

# The *Carex* Fen vegetation of northern New South Wales

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**Abstract:** The floristic composition and extent of *Carex*-dominated fens in the New South Wales New England Tablelands Bioregion and Barrington Tops area (lat 28° 41' S–31° 55' S; long 151° 23' E–152° 05' E) together with outliers from the central west (Coonabarabran) are described from 81 full floristic survey sites. These fens contained 234 vascular plant taxa of which 27% were exotic. The fens were dominated by herbaceous vegetation (96% of taxa). Cluster analysis of cover-abundance scores of vascular plant taxa from 81 plots placed within 71 separate *Carex* fens revealed three alliances: 1) *Carex appressa*, 2) *Scirpus polystachyus* – *Carex tereticaulis* and 3) *Carex gaudichaudiana* and seven communities:

- (1) *Carex appressa* – *Stellaria angustifolia* Fen
- (2) *Carex appressa* Fen
- (3) *Scirpus polystachyus* – *Carex appressa* Fen
- (4) *Carex tereticaulis* Fen
- (5) *Carex gaudichaudiana* – *Isachne globosa* Fen
- (6) *Carex* sp. Bendemeer – *Carex gaudichaudiana* Fen
- (7) *Carex gaudichaudiana* – *Glyceria australis* Fen

The distribution of alliances showed a pattern of east-west separation. The most easterly alliance shares many features with the *Carex gaudichaudiana* Alliance of the Monaro Region of southern NSW while the other alliances have no counterparts within the current literature.

We estimate that up to 5 000 ha of fen vegetation survive in the New England Bioregion of which 90% is on grazed land and only 0.2% is within conservation reserves. Seven outstanding examples of fens remain; most are examples of Community 5, with one representing Community 6 and none representing the other five communities. Many of these are not secured, and none of those within reserves are in their 'natural' state. We therefore strongly encourage measures to allow closure of drains, the opening of dams, and the rehabilitation of important fens such as Bishops, Racecourse and New Country Swamps.

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## Introduction

Mires, or peat-producing ecosystems, are systems broadly divided into rainfall-dependent bogs and groundwater-dependent fens (van Diggelen et al. 2006). In Australia, fens are described as occurring in catchments with mineral rich substrates (such as basalts and shales) that produce less acidic to alkaline soils higher in mineral nutrients often along watercourses on flat or concave valley floors (Costin 1959; Beadle 1981; Kirkpatrick 1983; Codd et al. 1998; Costin et al. 2000; Hope 2003; Keith 2004). These fens lack a prominent sclerophyllous shrub layer and are dominated by soft-leaved tussock sedges, grasses and semi-aquatic herbs (Beadle 1981, Kirkpatrick 1983, Keith 2004). Bogs in contrast, are those peatlands described as developing

predominantly on siliceous sandstones and granites on soils that are strongly acidic and poor in mineral nutrients. They usually have a characteristic sclerophyllous shrub layer (Whinam & Chilcott 2002, Keith 2004).

Investigations into Australian mires have largely ignored fens and have concentrated on bog environments (e.g. Millington 1954, Whinam et al. 2001, Whinam et al. 2002, Whinam & Hope 2005, Hunter & Bell 2007). However in general fens are more degraded, potentially under greater threat from grazing and hydrological disturbances due to their occurrence on fertile soils, and are far less likely to be represented in conservation reserves than bogs (Keith 2004).

In Australia fens occur along the eastern edge of the tablelands at altitudes above 600 m, from south of Stanthorpe in Queensland, south to Tasmania. *Carex gaudichaudiana* is considered to be the most common and dominant fen species (Beadle 1981; Costin 1959; Kirkpatrick 1983; Read 1994; Hope 2003; Keith 2004). Research has been restricted to southern alpine regions; Costin (1954, 1959) described one fen alliance in ecosystems of the NSW Monaro and discussed the transition with increasing acidity from *Carex gaudichaudiana* fen to a valley bog of *Carex gaudichaudiana*–*Sphagnum cristatum*, and eventually to raised bogs of *Epacris paludosa*–*Sphagnum cristatum*. McDougall & Walsh (2007) describe *Carex gaudichaudiana* fens as widespread in the valleys and low saddles in Kosciuszko National Park. In Tasmania fens are rare; these are dominated by *Carex gaudichaudiana* with *Eleocharis acuta* and *Poa gunnii* (Kirkpatrick 1983; Kirkpatrick & Harwood 1983; Reid et al. 1999). Beadle (1981) described three fen alliances, *Carex gaudichaudiana*, *Astelia alpina* and *Carpha*–*Uncinnia*–*Oreobolis*.

The *Carex gaudichaudiana* alliance of Costin (1954) is included in the Endangered Ecological Community *Montane peatlands and swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and the Australian Alps bioregions* (17 December 2004) under the NSW *Threatened Species Conservation Act* (1995). Despite the fact that fens occur as far north as Stanthorpe (Keith 2004) and are at least in part included within a listed endangered ecological community, no systematic study of fen ecosystems has been undertaken north of the southern alpine areas. Fens did not feature in the communities described in a systematic survey of the Guyra 1:100 000 Map Sheet (Benson & Ashby 2000).

The present study aimed to document the extent and distribution of these northern fens, to describe fen vegetation patterns across the landscape and to identify threats and conservation issues. Given the reported structural differences between bogs and fens, a comparison of the floristics of northern bogs and fens is included. This research forms part of a larger investigation of the patterns and processes within and between the three major types of wetlands in upland areas of northern New South Wales (Hunter & Bell 2007; Bell et al. 2008).

## Method

### Site selection

The survey area covered the New England Tablelands Bioregion and Barrington Tops (lat 28° 41' S–31° 55' S; long 151° 23' E–152° 05' E). In the absence of detailed

mapping of Northern Tablelands wetlands we divided the region into four equal subregions based on latitude and longitude. For a broader geographic comparison sites from outlier occurrences at Coonabarabran (NSW Central West) were added.

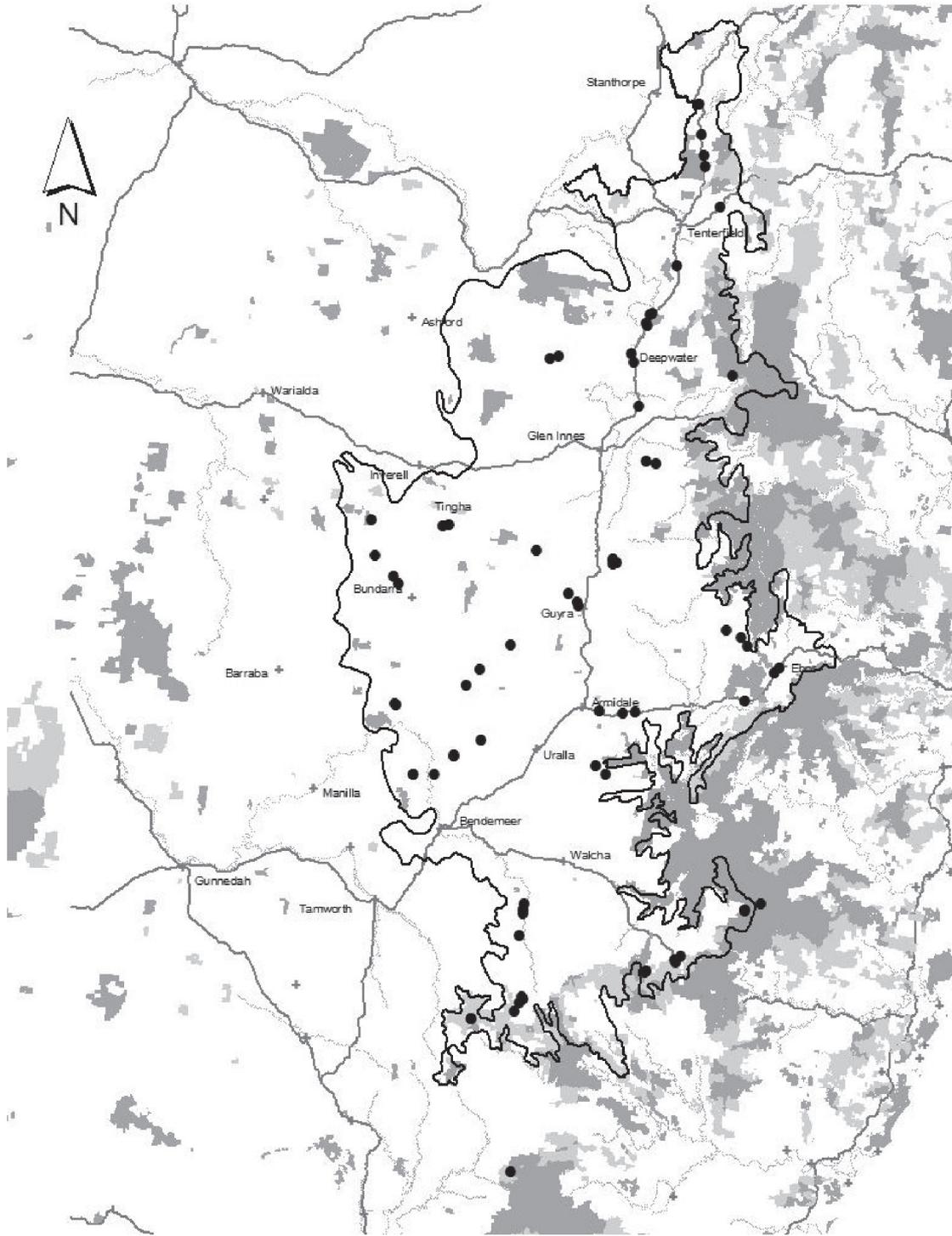
We defined fen communities as all those wetland sites which currently, or under the appropriate climatic conditions, could, accumulate peat, but do not have a shrub stratum. In northern NSW such sites are dominated by species of *Carex*.

Fens and bogs can generally be clearly separated by colour and texture in SPOT5 satellite images but are sometimes obscured by taller vegetation. Representative fen occurrences were selected by 1) visual inspection of SPOT5 imagery and 2) systematic traverse of each subregion using all major and some minor roads to verify SPOT5 analysis and identify smaller areas of occurrence. Mapping was not part of this initial process. Access to a number of freehold properties was gained with permission, but due to accessibility and time constraints the majority of fens surveyed were accessed on roadside easements, or on other public lands (TSR, Crown Lands, conservation reserves). The areas sampled encompassed the range of bedrock types present in the region. The most northerly sampled community (Liston) was 370 km from the most southerly (Barrington Tops). For the majority of sites (i.e. those within the New England Tablelands Bioregion), the study area was 150 km from east to west (Fig. 1), but with the inclusion of sites from Coonabarabran extended to 450 km. Mean annual rainfall ranges from 680 mm to 1460 mm.

### Survey methods

Vascular plants were scored using a modified Braun-Blanquet (1982) six point cover abundance scale in 81, 20 x 20 m square quadrats placed within 71 fens (Fig. 1). Elongated quadrats of the same area were used for elongated fens adjacent to creeks. Quadrats were placed randomly within the *Carex*-dominated vegetation; marginal areas were avoided. At least one quadrat was placed in each fen. Adjacent dominant overstorey species within the surrounding woodlands and forests were recorded but were not included within the analyses. Each fen surveyed was digitised and mapped with ArcView 3.2 and Geo-referenced SPOT5 imagery in order to measure individual areas. Species outside quadrats but within the fen communities were recorded but not used in formal analyses (Appendix 1).

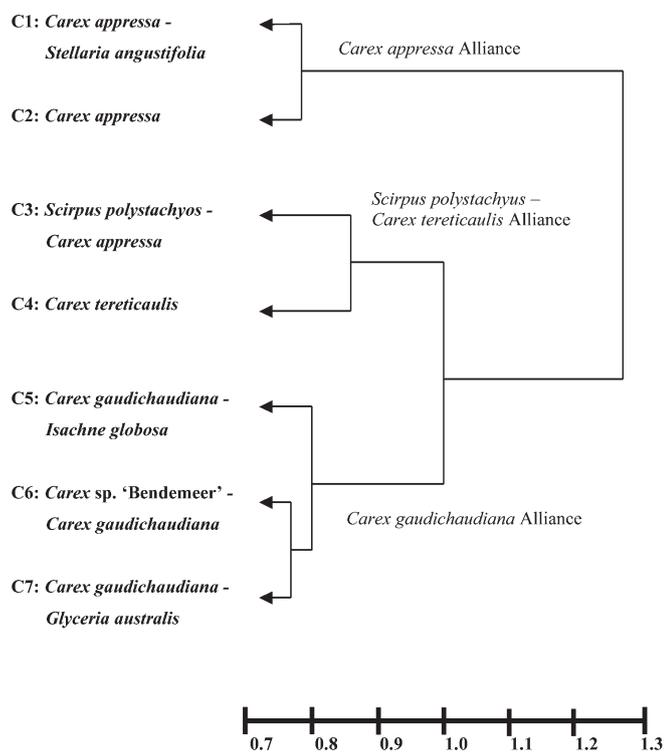
71 individual fens over an altitudinal range of 440–1360 m, and across a range of rock types; granite (31 sites), basalt (22 sites), metasediments (16 sites), acid volcanics (8 sites), sandstone (2 sites) and aeolian sands (2 sites),



**Fig. 1.** Location of sampled fens within the study area. Three additional sites were also placed within disjunct western occurrences around Coonabarabran. Dark grey = NPWS conservation areas; light grey = State Forests; black line = New England Bioregion; grey lines = major roads; crosses = major towns

**Table 1: Selected attributes of the seven defined fen communities.**

Fen community	Number of sites	Mean species richness (per 400 m <sup>2</sup> )	Number of species	Number of exotic species	Altitude (m)	Mean annual rainfall (mm)	Rock type
C1: <i>Carex appressa</i> – <i>Stellaria angustifolia</i>	26	7–43 (19)	134	45	579–1113	704–871	granite, acid volcanic, metasediment, basalt.
C2: <i>Carex appressa</i>	3	9–20 (15)	24	9	444–465	680–808	sandstone, acid volcanic
C3: <i>Scirpus polystachyos</i> – <i>Carex appressa</i>	3	17–33 (23)	54	11	900–1266	1068–1217	basalt
C4: <i>Carex tereticaulis</i>	2	21–23 (22)	42	12	1300–1350	931–958	aeolian sands
C5: <i>Carex gaudichaudiana</i> – <i>Isachne globosa</i>	27	8–34 (18)	110	28	800–1269	741–1457	granite, acid volcanic, metasediment, basalt
C6: <i>Carex</i> sp. 'Bendemeer' – <i>Carex gaudichaudiana</i>	6	16–34 (23)	72	21	1040–1313	844–1238	granite, metasediment, basalt
C7: <i>Carex gaudichaudiana</i> – <i>Glyceria australis</i>	14	7–31 (18)	87	31	850–1356	758–1057	granite, metasediment, basalt



**Fig. 2.** Summary dendrogram of full dataset of fen sites using Kulczynski association and flexible UPGMA fusion strategy

**Fig. 3.** Map showing the generalised distribution of Fen alliances across the New England Tablelands Bioregion. Boundaries are based on location of sites within each alliance.

were surveyed. The total fen area was 255 ha; average fen size was 3.8 ha. Most fens were small (from 0.1 ha) but there were several larger (up to 32.5 ha). Of the fens, 15 (20%) had one or more dams in them. Based on preliminary inspections of SPOT imagery, up to 5000 ha of fens are estimated to occur in the New England Tablelands Bioregion and that less than 100 ha are within conservation reserves (0.2%).

Analyses were performed using the PATN Analysis Package (Belbin 2004) on fen data alone, and on combined fen and bog data (bog data from Hunter & Bell 2007). All species and their relative cover were included; analyses used the Kulczynski association measure recommended for ecological applications (Belbin 2004) along with flexible Unweighted Pair Group arithmetic Averaging (UPGMA) and the default PATN settings. Semi-Strong-Hybrid Multidimensional Scaling (SSH) was used as the ordination technique to compare the floristics of bogs (Hunter & Bell 2007) and fens. Multidimensional scaling (MDS) moves objects around in a space defined by the number of dimensions chosen and the dissimilarities among sites in terms of their composition (Belbin 1995). Structural names were based on the most consistently dominant taxa in the herbaceous stratum. Species nomenclature follows that of Harden (1992–2002) except where recent taxonomic changes have been suggested (PlantNET 2006). To determine the effects of evapotranspiration a mean moisture index for each site was modelled using BIOCLIM within the ANUCLIM Vers. 5.1 software package (Houlder 2000) and regressed against species richness, a technique sufficient for this cross regional comparison.

## Results

Seven communities in three alliances were recognised at a dissimilarity measure of 0.78 (Fig. 2). Two alliances (*Carex gaudichaudiana* and *Carex appressa*) were the most common (almost 80% of sites) and these two species overwhelmingly dominated rankings of summed cover abundance scores. Other characteristic species were *Stellaria angustifolia*, *Isachne globosa*, *Epilobium billardierianum* var. *hydrophilum*, *Cyperus sphaeroideus*, *Scirpus polystachyus*, *Carex* sp. Bendemeer *Geranium solanderi* var. *solanderi*, *Haloragis heterophylla*, *Lythrum salicaria* and *Persicaria hydropiper*.

There was a strong east/west pattern in the distribution of alliances. The *Carex appressa* alliance is restricted to lower rainfall areas (< 870 mm p.a.) and is not found above 1110 m altitude (Fig. 3). The *Carex gaudichaudiana* alliance is, in contrast, restricted to altitudes above 800 m but occurs over a wide rainfall range.

Communities were largely herbaceous with only 4% shrub taxa overall. Species richness was highest in communities 3 and 6 and the lowest in community 2. No correlation was found between mean moisture index and species richness.

No clear relationship between altitude and rainfall, apart from broad-based east-west differences, was found in this study. Community 4 was restricted to aeolian sands but no other community was linked to changes in geology. Table 1 gives a summary of relevant attributes for each community.

234 vascular plant taxa were recorded in 51 families and 143 genera (Appendix 1). The families with the greatest number of taxa were: Poaceae (40), Cyperaceae (28), Asteraceae (27), Juncaceae (19), Fabaceae (10), Apiaceae (9) and Polygonaceae (9). The richest genera were: *Juncus* (19), *Carex* (8), *Cyperus* (6) and *Eleocharis* (5). 64 taxa (27%) were of introduced (exotic) origin.

### Vegetation community descriptions

#### *Carex appressa* Alliance

This alliance is generally restricted to west of the New England Highway, north from Watsons Creek and south of Bolivia and as far west as Copeton Dam with outlier occurrences near Coonabarabran.

#### Community 1: *Carex appressa* – *Stellaria angustifolia* (Fig. 4)

**Groundcover:** *Carex appressa*, *Stellaria angustifolia*, *Eleocharis acuta*, *Isachne globosa*, *Cyperus sphaeroideus*, *Geranium solanderi* var. *solanderi*, *Juncus australis*, *Carex gaudichaudiana*, *Haloragis heterophylla*, *Juncus vaginatus*, *Pennisetum alopecuroides*, *Hydrocotyle tripartita*, *Epilobium billardierianum* subsp. *hydrophilum*, *Epilobium billardierianum* subsp. *cinereum*, *Centella asiatica*, *Persicaria hydropiper*, *Juncus usitatus*, *Ranunculus lappaceus*, *Persicaria prostrata*, *Paspalum distichum*, *Eleocharis gracilis*, *Eleocharis dietrichiana*, *Carex* sp. Bendemeer.

**Shrubs:** *Leptospermum minutifolium*.

**Adjacent dominants:** most commonly *Eucalyptus blakelyi*, *Angophora floribunda* and *E. melliodora*. A number of other species were found around the fen edge which includes *Eucalyptus bridgesiana*, *E. laevopinea*, *E. banksii*, *E. nova-anglica*, *E. elliptica*, *E. pauciflora*, *E. dalrympleana*, *E. nicholii*, *E. dealbata*, *E. moluccana*, *E. sideroxylon* and *E. viminalis*.



Fig. 4. Community 1 *Carex appressa* – *Stellaria angustifolia*, fen within a travelling stock reserve near Armidale.

**Introduced taxa:** *Paspalum dilatatum*, *Holcus lanatus*, *Cirsium vulgare*, *Rubus anglocandicans*, *Verbena bonariensis*, *Rumex crispus*, *Trifolium repens*, *Hypochaeris radicata*, *Festuca elatior*, *Plantago lanceolata*, *Rosa rubiginosa*, *Conyza bonariensis*, *Rumex conglomeratus*, *Cyperus eragrostis*, *Anthoxanthum odoratum*, *Taraxacum officinale*, *Prunella vulgaris*, *Phalaris aquatica*, *Vicia tetrasperma*, *Verbena brasiliensis*, *Trifolium arvense*, *Sonchus asper*, *Juncus acuminatus*, *Echinochloa esculenta*, *Cynodon dactylon*, *Ciclospermum leptophyllum*, *Vicia sativa* subsp. *nigra*, *Verbena rigida*, *Trifolium pratense*, *Sonchus oleraceus*.

**Distribution:** distributed primarily west of the New England Highway from north of Bendemeer to Emmaville and Bolivia and as far east as Guyra and Armidale.

**Reservation:** only small linear creek line occurrences, totalling only 1 to 2 ha are reserved within Sepoy National Park and Ironbark Nature Reserve.

### Community 2: *Carex appressa* (Fig. 5)

**Groundcover:** *Carex appressa*, *Chenopodium pumilio*, *Bothriochloa decipiens*, *Senecio queenslandicus*, *Rumex brownii*, *Plantago debilis*, *Oxalis perennans*, *Hydrocotyle laxiflora*, *Portulaca oleracea*, *Plantago varia*, *Panicum simile*, *Lepidium pseudohyssopifolium*, *Lagenifera stipitata*, *Digitaria hystrichoides*, *Chloris truncata*.

**Adjacent dominants:** include *Callitris glaucophylla*, *Eucalyptus crebra* and *Corymbia trachyphloia*.

**Introduced taxa:** *Hypericum perforatum*, *Centaurea solstitialis*, *Alternanthera pungens*, *Trifolium subterraneum*, *Paspalum dilatatum*, *Paronychia brasiliensis*, *Conyza bonariensis*, *Cirsium vulgare*, *Calendula arvensis*.

**Distribution:** from Coonabarabran to Bugaldie.

**Reservation:** not currently known within a conservation reserve.

### *Scirpus polystachyus* – *Carex tereticaulis* Alliance

Two disjunct components of this alliance are described, the first, Community 3, occurs in the southernmost parts of the study area around Niangala to Nowendoc and south to Barrington Tops. The second, (Community 4) is known only from aeolian sand deposits on the eastern margins of Llangothlin Lagoon and of Racecourse Lagoon near Uralla.

### Community 3: *Scirpus polystachyus* – *Carex appressa* (Fig. 6)



**Fig. 5.** An example of the depauperate Community 2, *Carex appressa*, fen from private property near Bugaldie north of Coonabarabran.

**Groundcover:** *Scirpus polystachyus*, *Carex appressa*, *Geranium solanderi* var. *grande*, *Gratiola peruviana*, *Epilobium billardierianum* subsp. *hydrophilum*, *Stellaria angustifolia*, *Eleocharis sphacelata*, *Sparganum subglobosum*, *Ranunculus inundatus*, *Phragmites australis*, *Juncus alexandri* subsp. *melanobasis*, *Hypericum japonicum*, *Hydrocotyle tripartita*, *Glyceria australis*, *Eleocharis gracilis*, *Carex gaudichaudiana*, *Isolepis globosa*, *Carex fascicularis*, *Bulbine bulbosa*, *Baloskion stenocoleum*, *Pratia purpurascens*, *Pratia pedunculata*, *Neopaxia australasica*, *Myriophyllum variifolium*, *Myriophyllum lophatum*, *Lythrum salicaria*, *Juncus sandwithii*, *Isolepis crassiuscula*, *Hydrocotyle peduncularis*, *Gonocarpus micranthus* var. *micranthus*, *Euchiton involucratu*, *Eleocharis pusilla*, *Deyeuxia gunniana*, *Cyperus sphaeroideus*.

**Shrubs:** *Hakea microcarpa*.

**Adjacent dominants:** include *Eucalyptus nobilis*, *E. laevopinea* and *E. pauciflora*.

**Introduced taxa:** *Anthoxanthum odoratum*, *Holcus lanatus*, *Mimulus moschatus*, *Cirsium vulgare*, *Trifolium repens*, *Trifolium arvense*, *Lotus uliginosus*, *Vicia sativa* subsp. *nigra*, *Rubus anglocandicans*, *Prunella vulgaris*, *Poa pratensis*.



**Fig. 6.** An example of a Community 3: *Scirpus polystachyos*-*Carex appressa* fen from Ponderosa Ponds east of Nundle. This community is restricted to more southerly locations within the study area.



**Fig. 7.** Community 4 a *Carex tereticaulis* dominated fen restricted to two localities on the New England Tablelands. Found on aeolian sands at the margin of Llangothlin Lagoon within private property.

**Distribution:** found within the most southern localities of the study region from east of Nundle to the Barrington Tops area.

**Reservation:** reserved within Barrington Tops National Park, total reserved area unknown.

#### Community 4: *Carex tereticaulis* (Fig. 7)

**Groundcover:** *Carex tereticaulis*, *Myriophyllum variifolium*, *Schoenus apogon*, *Isotoma fluviatilis* subsp. *borealis*, *Hypericum gramineum*, *Euchiton involucratus*, *Poa sieberiana*, *Nymphoides geminata*, *Lachnagrostis filiformis*, *Juncus filicaulis*, *Hydrocotyle laxiflora*, *Eleocharis gracilis*, *Eleocharis acuta*, *Asperula conferta*, *Xerochrysum bracteatum*, *Utricularia dichotoma*, *Stellaria angustifolia*, *Scleranthus biflorus*, *Leiocarpa* sp. *Uralla*, *Juncus fockei*, *Juncus australis*, *Hydrocotyle tripartita*, *Hybanthus monopetalus*, *Geranium solanderi* var. *solanderi*, *Epilobium billardierianum* subsp. *hydrophilum*, *Cyperus sanguinolentus*, *Caesia calliantha*, *Brachyscome radicans*, *Acaena ovina*.

**Adjacent dominants:** include *Eucalyptus nova-anglica*, *E. viminalis* and *E. stellulata*.

**Introduced taxa:** *Holcus lanatus*, *Leucanthemum vulgare*, *Acetosella vulgaris*, *Trifolium repens*, *Taraxacum officinale*, *Rubus anglocandicans*, *Rosa rubiginosa*, *Festuca elatior*, *Dianthus armeria*, *Crepis capillaris*, *Conyza bonariensis*, *Anthoxanthum odoratum*.

**Distribution:** on the Northern Tablelands this community is restricted to aeolian sand deposits on the margins of Llangothlin Lagoon north east of Guyra and of Racecourse Lagoon near Uralla.

**Reservation:** not currently within the formal reserve network but included within a conservation agreement with DECC and the Uralla Shire Council.

#### *Carex gaudichaudiana* Alliance

This alliance occurs primarily east of the New England Highway south from Stanthorpe to Niangala with a south-western extension to the Watsons Creek area.

#### *Carex gaudichaudiana* – *Isachne globosa* Sub-alliance

#### Community 5: *Carex gaudichaudiana* – *Isachne globosa* (Fig. 8)

**Groundcover:** *Carex gaudichaudiana*, *Isachne globosa*, *Stellaria angustifolia*, *Lythrum salicaria*, *Carex appressa*, *Epilobium*



**Fig. 8.** New Country Swamp within Mummel Gulf National Park falls within Community 5: *Carex gaudichaudiana*–*Isachne globosa* and is one of the best remaining *Carex* fen remnants. A built-up road partially impounds the lower end.

*billardierianum* var. *hydrophilum*, *Scirpus polystachyus*, *Cyperus sphaeroideus*, *Viola caleyana*, *Ranunculus inundatus*, *Hydrocotyle peduncularis*, *Ranunculus lappaceus*, *Eleocharis sphacelata*, *Geranium solanderi* var. *grande*, *Lycopus australis*, *Juncus alexandri* var. *melanobasis*, *Geranium solanderi* var. *solanderi*, *Eleocharis gracilis*, *Juncus vaginatus*, *Gratiola peruviana*, *Hypericum japonicum*, *Hydrocotyle tripartita*, *Carex inversa*, *Juncus prismatocarpus*, *Carex* sp. *Bendemeer*, *Epilobium billardierianum* subsp. *cinereum*, *Persicaria hydropiper*, *Lachnagrostis filiformis*, *Haloragis heterophylla*, *Cyperus gracilis*, *Poa sieberiana*, *Juncus phaeanthus*.

**Shrubs:** *Leptospermum polygalifolium* var. *transmontanum*, *Hakea microcarpa*, *Epacris microphylla* var. *microphylla*.

**Adjacent dominants:** includes primarily *Eucalyptus nova-anglica*, *E. pauciflora*, *E. nobilis*, *E. acaciiformis*, *E. banksii*, *E. viminalis*. Other adjacent dominants less occasionally found also included *E. dalrympleana*, *E. blakelyi*, *E. radiata*, *E. saligna*, *E. brunnea*, *E. campanulata*, *E. macrorhyncha*, *Angophora floribunda* and *A. subvelutina*.

**Introduced taxa:** *Holcus lanatus*, *Cirsium vulgare*, *Hypochaeris radicata*, *Trifolium repens*, *Verbena bonariensis*, *Festuca elatior*, *Rubus anglocandicans*, *Anthoxanthum odoratum*, *Paspalum dilatatum*, *Prunella vulgaris*, *Conyza albida*, *Andropogon virginicus*, *Rumex crispus*, *Sonchus asper*, *Mimulus moschatus*, *Taraxacum officinale*, *Mentha X piperita* forma *piperita*, *Vicia sativa* subsp. *nigra*, *Plantago lanceolata*, *Phytolacca octandra*, *Paspalum urvillei*, *Myosotis laxa* subsp. *caespitosa*, *Lotus uliginosus*, *Lactuca serriola* var. *serriola*, *Juncus acuminatus*, *Echinochloa esculenta*, *Conyza bonariensis*, *Bidens pilosa*.

**Distribution:** primarily occurring on the eastern side of the New England Highway. Recorded from as far north as Liston south to east of Nundle. These include the most northerly-occurring fens.

**Reservation:** the most reserved assemblage. Recorded within Mummel Gulf National Park (New Country Swamp) and Werrikimbe National Park (Bishops and Racecourse Swamps) which combined may contain up to 60 ha.

#### *Carex gaudichaudiana* – *Carex* sp. *Bendemeer* Sub-alliance

#### Community 6: *Carex* sp. *Bendemeer* – *Carex gaudichaudiana* (Fig. 9)



**Fig. 9.** Community 6 *Carex* sp. ‘Bendemeer’ – *Carex gaudichaudiana* fen from west of Guyra.

**Groundcover:** *Carex* sp. Bendemeer, *Carex gaudichaudiana*, *Epilobium billardierianum* subsp. *hydrophilum*, *Carex inversa*, *Haloragis heterophylla*, *Geranium solanderi* var. *solanderi*, *Epilobium billardierianum* subsp. *cinereum*, *Cyperus sphaeroideus*, *Carex appressa*, *Scirpus polystachyus*, *Persicaria hydropiper*, *Juncus alexandri* var. *melanobasis*, *Geranium solanderi* var. *grande*, *Viola caleyana*, *Lythrum salicaria*, *Isachne globosa*, *Ranunculus lappaceus*, *Pennisetum alopecuroides*, *Juncus australis*, *Hydrocotyle peduncularis*, *Geum urbanum*, *Stellaria angustifolia*, *Poa labillardieri*, *Juncus prismatocarpus*, *Juncus bufonius*, *Hypericum japonicum*, *Hydrocotyle tripartita*, *Hemarthria uncinata*, *Euchiton involucratu*, *Eleocharis pusilla*, *Elatine gratioloides*, *Carex echinata*.

**Shrubs:** *Baeckea omissa*.

**Adjacent dominants:** included *Eucalyptus pauciflora*, *E. stellulata*, *E. nova-anglica* and *E. nobilis*.

**Introduced taxa:** *Holcus lanatus*, *Lotus uliginosus*, *Festuca elatior*, *Rumex crispus*, *Anthoxanthum odoratum*, *Rumex conglomeratus*, *Mentha X piperita* forma *piperita*, *Rubus anglocandicans*, *Daucus carota*, *Vicia sativa*, *Trifolium repens*, *Taraxacum officinale*, *Mimulus moschatus*, *Trifolium pratense*, *Sonchus oleraceus*, *Rumex obtusifolius* var. *obtusifolius*, *Rosa rubiginosa*, *Prunella vulgaris*, *Plantago lanceolata*, *Myosotis laxa* subsp. *caespitosa*, *Juncus tenuis*, *Crepis capillaris*.

**Distribution:** found south west of Walcha to Niangala in the south and north to Ebor and Guyra.

**Reservation:** not currently known from conservation reserves.

#### **Community 7: *Carex gaudichaudiana* – *Glyceria australis* (Fig. 10).**

**Groundcover:** *Carex gaudichaudiana*, *Glyceria australis*, *Persicaria hydropiper*, *Carex* sp. Bendemeer, *Stellaria angustifolia*, *Epilobium billardierianum* subsp. *hydrophilum*, *Haloragis heterophylla*, *Geranium solanderi* var. *solanderi*, *Scirpus polystachyus*, *Lycopodium australis*, *Juncus sarophorus*, *Carex inversa*, *Viola caleyana*, *Neopaxia australasica*, *Juncus australis*, *Eleocharis acuta*, *Cynoglossum australe*, *Cyperus sphaeroideus*, *Hydrocotyle tripartita*, *Elatine gratioloides*, *Carex appressa*, *Ranunculus lappaceus*, *Ranunculus inundatus*, *Juncus phaeanthus*, *Hypericum gramineum*, *Epilobium billardierianum* var. *cinereum*, *Eleocharis sphacelata*, *Cardamine paucijuga*, *Brachyscome radicans*, *Asperula charophyton*.

**Adjacent dominants:** include *Eucalyptus stellulata*, *E. pauciflora*, *E. acaciiformis*, *E. nova-anglica* and *E. blakelyi*.



**Fig. 10.** Community 7 *Carex gaudichaudiana* – *Glyceria australis* fen from Red Range east of Glen Innes. Note the large drain running through the centre of this very broad open depression. The fen is now restricted to an area not affected by the drain.

**Introduced taxa:** *Holcus lanatus*, *Festuca elatior*, *Rumex crispus*, *Cirsium vulgare*, *Vicia sativa*, *Anthoxanthum odoratum*, *Taraxacum officinale*, *Rubus anglocandicans*, *Typha latifolia*, *Rumex conglomeratus*, *Juncus articulatus*, *Hypochaeris radicata*, *Daucus carota*, *Vicia tetrasperma*, *Veronica anagallis-aquatica*, *Trifolium pratense*, *Sonchus asper*, *Medicago polymorpha*, *Lotus uliginosus*, *Lactuca serriola* var. *serriola*, *Cyperus eragrostis*, *Crepis capillaris*, *Verbena officinalis*, *Verbena bonariensis*, *Trifolium repens*, *Trifolium dubium*, *Plantago lanceolata*, *Paspalum dilatatum*, *Gamochoeta spicata*, *Echinochloa esculenta*, *Conyza bonariensis*.

**Distribution:** south east of Walcha north to the Red Range east of Glen Innes.

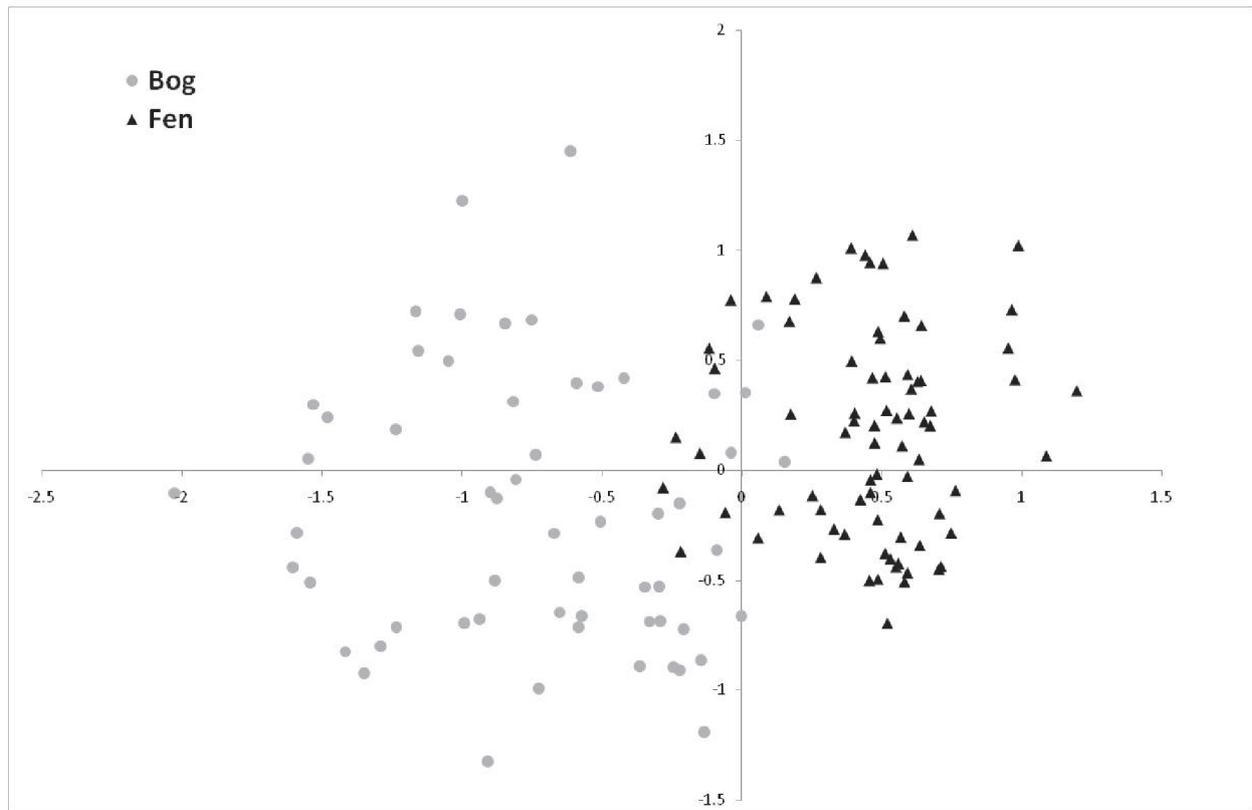
**Reservation:** not known from any conservation reserve.

#### *Comparison with New England Tablelands Bogs*

There was a clear distinction between fen and bog sites in ordination space with only a very slight overlap clearly indicating that these wetland types are separate assemblages (Fig. 5). Classification analyses separated bogs and fens at a dissimilarity measure of 1.86 with no overlapping of sites. Intermediate sites were in the minority, and were dominated by *Carex* spp. but had scattered shrubs such as *Hakea microcarpa*, *Baeckea omissa* and *Leptospermum polygalifolium*. Where fens and bogs occurred in the same wetland there was clear habitat-partitioning or a mosaic of both bog and fen communities, and apparently was the norm (e.g. Racecourse Swamp, Werrikimbe).

The two most species-rich families, in both bogs and fens, were Poaceae and Cyperaceae; Asteraceae and Juncaceae were well-represented and the genera *Juncus* and *Carex* were among the richest in both systems. In spite of these higher taxonomic similarities, species in fens and bogs were largely different (Hunter & Bell 2007; Fig. 11; Appendix 1). Shrubs were almost entirely absent in fens, and when present were in very low abundance; shrubs formed a distinct and prominent layer in the bogs. Trees were occasionally present in bogs but were absent in most fens. Gamma diversity in fens was lower, with 234 taxa in comparison to the 438 taxa in bogs (Hunter & Bell 2007). From a species-density perspective bogs were richer, having on average 26 species per 0.04 ha as opposed to 20 in fens. Bogs often exhibit within-habitat heterogeneity (hummocks and hollows) that may account for an increase in niches for other species. The almost total domination of the fen habitat either by tussocks or dense swards of *Carex* may result in a dearth of niches for other species or the competitive loss of species. Fens had more introduced taxa (27% as opposed to 6%); this increase may reflect the higher nutrient status and/or lower acidity of the fen environment.

Although there was a significant correlation between species density and mean moisture index in bogs as reported elsewhere (Hunter & Bell 2007, Jarman et al. 1988, Whinam & Hope 2005), we found no such correlation for fens. Explanations for this lack of correlation may include the origin of water. Fens in general source water from groundwater and runoff (Costin 1959, Beadle 1981, Kirkpatrick 1983, Codd et



**Fig. 11.** SSH ordination of New England Tablelands Bioregion fens and bogs. Bog data from the survey in Hunter & Bell (2007).

al. 1998, Costin et al. 2000, Hope 2003, Keith 2004) and therefore may not as be reliant as bogs on the storage of precipitation in peat.

Disturbance by stock grazing and hydrological disruption was severe at some bog sites. Based on our observations over a number of years, fen vegetation appears to encroach on former bog vegetation as a result of altered drainage and nutrient enrichment (Fig. 12) (Hunter & Bell 2007). An



**Fig. 12.** A fen encroaching into a shrub-dominated bog community along the Waterfall Way near Cathedral Rock National Park. This roadside remnant bog has a higher than normal influx of nutrients from the road and surrounding grazing properties and has been monitored by the authors for ten years.

increase in the fire frequency may cause the degradation of bogs as the rhizomatous *Carex* species regenerate more rapidly than the shrubs (Hope et al. 2005; Whinam *pers. comm.* July 2007).

## Discussion

This investigation has significantly expanded our understanding of the northern fens of NSW which are far more extensive than has been previously recognised. In common with communities further south, *Carex gaudichaudiana* is a characteristic dominant of fen communities, and its distribution along the eastern parts of the escarpment as far north as Stanthorpe follows that described by Keith (2004). In the New England Tablelands Bioregion the *Carex gaudichaudiana* Alliance has the broadest environmental amplitude; *Carex gaudichaudiana* is the dominant species in fens across Australia, New Zealand and New Guinea (Walker 1972; Wardle 1991; Mark et al. 1995).

However, in contrast to communities previously described, *Carex gaudichaudiana* is not the sole dominant of northern fen communities. Two other species of *Carex*, *Carex appressa* and *Carex* sp. Bendemeer (a previously undescribed species for Australia), are community dominants and delineate alliances whose distributions exhibit a strong geographic bias (Figs. 2 & 3). Fens also occur across a far greater range

of longitudes (as far west as Coonabarabran), and rock types, than previously described (Keith 2004).

Although *Carex appressa* has a broad distribution similar to *Carex gaudichaudiana*, its dominance in wetlands has not been previously reported. The *Carex appressa* Alliance is restricted to a narrow band of rainfall (680–870 mm p.a.) (Fig. 3; Table 1) and occurs at lower altitudes (not much higher than 1100 m) than the *Carex gaudichaudiana* Alliance (800–1360 m altitude; Fig. 3; Table 1). The two disjunct occurrences of the *Scirpus polystachyus* – *Carex tereticaulis* Alliance encompass a reasonably broad environmental amplitude but are both generally restricted to higher altitudes and rainfall.

Across the regional landscape, fens are most commonly found on the lowest parts of broad drainage depressions or in more or less narrow bands along creeks. Fens also occurred in two less predictable situations: on the beds of closed basin wetlands south of Walcha (Community 3) (described from their geomorphology as lagoons (Bell et al. 2008)) and on extensive seepage areas associated with drainage lines on or close to the margins of other more northerly lagoons (Llangothlin, Little Llangothlin and Racecourse Lagoons) (Communities 4, 5 or 7).

Keith (2004) infers that fens are more common on basalts and shales, and bogs on acidic substrates such as leucomonzogranites and sandstones. Our results for fens, as for bogs (Hunter & Bell 2007) indicate that substrate is less important as a driver of community patterns than variables such as rainfall, altitude and the origin of nutrients entering the system. We found fens were as likely on acid-forming substrates as on more basic rock types. Our extensive regional surveys suggest that both systems may occur as readily on any type of substrate. (Table 1).

The differentiation of bog and fen appears to be due to differences in acidity and nutrients, but at a level removed from the substrate. Fen water is generally bordering on eutrophic (van Diggelen et al. 2006); fens represent landscape sinks where nutrients derived from catchments are concentrated in streams and where nutrient-rich groundwater is close to the surface for much of the year (Weltzin et al. 2000, Hope 2003, van Diggelen et al. 2006). Bogs are oligo- or meso-trophic with nutrients derived from rain or nutrient-poor groundwater (Hope 2003). The underlying differences between rock types can be blurred depending on the extent of contact occurring between the mire community and the subsurface mineral soils. In fens found on granites in this study some characteristic bog taxa such as *Baloskion stenocoleum* and *Gonocarpus micranthus* occurred, but only in the narrow band between the fen and surrounding grasslands or woodlands, and not within the fen itself.

Where the level of nutrients and acidity do not change appreciably, but where the soil watertable is lower or inundation less frequent, *Carex* fens are described as grading into sod tussock grasslands (e.g. *Poa* grasslands; Costin 1959,

Kirkpatrick 1983). In similar situations in the New England Tablelands Bioregion, on a range of rock types, fens grade into dense *Pennisetum alopecuroides* swards; this tussock grass community often surrounds fens in grazed treeless, gently-sloping and shallow basin landscapes. In more heavily wooded landscapes, which are often, but not always, more deeply incised, fens form more linear communities, often associated with creeklines. The crowns of trees often meet over the creek. Given the extent of clearing for agriculture in these landscapes, we suggest that this pattern of fen-tussock grassland may have been more extensive previously, and that a woodland-fen pattern was, in the past, a more common scenario.

#### *Significant taxa in New England Tablelands fens*

Six fen taxa of conservation significance in the New England Tablelands Bioregion context were recorded.

#### ***Lysimachia vulgaris* var. *davurica* (Myrsinaceae)**

Listed as Endangered on the NSW *Threatened Species Conservation Act* (TSC) and previously known in the study area only from a single 1898 collection at Timbarra, east of Tenterfield. Rediscovered by us (D.M.Bell 294 & J.T.Hunter) south west of Walcha in a roadside reserve, though a few days later, after intensive grazing by travelling stock, no extant plants could be found (I. Telford *pers. comm.*).

#### ***Goodenia macbarronii* (Goodeniaceae)**

Listed as Vulnerable on the NSW TSC Act and coded 3VCi on RoTAP (Briggs & Leigh 1996). Found at a number of sites on the western side of the study area in the *Carex appressa* Alliance.

#### ***Asperula charophyton* (Rubiaceae)**

Listed 3RCa on RoTAP, and found in a fen on the margins of Little Llangothlin Lagoon. This species has a disjunct occurrence at Warrumbungle National Park though our observations on morphology and habitat preferences would suggest these may not be the same taxa (I. Telford *pers. comm.*).

#### ***Eryngium* sp. Little Llangothlin NR (D.M.Bell 56) (Apiaceae)**

Northern Tablelands endemic previously thought to be restricted to the edge vegetation of basaltic lagoons (Bell et al. 2008).

#### ***Leiocarpa* sp. Uralla (D.M.Bell NE 54142) (Asteraceae)**

Northern Tablelands endemic found only on damp soil on the margins of lagoons and other wet areas (Bell et al. 2008).

Two potentially new *Carex* species (K.L.Wilson *pers. comm.*) are *Carex* sp. Bendemeer (D.M.Bell 296 & J.T.Hunter), listed as the characteristic species of Community 6 and common to dominant in a number of sites and *Carex* sp. Tingha (D.M.Bell 339 & J.T.Hunter), a minor component of Community 6.

#### *Conservation Issues*

Fens are sensitive to small changes in groundwater flow (Van Diggelen 2006). In the New England Tablelands Bioregion many of the largest fens have been significantly altered,

reduced in size or completely destroyed by drains and dams; these activities still continue today (Fig. 13 & 14). Sites that may have once contained *Carex* fens are now grasslands, and on some soil types *Pennisetum* grassland rather than *Carex* fen are present in open depressions, suggesting that changes in moisture relationships could drive fen communities towards these and other grasslands. Recurrent fires may also cause degradation of the thin layers of peat or change its water holding capacity.

We estimate (based on inspection of SPOT5 imagery) that potentially 5 000 ha of fens exist in the New England Tablelands Bioregion. Of this less than 100 ha (0.2%) is within conservation reserves. Although some of the best remaining fens are in conservation reserves, even these have large drains or dams e.g. Bishops Swamp, Racecourse Swamp and New Country Swamp (Table 2, Fig. 12). The majority of remaining fens (98.8%) occur on private freehold land or on travelling stock reserves where they are under pressure from grazing. Costin (1959) records that fens in the Kosciuszko region were selectively overgrazed due to the palatability of *Carex gaudichaudiana* and that trampling of cattle caused drying out of the soil through degradation of peat and erosion. On the New England Tablelands differential palatability of the *Carex* dominants may affect community composition and structure where more than one species co-dominate. Both *Carex gaudichaudiana* and *Carex* sp. Bendemeer were readily eaten by grazing stock but grazing of *Carex appressa* was never observed (Fig. 15). The impact of grazing in fens thus requires further investigation.



**Fig. 13.** The deep drain in Bishops Swamp Werrikimbe National Park.

Almost all sites surveyed contained weedy exotic species typical of damp habitats, such as *Holcus lanatus*, *Festuca elatior*, *Cirsium vulgare*, *Rumex crispus*, *Trifolium repens* and *Rubus anglocandicans*. The abundances of weedy taxa were generally low, often with only one or a few individuals of each taxon. However, we consider that due to richness alone, weeds are a significant issue in the fens studied. We found that on average 26% of the flora was exotic in origin and that the number of exotics in individual sites was often over 50% of the taxa. Of 10 taxa present in a site near Coonabarabran, only *Carex appressa* was native. Most of the weed species feature in other wetlands in the region, e.g. in the lagoons (Bell et al. 2008), where these and other opportunistic species invade bare mud. Grazing pressure also potentially opens up the *Carex* canopy and results in 'safe sites' for minor weed invasion.

In the drier climates of Australia, mires, of which fens are a sub-category, are of strictly limited distribution (Hope 2003; Whinam & Hope 2005; Hunter & Bell 2007). In north



**Fig. 14.** Round Swamp, a former *Carex* fen near Niangala which has been converted to grassland by a series of drains, upstream dams and grading.



**Fig. 15.** An example of differential palatability. This fen east of Armidale was co-dominated by *Carex gaudichaudiana* and *Carex appressa*. The more palatable *Carex gaudichaudiana* has been selectively grazed out leaving prominent *C. appressa* tussocks.

**Table 2: Selected attributes for remaining examples of high quality Fens in the New England Tablelands Bioregion.**

Fen name	Location	Area (ha)	Tenure	Landuse	Rock Type	Hydrological disturbances	Fen community
Bells Swamp	30° 39' 57" S 151° 12' 34" E	11.7	Private	Grazing	Granite		C 5
Watsons Creek	30° 43' 01" S 151° 03' 49" E	4.9	Crown	Occasional grazing	Granite		C 5
Castlecrag	29° 21' 44" S 151° 53' 50" E	1.2	Crown		Granite	Runoff from Highway.	C 5
New Country Swamp	31° 17' 37" S 151° 58' 21" E	6.4	National Park	Conservation, adjacent Picnic Area	Metasediment	Dam	C 5
Racecourse Swamp	31° 08' 43" S 152° 13' 12" E	30.4	National Park	Conservation	Metasediment	Drain, off road vehicles.	C 5
Bishops Swamp	-31° 07' 36" S 152° 16' 39" E	18.8	National Park	Conservation	Metasediment	Drain	C 5
Little Llangothlin	-30° 05' 07" S 151° 46' 22" E	7.9	National Park	Conservation	Basalt	Outlet lowered by 1m but restored in 1990s	C 6

eastern NSW both fens and bogs are at their distributional and climatic limits. Any changes in regional climates that affect runoff and moisture levels in fen depressions such as increasing temperatures, decreasing rainfall or increasingly seasonal precipitation, may cause a decline in fen extent and their replacement with tussock grasslands (Pickering & Armstrong 2003).

The newly described *Carex* fens of the New England Tablelands Bioregion are some of the most threatened and under-represented communities in conservation reserves and should be targeted for reservation and rehabilitation. Seven outstanding examples of fens remain in the study region (Table 2) (based on the authors' appraisal of their size, composition, native diversity, low abundance of weeds and continuing threat); most are examples of Community 5, with only one representing Community 6; none represent the other five communities. Many of these are not secured and none of those in reserves are in their 'natural' state. We therefore strongly encourage measures to allow closure of drains, the opening of dams, and the rehabilitation of important fens such as Bishops, Racecourse and New Country Swamps (Table 2).

## Conclusion

Fens are an understudied and poorly-understood community in Australia. These rare, disjunct and threatened assemblages have been regularly dammed, drained and converted to pasture and this process is ongoing. In the New England Tablelands Bioregion 90% of the remaining remnants of this system are on grazed land with only 0.2% in reservation and of the handful of examples left in good condition none are both intact and in conservation reserves. It is imperative

that conservation efforts are applied to further protect these assemblages and that efforts are made to restore some of the more important examples. Surveys of similar assemblages in surrounding areas such as the North Coast and Hunter regions are needed, along with mapping and research into appropriate management techniques to enable their persistence in agricultural landscapes. Studies into changes in community dynamics driven by hydrology and nutrient influx and into dynamics of the key dominant taxa are required to improve management of these widespread but long overlooked communities.

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<i>Isachne globosa</i>	1	3	5	6	7	<b>Restionaceae</b>			
<i>Lachnagrostis filiformis</i>	1	3	4	5	6	<i>Baloskion stenocoleum</i>		3	5 6
<i>Lolium perenne</i> *	1					<b>Rosaceae</b>			
<i>Panicum simile</i>		2				<i>Acaena novae-zelandiae</i>		1	
<i>Paspalum dilatatum</i> *	1	2		5	7	<i>Acaena ovina</i>			4 6
<i>Paspalum distichum</i>	1			5		<i>Geum urbanum</i>		3	6 7
<i>Paspalum urvillei</i> *				5		<i>Rosa rubiginosa</i> *		1	4 6
<i>Pennisetum alopecuroides</i>	1			5	6 7	<i>Rubus anglocandicans</i> *		1 2 3	4 5 6 7
<i>Phalaris aquatica</i> *	1					<b>Rubiaceae</b>			
<i>Phragmites australis</i>	1	3		5		<i>Asperula charophyton</i>			7
<i>Poa labillardieri</i>	1			5	6 7	<i>Asperula conferta</i>		1	4
<i>Poa pratensis</i> *		3				<b>Scrophulariaceae</b>			
<i>Poa sieberiana</i>	1		4	5		<i>Gratiola peruviana</i>		3	5 6
<i>Sacciolepis indica</i>	1					<i>Mimulus moschatus</i> *		3	5 6
<i>Setaria gracilis</i> *	1					<i>Veronica anagallis-aquatica</i> *			7
<i>Setaria surgens</i>	1					<b>Sparganiaceae</b>			
<i>Sporobolus elongatus</i>	1					<i>Sparganium subglobosum</i>		3	5
<b>Polygonaceae</b>						<b>Typhaceae</b>			
<i>Acetosella vulgaris</i> *			4			<i>Typha latifolia</i> *			7
<i>Persicaria hydropiper</i>	1			5	6 7	<i>Typha orientalis</i>			5
<i>Persicaria praetermissa</i>				5		<b>Urticaceae</b>			
<i>Persicaria prostrata</i>	1			5		<i>Urtica incisa</i>		1	3
<i>Polygonum arenastrum</i> *	1					<b>Verbenaceae</b>			
<i>Rumex brownii</i>	1	2				<i>Verbena bonariensis</i> *		1	5 7
<i>Rumex conglomeratus</i> *	1			6	7	<i>Verbena brasiliensis</i> *		1	
<i>Rumex crispus</i> *	1			5	6 7	<i>Verbena officinalis</i> *			7
<i>Rumex obtusifolius</i> subsp. <i>obtusifolius</i> *				6		<i>Verbena rigida</i> *		1	
<b>Portulacaceae</b>						<b>Violaceae</b>			
<i>Neopaxia australasica</i>			3	5	6 7	<i>Hybanthus monopetalus</i>			4
<i>Portulaca oleracea</i> *		2				<i>Viola betonicifolia</i>		1	
<b>Primulaceae</b>						<i>Viola caleyana</i>			5 6 7
<i>Anagallis arvensis</i> *	1								
<i>Lysimachia vulgaris</i> var. <i>davurica</i>					7				
<b>Proteaceae</b>									
<i>Hakea microcarpa</i>		3		5					
<b>Ranunculaceae</b>									
<i>Ranunculus inundatus</i>	1	3		5	7				
<i>Ranunculus lappaceus</i>	1			5	6 7				
<i>Ranunculus</i> sp. A	1								
<i>Ranunculus</i> sp. aff. <i>lappaceus</i>				5					
<i>Ranunculus undosus</i>				5					