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EXECUTIVE SUMMARY

The Edward-Wakool system is a major anabranch and floodplain of the Murray River. It is a complex network of interconnected streams, ephemeral creeks, flood runners and wetlands intersected by irrigation channels. This system has a long history of regulated flows for irrigation, stock and domestic water supply but it is also recognised as having high native species richness and diversity, including threatened and endangered fishes, frogs, mammals, and riparian plants.

A range of environmental water use strategies have been proposed for the Edward-Wakool system (Hale and SKM 2011). This report focuses on the assessment of ecosystem responses to one of the watering strategies; delivery of freshes to the Edward-Wakool rivers to promote ecosystem function for in-channel flora and fauna. In 2011-12 Commonwealth environmental water was delivered to the Edward-Wakool system on three occasions. The three environmental watering actions were:

- November 2011 environmental watering in Colligen Creek
- February 2012 environmental watering in Colligen Creek and the Wakool River
- April to May 2012 environmental watering via irrigation escapes to the Edward and Wakool Rivers.

Delivery of environmental water in November 2011

In November 2011 5.5 gigalitres (GL) of Commonwealth environmental water was delivered to Colligen Creek in conjunction with 1.7 GL of water supplied by the New South Wales Government. The environmental water was used to gradually raise flows commencing on 19/11/11 and then lower flows over 20 days.

The primary objective for the November 2011 environmental watering was to “encourage movement of large bodied native fish such as Murray cod, silver perch and golden perch to initiate spawning and recruitment of these species” (CEWO 2012a). The environmental watering was also expected to maintain and enhance in-stream habitat.

Delivery of environmental water in February 2012

In February 2012 7.5 GL of Commonwealth environmental water was delivered to Colligen Creek and the Wakool River in conjunction with 6.9 GL of water supplied by the New South Wales Government. The environmental watering in Colligen Creek commenced on 8/2/2012 to build on an unregulated-flow event due to rainfall in the Murray catchment. The flow was maintained for five days before receding to baseflows by 1/3/2012. The delivery of environmental water to the Wakool River from the Wakool escape (providing water from the Mulwala Canal) commenced on 14/2/2012 but was reduced on 1/3/2012 and suspended on 6/3/2012 due to rainfall in the upper Murray catchment.

The objectives of the February 2012 watering action in Colligen Creek and the Wakool River were to “provide opportunities for small-bodied fish, such as Murray-Darling Rainbow fish and carp-gudgeons, to access important breeding and feeding habitat and improve the condition of the river and riparian ecosystems” (CEWO 2012b).

Delivery of environmental water in April to May 2012

During April and May 2012 39GL of Commonwealth environmental water was delivered into the Edward-Wakool system in conjunction with 0.3GL of water provided by the New South Wales Government. Releases were made from the Edward and Wakool Escapes from the Mulwala Canal. The environmental water was in addition to unregulated flows that had been delivered into the system via the Edward, Wakool and Yallakool irrigation escapes.

The objective of the April to May 2012 environmental watering action in the Edward-Wakool system was to “provide and maintain refuge habitats for remnant fish populations, particularly Murray cod, from hypoxic blackwater (water containing low levels of oxygen) that can severely impact fish” (CEWO 2012c). This watering action also contributed to the outcomes of environmental watering in the mid-Murray River system (refuge habitat and replenishment flows) (CEWO 2012d).

Monitoring of responses to environmental watering

Monitoring of ecosystem responses to environmental watering was undertaken in four rivers in the Edward-Wakool system; Colligen Creek in the northern part of the system, Wakool River and Yallakool Creek in the southern part of the system, and Little Merran Creek in the western part of the system. Parameters assessed were water quality, organic carbon, phytoplankton, biofilms, whole stream metabolism, leaf-litter breakdown rates, zooplankton, macroinvertebrates, frogs and fish. For the majority of the parameters sampling was undertaken monthly between September 2011 and early May 2012. Sampling of fish larvae was undertaken fortnightly between September 2011 and April 2012. Additional sampling of water chemistry was undertaken during the blackwater event in autumn 2012.

Hypotheses

Environmental water was delivered on the basis of the two main management objectives: 1) provision of freshes for fish and ecosystem function (November 2011 and February 2012 environmental watering) and 2) provide and maintain refuge habitats for remnant fish populations from hypoxic blackwater (April to May 2012 environmental watering). Hypotheses were developed separately for each objective.

Provision of freshes for fish and ecosystem function (November 2011 and February 2012):

- There will be a short-term increase in dissolved organic carbon and particulate organic carbon levels following the in-channel environmental watering, but the environmental watering is not expected to trigger a blackwater event in this system.
- Following environmental watering, there will be a change in the community composition of algal biofilms, with an increase in early successional algal taxa in this river.
- Increased flow variability due to environmental watering will ensure biofilm organic biomass remains below nuisance levels. Biofilm organic biomass is expected to be highest in rivers with a relatively constant discharge over this period.
- Increased flow variability due to environmental watering will maintain macroinvertebrate diversity (measured as total family richness) i) via the provision of additional habitat and food resources made available with bank inundation (organic matter) and potential increases in algal primary production and/ or ii) via disturbance which eliminates competitive exclusion in the community by continually allowing less competitive species opportunities to colonise (intermediate disturbance hypothesis, Townsend et al. 1997).
- Increases in river flow should select for invertebrates that are more flow-dependent, rheophilic, primarily through changes in habitat area and availability (Brunke et al. 2001; Reich et al. 2010).
- Increases in river flow should select for macroinvertebrate feeding groups such as filterers that utilise pelagic food sources which potentially increase with flow. In contrast, decreases in river flow should select for macroinvertebrate feeding groups such as collector-gatherers, scrapers or shredders that feed predominately on benthic food sources.
- Frog abundance (number of individuals calling and observed) will increase during the environmental watering in Colligen Creek in February 2012
- Spawning of some native fish species, as measured by the abundance of larvae, will increase following the environmental watering.

Environmental watering during blackwater events to provide and maintain refuge habitats (April to May 2012):

- Release of environmental water from irrigation escapes will provide localised refugia with higher levels of dissolved oxygen and lower levels of organic carbon.

Ecosystem responses to environmental watering

Provision of freshes for fish and ecosystem function (November 2011 and February 2012):

- **Very low dissolved oxygen concentrations were not observed during or after environmental watering events in Colligen Creek and the Wakool River.** Dissolved oxygen concentrations in all river reaches were above the 4mg/L threshold of concern for aquatic health between September 2011 and February 2012. However, it is important to note that none of the events monitored involved water inundating the flood plain (where low DO and 'blackwater' events can occur).
- **Environmental watering in Colligen Creek and the Wakool River in February 2012 did not result in substantial changes to organic matter type or quantity.** There was no evidence of blackwater associated with the environmental watering, as dissolved organic matter profiles were very similar in all four rivers from October 2011 to January 2012.
- **There was a positive response of phytoplankton biomass (water column chlorophyll-*a* concentrations) to environmental watering.** Chlorophyll-*a* concentrations in water from Colligen Creek were maintained after the environmental watering in November 2011, whereas over the same period chlorophyll-*a* levels reduced in Yallakool Creek, Wakool River and Little Merran Creek that did not receive environmental water.

- **Rates of the key ecosystem processes, primary production and ecosystem respiration, were not greatly changed after the environmental watering.** The major reason is that low nutrient concentrations in the water constrain primary production. Rates of primary production were greatly reduced during environmental watering. This is because primary production is also controlled by the turbidity of the water, which is a natural property of the fine soils in the catchment.
- **Nitrogen and phosphorus concentrations in these rivers were well below the level where excessive algal growth (and bloom formation) is likely.** High flows in mid-March 2012 in some streams resulted in higher concentrations of nutrients in the water.
- **The rate of ecosystem respiration increased faster with water temperature than the gross primary production rate.** Coupled with lower oxygen solubility at higher temperatures, this finding suggests that extended periods of high temperatures will greatly increase the likelihood of suboxic, even anoxic events, which may then cause fish kills and other undesirable outcomes.
- **The energy base of the streams was based on organic carbon from the floodplain (heterotrophic) rather than primary production from within the channel (autotrophic) under all flow conditions.** Despite the finding that the study streams were almost always heterotrophic, in-stream production through biofilms, phytoplankton and macrophytes is a very important source of carbon and energy to the aquatic foodwebs.
- **There was no apparent response of leaf-litter breakdown rates to flow regime as breakdown rates were similar among the four rivers.** This may suggest that leaf-litter breakdown rates are not sensitive indicators of changes in hydrological regimes in the Edward-Wakool system.
- **There was no response in organic biomass of biofilms to the environmental watering.** One month old biofilms in Colligen Creek showed no change in organic biomass after the November environmental watering, although there was evidence of a build up of inorganic sediment on the biofilms over this period.
- **The amount of active algal biomass (measured as chlorophyll-a) responded positively to environmental flows.** Chlorophyll-*a* concentrations of one month old biofilms from Colligen Creek remained relatively constant following the November 2011 environmental watering, whereas over the same period chlorophyll-*a* levels of one month old biofilms increased in the Wakool River and increased substantially in Yallakool Creek, as the constant discharge in these systems created conditions beneficial for rapid algal growth. The chlorophyll-*a* levels in Yallakool Creek in December did not approach nuisance levels outlined by Quinn (1991).
- **There was a seasonal increase in the abundance and number of observed taxonomic groups (diversity) of zooplankton from November to December 2011 in all four rivers, but these parameters did not appear to respond to environmental watering.** Patterns of abundance and diversity in Colligen Creek were comparable to the rivers not receiving environmental water.
- **There was an increase in the diversity of zooplankton in Colligen Creek following the November 2011 environmental watering, largely due to increases in a small number of rarely sampled taxon.** This suggests that environmental watering may promote diversity in this group.
- **There were mixed responses of macroinvertebrate biodiversity to the environmental watering.** Macroinvertebrate diversity was higher in Colligen Creek, Wakool River and Little Merran Creek than in Yallakool Creek. This suggests that the environmental watering in Colligen Creek did not increase family richness but maintained diversity. In contrast diversity was lower in Yallakool Creek which did not receive any environmental flows or the unregulated flow in September 2011.
- **The environmental watering did not increase the occurrence of macroinvertebrates that were more flow-dependent.** One potential reason for this could be antecedent drought conditions had already eliminated sensitive flow-dependent taxa from the system. Also, the estimation of flow-dependence for taxa was based on family-level responses to flow which potentially could overlook species-specific responses.

- **Changes in macroinvertebrate feeding groups reflected changes in flow regime in the four rivers.** Increased flow in Colligen Creek increased abundances of filterer feeding invertebrates that feed on pelagic food sources and decreased abundances of collector-gatherers that feed on benthic food sources. In contrast, there were increased abundances of scrapers and shredders that feed on benthic food sources in Yallakool Creek that had constant low flow. Environmental flow events tended to make rivers more similar in terms of macroinvertebrate communities, whereas communities tended to differ more with time in the absence of environmental flows.
- **There were consistent numbers of Murray cod larvae present in the study rivers, but no evidence of increases in spawning of this species in response to the environmental watering in Colligen Creek in November 2011.** Despite evidence of silver perch and golden perch adults occurring in the system, we did not detect these species spawning in response to the environmental watering with the sampling methodology employed in this project. Therefore no conclusion can be made regarding the effect of the environmental watering on spawning of these two species.
- **There was an increase in the abundance of carp gudgeon larvae in Colligen Creek following the November environmental watering.** This response can be attributed to the environmental watering because there was little or no increase in the abundance of carp gudgeon larvae in the Wakool River, Little Merran Creek or Yallakool Creek over this period.
- **There was no immediate response of frogs to the February 2012 environmental watering.** The abundance of frogs in Colligen Creek did not change in response to the February environmental watering or during the high flows in March. In contrast the abundance of frogs increased in March and April 2012 in Yallakool Creek, the Wakool River and Little Merran Creek with the most notable increase occurring in Yallakool Creek. The frog community in Colligen Creek was different to that in the three other rivers. It is inconclusive whether this was influenced by the environmental watering in Colligen Creek or reflects geomorphic features of the study reach. A more comprehensive understanding of frog responses to environmental watering could be gained by increasing the number of sample reaches within each river in order to capture the full extent of geomorphic diversity within each river.

Environmental watering during blackwater events to provide and maintain refuge habitats (April to May 2012):

- **During the blackwater event in early 2012, Colligen Creek, Yallakool Creek and the Wakool River that received environmental water via irrigation escapes, had faster recovery of higher dissolved oxygen levels than Little Merran Creek that did not receive environmental water.** Little Merran Creek, was the only system continuing to be affected by blackwater in April.

Summary of findings

The responses to environmental watering in the Edward-Wakool system in 2011-12 are summarised in Table i. There were a number of significant responses to the November 2011 environmental watering. This demonstrates there are clear ecosystem benefits of providing in-channel freshes to the Edward-Wakool system in spring. In contrast, there were almost no significant responses to the February 2012 environmental watering. As the discharge during the November 2011 and February 2012 events in Colligen Creek were of similar magnitude, the difference in the number of significant ecological responses between the November and February events could be attributed to either the seasonal timing of environmental watering or the influence of antecedent conditions. There were a number of significant responses to the April to May 2012 environmental watering in Colligen Creek, Wakool River and Yallakool Creek, particularly for those parameters relating to water chemistry and riverine productivity. This demonstrates that the environmental watering achieved the objective of mitigating the effects of hypoxic blackwater and was able to provide and maintain refuge habitat (favourable water chemistry) for fish populations.

Table i. Summary of ecosystem responses to environmental watering in the Edward-Wakool system in 2011/12.
N/A = not evaluated

Indicators	November 2011 environmental watering in Colligen Ck	February 2012 environmental watering in Colligen Ck and Wakool River	April to May 2012 environmental watering from irrigation escapes	Comparison among rivers over the whole study period (assessment of flow regime)
Water quality	No response detected	No response detected	Faster recovery of dissolved oxygen in rivers receiving environmental water	No marked differences except higher DO peaks in Colligen Ck and lower dips in Yallakool Ck Sept - Feb
DOC/POC	No response detected	No response detected	DOC levels reduced earlier in systems that received environmental water	N/A
Organic matter	Slight decrease in Colligen during peak flow	No response detected	Carbon load reduced earlier in systems receiving e-water	N/A
Phytoplankton biomass	Biomass in Colligen Ck remained stable after the e-watering but reduced in other three rivers	No response detected	Biomass maintained in the systems receiving e-water but reduced in Little Merran Ck	Little Merran Ck significantly higher biomass than other three rivers
Biofilm biomass	Algal biomass was maintained in Colligen Ck but increased in Wakool R and Yallakool Ck	N/A	N/A	N/A
Biofilm diversity	Increase in early successional diatoms in Colligen Creek	N/A	N/A	N/A
Whole stream metabolism	No response detected	No response detected	Depression in rates of primary production during high flows	No significant differences among rivers
Leaf-litter breakdown rates	N/A	N/A	N/A	No significant differences among rivers
Aquatic vegetation cover	N/A	N/A	N/A	Little Merran Ck had significantly lower % cover of aquatic vegetation

Table i (continued). Summary of ecosystem responses to environmental watering in the Edward-Wakool system in 2011/12.

Indicators	November 2011 environmental watering in Colligen Ck	February 2012 environmental watering in Colligen Ck and Wakool River	April to May 2012 environmental watering from irrigation escapes	Comparison among rivers over the whole study period (assessment of flow regime)
Zooplankton abundance and taxa richness	No response detected	No response detected	No response detected	Little Merran Ck had different community composition to other reaches
Macroinvertebrate biodiversity	N/A	N/A	N/A	Higher richness in Colligen Ck compared to Yallakool Ck but similar to Wakool R and Little Merran Ck
Macroinvertebrate Rheophily score	No response detected	Decrease in Rheophily score in Colligen Ck	N/A	No significant differences among rivers
Macroinvertebrate composition (FFG)	N/A‡	No response	N/A	Colligen Ck had higher abundance of filterers, predators & lower abundance of collector-gathers than the other three rivers
Macroinvertebrate abundance	No response detected	No response detected	N/A	No significant differences among rivers
Frogs	N/A	No response detected	No response detected	Frog composition different in Colligen Creek than other three rivers
Fish spawning/ recruitment	Increase in abundance of larval carp gudgeon. No response of other fish species	No response detected	No response detected	N/A

‡ Cannot evaluate since Colligen Creek differed from the other two – three rivers pre November 2011 environmental flow.