Vegetation Dynamics of the Menindee Lakes with Reference to the Seed Bank

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any other university or other tertiary institution and to the best of my knowledge and belief contains no other material previously published or written by another person, except where due reference is made in the text.

I consent to this thesis being available for copying and loan, if accepted for the award of the degree.

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Jason M. Nicol

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Summary

The Menindee Lakes are a series of shallow floodplain depressions on the Lower Darling River, approximately 300 river kilometres upstream from the confluence with the River Murray, in southeastern Australia. The system is the fourth largest water storage in the Murray-Darling Basin (1,680 Gl) and comprises of seven shallow deflation basins: Lakes Malta, Balaka, Bijiji, Tandure, Pamamaroo, Menindee, Cawndilla, and Lake Wetherell. Lake Wetherell was created by the construction of the Menindee Main Weir and subsequent flooding of the main channel of the Darling River and surrounding floodplain. Each deflation lake is individually connected to the Darling River with the exception of Lake Cawndilla, which is connected to Lake Menindee by Morton Boolka Channel.

The climate of the Menindee area is arid with a mean annual rainfall of 243.7 mm, average maximum temperature in January of 34.1° C and in July of 16.9° C. Due to the flat topography, local runoff is negligible and the impact of precipitation on the water budget of the lakes is negligible in comparison to evaporation, which exceeds 2.5 m $year^{-1}$. Prior to regulation, the Menindee Lakes would fill when river levels were higher than the sill level of the feeder creeks. When river levels receded, the lakes drained back to the Darling River leaving a residual pool, which would evaporate. The Darling River is one of the most variable rivers in the world and prior to regulation the Menindee Lakes were often dry for extended periods. The large lakes (Cawndilla, Menindee, Pamamaroo and Tandure) would fill on average every once every one to two years and the longest droughts lasted five years. The small lakes (Bijiji, Balaka and Malta) filled on average every two to three years with the longest droughts lasting eleven years.

Construction of the Menindee Lakes Scheme was completed in 1968 and is a series of small dams, regulators, weirs, channels and levees designed to conserve Darling River floodwaters. The main structure is the Menindee Main Weir, which raises the level of the river 12 m above the bed level, creating Lake Wetherell and filling Lakes Tandure, Bijiji, Balaka and Malta. This hydraulic head is used to gravity feed Lakes Pamamaroo, Menindee and Cawndilla. The hydrologic regime is now dictated by the operating procedures developed by the New South Wales Department of Infrastructure, Planning and Natural Resources. The priority of operations is to maximize the potential supply of water for all users and to maximize water quality within the lakes and Lower Darling River for human uses. Now the lakes are inundated for longer periods; rates of drawdown are more rapid and small to medium sized floods downstream of the scheme and in the Darling Anabranch have been eliminated. Despite increased permanency, large water level fluctuations are still common and drying cycles have not been lost entirely. Since the completion of the scheme Lake Malta has dried four times, Lake Balaka three times, Lake Bijiji twice, Lakes Tandure and Pamamaroo once, Lake Menindee five times and Lake Cawndilla four times. Of all of the lakes, Lake Malta is least impacted by regulation.

The vegetation dynamics and role of the seed bank have not been extensively investigated in ephemeral systems. The seed bank provides a mechanism for species persistence through unfavourable conditions and colonisation during favourable conditions. In ephemeral lakes, large and aseasonal water level fluctuations are common which may result in long periods of unfavourable conditions. Plants growing in these environments must be able to persist through unfavourable conditions for growth and survival. The main objectives of this study were:

- To investigate the seed density, species richness and composition of the seed banks of selected lakes.
- To determine if there are any within lake patterns in seed bank density, species richness and composition.
- Examine the effect of different water regimes on germination and recruitment from the seed bank.
- Determine water regime preferences for germination and recruitment of common species.
- Investigate vegetation change during an extended drought.
- Determine flood tolerances of *Xanthium occidentale, Cyperus gymnocaulos* and *Ludwigia peploides*.
- Investigate the interaction between nutrients and water regime on recruitment from the seed bank.

No information regarding the seed banks of the Menindee Lakes was available; therefore, a reconnaissance study was undertaken. The aims of this study were to determine the seed density, floristic composition, zonation with respect to elevation, differences between and within lakes and germination strategy (pattern through time) of Lake Malta, Bijiji and Menindee seed banks. Results showed that the seed bank of each lake had a different floristic composition and Lake Menindee had a depauperate seed bank (Lake Malta 27 species and 6,300-43,983 seeds m^{-2}, Lake Bijiji 24 species and 2243-27,417 seeds m^{-2} and Lake Menindee one species and 117-233 seeds m^{-2}). Within each lake, the seed density, species richness and composition was spatially variable but no zonation with respect to elevation was observed. In Lake Bijiji, the sampling site on the northern shore of the lake had a significantly less dense and less species rich seed bank than the other locations; however, this was not present in Lake Malta. Over 90% of the total germination from the seed bank from all lakes occurred in the first six weeks. This study also provided evidence that the seed bank around the edges of the lakes was concentrated in zones of organic matter deposition (strandlines).

The seed bank density and species composition of the strandlines and adjacent sediment was investigated in Lakes Cawndilla, Menindee, Tandure (large highly regulated lakes) and Malta (a small lake minimally impacted by regulation). Three hypotheses were tested in this study:

1. The strandline will have a denser and more species rich seed bank.
2. The strandline provides favourable microsites for germination and recruitment.
3. All species present in the seed bank will bet hedge.

The strandline seed banks of Lakes Cawndilla (strandline 25,753 seeds m^{-2} and adjacent sediment 2,730 seeds m^{-2}), Menindee (strandline 7,427 seeds m^{-2} and adjacent sediment 646 seeds m^{-2}) and Tandure (strandline 8,006 seeds m^{-2} and adjacent sediment 2,178 seeds m^{-2}) were significantly denser and more species rich than the adjacent sediment, whereas there was large, species rich seed bank outside the strandline in Lake Malta strandline (70,180 seeds m^{-2} and adjacent sediment 54,266 seeds m^{-2}). The organic component of the strandline may act to reduce evaporation from the soil and provide a favourable microsite for germination and recruitment. Of the 58 species present in all seed banks 37 bet hedged (had persistent seed banks).

The effect of water regime on recruitment from the seed bank and the optimal water regime for germination and recruitment of common species were investigated in a pond experiment. This experiment had three aims:

1. To test the hypothesis that different water regimes will give rise to different plant communities from the same seed bank.
2. Determine optimal water regimes for germination and recruitment of common species.
3. To formulate a testable conceptual model describing recruitment from the seed bank under different, controlled water regimes.

Different water regimes did give rise to different plant communities from the same seed bank. *Myriophyllum verrucosum* was the only species that germinated whilst submerged. All other species required exposed soil with high soil moisture to germinate. All terrestrial and floodplain species died if flooded, however several amphibious species were present that persisted whilst flooded, despite requiring exposed soil for germination. The conceptual model consisted of eight states (dependant on whether the soil was exposed or inundated, soil moisture content, duration of inundation and species present) that predicted which species would be present in each of the states (providing they were present in the seed bank).

A series of surveys to investigate recruitment from the seed bank in the field during a period of extended drought was undertaken over 488 days. This study had four aims:

1. To investigate the relationship between the extant vegetation and selected environmental variables.
2. To test a conceptual model that predicts how the environment changes with fluctuating water levels. The model consists of five states (windows of opportunity) that the system switches between; depending water level, elevation and the species present in the seed bank and extant vegetation. The five states are: window of opportunity closed due to inundation, window of opportunity open for germination establishment and reproduction (exposed soil with high moisture content in the top 7.5 cm), window of opportunity closed for germination but open for establishment and reproduction (low soil moisture in the top 7.5 cm), window of opportunity closed for germination and establishment but open for reproduction (top 15 cm low soil moisture) and all windows of opportunity closed because the soil is dry (low soil moisture to 40 cm).

3. To test the part of the conceptual model derived from the pond experiment.
4. To investigate the change in the germinable seed bank as the window of opportunity for germination opens, plants recruit and replenish the seed bank. This aim tests the hypothesis that the species that recruit will reflect the seed bank before the window of opportunity for germination opens, then when the window of opportunity for germination opens the seed bank will become less similar and then recover (reflect the recruited vegetation) after the species present have replenished the seed bank.

The floristic composition of Lake Malta was correlated with sediment exposure time and clay content, Lake Balaka with sediment exposure time, soil moisture and clay content, Lake Wetherell with elevation, canopy cover and elevation of the water relative to the quadrat and Lake Menindee with sediment exposure time, soil moisture, elevation and clay content. The floristic composition of Lake Cawndilla was not correlated with any of the measured environmental variables. As water levels fell the window of opportunity for germination opened once the sediment was exposed and closed when the sediment surface dried. The window of opportunity for establishment and reproduction did not close until the sediment dried further. For the most desiccation tolerant species the window of opportunity for growth and reproduction remained open. If the species composition of the seed bank was known, the pond model predicted the potential floristic composition. However, it did not take into account sediment exposure time.

Extended drought in the Darling catchment meant that the lakes did not fill during the study period and the effect of flooding could not be investigated in the field. Therefore, a pond experiment to test the effect of flooding on *Xanthium occidentale*, *Cyperus gymnocaulos* and *Ludwigia peploides* was undertaken. Three hypotheses were tested:

1. *Xanthium occidentale* when top flooded for more than two weeks will die. Plants partially flooded will survive, increase above ground to below ground biomass ratio and grow when water levels fall.
2. *Cyperus gymnocaulos* when top flooded for two weeks will show no adverse effects and grow when water levels fall. When top flooded for more than two weeks the above ground biomass will senesce and resprout when water levels fall. Plants partially flooded will show no adverse effects.

3. *Ludwigia peploides* when top flooded will rapidly increase above ground biomass in order to reach the water surface.

Each species generally responded as hypothesised. *Xanthium occidentale* also produced adventitious roots and lost stem rigidity when partially flooded. *Cyperus gymnocaulos* showed reduced growth rates when partially flooded compared to plants that were not flooded.

Water regime is only one factor that may influence the floristic composition derived from the seed bank. A pond experiment was undertaken to test the hypothesis that the combination of different soil nutrient concentrations and water regime will give rise to different plant communities from the same seed bank. The effect of different nutrient loadings however, had no effect on floristic composition and the differences could be explained by differences in water regime.

The sediment seed banks of the Menindee Lakes provide a mechanism for survival through droughts and floods. They are spatially variable and the strandline accounted for the majority of seed around the edges of the large regulated lakes. All but one species present in the seed banks of all lakes sampled required exposed sediment with high soil moisture to germinate and many species were very desiccation tolerant (especially terrestrial and floodplain species). Most species were intolerant to flooding as juvenile or adults; however, there were a few amphibious species present. Water regime influences the floristic composition derived from the seed bank but soil texture is also an important factor, whereas nutrients appeared to have no effect.