Chapter 6

Wetland vegetation responses to recent Environmental Contingency Allowance releases

Key findings

- Ecological responses to flow events differ seasonally. Delivery of environmental water in spring or early summer will produce a more vigorous and longer lasting response in wetland vegetation than an autumn flow.
- The spatial extent of the influence of ECA flows on vegetation in the Lower Gwydir wetlands may be limited. Recent ECA flow volumes were insufficient to wet all Ramsar wetland sites in the Gwydir Wetlands.
- All wetland sites monitored following ECA releases had resilient plant communities in the face of a modified water regime. Key wetland taxa emerged at all sites monitored.

Management recommendations

- Continue to include event-based vegetation monitoring in relation to reporting ecological outcomes from Lower Gwydir ECA releases.
- Future monitoring of vegetation responses to ECA flows should include quantifying changes in biomass as well as percent foliar cover.
- The spatial extent of impact from an ECA flow and the duration of flooding are likely to be maximised when ECA releases follow a natural flood event.
- Recognise that ecological responses to flow events will likely differ seasonally. Although significant flood events have occurred in winter in the Lower Gwydir floodplain, the region has a summer-dominant rainfall pattern and the timing of future ECA events should match this whenever possible.

6.1 Introduction

The provision of extra water to wetlands is a key ecological objective for the current management of ECA releases into the Lower Gwydir wetlands (NSW DIPNR, 2005a). Inundation of these wetlands is believed to achieve two main goals. Firstly, it helps to maintain diversity in the soil seed bank as plant species get the opportunity to set seed more often with increased flooding frequency, thus reducing the risk of seeds becoming non-viable in the soil due to lack of germination opportunities (Brock, 1998). Secondly, it helps maintain the growth vigour of existing native species which had previously been reported as declining in areas with reduced frequency and duration of inundation (McCosker, 1996). Vigorous growth is important for native species, especially grasses, in order for them to compete effectively with introduced invasive species such as lippia (Hobson, 1999; Roberts & Marston, 2000). The extent to which these desired outcomes are achieved will be influenced by the volume and timing of environmental water delivered. In order to manage future releases for vegetation objectives in an adaptive framework, robust before-after-reference-impact monitoring will be necessary to document the spatial and (particularly) temporal responses to recent releases.

The present study describes changes in wetland plant communities following two ECA flows into the Lower Gwydir wetlands in 2007. Each of these flow events was aimed at supporting the health of wetland plant communities in the core terminal wetland areas. The first flow occurred only in the Gingham Watercourse in April 2007, while the second in November 2007 was directed into both the Gingham Watercourse and Gwydir River.

6.2 Materials and methods

ECA hydrology and study sites. We monitored responses of wetland vegetation to two ECA releases in 2007 (Fig. 6.1). The first of these passed the Yarraman Bridge flow gauge from the 4th April to the 2nd of May, and was released solely into the Gingham Watercourse. Its average discharge at Yarraman Bridge was 265 ML per day, with a peak of 355 ML per day. Further downstream in the Gingham Watercourse at the Teralba gauge, flows averaged 196 ML per day and peaked briefly at 294 ML per day. The second ECA event was released into both the Gingham Watercourse and Gwydir River. It passed the Yarraman Bridge gauge from the 19th November to the 15th December, at an average rate of 514 ML per day and a peak of 651 ML per day. Downstream at the Teralba gauge, flows averaged 246 ML per day and peaked at 299 ML per day. Similarly, at the Millewa gauge near the end of the natural Gwydir River channel, flows averaged 253 ML per day and peaked at 315 ML per day.

For the April-May release, a series of monitoring sites was established along the Gingham Watercourse at “Joanville”, “Westholme”, Goddard’s Lease, “Munwonga” and “Crinolyn” (Fig. 6.2). In addition, two control sites were selected at “Allambie” and “Currigundi Station” on the Lower Gwydir River floodplain. The sites “Joanville” and “Westholme” were primarily water couch (*Paspalum distichum*) – spike rush (*Eleocharis plana*) meadows. “Goddard’s Lease” and “Munwonga” sites were dominated by cumbungi (*Typha domingensis*) close to the channel which gives way to water couch as elevation increases away from the channel. The “Crinolyn” site was once a water couch – spike rush meadow but now is dominated by lippia (*Phyla canescens*). The first control site, “Allambie”, was a grassy woodland site. The understorey was dominated by lippia, but also contained a number of aquatic species such as nardoo (*Marsilea drummondii*) and the sedge dirty dora (*Cyperus difformis*). The second control site, at “Currigundi” was on the floodplain of the Gwydir River. The site contained a significant amount of lippia, together with a range of native grasses such as Warrego summer grass (*Paspalidium jubiflorum*), terrestrial forb species (*Einardia nutans*), and aquatic species such as nardoo and dirty dora.

For the November release, two impact sites were selected on “Old Dromana” near the end of the Gwydir River channel and on “Bunnor” on the Gingham Watercourse. The vegetation on “Old Dromana” was dominated by water couch and lippia, while several other aquatic species such as water primrose (*Ludwigia peploides*) and water milfoil (*Myriophyllum variifolium*) were also present. By contrast, “Bunnor” was dominated by cumbungi (*Typha domingensis*) and water couch, and so this design allowed a comparison of the influence of ECA releases on two assemblage types. Both sites experience flooding every one to two years. Control sites for the November release were both located on “Munwonga” and did not receive any inundation from the environmental flow. The first of these was located in a water couch dominated meadow and the second was located on the edge of the Gingham Waterhole in an area of cumbungi, lignum (*Muehlenbeckia florulenta*) and water couch.

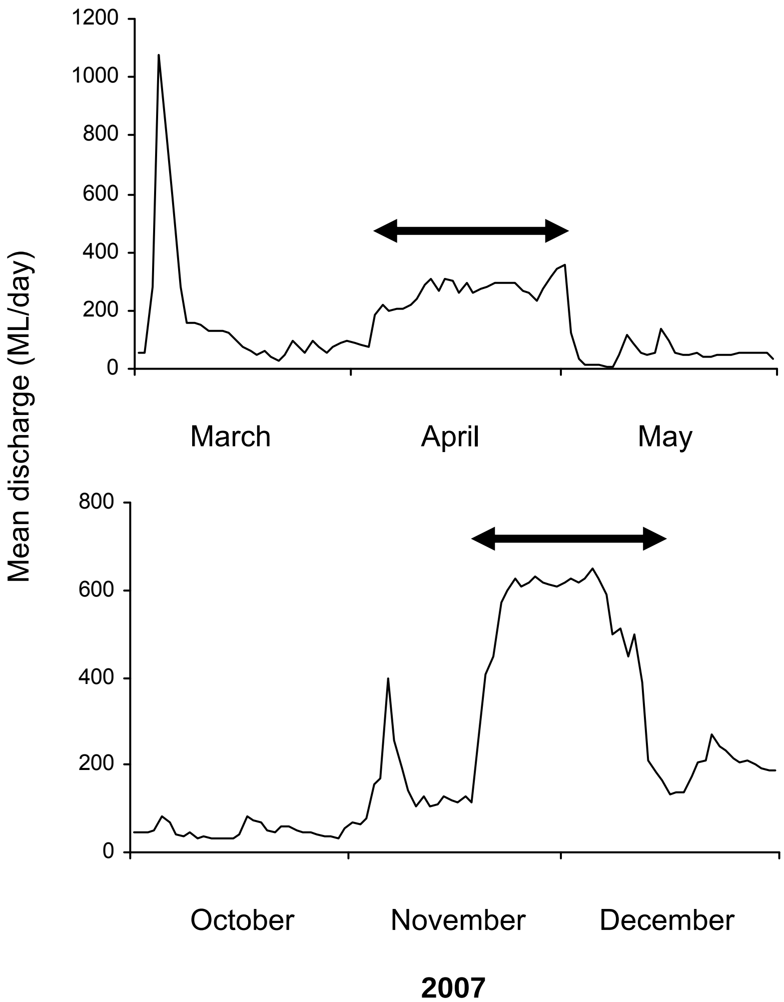

Fig. 6.1. Hydrograph of two environmental contingency allowance releases (arrowed) into the Lower Gwydir channels and wetlands, April–May and November–December 2007. Data are mean daily discharge rates from the Gwydir River flow gauge at Yarraman Bridge, courtesy of the NSW Department of Water and Energy.

Vegetation monitoring. Five fixed 50 m transects were established at each monitoring and reference site for the April release and six similar transects were established at each site for the November release. Along each transect 10 x 1m quadrats were randomly surveyed. For the November release. Along each transect 10 x 1m quadrats were randomly surveyed. For the April release, the species present and their percentage cover were monitored using visual estimates on a modified Braun-Blanquet scale (Mueller-Dombois & Ellenberg, 1974) on three occasions. The first monitoring took place in mid-March, two weeks prior to the start of the release. The second monitoring occurred in mid-May, approximately two weeks after the conclusion of the flow, and a third monitoring was conducted in mid-August, approximately 14 weeks after the release.

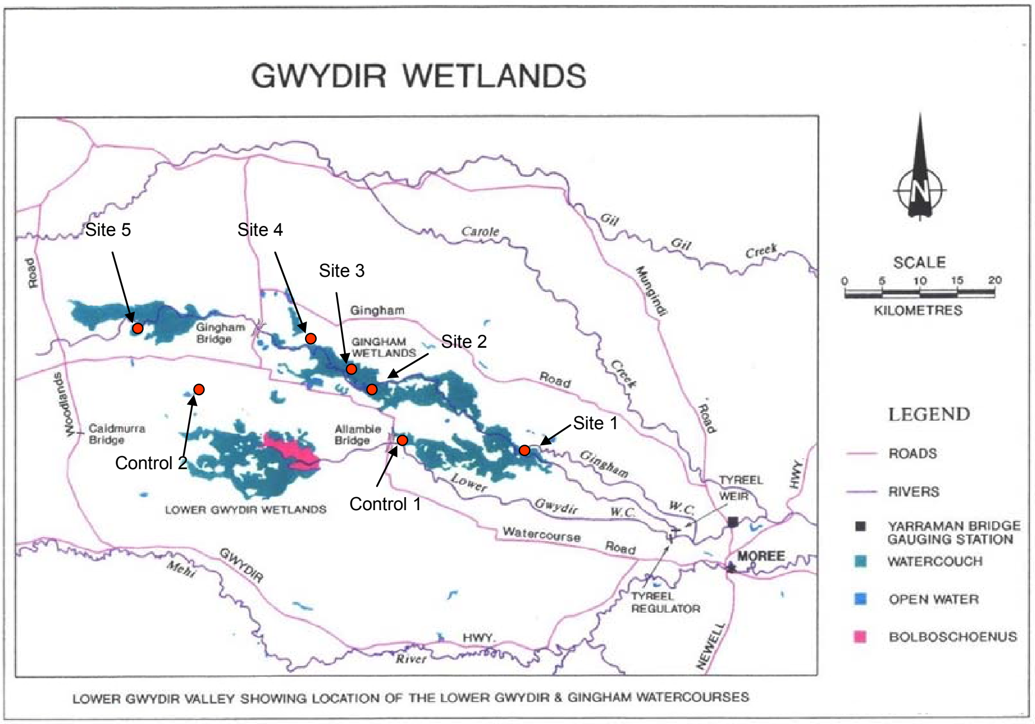

Fig. 6.2. Location of study sites along the Gingham Watercourse and Gwydir River sampled in relation to the April 2007 ECA release, March to August 2007. Site 1, “Joanville”; Site 2, “Westholme”; Site 3, “Goddard’s Lease”; Site 4, “Munwonga’; Site 5, “Crinolyn”; Control 1, “Allambie”; Control 2, “Currigundi”. Original map courtesy of Neal Foster.

For the November release, a point counting method trialled in wetlands in the Barmah-Millewa forest (Reid & Quinn, 2004) was used to quantify vegetation assemblage patterns. Macrophyte taxa present at 100 points along each transect were recorded at each survey time. Points were evenly spaced at a 0.5 m interval along each transect, which was sufficient to avoid re-sampling plants with adjacent points. The exception was at the second reference site where large lignum plants meant that several adjacent points were scoring the same plant. All sites were surveyed on three occasions, once before the flow in September 2007, and twice after the flow, in January and March 2008. This method of sampling was chosen in an attempt to detect smaller changes in plant community composition than was possible with the 1m^2 quadrat method used for the April 2007 release. The point counting method was faster than the traditional quadrat method at the first sampling period (September 2007) when vegetation was short and foliar cover of different species did not overlap. However, in January and March 2008, it became more difficult to use as the vegetation increased in vertical height and there was more opportunity for overlap of foliar cover by different species.

Data analyses. For the April release, percent cover data for all herbaceous species in each of the quadrats from each transect were collated for each site. Species were assigned to wetland functional groups based on how they germinate, establish and reproduce in relation to surface water (Brock & Cassanova, 1997; McCosker, 1999). Plant functional groups are a means of grouping plants together that exhibit a similar response to one or a range of specific

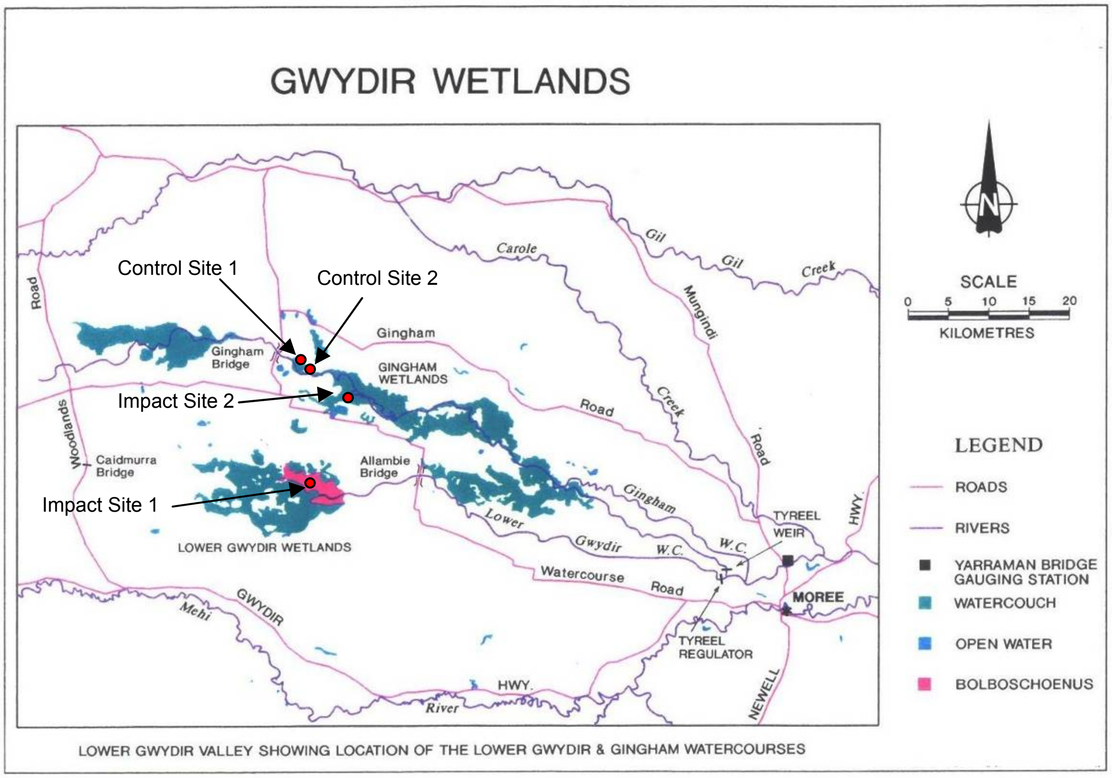

Fig. 6.3. Location of impact and reference study sites for monitoring vegetation responses to the November 2007 ECA release into the Lower Gwydir wetlands, September 2007 to March 2008. Impact site 1, "Old Dromana"; Impact site 2, "Westholme"; Control site 1, "Munwonga" A; Control site 2, "Munwonga" B. Original map courtesy of Neal Foster.

environmental conditions such as water regime (Roberts *et al*., 2000). Following the work of Brock & Cassanova (1997), wetland species can be grouped based on where they grow in a wetland and their life cycle traits in response to inundation. Four functional groups were used here, namely:

- Amphibious responders (AmR) – plants which change their growth form in response to flooding and drying cycles;
- Amphibious tolerators (AmT) – plants which tolerate flooding patterns without changing their growth form;
- Terrestrial damp plants (Tda) – plants which are terrestrial species but tend to grow close to the water margin on damp soils; and
- Terrestrial dry plants (Tdr) - those which are terrestrial species which don't normally grow in wetlands but may be encroaching into the area due to prolonged drying.

Cover, species richness and compositional data from the five transects were averaged before analysis. Cover and richness data were analysed using Statistix 7 (Analytical Software, 2000). For species richness data, analysis of variance was used on log transformed counts to examine the effects of timing and site on vegetation communities. Composition data were analysed using non-metric multidimensional (nMDS) scaling in PRIMER 6 (Clarke & Gorley,

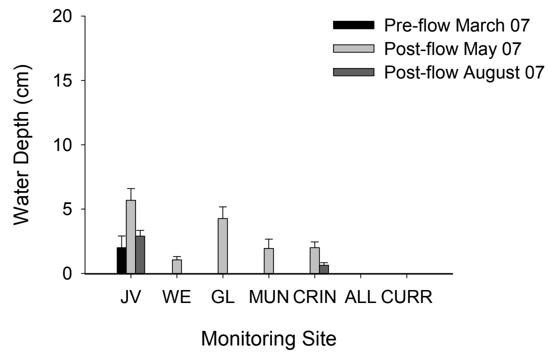

Fig. 6.4. Mean water depth +/- 1 SE at each monitoring site before and following the April 2007 ECA release, Gingham Watercourse. JV, "Joanville"; WE, "Westholme"; GL, Goddard's Lease; MU, "Munwonga"; ALL, "Allambie"; CURR, "Currigundi".

2006). nMDS was performed to compare the similarity of the plant communities between treatments over time. Analysis of Similarities (ANOSIM, Clarke & Warwick, 2001) was used to test for differences between species composition and percent cover within sites over time. SIMPER analysis (Clark & Warwick, 2001) was subsequently performed to examine which species were contributing most to the dissimilarity in species composition within sites at different times.

For the November release, macrophyte data were used to generate two data sets. The first was based on classification to the species level while the second was based on assigning plant species to wetland functional groups following Brock & Cassanova (1997). Where taxa scored in the survey had previously been assigned to a functional group by Brock & Cassanova (1997), the same classification was used. All remaining taxa were assigned to one of the same set based on field observations and descriptions of the species concerned in the Flora of New South Wales (Harden, 2002).

6.3 Results

April 2007 ECA release

Inundation levels. All impact sites along the Gingham Watercourse received inundation during the April release (Fig. 6.4). However, the "Joanville" site was already wet prior to the start of the flow, from water spilling from the Gingham Watercourse during stock and domestic flows. All other monitoring sites were dry where transects were placed prior to the release, and neither of the control sites received any surface flow throughout the monitoring period. Water had also spilled from the channel into the wetland at "Munwonga" although had not reached the study site. However, it is probable that this had contributed some raised sub-surface moisture beneath the transects. During the August monitoring, there was still

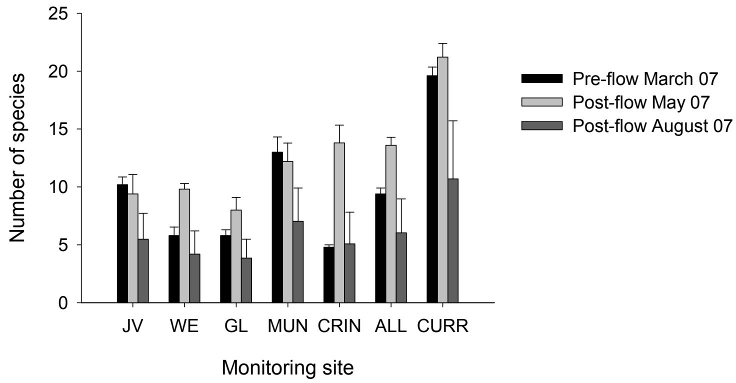

Fig. 6.5. Mean number of species +/- 1 SE at each monitoring site before and after the April 2007 release along the Gingham Watercourse, March to August 2007. See Fig. 6.4 for site codes.

Table 6.2 Analysis of variance of species richness responses to the April 2007 ECA release into the Gingham Watercourse. Data were log transformed prior to analysis.

Factor	*d.f.*	SS	MS	F	*P*
Site	6	1.154	0.192	22.65	< 0.001
Time	2	1.034	0.577	60.88	< 0.001
Site x Time	12	1.169	0.097	11.47	< 0.001
Residual	84	0.714	0.009		

water covering some transects on both “Joanville” and “Crinolyn”, although surface moisture at “Westholme”, “Goddard’s Lease” and “Munwonga” had since receded.

Species richness. Following the release of the environmental flow in April, three sites (“Westholme”, “Goddard’s Lease”, “Crinolyn”) experienced a significant increase in species richness (Fig. 6.5; Table 6.2). “Westholme” showed a significant increase between March and May, as did “Goddard’s Lease”. However, both sites also experienced a significant decline between May and August, a period when conditions were cold and generally dry.

“Crinolyn“ was the driest of the sites prior to the release, with much of the land surface devoid of vegetation. This site experienced a major increase in the number of species as numerous taxa germinated from the soil seed bank. At “Joanville”, some of the transects were inundated prior to the ECA release due to spillage from the channel, and the response to the flow in terms of germination and establishment of new species was weaker than at the drier sites further down the channel. At both control sites, small but not significant increases were detected due to the germination of a number of annual taxa.

Table 6.3. Number of new species detected at the Gingham Watercourse and control study sites following the April 2007 ECA release.

Functional group	“Joanville”	“Westholme”	“Goddard’s Lease”	“Munwonga”	“Crinolyn”	“Allambie” Control site 1	“Currigundi Station” Control site 2
Amphibious Responder	0	1	2	0	1	0	0
Amphibious Tolerator	1	2	2	0	3	0	0
Terrestrial Damp	2	2	2	0	4	3	1
Terrestrial Dry	3	5	5	8	8	9	6
Total	**6**	**10**	**11**	**8**	**17**	**12**	**7**

Species from the amphibious responder and amphibious tolerator functional groups comprised approximately one-third of the species that emerged after the April release (Table 6.3), while the remaining species belonged to either of the terrestrial groups. Many of these latter species germinated on the damp ground after the water from the ECA release had receded. However, following the April release, new amphibious species were only recorded at the Gingham Watercourse sites.

Lippia responses to inundation. From past research on the impact of inundation on lippia growth (McCosker, 1994), it is believed that lippia is favoured by shallow inundation for short periods while its growth is retarded under deeper and longer inundation. At most sites where lippia was inundated by the April release, algae was observed growing on lippia leaves and, where the lippia was submerged, it looked unhealthy. Where large areas of bare ground occurred, dispersed vegetative fragments of lippia were taking root in the wet soil.

The percentage cover of lippia varied markedly between and within sites (Fig. 6.6). For example, the transects at “Joanville” were situated on a slight gradient, resulting in transect 1 being only partially inundated and transects 2–5 receiving progressively greater inundation levels. The mean cover of lippia varied across the site accordingly. The highest percentage cover occurred along transect 1 which experienced the shallowest inundation. At sites where the duration of inundation was longest, the coverage of lippia was much lower. At “Crinolyn”, the percentage cover of lippia rose following the inundation period. There were a number of depressions which formed deep pools at this site, and the sides of these and the adjoining elevated ground provided a large area of moist soil on which the lippia could grow. Following the final monitoring period and as seasonal conditions warmed up, lippia completely covered the transects at this site.

Water couch responses to inundation. Water couch (*Paspalum distichum*) is one of the key native wetland plant species in the Lower Gwydir wetlands. At the temporal scale of our monitoring, the cover of live water couch decreased following the ECA release (Fig. 6.7). This response was thought to have been due to a mix of the weather conditions and grazing by livestock. Weather data from throughout the study period indicated good rain in late

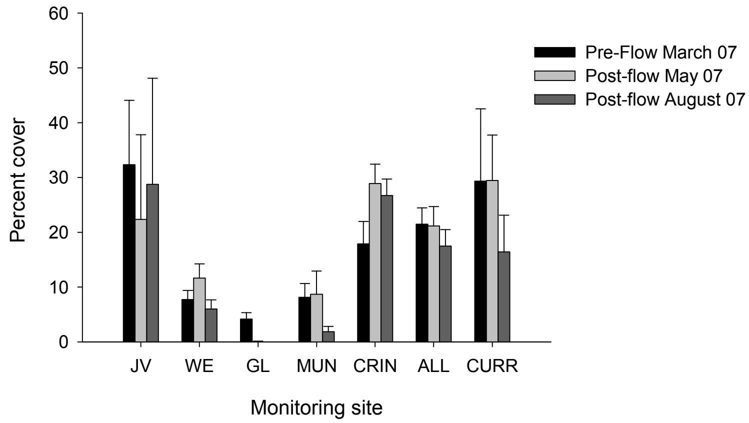

Fig. 6.6. Variation in mean percentage cover of lippia +/- 1SE at each monitoring site before and after the April 2007 release along the Gingham Watercourse, March to August 2007. See Fig. 6.4 for site codes.

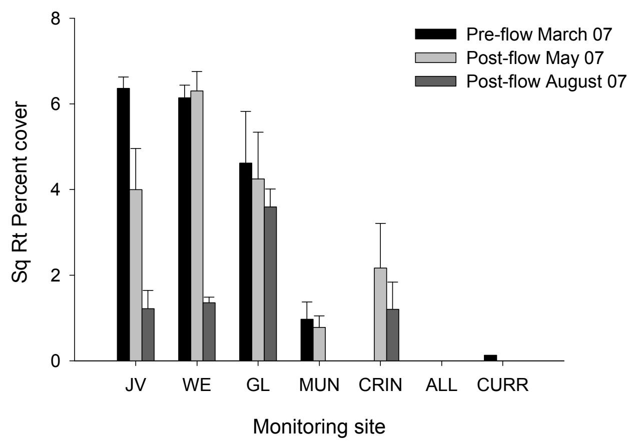

Fig. 6.7. Variation in mean square-root percentage cover +/- 1SE of water couch (*Paspalum distichum*) at each monitoring site before and after the April 2007 release along the Gingham Watercourse, March to August 2007. See Fig. 6.4 for site codes.

autumn and early winter (Fig. 6.8). Daytime temperatures remained warm which provided good conditions for germinating seedlings to grow and for existing species to take advantage of the high soil moisture provided by the ECA release. However, in late June and throughout July, a series of cold nights with heavy frosts stopped water couch growth. The species is frost sensitive and all above ground vegetation was killed off by these colder conditions. Only a few green leaves were visible around plant meristems and plants would need to re-shoot

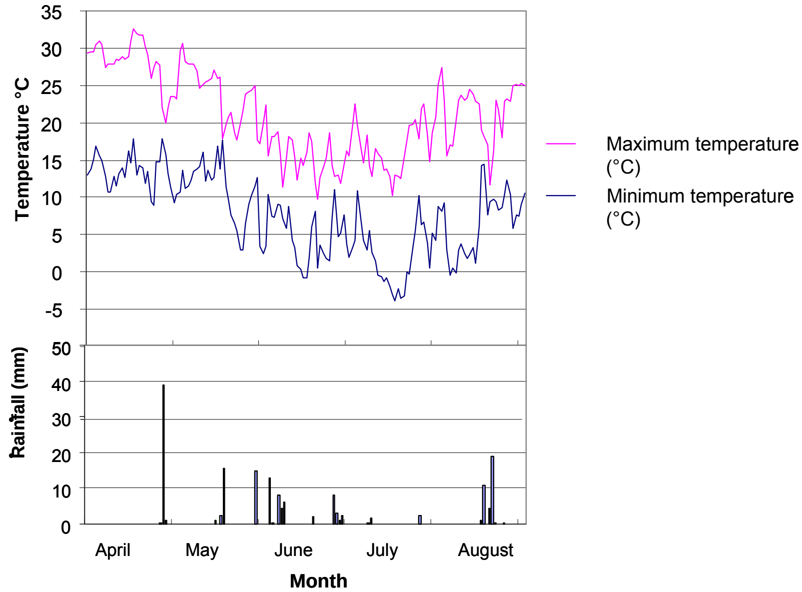

Fig. 6.8. Variation in rainfall, and maximum and minimum temperature at Moree, April to August 2007.

once warmer conditions arrived in spring. During the study period, water couch was not observed to flower or set seed.

Functional group responses at each site. We examined the response of individual plant functional groups at each site flooded by the April ECA release. At "Joanville", much of our study site was inundated prior to the ECA release and there was not a noticeable expansion in percentage cover of either the terrestrial or amphibious tolerator functional groups (Fig. 6.9). However, amphibious responders did increase in percentage cover over the survey period, most likely due to the prolonged period of inundation (Fig 6.4). The dominant species in this functional group at "Joanville" were nardoo (*Marsilea drummondii*) and water milfoil (*Myriophyllum variifolium*).

At 'Westholme", the transects were placed at a site that received only a shallow inundation and for a short period. The increase in biomass at this site was negligible, although the plant assemblages were dominated by the amphibious tolerator group (Fig. 6.10). These dropped substantially in their percent cover between May and August, due primarily to the impact of frost on water couch. In contrast, there was an increase in cover of terrestrial damp taxa as the damp soil in autumn encouraged the germination of annual plants or short term perennials. These plants grew slowly over winter before maturing and flowering in the following spring.

At "Goddard's Lease", the transects passed through water couch meadows and cumbungi (*Typha domingensis*) stands. The areas between the *Typha* were usually bare ground while around the *Typha* there was considerable vegetative litter. Following inundation, amphibious tolerator species such as water couch germinated and grew in bare areas but had been grazed out by the August monitoring period (Fig. 6.11). The amphibious responder water primrose (*Ludwigia peploides*) also increased in cover but was lying desiccated on the ground by the August monitoring as most pools of water on the site had disappeared.

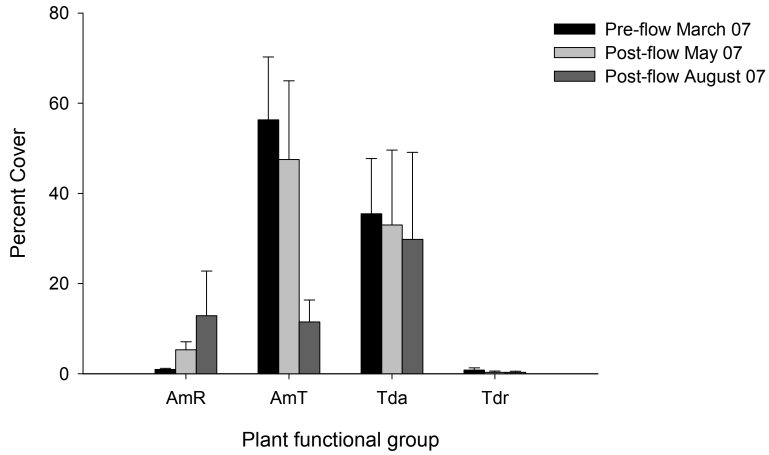

Fig. 6.9. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at “Joanville”, before and after the April 2007 ECA release, March to August 2007.

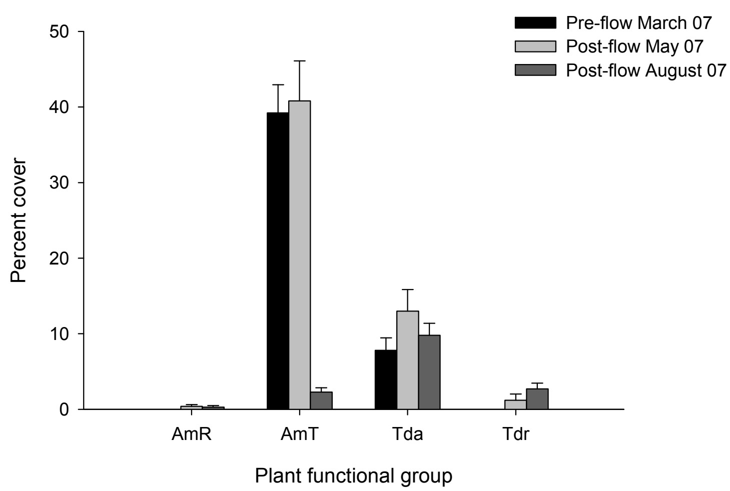

Fig. 6.10. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at “Westholme”, before and after the April 2007 ECA release, March to August 2007.

The “Munwonga” site was also dominated by *Typha* in the wetland but the transects also incorporated some areas dominated by terrestrial species. Water primrose (*Ludwigia peploides*) was the most common amphibious responder species at the site. It was present prior to inundation and became common in water pools that developed over the site. However, by August, the water had disappeared and the *Ludwigia* lay dessicated on the bare soil. This led to a reduction in the cover of amphibious responders (Fig. 6.12). The *Typha*

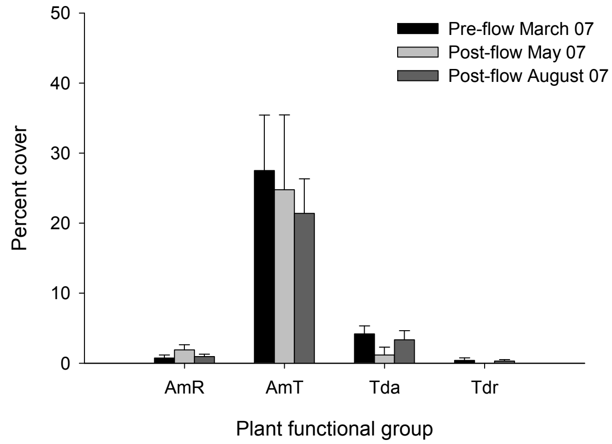

Fig. 6.11. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at "Goddard's Lease", before and after the April 2007 ECA release, March to August 2007.

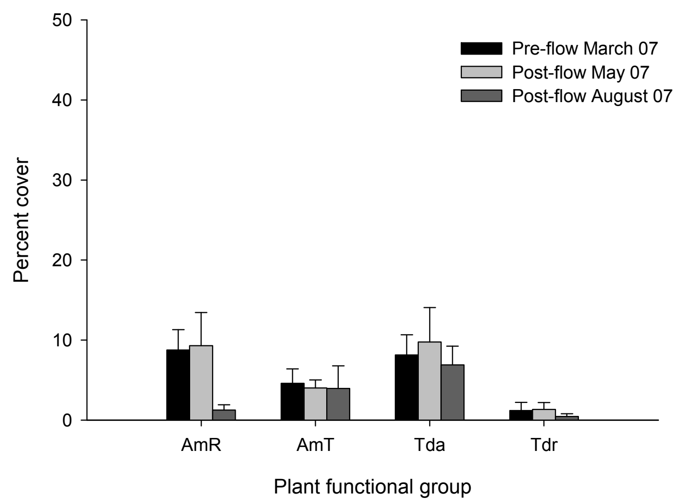

Fig. 6.12. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at "Munwonga", before and after the April 2007 ECA release, March to August 2007.

plants did not grow here during the monitoring period, although new shoots were observed coming through the ground leaf litter. This species may continue to grow through spring once temperatures increase. Again, the response of the vegetation at this site appeared to be influenced by the cold winter conditions, short period of inundation and presence of stock grazing the new vegetative material.

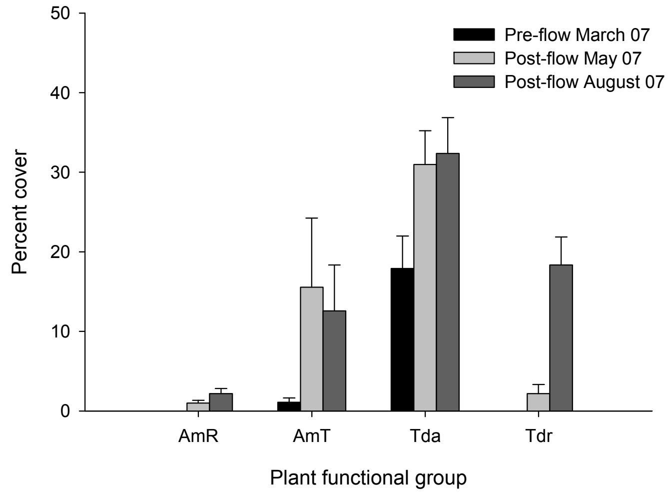

Fig. 6.13. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at "Crinolyn", before and after the April 2007 ECA release, March to August 2007.

Prior to the April release, the "Crinolyn" site was very dry and there was little vegetative cover. The functional group that responded most strongly to the flow here was the terrestrial damp species (Fig. 6.13). In areas where water levels were shallow and the period of inundation short, a range of species such as marshmallow (*Malva parviflora*) was common. Various medic species also germinated in large numbers in spaces between existing vegetation. Water lay in some parts of the site until at least August, and this resulted in substantial growth of several frost- tolerant amphibious species such as spike rush (*Eleocharis plana*) and swamp buttercup (*Ranunculus undosus*). Nardoo was also a common species across the site and grew vigorously in places where water remained.

The vegetative response to the ECA release was quite variable at "Crinolyn". In many parts of the site, it favoured terrestrial species such as lippia. However, where the water remained the longest, the response of amphibious species was the strongest. Furthermore, with water pooling at the site, frost did not appear to affect as many plant species as it did where the inundation period was short.

Neither of the two reference sites had been inundated by the December 2006 (Lower Gwydir River) and April 2007 (Gingham Watercourse) ECA releases, and both sites only received minor rainfall throughout the monitoring period. Most amphibious taxa only had negligible percentage cover (Figs. 6.14 and 6.15), and bare ground dominated both sites. The main species present on most transects at "Allambie" was lippia. Over the study period, the dominant change in the ground cover vegetation was the proliferation of various species of medic (mainly burr medic, *Medicago polymorpha*). The increase in cover of this species accounted for the rise in cover of terrestrial dry species (Fig. 6.14). Germination of this species appeared to coincide with late autumn and early winter rainfall. A similar pattern was observed at the second reference site at "Currigundi". The cold winter conditions prevented

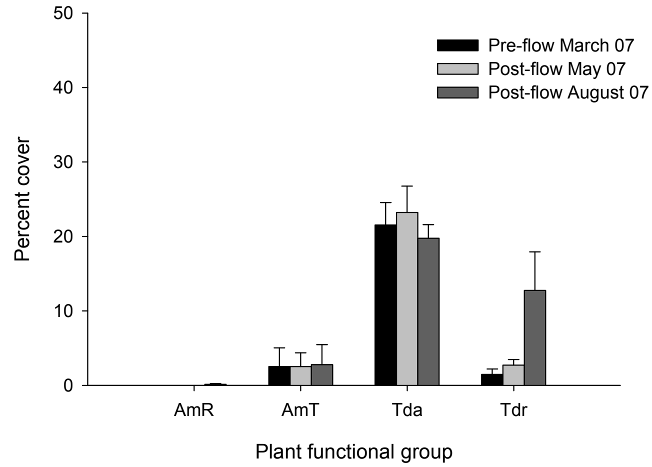

Fig. 6.14. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at “Allambie”, before and after the April 2007 ECA release, March to August 2007.

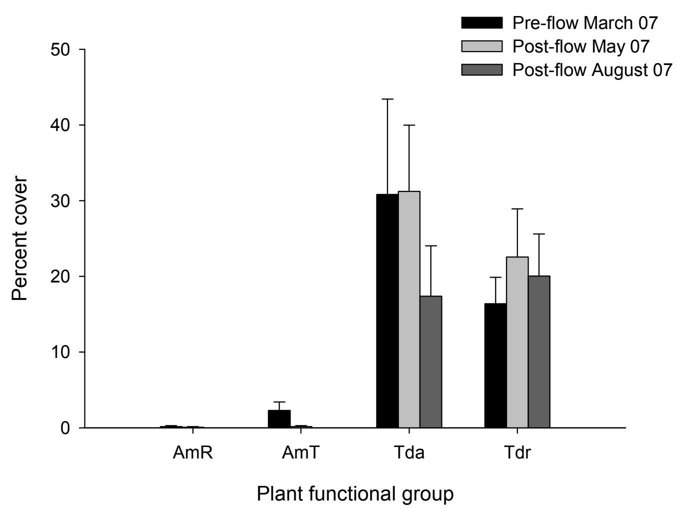

Fig. 6.15. Mean percentage cover (+/- 1 SE) of wetland plant functional groups at “Currigundi”, before and after the April 2007 ECA release, March to August 2007.

growth of most perennial grass species and the major change in vegetative composition in the plant community was caused by the increase in cover of burr medic.

November 2007 ECA release

Inundation levels. Flows from the November ECA event resulted in the impact sites being flooded to a depth of 20–50 cm. Additional inundation occurred in January and February 2008 from unregulated flows originating in the Horton River downstream of Copeton Dam. This extended the period of inundation to between 8–10 weeks at the impact sites. No water reached the control sites from the environmental flow or subsequent natural flows, and so these sites only received moisture from local rainfall. Variation in daily rainfall and temperature levels throughout the monitoring period at nearby Moree is shown in Fig. 6.16.

Vegetation response. A total of 60 macrophyte taxa were recorded from the four monitoring sites over the three monitoring times. The total number of taxa recorded from a single wetland ranged from 11 at "Bunnor" in September and "Old Dromana" in March through to 32 taxa from the second "Munwonga" control site in March. The most abundant species was *Paspalum distichum* which averaged 32 occurrences per transect and occurred in 64 out of 72 survey transects. The highest number of taxa at a monitoring site across all time periods was 39 at the second "Munwonga" control site, while the least was 20 at "Bunnor". The majority of taxa belonged to terrestrial functional groups (34 taxa versus 26 amphibious taxa). Many of the terrestrial taxa occurred at the control sites which were not inundated by the ECA release.

Responses to the November ECA release were variable among sites, both for total abundance/species richness and for the abundance of individual functional groups 6.17). For example, species richness decreased on "Old Dromana" following the release, while it increased significantly on "Bunnor" and at both control sites. At "Old Dromana", the vegetation response to the flow was prolific, with a pronounced increase in biomass comprised mainly of *Eleocharis sphacelata.* This growth in *Eleocharis* and the duration of flooding producing a reduction in species richness. At "Bunnor", the wetland had been heavily grazed prior to flooding and an increase in species richness occurred following the release. The increase in richness at the two control sites resulted from a wide range of terrestrial and amphibious species germinating and growing following summer rainfall.

At each of the wetland sites, total plant abundance rose from September to January (Fig. 6.17b). It continued to rise at '"Bunnor" which was flooded by the ECA but also at the two reference sites, suggesting a possible seasonal effect. At "Old Dromana" where cattle grazing had occurred both prior to and after the ECA release, abundances in March had fallen back to near the September level. However, this effect was not observed at "Bunnor" where stock did not graze the site after it was flooded. Patterns in changes to abundance of wetland functional groups were influenced by whether the site was inundated or not. Both "Old Dromana" and "Bunnor" experienced a statistically significant ($F_{1,2}$ = 24.1; $p<0.05$) increase in the abundance of amphibious responder (AmR) species. However, at "Old Dromana", this was due primarily to the increase in abundance of *Eleocharis sphacelata* while on "Bunnor" it was due to a rise in *Ludwigia peploides* abundance (Fig. 6.18c).

Amphibious tolerator (AmT) species also showed an increase in abundance at all sites between September and January (Fig. 6.17d), including *Paspalum distichum* (Fig. 6.18a). However, as the response occurred at both the flooded and reference sites, it was difficult to separate any response due to flooding from that due to other factors such as natural seasonal growth patterns or the influence of recent rainfall. However, the amount of vegetative matter in the shoot system of *Paspalum distichum* was observed to be considerably greater at flooded sites compared with the control sites.

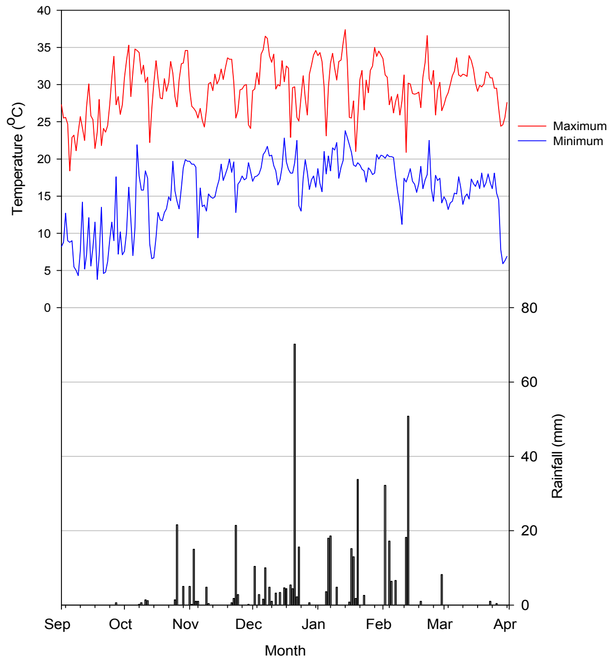

Fig. 6.16. Variation in daily rainfall and temperature levels throughout the monitoring period at Moree, month September 2007 to April 2008.

In contrast, the abundance of lippia showed a variable response following flooding (Fig. 6.18b). The analysis of variance of rank-transformed lippia abundance data detected a significant interaction effect ($F_{4,60} = 11.9$; $p<0.001$), indicating that the pattern of change in lippia abundance over time varied between wetlands. For example, lippia abundance dropped between September and January on “Old Dromana” and was barely detected by March. Lippia can not tolerate water depths of > 20cm for prolonged periods (McCosker, 1994), and the depth on “Old Dromana” was approximately 30 cm or greater for at least 4 weeks. This, in combination with competition from *Eleocharis sphacelate*, would have contributed to the reduced abundance of lippia. However at the “Munwonga” control sites which hadn’t been flooded, lippia abundance rose at each monitoring period, most likely from its ability to take advantage of the moist soil conditions and warm temperatures. At “Bunnor”, lippia was only detected in the third survey. The origin of these plants may have been germinants from the soil seed bank, although it seems more likely that they had established from plant fragments washed downstream with the ECA flow. Another weed that appeared on “Bunnor” was water hyacinth (*Eichhornia crassipes*). Again, the origin of the plants is not certain, although it also seems likely that they would have been flushed downstream.

Clearly, it is important to be aware of the potential for environmental flows to spread weed species, particularly when releases are timed to coincide with most favourable growing conditions for wetland plant species. On “Bunnor” the species which responded most positively to flooding was *Typha domingensis* which grew prolifically and provided very favourable conditions for water hyacinth survival.

Another common wetland species, pale knotweed (*Persicaria decipiens*) occurred at all monitoring sites (Fig. 6.18d). Abundance of *Persicaria* increased at all sites, and so it was

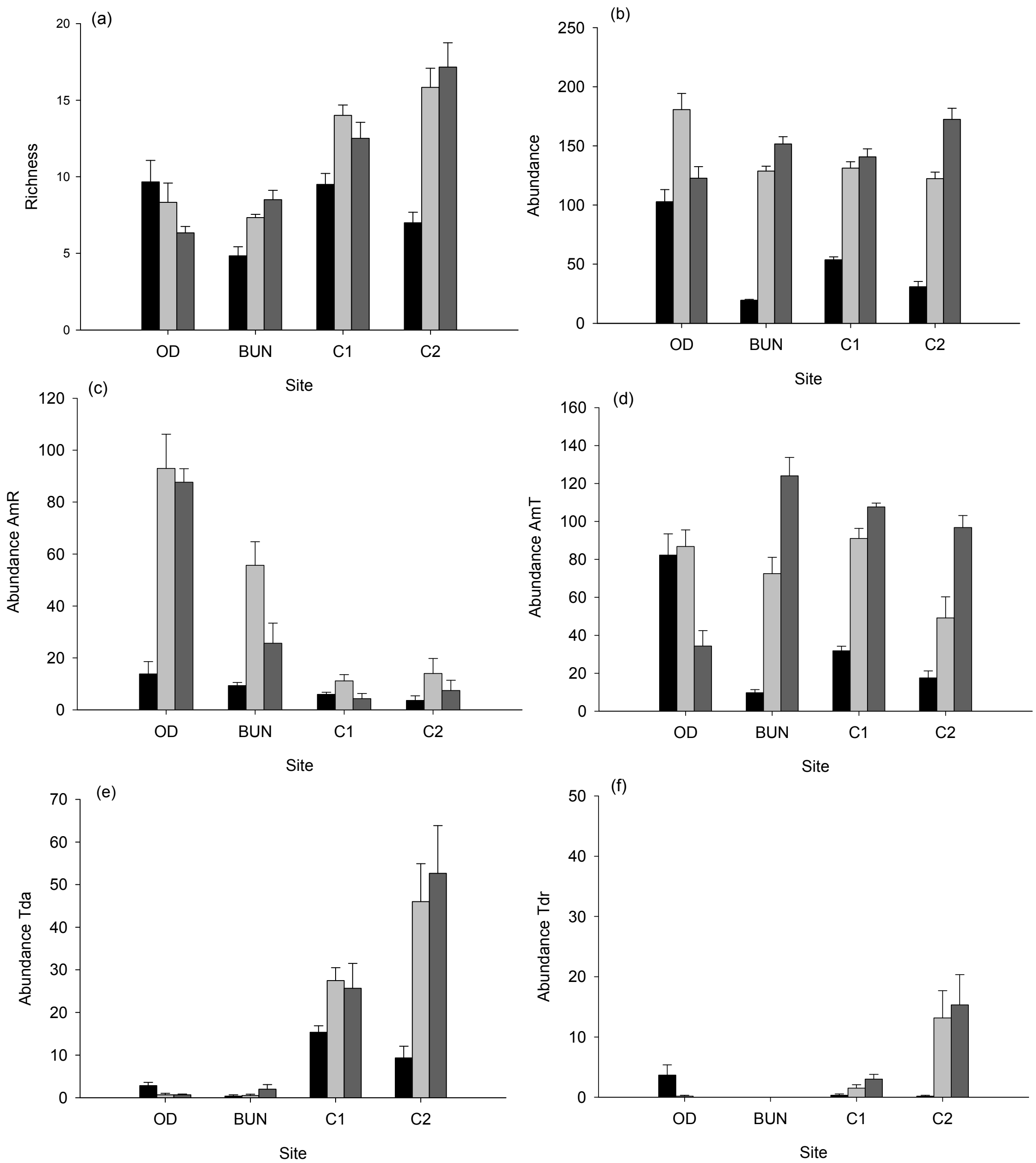

Figure 6.17 Variation in mean species richness, total abundance, and abundance of individual functional groups before and after the November 2007 ECA release into the Lower Gwydir wetlands, September 2007 to March 2008. Error bars are standard errors based on wetland means.

hard to separate seasonal trends from the effects of the environmental flow. However, the mean abundance of terrestrial species only increased at the control sites (Fig. 6.17e,f). Taxa in these functional groups grew in response to regular rainfall throughout December, January and February (Fig. 6.16).

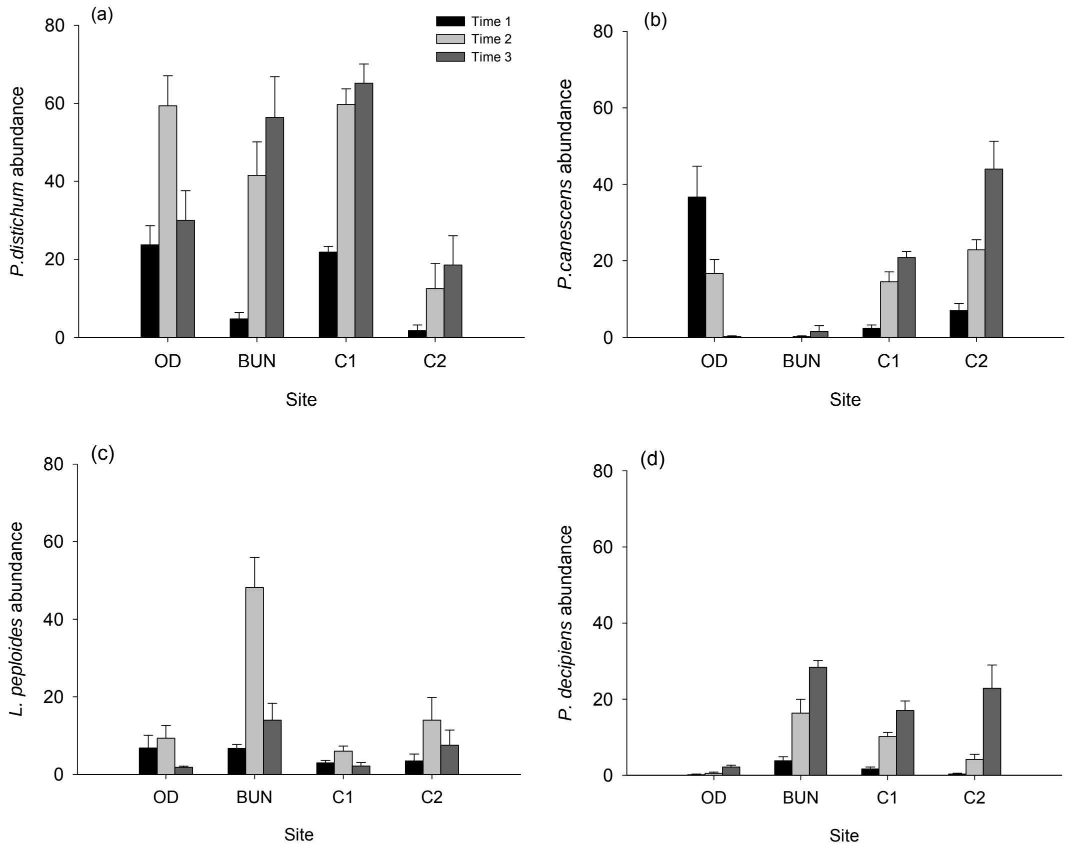

Figure 6.18. Variation in mean abundance of common amphibious plant species before and after the November 2007 ECA release into the Lower Gwydir wetlands, September 2007 to March 2008. Error bars are standard errors based on wetland means.

6.4 Discussion

The vegetation response to the two ECA releases was markedly different, and the vigour of the response to the November 2007 flow was noticeably greater. The arrival of this water in the warmer months of the year meant that it coincided with the growing season of many of the plant species. In addition, seasonal rainfall helped to prolong the period of high soil moisture. At flooded sites, there was a major increase in vegetative matter in the shoot system of most plant taxa compared with control sites which received only seasonal rainfall. In contrast, the April 2007 flow meant that water entered the Gingham Watercourse during autumn when seasonal conditions are cooler and day length is shortening. For the first four weeks after the flow arrived, there was a period of relatively favourable conditions for plant growth. However, heavy frosts during cold periods in late June and early July meant that most summer growing grasses became dormant and few plants of any functional group actually reached a stage in their lifecycle where they could flower and set seed. Subsequent dry winter conditions meant that there was only limited livestock feed available at most monitoring sites, and landholders having to allow grazing in wetland paddocks further reduced the net vegetative response. To illustrate the magnitude of the difference in response between seasons, it would be worth including monitoring of biomass in all future ECA monitoring activities. The main reason for suggesting this alternative approach is that with prostrate taxa, percent cover is often relatively high, even under moderate grazing pressure. It is the volume of the shoot material that changes most with increased growth vigour. This response is better detected through monitoring biomass changes rather than percent foliar cover alone.

Timing of flow also had an influence on lippia cover. In the November 2007, flow growth of perennial grasses such as native panic (*Panicum decompositum*) and water couch (*Paspalum distichum*) was vigorous. At “Old Dromana”, water couch cover increased in response to the arrival of water into the wetland and lippia cover decreased over time. By comparison, at the control sites there was an increase in cover of water couch but no decrease in lippia cover. The control sites were responding to seasonal rainfall alone. At the flooded sites, the combination of water depth and the large biomass of water couch appeared to create conditions unfavourable for lippia, resulting in it not being detected at the third monitoring period in March 2008. However, the outcome was not so successful in the April 2007 flow in the Gingham Watercourse. Lippia showed greater frost tolerance and entered a period of more rapid growth earlier in spring compared with native grasses. In particular, at “Crinolyn”, lippia expanded in cover considerably over the monitoring period (Fig. 6.4) and low-lying parts of the landscape became almost totally covered in this species. It, therefore, appears that if an objective of an ECA release is to promote growth of native grasses over lippia, it would be better to time the release for late spring or early summer to give native grasses the maximum time to exert a competitive advantage.

At any point in time, the plant community that exists in a wetland is a reflection of the water regime in the preceding weeks and months. Each plant species in the species pool for a wetland has particular conditions which assist its germination and establishment. When moisture conditions change, either with the introduction of water into a dry wetland or from the gradual recession of existing surface water, some species are able to tolerate the change while others cannot. The arrival of water in a wetland is a particularly important cue for the germination and establishment of aquatic plant species, and a reduced flooding frequency may result in a gradual loss of aquatic species as their seeds become less abundant in the soil seed bank. This may occur either through an inability of germinants to set seed before the wetland dries out or from seeds losing viability in the soil before appropriate germination cues occur. Environmental water allocations are intended to reinstate attributes of the wetland water regime lost through river regulation, such as increasing the frequency of inundation or extending the duration of flood events. The goal of this strategy is, therefore, to create conditions that are favourable for the germination and establishment of key wetland taxa. The main difficulty currently faced by water managers and committees responsible for the delivery of environmental water is that there are only limited data on the ecological requirements of many wetland species (Roberts, 2002). This knowledge gap is a constraint on implementing flow requirements for floodplain wetland systems.

Species richness of the amphibious responder and amphibious tolerator groups increased at most sites following each of the ECA flows monitored here. However, the winter flow was followed by a period of drawdown almost straight after the flow concluded, and there was little additional moisture from either flooding or rainfall to maintain soil moisture. In conditions where drawdown occurs relatively quickly, it has been observed to promote the germination and establishment of species known collectively as ‘mud flat annuals’ (Harris & Marshall, 1963; Salisbury, 1970; ter Heerdt & Drost, 1994). The observed response to the autumn flow showed that the majority of new species belonged to the terrestrial functional groups which established in the autumn and flowered in the following spring. Following the summer environmental flow, new species at the monitoring sites were mainly amphibious taxa. However, while some amphibious tolerator taxa seedlings were recorded at reference sites in January and March, the majority of new species were from the terrestrial functional groups (Table 6.2). These data illustrate the influence of water regime on plant community composition. The extended duration of inundation did not provide the conditions for terrestrial species to germinate in large numbers at flooded sites, and resulted in a noticeably different plant community.

Having established a mechanism, through the ECA Operations Advisory Committee, for increasing the frequency of environmental flows into the Lower Gwydir wetlands, managers of these events should also consider the timing of releases so as to maximise the duration of inundation. The best means of extending duration appears to be through backing flows onto natural events. When the soil is already wet, the spatial extent and duration of ECA inundation increases markedly as less surface water is lost into the soil profile. This was evident when comparing the area of inundation at sites such as Westholme in the April and November flow events. The November flow covered a much larger area to a greater depth. Nevertheless, the present study has illustrated that the objectives of promoting the health of wetland plant communities and providing conditions favourable for native species to compete with introduced species is achievable.

The main issue that remains a concern is the spatial extent of influence. In recent ECA releases, the Ramsar sites at “Old Dromana” and “Goddard’s Lease” have been partially or fully inundated, although less flow has reached “Crinolyn” and “Windella” further down the Gingham Watercourse. If these two downstream Gingham sites are to remain as target sites for environmental flows, it may be necessary to develop technical solutions to allow water to travel through the wetland system to reach the bottom without spilling at the top of the system. This study has illustrated that the vegetation communities throughout the whole of the Lower Gwydir wetland system have a high level of resilience to a variable water regime and, given the return of a more favourable hydrologic regime, have the capacity to develop a wet-phase plant community containing a variety of true aquatic taxa.