

Part 2

Responses of Lower Gwydir wetland and in-stream environments to flow variability



Chapter 5

Long-term analysis of the effects of inundation and grazing on vegetation communities in the Gwydir wetlands

Key findings

- Vegetation cover in all wetland plant communities is strongly correlated with river flows in the preceding three month period.
- Vegetation cover in the Gwydir Wetlands is dominated by native perennial species.
- Grazing impacts on wetland plant communities are influenced by plant morphological traits. In locations where tall herbaceous species dominate grazing breaks up canopy cover leading to an increase in light at ground level which promotes an increase in plant diversity at the local scale.
- Plants belonging to the amphibious responder functional group are most vulnerable to the impacts of livestock grazing.

Recommendations

- Delay grazing or maintain low stocking rates during the initial stage of wetland flooding to allow fragile plant species in the amphibious responder functional group to flower and set seed.
- Maintain conservative stocking rates (0.3-0.5 animals per hectare) to protect key native species from over grazing.
- Continue monitoring of the Lower Gwydir grazing-exclosure sites on an event-based basis.
- Prioritise research on the response of wetland soils to inundation and their role in supporting wetland condition and function.

5.1 Introduction

Grazing domestic livestock on inland river floodplains in Australia has occurred for over 150 years (Robertson, 1997). Livestock congregate in wetland areas particularly during low-rainfall conditions. The impacts of this behaviour on vegetation may include the direct loss of floodplain primary production, changes in plant community composition and introduction of exotic plant species (Robertson, 1998). Such impacts are a cause for concern for those charged with managing such areas and for members of the general population concerned with their conservation. In recent decades there has been a heightened awareness of the ecological value of these wetland systems (Williams, 1998; Jenkins *et al.*, 2005). In particular, the role wetlands play as bird breeding sites for migratory bird species and their biodiversity value in a largely altered agricultural landscape (Alexander *et al.*, 2008).

River regulation has resulted in profound changes to the hydrological regime of many floodplain wetlands. In the Gwydir catchment the frequency and duration of inundation has decreased resulting in a reduction in floodplain productivity (Kingsford, 2000). The ecological purpose of environmental flows has been to help re-establish linkages between the river and its floodplain wetlands but grazing has been identified as one factor that may limit the

recovery of ecological functioning in these systems (Robertson *et al.*, 1996). Given the current situation in Australia in relation to the availability of water for consumptive uses, there is pressure from all stakeholders in the water debate for environmental water to deliver maximum ecological benefit. Therefore, it is necessary to understand the nature of the disturbance caused by livestock grazing in wetlands and the resilience of these systems to such disturbance.

This study investigates the response in terms of changes in community composition of vegetation communities exposed to varying grazing pressure and inundation patterns. It takes advantage of a series of grazing exclosures established in 1994 to examine how grazing and an altered flooding regime are impacting on the Lower Gwydir wetlands and to gauge how resilient these wetlands are to such disturbances. Through understanding the impacts of the disturbance regime and monitoring the effect of measures implemented to sustain wetland vegetation, the subsequent findings can help guide future management decisions by agency staff and landholders.

5.2 Materials and methods

Study sites and inundation history. Data were collected from four Lower Gwydir floodplain sites with differing plant communities, to assess the impacts of grazing by livestock, feral species and macropods (Fig. 5.1):

“**Old Dromana**” – *Bolboschoenus fluviatilis* (marsh club-rush) reed bed near the downstream end of the Gwydir River system (29° 20' 46" S, 149° 17' 38" E);

“**Westholme**” – *Paspalum distichum* (water couch) open meadow mid-way along the Gingham Watercourse (29° 15' 45" S, 149° 23' 19" E);

“**Crinolyn**” – degraded *Paspalum distichum* community, partially invaded by *Phyla canescens* (lippia) near the downstream end of the Gingham Watercourse (29° 12' 53" S, 149° 08' 13" E); and

“**Birrah**” – *Paspalidium jubiflorum* (Warrego summer grass) grasslands, also near the downstream end of the Gwydir River system (29° 20' 24" S, 149° 21' 14" E).

These sites were originally established by University of New England researchers in 1994, and follow a randomised complete block design. At each site, there are four replicate blocks, with the three treatments randomly allocated once to a plot within each block (Fig. 5.2). The three treatments were:

GRAZED open plots that remained unfenced and unmarked;

PARTIAL partial grazing pressure, surrounded by cattle-proof fences to only exclude cattle while allowing access by macropods and feral pigs; and

UNGRAZED total exclusion of all mammal herbivores.

All PARTIAL plots were fenced with 0.9 m high 6 line mesh (BHP Waratah ‘hinged joint’) suspended 0.5 m above the ground. High tensile plain wire (2.5 mm) was used to support the top and bottom of the mesh. Wooden corner posts, stays and stay blocks were used in all plots, with 1.8 m BHP star pickets carrying the wire and mesh. UNGRAZED plots were

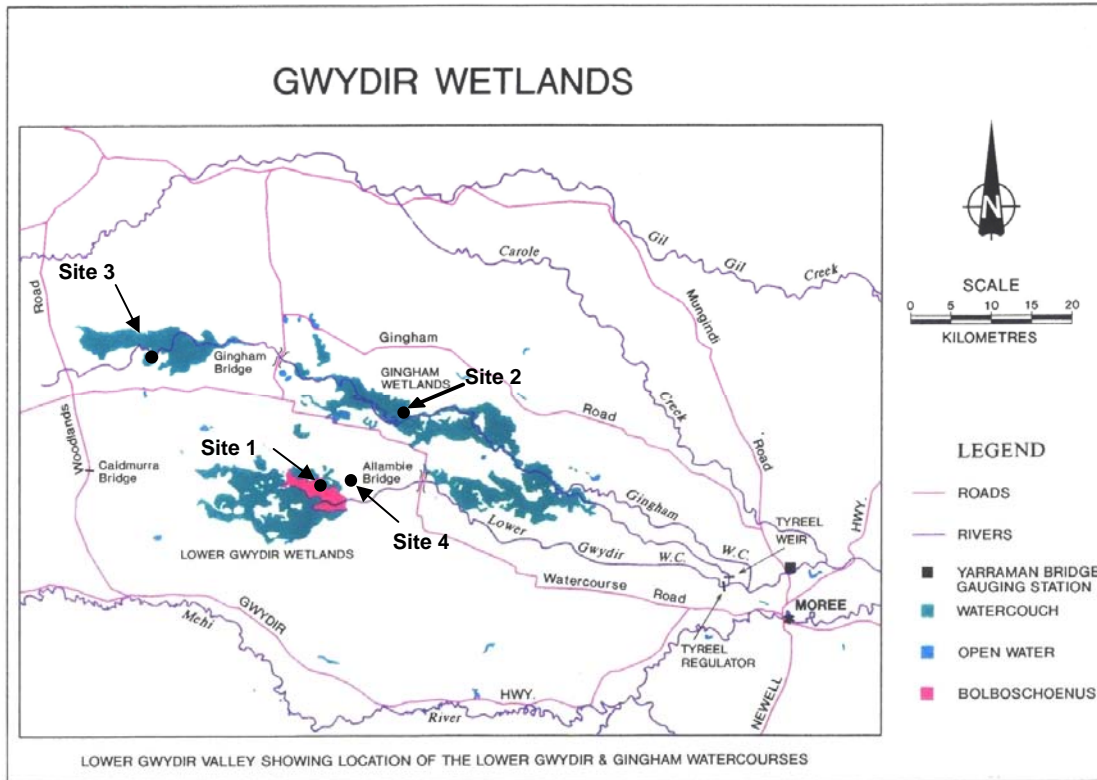
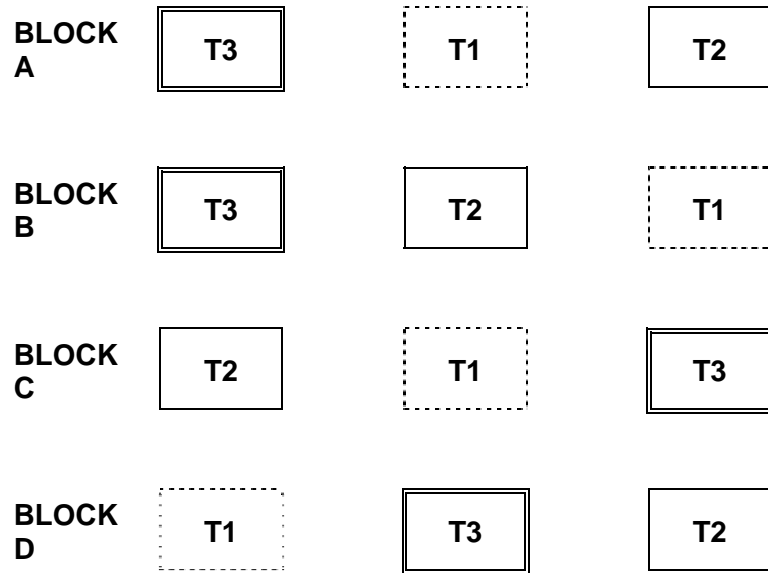


Fig. 5.1. Location of grazing enclosures in the Lower Gwydir wetlands. Site 1, “Old Dromana”; Site 2, “Westholme”; Site 3, “Crinolyn” and Site 4, “Birrah”. Original map courtesy of Neal Foster.

completely fenced with 1.5 m high 14 line internal deer fence (Cyclone ‘*strongline*’). A high tensile plain wire was again used on the top and bottom for support. Corner assemblies and pickets were the same as for PARTIAL plots (Fig. 5.3). In the period since construction, some UNGRAZED enclosure fences had suffered corrosion along their base. This was repaired in August 2007 by the application of an additional layer of hinged joint fencing.

The concept of site productivity in conjunction with evolutionary history of grazing has been used by Milchunas & Laurenroth (1993) as a means of predicting how a site will respond to grazing. The threshold value for distinguishing highly productive sites from low productivity sites is 200 g/m² of above ground primary production. “Old Dromana” and “Westholme” have experienced regular inundation, typically every 1-2 years, and are considered examples of productive sites. By contrast, “Crinolyn”, at the western end of the Gingham Watercourse, has traditionally experienced less frequent inundation and a marked reduction in the frequency and duration of flooding over recent decades. Productivity at this site is less than at “Westholme”. The site on “Birrah” is located higher on the floodplain near the end of the Gwydir River and experiences an inundation frequency of approximately every 5-10 years. It is considered to be less productive than the marsh club rush community at nearby “Old Dromana”.



T1 = GRAZED - unfenced;
 T2 = PARTIAL - exclusion of cattle while allowing free access to kangaroos, feral pigs and foxes; and
 T3 = UNGRAZED - exclusion of cattle, kangaroos, feral pigs and foxes

Fig. 5.2. Layout of experimental grazing exclusion plots at four sites in the Gwydir wetlands.



Fig. 5.3. A PARTIAL grazing enclosure on “Crinolyn” (left) and an UNGRAZED enclosure at “Birrah” (right). Photos: P. Berney.

Vegetation monitoring. Vegetation monitoring was conducted initially on an annual basis following the summer growth period but from 1995 to 1998, sampling became more intensive to monitor vegetation responses to flooding. From 2007 onwards, monitoring was conducted both before and after environmental flows. At all monitoring times for each treatment plot, 10 1 m² quadrats were randomly placed, and the presence of all vascular plants was recorded, as well as projected foliar cover data using a modified Braun-Blanquet scale (Mueller-Dombois & Ellenberg, 1974). This used a scale from 0 to 7 to estimate projected foliage

Table 5.1. Modified scoring system used to monitor vegetation cover in grazing exclosures, Lower Gwydir wetlands, May 1994 to March 2008.

Braun-Blanquet score	Projected Foliage Cover (PFC)
0	Not present
1	Only 1 specimen present
2	More than 1 specimen but scarce
3	<5% PFC, may be numerous small specimens
4	5-24% PFC
5	25-49% PFC
6	50-74% PFC
7	75-100% PFC

cover (PFC, Table 5.1). Antecedent conditions for each monitoring period are presented in Table 5.2. Our monitoring data span a period of 14 years from May 1994 to March 2008.

Data analyses. Data on per cent cover of all herbaceous species in each of the 10 quadrats in each plot were collated for each vegetation community sampled over the 13 monitoring times. Species were assigned to groups based on origin (native vs exotic) and life form (annual vs perennial) using information from Harden (2000–2002). Species were also assigned to wetland functional groups based on how they germinate, establish and reproduce in relation to surface water. Our classification was based on Brock & Casanova (1997), Harden (2000–2002) and records from previous research in the Lower Gwydir wetlands (McCosker, 1999). Cover of all species, natives, exotics, annuals, perennials, amphibious responders, amphibious tolerators, terrestrial damp and terrestrial dry was then calculated for each quadrat by summing the cover values for the relevant individual species. Richness was determined by counting the number of species per quadrat. The cover, richness and composition data from the 10 quadrats in each 25 m x 25 m plot were averaged before analysis. Cover and richness data were analysed using Statistix 7 (Analytical Software, 2000). For the univariate cover and richness data, repeated measures analysis of variance was used to examine the effects of year, grazing treatment and site. Due to drought conditions in the Lower Gwydir wetlands in early 1994, no data were available from “Crinolyn” in the first survey period. In order to avoid problems associated with this, only data from the second monitoring period onwards were included for the repeated measures analysis of variance.

Composition data were analysed using non-metric multidimensional scaling in PRIMER 6 (Clarke & Gorley, 2006). A sample versus species similarity matrix (Bray-Curtis similarity, 4TH root transformed) was used calculated in PRIMER based on average percent cover values for the 10 quadrats from each plot. Non-metric multidimensional scaling (nMDS) ordination was performed to compare the similarity of the plant communities between treatments over time. Analysis of Similarities (ANOSIM, Clarke & Warwick, 2001), and a Mantel (1967) type permutation test using the rank order of similarities, was used to test for differences in species composition and percent cover between grazing treatments over time. SIMPER analysis (Clarke & Warwick, 2001) was subsequently performed to examine which taxa were

Table 5.2. Timing of grazing-exclosure monitoring in the Lower Gwydir wetlands, 1994 to 2008, and prevailing inundation conditions.

Monitoring trip	Sites monitored	Inundation conditions	Comments
May 1994	“Old Dromana”, “Birrah”, “Westholme”	Dry; wetlands in draw down.	Sampling not possible at “Crinolyn” due to drought conditions
May 1995	All	Dry wetlands had last inundation during January 1995	
January 1996	All	Wetlands inundated following recent flooding	
July 1996	All	Wetlands inundated following significant flooding	
October 1996	All	Wetlands inundated following additional minor flooding	
May 1997	All	Still wet from summer flooding	
September 1997	All	Old Dromana wet, other sites drying out after 1-6 months of inundation	
March 1998	All	Old Dromana and Westholme experienced shallow inundation, Crinolyn and Birrah dry	
December 1998	All	All sites had experienced inundation in the previous five months	Inundation was deepest and longest at Old Dromana and Westholme.
May 2007	All	Dry, wetlands in drawdown	“Westholme had experienced minor flooding in a recent environmental flow
September 2007	All	Dry, wetlands in draw down	Good winter rainfall
January 2008	All	Old Dromana and Westholme inundated from a recent environmental flow. Crinolyn and Birrah both were dry, receiving only seasonal rainfall	Good summer rainfall received at all sites
March 2008	All	Old Dromana and Westholme still wet, Crinolyn and Birrah now dry	

contributing most to the dissimilarity in species composition between treatments at different times.

5.3 Results

A total of 147 species of herbaceous plants was recorded within the grazing exclosures between May 1994 and March 2008, with native and introduced species comprising 69% and 31% of taxa, respectively. Perennial species accounted for 49% of the species described, with annuals making up 45%, biennial species 3% and species described as annuals or short-lived perennials comprised a further 3%. Total cover averaged 61% across all sites and years.

However, the pattern of total cover when averaged across all sites varied markedly between monitoring periods (Fig. 5.4). The pattern in perennial cover mirrored changes in the total cover across all sites, indicating that patterns in total cover were driven by temporal changes in this functional group (Fig. 5.4 a). Many of the key perennial species also belong to the native functional group, therefore this group follows a similar pattern to the perennials (Fig. 5.4 c). Annual cover is generally less than perennial cover. Annual cover tends to peak in sampling periods following floods, May 1995, July 1996 or environmental flows January 2008 and March 2008. It also peaks during spring sampling times, October 1996 and September 2007 (Fig. 5.4 b).

Inter-annual variation in total cover of ungrazed plots correlated with Gwydir River flows at the Yarraman Bridge gauging station for the three months prior to each survey period (Pearson $r = 0.7002$, $P = 0.0357$) (Fig. 5.5). During periods of high flow, water spills from channels through the wetlands and inundates the floodplain and stimulates growth in the floodplain vegetation. Accordingly, cover of amphibious plants also varied with patterns in inundation (Fig. 5.6), and responded differently to terrestrial species. For example, amphibious responders reached their highest percent cover during the periods when the sites were inundated (January–October 1996), while terrestrial damp species showed the opposite pattern with their percent cover highest in the drier periods (May 1995, May 2007 and September 2007).

Patterns of temporal change in plant community composition were generally similar between sites and at each monitoring time. With few exceptions, there tended to be little difference between treatments, indicating that factors other than grazing were exerting a greater influence on observed changes in community composition (Fig. 5.6). By contrast, ordination of community composition at the site level did indicate significant differences in species composition (Fig. 5.7). “Birrah”, as the driest of the sites, was separated from the wetter sites at “Old Dromana” and “Westholme”, with “Crinolyn” appearing to represent an intermediate state. Due to these differences, each site will be discussed individually.

“Old Dromana” – Percent cover of the dominant *Bolboschoenus fluviatilis* peaked following periods of flooding (Fig. 5.8), although does not grow as vigorously on rainfall alone. When it does grow vigorously it forms a dense canopy that shades competitors and reduces local species richness. Grazing causes disturbance to the canopy as the plants are trampled and eventually consumed. This allows other species to grow under the modified environmental conditions. ANOSIM analyses showed that in May 2007, significant differences existed between the GRAZED and UNGRAZED treatments ($R = 0.771$, $P = 0.029$) and between the GRAZED and PARTIAL treatments ($R = 0.521$, $P = 0.029$). However, there was no significant difference between the PARTIAL treatment and the UNGRAZED treatment. Similarly, in September 2007, there were significant differences between the GRAZED and UNGRAZED treatments ($R = 1$, $P = 0.029$) and between the GRAZED and PARTIAL treatments ($R = 1$, $P = 0.029$).

Wetland vegetation – flooding vs grazing

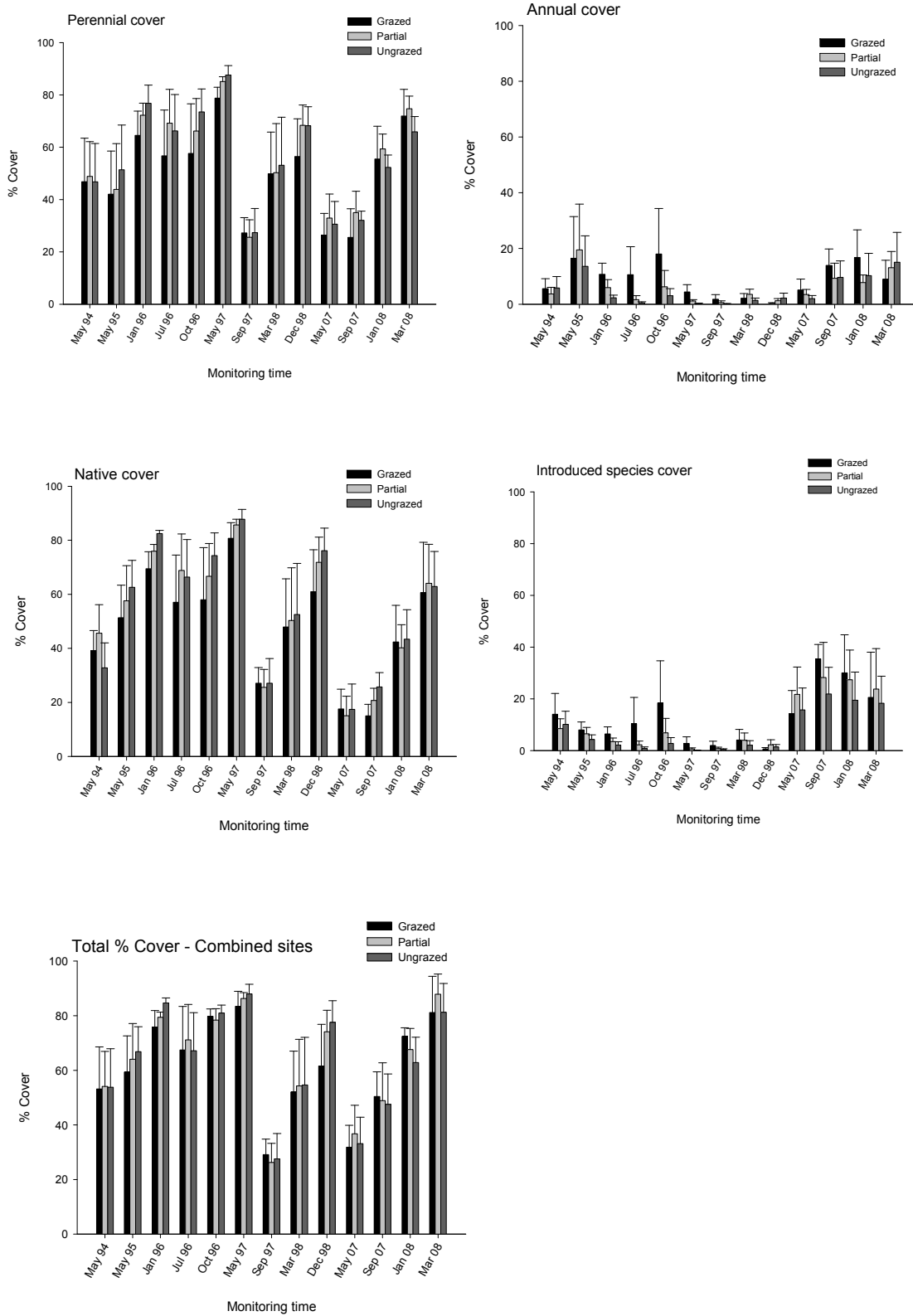


Fig. 5.4. Temporal variation in mean percent cover (± 1 SE) of herbaceous plants between grazing treatments in the Lower Gwydir wetlands, 1994 to 2008. Data were averaged across the four sites.

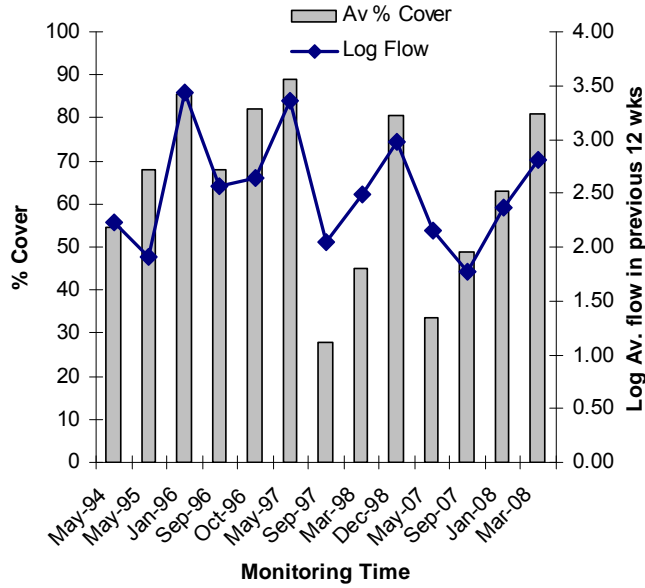


Fig. 5.5. Temporal variation in mean total percent cover of vegetation across the four wetland sites, May 1994 to March 2008, and log of average daily discharge in the Gwydir River at Yarraman Bridge over previous 12 weeks.

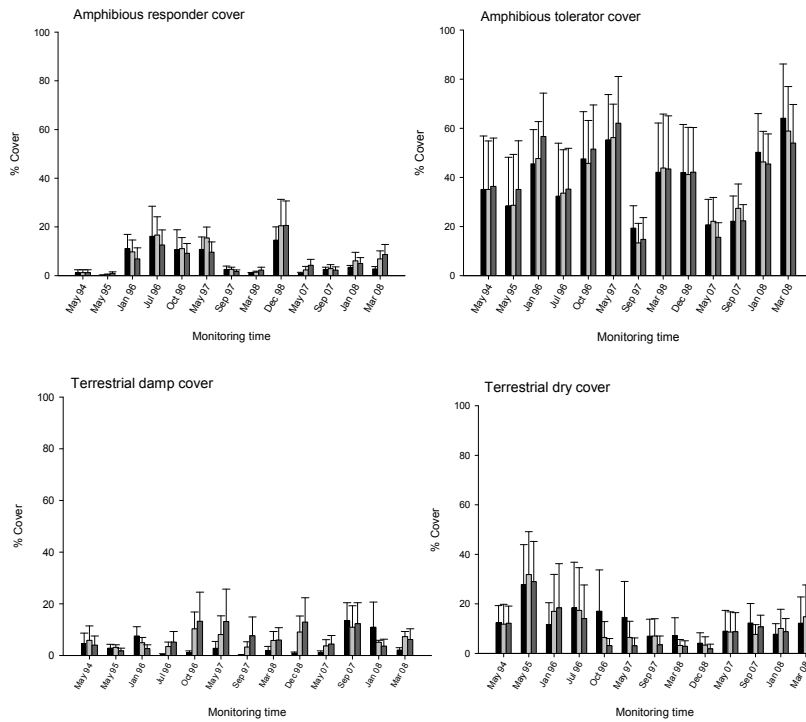


Fig. 5.6. Temporal variation in mean percent cover of herbaceous species arranged in wetland functional groups between grazing treatments in the Lower Gwydir wetlands, May 1994 to March 2008. Error bars are ± 1 standard error, and are averaged across the four sites.

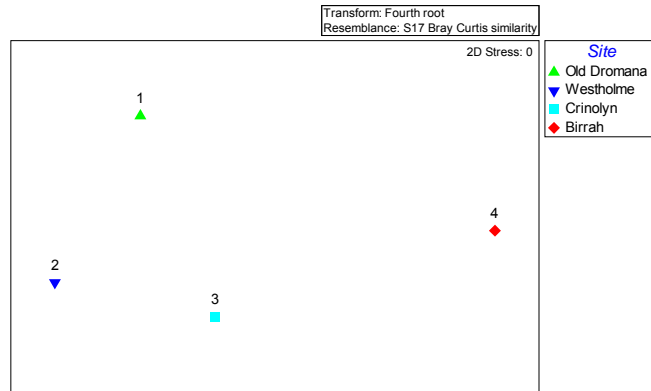


Fig. 5.7. Non-metric multidimensional scaling ordination of wetland plant community composition at four survey sites in the Lower Gwydir wetlands, 1994–2008. Data were pooled across the three grazing treatments.

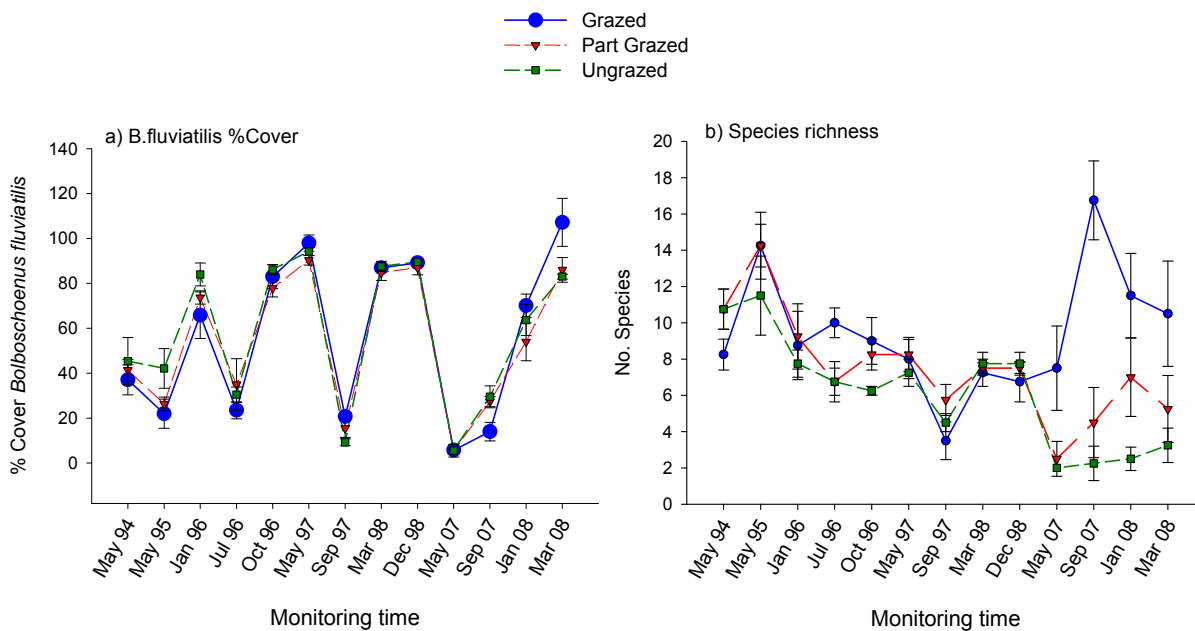


Fig. 5.8. Mean (a) percent cover of *Bolboschoenus fluviatilis* and (b) species richness on “Old Dromana” between the three grazing treatments, May 1994 to March 2008. Error bars are ± 1 standard error.

Another species that contributed to the significant difference between the GRAZED and UNGRAZED or PARTIAL treatments was the thistle *Cirsium vulgare*. This species was very abundant in grazed sites although almost absent from un-grazed sites. When the wetland

was flooded again in late November 2007, *B. fluviatilis* grew vigorously and reformed a dense canopy and species richness began to fall again.

Many of the species at the “Old Dromana” GRAZED sites were amphibious species. During flood periods, cover of taxa in all functional groups generally increased, although the extent of the increase for amphibious responder taxa in grazed sites was less (Fig. 5.9). Plants belonging to this functional group are often more delicate and appear to be negatively impacted by the presence of grazing.

“**Westholme**” – During initial survey periods, there were no significant differences in species composition between treatments, although significant differences were detected during 2007 (Fig. 5.10). In May 2007, ANOSIM detected a significant difference between the GRAZED and the UNGRAZED treatments ($R = 0.885$, $P = 0.029$), and between the GRAZED and PARTIAL treatments ($R = 0.656$, $P = 0.029$).

The vegetation community at this site was dominated by water couch, *Paspalum distichum*, and it was this species that contributed most to the observed treatment effect on plant cover (Fig. 5.10). This species had reduced cover in UNGRAZED plots, while other species such as *Persicaria decipiens*, *Persicaria orientalis* and *Rumex tenax* exhibited an opposite pattern. Once grazing is excluded, it appears to allow grazing-sensitive herbaceous species to grow more successfully, and these species end up shading out the *Paspalum distichum* to and reduce its dominance. Grazing at this site appears to aid in maintaining the dominance of *Paspalum distichum*.

The impact of wetland water regime on shaping plant community composition is evident at this site. Percent cover of the amphibious responder taxa which are adapted to surviving extended periods of inundation increased following floods in 1996, 1997, 1998 and environmental flows in 2007 (Fig. 5.11a). By contrast, the percent cover of terrestrial damp taxa was low throughout the mid 1990s period of regular flooding (Fig. 5.11b.). Prior to monitoring of the site in 2007, it had been several years since the site was flooded, and terrestrial taxa had become well established in the wetland. However, following inundation from the environmental flow in November 2007, percent cover of plants in this functional group fell substantially. Similarly for *Phyla canescens*, percent cover remained low while the site experienced regular floods but increased during the dry period prior to the November 2007 ECA release (Fig. 5.12). By the March 2008 monitoring period, *P. canescens* cover had decreased in all treatments. These impacts on the plant community composition probably occur because the duration of inundation at this site can last for several months. This provides an extended period of favourable growth conditions for established natives such as *P. distichum*. At sites where duration of flooding is less prolonged, such compositional changes were not observed.

“**Crinolyn**” – This site has traditionally experienced a lower frequency and duration of flooding than sites such as “Westholme” closer to the eastern end of the wetlands. Like “Westholme”, it had extensive meadows of *P. distichum*, although a substantial change in plant community composition has occurred since monitoring of this site began. In particular, the percent cover of *P. distichum* has decreased while the cover of *P. canescens* has increased (Fig. 5.13).

During 2007 and 2008, two ECA releases were made into the Gingham Watercourse. On both occasions, while the grazing exclosure sites at “Westholme” were inundated, those on “Crinolyn” remained dry. At present, the main source of moisture sustaining the plant

Wetland vegetation – flooding vs grazing

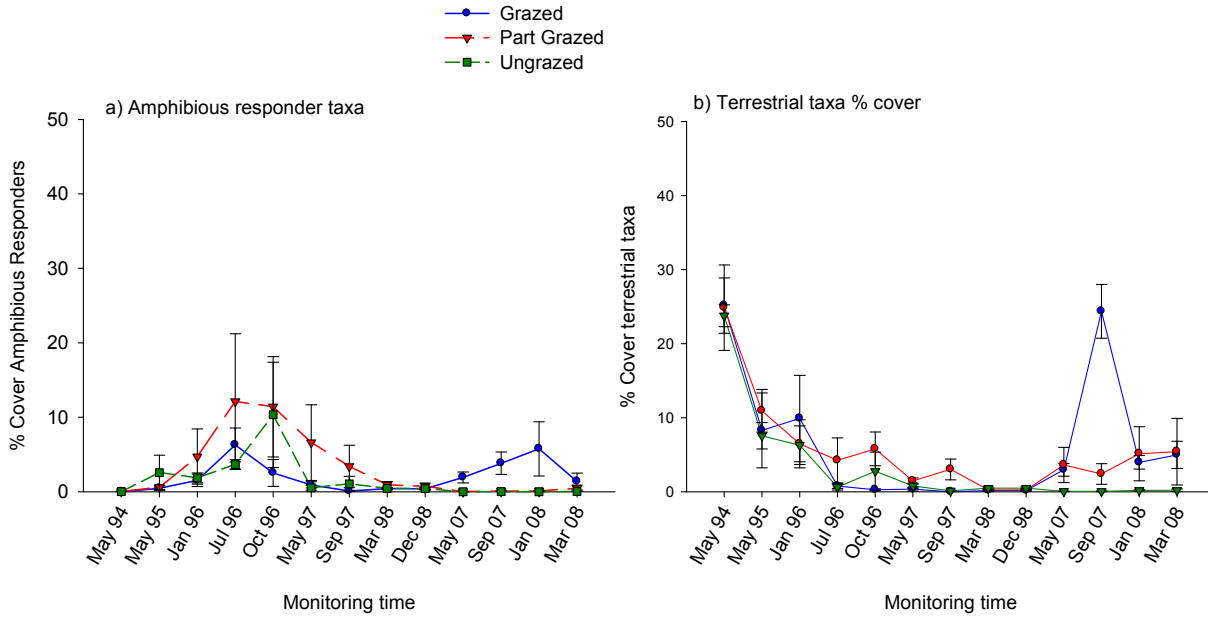


Fig. 5.9. Mean percent cover of (a) amphibious responder taxa and (b) terrestrial taxa on “Old Dromana” between the three grazing treatments, May 1994 to March 2008. Error bars are ±1 standard error.

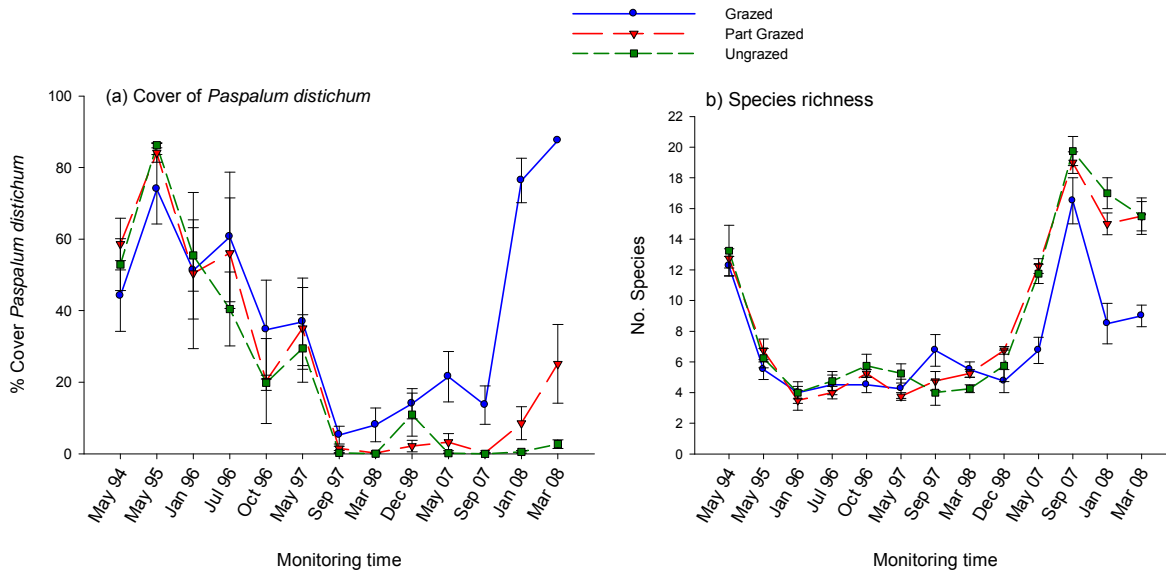


Fig. 5.10. Mean (a) percent cover of *Paspalum distichum* and (b) species richness on “Westholme” between the three grazing treatments, May 1994 to March 2008. Error bars are ±1 standard error.

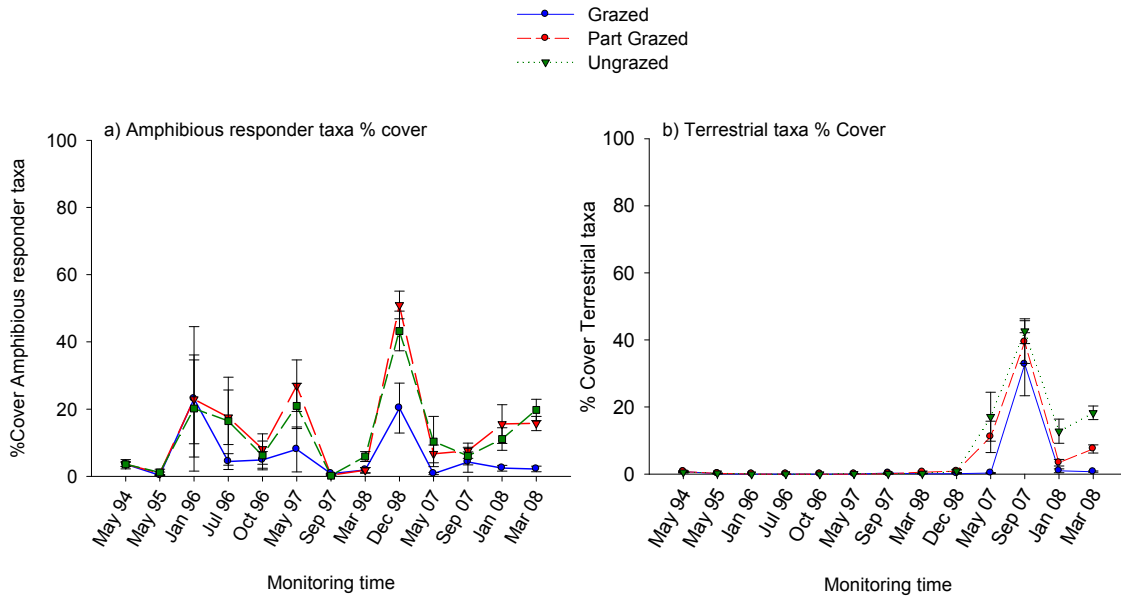


Fig. 5.11. Temporal variation in the mean percent cover of the (a) amphibious responder functional group and (b) terrestrial damp functional group between the three grazing treatments at “Westholme”, May 1994 to March 2008. Error bars are ±1 standard error.

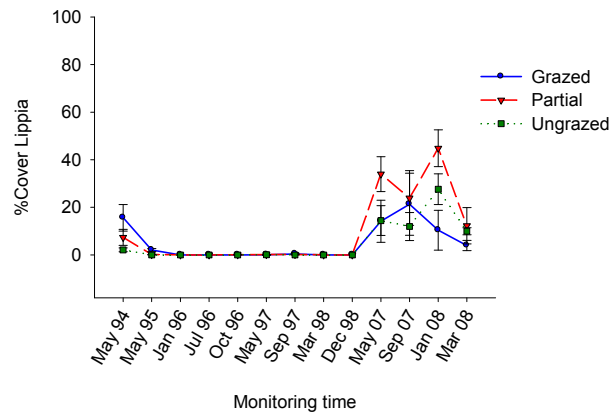


Fig. 5.12. Temporal variation in mean percent cover of lippia *Phyla canescens*, between grazing treatments at “Westholme”, May 1994 to March 2008. Error bars are ±1 standard error.

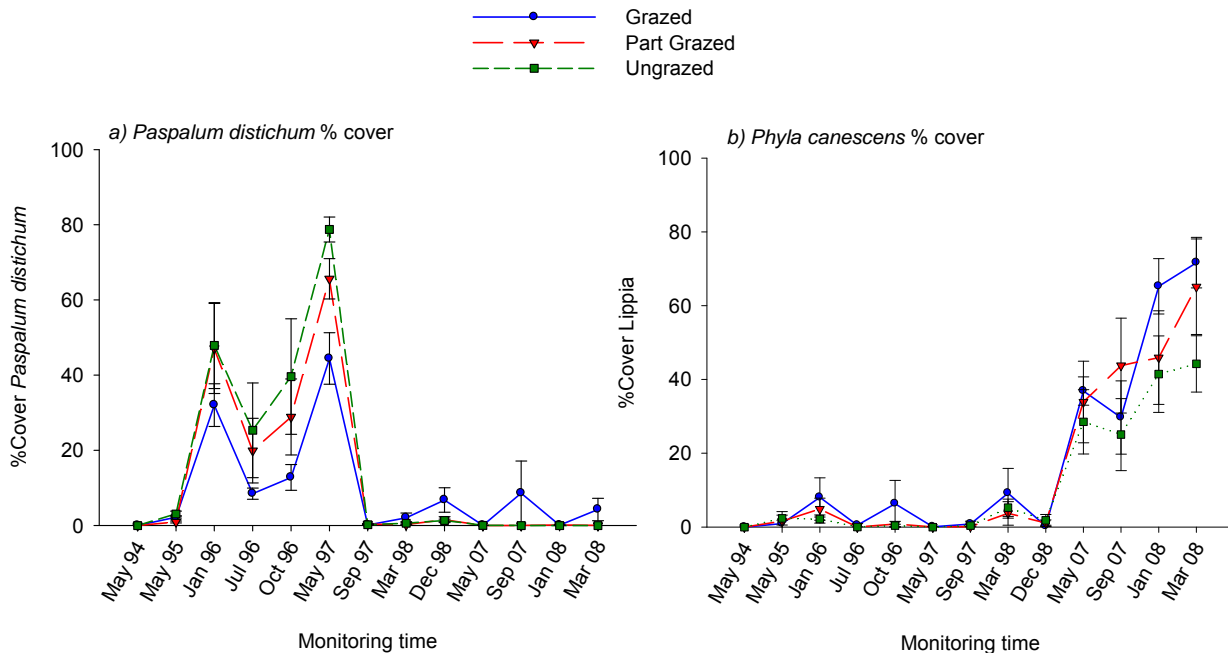


Fig. 5.13. Temporal variation in mean percent cover of *Paspalum distichum* and *Phyla canescens* between grazing treatments on “Crinolyn”, May 1995 to March 2008. Error bars are ± 1 standard error.

community on “Crinolyn” appears to be rainfall. Plants belonging to the amphibious functional groups tend to occur around depressions where small ephemeral pools form. The lack of prolonged inundation and the limited amount of moisture provided by rainfall appears to have created conditions ideal for the expansion of *P. canescens*.

GRAZED sites at “Crinolyn” had a lower cover of *P. distichum* in the three monitoring periods in 1996 and May 1997. By September 1997, the cover of *P. distichum* had dropped to almost zero. Flooding of the site in 1998 occurred in winter and there was no substantial response by water couch to this event. Apart from these times, there were no apparent differences between grazing treatments at this site.

“Birrah” – The location of the grazing exclosures on “Birrah” is higher on the floodplain than at the other three study sites. Here, the frequency of flooding is now approximately once every 5-10 years, and the plant community is characterised by taxa capable of tolerating inundation for short periods rather than true wetland taxa. The dominant grass at the site is Warrego summer grass (*Paspalidium jubiflorum*).

Trends in percent cover across grazing treatments were not consistent. *Paspalidium jubiflorum* showed significantly higher cover at GRAZED sites on some occasions, indicating that it may be tolerant to grazing. These peaks occurred when rainfall or flooding coincided with the growing season in summer (Fig. 5.14a). Cover of *Panicum decompositum* was high in May 1995 and through 1996 when the site was flooded for brief periods (Fig. 5.14b). Cover of this species has remained relatively low in recent years while the site has only received moisture from rainfall. Other grass species such as Queensland blue grass (*Dicantheum sericeum*), curly windmill grass and silky brown top (*Eulalia aurea*) have been

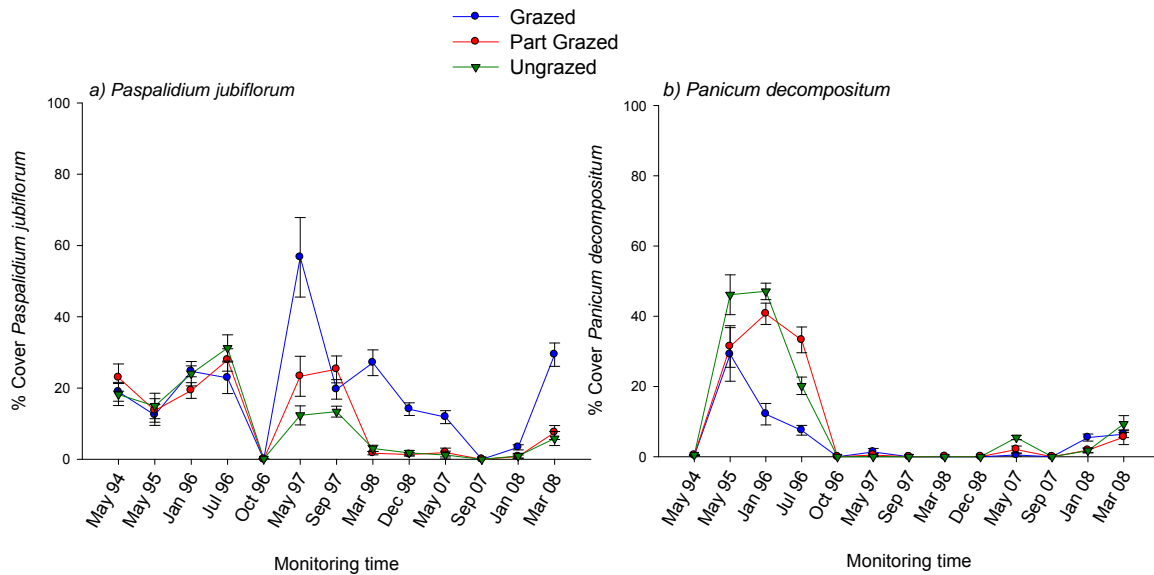


Fig. 5.14. Temporal variation in mean percent cover of (a) *Paspalidium jubiflorum* and (b) *Panicum decompositum* between grazing treatments on “Birrah”, May 1994 to March 2008. Error bars are ± 1 standard error.

recorded as having a small cover in some of the grazing exclosure sites (P. Berney pers. observation). This suggests that while their seeds are present in the soil seed bank, they are having problems in establishing in the extant plant community under the current grazing regime.

5.4 Discussion

The long-term data set that has been collected at the four wetland sites in the Lower Gwydir wetlands gives an insight into the way wetland water regime and grazing interact to shape plant community composition. The cover of vegetation was closely tied to the amount of water in the wetlands, with peaks in percentage cover closely coinciding with river flows in the previous three months. High river flows mean flooding in the wetlands and the floodplain wetland vegetation responds rapidly to the arrival of floodwater. The cover of perennial vegetation closely mirrored that of total cover, indicating that much of the positive response to flooding was driven by these species. Conversely, the cover of annuals and introduced species tended to peak during drier periods inbetween flood peaks. The impacts of grazing on the four wetland plant communities are then imposed upon these variations that occur as a result of the wetland water regime.

Studies of grazing from a range of locations around the world indicate that the response of a system to grazing is governed largely by the productivity of the site (Milchunas *et al.*, 1988; Proloux and Mazumder, 1998). Productivity is influenced by the level of soil nutrients at the site as well as the water availability. The Lower Gwydir wetland study sites would all once have been considered highly productive, but modifications to the water regime in recent

decades have reduced the productivity at sites such as “Crinolyn” and “Birrah”. In particular, “Crinolyn” has experienced an increase in the presence of lippia, and this has tended to outcompete the native species. At “Birrah”, the frequency of flooding has decreased but lippia is not so dominant at this site. The predicted response to the removal of grazing at productive sites is that there will be an increase in the biomass of tall grazing-sensitive plants which may result in a local-scale decrease in species richness through these species competitively excluding smaller ones. At less productive sites, removal of grazing may not lead to any major increase in biomass but usually results in an increase in species richness as there is an increase in the cover of small grazing-sensitive plants (Lunt *et al.*, 2007).

The impacts of grazing detected in the grazing exclosures were generally consistent with what models of grazing predict. There are some inconsistencies associated with the sites and the morphological form of the dominant species. These differences in response can be seen when comparing the two most frequently flooded sites, “Old Dromana” and “Westholme”. At “Old Dromana”, the dominant plant species is marsh club-rush, *Bolboschoenus fluviatilis*. Cattle grazing at this site leads to an increase in local species richness as the shading effect of the marsh club-rush is lost and other taxa such as swamp buttercup (*Ranunculus undosus*) and slender knotweed (*Persicaria decipiens*) can flourish under the reduced competition. However, the situation at “Westholme” was different where *Paspalum distichum* was the dominant species and grazing appeared to favour its dominance. At sites without cattle grazing, a range of tall herbaceous species were common and these shaded out the *P. distichum*. The morphological shape of this plant is more tolerant to grazing than tall herbaceous species with their apical nodes near the top of the plant.

Plants in the amphibious responder functional group were present during periods of flooding, although the cover of this functional group was frequently less at sites grazed by livestock in comparison to un-grazed sites. Plants in this functional group are delicate, often using water to support their stems while their leaves float on the water surface. Species in this functional group would, therefore, be susceptible to both grazing and the impacts of cattle moving through the wetlands. In contrast, amphibious tolerator plants are structurally more solid and appear better able to stand the impacts of cattle moving through the wetland and standing on them. Encouraging landholders to restrain from grazing their cattle in wetlands while there is water has merit as a means of reducing the impact of grazing animals on both fragile plants and the soil while it is in a soft condition.

Overall, the impact of grazing on wetland plant communities detected through this grazing exclosure experiment was small. Grazing has resulted in some changes to plant community composition, but in general the wetland ecosystem tends to be showing considerable resilience to the impacts of this disturbance process. In contrast, the changes in community composition associated with altered flow regime are considerably larger. It appears that flow regime is the most significant factor shaping plant communities in the Lower Gwydir wetlands. There are several possible reasons for the high level of resilience to grazing. Firstly, stocking rates are low (0.5-1.0 cattle per hectare) in comparison to figures reported from other parts of the Murray-Darling Basin (e.g. Robertson, 1988) where stocking rates as high as 12 cows per hectare were recorded. Secondly, soil type may be important in resisting some of the detrimental impacts associated with wetland grazing. Soils in the Lower Gwydir wetlands are usually grey cracking clays. These soils crack readily as they dry out, and are considered to be self-mulching due to surface soil and organic matter falling into cracks. Upon wetting, they swell and regenerate their structure which helps reduce the impact of pugging. These features also mean that seeds can successfully germinate and re-establish their species in

the extant plant community following periods of good rainfall or flooding. A third factor that is also relevant to the study wetland areas is that the topography of the landscape is very flat and water spreads across the floodplain during floods. This results in there being few low points around which cattle can congregate and concentrate any possible impacts. Any grazing pressure is spread more evenly over the floodplain.

Grazing will continue to be a major land use in the Lower Gwydir wetlands in the future and wetland paddocks will continue to play a key role in the grazing management scheme on many properties. Measures currently in use to protect the wetlands need to be promoted. Strategies that provide greater management control over stock movements, such as fencing of large wetland paddocks into smaller management units and strategic positioning of watering points, can help control the timing and the focus of grazing disturbance in wetland paddocks. Conservative stocking rates and protection from stocking following inundation and during flowering and seed-set are strategies that will also assist in minimising the impact of grazing cattle. These measures ensure a precautionary approach to wetland grazing is adopted. Further research, particularly on the impact of grazing on soil condition and the response of soil to wetting and drying, is warranted as soil condition is the slowest response variable to the impact of grazing in wetlands, but also the slowest to recover if allowed to deteriorate.