HYDROLOGY | FOOD WEBS | VEGETATION | WATERBIRDS | FISH

Gwydir River Selected Area

2021-22 Annual Summary Report

Appendix J – The effects of fire on microinvertebrate eggbanks in three vegetation communities in the Gwydir Wetlands, NSW

Report for the Commonwealth Environmental Water Office
September 2022

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Cover image: Wildfire burning through the Gwydir Wetlands State Conservation Area in September 2019 (Photo: David Preston DPE-EHG).

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Aquatic Ecology and Restoration

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Summary

Fire is a common phenomenon in Australia and overseas and is known to affect many ecological processes. We examined the effects of wildfire on the eggbank of invertebrates and bioavailable nutrients in the Gwydir Wetlands, northern NSW. Fire reduced the density and richness of hatching invertebrates but did not destroy the entire biota, suggesting some level of resilience in the invertebrate eggbank. Nutrients did not behave as predicted as less bioavailable nitrogen oxides were available from burnt soils while there were no overall differences in either soluble reactive phosphorus or dissolved organic carbon between burnt and unburnt wetland soils. Abundance and richness of microinvertebrates hatching from the eggbank varied in different vegetation types, reflecting an inundation gradient. The greatest number and richness of hatching invertebrates were found in the most frequently inundated typha reedbed community, followed by water couch marshlands and coolibah woodlands, the least frequently inundated community. Ongoing monitoring may indicate if fire and the current environmental watering regime has affected aquatic invertebrates into the future.

1 Introduction

Fire is a global phenomenon that appears in the geological record soon after the appearance of terrestrial plants (Bowman et al. 2009). Environmental disturbance through fire is widely known to affect many ecological processes and biodiversity (Kelly and Brotons, 2017, Heim et al. 2019). In wetland ecosystems, fire can affect water quality, soil chemistry, plant litter, microbes, and aquatic and terrestrial biota (Danilova et al. 2015, Klaus and Noss, 2016, Jancoski et al. 2019, Jansen et al. 2019, Wang et al. 2019, Heim et al. 2021). Fire can interact with hydrology and wetland management practices, such as grazing, to affect biogeochemical cycles, water quality and aquatic biota (Hossack et al. 2013, de Oliveira et al 2014, Nocentini et al. 2021). Heim et al. (2019) suggested that it is often difficult to predict the ecological effects of fire due to its interactions with other environmental factors.

Freshwater wetlands are highly productive systems and have high diversity of flora and fauna, many of which have behavioral and physiological adaptations to enduring hydrological extremes of inundation and drying (Williams 2006). Invertebrates play a critical role in wetlands (Boon and Shiel 1990) linking aquatic and terrestrial carbon sources to higher trophic levels such as fish and waterbirds (Lindholm and Hessen 2007). The deposition of desiccation-resistant eggs (or egg banks) in sediment is a common adaptation of microinvertebrates to ensure survival and persistence in most temporary wetlands (Williams 1998, Brock et al. 2003). Egg banks and emergence of microinvertebrates can be affected by a range of factors including vegetation structure, time since inundation, leaf litter, land use, water quality and biological interactions (Hann and Goldsborough 1997, Gleason et al. 2004, Ning and Nielsen 2011, Watkins et al. 2011, Nielsen et al. 2013, Zokan and Drake 2015). Fire can also affect egg banks and emergent microinvertebrates either directly through the application of intense heat (Wells et al. 1997, Blanckenberg et al. 2019), or indirectly through increased nutrient concentrations following inundation (Kobayashi et al. 2018, Cunillera-Montcusí et al. 2019).

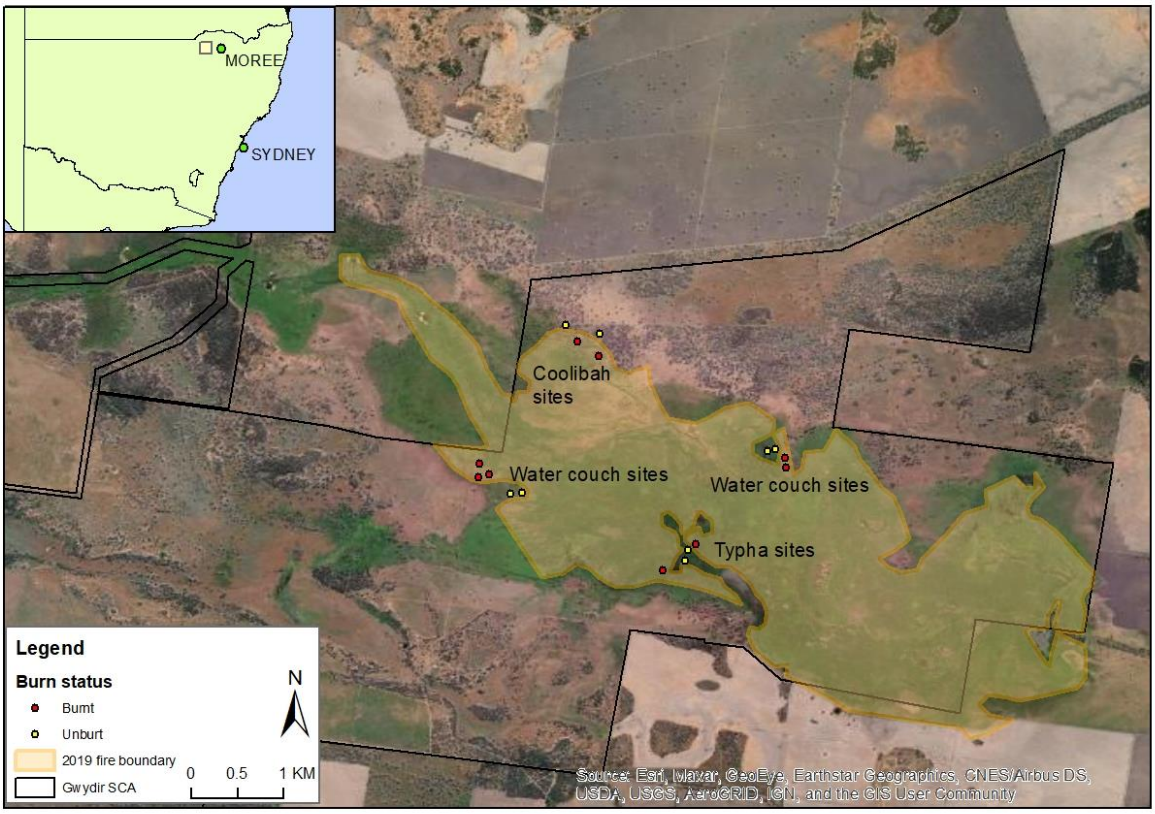
The Gwydir Wetlands are a biodiverse, highly fertile inland floodplain wetland complex located west of Moree in northern central NSW (Wilson et al. 2009). The wetlands are not only internationally recognised under the Ramsar Convention for their importance in supporting migratory and endangered wetland bird species, they also support substantial areas of floodplain and wetland vegetation communities that are poorly conserved in NSW (Wilson et al. 2009, Bowen and Simpson 2010). In September 2019, a wildfire burnt around 1,600 ha of the wetlands, primarily within the Gwydir Wetlands State Conservation Area (SCA). This included areas of ‘core wetland’ dominated by water couch (*Paspalum distichum*) meadows and vast stands of typha (*Typha orientalis*). Some fringing coolibah woodland was also burnt. Fire severity ranged from high to low throughout the fire ground (DPIE 2019) with available post-fire mapping too course to determine exact severity at the plot scale. A project established to investigate the ecological response to the fire. Here we report on the eggbank and water quality response to the fire and the associated influence of vegetation community on this response. We tested three hypotheses:

1. That eggbanks will be detrimentally affected by fire, resulting in a reduction in abundance and taxa. The first hypothesis was tested by taking soil from burnt and unburnt plots;
2. Invertebrates emerging from more frequently inundated soil will have more individuals and taxa. The second hypothesis was tested by taking soil from three vegetation community types, whereby the communities acted as surrogates for inundation frequency, in order of decreasing inundation typha, water couch and coolibah; and
3. Bioavailable nutrient concentrations would increase over time and be greater in burnt soils, being differentially released from sediments.

2 Methods

2.1 Sampling sites

Soil was collected from 17 locations within the Gwydir wetlands along the Gingham Watercourse within the Gwydir Wetlands SCA (Figure 1). Three vegetation communities were sampled four sites within typha reedbeds (typha), nine sites within water couch marshlands (water couch), and four sites within coolibah woodlands (coolibah). Within each vegetation community, paired burnt and unburnt sites were sampled, with each pair being located within a zone of similar inundation frequency to minimize the influence of inundation history on eggbank response. At each site, three replicate 20 cm x 20 cm x 10 cm sediment samples were collected giving a total of 51 samples. These replicate samples were separated by approximately 30 m at each site. Soil was disaggregated and left to air dry for at least two weeks before the commencement of the glass house experiment.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1 Location of field sites within and adjacent to the 2019 fire ground in the Gwydir Wetlands State Conservation Area (SCA).

2.2 Mesocosm setup and invertebrate sampling and processing.

Experimental methods follow those of Growns et al. (2020). Briefly, 250 g of homogenised soil from each replicate was placed in a 4 L container (mesocosm), filled with dechlorinated water and let stand for 28 days. The mesocosms were held in a climate-controlled glass house with natural light and temperatures set to emulate average September/October field conditions. After 28 days, the contents of each container were put through a 250 µm sieve. Invertebrates were subsampled if very abundant by using a technique similar to Marchant (1989). Cladocerans were identified to Bosminidae, Daphnidae, Chydoridae or other Cladocera (OC), ostracods to class, copepods to order and nematodes to phyla.

Bioavailable nutrient concentrations, including nitrogen oxides (NOx), soluble reactive phosphorus (SRP) and dissolved organic carbon (DOC), were estimated in each mesocosm at 2, 6, 12, 24 and 72 hrs following inundation. At each time interval water samples were taken by filling three 50 mL, thrice-rinsed pre-labelled PET vials with raw water and freezing samples until analysis. The volume of sample collected on each occasion was replaced with distilled water to maintain a constant water level in each mesocosm. In the laboratory, duplicate NOx and SRP samples were taken by filtering raw water through rinsed Whatman GF/C filters (effective pore size 0.7 µm) into 50 mL, thrice-rinsed pre-labelled PET vials and freezing until analysis. NOx and SRP analyses were performed by colourimetric method using a SEAL Analytical AQ400 Discrete Analyser using the AQ400 method no. EPA-118-C and EPA-127-A, respectively. TP content in the samples was determined after Kjeldahl digestion of unfiltered water sample, using a SEAL Analytical AQ400 Discrete Analyzer following AQ400 method no. EPA-135-C. Total Kjeldahl nitrogen was determined in the unfiltered water sample using AQ400 method no.EPA-151-C. TN was reported as the sum of TKN and NOx. DOC samples were analysed using the supercritical water oxidation technique (GE Analytical Instruments) using an InnovOx Total Organic Carbon Analyser (GE Analytical Instruments).

2.3 Statistical analyses

Permutational analysis of variance (PERMANOVA; Anderson, 2001) was used to test for differences in microinvertebrate abundance and number of taxa between burnt and unburnt plots (treatments) within each vegetation community using 9999 randomisations. Each source of variation was set as a fixed factor. Time was included as a covariate for analyses of bioavailable nutrients. Euclidean distance was used to form the similarity matrices between samples. Invertebrate abundance and nutrient data were log-transformed prior to analyses and nutrient concentrations below the limits of detection (LOD) were set at LOD/2 (Cohen & Ryan, 1989). All statistical analyses were conducted using PERMANOVA+ for PRIMER software (Anderson et al. 2008).

3 Results

3.1 Bioavailable nutrients

DOC and NOx concentrations changed significantly through time in the mesocosms (Table 1). Mean concentrations of DOC increased until 24 hrs and then decreased and did not differ significantly between treatments (Tr) or vegetation communities (VC; Table 1; Figure 2). The concentrations of NOx generally decreased over time (Figure 2) and differed significantly between VC and Tr and the interaction between the latter two factors. Pairwise tests could not distinguish any significant differences in NOx concentrations between burnt and unburnt soils in the different vegetation communities. However, mean NOx concentrations were generally lower in burnt soils compared with unburnt soils and generally lowest in water couch, followed by typha and coolabah (Figure 2). Concentrations of SRP were generally less than the limits of detection and did not change significantly over time; but, were significantly effected by Tr and VC and their interaction (Table 1; Figure 2).

Table 1 Pseudo-F values, significance levels and percentage variation explained by different sources of variation for bioavailable nutrients in the mesocosms.

	Nutrient		
Source of variation	Dissolved organic carbon	Nitrogen oxides	Soluble reactive phosphorus
Time	26.4*** (9%)	95.7*** (18%)	
Vegetation community (VC)		14.1*** (8%)	5.3** (5%)
Treatment (Tr) (Burnt vs unburnt soils)		13.6** (5%)	4.9** (3%)
VC x Tr		15.3*** (18%)	4.1** (7%)

Blank – not significant, ** $p < 0.01$, *** $p = 0.001$

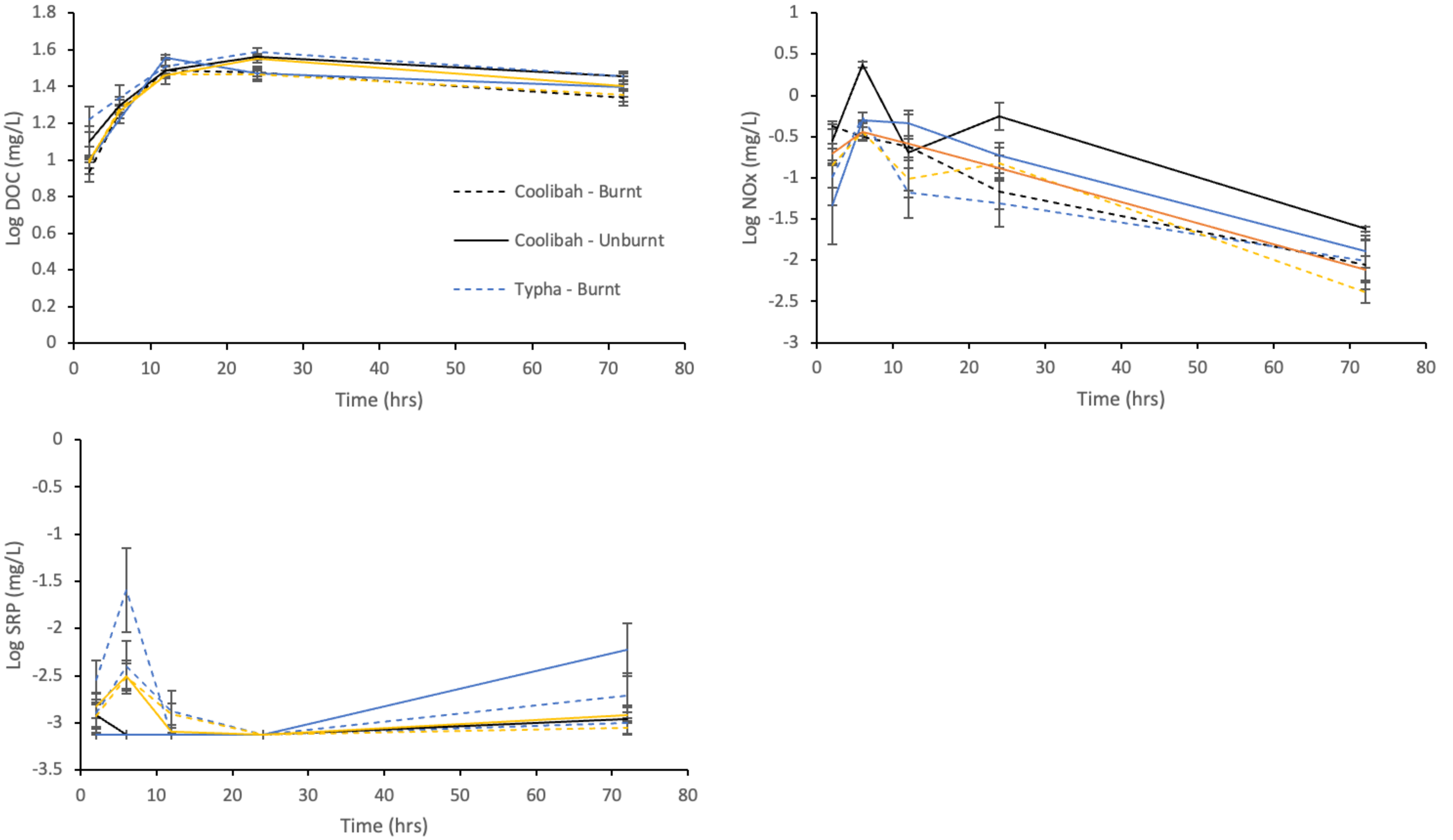
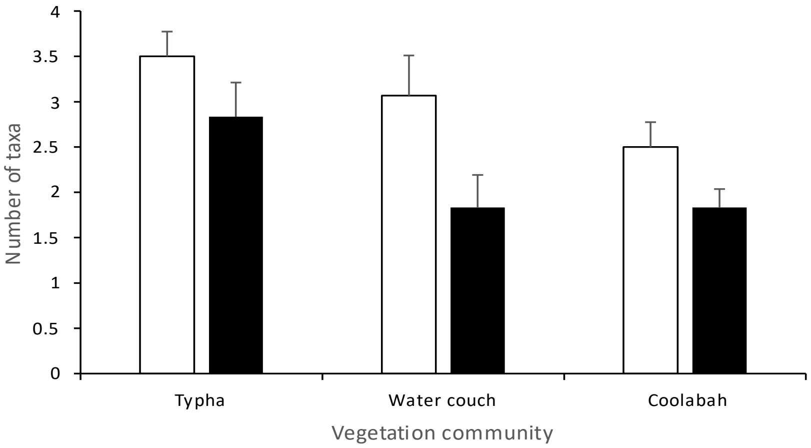


Figure 2 Mean (± S.E.) concentrations of dissolved organic carbon (DOC), nitrogen oxides (NOx) and soluble reactive phosphorus (SRP) over time and between burnt and unburnt soils in three vegetation types.

3.2 Invertebrates

A total of 15,443 invertebrates from 8 taxa was estimated from the mesocosms. Invertebrate abundance and number of taxa differed significantly between burnt and unburnt plots (pseudo-F = 4.5 and 6.4, $p < 0.05$ and $p < 0.01$, respectively) and vegetation communities (pseudo-F = 10.4 and 15.7, $p < 0.01$ and $p < 0.001$, respectively). The interaction between the two factors, treatment and vegetation type, was not significant for either invertebrate abundance or number of taxa, suggesting the effects of burning were consistent regardless of vegetation type.

Overall, the mean number of taxa was 29% less in the plots that had been burnt compared with unburnt plots (Figure 3). The mean number of taxa was greatest in the typha vegetation community (~ 3.5 taxa in the unburnt plots) followed by water couch (~ 3.1 taxa) and coolibah (~ 2.5 taxa). On average, the mean invertebrate abundance was 19% less in the burnt plots compared with the unburnt plots (Figure 3). The mean invertebrate abundance was greatest in the typha plots (~ 575 individuals per L), followed by water couch (~295 per L) and coolibah (~ 105).



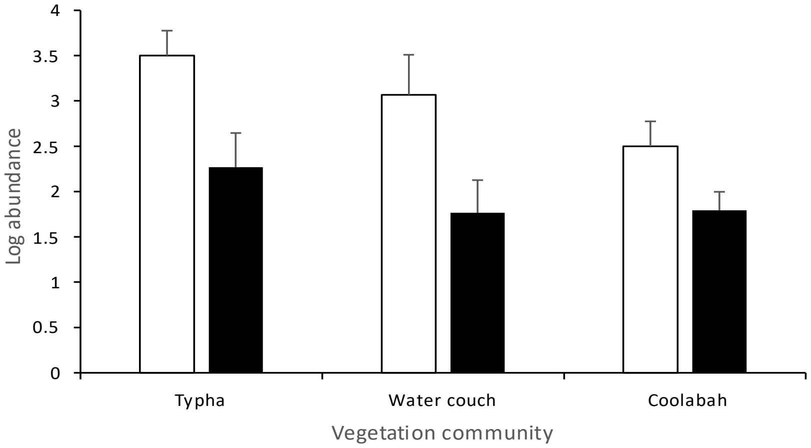


Figure 3 Mean abundance (± S.E.) and taxa in burnt (black columns) and unburnt (white columns) plots in three vegetation communities.

4 Discussion

We demonstrated that burnt soil samples had decreased microinvertebrate abundance and number of taxa. However, microinvertebrates still emerged from burnt plots indicating some level of resilience in the eggbank. The decrease in abundance and taxa is consistent with Blanckenberg et al. (2019) and Cunillera-Montcusí et al. (2019) who both demonstrated negative impacts of fire on invertebrates. The resilience of the egg bank is consistent with Wells et al. (1997) and Bright et al. (2016) who showed no effects of fire on crustacean resting stages. The tolerance of the eggbank in the Gwydir Wetlands to fire suggests that fire may not be an important conservation concern. Kobayashi et al. (2018) suggested that fire may benefit aquatic invertebrates by providing an increased food source due to the release of nutrients to increase the concentrations of algae and bacteria. However, we found no differences in either DOC or SRP between burnt and unburnt soil types and a decreased concentration of NOx in burnt soils. This suggests that potential recovery of invertebrates following fire may not be aided by increased food availability in our study area.

We also demonstrated that the microinvertebrate egg banks differed among three vegetation communities in one wetland system. The three communities, typha, water couch and coolibah form because of separate plant functional responses to differing inundation patterns (Brock and Cassanova 1997) with typha occurring in more frequently inundated areas and coolibah in areas of minimal flooding. The abundance and number of taxa decreased with decreasing inundation frequency. This result is consistent with a range of other studies that show decreasing abundance and richness of microinvertebrates with decreasing flooding (Siziba et al. 2013, Stenert et al. 2017, Jansen et al. 2019). Our results suggest that management of wetland hydrology is a key factor in maintenance of microinvertebrate populations. The preservation of the eggbank through mimicking the natural flooding regime is likely to be an important conservation tool to maintain the food webs that exist in the Gwydir Wetlands.

We have assumed that the invertebrate assemblages identified on day 28 reflect the dormant egg bank present in each treatment and vegetation type. However, as a part of a threat abatement strategy, only a fraction of the egg bank hatches during a single inundation (Brock et al. 2003, Brendonck et al. 2017). This suggests that if this experiment was repeated, different results may be produced. Different results may also have been obtained if the experiment was run over a shorter time frame as some of the taxa may have started breeding towards the end of the experiment. In addition, due to the sieve size used a group of invertebrates, the Rotifera, were not included in the present study although some authors consider they are an important group to consider in wetland conservation strategies (Angeler et al. 2010, Badosa et al. 2010).

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