Co-evolution and thresholds in arid floodplain and wetland evolution

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1. Introduction

Vegetation in arid floodplain wetlands consist of water dependent and flood tolerant species that rely on periodical floods in order to maintain healthy conditions. The floodplain often consist of a complex system of marshes, swamps and lagoons interconnected by a network of streams and poorly defined rills. Over time, feedbacks develop between vegetation and flow paths producing areas of flow obstruction and flow concentration, which combined with depositional and erosional process lead to a continuous change on the position and characteristics of inundation areas. This coevolution of flow paths and vegetation can reach a threshold that triggers major channel transformations and abandonment of wetland areas, in a process that is irreversible.

The Macquarie Marshes is a floodplain wetland complex in the semi-arid region of north western NSW, Australia. The site is characterised by a low-gradient topography that leads to channel breakdown processes where the river network becomes practically non-existent and the flow extends over large areas of wetland that later re-join and reform channels exiting the system. Due to a combination of climatic and anthropogenic pressures, the wetland ecosystem in the Macquarie Marshes has deteriorated over the past few decades. This has been linked to decreasing inundation frequencies and extent, with whole areas of flood dependent species such as Water Couch and Common Reed undergoing complete succession to terrestrial species and dryland.

In this presentation we provide an overview of an eco-hydraulic model that we have developed in order to simulate the complex dynamics of the marshes. The model combines hydrodynamic, vegetation and channel evolution modules. We focus on the vegetation component of the model and the transitional rules to predict wetland invasion by terrestrial vegetation.

2. Methods

2.1 Hydrodynamic simulation

A large scale approach has been used in order to minimize computational cost. A a quasi 2D-hydrodynamic model, the VHHMM 1.0 (Riccardi, 2000), was built on a 90 x 90 m squared resolution grid. This resolution describes the domain with a total of 40096 active elements which allows for feasible data processing and simulation of the site. Methods for model calibration are presented by Sandi-Rojas et al. (2014).

Daily discharges were obtained from the Pillicawarrina gauging station (No. 421147) located in the Macquarie River. The simulations were carried for a sequence of 23 consecutive years covering the period from June 1990 to May 2013. Initial conditions were assumed as no flow, which agrees with very low flows generally observed in June and May. After 2002 and until 2008, the discharges entering the Macquarie Marshes had a considerable reduction.

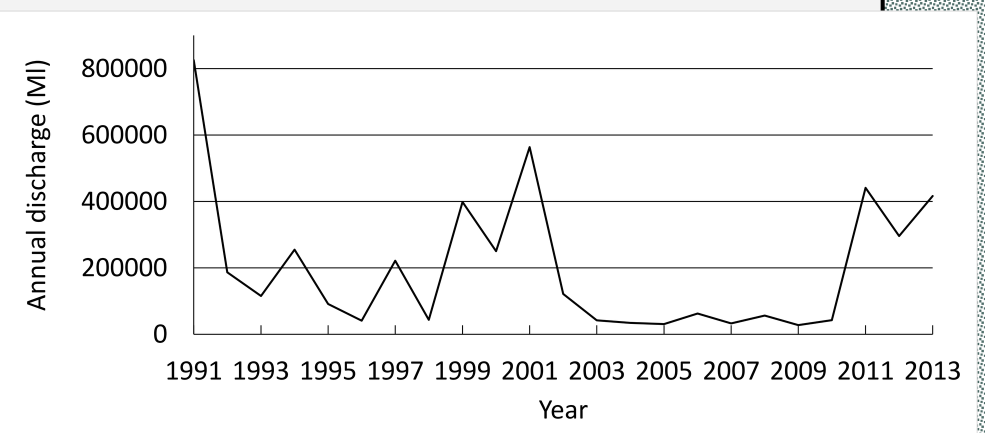

Figure 1. Series of simulated flows.

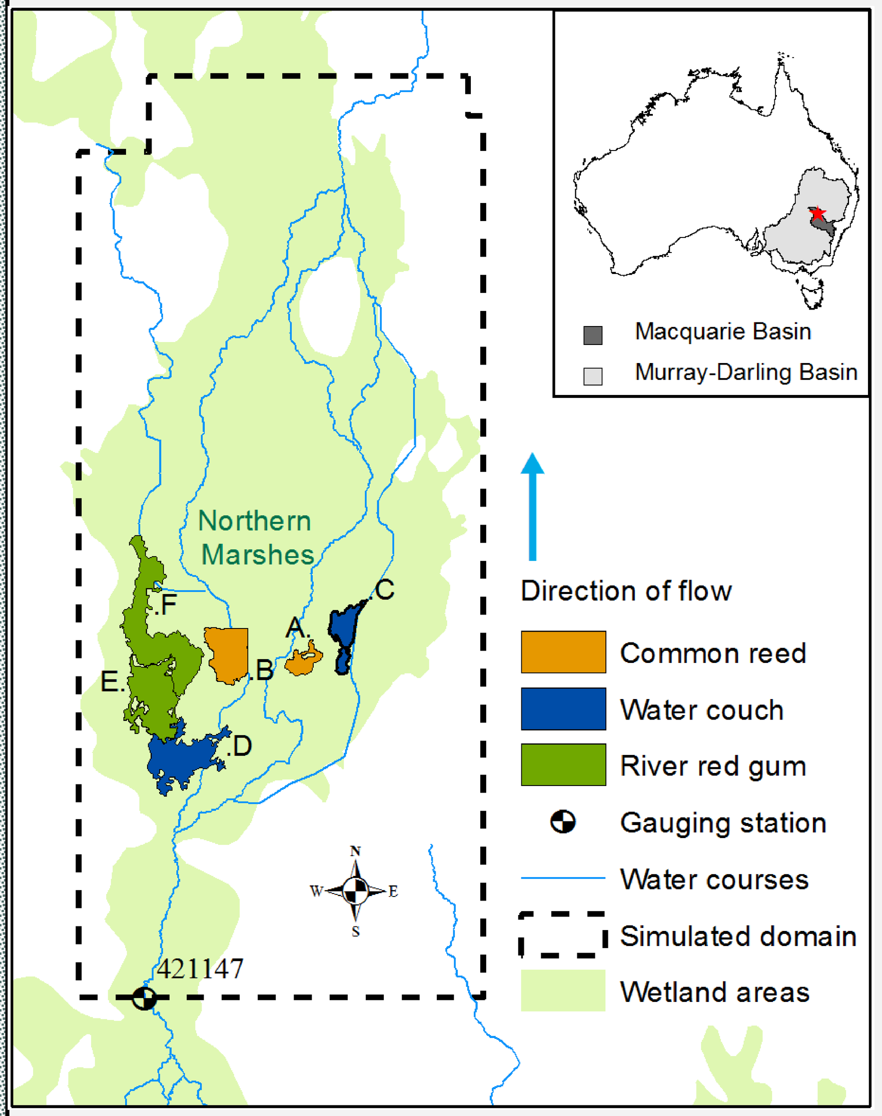

Figure 2. Location of the study site and selected vegetation patches.

2.2 Selected vegetation patches

Three different vegetation maps are available for the years 1991, 2008, and 2013. During the period from 1991 to 2008, most of Water Couch and Common Reeds transitioned to terrestrial species and dryland (Bowen and Simpson, 2010). Some of these patches showed a transition back to wetland vegetation by the year 2013. We have selected four vegetation patches of Common Reed and Water Couch (Figure 2) in order to see the effects of water delivery to understory species.

Forest and woodland overstory had very little change in extent from 1991 to 2008 (Bowen and Simpson, 2010), the condition of some of the patches was heavily affected. We have selected two River Red Gum patches. Patch E was reported to have 80% dead trees and the understory was encroach by terrestrial species in 2008.

A description of the conditions of each patch is presented in Table 1.

Table 1. Patch Transition history

Patch	Vegetation on 1991	Vegetation on 2008	Vegetation on 2013	Changes	Conditions
A	Common reed	Terrestrial	Common reed	Transitional	- Transition back to wetland understory by 2013
B	Common reed	Common reed	Common reed	Non transitional	- Good condition in 2008 and 2013
C	Water couch	Terrestrial	Terrestrial	Transitional	- Complete transition
D	Water couch	Water couch	Water couch	Non transitional	- Good condition in 2008 and 2013
E	River red gum	River red gum	River red gum	Non transitional	- <10 % dead trees - Chenopod shrubland invasion in 2008
F	River red gum	River red gum	River red gum	Non transitional	- 80% dead trees - Healthy mixed marsh understory during the whole period

2.3 Fractional coverage and minimum inundation

Use of seasonal fractional cover maps, developed by the Joint Remote Sensing Research Project (JRSRP) (OEH, 2014), in combination with a hydraulic description of the flow regime has proven to be a convenient approach for studying vegetation evolution in the Macquarie Marshes (Sandi et al., 2016). Changes in green and baresoil coverage can suggest critical conditions or succession of plant associations to terrestrial species; however, frequency of inundation is the determining factor for a vegetation succession. Our model estimates vegetation response according to water requirements which are different for every plant association. These requirements are time aggregated characteristics such as the range of inundation depth and the percent exceedance time during a hydrologic year (Sandi et al., 2015). We focus the analysis on the areas with minimal inundation. Water delivery strategies in the Macquarie Marshes estimate that an inundation period of three months is adequate for maintaining the health of most the plant communities; therefore, we consider the minimum inundation when 5 cm of water are exceeded 25% of the time.

3. Results

3.1 Understory species

Figure 3 presents the relation of minimum inundation against fractional green coverage for understory species during the period of 1991 to 2008. Results reveal that less than 15% of the patch area with minimal flood is a threshold for potential terrestrial and dryland vegetation invasion of Common Reed (Figure 3a). Fractional green data shows that in average 60 % of Patch B remains green even on the cases where minimum inundation approaches the area threshold (Figure 4a).

A similar analysis of the Water Couch patches showed some important differences in relation to critical conditions. First, the area threshold for minimum inundation is of 20% (Figure 3b), and transitional patch (Patch C) had frequency of adequate minimum inundation of 67% from 1991 to 2003 (Figure 6a). This shows that Water Couch is a less resilient species than Common Reed since it requires almost annual adequate minimum inundation in order to survive.

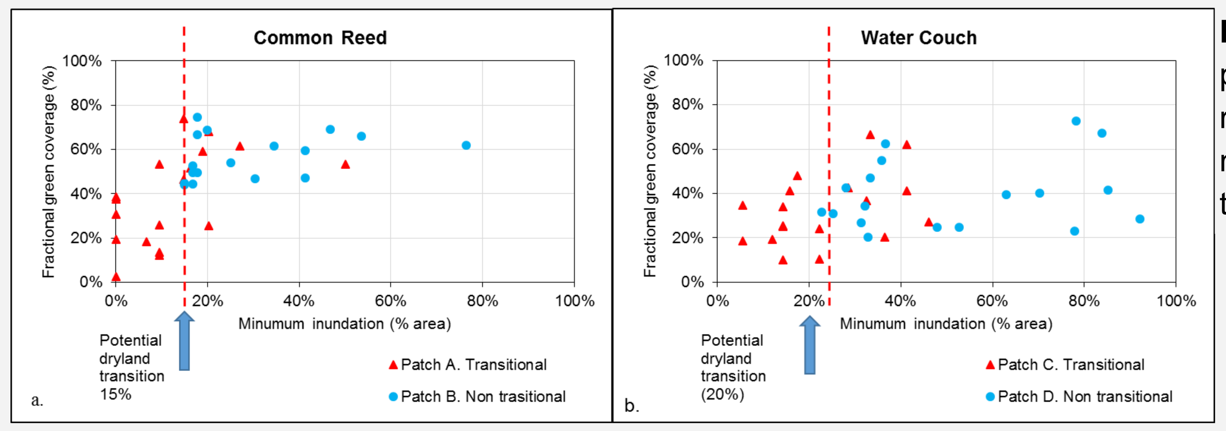

Figure 3. Thresholds for potential dryland and terrestrial species encroachment on wetland vegetation

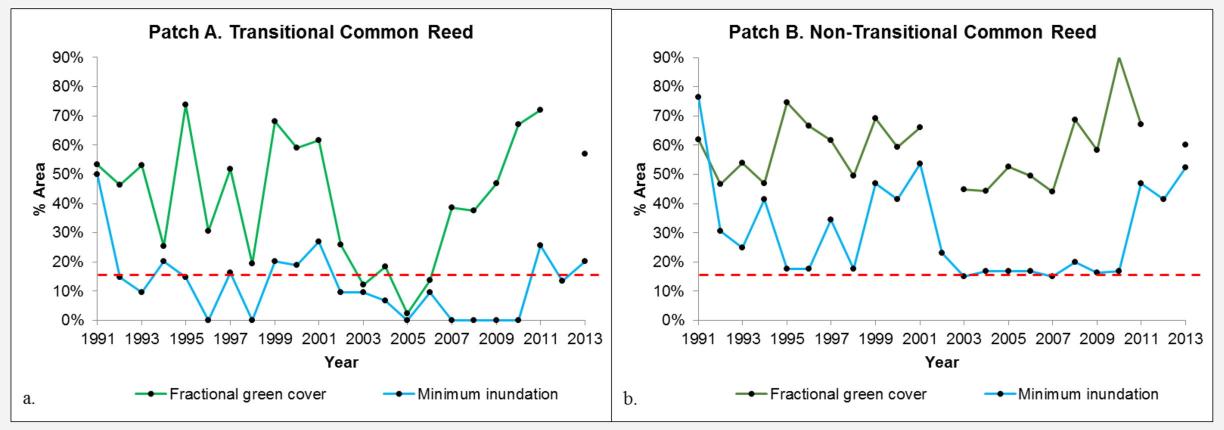

Figure 5. Fractional green cover and minimum inundation evolution for Common Reed patches.

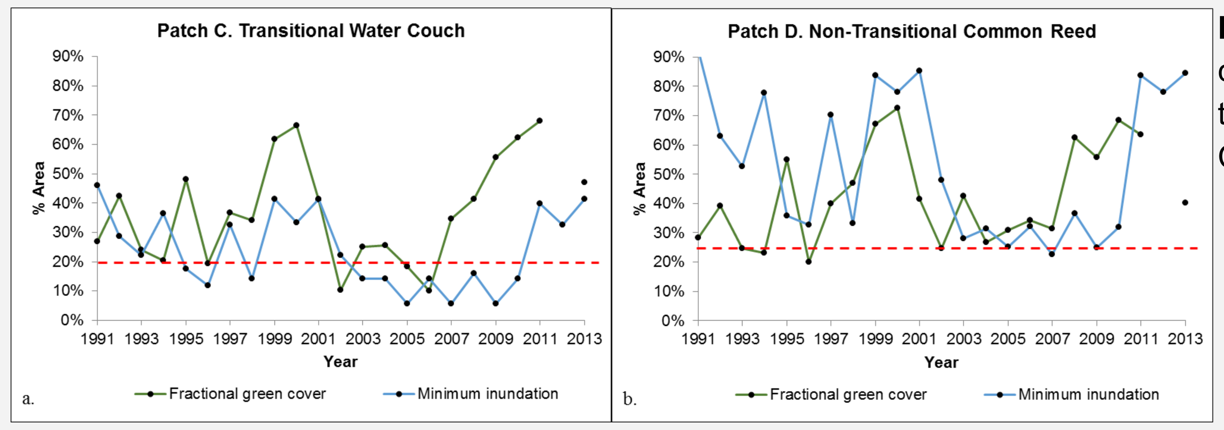

Figure 6. Fractional green cover and minimum inundation evolution for Water Couch patches.

3.2 Overstory species

Determining critical conditions for overstory species is complicated because trees can survive under a wide range of watering conditions. The understory of Patch E was reported as having invasion of terrestrial species by 2008 (Table 1) while understory present in patch F remained with healthy mixed marsh from 1991 to 2013. Patches of River Red Gum woodland that are closer to water courses receive more water than forests at the fringe of the marshes. Figure 7 presents green coverage and minimum inundation evolution in Patches E and F. An intermediate minimum inundation area threshold between Common Reed and Water Couch is used as an indicator of dry conditions for understory species in River Red Gum patches (Figure 7c).

Watering conditions in Patch E were insufficient to support understory species from 2003 to 2005 which is evidence by a drop of green fractional coverage. This is consistent with the position of Patch E, which is located further away from the water course than patch F and also higher in the floodplain. The dry period from 2003 to 2010 evidently lead to the reported dying of 80% of the trees of Patch E and colonization of terrestrial evidenced by the increased green coverage after 2006.

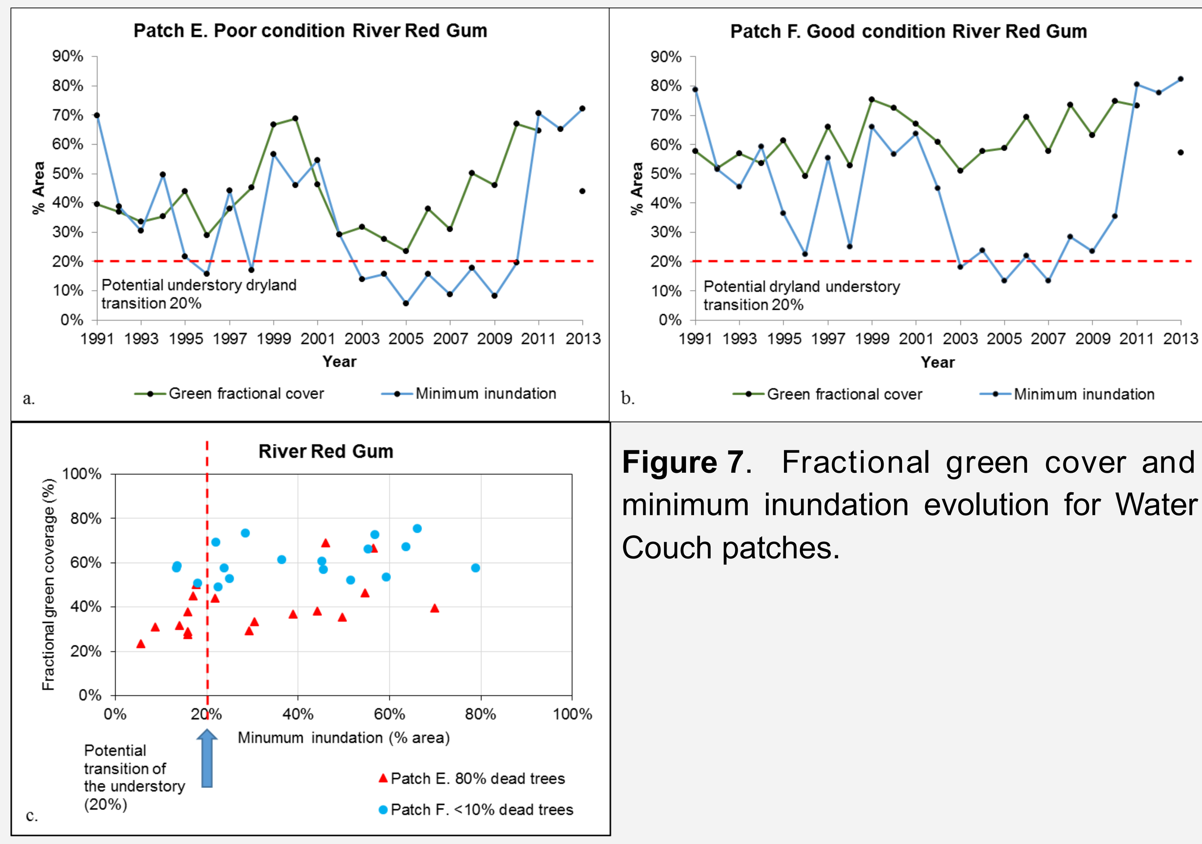

Figure 7. Fractional green cover and minimum inundation evolution for Water Couch patches.

Our results show that Patch F was able to maintain optimal conditions during the whole period of analysis. This is consistent with reported conditions and previous statistical analysis by Catelotti et al. (2015). Based on this results we propose the use of understory area thresholds as indicators for River Red Gum; however, a differentiation is necessary for patches with healthy wetland understory.

References

BOWEN, S. & SIMPSON, S. 2010. Changes in extent and condition of the vegetation communities of the Macquarie Marshes Floodplain 1991-2008: Final report to the NSW Wetland Recovery Program. Sydney: River and Wetlands Unit, Department of Environment, Climate Change and Water, NSW.

CATELOTTI, K., KINGSFORD, R. T., BINO, G. & BACON, P. 2015. Inundation requirements for persistence and recovery of river red gums (Eucalyptus camaldulensis) in semi-arid Australia. *Biological Conservation,* 184**,** 346-356.

OEH 2014. Seasonal fractional cover - Landsat, JRSRP algorithm, NSW coverage, Joint Remote Sensing Research Project.

RICCARDI, G. 2000. A cell model for hydrological-hydraulic modeling. *Journal of Environmental Hydrology,* 8.

ROBERTS, J. & MARSTON, F. 2011. *Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin*, Canberra, National Water Commission.

SANDI-ROJAS, S. G., RODRÍGUEZ, J. F., SACO, P., RICCARDI, G., WEN, L., SAINTILAN, N., STENTA, H., TRIVISONNO, F. & BASILE, P. A. 2014. Macquarie river floodplain flow modeling: Implications for ecogeomorphology. *River Flow 2014.* CRC Press.

SANDI, S. G., RODRIGUEZ, J. F., SACO, P. M., SAINTILAN, N., WEN, L. & KUCZERA, G. Development of a Vegetation Dynamics Model for Freshwater Wetland Assesment in the Macquarie Marshes. 36th Hydrology and Water Resources Symposium 2015 Hobart, Tasmania.

SANDI, S. G., RODRIGUEZ, J. F., SACO, P. M., WEN, L. & SAINTILAN, N. 2016a. Linking hydraulic regime characteristics to vegetation status in the Macquarie Marshes. *11th International Symposium on Ecohydraulics 2016.* Melbourne, Australia.

SANDI, S. G., RODRIGUEZ, J. F., SACO, P. M., WEN, L. & SAINTILAN, N. 2016b. Simulation of the vegetation state and flow regime interaction in the Macquarie Marshes. *River Flow 2016.* CRC Press.