the implications of climate change
     - Use decision support
     - Clearly identify separate impacts of natural drivers, human activities & a range of ecological processes, climate components & services
5. Develop integrative indicators for ecosystem health level
- Need to be practical as well as scientifically appropriate
- Mine each Project for informative & consistent relationships
- Devise protocols & interpretation packages
- Test in the 10-13 key sites
- Then transfer technology to partners & other managers
- To be done in part by an Honours student under our supervision

Limitations of present data & knowledge???
- How data rich are we really?
- How uneven is this across locations, habitats, taxa?
- Just how limited is the timeframe in terms of quantitative measures?
- What can we do with no water to release?
- Links that need to be managed:
  - How are the CERHO CLAMM modeling outputs re: hydrology & improvements going to be incorporated?
  - What is needed regarding inputs to social & economic evaluation?
  - etc...

Sorts of data to mine
- Salinity
- Water depth – flows, chips, input, output effects?
- Water clarity
- Vegetation type & biomass
- Substratum type
- Wave action & wind effects
- Pelagic & benthic animals – abundance, biomass?
- Biodiversity
- Fish catches
- Sediment and bed data – biofouling, hauled out?
- Nutrients?

Some techniques being assessed
- Structural equation modeling
- Classification & regression trees – CART
- Multivariate regression trees
- Bayesian modeling of fossil networks
- Error propagation modeling of spatial effects
- Simulation using chaos theory
- Water-quality modeling
- Weighted evidence inferential approaches
- Data & transition modeling of thresholds
- Ecodynamics for dynamic indicator systems

Example of use of CART modeling in an estuary


Proceedings of CLLAMM Futures Workshop #1, December 6-7 2006,
Possible scenarios to model

Management options
- Water releases as environmental flows
- Impoundment (e.g., with drawdown, dehumidify, etc.)
- Pay off the basin
- Weirs, diversions, etc.
- Harvest strategies

Climate
- Projections
  - Past, present, future
  - What is the projection from this?
  - Varying flood frequency, etc.

Propagation of effects downstream of barages
- How far down the system is a water release felt?
- What is the transfer of variation from one site to another?
- How does the response attenuate with distance and/or time delay?
- What is the degree of response specific to the magnitude and/or timing of the disturbance?

Specifically identify & quantify the scales in both space and time of the responses (e.g., spatial and temporal patterns) of the response to the disturbance.
Hydrodynamics, biogeochemistry and primary production – Barbara Robson

Proceedings of CLLAMM Futures Workshop #1, December 6-7 2006,
**What will be new?**

The model will be:
- Spatially explicit
- Operational
- Tailored to Coorong biogeochemistry
- Capable of longer-term “futures” (10 - 20 years) management scenarios

**Project Timetable**

- Plan for collaboration with Geoscience Australia (Ref. Huang) on chemistry

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**Hydrodynamic model**

[Diagram showing a hydrodynamic model with various locations and water levels]

**Good replication of water level**

[Graph showing a comparison between model data and real data]
Ruppia – keystone species?

- Resistance to predation
- Reserves or refuges
- Natural recruitment under cover
- Shallow water

The lagoon – an example of a switch in states?

Summary

- The system model will provide a tool to predict how the ecosystem responds to changes in key drivers (e.g., flow).
- The model will predict changes in water level, salinity, habitat area, nutrient cycling, and primary production.
- This should provide a basis for predicting ecological responses.
- The model will be designed to allow numerous short-term and long-term scenarios to be evaluated.
- We need help from the Cluster and stakeholders:
  - gathering data and understanding the system ecology
  - designing scenarios

Key biogeochemical knowledge gaps for the model:

- Importance of internal nutrient cycling vs external inputs
- Rates of denitrification, N fixation, and nitric reduces, IP burial
- How do these processes change in response to variations in salinity and vegetation cover?
- High salinities may lead to:
  - an increased abundance of green macroalgal and associated flora
  - precipitation of IP as authigenic minerals
  - increased algal productivity
- Developing plans to address this (subject to funding): fluxes at 5 sites, summer and winter.

Thanks particularly to Sebastian Lemontagne, Ian Webster and Pieman Cook for providing slides for this presentation.