
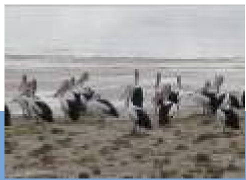



River Murray – Darling to Sea Ecological Community: Expert Technical Workshop Report

Threatened Species Scientific Committee
1 - 3 July, 2009
Adelaide

Image Credits: Lake Albert (G.Newton) Pelicans (G. Newton) River Murray Gorge (K. Walker) Wetlands (SA MDB NRM Board) Murray Mouth (K. Walker)

Threatened Species Scientific Committee

The establishment of the Threatened Species Scientific Committee is provided for under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act also sets out the functions of the Committee. These include advising the Commonwealth Environment Minister on the amendment and updating of lists for threatened species, threatened ecological communities, and key threatening processes together with the making or adoption of recovery plans and threat abatement plans.

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River Murray – Darling to Sea Ecological Community:

Expert Technical Workshop Report

Threatened Species Scientific Committee

1-3 July 2009, Adelaide

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Part A - Executive Summary, Introductory Material, Workshop Aims and Methods

Executive Summary - *Ecological Community Description*

An expert technical workshop was held in Adelaide from 1 – 3 July 2009 (see Appendix 1 for agenda and delegate list). Deliberations resulted in a number of key findings regarding the boundaries, characteristic features, benchmarking, and conservation goals of the ecological community (EC) under assessment - the '*Lower Murray River and associated wetlands, floodplains and groundwater systems from the junction of the Darling River to the Sea*' (RM-DS). A summary of outcomes from the workshop focus groups (groundwater; river and tributaries; wetlands and floodplain; biota) is provided at Table 1 on page 4.

Scope and Boundaries

The EC is a 'constructed' system that consists of a series of interconnected sub-units which include the river channel and its associated tributaries and wetlands, an infrequently flooded floodplain, and groundwater. The system is highly regulated. It incorporates the entire South Australian component of the River Murray (about three quarters of river reach length of the EC), with about one quarter of the river reach component having a shared boundary between NSW and Victoria. The EC ends at the junction (or confluence) of the Darling and Murray Rivers (near the town of Wentworth) and the workshop considered this as a sensible upper limit given habitat, biodiversity, and water quality changes upstream of this site. The region of the EC to be assessed is considered as distinctive due to its unique combination of landscape and habitat features and biodiversity elements. It was acknowledged that the region holds significant interest and connection for indigenous peoples, and information provided at the workshop confirmed that this region closely overlaps with the 'creation story' of the Ngarrindjeri.

In terms of floodplain boundaries for the EC, the workshop suggested that, as a general principle, the 1956 flood-line provides the best overall boundary for the system – biologically, hydrologically and geomorphologically. This line has also been well mapped and has been tested in other legislative/regulatory processes. However, it was strongly considered that the Eastern Mt Lofty Ranges watershed (which flows into the River Murray and Lake Alexandrina), although excluded by the 1956 flood-line, should be included within the EC. Inclusion of the Darling Anabranch (or part thereof) in the EC was also discussed as this may offer potential refuge habitat, however this aspect requires further investigation. In alignment with Ramsar Convention conditions, the various islands of the region are considered to be included within the EC.

Three main groundwater dependent/influenced sub-system types were identified:

- local groundwater system river-fed floodplain communities that occur along the length of the EC
- regional discharge fed systems
- subsurface stygofaunal communities – not yet documented.

The workshop suggested that a 'zone of influence' or 'buffer zone' concept be utilised for where actions on groundwater have a measurable influence on the ecosystem. This aspect requires further investigation.

Overall, the workshop highlighted up to six bio-geographical sub-regions within the EC region that have 'strong' ecological identities:

- *Coorong* – estuarine to hyper-marine, includes river mouth, 'end of system' marker of condition
- *Lower Lakes* – lake system with marginal wetlands and adjacent ephemeral saline ponds, regional groundwater input, plants different
- *Eastern Mt Lofty Ranges Watershed* - abundance of exotics, lack of natural floodplain, strong diadromous influence of fish; Eastern Mt Lofty tributaries are Marne River, Saunders Creek, Reedy Creek, Bremer River, Angas River, Finniss River, Tookayerta Creek, and Currency Creek. All but Marne, Saunders and Reedy feed into Lake Alexandrina.

Table 1: Sub-system Analysis – Summary of Outcomes

Groundwater	River & Tributaries	Wetlands & Floodplain	Biota
• accept system altered due to regulation • restoration to pre-European not feasible • protect healthy & potentially recoverable areas • connectivity critical - ground to surface water • local & regional scales important • 3 groundwater sub-ecosystems o local o regional o stygofauna • include Darling Anabranch in EC • 1956 flood line is best boundary for EC • include groundwater fed East Mt Lofty streams • 'zone of influence' concept for groundwater (i.e. where actions impact on EC - 15 km suggested) • groundwater behaviour important for EC description - robbing or augmenting the system • need to mimic 'natural' wetting/drying cycles • include anabranches & flowing creeks within certain radius • revegetation for salinity reduction • 5 bio-geographic sections: o Top o Valley o Gorge o Lower Lakes o Coorong	• focus on assets & areas of conservation value - not all areas of influence • connectivity is the central concept for the system o longitudinally o laterally o vertically • optimal EC includes a healthy terminal lake system, with estuary/sea connection • need to determine acceptable *benchmark* • acceptance that the current system is 'created' • in future - can water be supplied to maintain the EC we want to persist & list? • Tectonic control of the watercourse in past • channel - major driver of biodiversity for all system • Darling Anabranch now best area for Murray cod • Darling junction - useful upper limit of EC for habitat & cultural reasons • East Mt Lofty streams should be included (refugia) + local rainfall influence • traditional owners had diffuse boundaries • need to consider where 1956 flood line excludes important tributaries • possible boundary for Darling Anabranch - influence of Lock 9 weir pool between Oakbank & Worrys Dam • river role - keep mouth open • islands biological hot-spots • timing of wetting/drying cycle • set thresholds low - allow for variability & disturbance • engineered stability of water causing instability of ecology (& barriers to fish) • rate of change important for release of water • unique - in national psyche • 4 bio-geographic sections: o Coorong & Lower Lakes o Wellington - Swan Reach o Swan Reach – Lock 3 o Lock 3 - upstream	• ecosystem function needs protection, not just biodiversity • classify different assets, including ecosystem functions, services, & habitats • needs high temporal variability, but spatial variability dominates • aim for range of states for systems, not fixed • vegetation (terrestrial, aquatic) - distribution related to flow/flood • hydrological regime - duration, frequency, seasonality, quality, connectivity to wetlands • fish communities good indicators • trophic & habitat complexity important • 1956 flood line a good boundary • buffer zones important • groundwater not a good boundary, area too large - groundwater spp. best • connectivity driven by hydrology - vertical, longitudinal, lateral & temporal dimensions • local rainfall influences • weir & reach - a 'unit' • sedimentation & habitat fragmentation threats • ecosystem function, services and recruitment for condition thresholds • maintain trophic links • biotic & non-biotic thresholds • determine degree of loss • future sea level impacts • need small & large floods (overbank flows) • wetting/drying cycle • engineering for ecological benefit • address salinisation • 4 sections: Coorong & Lower Lakes, Lower River, Reclaimed Swamps & Gorge, Upper Reaches	• maintaining connectivity is paramount - key to biological & ecological integrity • broad-scale connectivity the goal • marine connection strong • Lower Murray distinct from other rivers due to high diversity over short distances • stygofauna unique • plants and fish the best indicators of 'ecological units' • colonial nesting birds probably hardest hit group to date • differing timeframe implications for recovery • marine influence - past & present • key biota (birds, fish, macroinvertebrates & flora) reinforce six defined regions • East Mt Lofty stream to be part of EC • 1956 boundary of floodplain • promote native flora & fauna above others • considered to have poor ecosystem health • seed store/egg bank - indicates recovery potential • recognise alternate states of components • Ngarrindjeri - wetlands are nurseries • system is unrecoverable when resources depleted (within & without) • timeframes for recovery • 6 sections: o Valley (Lock 10 - 3) o Gorge (to Mannum) o Swampland (to Wellington) o EMLR watershed o Lower Lakes o Coorong

- *Lower Swamps section* - reach between Wellington and Mannum; dominated by exotic plant species (e.g. willow, agricultural weeds) and has very little natural floodplain due to conversion to dairy swamps; (Reedy Creek flows into this section)
- *Gorge section* - Mannum to Overland Corner - valley and gorge plants and fish similar, but birds different, permanent large wetlands due to regulation; Marne and Saunders flow into this section of the Murray
- *Top Valley section* - junction of the Murray and Darling rivers (Wentworth, also Lock 10) to the beginning of the gorge at the Overland Corner (Lock 3), floodplains, lakes, anabranch systems, river losing water to groundwater.

Benchmark State

A benchmark state is the reference condition against which future evaluative comparisons can be made – it should not necessarily be equated as a target for management. The workshop accepted that this EC is a regulated, 'created' or 'constructed' system, and is therefore altered from its original, more natural condition. The weirs have been in place a long time (i.e. 72 - 87 years) and now there is a series of stepped pools formed by the weirs rather than a natural gradient through the river. Therefore using pre-European or pre-regulation condition as a benchmark state for the EC is less meaningful. Rather, pre-drought, good flow conditions (for example as occurred in the 1970s wet decade before there was a major shift in the system) were considered by the workshop as a more meaningful reference. In terms of conservation goals, it was considered that priority should be given to healthy and potentially recoverable areas. Experts considered that the majority of the system is recoverable, with the exception of a few highly salinised wetlands and the loss of very old trees such as 100 year old red gums, which provide complex habitat.

Key Characteristic Features

Flow was considered by the workshop to be the critical feature of the EC system – the 'maestro' or master variable that sustains all natural physical and biological processes. Flows provide freshwater, and perform flushing, dilution and transportation functions. Importantly, flow acts to keep the river mouth open and exchange with adjacent coastal waters (i.e. end-of-system concept). An adequate flow regime is needed (based on volume, frequency and timing) to ensure over-bank flow and wetting/drying requirements of wetlands and the floodplain. Flow is an enabler of connectivity. Other key characteristic features were identified by the workshop as:

- *hydrological connectivity* – central for maintaining a healthy functioning ecosystem (ecological community); driven by flow; three main dimensions for operational connectivity – vertical (groundwater/surface water), longitudinally (along river to sea), laterally (across banks and floodplain).
- *salinity* – key variable influencing biological sub-communities and productivity, particularly in lower reaches
- *temporal variability* – key feature of the natural ecosystem; regulation reduces temporal variability and leads to a dominance of spatial variability
- *distinctiveness* – EC region is ecologically different from its parent rivers; high degree of habitat diversity with key unique elements occurring over short distances; key biota reinforce the six defined sub-regions
- *iconic* - the region of the EC is a 'one of a kind' system in the national context and different from other river systems due to its complex features, habitat heterogeneity, and high levels of biodiversity over relatively short distances. The River Murray holds an important place in the national 'psyche'. The region of the EC has great significance for the Ngarrindjeri people as it is part of their traditional home and an integral part of their creation story.

Conservation Goals

The workshop consensus held that maintenance and increased resilience should be the guiding principle for conservation of the EC (i.e. not just biodiversity conservation). The optimal EC was considered to include a healthy terminal lake system, with an estuarine component connected to the sea. Characteristics of a healthy ecological community should also include trophic and habitat complexity, with no loss of key native species and presence of comparatively few alien species.

Achieving enduring connectivity and temporal variability (e.g. adequate wetting/drying cycles) were considered as major conservation goals for the EC. A useful indicator may relate to the role of the river to keep the mouth open. Broad-scale connectivity should also be a goal, i.e. rather than managing wetlands etc. in isolation. Issues were raised by the workshop regarding the future availability of water for the system and it was agreed the aim should be to hold onto as much ecological character as possible until the water comes. However, it was recognised that rather than having an EC with a fixed 'good condition', there are a range of acceptable 'states' for each sub-community type - i.e. there are various states of the essential character of the system. Overall, the aim should be to turn the system towards a more sustainable one than we have at present.

Executive Summary – *Threats*

Key Findings

A panel of experts provided a brief introductory commentary on what are considered some of the major threats to the EC – these were:

- Climate change
- Salinity
- Acid sulfate soils (ASS)
- Flow regulation/extraction
- Invasive species
- Land clearing/revegetation

From these overviews and resultant discussions the following key findings emerged. A summary matrix of outcomes is provided at Table 2 on page 8. There was agreement by the workshop that invasive species should include or be renamed 'problem' species for the purposes of the EC assessment. In addition to exotic species (invasives), over-abundant native animals and domestic stock can also pose a serious threat the system.

The overarching threat to the EC system was considered by the workshop to be climate change; it is a threat that will exacerbate the impacts of all other threat types. A certain level of climate change is already 'locked in' to the climate system and future projections suggest a warming and drying trend, with substantial declines in rainfall and inflow to the southern Murray-Darling Basin[1]. Future policies, plans and strategies regarding balancing the levels of environmental flow and extraction to achieve and maintain ecosystem health were considered to be critical to the future of the EC. The workshop held the view that at this juncture, to reclaim the Murray there needs to be provision for more water for the environment.

Experts at the workshop considered overwhelmingly that flow regulation is the most important specific threat to the RM-DS EC. This includes diversions and abstractions, with abstraction from both regulated and unregulated parts of the system. Importantly, flow regulation has changed the system from its natural state to a 'constructed' state – with a series of stepped weir pools. This has created a lack of temporal and spatial variability that the system needs for optimal health. The loss of floods under current extended drought conditions has also created problems for the wetlands

Newton, GM 2009 Australia's environmental climate change challenge: overview with reference to water resources. Australasian Journal of Environmental Management 16: 130 -139 and floodplain. Despite the various negative or limiting impacts of regulation, it was also seen as a potential tool to help address this aspect, for example to reinstate water variability and reintroduce wetting/drying cycles for some of these sub-systems. It could also be manipulated to increase the magnitude of in-channel flow pulses.

The workshop considered that with some threats the system has the ability to recover, particularly with the assistance of intervention. Both the threats of salinity and acid sulfate soils are currently being actively addressed with remedial action, for example liming for ASS, and salt interception schemes for salinity. (Note, some considered liming is unlikely to be an effective general treatment). Re-flooding is preferred, but recent science seems to indicate that reversal through re-flooding is a long-term prospect. Introduction of wetting and drying cycles with sufficient flows to remove oxidation/reduction products to the sea is preferred). The workshop held the view that the current degradation in the region of the EC caused by salinity and ASS has the potential to recover, with perhaps the exception of a few highly salinised smaller wetland areas.

Invasive (or problem) species can have a broad range of impacts and can potentially be ‘ecosystem engineers’ causing significant change to habitats and composition of native species. Once established invasive species are extremely difficult to eradicate and the workshop felt that some priority should be given to identifying high risk taxa and keeping them out (e.g. *Tilapia*). Rivers such as the Murray naturally have a distinctive, erratic hydrographic signature. A consequence of this is that the native flora and fauna are likely to include species with wide tolerance to environmental change, opportunistic life cycles and a capacity for rapid dispersal. Most native species of plants and animals rely on variability of conditions to cue for reproduction and dispersal. However, regulation and infrastructure has increased the stability of seasonal and inter-annual water levels (although daily levels may be more variable) and, as a general rule, this has discouraged native species and favoured non-natives.

For example, in the region of the EC there are about 150 invasive plant species (although only a small fraction are abundant and widespread), the common pest mammals and birds, and several introduced fish species. In particular, carp (*Cyprinus carpio*) is a significant problem and has led to increased turbidity and loss of aquatic plants (particularly macrophytes), insects and native fish. The marine invader, the tubeworm *Ficopotamus enigmaticus,* has also caused problems downstream, leading to the death of many turtles in the Lower Lakes.

A significant proportion, 50 - 80%, of the land within the EC has already been cleared, however there are now good controls in place regarding further land clearing. There appears to be damage to vegetation caused by cattle, sheep and horse grazing in some places. Importantly, extended drought conditions, coupled with river regulation and abstraction, have resulted in the loss of many older trees that will be difficult to replace - this may constitute a continuing threat to biodiversity as such trees provide complex habitat to a range of biota. There also appears to be a current trend of a shift in floodplain plant species composition towards adjacent terrestrial upland community species – with suggestions that some plant species now common on the floodplain were not present 30 years ago.

Newlart Lagoon, near Renmark. Soils acidified on drying out, and afterwards refilling resulted in the water turning acidic (Source: Paul Shand, CSIRO).

Table 2: Threats Matrix - summary of key points and issues raised by panel plenary session.

Threat Aspect	Climate Change (CC)	Salinity	Acid Sulfate Soils	Flow regulation/ extraction	Invasive/ Problem Species	Land clearing/ revegetation
Status	• prolonged drought • warmer & drier trend to persist • up to 45% runoff reduction predicted for MDB • impacts of climate change greatest in south-east MDB • projections re Murray mouth – no flow half time	• naturally saline groundwater • elevated salinity in channel water & floodplain soil	• sulfidic soils common • high proportion of exposed (dry) soils in system (e.g. Lower Lakes)	• highly regulated system • extraction - huge diversions, over-allocation, unregulated abstraction • reduced by CC & extended drought	• various weeds, including natives • 8 key mammals • 11 fish – carp • risk of Tilapia & other 'sleepers' • invertebrates? • disease risk	• ½ pre-European cover cleared • greatest change to agricultural landscapes • clearing now limited in SA • replanting programs
Impacts	• reduced inflows • increased temperature & extreme hot days • exacerbate other threats • distributional shift of biota & phenotypic change • increased erosion • increased weed invasion • biodiversity loss & change	• degradation of habitat • species loss or recruitment failure • species composition change • > invasive species	• detrimental effects on biota i.e. from acidification, deoxygenation, toxic heavy metals • recruitment impairment • nutrient pathways affected	• reduced water levels (below ADH in LL) • > salinity, ASS • loss of flow variability and range • weirs created series of stepped pools • biota loss & barrier to migration/dispersal	• habitat change • replace natives • competition with native species • grazing damage by stock • vectoring disease e.g. *Lernaea* • > marine invaders	• loss of habitat • soil erosion • change in water resources (S&G) • salinisation • acidification • biodiversity loss • > drought & CC • nutrient runoff
Abatement potential	• address over-allocation • accept 'natural' redistribution of biota • build resilience, reduce other threats • support refugia • > environmental flows • utilise infrastructure to advantage	• flow management; low flow exacerbates, high flows flush salt out • salt interception schemes • revegetation - limit groundwater seepage	• no silver bullet! • keep soils wet • caution when re-wetting (may remobilise metals) • revegetation • adding lime	• increase water for environment • utilise infrastructure to advantage • reinstate flow variability (bring back small floods with overbank flow) • need pulsed flows	• with return of environmental flows • changed regulation could change species • targeted removal strategies • risk assessments	• control of land clearing and forestry • prevent dying of older trees • site specificity issues • revegetation programs
Acceptable levels	• accept biota redistribution • 'triage' approach to protection/management	• below tolerance threshold of freshwater & floodplain biota	• below tolerance threshold of biota (e.g. fish ~> pH 5)	• river mouth open & flowing to sea • small & large floods occur- wet floodplain • no species loss	• accept we have an evolving flora • no further loss of native species	• balance short & long-term gains
EC issues	• geographic/habitat limits to redistribution • refugia - priority protection • don't sacrifice parts of system (valuable habitat)	• tolerance threshold of key species, for whole lifecycle • may be long time frames for recovery	• aim for natural wetting & drying cycle	• need to re-instate flow variability	• determine what is 'natural' and what are acceptable levels	• affects of future carbon credit policies

Executive Summary – *Listing Criteria*

Applicability to Aquatic Ecosystems

In order for an ecological community to be listed under the EPBC Act, at least one of six criteria contained in the EPBC Regulations 2000 must be met. These criteria determine under which category an ecological community is eligible to be listed (e.g. critically endangered, endangered, vulnerable). The six listing criteria are:

1. Decline in geographic distribution
2. Small geographic distribution coupled with demonstrable threat
3. Loss or decline of functionally important species
4. Reduction in community integrity
5. Rate of continuing detrimental change
6. Quantitative analysis showing probability of extinction.

Listing criteria (and associated thresholds as in the Guidelines) were, in general, considered applicable by workshop participants, but the need for some evolution and additions to allow for the complexity and dynamism of a large, complex aquatic system and its biota was recognised. A number of key findings were elucidated which will assist in this adaptive process, including a greater emphasis on ecological functionality as opposed to geography, and greater inclusion of temporal aspects. A number of challenges were also identified, such as data availability, effects of engineering works, cumulative impacts of threats, natural versus anthropogenic variability, trophic cascade effects, etc.

In particular it was recognised that the listing criteria need to take account of the fact that:

- aquatic systems have a high degree of temporal, spatial and qualitative variability of surface water; and
- groundwater hydrodynamics and quality are key drivers that affect the performance and therefore the degree of vulnerability of aquatic systems.

To date (mid 2009), most of the 45 or so listed threatened ecological communities, the majority of which are terrestrial, vegetation-based systems, have triggered mainly (70%) on Criterion 1 and 2. However, the workshop recognised that Criterion 3 and 4 are more fundamentally relevant to the assessment of aquatic ecosystems, as these pick up on the critical aspect of ecological functionality. In most cases, geographic distribution or extent is of less relevance to complex and dynamic aquatic ecosystems. It is also likely that Criterion 5 will become more relevant as more data becomes available on aquatic health through initiatives such as the High Conservation Value Aquatic Ecosystem Framework and the Sustainable Rivers Audit.

Gorge section of the River Murray, SA (Source: SA MDB NRM).

Specifics of Listing Criteria and the River Murray – Darling to Sea EC

The River Murray-Darling to Sea ecological community (RM-DS EC) was considered a hybrid between the terrestrial systems listed to date, and aquatic systems. Participants concluded that the nominated EC of the RM-DS should proceed to assessment guided by the outcomes of this workshop in terms of its definition, boundaries and major characteristics. It was accepted that for the RM-DS EC we are dealing with a 'constructed' system with values that are distributed across a range of 'connected' sub-units. The need to identify what 'holds it together' was recognised as essential. The main contenders from workshop deliberations were flow regime, connectivity, and saltwater-freshwater flooding interaction. There was discussion regarding the potential for different components of the system to trigger different criterion, however it was felt that this approach would: i) not align with the intent of the nomination as a 'holistic' functioning ecological entity, and ii) the imprimatur of the Threatened Species Scientific Committee (TSSC) to aim for the greatest possible extent – especially where there is a clearly demonstrated relationship between components of the broad-scale community.

The need to recognise water quality and source for an aquatic system (be it rain, river or groundwater) and changes in quality, was also identified as central to the assessment process. Several benchmark states (baselines, reference conditions) were proposed by the workshop regarding listing criteria assessment and 'natural' or 'healthy' condition of the RM-DS system (see previous discussion p.5) – the pre-drought, good flow conditions of the 1970s was considered a useful reference condition or 'benchmark state' for the system.

A significant outcome was the importance of Indigenous cultural aspects in the assessment process and the recognition that we are dealing with a 'living' system of great significance to story, particularly of the Ngarrindjeri people. In particular, it came to light that the major creation story of the Ngarrindjeri takes place over the proposed region of the RM-DS EC, that is from the sea to the junction with the Darling River. It is considered vital that the Ngarrindjeri and other indigenous groups partner in the assessment process and are included as an important source of information.

Several keystone and foundation species were put forward by the workshop. These include:

- *Fauna*: Murray cod, Murray River crayfish, the freshwater turtle (*Emydura)*, small native fish assemblage, mussels/snails
- *Flora*: red gum, black box, Melaleucas, coobah, Lignum, *Ruppia tuberosa* (Coorong lagoon).

In terms of rehabilitation interventions as is happening currently for the Coorong and Lower Lakes (e.g. bioremediation), it was determined that the Threatened Species Scientific Committee will consider the situation as it is and make a judgement. This would be important contextual information to contribute to the listing assessment and decision making process.
Importantly, the workshop proposed that the RM-DS EC, although currently (mid 2009) experiencing critical environmental decline, particularly in the Coorong and Lower Lakes, is considered to be recoverable if appropriate measures are taken in appropriate timeframes, i.e. there is a high level of restoration potential. However, there may be some differences to this generality in certain components or sub-units of the EC, particularly if compared to a pre-European standard as opposed to an acceptable contemporary standard. The ongoing impacts of climate change and water regulation policies on the entire Murray Darling Basin will also have a significant influence on the ecological community into the future.

A Murray turtle, Emydura macquarii, with shell encrusted by the calcareous tubules of the tubeworm, Ficopotamus enigmaticus, Lake Alexandrina, 2009. Source: Keith F Walker.

Introductory Material

The EPBC Act and Listing Process for Threatened Ecological Communities

Matt White (Director Ecological Communities, DEWHA)

About the EPBC Act

The *Environment Protection and Biodiversity Conservation Act* (EPBC Act) came into effect in July 2000. This premier Commonwealth legislation improves on the environmental legislative reforms of the 1970s and the *Endangered Species Protection Act 1992*. The EPBC Act focuses on nationally significant aspects of the environment and provides for the identification and protection of matters of National Environmental Significance (NES).

Matters of NES as defined under the Act include: areas of World and National Heritage, Ramsar wetlands, threatened species and ecological communities, migratory species, Commonwealth marine areas, and nuclear actions. The Act promotes conservation of biodiversity, recognises indigenous interests, lists threatened species and ecological communities and associated recovery plans, and provides for high level environmental planning, such as the marine based Bioregional plans. Importantly, the EPBC Act regulates:

- matters of NES
- Commonwealth land, places and actions
- international wildlife trade
- listed species in Commonwealth areas
- the Australian Whale Sanctuary.

The Approval Process

The Act is unique in that direct powers of approval lie with the Australian Government Environment Minister. An 'action' that is likely to have a significant impact on a matter of NES cannot be undertaken without approval of the Minister. The Act provides administrative guidelines to aid with the determination of 'significance'. An action constitutes a physical interaction or material change to the environment, including a development activity or capital works (e.g. road building, bulldozing, landuse change), or a downstream impact on wetlands etc.

It is important to note that ongoing land use or activities that were legal and routine before the EPBC Act commenced, are exempt. The Commonwealth does not become involved in developments where those risks have been eliminated by design or by State/Local regulation or planning. Strong penalties may apply for breaches of the EPBC Act, for example up to $5.5 million for civil matters and up to seven years gaol for criminal matters. There are about 500 compliance and enforcement incidents reported per year.

Specifically, the EPBC Act allows for the listing of nationally threatened species, nationally threatened ecological communities, and key threatening processes, and their associated recovery plans and threat abatement plans. For new listings since 2007, the preparation of 'a conservation advice' is required at the time of listing. Further information and guidance is produced to assist the determination if an action should be 'referred'. Note, the Minister determines (based on advice from the Threatened Species Scientific Committee) whether to have a recovery plan, taking into account existing management plans.

The Listing Process

The listing process for threatened ecological communities (EC) begins with the receipt of nominations from the public. These are strategically assessed by the Threatened Species Scientific Committee for suitability and a Proposed Priority Assessment List (PPAL) is forwarded to the Environment Minister for approval. Based on the Minister's determination, this list then becomes the Finalised Priority Assessment List (FPAL). For assessment of the ecological communities on the FPAL, the Department relies heavily on input and data from experts, including those from State/Territory agencies. Expert consultation also generally includes the holding of a technical workshop. In particular, the definition of an ecological community under the EPBC Act has a considerable amount of flexibility and the expert advice sought assists with refining the scope, context and boundary for a particular EC. The listing criteria, as set out in the Regulations of the EPBC Act, provide the enabling foundation for nomination and listing assessments. Assessment of listing criteria may also involve the analysis of thresholds for assigning conservation status (i.e. critically endangered, endangered, vulnerable) and expert advice is sought to assist with this aspect.

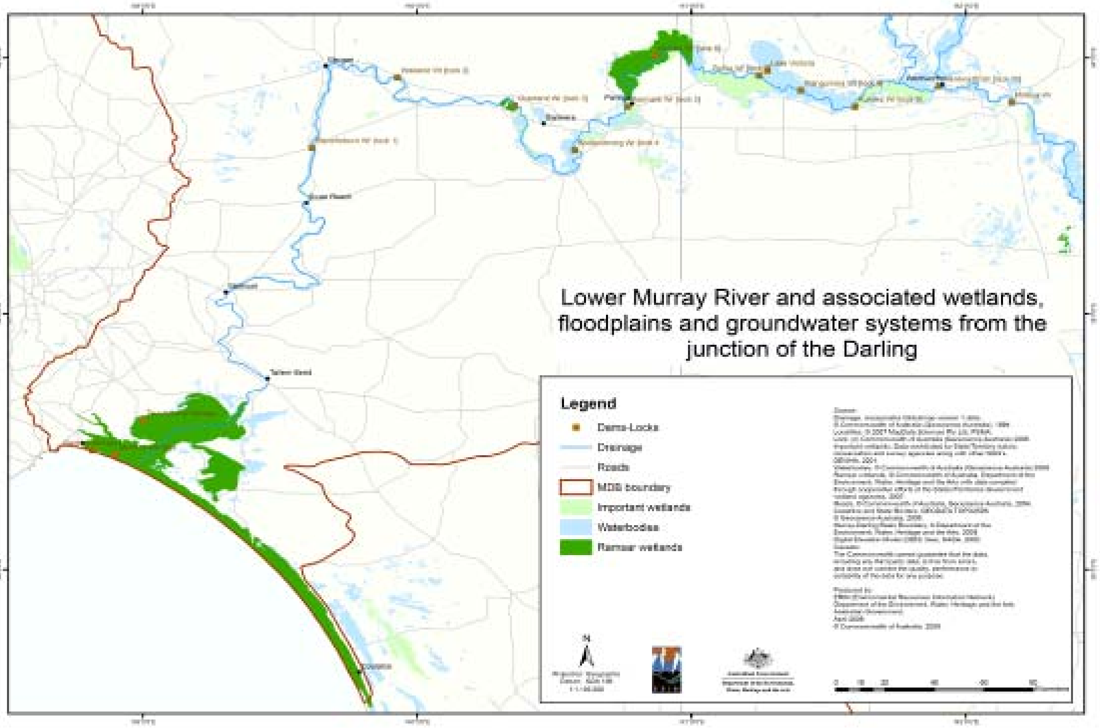
A period of public consultation is also part of the preparation of listing advice. Taken cumulatively, this approach ensures that listings are both scientifically robust and legally defensible. It is also important that the definition of an ecological community listed under the Act should be described in such a way as to allow a lay-person to recognise the listed threatened ecological community in the field. Lastly in the process, a listing advice is forwarded to the Environment Minister, via the TSSC, for a final determination. If accepted for listing, the Department then publishes a 'listing' and a 'conservation' advice, and a 'policy statement' to assist the community with how to identify the EC, how to manage it, conservation actions, etc.

The confluence of the Darling River and River Murray (Source: John O'Neil, Wikipedia).

River Murray–Darling to Sea EC

An expanded version of the original nomination (i.e. the Coorong and Lower Lakes) was included on the August 2008 FPAL – as '*the Lower Murray River and associated wetlands, floodplains and groundwater systems from the junction of the Darling to the sea*' (RM-DS). It related to the conservation theme at the time of, 'rivers, wetlands and groundwater dependent species and ecosystems of inland Australia'. The TSSC agreed that there was greater conservation benefit in expanding from the Coorong and Lower Lakes (already Ramsar listed – an NES) to include the region of upstream influence and impacts, as well as the interdependent groundwater, floodplain and wetland components of the system. The River Murray-Darling to Sea is unique in that it represents the first riverine system to be assessed under the EPBC Act as a threatened ecological community. It therefore also poses a challenge with respect to the listing assessment criteria used, as these were initially developed for terrestrial vegetation-based systems. (Note: part of the technical workshop focussed on the suitability of listing criteria for such aquatic systems). There is a three year assessment period for this EC which ends in September 2011.

If the ecological community is assessed and approved by the Minister to be endangered or critically endangered, it will have full legislative protection under the EPBC Act. Other benefits include leverage for funding opportunities which may support conservation actions to maintain and enhance good quality remnants, or to restore degraded sites to better condition. Another important benefit is the generally increased awareness of the EC and a bringing together and analysis of disparate information, thereby building on knowledge and increasing access to knowledge. This could also potentially complement any future 'strategic assessment' initiatives.



Map of the region of the River Murray-Darling to Sea EC.

Threatened Species Scientific Committee: Approach and Key Concepts

Bob Beeton (Chair, TSSC)

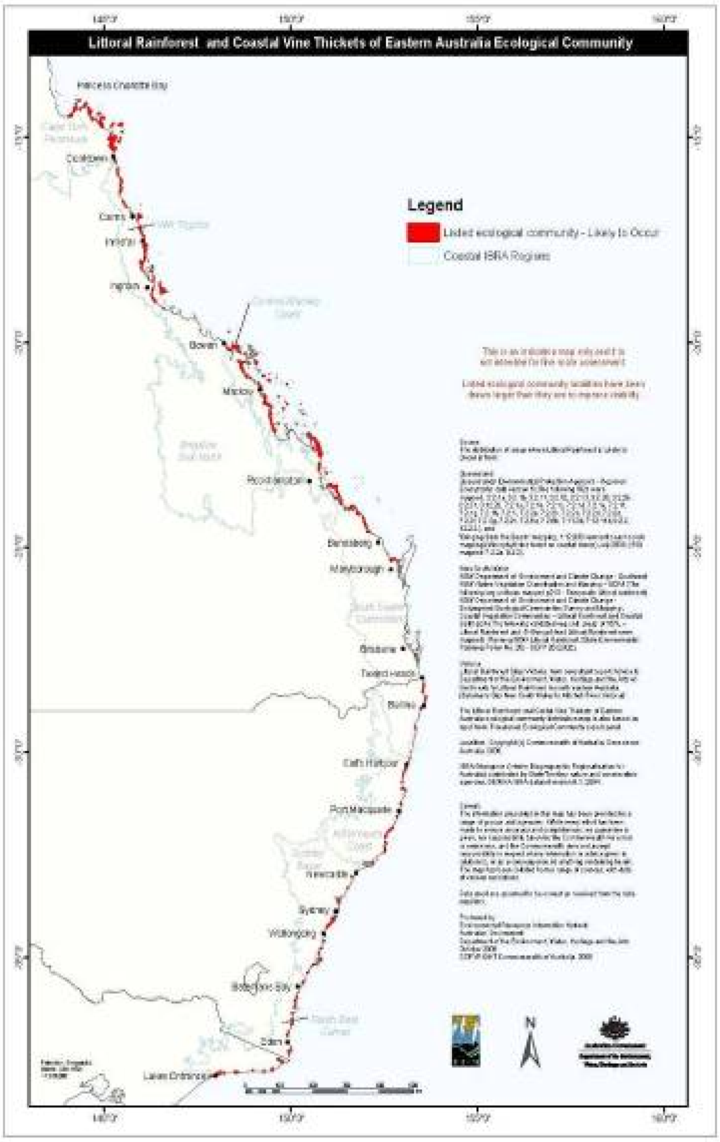
The Threatened Species Scientific Committee (TSSC) was first appointed in 2000 by the then Environment Minister. Importantly, at that time, it was determined that the Committee's advices and how they derived them, would always be published (i.e. be publicly available). Also, the Committee's meetings are open to departmental officers – 'the person who prepares the paper presents the paper'. The Committee regards the standard of work as being of a high order and of the highest scientific rigour. At times, the Committee also needs to exercise scientific or ecological judgement in their deliberations. The TSSC uses a peer-oriented, strongly scientific process to arrive at the recommendations we make to the Minister. We are not trying to fit the EC to a theory of ecology, we are trying to fit it to a conservation outcome.

Adaptable Approach to Defining ECs

The EPBC Act (s. 528) defines an ecological community extremely broadly – it is the extent in nature within the Australian jurisdiction, it has to be an assemblage of native species, and it has to meet additional criteria as specified by the Regulations. The Committee in recent years has been endeavouring to increase conservation outcomes by moving away from listing individual species (i.e. a specie- centric approach) and moving towards managing the threats and condition of ecological communities. However, defining ecological communities has been challenging, for example: what constitutes the EC?, what is the extent to which different levels of condition (degradation) affect the defined identify?, and what is the national extent? The TSSC has moved away from the more traditional, hierarchical definition of ecological community, and adopted a more practical approach that fits within the statute definition of an EC. In effect the Committee is wandering up and down the hierarchy of what ecologists would recognise as a community and sometimes we are going at least to ecosystems.

The national listing of an EC recognises that its long-term survival is under threat. The Committee, in concert with expert and technical workshop advice, has taken an adaptable approach of combining like ECs, where possible, to achieve a greater national perspective. For example, the listed EC, '*the Community of Native Species Dependent on Natural Discharge of Groundwater from the Great Artesian Basin*' was originally based on a series of separate nominations for individual spring communities in Queensland. However, the listed EC covers hundreds of springs, mounds, seepages, etc, that vary in size from less than 1 m^2 to over 100 hectares; they occur across Queensland, South Australia and New South Wales, spanning tropical and temperate semi-arid climates. While species compositions may vary, the linking element of the EC in this case is that they all depend on natural discharge of ground waters from a common source – the Great Artesian Basin, into a largely semi-arid environment. That is a geographic description.

Alternatively, with the *Littoral Rainforest and Coastal Vine Thickets of Eastern Australia*, the Committee listed the EC on structural grounds. This EC covers rainforest within two kilometres of the coast from Cooktown, Queensland to Lakes Entrance, Victoria. Species composition is highly variable, but vegetation structure and maritime influence are the unifying elements. Yet another example is Brigalow, which was recognised as a threatened ecological community on the basis of two dominant species. This listing now encompasses some 37 regional ecosystems mapped in Queensland and New South Wales. This adaptable approach has passed the test of time and has achieved good cross-jurisdictional support.



Map of the Littoral Rainforest and Coastal Vine Thickets of Eastern Australia EC, habitat to over 70 listed plants and animals, formed from a series of disjunct and localised stands/patches of rainforest/thicket on a range of landforms.

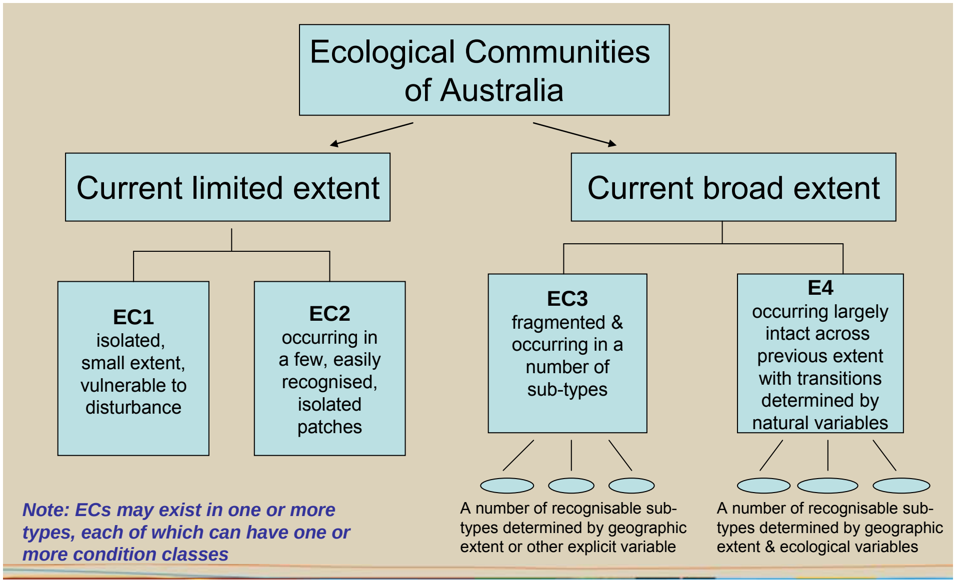
Types and States (Condition) of Ecological Communities

The definition of ECs also allows for the recognition of different states, and for each ecological community allows for up to three condition classes:

- good quality remnants,
- degraded but recoverable remnants, and
- irrecoverable remnants.

However, to date this has been applied mainly to terrestrial vegetation, with its application to complex aquatic systems untested. The Committee accepts that within the listing of an EC, there can be different condition classes. The use of this adaptable approach evolved by the TSSC enables better account for regional variation and condition to optimise conservation outcomes. Importantly, the description and condition thresholds of the EC in the listing advice are always the definitive source of information for identifying a nationally threatened ecological community and any mapped vegetation units should only be used as a guide. (Note: the development of thresholds for condition classes involves input from technical experts).

The Committee considers that there are basically two types of ECs. There are those of current limited extent, for example small isolated remnants vulnerable to disturbance (e.g. Mabi Forest on the Atherton Tablelands), and there are those of 'broad extent' (see figure below). The former may be isolated and small in extent (E1), or occur in a few isolated patches (E2); the latter may be fragmented and occur in a number of subtypes (E3), or they can be largely intact (E4).



TSSC Framework for understanding ecological communities.

The TSSC recognises that a threatened ecological community may have a range of 'states' which need to be expressed and clearly identified. For each state, 'Condition Classes' are identified as points along a continuum (i.e. from the most intact to levels of degradation such that it becomes locally extinct). Using E3 as an example, it may be possible to have a sub-type with a number of states that may be considered high quality or at various levels of degradation. That is to say, not all expressions of a listed EC are equal, for example, they may be unmodified, modified but recoverable, or beyond recovery. The 'beyond recovery' state is something that is possibly for (management) action but not necessarily for listing. However, recoverability is somewhat of a subjective notion – for example, some areas have been irretrievably converted to, say, wheat fields or houses or put under dams – these are absolutely beyond recovery. So, when considering an EC, the Committee endeavours to 'draw the line' where/when the community may come back.

It is important to note that the reference point for determining condition is also somewhat flexible. It may be pre-European condition or some other benchmark state, particularly if we are now dealing with a 'constructed' system, as is the case with regulated rivers. The TSSC recognises that it should be possible to restore or create systems that have high biodiversity value and which are, in fact, artefacts – although that may be more of a natural resource management activity. The Committee has also discussed the potential use of 'buffer zones' around listed entities which would be 'artificial constructs'. These would be zones of influence that, although not the legally defined EC, deserve consideration in determining 'significant impact' under the EPBC Act, and would guide mitigation and restoration actions.

Criteria for Listing Threatened Ecological Communities under the EPBC Act

Gina Newton (Assistant Director, Ecological Communities, DEWHA)

A vital aspect of the assessment process of an EC is the interpretation and assessment of 'listing criteria' as set out in the EPBC Regulations (Reg. 7.02). The listing criteria provide the enabling foundation for both nomination and listing assessments. They were adapted from international guidelines for threatened species. The Threatened Species Scientific Committee (TSSC) has adjusted the criteria and provided additional explanation for their application to ecological communities in its 'Guidelines'.

While the Guidelines 'allow for' aquatic ECs, to date they have mostly been applied to terrestrial vegetation-based ECs. There are six criteria and, in the past, these have had varying rates of application in terms of being triggered for an Australian threatened ecological community. For example, for the 45 or so ECs listed to date (mid 2009), Criterion 1, 2 & 4 have triggered the most (68%, 70% and 20% respectively), while Criterion 3 and 5 have hardly ever triggered (9% and 2% respectively), and Criterion 6 has not been triggered at all. Table 3 on page 17 provides a brief description of each criterion.

Another important consideration for an EC assessment is the fact that it relies almost exclusively on existing available data. In addition to published academic studies, much data is State/Territory based rather than Commonwealth based. To address this requirement, experts from all relevant jurisdictions are involved from the start of the assessment process. Importantly, all criteria are assessed, but a criterion cannot be triggered without requisite 'evidence' to merit listing at a certain level of conservation status (i.e. vulnerable, endangered, and critically endangered).

To assist with the assessment process, each criterion also specifies indicative thresholds against each conservation category (see Table 4 on page 18). The criterion with the highest conservation category is used to assign conservation status for the final listing of the EC. As an example: C1 may be 'critically endangered', C2 'endangered', C3 not met, C4 'vulnerable', and C5 and C6 not met - the EC if listed, would then have the category of 'critically endangered'.

The Guidelines also provide indicative thresholds for each of the categories for each of the six criteria. Threshold variables are used for establishing 'condition classes', for example: patch size, connectivity, species presence, etc. A number of assessment criteria also use timeframe thresholds to consider the possibility of restoration of the EC. For example:

- *immediate future (or past)*
  - next (past) 10 yrs, or 3 generations of any key long-lived species, to a maximum of 60 yrs
- *near future (or recent past)*
  - next (past) 20 yrs, or 5 generations of key long-lived species, to a maximum of 100 yrs
- *medium-term future (or past)*
  - next (previous) 50 yrs, or 10 generations of key long-lived species, to a maximum of 100 yrs.

Thresholds applied to date have been for terrestrial, vegetation based systems – it remains to be determined how, and/or, if the indicative thresholds and timeframes apply to aquatic ecological communities. Indicative thresholds as developed for vegetation systems are provided in Table 4.

Table 3: A brief overview of the six listing criteria under the EPBC Act.

Criteria	Description
1. ***Decline in geographic distribution***	• a decline in total area of the EC without necessarily a concomitant contraction in its range, or • a decrease in the range over the whole or part of the area in which the community originally existed, or • fragmentation of the community through a decrease in the size of patches. In order to meet this criterion there needs to be a measurable change. To determine this we need to know the original extent of the EC, its current extent, and how the decline relates to the thresholds (see Table 4 on page 18).
2.Small geographic distribution coupled with demonstrable threat	This criterion applies to ECs that have a small geographic distribution (on a national scale) and for which a threatening process exists within an understood or predicted timeframe. A small geographic distribution implies an inherently higher risk of extinction from the threat. This criterion does not apply to small ECs that are not subject to a threatening process – the intent is rather, to capture naturally rare or highly fragmented communities under threat.
3***. Loss or decline of functionally important species***	This criterion refers to native species that are critically important in the processes that sustain or serve a major role in the EC, and whose removal would potentially precipitate a negative structural or functional change that may lead to extinction of the EC. This criterion has two inseparable components for assessment: there must be a decline in the population of the functionally important species (FIS), and restoration of the EC is 'not likely' to be possible within a specified threshold timeframe (see Table 4 on page 18). The decline of the FIS must be halted or reversed to ensure continuation of the EC.
4***. Reduction in community integrity***	This criterion recognises that an EC can be threatened with extinction through ongoing modifications that do not necessarily lead to total destruction of all elements of the community. Changes in integrity can be measured by comparison with a benchmark state that reflects the 'natural' condition of the EC with respect to its abiotic and biotic elements and processes that sustain them. The criterion recognises detrimental change to component species and habitat, and to the processes that are important to maintain the EC. Importantly, it allows for recognition of a problem at an early state (e.g. disruption of process evident but no measurable decline in integrity of EC as yet). Regarding the regeneration aspect of thresholds (see 4) this relates to re-establishment of an ecological process, species composition and community structure within the range of variability exhibited by the original community. Among other things, this criterion would include invasion of non-native species, and physical environmental changes sufficient to lead to ongoing change in biota.
5. **Rate of continuing detrimental change**	Continuing detrimental change refers to a recent, current or projected future change for which the causes are not known or not adequately controlled, and so is liable to continue unless remedial measures are taken. Detrimental change may refer to either i) geographic distribution or populations of critically important species, or ii) degradation or disruption of an important process. The detrimental change can be observed, estimated, inferred or suspected. Natural fluctuations do not normally count as continuing change, but an observed change should not necessarily be considered to be part of a natural fluctuation unless there is evidence for this. 'Ecological judgement' may be exercised to apply this criterion if adequate data are not available.
6. ***Quantitative analysis showing probability of extinction***	Can include any form of analysis that estimates the extinction probability of and ecological community based on known characteristics of: important species or components, habitat requirements, ecological processes, threats, and any specified management options. The TSSC recognises that this is an emerging area of science and will examine any acceptable modelling (with the concomitant use of peer review).

Table 4: Indicative Thresholds for vegetation-based systems.

	Criteria 1	**Criteria 2** (small distribution plus demonstrable threat)			**Criteria 3**		**Criteria 4**	**Criteria 5**	**Criteria 6**
Indicative Threshold/ Conservation Threat Status	Decline in geographic distribution	Area of Occupancy (actual area covered)	Extent of Occurrence (measure of geographic range)	Average Patch Size	Decline of a functionally important native species	Restoration Timeframe (not likely within)	Regeneration Timeframe (change in integrity such that regeneration is unlikely in)	Detrimental Change (immediate past or Immediate future)	Probability of extinction or extreme degradation over all geographic distribution
Critically Endangered	Very severe ≥95%	< 10 km^2 (1000 ha)	<100 km^2 (10,000 ha)	generally <10 ha	Very severe ≥80% (over last 10 yrs or 3 gens. if >)	Immediate future next 10 yrs (or 3 gens.→ max 60 yrs)	immediate future next 10 yrs (or 3 gens.→ max 60 yrs)	Very severe ≥80%	At least 50% in immediate future
Endangered	Severe ≥90%	< 100 km^2 (10,000 ha)	<1000 km^2 (100,000 ha)	generally < 100 ha	Severe ≥50% (over last 10 yrs or 3 gens. if >)	Near future next 20 yrs (or 5 gens.→ max 100 yrs)	Near future next 20 yrs (or 5 gens.→ max 100 yrs)	Severe ≥50%	At least 20% in the near future
Vulnerable	Substantial ≥70%	< 1000 km^2 (100,000 ha)	<10,000 km^2 (1,000,000 ha)	N/A	Substantial ≥20% (over last 10 yrs or 3 gens. if >)	Medium-term future next 50 yrs (or 10 gens. → max 100 yrs)	Medium-term future next 50 yrs (or 10 gens. → max 100 yrs)	Substantial /Serious ≥30%	At least 10% in the medium-term future

Key:
< = less than
> = greater than
≥ = grater than or equal to
max = maximum
gen = generation

Aquatic Ecosystem Classification – A National Scheme

Chris Auricht

A new Australian National Aquatic Ecosystem Classification Scheme is being developed as part of the High Conservation Value Aquatic Ecosystem Framework. This work is currently underway under the auspices of the NRM Ministerial Council (and managed by the Department) to support determination of conservation significance of aquatic ecosystems. It is likely that the assessment process of the River Murray-Darling to Sea EC will have relevant linkages with this work and may benefit from associated information and analysis.

All jurisdictions have agreed to actions under the National Water Initiative (NWI), which aim to produce a more cohesive national approach to aquatic ecosystem (AE) classification, and to increase the efficiency of Australia's water use - leading to greater certainty of water use for the environment. The Aquatic Ecosystem Task Group is developing a nationally coordinated approach and overseeing development of a national policy framework for the identification, classification and management of high conservation aquatic environments. The main objective of this process is to provide a nationally consistent approach for the identification and classification of aquatic ecosystems, and to provide a practical, scientifically robust tool to help meet NWI commitments, particularly where regions cross jurisdictional boundaries. It is not intended as a regulatory or conservation mechanism.

Other important goals of the process are to:

- identify aquatic ecosystems of high conservation value (HCVAE) and differentiate between HCVAEs of national and regional importance
- improve knowledge of HCVAEs, information sharing, and cross-jurisdictional coordination
- guide planning, investment and management decisions
- assist in meeting national and international obligations for protection of aquatic ecosystems.

For the purposes of this process, aquatic ecosystems are those that depend on flows, and/or periodic or sustained inundation/water logging for their ecological integrity (they do not generally include marine waters). HCVAEs are those that meet the criteria outlined in the HCVAE framework. An endorsed guiding principle is that the determination of HCVAEs will be based on ecosystem functioning.

One of the main issues with development of this process is that current classifications and mapping datasets are numerous, fragmented and inconsistent across jurisdictions. For example, a recent review of 135 wetland datasets revealed that many don't have information on extent. Given the variable status of knowledge and the variety of classification schemes currently in existence, it is not practical to have a uniform set of classes within the scheme. Rather, the national scheme is designed to be flexible and provide a structure that will support future development and incorporation of nationally agreed components as they become available. We are endeavouring to develop a consistent typology that can be supported by conceptual models and diagrams and lead through to such aspects as identification of assets, drivers and values, threatened condition indicators and assessments, and prioritisation - all within an adaptive management framework.

The classification scheme is based on a three tier approach:

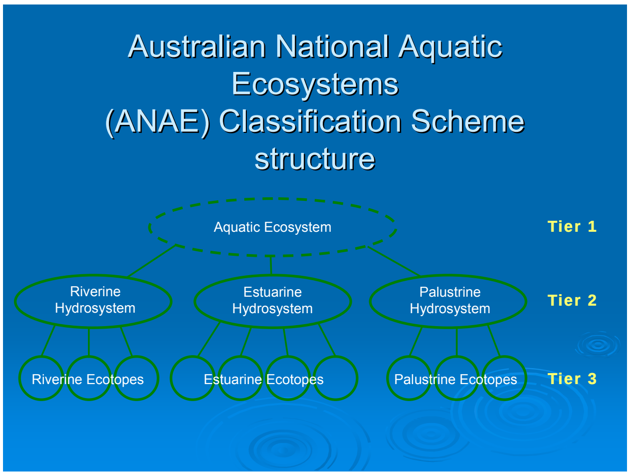
Tier 1: Aquatic Ecosystem – usually larger systems identified using the concepts of ecological functioning and integrity (the basic unit for identifying HCVAEs consists of one or more hydrosystems). A geographic area that consists of a single hydrosystem or an aggregation (complex) of spatially or ecologically connected hydrosystems.

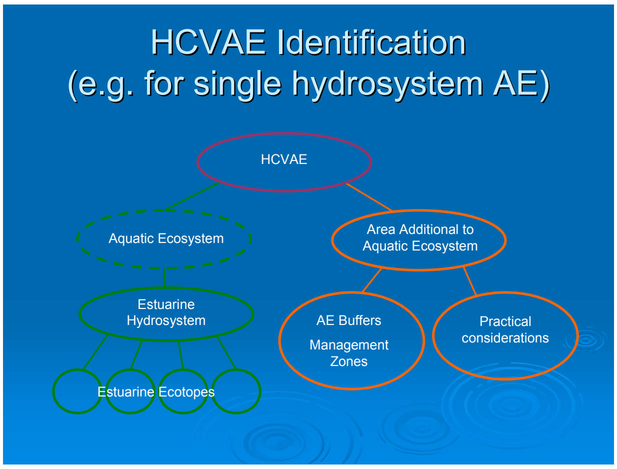
Tier 2: Hydrosystems – organising entities e.g. estuaries, rivers, complexes of swamps and lakes. A geographic area of an AE that consists of a single ecotope, or an aggregation (complex) of connected ecotopes. Primarily identified by form, fabric (geomorphology) and flow regime. Subsystems may be identified.

Tier 3: Ecotopes – areas of similar habitat that can be identified or mapped e.g. palustrine wetland. A geographic area of a hydrosystem with a homogeneity of definable and mappable ecological attributes - e.g. wetland type, vegetation community, substrate, or water regime that make it distinguishable from other areas.

Current agreed Aquatic Ecosystem Classes are:

- Marine
- Estuarine (i.e. with a mixture of fresh and saltwaters)
- Riverine (i.e. with flowing fresh water)
- Lacustrine (e.g. lakes)
- Palustrine (basin; e.g. wetlands without flowing water)
- Subterranean (i.e. groundwater)
- Nival (i.e. related to snow)
- Reservoir (artificial water bodies)
- Coastal foreshore





Australian National Aquatic Ecosystems Classification Scheme structure and an example of a high conservation value aquatic ecosystem for a single hydrosystem (Source: Chris Auricht)

With respect to determination of a HCVAE, there are several important elements to consider:

- *Core Area* – core areas that have been identified as of high conservation
- *Linkages* – critical relationships or connections between different core components within a site that maintain key ecological processes
- *Core Area and Linkage Buffer Zones* – areas that enhance and/or protect habitat quality within the core area and their linkages, and help mitigate threats
- *Management Zones* – additional areas that are critical for management and protection of key species and other identified high conservation values within Core Areas, Linkages and their Buffer Zones.

Given that connectivity (i.e. linkages) is a fundamental premise for ecosystem function in aquatic systems, there are several high level questions that need to be addressed as part of the process:

- Is there geographic connectivity?
  - Does the hydrosystem share the same area as another hydrosystem (e.g. an interspersed series of lakes (lacustrine hydrosystem) and swamps (palustrine hydrosystem) on a riverine floodplain)?

  - Are the hydrosystems contiguous?
- Is there hydrological connectivity?
  - Groundwater and surface water connectivity.
  - Flood regimes for aquatic landscape connectivity (e.g. floodplains).
- Are there shared geomorphological processes?
  - Connected sediment budgets.
  - Dependence of flood regimes as a geomorphic process.
- Are there shared chemical influences?
  - Salinity influence i.e. tidal or via salt spray?
- Is the biota in the aquatic ecosystem dependent on the participating hydrosystems or ecotopes?
  - Source or sink of primary productivity (energy and nutrient flows).
  - Fauna may depend on a number of hydrosystems for foraging or breeding purposes.

In addition, any identified connectivity should have a measurable effect on the ecology and function of the core AE for them to be deemed connected.

Next steps in this process include future trials to assess the ability of the national AE classification scheme to support the determination of national HCVAE sites at drainage division level, and the development of a common language guide.

Gorge section of the River Murray, SA (Source: Keith Walker).

Workshop Aims and Methods

Ecological Community Description

Aim

- Identify key descriptive aspects and characteristics of the ecological community of the *“Lower Murray River and associated wetlands, floodplains and groundwater systems from the junction of the Darling River to the Sea”* (RM-DS).

Background and Methods

An important aspect of the assessment process (and ongoing operational aspects if the EC is listed by the Minister), is a scientifically acceptable and ‘workable’ (i.e. read practical, rational, sensible, legally enforceable) definition of the threatened ecological community, with quantitative or qualitative descriptions of the EC’s physical boundaries, major components, and condition. If listed, the EC will be both a ‘scientific’ and a ‘legal’ entity. Outcomes sought from the workshop related to description of major features, boundaries, connectivity aspects, condition thresholds and restoration/management issues. These outcomes will contribute to the listing assessment, with the ultimate goal being the future recovery/conservation (and sustainable use) of the EC.

Four breakout discussion groups were designed around four major functional components (focus sub-system) of the EC, *Groundwater; Rivers and Tributaries; Wetlands and Floodplains; and Biota*. Each group used the same set of questions to structure their discussions, as below:

1) ***Major Description Features:*** What are the major ecological and bio-geo-physical features that describe and define your focus component of the EC? (e.g. geographic location, position in landscape, climate factors, structure, etc…..).

2) ***Boundaries:*** a) What are the ‘workable practical’ boundaries of the EC in relation to your focus component? b) What is in and what is out? c) Where does it start and end? d) What are the issues that may blur these boundaries?

3) ***Connectivity:*** a) What are the main connectivity features of this focus component of the EC compared with the three others? (e.g. distance, process, functionality, etc). b) What are the main issues for ensuring future functional connectivity of your focus component?

4) ***Condition (Thresholds):*** a) What is the optimal condition/functionality of this component of the EC and what would be the levels of acceptable change? b) When is the component too degraded to be ecologically functional/too difficult to restore and hence excluded from the EC? c) What (measurable) condition indicators are important?

5) ***Restoration/Management*:** a) What are the broad priority conservation and management actions to maintain or restore condition?

6) ***Variation:*** Your Group has been provided with maps of the EC region as artificially divided into four discrete sections. How would you meaningfully divide the region into distinct sections and why? The four map regions provided were:

    1) Sea to Tailem Bend
    2) Tailem Bend to Flood Lock 1
    3) Flood Lock 1 to Flood Lock 5
    4) Flood Lock 5 to Wentworth (i.e. join with the Darling).

Threats

Aim

- Identify priority threats to the River Murray-Darling to Sea ecological community.

Approach

A panel of six experts provided a brief introductory commentary on what are considered to be some of the major threats to the ecological community of the RM-DS. These overviews have been summarised and supplemented with further information for the workshop report. The six threats were:

- Climate change
- Salinity
- Acid sulfate soils (ASS)
- Flow regulation/ extraction
- Invasive species
- Land clearing/ revegetation

A plenary general discussion was held following the expert presentations, with each of the threats discussed according to their status, impacts, abatement potential, acceptable levels and other EC related issues. Key points and issues raised from the discussion were analysed and summarised for the report in a Summary Threats Matrix (see Table 2 on page 8).

Listing Criteria

Aims

- Consider suitability of current legislated Listing Criteria and Guidelines to aquatic systems, and options for future enhancement.

- To inform the assessment process for the ecological community '*Lower Murray River and associated wetlands, floodplains and groundwater systems from the junction of the Darling River to the Sea*'.

Methods

The River Murray - Darling to Sea (RM-DS) EC is a 'test case', as it is the first time that the listing criteria (and their indicative associated thresholds) will be assessed for a complex, dynamic river system. Therefore consideration is needed regarding interpretation of the criteria and how they should be applied to aquatic ecosystems in general, and to the RM-DS EC specifically.

The 6 Listing Criteria are as follows:

1. Decline in geographic distribution
2. Small geographic distribution coupled with demonstrable threat
3. Loss or decline of functionally important species
4. Reduction in community integrity
5. Rate of continuing detrimental change
6. Quantitative analysis showing probability of extinction

Workshop delegates were assigned to four groups (to ensure a multi-disciplinary mix – see Appendix 3), with each group chaired by a member of the Threatened Species Scientific

Committee. Each group then considered and discussed the six listing criteria against a set of standard questions. Results were reported back in a plenary session which enabled further discussion and questions to be addressed. Summaries of major outcomes are provided for each criterion. Universal key findings (i.e. findings common to multiple groups) were also highlighted.

The questions addressed for each criterion were:

1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?
2. How do we best measure this Criterion in aquatic ecosystems?
3. What are the challenges/impediments/issues for applying this Criterion to aquatic systems?
4. How can the Criterion be adapted better for aquatic ecological communities?
5. How does the Criterion work for the RM-DS EC?

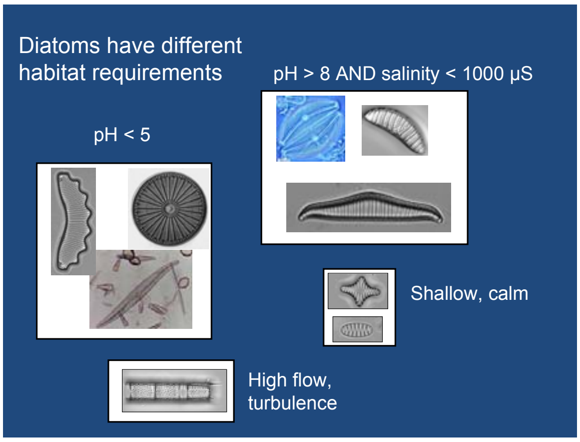
Part B - Workshop Outcomes 1: Ecological Community Description

Setting the Scene Presentations – Key Messages and Issues

The following presentations were provided by invited experts during the workshop to help set the scene for workshop discussions (hence they are current to mid 2009). Key messages and issues from these presentations are summarised below.

Palaeo-history of the Lower River Murray
Jennie Fluin, University of Adelaide

Palaeoecology is the study of aquatic sediments, including physical and chemical properties and the plant and animal remains, to inform about past environmental conditions. Each layer of sediment represents a different slice of time in history, ranging from last year to thousands of years ago (i.e. palaeo-data can provide 10,000 years of evidence for lower River Murray). In particular, diatoms (single-celled algae with a silica skeleton) are extremely abundant in aquatic environments and have excellent preservation, remaining intact for hundreds of millions of years. Diatoms have specialised habitat requirements and are very sensitive to environmental change, with particular species dominating in different environmental conditions.



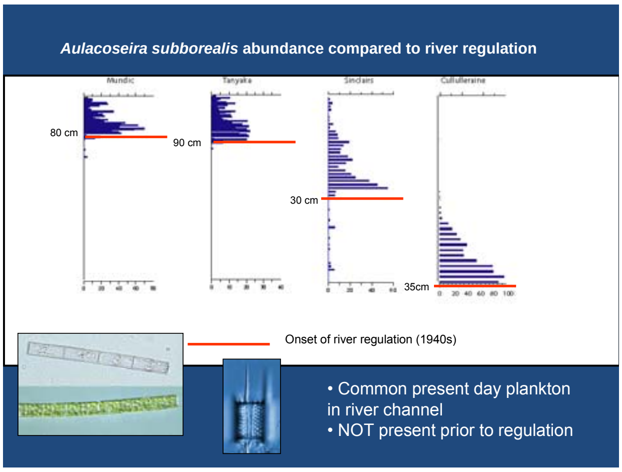
Different diatom types found in different aquatic conditions (Source: Jennie Fluin, University of Adelaide).

Wetlands are generally dominated by diatoms that reflect shallower, calmer conditions. By comparison, the chain diatoms need turbulence and are more abundant in the river channel.

Changes in palaeo-diatom fauna of the River Murray are linked to increased post-regulation sedimentation rates and turbidity. (Importantly, there is a high risk of some wetlands ceasing to exist due to siltation). Much of the sedimentation is coincident with land clearing. A change in species composition and dominance of the diatom fauna is evident post-regulation of the lower River Murray, with some species no longer present. Macrofossil records have also shown the riparian bulrush, *Typha* comes in when the river was regulated, but was not present in the previous 2500 years.

Diatom palaeo-records have shown a cyclical switching between dry and wet, with highly variable flows and 50 to 100 year cycles of high flow versus low flow (i.e. short term (decade) and long term (century) average flow patterns. There is an obvious relationship between palaeo-flow, palaeo-climate, and changes in aquatic vegetation with flow regime.

For the Lower Lakes, a 7000 year record indicated that less than 5 - 10 % of the diatom taxa in lake Alexandrina were marine and that the pH was always alkaline (i.e. no evidence of acidification in cores). For a site just behind the barrages near the mouth, estuarine taxa were consistent pre and post barrage. However, the palaeo-diatom fauna showed the presence of marine taxa prior to the barrage with none post-barrage, and an increase in non-marine sourced salinity in the past 30 years. Similarly, marine foraminifera are no longer present after the barrage was constructed, and periods of their absence prior to the barrage indicates periods of mouth closure. So prior to regulation, for most of the past 700 years, river flow rate was high enough to maintain an open river mouth (the exception is four discernible mouth closure events). There is a massive increase in sedimentation post barrage.

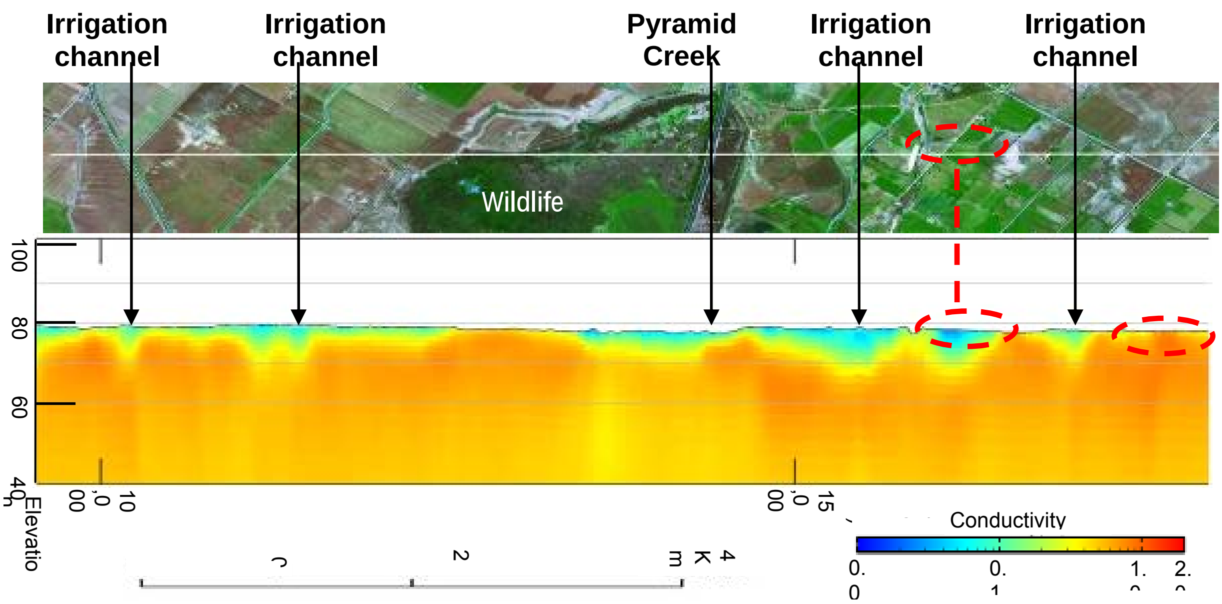


Present day plankton in the river channel, not present prior to regulation (1940s)(Source: Jennie Fluin, Uni. of Adelaide).

Groundwater Connections - Hydrogeology

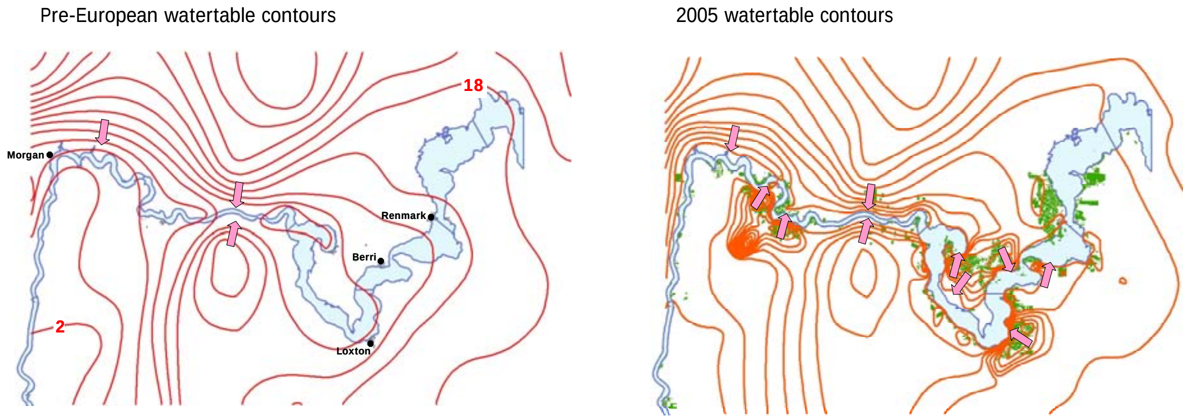
Jane Coram, Laura Gow (Geoscience Australia), Steve Barnett (Department of Water, Land and Biodiversity Conservation SA), Emily Slatter (Bureau of Rural Sciences)

Understanding groundwater processes is important to understanding and delineating groundwater-influenced ecosystems. For example, many wetland and other groundwater influenced ecosystems can be influenced by local out-seepage and/or regional groundwater flow processes (e.g. from 10 – 100 km away). In these instances, the hydrology of the aquifer and the health of the wetland ecosystem can be closely connected. This hydrology can be disrupted by both local and/or more widespread hydrological changes, such as by groundwater abstraction, or by reduced recharge to groundwater aquifers. Mapping of groundwater is currently underway using airborne electromagnetic surveys and remote sensing with field validation. In particular, the aerial electromagnetic surveys have shown leakage at depth from existing irrigation. The presence of flush zones (leakage from river) has implications for the ecosystems that overlay them. For example, there may be the potential for increased resilience to drought and extended dry weather for those ecosystems that overlay a flush zone, compared to those that do not and are fed by highly saline groundwater.

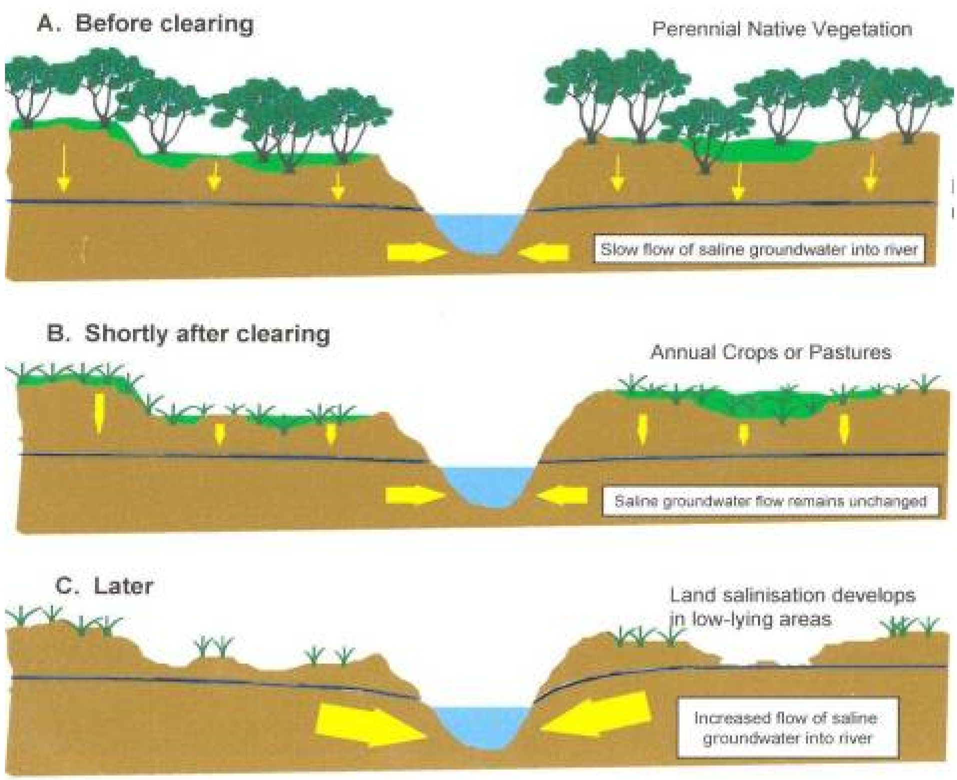


Leakage from existing irrigation in a section of the River Murray (Source: Emily Slatter, BRS).

Importantly, groundwater often connects the River Murray, wetlands and Lower Lakes with salt. The low floodplain of the downstream Murray acts as a drain for the regional aquifer systems of the entire Murray-Darling Basin, which contain mostly saline groundwater. Natural inflows of groundwater are enhanced by irrigation and land clearing. The clearing of deep-rooted native vegetation from the floodplain has led to an increase in recharge, with the watertable rising and increased discharge of groundwater to the river.



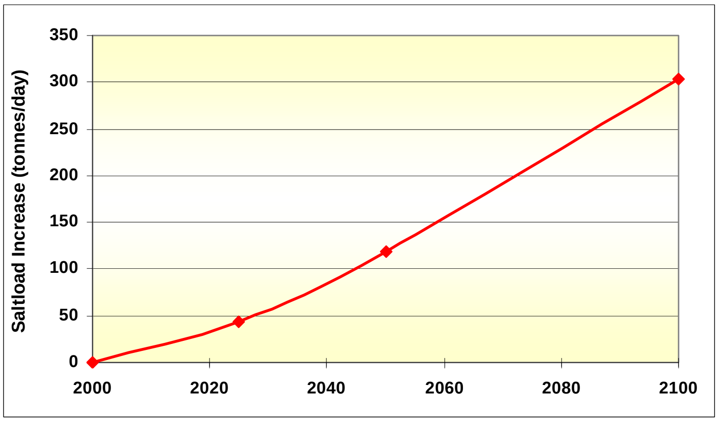
Postulated pre-European (and pre-regulation) watertable contours compared to a recent map from 2005 (i.e. post regulation); over the years irrigation development has led to mounds and enhanced discharge of saline groundwater (Source: Steve Barnett, DLWBC).



Influence of land clearing and removal of deep-rooted native vegetation on groundwater recharge and salinisation (Source: Steve Barnett, DWLBC – diagram by Peter Cook, CSIRO).

Groundwater contributes a considerable amount of salt to the system each year, and there is now a statewide salt interception scheme in South Australia.

During pre-regulation the river channel had a natural gradient. Now the depth of the watertable (i.e. groundwater level) increases as you go upstream to the next Lock – i.e. creating a stepped rise, rather than the previous gradual gradient that would have naturally fluctuated up and down with flow change seasonally and annually.

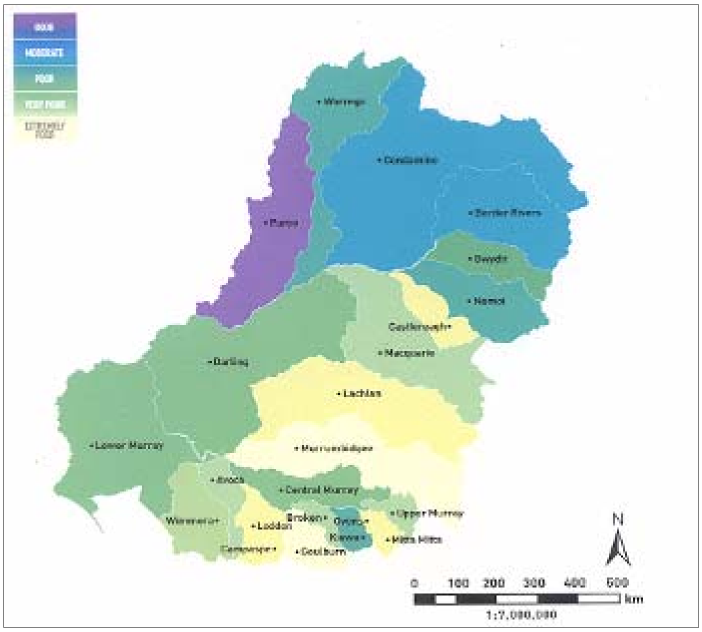


Salt interception bore and control, and projected increase in salt loads to river and floodplain due to land clearing (Source: Steve Barnett, DWLBC).

Sustainable Rivers Audit 2004 – 2007: How did the Lower Murray Valley fare?

Keith Walker (TSSC)

The sustainable rivers audit (SRA) of river ecosystem health surveyed 23 valleys within the Murray-Darling Basin. The first report covers the period 2004 to 2007. The Lower Murray Valley received an overall rating of 'poor'.



Rating	*Valley*	*Rank*
GOOD	*Paroo*	*1*
MODERATE	*Border Rivers, Condamine*	*2*
POOR	*Namoi, Ovens, Warrego* *Gwydir* *Darling, Lower Murray, Central Murray*	*3* *4* *5*
VERY POOR	*Upper Murray, Wimmera* *Avoca, Broken, Macquarie* *Campaspe, Castlereagh,* *Kiewa, Lachlan, Loddon, Mitta Mitta* *Murrumbidgee, Goulburn*	*6* *7* *8* *9*

Indicators grouped as 'themes' were used as the basis of this first assessment – they were: fish, macroinvertebrates, and hydrology. Future work will introduce physical form and vegetation indicator themes, and possibly waterbirds. For the purposes of this first audit, only the riverine channels were surveyed, not the floodplains. Also, the Lower Lakes and Coorong were not included.

For each indicator theme, the rating was 'poor'; an overview of the assessment follows:

- Fish: POOR
    - indicators - expectedness, nativeness, alien versus native species, biomass
    - 22 sites, including Mt Lofty Zone
    - 40% of expected species, 13 species absent (barrages)
    - dominated by carp and gambusia, (50% of the fish biomass is carp)

- Macroinvertebrates: POOR
    - indicators - expectedness, SIGNAL OE score, family richness
    - 33 sites, including Mt Lofty Zone
    - 15 common families, dominated by crustaceans and molluscs (not insects)
- Hydrology: POOR
    - flows highly modified by diversions
    - massive reductions in flow magnitudes
    - dominated by low flows (<5000 ML/d)
    - pronounced changes in interannual variability and seasonality (to a lesser extent).

Note, the work of this first report of the SRA is considered as 'provisional – with the focus of future work to expand on indicator themes and incorporate the wider ecological community (for example the floodplain and Lower Lakes). However, this work does indicate things are not well.

Coorong and Lower Lakes – Status Report

Kerri Muller (Kerri Muller NRM)

The terminal systems of the River Murray are the Coorong and Lower Lakes – a region formed some 7000 years ago. It represents the homeland for the Ngarrindjeri people and is a source of spiritual renewal to the community (in the past it also represented a thriving economy). The region was nominated as a Ramsar site in 1985, and a Living Murray Icon Site in 2004. A comprehensive Ecological Character Description (ECD) was published in 2006, which defined ecosystem components, processes and services. In particular, the ECD defined and recorded 23 wetland types, and recorded 77 bird species, 7 endangered or vulnerable plant species, 49 fish species, and 10 frog species (including the EPBC Act vulnerable listed Murray cod and southern bell frog). The ECD is being considered for updating and limits of acceptable change are being investigated.

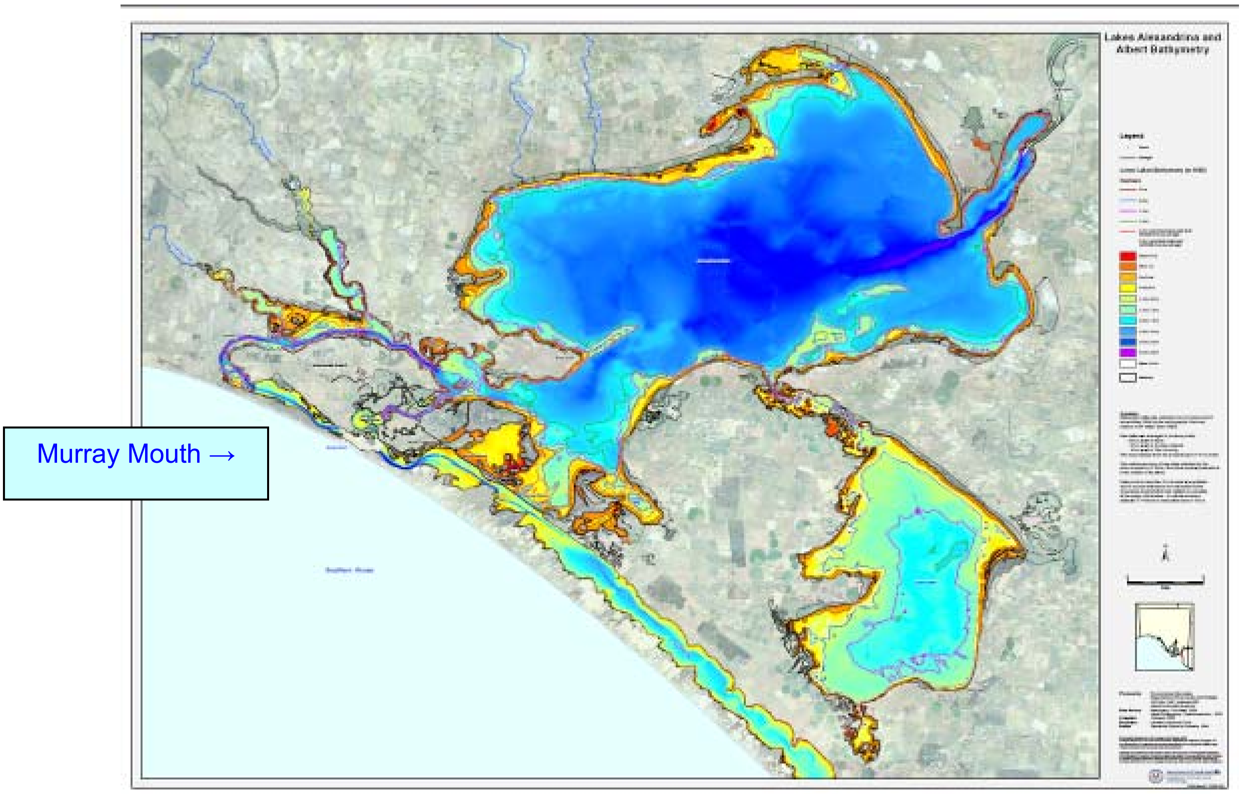


Image of Coorong and Lakes Alexandrina and Albert showing bathymetry contours (Source: Kerri Muller).

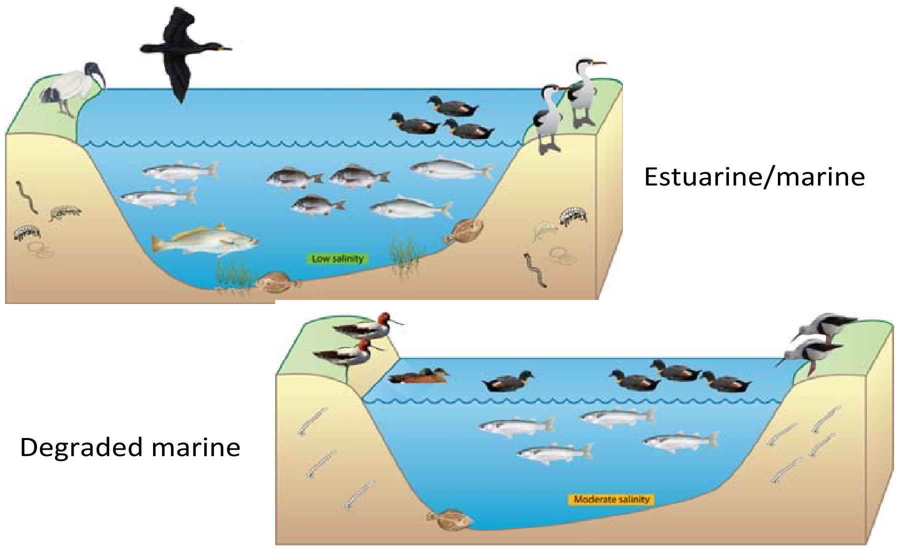
Importantly, waters of this system used to range from fresh to hypersaline - however, now they are saline to hypersaline. The lakes are extremely shallow and are therefore vulnerable. Over the past decade there has been severe degradation of the system. Lake levels are usually 0.8 to

0.6 m AHD which is controlled by Lock 1, with the barrages the only lever for discharge (Note, the barrages have been closed since 2006). Lake Albert was disconnected with bunds in March 2008. As of May 2009, the levels are at -1.0 m below sea level. There was abundant littoral vegetation prior to 2006, now submerged aquatic plants are highly restricted and most persist only in fringing wetlands. Thousands of hectares of acid sulfate soils have been exposed, with the concomitant risks of rewetting and remobilising heavy metals, and acidification and deoxygenation of waters. There has been significant loss of connectivity, habitat, and ecological character and services. Some of the tributaries are able to provide some refuge, as they still contain fresh non-acidic waters. The previous 'healthy' estuary of the Coorong is gone as are keystone plants – it is now effectively an aquatic desert. The next five years are considered critical to the potential recoverability of the region. Bioremediation works are currently underway. At this juncture, it is considered that re-filling the lakes with seawater is a risky option.

Modelling Current and Future Condition of the Coorong

Rebecca Lester and Peter Fairweather (Flinders University)

Recent conceptual modelling of current and future condition of the Coorong (by Flinders University) is exploring the effects of climate change under different management regimes. The aim is to develop an ecosystem response model (ERM) to predict future condition in the Coorong. The CSIRO Murray-Darling Basin 'Sustainable Yields' estimates are being used as a major input to this process, as well as the CSIRO Ecosystem State Model (by Ian Webster). A set of co-occurring biota (vegetation, fish, birds, macroinvertebrates) and environmental conditions are being used in the modelling process.



Some examples of ecosystem states from the Ecosystem Response Model (Source: Rebecca Lester, Flinders University).

Key messages from outcomes of 300 scenarios used in the modelling research to date are:

- Climate change has the potential to devastate the Coorong (salinities expected to rise to supersaturated levels)
  - at current extraction levels
- But relatively small amounts of water will mitigate the worst effects
  - e.g. The Living Murray & other similar initiatives
- Other interventions (e.g. engineering types) are less effective
  - but may be necessary before flows return
- In the absence of barrage flows
  - dredging (or similar) at Murray Mouth to keep it open is absolutely essential
  - SLSRS will have a big short-term impact (south lagoon salt reduction scheme)
    - Channel works + pumping best option for South Lagoon states

   - Additional south east water has a longer lasting impact than SLSRS
- But none replicate the effect of barrage flows.

In conclusion, there is no substitute for barrage flows. Climate change does not have to destroy the Coorong ecosystems – extraction levels play a much bigger role. Additional freshwater is urgently needed for the system – the River Murray should be the major source.

Current major research initiatives – Riverland and Chowilla

Tony Herbert (CSIRO)

Regarding managed and drought related events, weir manipulation (i.e. raising Lock 5 and 6) is an important component. Research assessments here include: biofilm succession, and changes in riparian vegetation, fish recruitment and river red gum condition.

Weir pool raising at Lock 5 - normally about 50 cm below this level (Source: Tony Herbert, CSIRO).

In the Riverland, the only way to get water into the wetland sites is currently through pumping. There have been some great benefits of this, including frog and wading bird recruitment. However, some wetlands are currently closed as a water saving measure.

There are some new initiatives occurring, using gravity around weirs to inundate the floodplain. Locks 5,6,7 and 8 are to use new structures on anabranches around weirs to back flood. At Chowilla, Lock 6, there is a proposal to construct new structures to allow several thousand hectares of inundation. There will be detailed assessments on over and understory vegetation responses, water quality changes, and faunal responses.

Managing for the needs of fish poses a particular challenge – how to provide for management needs for fish, especially those species that require fast flowing conditions. The effects of fishways in anabranches, etc. are being considered, as well as how fish move between habitats and recruit (most of this work is being done by SARDI).

Opportunities for research include the establishment of good baseline datasets and short term and long-term cumulative responses to operating new structures on the river. The Murray-Darling Basin Authority (MDBA) is running projects (e.g. ‘Bundled Hypotheses’) to answer key questions around managed flows and environmental events (e.g. retaining floodwater on floodplain, food web responses to flow enhancement, water bird responses, and effects on native trees).

The Coorong, Lower Lakes and Murray Mouth: Directions for a Healthy Future

Russell Seaman (Department of the Environment and Heritage, SA)

Prior to 2007, the lakes were full, and operation of the barrages to achieve ecological function was well understood. However, in 2007 we were introduced to a crisis – water level at the terminal end of the River Murray dropped below sea level due to reduced inflows, resulting in problems with acid sulfate soils (ASS) and increased salinity. This led to habitat collapse and lost connectivity within the system of the Lower Lakes. 2008 was a period of learning and increasing understanding of the new conditions and what to do about them. In 2009 we are into 'Emergency' management. The scale of the issue is immense and there have been over 20,000 hectares of sulfuric material in 2008/9. The Lakes, Coorong and River have a high risk from acid, aluminium and other heavy metals, and deoxygenation.

Currency Creek, 3rd April 2009 showing extensive drying and exposure of soils (Source: Russell Seaman, DEH SA).

There are four logical management scenarios:

- do nothing
- remediate
- introduce seawater
- provide freshwater.

The adaptive management approach taken by South Australia has to date focussed on remediation - specifically bioremediation of acid sulfate soils, and better understanding of re-wetting and transport of metals. Soil stabilisation against erosion is a primary objective to assist with managing the acid risk. A medium term (1-3 year) research goal is investigating how to re-establish the carbon cycle and wetland function, along with how to put humates back into the soil and how to buffer toxins.

Bioremediation promotes sulfate reducing bacteria in the system to convert dissolved sulfate to sulphide minerals while consuming the acid – however certain conditions are needed for this, such as saturation, iron, and organic matter to feed the bacteria. Addition of limestone and organic matter helps to buffer the acidity and keep the bacteria functioning.

An overview of the bioremediation option – promote or enhance natural bioremediation of acid sulfate soils follows:

1. Primary management options – maintain saturation of acid sulfate soils, e.g. increase river flows, install regulators, control evaporation;

2. Secondary management options – add limestone, organic matter (revegetation) and/or iron to water bodies and exposed sediments (to allow bacteria to function at depth).

Progression of acid sulfate soils in Lower Lakes (Source: Russell Seaman, DEH SA).

Crop cover trials are currently underway, and a rehabilitation program for lake riparian vegetation, to prepare the edges for refilling at a later time.

The adaptive management cycle is being informed by conceptual modelling to assist with research design and management actions.

Air tractors are being used for seeding and limestone dosing – as of mid 2009, getting good results and germination (Source: Russell Seaman, DEH SA).

Key Findings and Issues for Further Exploration

Detailed results are provided for each focus sub-system in a 'key outcomes matrix' in the following section, along with some suggested workshop insights and guiding principles. A number of key findings were apparent that related to benchmarking the ecological community, its boundaries, its coverage and main features, and conservation goals. These are detailed below. The workshop expert group discussions also led to a number of questions or issues to be explored further. These, detailed below, related specifically to the benchmark state, boundaries and zone of influence, condition thresholds, biota loss, and how islands fit in.

Benchmark State

- For the purposes of the assessment process for this EC, a *benchmark state* will be used as the reference condition against which future evaluative comparison can be made. The benchmark state should reflect as closely and practically as possible, the natural condition of the community with respect to the composition and arrangement of its abiotic and biotic elements and the processes that sustain them. Suggestions for a benchmark state for the EC included pre-European condition (early 1800s, including hydric soil mapping), pre-regulation condition (early 1900s), and pre-drought good flow conditions, for example, the 1970s wet decade prior to the major shift in the system. This latter option was considered as the most appropriate and practicable. [Note: the benchmark state should not necessarily be equated as a target for management].

- The workshop accepted that this EC is a regulated, 'created' or 'constructed' system and is therefore altered from its original, more natural condition. The weirs have been in place a long time (i.e. 72 - 87 years). Now there is a series of stepped pools formed by the weirs rather than a natural gradient through the river. Therefore using pre-European or pre-regulation condition as a benchmark state is less meaningful.

- An equitable balance between water resource use and environmental sustainability may be a useful concept for determining a 'reference condition' (i.e. benchmark state).

Boundaries

- A majority view of the workshop was that the 1956 flood line provides the best overall boundary for the system - biologically, hydrologically and geomorphologically. It is being widely used in South Australia, is legally defensible, and has been well mapped. It has also been used in the Ramsar definition for the Lower Lakes. However, the Eastern Mt Lofty Ranges watershed (which flows to the lower Murray and Lake Alexandrina) is excluded by the 1956 flood line and should be considered for inclusion within the EC.

- The Darling River junction was considered a good upper limit for the EC - with importance from both habitat and cultural perspectives (e.g. Ngarrindjeri creation story). The upper boundary of influence of the weirs was also suggested as an upper limit, although there was less support for an artificial structure as a boundary.

- Overall the workshop highlighted up to six bio-geographical sub-sections within the EC region that have 'strong' ecological identities:

    - *Coorong* – estuarine to hyper-marine, includes river mouth, 'end of system' marker of condition
    - *Lower Lakes* – lake system with marginal wetlands and adjacent ephemeral saline ponds, regional groundwater input, plants different
    - *Eastern Mt Lofty Ranges Watershed* - Swampland section - Wellington to Mannum - abundance of exotics, lack of natural floodplain, strong diadromous influence of fish; Eastern Mt Lofty tributaries are Marne River, Saunders Creek, Reedy Creek, Bremer River, Angas River, Finniss River, Tookayerta Creek, and Currency Creek. All but Marne, Saunders and Reedy feed into Lake Alexandrina.

- o *Lower Swamps section* - reach between Mannum and Wellington; dominated by exotic plant species (e.g. willow, agricultural weeds) and has very little natural floodplain due to conversion to dairy swamps; (Reedy Ck flows into this section)
- o *Gorge section* - Mannum to Overland Corner - valley and gorge plants and fish similar, but birds different, permanent large wetlands due to regulation; Marne and Saunders flow into this section of the Murray
- o *Top Valley section* - junction of the Murray and Darling rivers (Wentworth, also Lock 10) to the beginning of the gorge at the Overland Corner (Lock 3), floodplains, lakes, anabranch systems, river losing water to groundwater.

What's In, What's Out

- The channel is considered the key to the system's ecological functioning and the major driver of biodiversity for the whole ecosystem.

- A 'zone of influence' concept was considered most critical for the groundwater element of the EC. For the riverine element, it was considered the main focus should be on the assets and areas of conservation value, not necessarily all areas of influence. *[But consider next point].*

- Tributaries and anabranches, are seen as critical 'refugia' for flora and fauna in the system, and an important source of recruitment of biota and inputs to bio-geochemical pathways - with two-way exchange occurring between them and the river channel.

  - o In particular, the Darling Anabranch, if in good condition may be a potential refuge habitat for biota of the EC (especially Murray cod) and also has cultural significance.

  - o Similarly, the Eastern Mt Lofty streams are considered significant for refugia and exchange; important for connectivity to local rainfall, and refugia for biota.

- Priority for the EC should be given to healthy and potentially recoverable areas - i.e. not unrecoverable areas. However, experts consider that the majority of the system is recoverable, with the exception of a few highly salinised wetlands and the loss of very old trees, e.g. river red gum, black box - which provide complex habitat and take over 100 years to replace the same level of complexity.

Key Characteristics of the RM-DS EC

There was strong support from the expert community that the River Murray-Darling to Sea is a unique 'environmental unit' that is different from its parent rivers, the Darling and the remainder of the Murray, and therefore warranting of ecological community status in a national context. The following points were raised to this effect regarding the River Murray-Darling to Sea EC:

- the EC extends over 830 river-km from Wentworth NSW to Goolwa SA; it is formed by two dissimilar rivers—the Darling from the north and the Murray from the east—and its ecological character combines features of both
- the hydrology of the RM-DS is influenced more by the Murray than the Darling, and is unaffected by other tributaries (although, the high turbidity of Darling water, due to suspended clays, may also be a feature of the RM-DS, depending on the relative contributions of the parent rivers)
- the flow regime of the RM-DS, hence overbank flows and hydraulic connectivity, are highly modified by 10 weirs on the channel, about 200 km of riverbank levees, numerous offstream wetland regulators and by three temporary weirs (The Narrows, Clayton Bay, Currency Creek) and five barrages on Lake Alexandrina
- deep limestone strata and saline groundwater (and marine fossils in the river cliffs) reflect repeated marine incursions over the last 20 million years
- the regional geomorphology is highly diverse, including four tracts:
  - o Floodplain tract (Wentworth to Overland Corner), with the river meandering westward over a 10-20 km wide floodplain, with extensive wetlands and woodlands

  - Gorge tract (to Mannum), where the river's course is realigned southward and the floodplain is constrained to 4-5 km, within a 30-m deep limestone gorge
  - Swampland tract (to Wellington), with the river flowing through areas that formerly had extensive riparian swamps, now reclaimed for agriculture and protected by levees, and
  - Lakes tract, including the Coorong, Lakes Alexandrina and Albert, and the Murray Mouth
- the geomorphic diversity is reflected in diverse aquatic and terrestrial habitats, and correspondingly high levels of biodiversity
- the RM-DS has a mixed assemblage of zooplankton derived from the Darling, which has a typical lotic assemblage (potamoplankton) dominated by rotifers, and the Murray, which has a lentic assemblage dominated by micro-crustaceans typical of impoundments and wetlands
- the fish fauna shows a strong marine/estuarine influence, owing to the region's proximity to the river mouth. About half of all fish species recorded from the Murray-Darling Basin occur in this region
- regional threats include salinisation of soil and water, extensive areas of acid sulfate soils, severe declines of floodplain trees, changed flows, and sediment accumulation at the river mouth
- the RM-DS EC includes three Ramsar-listed *Wetlands of International Importance*, namely: Riverland (Chowilla-Lindsay-Walpolla); Banrock Station; and the Coorong, Lower Lakes and Murray Mouth
- the Coorong, in particular, is a coastal lagoon dependent on flows from the Murray, but with a strong marine influence; it has a distinctive flora and fauna, and is globally significant as a habitat for migratory waterbirds
- the RM-DS has a distinctive indigenous culture represented mainly by Ngarrindjeri people.

Key Features

- ***Flow*** is the critical feature of the EC system (i.e. the master variable or 'maestro'), sustaining all natural physical and biological processes. Flows provide freshwater, and perform flushing, dilution, and transportation functions. Flow acts to keep the river mouth open. An adequate flow regime is needed (based on volume, frequency and timing) to ensure over-bank flow and wetting/drying requirements of wetlands and the floodplain. Flow enables connectivity.

- ***Hydrological Connectivity*** is central for maintaining a healthy, functioning ecosystem (ecological community) - connectivity is driven by hydrology (i.e. flow). There are three main dimensions for operational connectivity: vertically (i.e. groundwater with surface water), longitudinally (i.e. along river to sea; freshwater to marine), and laterally (i.e. out across banks, wetlands and the floodplain; terrestrial to aquatic). The temporal dimension is also important. Two-way flows are a particularly important aspect of lateral and vertical connectivity.

- ***Salinity*** is a key variable for the system, particularly the lower reaches (Coorong and Lower Lakes) where it controls biological sub-communities and therefore productivity. The system needs a more 'natural' salinity gradient than is currently present.

- ***Temporal variability*** is a key characteristic of the EC's 'natural' ecosystem. However the degree of ecological requirement for temporal variability will differ for the different components (sub-systems) of the EC. Regulation reduces temporal variability and leads to a dominance of spatial variability.

- ***Distinctiveness*** The Lower Murray is ecologically different from its parent rivers, and is a distinctive 'environmental unit' for research and management. The distinctive nature of the region is reflected by the high degree of physical habitat diversity (and see above Key Characteristics). This high level of habitat heterogeneity (or patchiness) in turn reflects high biodiversity, with key unique elements occurring over relatively short distances.

- ***Iconic.*** The region of the EC is a 'one of a kind' system in the national context and different from other river systems due to its complex features, habitat heterogeneity, and high levels of biodiversity over relatively short distances. The River Murray holds an important place in the national 'psyche'. The region of the EC has great significance for the Ngarrindjeri people as it is part of their traditional home and an integral part of their creation story.

Conservation Aspects & Goals for the RM-DS EC

- Maintenance and increased resilience should be the guiding principle for conservation of the EC (i.e. not just biodiversity conservation).

- The optimal EC should include a healthy terminal lake system, with an estuarine component connected to the sea. Characteristics of a healthy ecological community include trophic and habitat complexity, with no loss of key native species and presence of comparatively few alien species.

- Achieving enduring connectivity and temporal variability should be major conservation goals for the EC. A useful indicator may relate to the role of the river to keep the mouth open. Broad-scale connectivity should be the goal, i.e. rather than managing wetlands etc. in isolation.

- Issues were raised regarding the future availability of water for the system and it was agreed the aim should be to hold onto as much ecological character as possible until the water comes. A top priority is the allocation of water to the environment.

- Regulation could be used to benefit certain aspects (e.g. wetland or floodplain refugia) - although rates of change are important when releasing water. However, overall, engineered stability of water levels is causing ecological stability, which in turn favours alien species. Most native species of plants and animals rely on variability of conditions to cue for reproduction and dispersal. Engineering has increased stability of seasonal and inter-annual water levels (although daily levels may be more variable) and this has discouraged native species and favoured non-natives.

- Achieving wetting & drying cycles at an appropriate temporal and spatial scale is a significant goal to maintain ecosystem function of wetlands and floodplains.

- Rather than having an EC with a fixed 'good condition' it was recognised that there are range of acceptable 'states' for each sub-ecosystem type - i.e. there are various states of the essential character of the system.

- Native flora and fauna should be promoted above other species.

- There is a need to consider cultural flows and indigenous interests and these should be considered alongside environmental flows for future planning.

Issues for Further Exploration and Decision

Benchmark State

- Need to determine what the benchmark state is for restoration and maintenance of ecological function for the EC given the step change in rainfall from climate change that has already occurred, likely future climate change related impacts, and other threats or risks such as water allocations, land clearing, salinity, ASS, and invasive species. How much change is acceptable?

- The main objective needs to be identified and articulated for the listing of this EC. Examples raised were:

    - to maintain the full diversity and variability of the systems that are currently there *[but much of this is severely degraded]*
    - to reclaim the 'original' flow regime to support the ecosystems that are currently there *[which implies restoration to degraded aspects]*

- o to attempt to adapt the systems to a new state based on a 'likely' future *[this approach has a lot of uncertainty, but aligns with the concept of increasing resilience]*.

The aim should be to turn the system towards a more sustainable one than we have at present.

Boundary and Zone of Influence

- There is a need to determine and clearly map the boundary for the EC based on the foundation of the 1956 flood line, including quantifying any 'buffer zone' or 'zone of influence' distances (in m or km).

- There needs to be clarity regarding the distance out from the river channel for aspects such as groundwater influence and the inclusion of anabranches, creeks and streams. For example, it was suggested that for groundwater, the radius could be 15 km. *[But this seems rather large and may not be practical].*

- If the 1956 flood line is used, it may be necessary to consider the 'less clear' aspects of the line around tributaries, and the top (Lake Victoria to Wentworth) and bottom (Wellington) ends of system.

- A clearly defined, 'hydrologically' based cut-off point would be needed if the Darling Anabranch were to be included in the EC. [*Note, subsequent to the workshop it was determined that the Darling Anabranch would not be in scope*].

Condition Thresholds

- Only qualitative aspects of 'condition thresholds' were addressed by the workshop.

- Condition thresholds should be set low to allow for natural variability and varying levels of disturbance.

- There are non-biotic and biotic condition thresholds to consider for this EC.

- To achieve more detailed and focussed attention on this aspect, it is recommended that a small technical workshop be held as a follow-up. Attention should also be given to articulating 'tipping points' of irreversible change.

Biota Loss

- There is a need to determine, quantitatively if possible, the degree of loss to date for key species or sub-assemblages in the EC.

Islands

- Islands are an important connectivity feature for the system (terrestrial to aquatic) and they are/were biological hotspots. There is a need to determine if and/or how islands are incorporated within the region of the EC. [*Note, subsequent to the workshop it was determined that islands are within the scope of the RM-DS EC, as they are included within related Ramsar listings*].

River Murray mouth (Source: Keith Walker).

Groundwater and the RM-DS EC

The following statements and summary matrix provide a synthesis of key outcomes from the groundwater sub-system focus group discussions and ensuing workshop plenary deliberations.

Workshop Insights and Guiding Principles

There are three types of groundwater influences in the system - local, regional and subsurface stygofauna. There are also 'losing' and 'gaining' sections of the system with respect to groundwater.

Groundwater needs to be managed in conjunction with surface water (i.e. they are not two separate systems) and can be an asset or a threat (i.e. if highly salinated).

While the current aim is to maintain a mosaic of different salinity groundwater influenced ecosystems, there is recognition that hydrological systems are now altered due to river regulation (which is unlikely to be changed), thus restoration of pre-European hydrology and ecosystems is unlikely to be a feasible option.

The aim of restoration and management should be to protect what is healthy, recover what can be recovered, and don't invest in areas that can't be recovered.

There is a need to understand if we are dealing with regional groundwater processes or local groundwater processes. For a local system, you can use recharge management through vegetation as a way of reducing recharge and movement of salt. But for regional groundwater flow systems, which fill up hundreds of kilometres away, revegetation of such large areas is a less practical option.

Observed features in Coorong (February 2008) giving evidence for past and current groundwater discharge in the South Lagoon. (a) carbonate tube 'tufa' at Policeman Point; (b) stranded pools at Stony Well; (c) active seep showing disturbed sediment south of Parnka Point
(Source Geoscience Australia: http://www.ga.gov.au/ausgeonews/ausgeonews200809/groundwater.jsp).

Aspect	Groundwater - Key Outcomes
Major Features	• 3 groundwater dependent/influenced ecosystem types were identified: o local groundwater system river-fed floodplain communities (driven by small-scale groundwater dynamics and ebb/flow discharge from the river, and regional groundwater inputs) - occur all along the lower River Murray, including Darling Anabranch fed by Darling groundwater systems) o regional discharge fed systems at the end of the River Murray flood plain - the Lower Lakes o subsurface stygofaunal communities (i.e. which exist in the groundwater system but not yet documented for the Lower Murray)
Boundaries	• 1956 flood-line considered a pragmatic delineation of the limits of the RM-DS ecological community zone - i.e. mapped, legally defensible, has accord with other management planning approaches • however, this excludes ecosystems/communities fed by groundwater from the Eastern Lofty Ranges, as this is outside the lower Murray floodplain • incorporate a 'zone of influence' concept - i.e. where actions on groundwater have a measurable influence on the ecosystems - up to15 km from 1956 flood-line suggested (includes irrigation district and is basis of a current groundwater model) – this would vary along the system • from a groundwater perspective, there were a few uncertainties regarding boundary between Lake Victoria and the Darling River at top end of system, and the boundary below Wellington, and around the Lower Lakes
Connectivity	• groundwater is integrally connected across local and regional aquifers (laterally and horizontally) • processes of groundwater connectivity well understood for lower Murray (Coonambidgal & Monoman Formations, overlying Blanchetown Clay & Parilla Sands) • main issues for ensuring connectivity are: o river flows and floods, including volume and timing of flows o maintaining beneficial groundwater inputs to ecosystems while preventing detrimental inputs o maintaining groundwater recharge where it supports groundwater influenced ecosystems o extracting groundwater where its discharge would be detrimental to groundwater influenced ecosystems (e.g. salt interception schemes)
Condition Thresholds	• some unrecoverable condition issues are: o accumulation of salts in unflushable zones where flooding cannot move salts - e.g. up-gradient of locks where there are low permeability soils o river regulation where there is little opportunity to alter regulation while weir remains in place • most condition issues are recoverable: o acid sulfate soils can be managed (but not where there are areas with no buffering capacity) - maintain wetting to avoid further acidification o saline groundwater discharge into ecosystems - salt interception schemes can manage (providing knowledge of location; mapping from airborne electromagnetic sensing can help) o high water tables and waterlogging in association with weirs - manipulate weir pool heights to influence river height and dynamics (e.g. timing) • measurable condition indicators include: o vegetation health indicators (e.g. seed production) o remote sensing of vegetation health and groundwater dynamics o salinity and acidity of soil and water o stygofauna monitoring

Aspect	Groundwater - Key Outcomes (continued)
Restoration/ Management	• identification of recoverable areas is a priority and aim to protect what is healthy • manage groundwater and surface water in conjunction with one another • for recoverable and healthy areas, potential management strategies include: o controlling groundwater inflows where they are damaging to ecosystems o introducing fresh water to systems through bank recharge and allowing surface inundation o regulate freshwater pumping and diversion o planning and managing wetting and drying cycles conjunctively to mimic natural flood regimes o regarding clearing-induced increase in salt loads - revegetation schemes for salinity reduction benefit, may be OK for local groundwater systems, but not economic or timely for regional groundwater • different management *zones* have different issues and require different management strategies
Variation from 4 map divisions presented at workshop (i.e. i) Mouth to Tailem Bend (essentially Coorong & Lower Lakes) ii) Tailem Bend to Lock 1 (Blanchetown) – (essentially river channel and gorge) iii) Lock 1 to Lock 5 (Paringa) – (essentially river channel bend & wetlands) iv) Lock 5 to Darling junction (flood plains)	• 5 sections suggested: o 1) Top of system, the plains downstream of Darling River junction, including the anabranch systems, down to Lake Victoria - river losing water to the groundwater system or has no interaction with the regional groundwater system; Anabranches and flowing creeks add to environmental diversity; an environmentally diverse area, deserving of separate treatment o 2) Valley zone - downstream of Lake Victoria to Lock 3, a broad valley system with anabranches and flowing creeks adding to diversity; river increasingly gaining from the groundwater system, so saline discharge into the river and floodplain assets badly impacted by salinisation; groundwater influenced ecosystems become increasingly important; this is the zone where engineered management options like salt interception schemes become important o 3) Gorge zone - of large wetlands which under current river management have become permanent - At gorge zone from Lock 3 down to Mannum; important management includes wetting and drying strategies - however these can lead to acid sulfate soils, and need to manage for that as well o 4) Lower Lake zone where the river's held artificially high by the barrage and discharging into adjacent areas - main management issues are maintaining the water in the system, drying of Lake Albert, and acid sulfate soils. High value saline ecosystems in ephemeral saline ponds bordering lakes o 5) Coorong a separate system due to connection with ocean (Murray Mouth), as well as input from regional groundwater flow (from south or southeast) and surface water flow (contributions of each unclear)

Rivers and Tributaries and the RM-DS EC

The following statements and summary matrix provide a synthesis of key outcomes from the rivers and tributaries sub-system focus group discussions and ensuing workshop plenary deliberations.

Workshop Insights and Guiding Principles

For conservation benefit of the ecological community, the focus should be on the assets and the *area* of conservation.

Connectivity is a central concept for this system - longitudinally, laterally, and vertically with groundwater.

The Lower Murray has limited tributaries - main inflows to the Lower Murray would be the Darling Anabranch (variable) and Marne; flowing into Lake Alexandrina are the streams Angas and Bremer, and the Currency Finniss systems.

Patches in Mt Lofty have been EPBC Act listed - a lot to be learnt from that catchment.

Optimal EC includes - terminal freshwater lakes on Australia's largest river system with an estuary that is connected to the sea, with healthy, productive channels and floodplains.

A central process to maintain ecosystem integrity, is the two-way process of the exporting of resources out of the river channel and the importing of resources back in.

There is a need to determine a 'benchmark state' (reference condition) for the system. What state should condition be judged from in order to determine improvement or decay of condition?

History of management has created the current ecosystem and future management must take this into account.

Can the water be supplied to maintain the ecosystem that we want to persist and list? We should aim to hold onto ecological character as much as possible until the water comes.

Cliffs in Gorge Section (Photo: SA MDB NRM Board)

Aspect	Rivers and Tributaries - Key Outcomes

Major Features	• 3 major components:
	  o 1) Lowland River (from Darling down) characterised by:
	    ▪ salt intrusion; well defined floodplain; low relief; well defined gorge system; limited tributaries (Mt Lofty Ranges - provides freshwater refuge) [defined wetland channel system]
	  o 2) Lower Lakes (terminal lake system)
	  o 3) Coorong (was only estuary in Murray-Darling Basin)
	• tectonic control of system's course
	  o low relief and no delta
	  o abrupt change in course direction (north/south fault controlled)
	  o key connection with groundwater
	• channel is a major driver of biodiversity in whole system
	• biogeochemistry of whole system really important
	• a fast flowing Darling Anabranch may be best place for fish like Murray cod

Boundaries	• prepared to accept Darling Junction (confluence) as the upper limit of EC • but, recognise for management, a more logical boundary would be the start of the ponding system at the cascades at Mildura - i.e. Lock 11 • Darling Anabranch - importance as habitat, also importance culturally to Ngarrindjeri people (beginning of their creation story), e.g. swan breeding • tributaries should be included, including Eastern Mt Lofty streams (but how far up do you go?) - enhances connectivity • lower limit should extent to the sea (noting, near shore coastal environments supported by river exports of nutrients, lower islands etc.) • note: external influences outside these boundaries are important for management; traditional owners had diffuse boundaries • some question of 1956 flood line around tributaries - as these will supply major conservation benefit (i.e. refugia) • possible boundary for Darling Anabranch - influence of lock 9 weir pool between Oakbank and Worry's Dam

Connectivity	• groundwater to river connectivity (changed balance):
	  o major shallow tables, saline, salt loads into river - a 'gaining' system (but not upstream of lock)
	  o lateral recharge important for wetlands and floodplain vegetation
	• longitudinal connectivity (critically important):
	  o flooding of surface water down channel
	  o movement of fish (+ spawning) and other species
	• lateral connectivity:
	  o 2-way process - flooding of surface water into billabongs, wetlands, etc and providing resources to channel when water returns (i.e. exporting out and importing back in nutrients, organisms, etc);
	  o connectivity of tributaries to river - independent of river level?
	  o floodplains and wetlands are threatened if not connected to channel
	• connectivity with the sea - was the role of the river to keep the mouth open (i.e. sea entry critical for 'freshening' the hypersaline Coorong system; drainage has diverted freshwater from the southern Coorong)
	• terrestrial/aquatic connectivity - mixing around islands - islands were biological hot spots, e.g. Hindmarsh Island
	• disconnection - barrages and locks lead to disconnection - we now have a series of stepped pools rather than a natural gradient through the river system; alternatively, weirs give some connectivity in some pockets during low flows (usually lateral rather than longitudinal)
	• rates of change during wetting and drying are important
	• biogeochemical cycles have been disrupted
	• connectivity to rainfall (evaporation; Mt Lofty Ranges)
	• connectivity to riparian vegetation - e.g. lignum (suffering); river red gums and groundwater connection through root zones (most within 50 m of river)

Aspect	**Rivers and Tributaries - Key Outcomes (continued)**

Condition Thresholds	• flow the critical factor - optimum flow will maintain all natural processes - supplies freshwater and a 'flow regime' (<35,000 ML/day - no overbank)
	  o threshold is a sufficient flow to keep the mouth open (i.e. the sea connection) - 'end-of-system marker' for condition of Murray
	  o elevated floodplains means that large floods and pattern is important
	• salinity is a 'master' variable in lower reaches (we want a more natural salinity gradient in the Coorong and Lower Lakes - controls biological community); when tip over 30 to up to 240 ppt at top (need marine on outside, truly estuarine 10 - 15, then up to 100 ppt in the South Lagoon of the Coorong - but hard to manage)
	• temporal and spatial variability important (differs for different components)
	• thresholds set low to acknowledge natural variability and disturbance level

Restoration/ Management	• A) top priority is the allocation of water to the environment (avoid 'irrigation ditch to terminal lake' syndrome) - but with time community will may erode • recognise there is limited water but limited water has been shown to give a good response in floodplains and Coorong • water could solve problems in the channelised part of this EC • B) pumping and engineering works - could be used to help maintain refugia, but not the best or a long-term solution • engineered stability of water levels is causing instability in ecology • manipulation of inundation - if had natural flows, weirs are a barrier for fish, but in low flow they do give scope to regulate - manipulate wetting-drying cycle for refuge areas - but need to slowly wet and flush (i.e. problems with re-wetting parched acid sulfate soils) • rates of change very important - how to release water • don't yet know what flows will get once the *Basin Plan* is in place, and allocations for people and environment set, and given the step change in rainfall from climate change • has management created the current ecosystem? • C) what is the benchmark for restoration? - 1920s barrage in; 1956 big flood; 1970s wet decade; 1985 RAMSAR listing… • a Ramsar survey done in 1985 found 23 wetland types • natural flow paradigm - if cannot go back to a 'natural' state - then what is the benchmark to judge condition? What can we get for current conditions of climate, water allocation, land clearing? • define what it is about this system that needs saving - it is 'one of a kind' (important in national psyche) - go back to defining characteristics of system and determine how much change is acceptable • what does changing character mean for EC listing? - use reference notion - don't have to go back to pre-regulation - use a period of time when system developing, e.g. system of 1970's water regime; 1970's is when there was a major shift in the system • D) view of group is that the system is recoverable - o from ASS (pH and metals) and hypersalinity (except for some heavily salinised wetlands that might not come back) • E) need to consider cultural flows and indigenous interests - put alongside environmental flows for future planning - system a 'living footprint'

Variation from 4 map divisions presented	• how to break the system up - 3 major divisions (+ 1 subdivision):
	  o 1) Coorong and Lower Lakes
	  o 2a) Wellington to Swan Reach (tributaries, changes to floodplain, SA potable water diversion) - highly modified part
	  o 2b) Up to Lock 3 (Swan Reach to Lock 3) - Gorge section and groundwater accession
	  o 3) Locks upstream (above Lock 3) - broader floodplain, lateral connectivity more important, red gum-black box transition
	• not clear how far up Darling Anabranch would need to go for a clear 'hydrologically based' cut-off point

Wetlands and Floodplains and the RM-DS EC

The following statements and summary matrix provide a synthesis of key outcomes from the wetlands and floodplains sub-system focus group discussions and ensuing workshop plenary deliberations.

Workshop Insights and Guiding Principles

Ecosystem function needs protection, not just biodiversity (e.g. consider the consequences of reducing the amount of floodplain next to the river, e.g. reduction in productivity).

Wetlands and riparian species have evolved to sustain themselves under a range of water regimes.

To aid assessment, classify different assets (including functions, ecosystem services, and habitats) within the system and use conceptual models and diagrams to describe changes between states, etc.

Some suggested it is better to go with hydrology rather than vegetation – as this would pick up the changes in flow regimes that are part of the threats; however, vegetation can represent the long-term plant water availability of an area (i.e. an integrated measure of soil properties, water table depth, groundwater salinity and flooding regime) – ‘Ecohydrological’ classification is a popular approach at present.

The system has a high degree of ‘natural’ variation that is temporally driven, and that has been changed by regulation, which has resulted in spatial variation being more dominant.

A goal should be to maintain and increase resilience of the ecosystem to survive future drought or water decline (and potential impacts of climate change).

Characteristics of a healthy ecological community include: dependence and interaction between trophic levels; no loss of key species; trophic and habitat complexity.

There is a need to determine the main objective. Are we trying to maintain the full diversity and variability of the systems that we currently have? OR, Are we trying to reclaim the original flow regime to support the ecosystems that are currently there? OR, Do we attempt to adapt the systems to a new state based on what we’re likely to have? (Link to benchmark state).

May need to do more work on managing different states, as opposed to keeping it fixed in one ‘good condition’ state.

Lower Murray Wetland (Source: SA MDB NRM Board)

Aspect	Wetlands and Floodplains - Key Outcomes
Major Features	• terrestrial, semi-aquatic and aquatic vegetation - o red gum, black box, coobah, lignum, semi-aquatic emergent species o distribution (longitudinal, vertical) and variability related to flood dependence on water regime – natural pulses o adds to trophic and habitat complexity o changes in vegetation associations with flood frequency o distinction between upper-river and lower-river vegetation • hydrology – o needs to include full variability of hydrologic regime (e.g. duration, frequency, seasonality & quality, etc.) o natural condition – temporal variability on floodplains, but with river regulation variability more spatial now • fauna – fish o generalist fish community around Mannum related to flow regimes and permanent connectivity of wetlands o lower lakes & swamps are more diverse • trophic and habitat complexity important
Boundaries	• hydric soils (i.e. soils showing signs of flooding) – clearly defined and clear boundary; link to pre-1760 (pre-European – (potential reference condition) mapping and 1956 flood boundary • 1956 flood boundary – used in SA planning laws (regulatory, policy implications); known on ground but does it include riparian zones, buffer zones, etc.? Yes it would include the entire floodplain – use as maximum outer boundary • 1870 flood was bigger (went into black box) – raises interface with Mallee country. (Note: slightly bigger for Murray, but not SA?) • 1760 and pre-settlement for vegetation mapping • need to capture flood dependent species • buffer and management zones are important – are part of recovery/management processes • groundwater probably not a good boundary, much larger area – may be better to think of groundwater dependent species
Connectivity	• connectivity driven by hydrology (process is flowing water and associated habitat) • longitudinal, lateral, vertical (river and groundwater) and temporal dimensions – all important • temporal connectivity – duration effects e.g. denuding of seed/egg banks of aquatic species, may favour invasive species • local rainfall an additional water source linked to flow regimes, also has temporal effects (promotes seed germination, etc.) • each weir and its reach may function as distinct ecological units • sedimentation is a natural connector, but current levels are a threat o lot of wetlands getting shallower o mainstream pools and stream depressions filling up o flushing mechanisms important • if connected, floodplains provide a percentage of carbon regime and contribute to instream food webs (which are generally mainly autochthonous (within), with a small proportion allochthonus (without) in flowing river channels • fragmentation of habitat – e.g. less vertical habitat for small fish (e.g. billabongs)

<table>
<tr><th>Aspect</th><th>Wetlands and Floodplains - Key Outcomes (continued)</th></tr>
<tr><td>Condition Thresholds</td><td>

ecosystem function and services highly relevant, and population dynamics, namely the ability to re-establish/regenerate/restore, i.e. from:

propagules & seed/egg banks, population dynamics
access to connectivity pathways

degree of maintenance of food sources and trophic interaction (i.e. interaction between trophic levels indicates the degree of health)
extent of intactness of the geomorphology of the system (i.e. there are non-biotic and biotic condition thresholds)
high quality may relate to pockets where ‘original’ suite of fish left
need to know degrees of loss of key components e.g. woodlands % area
characteristics of ‘degraded’, noting that recoverability is still possible:

high salinity threshold in water; accumulating salt/ no flushing
‘wrong’ flow regimes; lack of water
nutrients; declining food sources
lack of ability to regenerate (no propagules, or connectivity)
irretrievable loss of habitat; tree loss (e.g. red gum death)

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<tr><td>Restoration/ Management</td><td>

aims of restoration/management should be:

focus on restoring functionality
manage Coorong/Lower Lakes as estuarine system with interface between salt and freshwater - i.e. to avoid acid sulfate mess (let nature return to freshwater later if enough water)
manage (control) any shift in state and sustain processes
keep essential character; includes various states via timing & duration
identify riparian areas at greatest risk (e.g. river red gum - already know how much might be lost without watering)
maintain all aspects of hydrological regime
build up resilience of entire floodplain
must address floodplain salinisation due to regional groundwater
need to recognise there are tipping points that may result in irreversible change (e.g. river red gums)

maintain trophic and habitat complexity
to achieve a more natural water regime with lateral and longitudinal connectivity - tipping point is lack of small floods (<1 in 4 frequency) but large floods/flows also needed for overbanking to re-establish broader lateral connectivity
small flood flow = 65 000 ML/day for 60 days is a 1 in 2-3 year flood event, but need to define what processes this will support
manage the pool level of the main stream for annual cycles - extremely important (i.e. not just 1 in 5, 1 in 10, etc) - wetting/drying cycle
issue of sea level change impacts (i.e. do the barrages need raising – are they at the end of their working life?)
would need more active management to restore EC after water returned
for restoration:

reduce overallocation (drought not entire cause of current problems)
return water of sufficient quality - use floods to build up resilience of components to resist drought
2000 GL per annum needed, pulsed with over-bank flows of sufficient duration (see above)
if use engineering solutions - should also aim for ecological benefits
address salinisation and build up resilience

in terms of management, may be best to use weir reaches as the ecological functional unit

</td></tr>
<tr><td>Variation from 4 map divisions presented</td><td>

description at four regions a good high level split - but also need to manage within the reach level
Coorong and Lower Lakes; Lower River; Reclaimed swamps/gorge; Upper reaches

</td></tr>
</table>

Biota and the RM-DS EC

The following statements and summary matrix provide a synthesis of key outcomes from the biota sub-system focus group discussions and ensuing workshop plenary deliberations.

Workshop Insights and Guiding Principles

The whole is greater than the sum of the parts.

Rivers are connected systems - maintaining connectivity is paramount.

The diversity of habitats in the Lower River Murray area (from Sea to Darling) makes it distinct from the remainder of the Murray and the Darling River, and reflects a higher biodiversity.

Past research suggests that plants and fish are reasonably good indicators of ecological 'units' in the region, but birds, particularly colonial nesting waterbirds (CNW) are now less useful (with several important colonies now extinct). This group of birds, i.e. the CNW, may be the hardest hit by degradation of the MDB.

An equitable balance between water resource use and the environment's sustainability may be a useful concept for 'reference condition' considerations.

There are important timeframe implications for recovery - this varies across communities, e.g. red gum versus understorey of aquatic macrophytes.

Pelicans in gorge section of River Murray (Photo: SA NRM Board)

Murray Cod (Photo: Gunther Schmida, MDBA website)

Aspect	Biota - Key Outcomes
Major Features	• marine influence - past and present - has implications for biota o legacy is limestone and salt in the geomorphic sense o diadromous fish as present ecological linkage to marine influence o groundwater environment has higher salinity below the MD junction • River Murray and floodplain seen as a green corridor through arid zones, and there are gradients of distribution around and within this EC • difficult to distinguish the regional flora and fauna, but quite easy to distinguish groups within the 6 defined regions (see below) • waterbirds - no distinct species in this area • key elements of biota (birds, fish, macroinvertebrates and flora) all show patterns to reinforce 6 sub-divisions (i.e. based on plants/animals present): o Valley section - the top end, lock 10 or lock 11 to Overland Corner o the Gorge - Overland Corner to Mannum (valley and gorge plants and fish similar but birds different; some gorge plants similar to Lower Swamps) o the Lower Swamps - the reach between Mannum and Wellington (plants and fish different from Valley, Gorge and Lower Lakes) o Eastern Mt Lofty Ranges east watershed o Lower Lakes - Alexandrina and Albert (plants different) o Coorong - includes the north and south of Glenelg and Murray Mouth (estuarine birds) • East Mt Lofty is distinctive in terms of fish due to stream habitats and genetically distinct populations – different to Lower Murray floodplain but Eastern Mt Lofty streams should be part of EC due to hydrological influence and refugia potential • Lower Murray swamps (Mannum to Wellington) are distinct due to abundance of exotics, lack of natural floodplain. In terms of fish there is a strong diadromous influence • the Coorong and the Lower Lakes are each unique in their natural state • stygofauna is likely to be unique in the River Murray area- work in progress
Boundaries	• 1956 flood as boundary of floodplain: o a potential boundary (although a 1 in 100 year event) o historically a 1 in 13 year flood equalled the extent of the 1956 flood o probably a useful working boundary – used in SA planning o used for Ramsar definition • biological/hydrological/geological boundary compatible with 1956 flood line (Mt Lofty excluded by 1956 flood boundary) • context for the boundary is the timeframe within which recovery is possible and the state to which we would try to restore the system sets the temporal boundary (i.e. timeframe aspects to boundary) o need to establish more clearly - pre European, pre regulation, legislative context o try -50 and 50 + as reference (remnant natural values as focus) • community boundary also has cultural context o creation stories for this Murray area - has mythological integrity, cultural stories underpin/support the extent of the area under study • Lock 11 (Mildura) is an alternative boundary for the EC - but don't favour using a lock as a recognisable boundary point
Connectivity	• rivers are connected systems - connectivity paramount • connectivity is the key to maintaining biological and ecological integrity • broad scale connectivity should be the goal, i.e. rather than managing wetlands etc. in isolation • marine connection (and marine and fresh connection), as part of connectivity as a whole, laterally and longitudinally, is vital in maintaining a substantial segment of the biota • under Ngarrindjeri culture, all things are 'connected'

Aspect	Biota - Key Outcomes (continued)
Condition Thresholds	• consider definition of a working river (i.e. as per CRC definition) • promotion of native flora and fauna above other species • SRA (Sustainable Rivers Audit) - poor ecosystem health (relative to optimal or reference condition) • consider what is the reference condition? • consider when is the EC too degraded to be ecologically functioning? • seed store/egg banks within wetlands could be used as a measure of presence of a species within a wetland and may allow for recovery even when species are deemed to be absent [potential condition threshold] • using Lake Albert as an example: o altered states are not necessarily bad, maybe just different o alternative ecosystem functions during dry 'degraded' phases o ramifications of alternate states being recognised - needs to be considered during assessment • Ngarrindjeri perspective - wetlands referred to as 'nurseries' • a system is irrecoverable when autochthonous (within) and allochthonous (without) reserves are depleted
Restoration/ Management	• inherent variability of this system points to its resilience timeframe implications for recovery (vary with sub-community) • different elements will be recoverable under differing timeframes • recoverability - impossible versus slow i.e. potential)
Variation from 4 map divisions presented	• 6 geomorphic divisions with strong ecological identities (i.e. ecologically distinctive): o Valley Section - Murray/Darling Junction (Lock 10) to beginning of the gorge at Overland Corner (Lock 3) o Gorge Section - turns southward near Morgan (Lock 2) and leaves the gorge around Mannum o Swampland Tract - Mannum to Wellington o Eastern Mt Lofty Ranges (EMLR) Watershed - includes streams like the Marne, Saunders flowing into the Murray, and the Angas, Bremer and Finniss Rivers, and Currency Creek flowing into Lake Alexandrina o Lower Lakes o Coorong

Key Plenary Discussion Points – Description of Ecological Community

It seems to be accepted that we are dealing with a constructed system that maintains significant biological values, but these values probably need better definition.

Defining the purpose for listing is important - is the EC going to be listed on some fundamental aspect of its ecological, geophysical or biological nature?

It seems to be recognised that the region falls into about six zones, and within each zone there can be a variety of types of ecosystems (i.e. sub-communities).

In circumscribing the community - we need to define the whole, and then we need to define the subdivisions that exist within the whole.

The 1956 flood line seems to be a strong starting point for a boundary of the system. However, a 'zone of management' concept is also relevant - the suggestion was 15 km (this probably varies according to width and location along the river, e.g. Flinders Ranges side or other).

The upper delineation of the community was informed by discussion relating to the Murray/Darling junction, the Darling Anabranch, Lock 10 and Lock 11. The majority view held with the actual junction concept (which also is close to Lock 10 and overlaps with indigenous cultural concerns). There was concern that a man-made structure was less suitable as a delineating boundary for the system.

Change in groundwater behaviour may be an important aspect of circumscription - i.e. where groundwater is being lost from the system as opposed to where it is augmenting the system (around Lock 7).

When considering boundaries of the system, we need to consider longitudinal and natural connectivity and two-way flows. Given that we are dealing with a 'constructed' system, those flows might not necessarily be what was historic - however they still might be for nutrient exchange or other purposes, like movement of biota.

A core component of the system is now a series of stepped lakes (i.e. due to infrastructure), which along with the groundwater - possibly now drive the whole system. However, in terms of the EPBC Act, it may prove challenging to accept as permanent the 10 locks that fall within the system. There were issues raised with using the existing weir pools as a means to delineate the system (at least in the upper reaches), as the weirs are actually a highly modified (i.e. artificial) environment. It was felt that there may indeed be scope for recovery in the future that may possibly involve changing configuration or mode of operation of the weirs. We may need to consider in further detail how the weirs influence flow, groundwater, change in salinity patterns, etc. Where their upper boundary of influence ends, may be a boundary.

River dynamics and groundwater dynamics are considered key to the integrity and functioning of the system, as are the small and large floods.

Connectivity to the sea is important - there may be a decision rule associated with the system to ensure that there is sufficient flow to keep the mouth open [*potential condition threshold*].

There is an emphasis on the need for variability, which reflects the multi-varied character of the system and the fact that the components of the system can exist in various states. (For example, some of the wetlands are probably dry more often than they are wet, but that doesn't take away the notion that they are significant wetlands).

The EPBC Act was discussed with respect to there being a perception of too strong an emphasis on stopping actions and significant impact. The Chair of the TSSC reiterated the purpose of the Act is to protect biodiversity and the environment - which includes positive management actions to improve the environment. The adoption of conservation advices and the like can also contribute toward positive outcomes via directing Commonwealth investment. With regard to listing the River Murray - Darling to Sea EC under the Act, the aim would be to turn back the system towards a more sustainable one than the one we have right now.

It was acknowledged that there are many pre-existing actions in the region of the River Murray - Darling to Sea EC (i.e. occurred prior to the commencement of the EPBC Act) and most of these would be considered as ‘continuing use’ under the related clause of the Act. These could potentially be threats.

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Part B - Workshop Outcomes 2: Threats

Part B - Workshop Outcomes 2: Threats

Threats and Future Trends

Climate Change

A recent Pew Centre report on *Aquatic Ecosystems and Global Climate Change*[1] reported:

- *Increases in water temperatures as a result of climate change will alter fundamental ecological processes and the geographic distribution of aquatic species. Such impacts may be ameliorated if species attempt to adapt by migrating to suitable habitat. However, human alteration of potential migratory corridors may limit the ability of species to relocate, increasing the likelihood of species extinction and loss of biodiversity.*
- *Changes in seasonal patterns of precipitation and runoff will alter hydrologic characteristics of aquatic systems, affecting species composition and ecosystem productivity. Populations of aquatic organisms are sensitive to changes in the frequency, duration, and timing of extreme precipitation events, such as floods or droughts.*
- *Aquatic ecosystems have a limited ability to adapt to climate change. Reducing the likelihood of significant impacts to these systems will be critically dependent on human activities that reduce other sources of ecosystem stress and enhance adaptive capacity.*

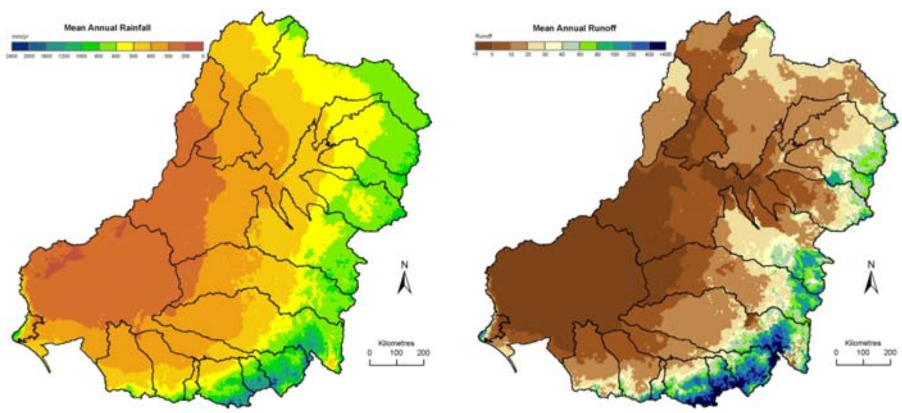
The impacts of anthropogenic induced climate change lead to increased temperature and reduced rainfall. Reduced rainfall and changed seasonality of rainfall can have a significant effect runoff (in general, a 1% decline in rainfall equates to a 2-3% decline in runoff). In addition, changes to local rainfall patterns can have an important influence on associated wetlands (averaged annual rainfall and modelled runoff are shown by figure below). The region of the River Murray - Darling to Sea is relatively small compared with the entire Murray-Darling Basin (MDB). However, being at the terminal end of the system it is almost entirely dependent on water inflow from upstream.

RAINFALL

457 mm averaged over MDB

RUNOFF

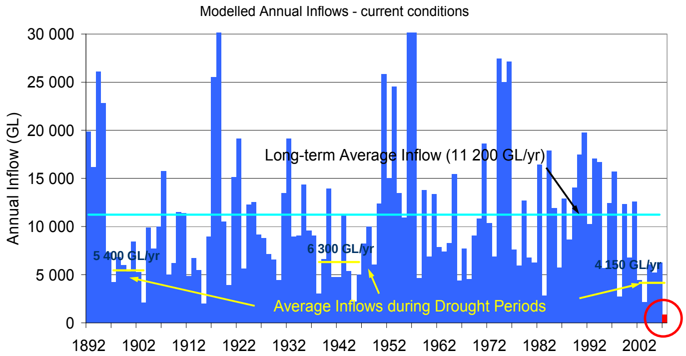
27 mm averaged over MDB



Note: There is a clear east–west rainfall and runoff gradient, with most of the runoff in the MDB coming from upland catchments in the south-east (Source: CSIRO).

River Murray inflows up to 2006 (the driest year on record to date (mid 2009) - see figure below), demonstrate that there have been dry periods in the past, however the recent extended dry period is the driest. The drought conditions in the south of the MDB worsened in 2007 and 2008[2]. In addition to the impacts of reduced rainfall on runoff, recent research has shown that a rise of 1° C leads to an approximate 15% reduction in the climatological annual MDB inflow[3]. It has been suggested that a 1 to 3° C temperature rise by 2050, as projected by the IPCC's 2007 Fourth Assessment Report, would lead to a 15 - 45% reduction of inflow to the MDB, which would greatly exacerbate the impact of a projected 10 - 15% rainfall reduction[4].

Murray-Darling River



The consequences of the drying trend for the Murray-Darling Basin are becoming particularly acute, with water levels and inflow at historical lows and insufficient to meet critical human and ecosystem needs for major regions of the system. The landmark Sustainable Yields Project of CSIRO reported that surface water availability across the entire MDB is expected to decline due to climate change, with a very substantial decline likely in the southern and south-east of the MDB where the impacts of climate change are expected to be the greatest[1]. Under continuation of current water sharing arrangements, much of the impact of reduced surface water availability would be transferred to the riverine environments along the River Murray, including the Lower Lakes and the Coorong[2]. Projections suggest flow at the Murray mouth would cease almost half of the time and severe drought inflows to the Lower lakes would occur in 13% of years[2].

By 2030 the median decline in flows for the entire Basin is projected to be 9 -11% in the north and 13% in the south[2]. Under a worst case scenario, the average annual runoff for the northern half of the Basin may reduce by 30 per cent and in the southern half of the Basin the average annual runoff may reduce by up to 40 per cent[2]. Importantly, the best estimate 2030 climate, while less severe than a continuation of the recent climate, would still lead to significant increases in the average period between beneficial floods for all assessed environmental sites[4].

Natural systems in the MDB, which are already under pressure from reduced inflows from a drying climate and over-allocated water for irrigation, are also likely to be further impacted by climate change. For example, climate change could accelerate woody weed invasion and when this is combined with overstocking of livestock such as cattle and sheep, is likely to lead to increased erosion and an overall loss of biodiversity. Major impacts are also expected to river red gum forests, due to decreased flooding events, and to nesting birds and aquatic species, particularly iconic species such as the Murray Cod.

River Murray near Murtho, South Australia. Photo: John Baker (MDBA website).

1. Poff, NL, Brinson, MM, Day Jr, JW. (2002) Aquatic Ecosystems and Global Climate Change: Potential impacts on inland freshwater and coastal wetland ecosystems in the US. Pew Centre on Global Climate Change Report. http://www.pewtrusts.org/our_work_report_detail.aspx?id=30677
2. CSIRO (2008) Water availability in the Murray-Darling Basin. Summary of a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, CSIRO, Australia.
3. Cai, W., and T. Cowan. 2008. Evidence of impacts from rising temperature on inflows to the Murray-Darling Basin. *Geophysical Research Letters*, V35, L07701, doi: 10.1029/2008GL033390.
4. Cowan, T.D., and W. Cai. 2009. Are declining river inflows linked to rising temperatures? A perspective from the Murray-Darling Basin. 18th World WMACS/MODSIM Congress, Cairns, Australia 13-17 July 2009.

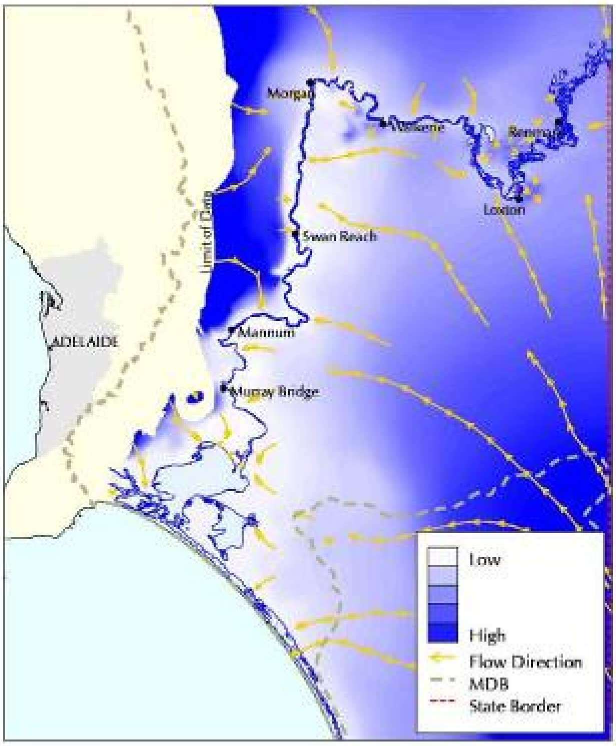
Salinity

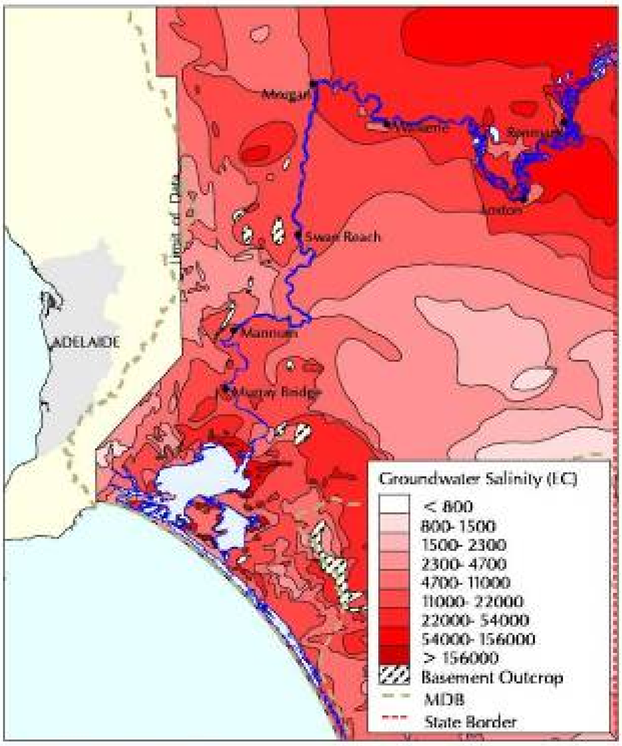
The MDB Salt Story

Over millions of years, the Murray Darling Basin's flat terrain, low rainfall and high levels of evaporation have combined to concentrate salt in the soil and groundwaters of the region. Prior to European settlement, native vegetation helped to keep the salt levels mostly in balance. However, human activities - particularly in the past 100 years, have had a major impact. Agricultural development and irrigation along the River Murray, land clearance (particularly of deep rooted vegetation), and the control of the river water by weirs and dams have caused large amounts of saline groundwater to rise and increased saline discharge into the river system. Rising groundwater is mobilising salt stored in sub-soils and bringing it to the soil surface or carrying it laterally into streams. The River Murray is the only 'drain' from the Murray-Darling Basin and provides a channel for the salt to exit the Basin. However, about 80% of the Basin's water is diverted for consumption, principally irrigation, resulting in less flow to dilute the saline water. As a consequence, large quantities of salt flow down the River Murray every day (for example, 4000 ML/day flowing past Morgan can carry about 1000 tonnes of salt). A program of six salt interception schemes is underway for the river, with four already in place in SA; when completed, an estimated 850 tonnes per day will be intercepted. (Note: Water > 800 EC is unsuitable for irrigating most horticultural crops, while 800 EC is the accepted maximum level for domestic consumption in larger towns and cities (Australian Drinking Water Guidelines); seawater is about 45 000 EC).

The River Murray is the lowest point in the landscape (i.e. bright blue areas are highland in the map below left). The river is capturing surface water from the 1 million square kilometres of the MDB catchment. The exit is the ocean at the northern end of the Coorong (i.e. when the mouth is open).

The river is also capturing groundwater. Flow lines of groundwater to the system are shown in yellow in the map below to the left. Importantly, the river is flowing through highly saline groundwater - with some regions of a salinity higher than seawater (see map below right). Therefore, changes to the dynamics of groundwater can change the salt loads into the river. On average, the river carries 1 to 2 million tonnes of salt a year out into the ocean. However, due to the low flows experienced over the last five or so years, salt is accumulating in the Basin - including both floodplains and river channel.



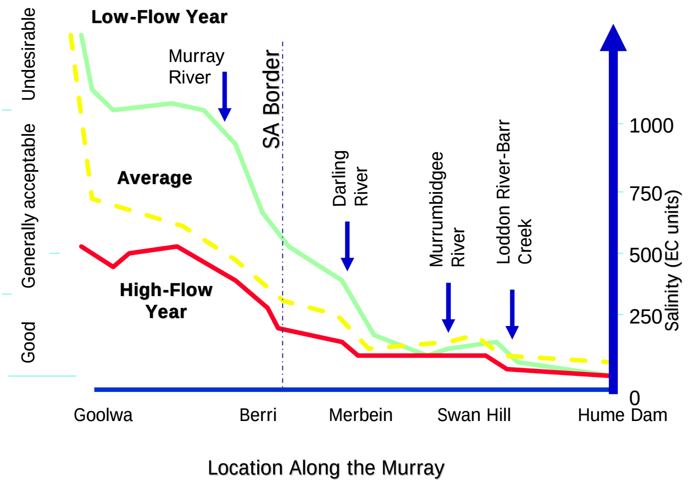


Maps of the Murray River in South Australia - showing to the left, landscape height directional flow of groundwater, and to the right, groundwater salinity (EC), (Source: Phil Cole, MDBA).

Examples of saline seepage to the Lower Murray floodplain (Source: Phil Cole, MDBA)

Salinisation of the landscape and river can be devastating (see above photos). The saline groundwater rising on the floodplain of the Pike River is emerging due to pressure (groundwater drainage) from adjacent irrigation farms. At the site just downstream of Lock 4 (Bookpurnong, near Berri), the wetland is bordered to the highland to the right by citrus irrigation. The salt load flows straight into the river - which could be 100 tonnes of salt per day in a non-drought year. These processes can happen quite quickly, for example, the site of the Pike River region was very healthy only some 30 years ago.

Importantly, salinity is the main determinant of diatom species composition in the Lower Murray, outweighing the effects of flow velocity, pH and nutrients[2]. As diatoms are the dominant phytoplankton in the Murray, salinity changes may prove to have indirect effects on grazing invertebrates, particularly zooplankton[2].



The figure above demonstrates the influence on salinity of high and low flow years in the river channel (i.e. excluding floodplain). Salinity of under about 500 EC is considered good water quality, which is achieved in the years of higher-flow. However, under low flow conditions, salinities are significantly higher, reaching hypersaline conditions in the Coorong. As the figure above demonstrates, the region of the River Murray - Darling to Sea is the region of the entire MDB system that is most impacted by salinity.

Overall, about a quarter of the salt comes down the Darling, about another quarter comes from the irrigation districts in Victoria and New South Wales, another quarter comes from the groundwater systems in South Australia, and the rest is diffuse from all throughout the system. The recent *Water Act 2007*, mandates for a ‘Water Quality and Salinity Management Plan’ under the ‘Basin Plan’ which will involve setting salinity objectives and targets.

1. CSIRO (2008) Water availability in the Murray-Darling Basin. Summary of a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, CSIRO, Australia.
2. Walker, KF. 2006. Serial weirs, cumulative effects: the Lower River Murray, Australia. In: R Kingsford (ed), The Ecology of Desert Rivers, Cambridge University Press: 248-279.

Acid Sulfate Soils

River Murray and ASS

Acid sulfate soils (ASS) are those soils and sediments that contain sulfuric acid, or have the potential to form sulfuric acid when exposed to oxygen in the air (or water) (i.e. from unoxidised iron sulfides (pyrite)). Acid sulfate soils form naturally when sulfate-rich water (e.g. saline groundwater, sea water) mixes with sediments containing iron oxides and organic matter. Potential for acidification was recognised in Lake Albert as early as 1929, which was a pre-barrage time (and the second oldest recorded observation of ASS in Australia). The river system has always had the 'raw materials' to form acid - sulfate, iron, organic matter, bacteria. Potentially acidic (sulfidic) soils are common in the River Murray; when sulfidic soils oxidise, their pH drops below 4. For example, at Wellington there is about 40 m of sulfidic (pyritic) clay in the river channel. Before European interference, acid would have formed seasonally when river levels dropped, and the acid products would be flushed to the sea at periods of higher flow. Biota would have adapted to these conditions. If left undisturbed and covered with water, sulfidic sediments pose little threat. However, when exposed to oxygen, such as under drought conditions, chemical reactions may lead to the generation of sulfuric acid. When these sulfuric sediments are re-wetted, there is a risk that significant amounts of sulfuric acid and heavy metals may be released into the water leading to acidification, deoxygenation (when monosulfides oxidise), contamination and the release of noxious gases. These risks can lead to irreversible damage to the environment and serous impacts on water supplies and human health. The extent and importance of ASS in the River Murray, lower lakes and adjacent wetlands has only recently been fully appreciated[1].

Current Status

The current drought (as at mid 2009) has lead to the exposure of large sections of river bank, wetlands and lakes that once contained high levels of unoxidised (reduced) iron sulfides. Many river and wetland sites between Wentworth (the Darling junction) and the Coorong have been evaluated for acid sulfate soils. These soils occur throughout this system, particularly in large stretches of the river in South Australia around Renmark, Blanchetown and Murray Bridge, as well as in lakes Albert and Alexandrina, near the mouth. Metavoltine, a yellow mineral previously only ever recorded in acid mine drainage, has been recorded near Murray Bridge. It has proved difficult to predict in advance whether wetland soils are likely to acidify.

The installation of weirs and barrages has provided for a stable pool level for about 70 years, and that has had the effect of producing wetland environments that have retained the sulfur as pyrite in their soils - i.e. instead of having the normal oxidation, reduction and flushing cycle - that cycle has been interrupted. The permanent inundation of the river, wetland and lake systems has therefore had a significant impact on the formation of soils in these ecosystems because of the loss of natural wetting-drying cycles, which is so important to biodiversity and wetland functioning. This change has promoted the significant build-up of sulfide minerals (mostly iron pyrite) and sulfidic materials in these newly formed subaqueous soils. Evapo-concentration and decreased flushing increases salt concentrations and alkalinity - high sodium in sulfidic soils results in formation of acidic minerals that are very water soluble.

Irrigated agriculture on river flats has also probably helped maintain subsoils in a reduced state and applied sulfate sourced from fertilisers. River banks are largely already mildly acidified due to past wetting and drying cycles, and removal of carbonate. Sulfidic groundwater systems that occur at depth may also impact on receiving environments.

Impacts

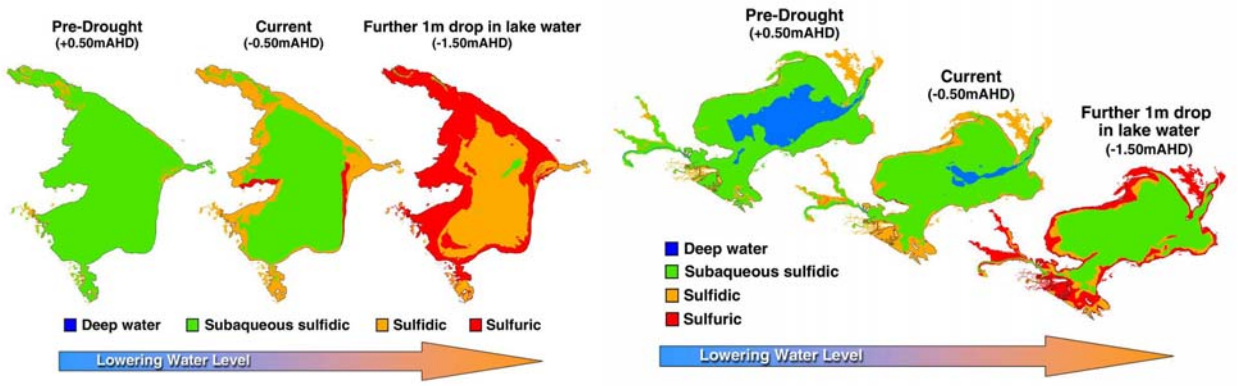
1. Fitzpatrick, R, Grealish, G, Shand, P, Marvanek, S, Thomas, B, Creeper, N, Merry, R, and Raven, M. 2009. Preliminary Assessment of Acid Sulfate Soil Materials in Currency Creek, Finniss River, Tookayerta Creek and Black Swamp region, South Australia. Land and Water Science Report CLW 01/09.

The presence of sulfidic materials can potentially have serious environmental consequences relating to: soil and water acidification if oxidation occurs; deoxygenation of water; or formation of malodours (e.g. H_2S). Previous work by CSIRO Land & Water and others in the MDB has identified occurrences of sulfidic, sulfuric and monosulfidic black ooze materials in a range of subaqueous soils and sediments[1]. Recent studies have also shown potential risks from the remobilisation of metals, especially following oxidation and re-wetting, including Al, As, Cd, Co, Be and Ni in oxidised ASS[1] - particularly when pH values drop below about 5. Re-wetting of exposed banks helps to absorb and counteract acidity from the slightly basic river water, but toxic metallic salts created during the process can also be washed into the main stream. Where residual alkalinity in ASS is used up, clays usually provide buffering at pH values between 3.5 and 4, but sandy materials have little buffering and pH values can be much lower.

Examples of extreme ASS impacts are shown by photos (above) of Jury Swamp - with exposure of sulfidic soils with pH values of 2.5, and at Tareena Billabong. In early 2007, Tareena Billabong (south-west NSW) was isolated by sandbagging from Salt Creek and the River Murray as an option to generate water savings and help mitigate drought-related problems in the MDB. In early 2008, a massive fish kill probably resulted from toxicity and deoxygenation caused by acidification from nutrient-rich submerged banks exposed to air for the first time in decades.

Future Trends

The prolonged drought has caused water levels to recede in the river and wetland systems of the Murray, including the freshwater Lower Lakes which have begun to dry, uncovering extensive areas of sulfidic material in the subaqueous soils. Alkalinity and pH are being monitored in exposed soils to assess the risk from acid sulfate soils (critical alkalinity values set). The focus is on mapping soil acidity and understanding the future risks by monitoring how acid is generated, transported and neutralised, as well as assessing the effectiveness and practicality of alternative management strategies such as seawater, liming, re-vegetation, or re-flooding. A decrease from -1m to -1.5m AHD may expose up to 20-30 000 ha of potentially sulfidic soils.



Lake Albert ***Lake Alexandrina***

Combined bathymetry, soil and vegetation mapping in GIS was used to predict the distribution of the various subtypes of ASS according to predictive scenario maps (Note: -0.5 m is the approximate level during early 2008, and -1.5 m AHD is an extreme case, should Lower Lake inflows persist. Source: CSIRO .2009).

Abatement Potential

With a return of 'normal' flows, acidified soils should be covered with water and re-establishment of reducing conditions should result in re-formation of iron sulfides, a process which creates alkalinity and is usually benign. This process is expected to be much slower than oxidation/ acidification. Significant 'flushing' flows are needed to help move acidification products to the sea. Introduction of sea water with its alkalinity (about half that currently found in Lower Lakes) has the potential to re-establish reducing conditions, but it is difficult to predict effectiveness without adequate tidal flushing. The contribution of groundwater alkalinity is difficult to assess. If water levels decrease further (as of mid 2009), the application of lime, currently used to try to treat hot spots, may not be adequate to neutralise the expected rapid increase in acid production (often large). It is likely that the river and wetland environment have experienced these current conditions in the past and recovered, though river management and the confounding influence of climate change have changed the baselines. The aim should be to reproduce something of the seasonal variations and ensure flushing flows.

Flow Regulation

Operational Flow and Infrastructure of the River Murray

The Murray-Darling Basin is one of the most intensively regulated river systems in the world, reflected in the extent of diversions and the numbers of dams, weirs, barrages, bunds, blocking banks, causeways, levees and other regulating structures. The Lower River Murray (below the Darling junction) has 10 weirs from Wentworth (Lock 10) to Blanchetown (Lock 1), built originally (1922-1937) to promote year-round riverboat transport, but is now used mainly to preserve stable levels for irrigation[1](and see Appendix 2). The weirs have little effect on through-flow but exert a major influence on water-level variability in the channel and on connectivity with floodplain wetlands and woodlands. In general, the effect of weir operations is to maintain a steady upstream pool level except when flows exceed storage capacity. During high flows the panels and `stop logs' forming each weir are removed, then reinstated during the flood recession. At other times the river level is maintained near a target 'pool level'. The degree of control increases downstream towards Lock 1, as successive weirs dampen flow variations[1]. There are also levees, offstream regulators, and tidal barrages near the river mouth, and 'temporary' weirs and other structures were recently installed (mid 2009, or are planned) in Lake Alexandrina.

Over the last century, diversions of water from the Murray channel have increased, chiefly for agriculture. Today, these diversions, 95% of which are used for irrigation, account for more than two thirds of the Basin's mean annual runoff. Water storage capacity and diversions have increased greatly since the 1920s, and especially since the 1950s. This storage capacity provides the ability to influence the flow regime. In addition, private storage capacity (particularly farm dams) has increased in recent decades. Increased storage provides greater opportunity to modify flow patterns relative to natural conditions.

Flows in the River Murray Channel can be classified into three operating 'modes'[2]:

• Supplying mode - *when some or all of major storages (Dartmouth and Hume reservoirs, Lake Victoria or the Menindee Lakes) are drawn down;*

• Storing mode - *when the large storages are filling and the flows downstream of these storages are confined to the Channel but meet or are in excess of that required to meet downstream requirements;*

• Spilling mode - *when flow exceeds Channel capacity at some site, typically when at least one of the headwork storages is spilling.*

Different operating modes can operate simultaneously in different reaches of the river. This classification provides a useful framework for understanding current river operations, and, in the future, environmental flow procedures could be tied to a mode of operation on a reach-by-reach basis, and coordinated between reaches. There are a number of operational and environmental issues and uncertainties that increase the complexity of meeting flow targets (e.g. diversions, minimum flows, environmental targets) along the channel (including those associated with the use of environmental water allocations) during each operating mode. There are many rules for management of flows along the channel applied to protect specific environmental values.

Lock 6, near Renmark (Source: K. Walker).

Hume Dam (Source: MDBC).

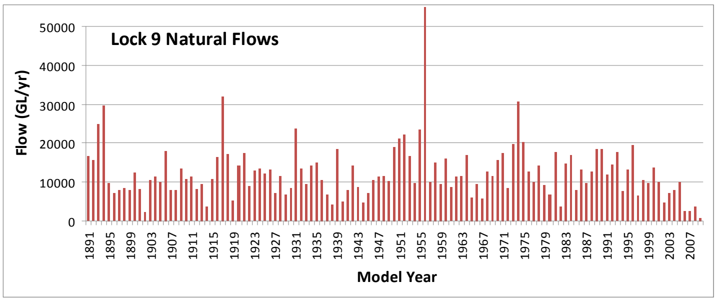
Implications

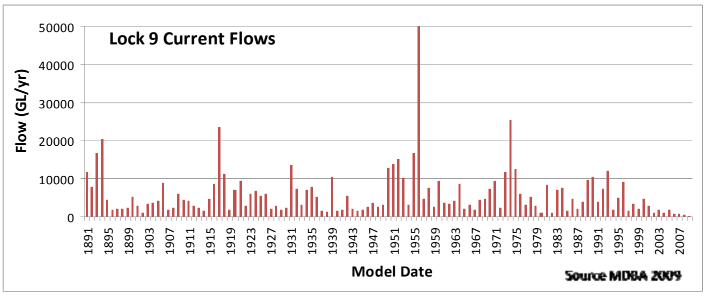
Flow is considered the 'master variable' (or maestro) for the Lower Murray system (i.e. RM-DS). As a consequence of flow management and operation of infrastructure, changes to the flow regime of the Murray have been considerable at annual, seasonal and daily scales. The extent of impacts depends on the location along the river. The proportion of flow within the river channel as opposed to on the floodplain has changed, with the greater proportion of flow now contained within the river channel. There are significant threats to the environmental values of the floodplain-river ecosystem associated with these changes to flow regime.

The main impact of regulation in the South Australian section of the Murray is the reduction in overall flow volume (Increased stability of water level and reduced variability are also important impacts). There are eight months (November - June) when the median monthly flow is less than the minimum median monthly flow in any month under natural conditions. The seasonality is similar to the natural pattern, although the duration of high flows is considerably truncated under current operating conditions[2]. Before river regulation there was a high degree of seasonal and inter-annual variability in the flows and/or water level in the channel. Regulation has reduced variability at this scale, although water levels may now fluctuate more rapidly as a result of weir operations. Small floods with a return time of less than seven years have been almost eliminated in much of the Lower Murray, and once-temporary floodplain areas below normal pool levels are now permanently inundated. The Lower Murray is virtually a series of cascading pools (weir pools occupy 52% of Murray length[3]). Regulation has extended the area of permanently flooded wetlands, with 70% of wetlands in the Lower Murray now connected to the river at pool level[3].

Hydrographic Signature

River ecosystems are governed by the flow regime. The Lower Murray has no major tributaries, and its hydrographic behaviour is usually determined by flows from the middle and upper Murray rather than from the Darling River[3]. The Murray has a highly variable regime with an erratic pattern of highs and lows. Over the past 100 years, there have been significant shifts in climate, with dry and wet periods at decadal scales, and a series of significant droughts (e.g. Federation drought, World War II drought) and floods (e.g. the 1950s) – see graphs below. In the latter part of the 20th Century, the river flow regime was dominated by low flows (<5000 Ml/day), owing to intensive regulation. High flows (>20 000 ML/day) were little affected, because the river would overflow the weirs. Ecologically, the most significant changes to the natural pattern were from the reduction in the frequency of moderate flows (5000 to 20 000 ML/day).





Disconnection and Future Trends

Each dam, weir or other flow regulator, represents a disconnection for a floodplain-river ecosystem, and the cumulative effects for the Murray have been profound. This challenges the task of managers concerned with recovery or restoration. The natural flow regime should persist as the template, because it contains the cues for reproduction of the biodiversity we are seeking to preserve. The last decade or so may represent a foretaste of the future to come under climate change. CSIRO research projects a possible 30 to 45% reduction in flow[3].

1. Walker, KF. 2006. Serial weirs, cumulative effects: the Lower River Murray, Australia. In: R Kingsford (ed), The Ecology of Desert Rivers, Cambridge University Press: 248-279.
2. Living Murray Foundation Report, 2005: Chapter 7 Information Base for the River Murray Channel. **http://www.mdbc.gov.au/subs/dynamic_reports/foundation_report/7.html**
3. CSIRO (2008) Water availability in the Murray-Darling Basin. Summary of a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, CSIRO, Australia.

Invasive (Problem) Species

Definition and Traits

An invasive species is generally considered as a non-native species whose introduction does, or is likely to, cause economic or environmental harm or harm to human, animal, or plant health. Often excluded from this definition are:

- *overabundant native species (e.g. crown-of-thorns starfish)*
- *plants and animals under domestication or cultivation and under human control (e.g. cats)*
- *species whose beneficial effects are deemed to outweigh any negative impacts (e.g. cows).*

However, for the purposes of this EC assessment - all of the above are considered under the 'invasive species' banner. Common traits of invasive species are:

- *biologically hardy, i.e. tolerant of broad environmental conditions, generalist diet*
- *ecologically hardy, i.e. fast growth, early maturation, high reproductive output, short generation times*
- *opportunistic, i.e. move into disturbed environments and out-compete native species which may have already impaired resilience*
- *often are relieved from the pressures of predation or parasites of their native territory/country.*

European Carp from Lower Murray (Source: Ben Smith, SARDI)

Noogoora burr (Xanthium occidentale) (Source: Castlereagh Macquarie County Council website)

Range of impacts

Invasive species can have a broad range of impacts and can potentially be 'ecosystem engineers', causing significant environmental changes which alter the composition and abundance of native plant and animal communities. Specific impacts may include:

- competition for food, nutrients, light, nest sites or other vial resources
- dislocation of native species from preferred habitats
- predation
- causing or vectoring diseases
- spreading weed seeds
- reducing agricultural/horticultural production.

Invasive species are often a key threat (after habitat loss) to species of conservation concern. A priority should be the identification of high risk taxa and keeping them out. Once established, invasive species are extremely difficult to eradicate.

Scope of the Problem in the Lower Murray (RM-DS)

Rivers such as the Lower Murray naturally have a distinctive, erratic hydrographic signature. A consequence of this is that the native flora and fauna are likely to include species with wide tolerance to environmental change, opportunistic life cycles and a capacity for rapid dispersal. Most native species of plants and animals rely on variability of conditions to cue for reproduction and dispersal. However, engineering has increased the stability of seasonal and inter-annual water levels (although daily levels may be more variable) and this has discouraged native species and favoured non-natives.

Weeds

There are about 150 invasive plant species, but only a small fraction are abundant and widespread in the Lower Murray. Willows (*Salix* spp.) form dense monospecific stands along the banks in the highly regulated conditions; weeds like noogoora and California burr (*Xanthium* spp.) form large persistent soil seed banks on the floodplain awaiting the next over-bank flow; lippia (*Phyla canescens*) is another species of concern that can form extensive dense mats on the floodplain that exclude almost all other species. Native species that have increased in abundance due to river regulation include the bulrush (*Typha* spp.) and common reed (*Phragmites australis*), which are well adapted to stable water levels.

Mammals & Birds

There are 8 key species of pest mammals in the region, e.g. rabbits, foxes, wild cats, wild dogs, mice. Pest birds include, for example, starlings, blackbirds, sparrows, etc.

Fish

There are at least 11 introduced fish species in the MDB (plus tilapia is a close-by, potential invader) with 6 key species for the Lower Murray): common carp, redfin perch, eastern gambusia, brown and rainbow trout, oriental weatherloach (not yet in SA). Of these, carp is the one of the greatest threats to the ecosystem.

The spread of carp (*Cyprinus carpio*) throughout the Murray-Darling Basin coincided with widespread flooding in the 1970s[1]. Introduced carp are now the most abundant large freshwater fish in the MDB. Carp can tolerate a range of water temperatures, salinity levels and polluted water (they prefer dark, murky waters). Higher carp densities have been found to be closely linked with riverine systems affected by dams and agriculture. There are about 10 different strains of carp in the MDB. It is likely that carp do not spawn in the Murray upstream of Barmah-Millewa Forest. Research in SA found that carp are always the first fish into wetlands when waters rise, but the last to leave. Carp can increase water turbidity and damage aquatic plants and insect populations through their bottom-feeding behaviour, degrading aquatic systems including wetlands. They may displace native fish species and make aquatic habitat less suitable for native fish breeding and survival, and compete for resources. Estimates suggest that carp generates an annual cost impact of close to $16 million per year[1].

Invertebrates, Diseases and Parasites

An important marine invader is the tubeworm (Polychaeta: Serpulidae) *Ficopotamus enigmaticus*. It forms calcareous masses on submerged hard surfaces in brackish water, and has killed many turtles in the Lower Lakes. Other invertebrate pests include, for example, locusts/grasshoppers. Many invasive species carry diseases and parasites.

Related Policy Initiatives and Strategies

A range of policies and strategies (underpinned by considerable investment in containment, incursion control and research) have been developed to address various aspects of invasives:

- Australian Pest Animal Strategy (DEWHA) – a national strategy for the management of vertebrate pest animals.(released in 2007)
- Australian Weeds Strategy (DEWHA) – a national approach for weed management.
- Native Fish Strategy for the MDB (MDBA) – controlling alien fish is one of the six 'Driving Actions' required to achieve the goal of rehabilitating native fish populations to 60% of pre-European levels in 50 years
- Draft Regional Pest Management Plan (SA MDB NRM Board) – priority given to terrestrial vertebrates and weeds but also includes recognition of aquatic pests
- National Threat Abatement Plans for some species (DEWHA) e.g. European red fox
- AusBIOSEC (Whole of Government) - the Australian Biosecurity System for Primary Production and the Environment, which covers all invasive plants, animals and diseases, of the terrestrial and aquatic environment that could be harmful to primary industries, the natural and built environments, and public health.

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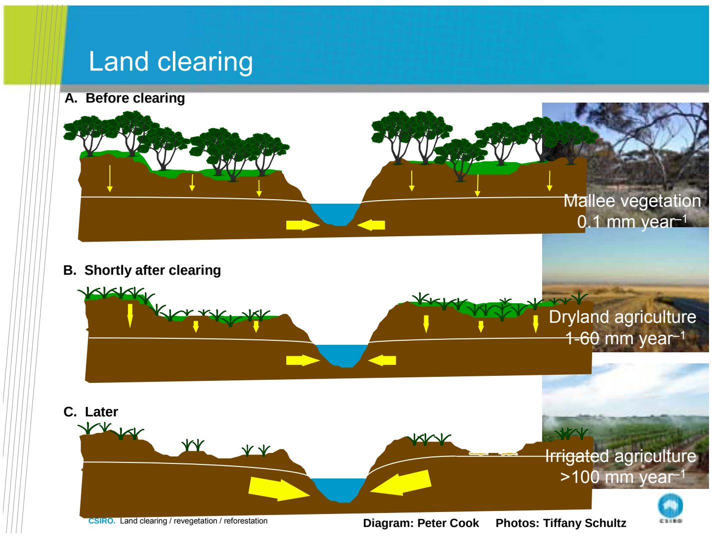
1. European Carp, Invasive Animals CRC http://www.invasiveanimals.com/invasive-animals/fish/european-carp/index.html, viewed 19/10/2009.

Land Clearing/ Revegetation

Historical aspects

Since European settlement, the Murray-Darling Basin has been the location of some of the most extensive and dramatic vegetation cover changes in Australia. For Australia as a whole, some 20% of the native vegetation has been cleared for agricultural and other purposes[1]. By comparison, at least half of the Basin's pre-European vegetation cover has been removed[1]. Some of the major changes for the Basin have been the clearing of eucalypt woodland and shrubland in the drier areas and their replacement by crops and pastures. South Australia, in particular, has experienced significant land clearance (>80%), with some of the worst problems in the Mallee areas that were cleared for grazing. In addition, large areas of native vegetation have also been thinned rather than cleared – usually in relation to agricultural activities, but also at times for urban development. Overall, the most dramatic change in the Murray-Darling Basin's vegetation cover and land use is that from one of natural vegetation (though not unmodified) to agricultural landscapes. Much of the clearing has occurred relatively recently, i.e. over the past 50 years. Land clearing continues in parts of the Basin, but measures are being taken to stop or reduce it. For example, in South Australia, farmers have to obtain planning permission before they can clear native vegetation and applications are often rejected. Also, large numbers of trees are now being planted by government and community supported revegetation programs across the Basin.

About 80% of land in the MDB lies in arid and semi-arid regions. Vegetation clearance has resulted in widespread degradation of the land, including: loss of habitat for native plants and animals; deteriorating soil structure; acidification; loss of topsoil through erosion; and river siltation. Widespread dryland salinity is also a major consequence of vegetation clearance. Changes to the vegetation cover, primarily the removal of the native grasses, shrubs and trees, have changed the natural water balance. In particular, the clearing of native vegetation in has led to increases in groundwater recharge of up to two orders of magnitude in some locations in South Australia [3]. Clearing and replacing of deep rooted native trees and grasses with annual crops and pastures have meant that naturally occurring salts are brought to the land surface with rising groundwater and the watertable gradient may drive groundwater (and salt) towards the river. Importantly, recent research suggests that land clearance and loss of vegetation may be a significant contributing factor in climate change and exacerbation of droughts at a regional scale[2].



The figure above demonstrates the relative time delays in soil saturation to the water table and then transmission by pressure to the river valley. For example, with the Mallee vegetation in place, most of the rainfall is used up by the plants. However dryland and irrigated agriculture results in more saline laden groundwaters entering the river channel, and this is probably exacerbated by low surface water inflows due to drought and water extraction from the river.

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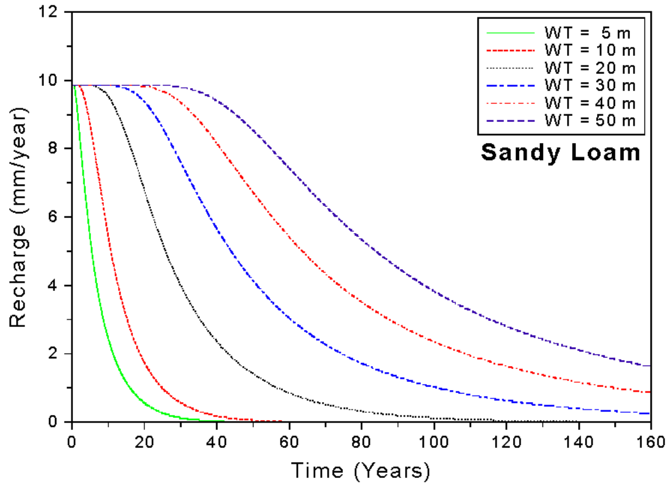
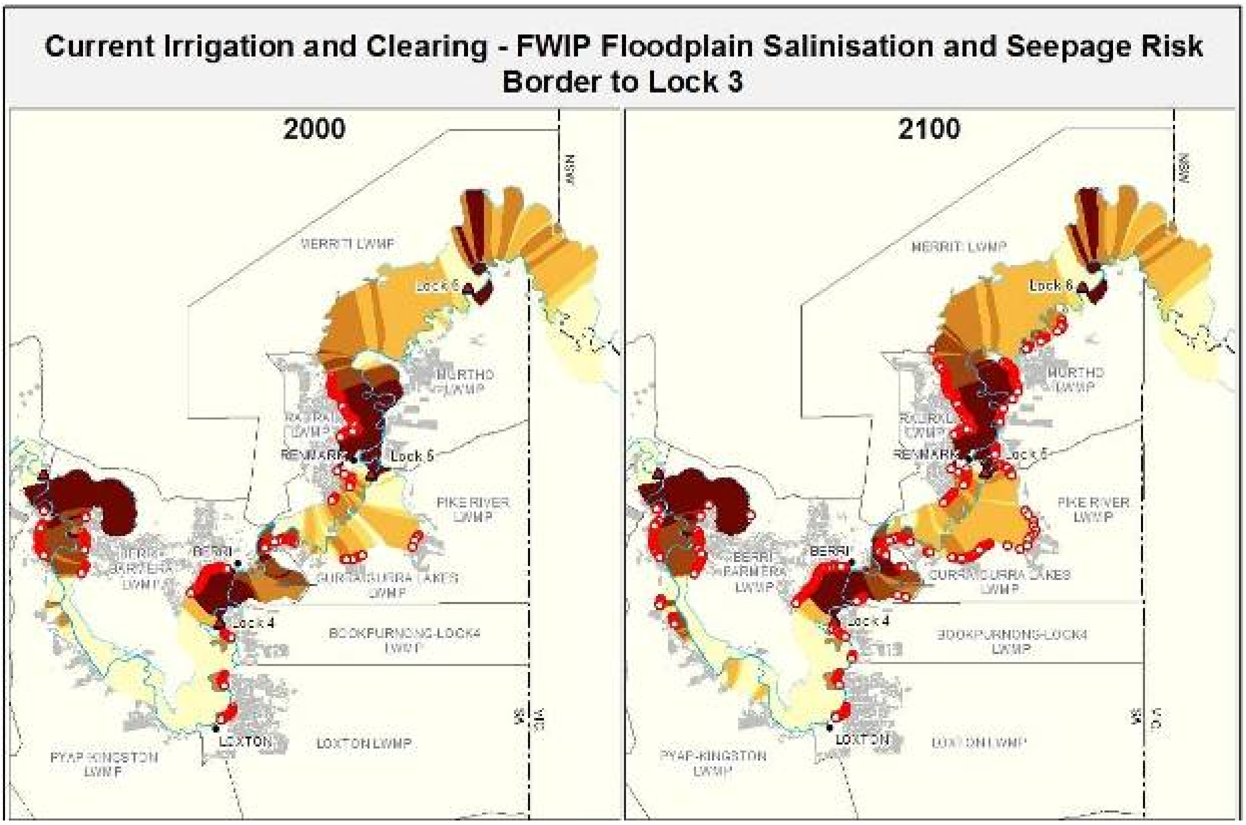
2. McAlpine CA, Dyktus, J, Deo, RC, Lawrence, PJ, McGowan, HA, Watterson, IG, Phinn, SR (2007) Modelling the impact of historical land cover change on Australia's regional climate. Geophysical Research Letters 34. L22711 doi: 10.1029/2007GLO31524 http://dx.doilorg/10.1029/2007GLO31524
3. Allison, GB, Cook, PG, Barnett, SR, Walker, GR, Jolly, ID and Hughes, MW. (1990) Land clearance and river salinisation in the western Murray Basin. Journal of Hydrology, 199 (1-4): 1-20.



Recharge (mm/year) versus water table depth (Source: Peter Cook, CSIRO)

There are significant time delays for recharge of groundwaters from the surface. For example, soil profiles in the Mallee can be 30 - 40 metres, which would take in the order of 100 years for a 5 mm recharge.

CSIRO is undertaking modelling of revegetation in the River Murray corridor to assess potential benefits to addressing the salinity problem. When the models tested revegetation effects 100 years out, the outcome was a very small benefit at Morgan. This suggests it takes much longer than 100 years to reduce salt inflows to the valley by revegetating the highland. When the modelling includes salt interception schemes (SIS) there is significant reduction in risk (although there are still some residual risks from floodplain salinisation from weir pool levels).



Floodplain salinisation risk (Source: Kate Holland, CSIRO)

The issue of carbon benefits is also being investigated with respect to revegetation of the region, which may provide incentives to farmers in the future (i.e. potential increase in profits to farmer from selling carbon permits).

Plenary Panel General Discussion - Key Points and Issues

Climate Change – key points and issues

- The important aspect of climate change as a threat is that it is likely to exacerbate the impacts of all the other threats - like, altered flows, salinity, ASS, etc.

- There is likely to be distributional change among biota, with a north to south shift. If ecosystems start moving on a trajectory of change with climate change, then a) how do we recognise that? and b) should we try to interfere with it? Are we going to try to hold the clock stationary at 2009 or accept the reality that the system is changing? We should not say we are necessarily going to lose a lot of species, we are just going to get a redistribution of them (particularly the floodplain species). A critical point here, however, is that vegetation types can only move if they have somewhere to move to (i.e. thin blue/green line concept).

- The challenge from climate change is bigger than that of addressing existing over-allocation. Climate change is going to reduce inflows to the system to such an extent that we need to totally renegotiate the sharing of water and decide what is the minimum amount needed for environmental health. All the calculations we have to date were based on the old inflow equations.

- There is the aspect of increasing temperatures as well. We need to keep a watching brief on that. We are now getting temperature thresholds on extreme hot days that biota are not used to. The number of days over 35° C and 40° C are a real threat, and according to CISRO and the Bureau of Meteorology they are likely to increase.

- Phenotypic change will also be important - e.g. flowering times, match-mismatch between predator and prey, etc.

- We need to enhance system resilience (as we cannot micro-manage everything). For the Lower Murray region, connectivity to the water is the critical aspect (i.e. rather than temperature gradients). The issue of water sharing is also important.

- It is likely that what we are facing now, in terms of climatic trend, is likely to persist (i.e. warmer, drier). That is what we should be planning for (across the whole MDB) - that should be our baseline (for 5 years at least).

- We should not be so pessimistic as to write-off (or sacrifice) parts of the ecosystem yet, even considering the climate record of the past decade. We don't want to lose valuable habitats.

- It could be that a possible consequence of climate change is that the main channel becomes a refuge area for many of the species which were perhaps out on the floodplain. You may also get encroachment closer to the river of floodplain vegetation. Therefore, the main channel is a really important 'refuge' area (especially for plants), particularly under climate change. However, this may not be the case for small-bodied fish, particularly if they do not have appropriate habitat to hide from predators (we are seeing that at present in the lower sections of the Lower Lakes and below Blanchetown).

- There is great concern that we might lose whole ecosystems, e.g. entire wetlands, including iconic and Ramsar wetlands could potentially disappear. Some are already very threatened and there is a large investment in research and restoration for some of them. An important question may be - is a triage approach appropriate for directing effort and investment?

- Under a climate change future, there may be increased pressure in from landholders to maintain lifestyle and livelihood at the expense of the environment.

Salinity – key points and issues

- In the river channel, what is important is the salinity tolerance of freshwater organisms and their critical thresholds beyond which you would lose members of the freshwater community.

- There is also a salinity threshold for vegetation on the floodplains - particularly the threat from rising regional groundwater which is as saline as the sea in most of the area that we are looking at. We know the tolerance levels for black box and red gum, and they are highly vulnerable to salt.

- The whole life-cycle of a species needs to be considered with respect to salinity tolerance. Often the juveniles or the propagating individual are more susceptible to salinity than the adults. Indeed, the big issue is recruitment. We need to make sure that reproduction occurs on a scale that is sufficient to sustain the populations into the future.

- Salinity is exacerbated by flow conditions. Salt will concentrate if not flushed out under higher flow conditions. Therefore it is the periods of low flow that are the problem. Flow management is important to help address the salinity issue and could also be considered a joint threat. Similarly, acid sulfate soils issue can be considered a joint threat.

- There is a long-term impact apart from the impact on species themselves and their local extinction. There are also impacts on long-term habitat. For example, the habitat values associated with long-lived trees like red gum and black box, which support a whole range of other species. Regarding replacement, it would take hundreds of years to provide trees with similar habitat complexity.

- Abatement strategies are flushing flows and floods. Is the average flushing of the river system enough to remove average inflows of salt into the system? Not at present.

- Salt interception schemes (engineering options) can delay or reduce the impact of salinity moving into and through the river system. Regarding removal of the weirs, that would be likely to have a short-term increase in river salinity due to the accumulated salt in the floodplain soil being purged into the river.

- Given that there may always be salt in the system, what would the acceptable situation be? Vegetation such as the long-lived big trees (i.e. species that cannot move) are a major indicator. Another indicator may be persistent salinity gradients between fresh to hypersaline between the Lower Lakes and Coorong. Another may be water quality or EC or the channel water - acceptable levels would probably be something like 'what we can drink'. However, it would be important to define a salinity level from an ecological point of view, because that is probably different from what is defined for human use.

Seepage. Photo: Kate Holland

Salinisation. Photo: Kate Holland

Acid Sulfate Soils – key points and issues

- Specific effects of acid on biota is generally not good (some invertebrates and single celled organisms an exception). One of the main impacts of acid sulfate is the point source impacts on local areas which can interrupt physiologically and behaviourally the migration pathways of things such as young fish. This in turn leads to recruitment impacts.

- There are thresholds for biota. For fish and other fleshy organisms it is about a pH of 5.

- Nutrient pathways are affected by acid, e.g. in agriculture, when pH drops below about 6 - 4 things like nitrifiers (i.e. that put nitrate into the system) progressively stop working.

- Monosulfides (MBOs) in acid sulfate soils also mean a risk of deoxygenation on disturbance, with related implications to biota.

- There is no silver bullet solution. Solution may be similar to that for salinity, i.e. getting the area back under water again - although there may be a lag involved in benefit. But it is never a simple solution, there is a need to tailor it to the particular circumstance. Adding lime and revegetation are other abatement strategies - particularly for 'hot spot' locations. There may be places where you want to control the surface condition by growing plants; you may want to put organic carbon into the system to provide energy to drive reduction processes on re-flooding. When acidification is reversed, you reduce the system again, and you create alkalinity. So in a closed system there is no net gain or loss - but these are open systems.

- A combination of approaches, carefully thought through, is probably best, but the ideal solution is to keep those acid sulfate soils wet. There is a caution however, as constructing more weirs to keep the soils wet is somewhat ironic, as a large proportion of the accumulation of ASS is caused by weirs and barrages in the first place.

- There is also caution regarding the timing and duration of wetting and the need to control refill. If the exposed areas are wet too quickly, the acids and associated heavy metals move into the water and affect biota. The system naturally has evolved under a wetting and drying regime. What are the differences of returning to a wetting and drying regime as a long-term solution, as opposed to just keeping them wet in the short term? It depends on the aim, however it would be possible to get it back to the system in place before the current drought. There needs to be flushing flows to keep the burden of sulfur moving along the system. It is also important to be aware of how that material moves downstream - i.e. in an acidic sludge or mixed and diluted? This will in turn affect riverine pH and the precipitation of dissolved metals, and subsequently, how aquatic biota respond. For example: at high levels precipitated aluminium can clog fish gills and create a fish kill; wetting of monosulfidic ooze can create a deoxygenation event downstream. There needs to be care with how acidic material is flushed and mobilised.

ASS with accumulation of white & yellow Na-Mg-Fe-Al-sulfate-rich minerals; pH 2.5 (Source: CSIRO).

Monosulfides (monosulfidic black ooze) able to remove most of the oxygen, Paiwalla wetland (Source: CSIRO).

Flow Regulation – key points and issues

- The current ‘drought’ in the River Murray is principally by a lack of rainfall/runoff combined with diversions (over-allocation). To reclaim the Lower River Murray, there needs to be provision made for water for the environment.

- Extraction of water is the number one threat to the system; the major threat to all ecological values. Over-use of water from the system is a huge problem (includes farm dams high in catchment). Extraction should be seen as a separate class of threat to loss of flow variability.

- We need to consider pumping/abstraction from the regulated and unregulated parts of the system. There is a proportion of abstraction that remains unregulated.

- Modelling work supports that it is the extraction levels rather than the current drought that is the major problem for the terminal end of the system (i.e. Lower Lakes and Coorong).

- The loss of flow variability is a major issue for the system. For example, the ASS problem may not be as severe if we had variable lake levels. Recreating some of that flow variability is going to be extremely important - we need to keep the range of variability there.

- We have lost the small floods; we have lost the over-bank flows getting the water onto the floodplain and leaving it there long enough for lifecycles to play out. To repair the system we need to reinstate those over-bank flows. We need pulsed flows. We do not need some average annual amount that is just going down the main channel.

- Issue of raised water levels from the weirs and what that means for floodplain groundwater levels. The hydraulic effects of the weir pools are believed to be responsible for significant salt accessions to the river – the saline groundwater is forced down under the pools, but forced nearer the surface in areas downstream of each weir, and is entrained by the river.

- We have a highly regulated system, for which some aspects can be used to advantage. On the Chowilla floodplain there are creeks that bypass Lock 6 - so we can get flow into that part of the system. In the Pike there are creeks that bypass Lock 5; the Katarapko Creek bypasses Lock 4; and the Banrock system bypasses Lock 3. So there are parts of the system that can be operated in a way to better mimic natural processes.

- It is unlikely that we would ever get rid of the weirs. We need to think about how we use them to manipulate water levels etc, to get water onto the floodplain. All of the weirs are of the overflow type - and you get a lot of sedimentation behind these. If you could open up the bottom of the weirs and get a lot of that organic material going downstream, there may be some ecological advantage. We need to use the weirs to provide ecological benefit at a minimal cost. However, some consider over-engineering of this system as a threat, even if aimed at providing environmental benefit, and it may not be a sustainable solution in the longer-term.

- The infrastructure involved in flow regulation creates barriers for migration and dispersion of biota - which is causing ecological fragmentation. This needs to be mitigated.

- What is a sustainable solution for flow management? How do we know when we have got it right? Perhaps we wouldn’t have dredges in the Murray Mouth; it would be opened by river flow. We would have the organisms and communities that we would expect to find, with none lost. Also, there would be no need to artificially pump wetlands.

- There may also be more pipelines supplying irrigation districts rather than natural environments. Considering the Lower Lakes integrated pipeline - where there is flowback, we may be able to disconnect the lake level management from irrigation supply. The same applies for the river reach. A lot of weir pools can’t be manipulated because of off-take pipes.

Invasive (Problem) Species – key points and issues

- One of the key potential threats is an invasion of the fish, tilapia - which is currently not in the system. Also weatherloach and similar species are progressively moving down towards the South Australian border. There is already carp in the River Murray, which is a significant, if not the main, current threat from an invasive species.
- A lot of damage to vegetation has been done by cattle, sheep and horses in some places - with the survival of young plants limited by grazing.
- There is agreement that invasive species should include or be renamed 'problem' species for the purposes of the EC assessment. In addition to exotic species (invasives), over-abundant native animals and domestic stock can pose a serious threat the system.
- Vectoring of disease - for example, *Lernaea* is a particularly vicious parasitic copepod which badly affects Murray cod and probably causes cryptic mortality.
- With climate change there is the potential for pests such as the cane toad to reach SA. There are increasing reports of changes in 'invasive' ant community structure - some are responding to permanent water and food supplies (i.e. becoming invasive) .
- Two native species, *Typha* and *Phragmites,* are 'invasive species' in wetland environments.
- With the current drought, it is apparent in the Lower Lakes that marine invaders (like the tubeworm *Ficopotamus enigmaticus*) are coming in. If the future of the Lakes is that they become a more estuarine environment then there may be an increase in marine invaders.
- Consider there are two types of invasive plant species in the Murray-Darling Basin:
    - those that are symptomatic of what we have made of the river system e.g. willows, *Typha*, *Phragmites*, carp - i.e. species that are very well adapted to the stable water levels due to river regulation. If you look at photos of the river banks in the 1930s they are bare - not a blade of grass on them (but not for Lower Lakes). Now there are quite often monospecific stands of *Typha* and *Phragmites*. It is not a natural situation - even though they are native species, they must be having an impact on the biodiversity, as nothing grows under a dense stand of *Phragmites*. Willows have an enormous impact on habitat structure and nutrient flows in the Valley section.
    - those species well adapted to the current natural environment - particularly the floodplain environments. Species like burrs - *Xanthium (e.g. occidentale, californicum)* and heliotropes - *Heliotropium* (e.g. *curassivicum, europaeum, supinum*). These plants germinate as the water levels recede, and they like it hot. They have quite deep root systems and are quite drought tolerant. Lippia (*Phyla canescens*) is also a major floodplain weed that is well adapted to various conditions.
- If there is a return of environmental flows or an increase in variability, as in a recovery phase - we are likely to see an increase of species that are from areas with similar hydraulic regimes and similar climates.
- Other exotic invasive plants of concern are: exotic *Juncus* (spiny rush; highly saline tolerant, can obstruct water flow) - taking over the exposed acid sulfate soils in the Lower Lakes, and Lippia (*Phyla canescens*) which competes with the native grasses.
- Australia is showing an evolving flora . Assemblages of plant species are adapting to the type of environment that we have produced (e.g. different flow regimes). If we don't want them (e.g. weeds), then we need to change the system of regulation.
- Risk assessment of 'invasives' should take into account the species likely to be big ecosystem engineers, i.e. that affect the recruitment of other species that are native to the system and have ecological 'flow on' effects downstream (e.g. replacement of lignum).

Land Clearing/ Revegetation – key points and issues

- Land use change impacts on water resources at a sub-catchment level can be as significant as those projected for climate change, i.e. 20 - 45% change in water availability over a 30 - 50 year time frame. For example, in Victoria dairy, crops, viticulture and forestry have all moved into traditionally broad-acre grazing land.

- Forestry development in the Eastern Mt Lofty region is important. It has the potential to draw down water tables and affect flows in Eastern Mt Lofty streams and therefore RM-DS EC.

- Land clearing has virtually ceased in South Australia, so the broad-scale matters are now over. There is an issue, however, in the one or two kilometres back from the river, particularly the river slopes and in the valley part of the system - where recharge from rainfall could be quite high (i.e. lesser depth to groundwater). There is a concomitant issue regarding revegetation and recharge management very close to the valley zone.

- While land clearing has been stopped, there is tree clearing/dying on the floodplain from the extended drought. That is a really big threat at present - the loss of trees across the floodplain due to drought.

- A general issue related to change in water resources is a change in habitat and energy resources for food webs. Just putting back particular types of trees may not necessarily underpin ecological recovery. Need caution when using the terms 'revegetation' and 'reforestation'.

- Future considerations of carbon credits need to consider appropriate species selection for the region and potential impacts on local biodiversity.

- Other threat related issues include nutrient runoff (nutrient pulses) and recovery from bush fire (including ash fall and impacts on biological oxygen demand).

- Although reforestation might reduce sediment loss and improve groundwater control, there is greater concern that it will reduce flow.

- Threats from revegetation and reforestation can be limited if managed appropriately. However, that could change in the future, e.g. with biofuel production. It would depend on how much water is used and what the reduction to runoff is.

- There is site specificity for this issue. There is current consideration of redirecting fresher water from further south to get a larger volume of water into the southern part of the Coorong. Between the source of that water and the Coorong there is about 50 000 hectares of blue gums being planted. There are also large plantings across the border in Victoria that intercepts the water that would normally go into Mosquito Creek, Morambro Creek and a couple of others. Hence, attempts to get the water into the southern part of the Coorong are being frustrated by some of these forestry activities.

- The current process by MDBA of assessment of risks to runoff in the MDB is looking at a range of factors, including climate change, bush fires, farm dams, groundwater and plantations. Each of these five factors is showing up as being significant in total runoff in the Basin. So, in terms of what we are considering for the Lower Murray, anything that is reducing runoff into that sector, therefore, is a threat.

PART B – Workshop Outcomes 3: Fitting Listing Criteria to Aquatic Systems & RM-DS EC

Universal Key Findings

For aquatic systems in general

- The 'Ecological Community' (EC) of a large complex aquatic system often consists of sub-units of different biophysical complexity – therefore it may be considered as a 'constructed' EC – however these components are united/connected by common functionality features.
- There is a need to ensure legally defensible boundaries and attributes.
- Flow regime (surface and groundwater) is a key (integral) ecological process – there is a need to consider 'natural' versus 'managed' flows and wetting-drying cycles.
- Connectivity is critical – as is the rate of disconnection and fragmentation.
- Changes in water quality and source is also a central aspect for the assessment process.
- It is important to demonstrate (proof of concept) a species is 'keystone' or 'foundation'.
- Need to investigate where/how the assessment can link into Indigenous mapping and knowledge.
- The assessment process should not just be about population sustainability, but it should also be about demographics e.g. age structure (old riparian trees or fish), recruitment levels, etc.
- There is a need to consider/allow for time-lag effect between disturbance (threat) and impact on functionality (may take years) – 'lag time between action and outcome'.
- Flexibility with times and sizes for criterion thresholds may be important.
- 'Uniqueness/rarity of community or components should be considered when applying criteria.

Challenges

- Natural variability - temporal and spatial; natural versus anthropogenic (e.g. climate change, engineering interventions and uncertainty of how flow regime affected by engineering works/interventions).
- Data availability and lack of knowledge (e.g. hydrological models, stygofauna, etc).
- Consider and differentiate/demonstrate trophic cascade effects (i.e. flow-on effects).
- Dealing with cumulative impacts of threats in aquatic systems – likely to be more magnified/complex than with terrestrial systems.
- Identification of triggers and tipping points – understanding when shifts to different states occur – also hysteresis (time lag) effects (including irreversible outcomes).
- Incorporating a 'zone of influence' concept - geographically based but temporally variable.

For the River Murray – Darling to Sea EC in particular

- Establish a quality baseline (reference condition) – options: 1956 floodline; hydric soils (to few m); 1970's high flow period; pre-regulation; pre- European (but last two are harder to quantify).
- Keystone/foundation species – Murray cod (*Maccullochella peelii peelii*), Murray River crayfish (*Euastacus armatus*) river red gum (*Eucalyptus camaldulensis*), black box (*Eucalyptus largiflorens*), *Ruppia* sp.
- Key indicators of decline – spread of salinisation, acid sulfate soils/pH, fish fauna, old trees, water level, invasive species (invasion by carp a standout), groundwater extent.

Listing Criteria Analysis

CRITERION 1: Decline in geographic distribution

This criterion refers to:
- a decline in total area of the EC without necessarily a concomitant contraction in its range, or
- a decrease in the range over the whole or part of the area in which the community originally existed, or
- fragmentation of the community through a decrease in the size of patches.

In order to meet this criterion there needs to be a measurable change. To determine this we need to know what was the original extent of the EC, what is its current extent, and how the decline relates to the criteria thresholds (see Table 4, page 18).

Question	C1: Response
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• overall does not work well for large complex and dynamic aquatic systems • may work well for components (sub-units) of these systems or discrete aquatic systems, e.g. wetlands • linear nature of rivers is an issue (i.e. won't get contraction in linear geographic extent compared to contraction in area) • loss of geophysically important ecological functionality is more important (i.e. change in functional extent compared to geographic extent)
2. How do we best measure this Criterion in aquatic ecosystems?	• mapping key elements like hydric soils (to few metres deep), vegetation/state change, flow/flooding regime change • biotope edge effects and change • map decrease from pre-European perspective (assume this reference condition)
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• quality of baseline critical (acknowledge assumptions) • lack of knowledge (e.g. stygofauna) • engineering works affect flow regime • natural variability (temporal and spatial) and climate change • different components of system (sub-units) have different conditions and complexity (may change) • needs to be legally defensible • endeavour to link to Indigenous mapping and knowledge
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• use a 'likely to occur' delineation for an indicative approach • recognise temporal variability and extent • take into account community 'rarity' value • identify & understand when shifted to a different state (e.g. intermittent to permanent wetlands) • need a legally defensible line • consider importance (and a measure) of connectivity • quality needs to be considered as well as extent • incorporate 'zone of influence' concept
5. How does the Criterion work for the RM-DS EC?	• this criteria doesn't work well for RM-DS EC as a whole • Coorong and Lower Lakes very different components than River Murray corridor – may work for sub-units • deliberate disconnections (e.g. some wetlands) and indirect (e.g. estuary to sea) • spread of salinised floodplain a good indicator and decline in groundwater extent due to rising salinity • massive range constrictions of fish distribution (e.g. Murray cod, golden perch (*Macquaria ambigua*), Murray hardyhead (*Craterocephalus fluviatilis*) in wetlands) • loss of woodland habitat in floodplains • other baseline options – pre-regulation, 1956 floodline

CRITERION 2: Small geographic distribution coupled with demonstrable threat

This criterion applies to ECs that have a small geographic distribution (on a national scale) and for which a threatening process exists within an understood or predicted timeframe. A small geographic distribution implies an inherently higher risk of extinction from the threat. This criterion does not apply to small ECs that are not subject to a threatening process – the intent is rather to capture naturally rare or highly fragmented communities under threat.

Question	C2: Responses
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• overall it is difficult to argue that geographical distribution is small for a large, complex river system • could work for small, isolated aquatic systems or even long, linear streams with a small surface area • could work well for naturally rare or fragmented wetlands
2. How do we best measure this Criterion in aquatic ecosystems?	• could potentially use surrogates, such as certain characteristic life forms e.g. fish distribution • change to hydrology, e.g. lotic (flowing) to lentic (still)
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• does 'small' depend also on a temporal or climatic aspect as well as geomorphology? • hydrological (and ecological) disconnect • change to frequency or size of key flow events a threat that can lead to changed state • how do we deal with cumulative impacts of threats with aquatic systems? – likely to be more magnified than with terrestrial systems
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• rarity of community composition and/or fragmentation could be critical (and measurable) features • measures of flooding frequency and intensity – demonstrable threat • scope to change concept of small size – e.g. river/stream a narrow, linear band in landscape • allow for well defined area of occupancy
5. How does the Criterion work for the RM-DS EC?	• as a whole, the RM-DS EC would not trigger this criterion as it stands because it's difficult to demonstrate (legally) 'small' geographic distribution, except for components (sub-units) downstream in the system (e.g. Coorong, Lower Lakes, some specific wetlands) • threats are undeniable • key 'trophic' species disappearing from specific sites (e.g. small fish, turtles) • flow-on effects to Indigenous icons, e.g. pelicans

CRITERION 3: Loss or decline of functionally important species

This criterion refers to native species that are critically important in the processes that sustain or serve a major role in the EC, and whose removal would potentially precipitate a negative structural or functional change that may lead to extinction of the EC. This criterion has two inseparable components for assessment: there must be a decline in the population of the functionally important species (FIS), and restoration of the EC is 'not likely' to be possible within a specified threshold timeframe (see Table 4, page 18). The decline of the FIS must be halted or reversed to ensure continuation of the EC.

Question	C3: Responses
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• yes, a potentially powerful criterion which describes the situation well • need to postulate how the species is/are important and this is data dependent (i.e. foundation or functionally important)
2. How do we best measure this Criterion in aquatic ecosystems?	• need to demonstrate a keystone species (by concept is OK, e.g. apex predator) • look at health or population dynamics of key elements (e.g. fish, trees, migratory birds, invertebrates), i.e. canopy extent, distribution, abundance, biomass, productivity, size/age class, demographics, level of recruitment, etc. • landuse and occupancy mapping of Indigenous people
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• defensibility • defining how functionally important species linked to processes • how to differentiate trophic cascade (flow-on effects) from disturbed state? • Indigenous consultation a key component but not explicitly stated for criterion • knowledge limited on functionally important species of groundwater systems • not just about population sustainability – demographics important too, e.g. need 'old' trees • species are already becoming extinct – what if there are none left of the keystone species? • connectivity issues – e.g. diadromous fish
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• need proof of concept of keystone and foundation species • may need flexibility with generation times for criterion thresholds e.g. invertebrates, annual plants, etc. • rather than just loss or decline in numbers, changes to other aspects of functionally important species need consideration e.g. age class structure, distribution, canopy extent, productivity, level of recruitment, etc. • allow for time-lag between disturbance (threat) and impact on functionality (i.e. may sometimes take years, but generally good understanding exists of likely effects) and time-lag to get functionality back • compare to other case studies i.e. where there have been re-introductions
5. How does the Criterion work for the RM-DS EC?	• keystone/foundation species may be functionally important to a certain component (sub-unit) rather than the entire EC • Murray cod a functionally important species (apex predator) • records of early fishers would be useful • cultural issues and connections need to be factored in • strong argument for river red gum – important habitat for so many other species and processes (homes, nesting, nectar, soil stability, nutrients, woody habitat, etc.), level of seed set driven by frequency and timing of flooding • Black Box may be just as or more important than River Red Gum – juvenile release rates better
6. What are the keystone species or assemblages for the Lower Murray – Darling to Sea EC?	• potential keystone species are Murray cod, Murray River crayfish, freshwater turtle (*Emydura*), mussels/snails, small native fish assemblage • potential foundation species are river red gum, black box, melaleucas, coobah, lignum, *Ruppia tuberosa* (in Sth Lagoon of Coorong)

CRITERION 4: Reduction in community integrity

This criterion recognises that a EC can be threatened with extinction through on-going modifications. Changes in integrity can be measured by comparison with a benchmark state that reflects the 'natural' condition of the EC with respect to its abiotic and biotic elements and processes that sustain them. The criterion recognises detrimental change to component species and habitat, and to the processes that are important to maintain the EC. (Note, changes do not necessarily have to lead to total destruction of all elements of the community). Importantly, this Criterion allows for recognition of a problem at an early state/stage (e.g. disruption of process evident but no measurable decline in integrity of EC as yet). Regarding the regeneration aspect of thresholds (see Table 4) this relates to re-establishment of an ecological process, species composition, and community structure within the range of variability exhibited by the original community.

Question	C4: Responses
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• yes – very applicable to aquatic systems at a range of scales and levels • provides opportunity to pick up the overarching significance of flow regime as an integral ecological process • loss of connectivity (e.g. to the sea)
2. How do we best measure this Criterion in aquatic ecosystems?	• flow is linked to a number of processes and is well documented (with large body of evidence to support that flow is important) – can describe changes in many facets e.g. frequency, size, etc. • dominance of invasive species, or, relative abundance of native versus exotic species (e.g. carp, willow, etc) • water level • native fish populations • number and intensity of algal blooms • changes in species abundance and composition
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• in general a lack of data for most aquatic ECs (i.e. in many catchments hydrological models are poor, lack of flow data, no calibration, etc.) • time lag in getting functionality/integrity back (e.g. long time for 'old' trees) – some threats have long lag effects e.g. groundwater, salinity • irretrievable loss of native species • changes to substrates • trophic flow-on effects (cascades) • macrophytes very important – regeneration impacted by carp • biophysical impacts – connectivity important • changes to landscape impact on system resilience • engineering interventions – effects difficult to identify • cultural input to criterion – e.g. *Cyprus gymnocaulos,* a sedge used for weaving – how is this captured?
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• criterion thresholds – consider short generation times for invertebrates; 'past/future' concept timing • build in flexibility • need to determine critical timelines for linking flooding and organism lifecycles
5. How does the Criterion work for the RM-DS EC?	• works very well (Murray unique in that a lot of historical data on flow and other aspects – back to 1891) • estuarine species have been reduced or lost • algal blooms and weeds (e.g. *Lippia*) a threat • recruitment potential affected – seed/egg bank function • invasion by carp is a standout – massive alteration to community composition, key species loss • flow regime critical • appropriate salinities (& pH) need to be re-established within 10 years or integrity gone – trigger 'critically endangered'

CRITERION 5: Rate of continuing detrimental change

Continuing detrimental change refers to a recent, current or projected future change for which the causes are not known or not adequately controlled, and so is liable to continue unless remedial measures are taken. Detrimental change may refer to either i) geographic distribution or populations of critically important species, or ii) degradation or disruption of an important process. The detrimental change can be observed, estimated, inferred or suspected. Natural fluctuations do not normally count as continuing change, but an observed change should not necessarily be considered to be part of a natural fluctuation unless there is evidence for this. 'Ecological judgement' may be exercised to apply this criterion if adequate data are not available.

Question	C5: Responses
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• yes – decline is accelerating
2. How do we best measure this Criterion in aquatic ecosystems?	• lag effects are a complicating factor and need to allow for them – partial disconnect between flow and community change • diversions versus inflows – difference between natural and managed river condition (but difficult to quantify pre-European hydrology) • natural flows versus un-natural flows – measure of water movement through system (e.g. flooding of river red gums dropped from once every X years historically, to once in Y years now) • shift in salinity regime • connectivity – increasing disconnection of the system • water quality and source
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• natural variability in Australian landscape • demonstration • lag effect of threats and ongoing impacts • rate of change of health can spiral and have flow-on effects (e.g. trophically) • pace of regulatory change; water management plans • climate change coupling to inflows • lack of monitoring of threats e.g. groundwater usage
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• flexibility to allow for lag effects of both impacts and restoration/recovery times • recognition that impacts operate over long time scales • tipping points need to be factored in
5. How does the Criterion work for the RM-DS EC?	• rate of disconnection (e.g. to wetlands, river to sea) • proportion (%) of inflow compared to extraction • significant detrimental change (70%) occurred in last 10 years on river floodplain • decline in river red gums well documented • cap established in MDB flows in 1994-95 (dry since then) • acid sulfate soils a potential indicator • salinity in Lower Lakes • disconnection with ocean

CRITERION 6: Quantitative analysis showing probability of extinction

This criterion can include any form of analysis that estimates the extinction probability of an ecological community based on known characteristics of: important species or components, habitat requirements, ecological processes, threats, and any specified management options. The Threatened Species Scientific Committee recognises that this is an emerging area of science and will examine any acceptable modelling (with the concomitant use of peer review).

Question	C6: Responses
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• yes – potentially • could be applied conceptually • need well defined community and understand when it changes to something different (i.e. flips to another state)
2. How do we best measure this Criterion in aquatic ecosystems?	• data dependent • proof of role of keystone species • if no data or examples, could use conceptual modelling
3. What are the challenges/impediments/ issues for applying this Criterion to aquatic systems?	• data availability • proof of keystone species • it is not a challenge that river red gum (or whatever) also occurs outside nominated area • could be useful for applying 'tipping points' to a system • climate change
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• trying it out – robust method needed for ecological communities • how is extinction defined? – complete extinction versus local extinction – both are relevant for consideration of EC • scope to apply PVA type analysis to selected species but that may not capture the sense of community
5. How does the Criterion work for the RM-DS EC?	• Coorong modelling from Flinders University has good potential (Rebecca Lester and Peter Fairweather) • use species listed under Criterion 3 (i.e. keystone or foundation species) to try it out • focus on river red gum and/or black box as there is more literature and data and they have complementary roles • black box is a classic example of the sliding baseline – on the way out since 1956

Appendix 1: Workshop Agenda and Delegate List

Department of the Environment, Water, Heritage and the Arts

'River Murray-Darling to Sea' Ecological Community Assessment: Expert Technical Workshop

Wednesday 1 July 2009

Workshop Session One: Prelude and Process
Chair: Bob Beeton

4.0 **Welcome and housekeeping**
Bob Beeton and Gina Newton

4.15 **The EPBC Act, processes for listing and protecting threatened species and ecological communities.**
Matt White

4.45 **The Threatened Species Scientific Committee Perspective – historical facets and lessons learnt from large, complex nominations (e.g. Littoral rainforest) & Key Concepts**
Bob Beeton

5.20 **Outcomes sought from this workshop. How we would like you to contribute.**
Matt White

5.30 **Questions and Discussion**

6.00 **Workshop Dinner: The Monastery (Note: BYO)**
Presentation: *'A virtual field trip of the River Murray – Darling to Sea'*
Judy Goode

Thursday 2 July 2009

Workshop Session Two: Setting the Scene
Chair: Bob Beeton

9.00 **Paleo-history of the Lower Murray**
Jennie Fluin

9.15 **Groundwater connections and Aerial Electro Magnetic surveys**
Jane Cooram/BRS TBA

9.30 **Sustainable Rivers Audit 2004-2007 – How did the Lower Murray Valley fare?**
Keith Walker

9.45 **Coorong and Lower Lakes – Status report**
Kerri Muller/ Rebecca Lester

10.00 **Current major research initiatives, including bioremediation**
Russell Seaman/Tony Herbert

10.15 **MORNING TEA**

10.35 **Workshop Session Three: Breakout Groups I – Describing the EC of the River Murray – Darling to sea**
[Note: Each group has a different topical focus, but addresses the same set of questions. Questions will have aspects related to Data; Connectivity/interactions; Functionality; Key Characteristics – species, geology, soils, climate, elevation, landscape, etc.; Boundaries – what's in, what's out?]

Group 1: Connecting Groundwater
Chair: Phil Cole
Rapporteur: Jane Coram

Group 2: River and Tributaries
Chair: Ian Overton
Rapporteur: John Sherwood

Group 3: Floodplain and Wetlands
Chair: Anne Jensen
Rapporteur: Glen Scholz

Group 4: Biota
Chair: Keith Walker
Rapporteur: Michelle Kavanagh

12.30 to 1.30 LUNCH
[Rapporteurs prepare reports via PowerPoint]

1.30 Workshop Session Four: Report Back and Discussion
[Rapporteurs report back with PP presentations: 10 mins each + 5 mins for questions]

1.30 – 1.45 Group 1: Connecting Groundwater
Rapporteur: Jane Coram

1.45 – 2.00 Group 2: Rivers and Tributaries
Rapporteur: John Sherwood

2.00 – 2.15 Group 3: Floodplains and Wetlands
Rapporteur: Glen Scholz

2.15 – 2.30 Group 4: Biota
Rapporteur: Michelle Kavanagh

2.30 – 3.00 Plenary General Discussion 1: Challenges, Gaps & Issues
Chair: Bob Beeton

3.00 – 3.30 AFTERNOON TEA

3.30 Workshop Session Five: Plenary Panel - Threats to the Lower Murray – Future Trends
[panel of 6 experts speak for 5 minutes each on threats to the Lower Murray system]
Facilitator: Paul Dalby

3.35 Climate Change
Roger Jones
3.40 Salinity
Phil Cole
3.45 Acid Sulfate Soils
Richard Merry
3.50 Flow regulation/irrigation/management
Keith Walker
3.55 Invasive Species
Ben Smith
4.0 Land Clearing/revegetation/reforestation
Kate Holland

4.05 – 5.15 Plenary General Discussion 2: Threats to Lower Murray – Threats Matrix (see below)
Facilitator: Paul Dalby

6.30 Taxi's ordered for trip to pre-booked restaurant dinner for those wanting to attend

Friday 3 July 2009

9.0 Workshop Session Six: Breakout Groups 2 – Fitting Criteria to River Murray – Darling to Sea EC

9.05 A new approach to classification of Aquatic Ecosystems
Chris Auricht

9.20 Background to Six Ecological Community Listing Criteria and how criteria applied in practice; Instructions for Breakout Groups and Required Outcomes
Gina Newton/Matt White

9.45 – 10.45 Group 1: Criteria 1, 2, 3, 4, 5, & 6
Chair: Peter Harrison
Rapporteur: Gina Newton

Group 2: Criteria 1, 2, 3, 4, 5, & 6
Chair: Bob Beeton
Rapporteur: Anthony Hoffman

Group 3: Criteria 1, 2, 3, 4, 5, & 6
Chair: Rosemary Purdie
Rapporteur: Matt White

Group 4:Criteria 1, 2, 3, 4, 5, & 6
Chair: Keith Walker
Rapporteur: Vishnu Prahalad

10.45 – 11.15 MORNING TEA

11.15 – 12.30 Report Back and Plenary General Discussion 3
Chair: Bob Beeton
[Rapporteurs provide 5 minute report back each with no questions, followed by general questions and discussion]

12.30 – 12.45 Workshop Wrap Up by Chair, Bob Beeton

12.45 Workshop Close

1.00 – 2.00 Light LUNCH provided for those who can stay.

Threats Matrix (e.g. indicative guide for Session 5 discussions)

Aspect	Climate Change	Salinity	Acid Sulfate Soils	Flow regulation/ irrigation	Invasive species	Land clearing/ revegetation
Original state						
Current state						
Future trend/ Scenario						
Abatement potential						
Acceptable level?						
EC considerations						

Delegate List

Lower Murray, Sea to Darling – Invitees for Technical Workshop – 1-3 July 2009

Name	Affiliation/Expertise
☺Dr Chris Auricht	Habitat mapping; Aquatic Ecosystem Classification
☺ Steve Barnett	Groundwater/ SA DWLBC
☺ Paul Barraclough	DEWHA Ecological Communities Section
☺Prof. Diane Bell	Consultant/Social anthropology/ Indigenous
☺Prof. Bob Beeton	Chair, Threatened Species Scientific Committee (TSSC)
☺Dr Tumi Bjornsson	SA Dept. Water, Land and Biodiversity Conservation (DWLBC)
☺Deb Callister	DEWHA/ Coorong, Lower Lakes, Wetlands
☺Phil Cole	Murray Darling Basin Authority; Salinity, local knowledge
☺Dr Marcus Cooling	Consultant/ floodplain vegetation
☺Dr Jane Coram	Geoscience Australia/groundwater
☺Dr Paul Dalby	Consultant/wetlands/Fleurieu Peninsula
☺Joe Davis	MDBA, flow patterns in Lower Murray, engineer
☺Angela Duffy	SA Dept. Environment and Heritage, TECs
☺Prof Peter Fairweather	Freshwater biodiversity, ecology
☺Dr Mike Fleming	NSW DECC – Biodiversity Conservation, terrestrial
☺Dr Jennie Fluin	University of Adelaide/ paleolimnologist
☺Dr George Ganf	University of Adelaide, vegetation
☺Judy Goode	SANRM Board/River Murray Environmental Manager
☺Dr John Harris	River Sustainability Audit/ Consultant
☺ Prof. Peter Harrison	Threatened Species Scientific Committee
☺Dr Michael Hammer	Consultant, Murray Fish
☺ Steve Hemming	Flinders University/ Indigenous
☺Tony Herbert	SAMDBNRM Board/ Chowilla management
☺ Anthony Hoffman	DEWHA Ecological Communities Section
☺Dr Kate Holland	Groundwater, Landuse, Mallee clearing/CSIRO
☺Dr Anne Jensen	University of Adelaide/ floodplain vegetation
☺Dr Roger Jones	Victoria University/ climate change and water resources
☺ Simon Kaminskas	DEWHA Species Listing Section/ fish ecology
☺Michelle Kavanagh	Murray Darling Freshwater Research Centre, Knowledge Broker
☺ Dr Sebastien Lamontagne	CSIRO Land and Water, SYP, local knowledge
☺Remko Leijis	SA Museum/ Groundwater biota
☺Ben Leonello	InfraPlan/ SAMDBNRM Board/ Wetland, climate change
☺Dr Rebecca Lester	Flinders University / Hydrological modelling
☺Lance Lloyd	Loyd Environmental Services/ Env. Flows, Chowilla ECD
☺Kate Mason	SAMBBNRM/ lake ecology
☺Dr Richard Merry	Acid Sulphate Soils/CSIRO
☺Dr Kerri Muller	Consultant, Lake Alexandrina, sediments
☺Dr Gina Newton	DEWHA Ecological Communities Section/ aquatic ecologist
☺Dr Jason Nicol	SARDI/ aquatic + floodplain vegetation
☺ Colin O'Keefe	DEWHA ERIN/ mapping
☺Dr Rod Oliver	CSIRO WfHC/ Primary Production, water quality, nutrients
☺Dr Ian Overton	CSIRO WfHC, Leader Environmental Water/ Flow, Vegetation
☺Marcus Pickett	SA Conservation Council/ ornothologist
☺ Vishnu Prahalad	University of Tasmania/ HCVAE process
☺Dr Rosemary Purdie	Threatened Species Scientific Committee
☺Dr Julian Reid	ANU Fenner School/ Coorong birds
☺Grant Rigney	SA NRMBoard/ Indigenous
☺Dr Dan Rogers	DEH/ birds, restoration ecologist
☺Glen Scholz	DWLBC SA/ habitat classification, wetlands
☺Russell Seaman	DEH, Lower Murray Futures, habitat mapping
☺As. Prof. John Sherwood	Deakin University/Estuarine Hydro-Chemist
☺Emily Slatter	BRS Water Sciences - groundwater
☺Nerida Sloane	DEWHA/ Coorong, Lower Lakes, Wetlands

☺Dr Ben Smith	Invasive species, fish/SARDI
☺Dr Nick Souter	Consultant/DWLBC; modelling ecological function
☺Tracey Steggles	SA MDBNRM – wetland ecologist
☺Alys Stevens	SA Conservation Council/ criteria Fleurieu Peninsula wetlands
☺Dr John Tibby	University of Adelaide
☺Dr Eren Turak	Ecological river typology/condition/Dept. Env. & Climate Change
☺Rebecca Turner	SA MDBNRM Board
☺Paul Wainright	SA DEH, Senior Wetlands Officer
☺As. Prof. Keith Walker	TSSC Uni. of Adelaide, EWSAC/ water quality, invertebrates
☺Dr Todd Wallace	CSIRO/MDFC, Mildura Lab., vegetation, nutrients, River Murray
☺Peter Waanders	SA DWLBC/ Wetlands
☺Mark Walter	DWLBC RM Assessments
☺Matthew White	DEWHA/ Director Ecological Communities Section
☺Dr Qifeng Ye	SARDI – Environmental Management Rivers & Lakes
☺Brenton Zampatti	SARDI (formerly ARI, Vic) - Fish

Appendix 2: Characteristics of weirs and weir pools on the Lower River Murray. Source: MDBC (2004).

Structure name	Year built	Upper level (m)	Dist. from Murray Mouth (km)	Weir pool length (km)*	Storage capacity (GL)	Removal lowest flow (ML/d)	Removal highest flow (ML/d)	Reinstatement lowest flow (ML/d)	Reinstatement highest flow (ML/d)
Lock & Weir 1 - Blanchetown	1922	3.3	274	88	64	49,000	59,000	74,000	84,000
Lock & Weir 2 - Waikerie	1928	6.1	362	69	43	58,000	68,000	56,000	66,000
Lock & Weir 3 - Overland Corner	1925	9.8	431	85	52	58,000	68,000	66,500	76,500
Lock & Weir 4 - Bookpurnong	1929	13.2	516	46	31	58,000	68,000	68,000	78,000
Lock & Weir 5 - Renmark	1927	16.3	562	58	39	62,000	72,000	72,000	82,000
Lock & Weir 6 - Murtho	1930	19.2	620	77	35	55,000	65,000	67,500	77,500
Lock & Weir 7 - Rufus River	1934	22.1	697	29	13	24,000	34,000	30,500	40,500
Lock & Weir 8 - Wangumma	1935	24.6	726	39	24	40,000	50,000	47,000	57,000
Lock & Weir 9 - Kulnine	1926	27.4	765	60	32	48,000	58,000	55,000	65,000
Lock & Weir 10 - Wentworth	1929	30.8	825	53	47	48,000	58,000	55,000	65,000

*Weir pool length is generally the distance between the weirs (i.e., the river is a series of ponded lakes at low flow), except for Weir 6, which is shorter, but of an unknown length.

Appendix 3: Workshop breakout groups for Listing Criteria session and detailed results

<table>
<tr><th colspan="2">'Lower Murray' EC Assessment: Expert Technical Workshop
Session Six:
Fitting Listing Criteria to Aquatic Ecosystems</th></tr>
<tr><td>Group 1
Chair: Peter Harrison
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Rapporteur: Anthony Hoffman</td></tr>
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Deb Callister
Jane Coram
Mike Flemming
Laura Gow
Anne Jensen
Lance Loyd
Jason Nicol
Glynn Ricketts
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Steve Heming
Simon Kaminskas
Michelle Kavanagh
Kerri Muller
Dr Ian Overton
Emily Slater
Peter Waanders
Paul Barraclough
Phil Cole</td></tr>
</table>

Criterion One - Decline in geographic distribution. (AS = Aquatic Systems)

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Not well for entire AS but yes for elements of AS • AS linear & principally defined by landform & subject to change • extent & fragmentation • may work with components • hydrological change (dead trees) • contraction of 1956 floodline • mixing zone declined • connectivity with sea lost	• Not for large complex AS • yes for small discrete systems • e.g. Lower Lakes OK for geographic distribution and extent • rather than extent and decline, the loss of geophysically important functionality is important for AS	• Yes works for some AS like wetlands. • won't get contraction in linear geographic extent for this EC, but may get contraction in area • geomorphology important in determining extent [of this EC] (rather than water levels) - & will not change much	• Not particularly appropriate - ecological functionality rather than geography • ecological parts contracted, not the physical components (i.e. ecological functionality more important than geographic extent)
2. How do we best measure this Criterion in aquatic ecosystems?	• mapping key elements • hydric soils key (down to few metres) & shows historical • vegetation change, e.g. map decline in red gum & black box trees (~saline soil) • flow regime change • state change, e.g. wetland from sedge to sandfire • baseline? maybe last 30 yrs vegetation or pre-regulation (past & future 50 yrs) • Surveyor General mapped ~1900 • 1956 formation of clay • biota - pre European too hard • fish community altered - got baseline data (size class data) • 2004-2007 best wetland data • natives compared to exotics instream	• patterns of flooding regime (frequency) have changed • the system is zoned and there is a contraction of zones due to changes in flooding • conductivity and pH measures have changed • edges of the community being driven by changes in characteristics of the water body	• 1750 perspective - old floodplain areas may be determined (decrease can be measured) • old irrigation farms going back to original vegetation	• riverine components not changed, but Palustrine (wetland) components have • 50% loss of wetlands compared to 'natural' (pre-European) • assume reference condition is pre-European • natural versus current distribution and quality • satellite imagery - hydric soils • aerial photography
3. What are the challenges, impediments & issues for applying	• quality of baseline critical (get right data as baseline & acknowledging assumptions) • impediment is having a defensible threshold for a change in state	• engineering works are affecting flow regime • groundwater stygofauna distribution - lack of knowledge	• would not stand up well to a legal challenge • good evidence that can interpret natural variation in geographic distribution	• mobility of aquatic components • temporal and spatial variability scales important • applying criterion for different components is difficult as they

this Criterion to aquatic systems?	• deeply connected lotic systems are difficult • allow for variability in system between different components • link to cultural (Indigenous) land use mapping process - fish, medicine plants, swanning sites, etc.	• loss of variability becomes an important threshold consideration • change in structural complexity of components (e.g. channels, ephemeral lakes, floodplain) • AS naturally dynamic - do we seek to manage dynamics or reduce?		have different physical conditions
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• change in functional extent more important than geographical extent • understand when shifted to a different state • recognise temporal variability (and extent) - temporal element critical for AS • use of modifiers and core set of attributes • hydrological change cycles - timeframe important • doesn't take into account rarity value	• need a legally defensible line • use a 'likely to occur' delineation for an indicative approach • change in ecotype (e.g. temporary intermittent wetlands increased to permanent wetlands by barrages 30%, etc.)	• importance of connectivity • quality needs to be considered as well as extent	• rarity - composition of the flora (community rather than species) across the entire EC system (i.e. community rarity rather than species rarity) • water regime - provision of water to habitat types that shape and sustain the community • 'zone of influence' (water regime) - extent
5. How does the Criterion work for the RM-DS EC?	• Lower Lakes and Coorong so different from Murray corridor • levies & flood mitigation works (no more 1956 floodline!) • wetlands deliberately disconnected (disposal basins) • if use elements of AS, e.g. estuary, Lower Murray swamps • spread of salinised floodplain • Murray cod and golden perch - massive contractions, no recruitment since 2004 • loss of woodland habitat in floodplains (historical mapping) • Murray hardyhead in disconnected wetlands	• lower swamps down to 7%; reclamation work altered nutrient & sulphate regimes • deliberate disconnection of wetlands (will they restore?) • groundwater ecosystem declining in extent due to rising salinity • unless major change in water regime, restoration time for red gum & black box is not likely • probably also for flood dependant perennials • system driven by saltwater-freshwater flooding interaction	• for Lower Murray - connectivity is critical • won't apply to Chowilla, White Cliffs section • may apply to wetlands around Coorong (but not broadly to Coorong) • don't consider this criteria will work well for RM-DS EC as a whole	• wetlands most affected and lost (50%) - from levees and agriculture • diversity lost to monocultures • 1956 flood boundary a useful consideration of the boundary for this EC

Criterion Two - Small geographic distribution combined with demonstrable threat.

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Yes may work for small isolated AS (e.g. terminal lakes approach) • would work quite well for naturally rare and fragmented wetlands • EC of RM-DS not small, but may have small components • rules for demonstrability? - on a case by case basis - but must be legally defensible	• May apply to long, linear (narrow) fast flowing streams (i.e. in terms of area is small GD)	• Yes - for certain AS	• No - difficult criteria to apply, hard to argue that geographical distribution is small for large, complex river systems
2. How do we best measure this Criterion in aquatic ecosystems?	• could measure and depend on lifeforms • change in hydrology, e.g. lotic habitats - Anabranch only example left as lotic, main river is now lentic	• surrogate - freshwater fish distribution - substantially reduced from changes to flooding regime		
3. What are the challenges, impediments & issues for applying this Criterion to aquatic systems?	• if a big and complex system then cannot have a 'small' geographic distribution • does 'small' depend also on phase of climate or a temporal aspect? • what about ecological or hydrological disconnect?	• missing key flow events could cause changed state e.g. wet state change may affect seed bank		• EPBC Act not retrospective before 2000 • continuing actions like irrigation, grazing, etc - still a diffuse continuing threat • how deal with cumulative impacts in terms of AS?
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• rarity and/or fragmentation could be critical features • any scope to change concept of size (i.e. river channel a narrow band, e.g. aquatic corridor in Mallee landscape) • allow for well defined area of occupancy	• changes in flooding frequency and intensity may affect species		
5. How does the Criterion work for the RM-DS EC?	• as a whole the RM-DS EC would not trigger on this criterion, except for elements downstream in system (e.g. Coorong, Lower Lakes)	• key 'food' species disappearing from specific sites, e.g. Coorong • Indigenous icons affected – e.g. pelicans	• threats are undeniable • difficult to demonstrate (legally) 'small' geographic distribution • RM-DS EC likely not 'small'	• government actions (e.g. Wellington Weir EIS; Basin Plan is an 'action')

Criterion Three - Loss or decline of functionally important species.

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Yes but need to postulate how important species are and this is data dependent	• Yes	• Yes	• Yes - potentially powerful criteria which describes the situation
2. How do we best measure this Criterion in aquatic ecosystems?	• what is the test for a suitable criteria? (i.e. demonstrate a keystone species, etc) • look at health or population dynamics of key elements, e.g. extent, distribution, size class demographics (e.g. fish, trees)		• current status of fish community - well documented native fauna in general 10% abundance/diversity • need to consider age class, canopy extent, distribution and abundance, biomass, level of recruitment	• early records of fish abundance (including anecdotal?) • land use and occupancy mapping of Indigenous people • components and processes through floods • migratory birds • floodplain trees • estuarine macroinvertebrates
3. What are the challenges, impediments & issues for applying this Criterion to aquatic systems?	• how to defend? • EPBC Act - indigenous consultation a key component - embedded in criteria but not explicitly stated (particularly important aspects of iconic species) • restoration tricky for groundwater systems • how to differentiate trophic cascade from disturbed state? • not just about population sustainability - need old versions of trees (i.e. versus restoration of new which may take 100s of years)	• species are becoming extinct in the wild, e.g. pigmy perch (EPBC listed) restricted to highly engineered areas like irrigation systems • change of substrates is influencing species like catfish, trout cod, gudgeons - affected by sedimentation (demersal egg layers); small prey fish reduced - What are the flow-on effects?	• what if there are none left of the functionally important species (e.g. Murray cod)? • diadromous fish (i.e. that need to migrate to sea and back - system no longer connected to sea)	• trophic level interactions and productivity associated with pelagic community - autochthonous (very little allochthonous) - starved for food and energy → key threshold value • how functionally important species linked to processes
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• compare to examples like Yellowstone National Park where wolves reintroduced • need proof of concept of keystone and foundation species • need to be more flexible with	• allow for time lag between disturbance and impact on functionality	• not just general decline in species abundance, but also need to consider how age class, canopy extent, distribution, biomass, level of recruitment, productivity, etc.	

	generation times for thresholds - e.g. invertebrates, range of lifeforms, *Ruppia* an annual		have all been affected by the threatening process	
5. How does the Criterion work for the LM-DS EC?	• Murray cod - apex predator - keystone concept (keystone species) • Cultural issues need to be factored in i.e. cultural connection to Murray cod and red gum (e.g. shields, canoes) • strong argument for red gum (critically endangered) - important habitat for so many species (homes, nesting, nectar, soil stability, woody habitat, etc)	• decline in red gum and black box (time criteria may not be relevant as are long lived species) - salt into root system, reduced freshwater - recruitment down and insufficient to replace old trees → time lag in getting functionality back	• Murray cod a functionally important species but bony herring (bream) also very important to ecosystem function but they are not badly affected to date • refer to RAMSAR listing • loss of riparian vegetation in general	• records of early fishers may be useful (even anecdotal)
6. What are the keystone species or assemblages for the River Murray-Darling to Sea EC?	• *Ruppia tuberosa* in Coorong lagoon • black box may be just as or more important - juvenile release rate • red gum as foundation species, also coobah, *Lignum*, *Ruppia* • biofilm snails (Keith Walker)	• red gum - differential mortality, level of seed set driven by frequency and timing of freshwater • suspect submerged vegetation could be organising system (e.g. in Lower Lakes → fish)	• mussels - data on significant changes but may not be functionally important to whole EC • big trees like red gum and black box (for nutrients, habitat, insect and bird fauna, snags, etc) - river red gum and possibly black box likely to trigger this criteria. • Potentially a range of other species may trigger also, e.g. Lignum, Ruppia (critical at Coorong end; impact on Murray hardyhead and other aquatic fauna), Melaleucas removed in a lot of areas	• Murray cod; golden/silver perch, catfish, small native fish, Murray River crayfish • all submerged aquatic plants e.g. *Ruppia* • snails and other invertebrates • river red gum, black box, floodplain trees • Murray turtle, *Emydura*

Table 5: Criterion Four - Reduction in community integrity.

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Yes - totally applicable at a range of scales and levels • provides opportunity to pick up the overarching significance of flow regime as a key ecological process	• Yes - widespread loss of functional integrity • flood dependant species and community level in decline	• Yes - very important for aquatic systems • loss of connection to sea (changes to fish fauna)	• Yes
2. How do we best measure this Criterion in aquatic ecosystems?	• flow linked to a number of processes and well documented (i.e. huge body of evidence to support that flow is important and can describe changes in many facets of flow - temporal, frequency, size, etc.)		• dominance of invasive species • number of algal blooms • changes in species abundance and composition (especially vertebrates) • changes (balance) between native and non-native species - aquatic and terrestrial	• relative abundance of native versus exotic species (e.g. willow, carp) • native fish populations • water level
3. What are the challenges, impediments & issues for applying this Criterion to aquatic systems?	• in general lack of data for most aquatic ECs would be an impediment (in most catchments hydrological models poor and no natural flow data, no calibration, etc)	• time lag in getting functionality back • irretrievable loss of native species (but not any immediate invasion of invasive/exotic species RM-DS) • change to substrates • trophic flow-on effects	• algal blooms - managed by flow regimes but a potential threat • macrophytes very important - regeneration impacted by carp (is there evidence?) especially in lagoons and wetlands • biophysical impacts - connectivity important • some threats have long lag effects e.g. groundwater, salinity • to reinstate age structure would require a lot of time (e.g. old trees) • system has natural resilience but changes to landscape have impacted on this immensely	• processes of connectivity affect integrity - e.g. allochthonous versus autochthonous (energy and carbon) • timescales involved in changes - what is appropriate to what community or process? • engineering interventions - effect of each is difficult to identify

4. How can the Criterion be better adapted for aquatic Ecological Communities?	• regarding thresholds - similar to restoration issue of timeframes, etc. • consider short generation times for invertebrates and some plants - particularly with respect to thresholds • flexibility		• generally, appropriate thresholds for aquatic systems (such as Coorong) • need to work out critical time when need to get floods for lifecycles •	
5. How does the Criterion work for the RM-DS EC?	• works very well • the River Murray is unique in that there is a lot of historical data on flow and other aspects (back to 1891) • *Lignum* should be listed, distribution declining	• estuarine species have been restricted, reduced or lost • recruitment affected - seed and egg bank function • system is zoned and there's a contraction of zones due to changes in flooding regimes (decline in geophysically important functionality)	• invasion by carp is a standout - caused massive alteration in community - loss of several important aquatic species and changes in invertebrate composition • flow regimes critical • Keith Walker studies on mussels and spiny crayfish - replacement of fluvial systems (flowing river turned into pools) → profound changes in distribution and abundance • *Lippia* another key threat • estuary dependent organisms lost or declining due to hypersalinity in Coorong (need to restore integrity within 10 years or less) - including barrage fishways shut for 3-4 years → huge decline in recruitment • what are the critical timeframes to reinstate red gums to appropriate age structure? • overall - appropriate salinities need to be re-established within 10 years or integrity gone - so would probably trigger 'critically endangered'	• carp - lot of biomass and productivity locked up - lot of habitat degradation • willows

Table 6: Criterion Five - Rate of continuing decline.

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Yes and no - nature of Australian variability	• Yes - accelerating (e.g. tree health)	• Yes	• Yes - e.g. rates of decline in the Lower Lakes rapid in the last 5 years (substantial period of low flow and disconnection)
2. How do we best measure this Criterion in aquatic ecosystems?	• partial disconnect between flow and community change - lag effects a complicating factor • diversions versus inflows • connectivity (increasing disconnection of the system)	• shift in salinity regime	• natural flows versus un-natural flows better measure of effect of water movement through system (e.g. flooding of red gums dropped from once every X years to once in Y years) • difference between natural and managed river condition (but can't quantify 1750 hydrology)	
3. What are the challenges, impediments & issues for applying this Criterion to aquatic systems?	• demonstration • natural variability • lag effect and ongoing impacts • rate of change of health can spiral and have flow-on effects (e.g. trophically) • pace of regulatory change • climate change coupling to inflows	• adaptive management research exists • water management plans exist	• can argue natural climate and anthropogenic influences (i.e. climate change coupling) • some threats have long lag effects, e.g. groundwater, salinity	• 30,000 ha of irrigation development in SA - intensifying degradation • groundwater usage not well monitored
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• lag effects around recovery time • impacts operate over long time scales • tipping points need to be factored in			
5. How does the Criterion work for the RM-DS EC?	• rate of disconnection • % of inflow compared to extraction (rather than just extraction) • appropriate extraction %	• significant detrimental change (70%) has rapidly occurred in last 10 years on river floodplain -	• decline in red gums well documented • cap established in MDB in 1994-95 flows - system	• decline caused disconnect to wetlands and ocean • water allocation problem - rapid allocations in 1980s and

	• is the rate of diversions still increasing? - but not much more to take	documented information about decline from 1985 to current date	depauperate then and worse since (dry decade since 1997, especially last few years) • acid sulfate soils potential indicator - critical for Lower Lakes - timeframe, impact of re-flooding on fish etc. unknown • salinity in Lakes and Coorong - work done on projections	1990s - no surplus in the system

Criterion Six - Quantitative analysis showing probability of extinction.

Questions	Group 1	Group 2	Group 3	Group 4
1. Does this Criterion work for (complex, dynamic) aquatic ecosystems?	• Yes - possible if have a well defined community and understand when it changes to something different (i.e. demonstrate that flip to other state is permanent)	• Yes - potentially	• Yes - can be applied conceptually (e.g. Coorong)	Yes - some scope for application
2. How do we best measure this Criterion in aquatic ecosystems?	• data dependent • proof of role of keystone species • if no data or examples use modelling (Moktop?)		• data needs to be available	
3. What are the challenges, impediments & issues for applying this Criterion to aquatic systems?	• data availability • proof of keystone species • not a challenge that red gum also occurs outside nominated area • cultural input to Criterion - *Cyrpus vegiatus* and sedge used for weaving		• how is extinction defined? - complete extinction or local extinction in EC? (e.g. could lose things from Coorong forever, but they occur somewhere else) • local extinction is relevant in consideration of EC	• scope to apply PVA type analysis to selected species but that may not capture sense of community as well as Lester modelling • cultural aspect - have to keep it a living system or we will lose something immeasurable
4. How can the Criterion be better adapted for aquatic Ecological Communities?	• trying it out - robust method needed for Ecological Communities			
5. How does the Criterion work for the RM-DS EC?	• Coorong modelling (Flinders University) has potential • use species listed under Criterion 3 (i.e. those identified as potential keystone species) to try it out • focus on red gum &/or black box as more literature/data and a stronger case • argument for having red gum and black box together as they have complementary roles	• modelling work being done for Lower Lakes (Rebecca Lester, Peter Fairweather - Flinders University) • Murray Futures Project will be looking at Murray River up to SA/VIC border		• Coorong conceptual modelling by Lester and Fairweather a good start

	• black box is a classic of the sliding baseline - on the way out since 1956 floodline • river coobah and black box both important to water bird breeding but to a different suite of birds than breeding in river red gum - published data on this • Ruppia - historic data- potentially something could be done with this			