Montane lakes (lagoons) of the New England Tablelands Bioregion

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Abstract: The vegetation of montane lagoons of the New England Tablelands Bioregion, New South Wales is examined using flexible UPGMA analysis of frequency scores on all vascular plant taxa, charophytes and one liverworts. Seven communities are described-

1. *Hydrocotyle tripartita – Isotoma fluviatilis – Ranunculus inundatus – Lilaeopsis polyantha* herbfield

2. *Eleocharis sphacelata – Potamogeton tricarinatus* sedgeland

3. *Eleocharis sphacelata – Utricularia australis – Isolepis fluitans,* herbfield

4. *Utricularia australis – Nitella sonderi* herbfield

5. *Eleocharis sphacelata – Utricularia australis – Ricciocarpus natans* sedgeland

6. *Carex gaudichaudiana – Holcus lanatus – Stellaria angustifolia* sedgeland

7. *Cyperus sphaeroides – Eleocharis gracilis – Schoenus apogon – Carex gaudichaudiana* sedgeland.

58 lagoons were located and identified, only 28% of which are considered to be intact and in good condition. Two threatened species (*Aldovandra vesiculosa* and *Arthaxon hispidus)* and three RoTAP-listed taxa were encountered during the survey.

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Introduction

Temporary wetlands are far more common and widely distributed in Australia than are permanent lakes and swamps (Paijmans 1985); in the New England Bioregion, on the New South Wales Northern Tablelands, shallow lentic wetlands are a feature of the flat terrain derived from Tertiary basalt flows. More than 70% of these montane wetlands have been drained or dammed (Brock *et al*. 1999; Keith 2004).

Keith (2004) refers to the intermittent and semi-permanent wetlands found on deflation hollows of the NSW Northern Tablelands and the Southern Tablelands Monaro region as montane lakes; Jacobs & Brock (1993) describe these wetlands as ephemeral lakes and swamps. However Paijmans *et al*. (1985) restricts lakes to those water-bodies greater than 1 m deep when full, a definition that would exclude all but two of the wetlands on the New England Tablelands Bioregion. Timms (1992) discusses the pitfalls of attempting to define lakes in Australia where many lakes are ephemeral, and in his study excluded small water bodies (ponds; <1 ha) and those where vegetation dominates the water surface (swamps). We have reservations about using the term lake for these New England Tablelands wetlands, since all are dominated by emergent macrophytes, most are shallow, and a few are less than 1 ha. It is symptomatic of this confusion over terminology that sees Benson & Jacobs (1994) describe these systems on the Monaro as lakes, while describing all vegetation communities present as marshes. Globally these systems would probably best be described as semi-permanent or ephemeral marshes (Usback & James 1993). Like some of the geomorphological literature (Walker 1976; Haworth et al. 1999) and local custom, we will refer to these wetlands as lagoons (Usback & James 1993; Bell & Clarke 2004; Benson & Ashby 2000).

The Northern Tablelands lagoons are shallow (mostly < 1.5 m deep) upland wetlands and ponds, typically located in saucer-shaped areas of negative relief with closed or semi-closed drainage, on flat or gently undulating landscapes associated with Tertiary basalt flows (Walker 1977). A distinguishing feature are their well-defined and apparently wave-cut banks that contrast with sandy lunettes on their downwind shores, both features indicating that they formed under climatic conditions different from the present.

Lagoons differ from other regional wetlands in morphology and location. Most are oval-shaped, often with distinct rocky margins, though with considerable recent silt accumulation on their edges. They occur above 900 m, close to the top of the Great Divide or to adjacent leading ridges, and inland of the 1000 mm rainfall isohyet. They are not found in the wettest areas of the eastern 'falls country', but in more inland areas prone to cycles of wetting and drying, where weathering by watertable fluctuation is more intense. Retention of water in the closed basins is facilitated by drainage impediment caused by the accumulation of the secondary products of weathering, such as stiff clays and the duricrusts ferricrete and silcrete. These secondary products are most commonly associated with basalt weathering but may occasionally form from different rock types under similar environmental conditions, probably that of marked seasonal variation in watertables and subsequent precipitation of duricrust minerals.

Lagoons receive water from their relatively small catchments by combinations of hydrological processes; some are mainly stream-fed, some spring-fed and some fed by overland flow. Most lagoons were probably initiated by return-flow sapping at the base of basalt rises, and some have marginal peatlands that may retain moisture when the central basin is dry. Though largely closed systems, water may spill into the adjoining major river catchments, the Clarence, Macleay or Gwydir, in extreme floods.

Similar lagoons are found in low relief tableland areas along the Great Divide e.g. the Monaro (Pillans 1987; Benson & Jacobs 1994). Although most often associated with basalt lithologies, they are not volcanic in origin. Apart from obvious differences in morphology to volcanic maars, the superficial nature of the drainage-divide lagoons was demonstrated by Coenraads (1989) who drilled through the basement of four Glen Innes lagoons to the underlying country rock.

Some lagoons have either sand dunes or clay-rich mounds on their eastern (lee) side called 'lunettes' (because of their typical wind-formed crescent shape), and probably products of deflation or wave action formed under different climatic conditions during the glacial cycle of the last 2 million years (Pillans 1987). Unlike most lakes, their basins tend to be renewed by deflation (wind erosion) over periods of tens of thousands of years, and as their catchments are small, they are rarely completely infilled. Lagoon sediments are rarely more than several metres deep, and radiocarbon dating of the peat fraction indicates that the present cycle of sedimentation commenced approximately 15 000 years ago, as climate became wetter and warmer after the last Glacial Maximum (Haworth 1994; Haworth et al. 1999).

Since European settlement the hydrology of the Northern Tableland lagoons has been extensively altered by agricultural practices such as draining, impoundment, excavation and grazing (Walker 1977; Brock et al. 1997; Benson & Ashby 2000). A preliminary inventory using map and air photo analysis (Walker 1977) identified 29 lagoons in New England but since Walker's 1977 study it has become obvious that there are more lagoons in this region, and that the majority are highly modified, and the vegetation communities in them are under threat. Vegetation typical of these lagoons is included in the Endangered Ecological Communities *Upland Wetlands of the Drainage Divide of the New England Tableland Bioregion* (listed under the NSW *Threatened Species Conservation Act 1995*) and *Upland wetlands of the New England Tablelands and the Monaro Plateau* (listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*).

Management and conservation initiatives require an up-to-date understanding of the extent and condition of these lagoons. Past descriptions of vegetation have either been limited to a single site (Millington 1949), or have focussed on a sub-regional scale i.e. lagoons of the Guyra 1:100 000 Map Sheet (Benson & Ashby 2000). Other investigators have dealt with the ecology of individual taxa or groups of taxa, e.g. *Myriophyllum variifolium* (Brock 1991), the family Characeae (Casanova 1993; Casanova & Brock 1999), the relationships between *Glyceria australis* and *Juncus articulatus* (Smith & Brock 1996), or co-existence within the genus *Eleocharis* (Bell & Clarke 2004). Other work has focussed on seedbanks (Brock 1998); a long-term vegetation survey of six lagoons revealed habitat partitioning (zonation) in both standing vegetation and soil seedbank (Bell 2000).

Some temporary wetlands species display considerable morphological plasticity with different architectural forms, one for growing in the water column and another for surviving on damp mud (Brock 1991). These species are termed amphibious responders by Brock & Casanova (1997), who allocated Northern Tablelands wetlands species into three broad functional groups based on their establishment characteristics.

It is our intention to 1) investigate the location, extent and integrity of lagoons on the Northern Tablelands Bioregion and provide a current inventory; and 2) describe lagoon vegetation community patterns and their compositional and distributional gradients. This study forms part of a broader investigation on montane wetlands systems of the Northern Tablelands (Hunter & Bell 2007).

Methods

The vegetation of six of the least disturbed lagoons (Llangothlin, Little Llangothlin, Pinch, Billybung, Kolora and Wyanbah Lagoons) was sampled in January 1998. The lagoons had, at that time, been experiencing relatively high rainfall for the previous three years and all but Wyanbah held water. The southern and northern ends of the 250 hectare Llangothlin Lagoon and the grazed and un-grazed sides of Billybung Lagoon were considered as separate sites; 3 transects per site (24 transects total) were placed perpendicular to the shoreline from the approximate high water mark to a few metres into the central *Eleocharis sphacelata* stands. The lower edge of the *Carex gaudichaudiana* stands, where they occurred, were deemed to be the high water mark; if *Carex* was absent, the grass *Hemarthria uncinata* marked the upper end of the transect.

The presence/absence of all vascular plant species, charophytes and the large floating liverwort *Ricciocarpus natans* was recorded in contiguous 0.5 m x 0.5 m (¼ m^2)

quadrats along the whole length of each transect. Both charophytes and *Ricciocarpus natans* are often common to dominant elements of these communities (Casanova 1993). After sampling, vegetation was stratified along transects into two to four visually distinct bands per site. Multivariate analysis data consisted of frequency scores for each species in plots consisting of six contiguous quadrats (total area 3.00 x 0.5 m) from a random position within each band (68 plots in total). Frequency scores ranged from one (present in one quadrat in the plot) to six (present in all quadrats). Nomenclature follows that of Harden (1990–1993) except where recent changes have occurred (PlantNET 2006). Species life history types (submerged, floating submerged, floating-leaved, emergent and terrestrial) were allocated to each species. Terrestrial species were those not normally found in intact wetlands in either their dry or flooded states.

The depth profile of each transect was measured at 1 m intervals using a datum point at the high water end of the first transect and measuring depths with a dumpy level. Transects varied in length from 62 m (Billybung un-grazed) to 362 m (Little Llangothlin). Water depth at the deepest point on transects varied from zero at Wyanbah to 1.39 m at Little Llangothlin Lagoon.

All lagoons were visited from 1989 to 1992 and in 2006 (first author, 20 sites only) and opportunistically on other occasions. Landholders were asked about the history of each lagoon, particularly on the history of hydrological changes such as drainage and impoundment. Each site was traversed and vegetation, water depth and hydrological changes noted. In 2006 a number of newly identified sites were visited.

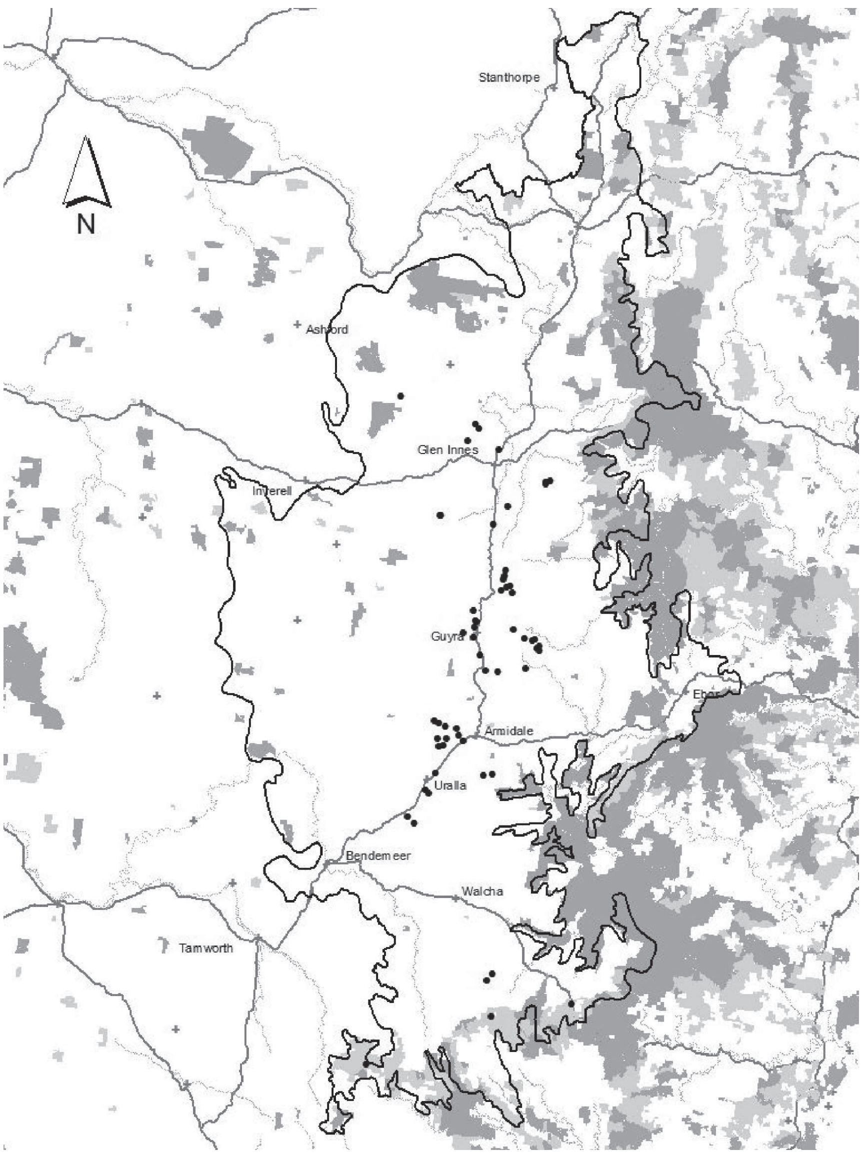


Fig. 1. Location and extent of lagoons of the New England Tablelands Bioregion. Circles are lagoon locations, dark grey are National Park estate and light grey is State Forest estate, dark line is the boundary for the New England Tablelands Bioregion.

Table 1. Distribution, description and condition of montane lagoons on the Northern Tablelands Bioregion of NSW.

Lagoon Group	Lagoon	Tenure	Lat/Long	Altitude (m)	Basin area (ha)	Parent material	Hydrological disturbance	Notes
	Kings Plains	Private	29°38′02″S 151°26′40″E	930	2	Basalt		Apparently intact, very shallow.
Glen Innes	Clarevaulx	Private	29°37′06″S 151°40′30″E	1010	140	Basalt	Drained	Multiple drains.
	Dunvegan	Private	29°37′55″S 151°41′09″E	1013	14	Basalt	Drained	Pipe in low wall to manipulate drainage. Western side ploughed and sown to fescue.
	Reddestone	TSR/Private	29°40′03″S 151°38′49″E	1034	30	Basalt	Drained	Much altered. Drain through centre plus 2 dams interrupt drain. V-shaped wall further north across basin. Original area difficult to determine.
	Treriffiths	Private	29°41′33″S 151°45′00″E	1081	2	Basalt	Small dam at margin	Essentially intact.
	John Ryall	Private	29°47′05″S 151°55′13″E	1186	7	Basalt		Essentially intact. Low wall at northern end appears to have no impact on hydrology.
	Glen Athol North	Private	29°47′17″S 151°54′19″E	1185	4	Basalt	Slight impoundment	Divided by a raised mound (& ditch) supporting east/ west fence.
	Glen Athol West	Private	29°47′41″S 151°54′00″E	1185	5	Basalt	Drained	Three wide shallow drains, road-works across north-east corner.
	Blair Hill	Private	29°51′32″S 151°46′40″E	1269	4	Basalt		Intact, shallow but badly trampled by cattle.
	Barleyfield-Glencoe	Crown Land	29°54′32″S 151°43′50″E	1144	10	Basalt		Intact.
	Novar	Private	29°52′53″S 151°33′29″E	1345	<1	Basalt	Slight	Very shallow. Small ditch dug in basin with low bank.
	West Novar	Private	29°52′47″S 151°33′08″E	1342	<0.5	Basalt	Impounded	Very shallow. Edge of wetland excavated to form high dam wall.
Llangothlin	North Llangothlin	Private	30°02′29″S 151°46′08″E	1362	7	Basalt/ granite	Impounded	No wetland vegetation.
	Llangothlin	Private	30°03′30″S 151°45′54″E	1354	410	Basalt/ granite		Outlet lowered previously then restored.
	South Llangothlin	Private	30°04′02″S 151°45′45″E	1368	3	Basalt		Intact, very shallow.
	Little Llangothlin	Nature Reserve	30°05′11″S 151°47′00″E	1355	100	Basalt/ granite		Outlet lowered previously then restored in 199?
	Billy Bung	Private/ Nature Reserve	30°05′26″S 151°46′24″E	1363	25	Basalt		Essentially intact. Never drained.
	Tubbamurra	Private	30°06′01″S 151°45′17″E	1355	4	Basalt	Drained, dam in lagoon bed	Drained at outlet, some excavation for road-fill.
	Abbey Green	Private	30°06′17″S 151°47′29″E	1351	11	Basalt/ granite	Drained	Outlet lowered 60 cm, older shallow drainage system.
	Kyoma	Private	30°07′45″S 151°43′05″E	1348	3	Granite-silcrete		Very shallow. Slightly impounded by road. Silcrete and silcreted conglomerate boulders on lagoon bed.

Guyra	Everetts Flat	Private	30°09′20″S 151°39′35″E	1312	27	Basalt/ granite	Drained	2m deep drain to south, partly cultivated.
	Little Waterview	Private	30°11′00″S 151°40′01″E	1318	5	Basalt	Drained	Central drain.
	Waterview	Private	30°11′13″S 151°40′22″E	1317	11	Basalt	Impounded	Used for abattoir waste water for many years.
	Elmwood	Private	30°12′10″S 151°39′55″E	1320	16	Basalt		Cultivated.
	Sabot	Private	30°13′17″E 151°37′40″S	1325	5	Basalt		Intact.
	Mother of Ducks	Private/ DEC	30°14′00″S 151°39′30″E	1315	430	Basalt	Drained	Outlet lowered 2m, partly enclosed by dyke & moat.
	Pinch (Dittons, Black Mountain, Little)	Private	30°17′05″S 151°40′56″E	1335	43	Basalt	Drained	System of marginal drains feeding into lowered (now approx 80 cm) outlet, but impact on vegetation slight.
Brockley	Bald Blair	Private	30°12′45″S 151°47′30″E	1277	25	Basalt	Impounded in 1960s	Loss of all aquatic vegetation.
	Kolara	Private	30°14′13″S 151°49′46″E	1330	8	Basalt		Essentially intact, drained previously but restored, small dam near outlet.
	Edenglen (upper)	Private	30°14′40″S 151°51′26″E	1312	8	Basalt	Drained	Deep central drain, outlet lowered.
	East Edenglen (lower)	Private	30°14′33″S 151°51′48″E	1306	6	Basalt	Drained	Drainage system with central drain, outlet lowered at least 60 cm.
	Brockley Swamp	Private	30°16′20″S 151°52′40″E	1282	20	Basalt	Drained	Central drain excavated 1980s, outlet now on opposite side to natural outlet. Drain deepened in 1994.
	Little Brockley	Private	30°16′00″S 151°52′10″E	1300	2	Basalt	Drained	Site difficult to identify because of drainage.
	East Brockley	Private	30°15′45″S 151°52′40″E	1290	2	Basalt	Drained	Site difficult to identify, apparently covered by an airstrip.
	Loch Abbra	Private	30°19′27″S 151°49′51″E	1306	8	Basalt	Dam wall across northern end	Essentially intact, dam wall not effective.
	Anthony’s	Private	30°20′05″E 151°44′20″S	1335	1	Basalt	Impounded	Loss of all aquatic vegetation.
	Copnor	Private	30°19′45″S 151°41′50″E	1330	1	Basalt		Apparently intact.
Armidale	Primrose Hill (Hillwood)	Private	30°28′19″S 151°31′32″E	1075	6	Greywacke	Drained, two dams in lagoon bed	Old drain non-functional, bore in catchment.
	Pansyfields	Private	30°28′44″S 151°32′32″E	1079	2	Basalt	Drained	Very shallow.
	Saumerez Ponds	Private	30°29′23″S 151°33′49″E	1050	24	Basalt	Impounded then drained	Vegetation more or less intact but outlet slightly lowered. Pipe in dam wall to allow drainage.
	Tanglewood (Nandewar)	Private	30°29′52″S 151°36′02″E	1086	3	Basalt	Dam in lagoon bed	Dam spoil used to extend landing strip along lagoon edge.
	Green Wattle	Private	30°30′52″S 151°36′27″E	1070	2	Basalt	Dam in lagoon bed 1992	Shallow.

Lagoon Group	Lagoon	Tenure	Lat/Long	Altitude (m)	Basin area (ha)	Parent material	Hydrological disturbance	Notes
	Pinegrove (Saumerez Airport)	Private	30°31′24″S 151°33′58″E	1044	3	Basalt	Small dam at one end	Essentially intact but soil disturbed by cattle trampling and worm digging.
	Wyanbah (Airport)	Crown Land	30°31′51″S 151°37′18″E	1086	4	Basalt		Essentially intact, minor soil excavations around edge for road building.
	Dangarsleigh	Private	30°38′00″S 151°41′16″E	1043	1	Basalt	Drained then impounded	Very shallow, margin eroded. Drained long ago, dam wall erected across drain.
	Thomas	Private	30°32′44″S 151°33′13″E	1034	4	Basalt/ silcrete		Essentially intact. Two outlets, apparently slightly lowered.
	Strahle	Private	30°32′51″S 151°32′27″E	1043	6	Basalt	Drained	Old drain, much trampled by cattle.
	Sawpit Swamp	Private	30°31′28″S 151°32′07″E	1062	<1	Basalt		Very shallow.
	Barleyfields - Uralla	TSR	30°37′24″S 151°31′42″E	1069	6	Basalt	Minor	Small dam above margin, worm digging. Old highway partially encroaches on western side.
Uralla	Dangars	TSR	30°40′53″S 151°30′12″E	1022	55	Granite-derived sediment	Impounded	Extensive wall erected in 1850s to increase capacity for use in goldmining. May have once been more extensive.
	Racecourse	Uralla Shire	30°40′23″S 151°29′30″E	1030	20	Granite		Intact. Racetrack around edge, also boating. Lagoon bed ploughed in 1980s to grow oats.
	Kentucky	Private	30°45′″S 151°26′″E	1062	4	Porphyrite	Drained	Drained long ago.
	Taylors	Private	30°46′07″S 151°27′20″E	1050	7	Diorite	Shallow drain	
Walcha	Round Swamp	Private	31°12′19″S 151°42′33″E	1276	45	Basalt	Drained then impounded	Impounded in late 1990s across old drain. Total loss of wetland vegetation by 2004.
	The Lakes (Brackendale)	Private	31°13′23″S 151°41′28″E	1264	20	Basalt	Impounded	Total loss of wetland vegetation.
	Yarrowitch	State Forest	31°17′40″S 151°58′25″E	1128	8	Basalt	Drained	System of drains in lagoon bed, outlet lowered.
	New Country Swamp	National Park	31°19′42″S 151°52′10″E	1166	15	Basalt/slate		Essentially intact. Outlet affected by road to picnic area but apparently not raised.
	South Head	State Forest	31°27′35″S 151°16′55″E	1210	<1	Basalt/slate		Very shallow. Margin no longer intact due to erosion.

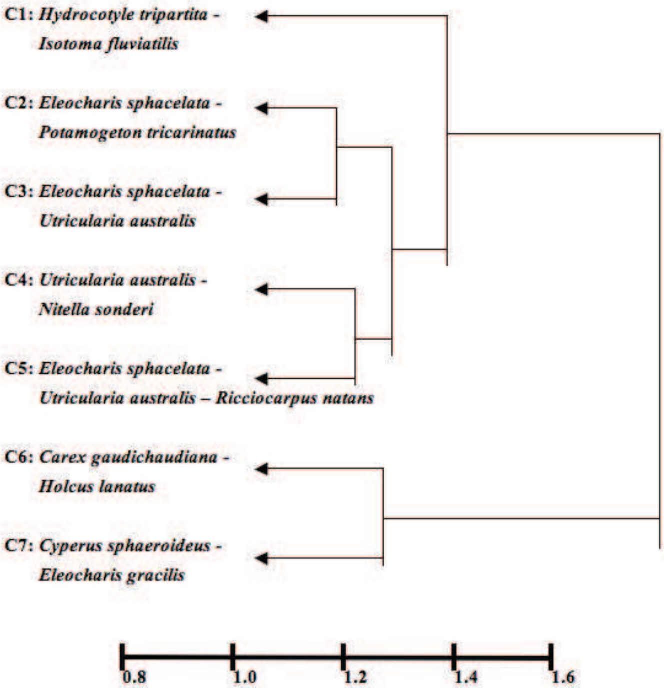


Fig. 2. Summary dendrogram of full dataset of sites using Kulczynski association and flexible UPGMA fusion strategy.

Analyses and data exploration used options available in the PATN Analysis Package (Belbin 1995a). For the final presentation, all species and their relative cover scores were included, and the analysis performed 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. Community structural names are based on the most consistently dominant taxa or, in the case of *Eleocharis sphacelata*, on the tallest emergent taxa. Semi-Strong- Hybrid Multidimensional Scaling (SSH) was used as the ordination technique. 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 1991b). SSH calculates the level of stress, which is the miss-match between distances between points and the best estimate of the same values (Belbin 1995b). Simple regression was used to follow the changes in species richness against basin depth.

Results

Lagoon site details and condition

We identified 58 montane lagoons in the New England Tablelands Bioregion (Table 1). These wetlands are most common in the Guyra-Llangothlin area and west of Armidale, with scattered sites near Glen Innes, Uralla and south of Walcha (Fig. 1). While this list is comprehensive for known lagoons, it is likely that others on basalt-derived terrain may yet be undiscovered.

Lagoons range in altitude from 930 m (Kings Plains) to over 1360 m (Billybung, South Llangothlin), and from Kings Plains northwest of Glen Innes in the north to just north of Hanging Rock in the south (Fig. 1). Wetlands range in size from less than 1 ha to 430 hectares. Only two, Mother of Ducks (430 ha) and Llangothlin (410 ha) are substantial in size; two others, Clarevaulx (140 ha) and Little Llangothlin (100 ha) are moderately large; 16 are of medium size (10 –100 ha), the largest of these is Pinch Lagoon at 43 ha. The remainder (66 %) are small (<10 ha) with 6 of these less than 1 ha in area.

22 lagoons have more or less intact basins supporting wetland vegetation. Of these, five are small and very shallow and only hold water intermittently, and in a further two (Strahles, Blair Hill) the basin sediments are much disturbed by cattle trampling and the vegetation appears restricted to no more than a handful of species. Only 15 (28%) of lagoons could be considered intact and in good condition. Only one of each of the two substantial and two large lagoons (respectively, Llangothlin and Little Llangothlin) is intact. Of the 16 medium lagoons, only four (25%) are intact and of the 38 small lagoons, only nine (24%) are intact or deep enough to hold water frequently.

Disturbance to basin hydrology is common; lagoons have been drained, impounded or have had dams sunk into basin floors. Drainage has involved simply a lowering of the outlet (which usually requires cutting through a layer of ferricrete) or lowering of the outlet in conjunction with drainage via either a single central drain (Edenglen) or a network of drains (Clarevaulx, Glen Athol West). Mother of Ducks lagoon outlet has been lowered by a massive 2 m. A large central ditch excavated into the basin at Brockley Swamp cuts through the lagoon margin; water now drains in the opposite direction to the original overflow outlet. The outlets of three lagoons (Llangothlin, Little Llangothlin and Kolara) have been restored to their approximate original levels after past lowering. Other disturbances include the construction of a wall across part of the basin to prevent water reaching private grazing and cropping land (Reddestone). Roadworks or airstrips impinge on the edges of some lagoon basins (Glen Athol West, Barleyfields-Uralla, Tanglewood). Three lagoons (Dangars, Barleyfields-Uralla and Edenglen) provided water for nineteenth century goldmining (*pers. com.* Arnold Goode, Ron Sisson). Pinegrove and Barleyfields-Uralla are often subject to worm-digging to provide fishing bait. Previous recreational uses of the lagoons included boating (Racecourse, Mother of Ducks) and public swimming events (Dangars).

Almost all lagoons (85 %) occur on private property. Only six are on public land with a further three partly on public and partly on private land (Billybung, Mother of Ducks, Reddestone). All but five lagoons (Little Llangothlin, Racecourse, New Country Swamp, part of Mother of Ducks, Billybung) are currently grazed by cattle; a few lagoons are grazed only by sheep (Wyanbah, Kolora).

Vegetation patterns

Seven communities were defined at a dissimilarity of 0.9 (Fig. 2) and these occurred within three major divisions (Figs. 2 & 3). These major divisions highlight an inferred water depth environmental gradient running from the top right hand corner to the bottom left hand corner of the ordination (Fig. 3).

Floristics

A total of 173 vascular plant taxa in 48 families and 117 genera were recorded from the six sites (94 taxa), and from opportunistic collections at other lagoons over 16 years (an additional 86 taxa). Six charophytes (in the genera *Chara* and *Nitella*) and one large floating liverwort were also recorded. Families with the most taxa overall were: Poaceae (28 species), Cyperaceae (25 species) and Asteraceae (24 species). The richest genera were: *Juncus* (9 species), *Eleocharis* (6 species), *Cyperus* (6 species) and *Carex* (5 species). 43 taxa overall (24 %) were exotic but only 9 exotic taxa were recorded in the transect survey (10 %).

The most frequent species encountered was *Myriophyllum variifolium*, recorded in 52 of the 68 plots (76 %). Other frequent species were *Glyceria australis*, *Hydrocotyle tripartita*, *Utricularia australis*, *Eleocharis pusilla*, *Eleocharis dietrichiana*, *Potamogeton tricarinatus* and *Isotoma fluviatilis* subsp. *borealis*.

Most taxa displayed an emergent life form but there were 5 submerged species, 7 floating leaved species, 3 free-floating species and 2 floating-submerged species. 18 strictly terrestrial species were recorded from drained and shallow lagoons.

Vegetation assemblages

Physiographic Position: Lagoon edges

Restricted, in unmodified systems, to the lagoon edge towards the top of basin slopes at study sites but commonly occurs over the whole basin if very shallow (drained or in-filled).

Community 1: *Hydrocotyle tripartita – Isotoma fluviatilis – Ranunculus inundatus – Lilaeopsis polyantha* herbfield

Environmental relationships: Water-level fluctuations are a feature of this habitat; many species here belong to Brock and Casanova (1997)'s amphibious group.

Emergent: *Myriophyllum variifolium, Eleocharis pusilla, Hydrocotyle tripartita, Isotoma fluviatilis* subsp. *borealis, Lilaeopsis polyantha, Eleocharis dietrichiana, Ranunculus inundatus, Glyceria australis, Eleocharis acuta, Lachnagrostis filiformis, Brachyscome radicans, Stellaria angustifolia, Crassula helmsii, Isolepis fluitans, Cyperus sanguinolentus, Gamochaeta americana, Myriophyllum lophatum, Epilobium billardierianum* subsp. *hydrophilum, Juncus fockei, Holcus lanatus, Elatine gratioloides, Rorippa palustris, Amphibromus nervosus, Panicum obseptum, Juncus vaginatus, Carex gaudichaudiana, Amphibromus sinuatus, Persicaria hydropiper, Eragrostis* sp., *Utricularia dichotoma, Spirodela punctata, Ricciocarpus natans, Limosella australis, Eleocharis sphacelata, Pennisetum alopecuroides,*

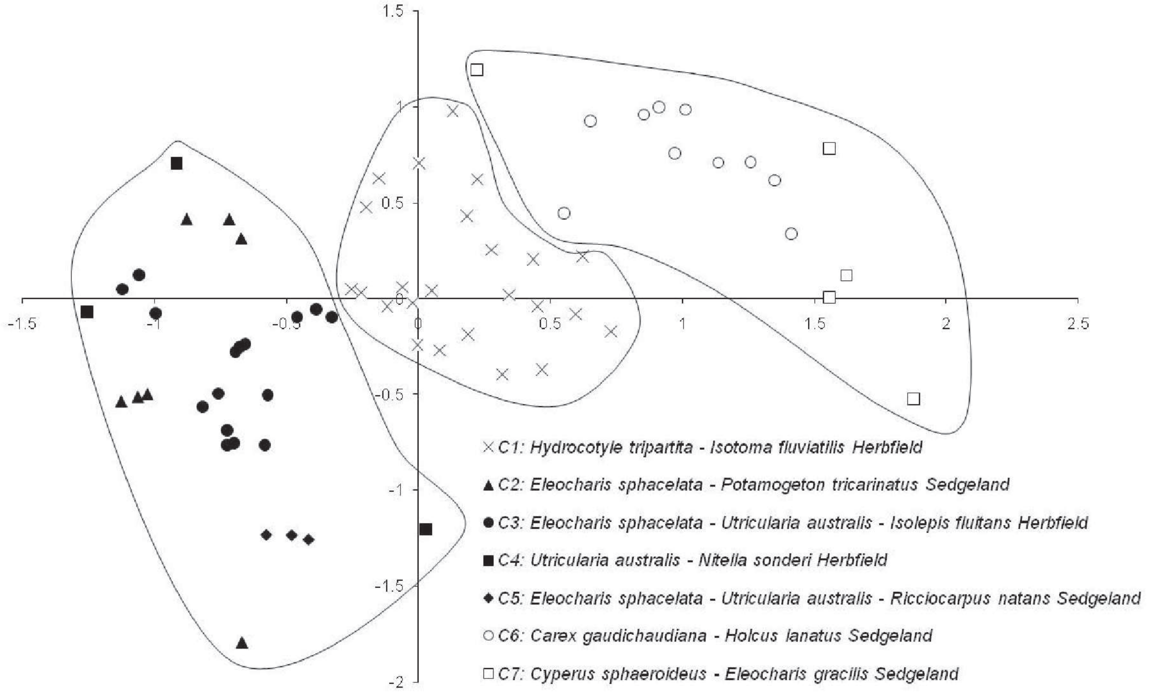


Fig. 3. Ordination scattergram of seven lagoon communities within three major physiographic groups using flexible UPGMA and SSH (Belbin 1995a). Basin depth increases from right to left.

Paspalum distichum, Juncus articulatus, Hemarthria uncinata, Schoenus apogon, Juncus bufonius, Euchiton involucratus, Centipeda minima, Rumex crispus, Hypericum japonicum, Asperula charophyton, Trifolium repens.

Floating-leaved: *Nymphoides montana, Potamogeton tricarinatus, Nymphoides geminata, Brasenia schreberi*.

Floating-submerged: *Aldrovandra vesiculosa, Utricularia australis*.

Variability: Recorded at all six sites. A generally species-rich community (mean richness 15, range 11–23) with fewer species at the very shallow temporary Wyanbah Lagoon.

Notes: In most drained lagoons and in shallow, presumably long in-filled lagoons, elements of this community occur across the whole basin. Often, where substantial hydrological disturbance has occurred, a few species of this community (e.g. *Hydrocotyle tripartita* and *Lachnagrostis filiformis*) are the only wetland species that remain, occurring alongside common terrestrial pasture species, both exotic and native.

Physiographic Position: Lagoon basins

Restricted to the lagoon basin in deeper water. Generally only occurs in intact lagoons with little or no hydrological disturbance. Elements of this community (*Eleocharis sphacelata* and *Myriophyllum variifolium*) may occur in some in-filled lagoons (Wyanbah, Barleyfields) and in some drained lagoons (Edenglen).

Community 2: *Eleocharis sphacelata – Potamogeton tricarinatus* sedgeland

Environmental relationships: Occurring in deepest parts of some lagoons.

Emergent: *Eleocharis sphacelata, Myriophyllum variifolium, Glyceria australis, Eleocharis dietrichiana, Panicum obseptum*.

Floating-leaved: *Potamogeton tricarinatus, Nymphoides montana, Nymphoides geminata*.

Variability: In the transect survey only recorded in the shallow Wyanbah, in Little Llangothlin Lagoons and at the northern end of Llangothlin Lagoon.

Notes: Characterised by high cover and abundance of both *Eleocharis sphacelata* and *Potamogeton tricarinatus* (where it occurs). In Little Llangothlin Lagoon often an *Eleocharis sphacelata* monoculture. This community is characterised by low species richness (4.4, range 1–8) and the floating submerged plant *Utricularia australis* is absent (compare to Communities 3, 4 and 5).

Community 3: *Eleocharis sphacelata – Utricularia australis – Isolepis fluitans* herbfield

Environmental relationships: Occurring in deeper parts of smaller or shallower lagoons and at intermediate depths of large, deeper sites.

Emergent: *Myriophyllum variifolium, Isolepis fluitans, Eleocharis sphacelata, Glyceria australis, Isotoma fluviatilis* subsp. *borealis, Hydrocotyle tripartita, Brachyscome radicans, Amphibromus sinuatus, Ranunculus inundatus*.

Floating-leaved: *Potamogeton tricarinatus, Nymphoides montana*.

Floating submerged: *Utricularia australis*.

Variability: In the transect survey found at all sites except Wyanbah. Not present at Little Llangothlin Lagoon where intermediate depths were mostly open water.

Notes: Essentially represents communities at intermediate depths where relatively shallow water and vegetation cover prevent disturbance by wind. Extensive in the deeper centre of Little Llangothlin Lagoon and covers almost the whole surface of Llangothlin Lagoon except for part of the southern end where open water and stands of *Myriophyllum variifolium* are common. Mean richness six (range 3–11).

Community 4: *Utricularia australis – Nitella sonderi* herbfield

Environmental relationships: Occurring at sheltered intermediate depths of large lagoons where cover of emergents and floating-leaved plants is low and patchy.

Emergent: *Myriophyllum variifolium, Isolepis fluitans, Paspalum distichum, Eleocharis pusilla*.

Floating: *Ricciocarpus natans*.

Floating-leaved: *Potamogeton tricarinatus*.

Floating-submerged: *Lemna trisulca*, *Utricularia australis*.

Submerged: *Nitella sonderi*, *Nitella cristata*, *Chara muelleri*, *Potamogeton crispus*, *Najas tenuifolia*.

Variability: Only found in the transect survey at the southern end of Llangothlin Lagoon but noted on other occasions at Racecourse (Casanova 1993) and Little Llangothlin Lagoons.

Notes: Characterised by submerged species, sparse cover of emergents and floating-leaved species and relatively high light penetration into the water column. Low richness (7.7, range 7–9) and extreme patchiness of all species is a feature of this community.

Community 5: *Eleocharis sphacelata – Utricularia australis – Ricciocarpus natans* sedgeland

Environmental relationships: Occurring in sheltered deeper parts of large lagoons.

Emergent: *Myriophyllum variifolium*.

Floating: *Ricciocarpus natans*.

Floating-submerged: *Lemna trisulca*.

Submerged: *Utricularia australis*.

Variability: Southern end of Llangothlin Lagoon only.

Notes: Characterised by floating and floating-submerged species in sheltered relatively deep water between clumps of *Eleocharis sphacelata* and low cover of emergents such as *Myriophyllum variifolium*. Low richness (5, range 4–5).

Physiographic Position: Lagoon margins

Restricted to damp lagoon margins at or near the high water mark and fed by seepage.

Community 6: *Carex gaudichaudiana – Holcus lanatus – Stellaria angustifolia* sedgeland

Environmental relationships: Occurring at damp margins of lagoons at approximately high water mark where seepage is present.

Emergent: *Holcus lanatus*, *Glyceria australis, Carex gaudichaudiana, Stellaria angustifolia, Hydrocotyle tripartita, Eleocharis dietrichiana, Eleocharis pusilla, Eleocharis acuta, Epilobium billardierianum* subsp. *hydrophilum, Lachnagrostis filiformis, Asperula charophyton, Neopaxia australasica, Anthoxanthum odoratum, Isolepis fluitans, Gamochaeta americana, Myriophyllum variifolium, Isotoma fluviatilis* subsp. *borealis, Brachyscome radicans, Trifolium repens, Viola betonicifolia, Juncus fockei, Spiranthes sinensis, Myriophyllum lophatum, Amphibromus nervosus*.

Variability: Within the transect survey only at Billybung and Little Llangothlin Lagoons but common at many other sites where seepage occurs at margins at the base of basalt slopes (e.g. parts of Kolora and Pinch Lagoons, Thomas Lagoon and Abbey Green Lagoon). A relatively rich community (9.9, range 7–15).

Notes: Appears to be a transitional community not strictly part of the lentic wetland but fed by seepage from the surrounding slopes, similar to *Carex* sedgelands of swampy, drainage line and creek-line areas in other parts of the Northern Tablelands.

Community 7: *Cyperus sphaeroideus – Eleocharis gracilis – Schoenus apogon – Carex gaudichaudiana* sedgeland

Environmental relationships: Restricted to damp margins of Llangothlin Lagoon at approximately high water mark and fed by seepage from the base of the slope and from the lunette.

Emergent: *Cyperus sphaeroideus, Eleocharis gracilis, Hydrocotyle tripartita, Holcus lanatus, Hypericum japonicum, Eragrostis* sp., *Schoenus apogon, Stellaria angustifolia, Carex gaudichaudiana, Pennisetum alopecuroides, Myriophyllum lophatum, Epilobium billardierianum* subsp. *hydrophilum, Ranunculus lappaceus, Gamochaeta americana, Sacciolepis indica, Hemarthria uncinata, Hypochaeris radicata, Brachyscome radicans, Trifolium repens, Eriocaulon scariosum, Prunella vulgaris, Lachnagrostis filiformis, Crassula helmsii, Glyceria australis, Arthraxon hispidus, Gonocarpus micranthus, Leucanthemum vulgare, Leiocarpa* sp. 'Uralla' (D.M. Bell), *Eryngium* sp. 'Little Llangothlin NR' (D.M. Bell 5 6) A, *Eleocharis dietrichiana, Neopaxia australasica, Lilaeopsis polyantha, Euchiton involucratus, Spiranthes sinensis, Isotoma fluviatilis* subsp. *borealis, Eleocharis atricha, Festuca elatior, Austrostipa inaequiglumis, Amphibromus nervosus, Hydrocotyle peduncularis, Isolepis fluitans, Dichondra repens, Haloragis heterophylla, Hypoxis hygrometrica, Juncus vaginatus, Juncus articulatus, Juncus bufonius, Microtis unifolia, Phragmites australis, Solenogyne bellioides, Utricularia dichotoma*.

Floating leaved: *Potamogeton tricarinatus*.

Variability: Only at Llangothlin Lagoon margins close to granite-derived soil and the sandy lunette.

Notes: Similar to Community 6 but more species-rich (mean 25, range 21–31), similar in part to *Carex* sedgelands.

Environmental gradients and community distribution

Species richness generally decreases with depth (Fig. 4) and communities at lagoon margins are consistently richer in species than those in deeper water. Margin communities typically occupy only a small part of the basin (Figs. 5 and 6), and edge (Community 1) and deeper communities (e. g. Communities 4 and 5) are more extensive (Communities 6 and 7).

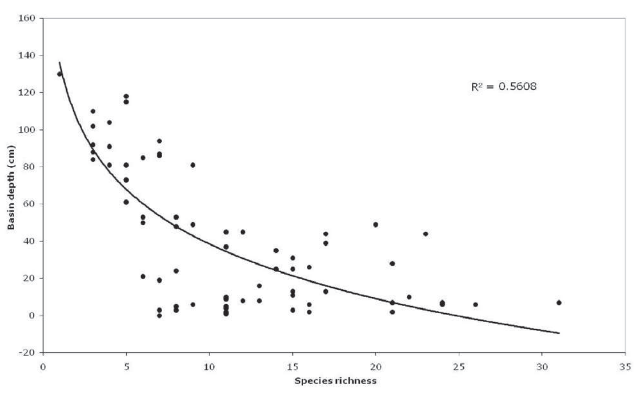


Fig. 4. Relationship between species richness and basin depth in six lagoons on the Northern Tablelands Bioregion of New South Wales.

All but a few lagoons have basaltic substrate and those that are on other bedrocks (e.g. Racecourse, Kyoma) are close to the edge of basaltic landscapes and are thought to have developed on them (Walker 1977; Haworth 1994). The influence of acid granite soils is seen particularly at the margins of Llangothlin and Little Llangothlin where soils have a high sand content (Bell 2000) and species such as *Baloskion stenocoleum* and *Eleocharis atricha*, that are more typical of acidic soils, occur.

Discussion

Distribution and extent

Lagoons are more numerous and extensive than previously described (Walker 1977; Keith 2004). Of the 58 lagoons identified all but New Country Swamp contain or potentially contain the listed Endangered Ecological Community. Many more may have been lost due to drainage or natural in-filling processes or to in-filling exacerbated by clearing and grazing (Haworth 1994; Haworth & Gale 1999). Some landholders refer to parts of their property that briefly hold water after rain – no doubt some of these areas were lagoons that have become silted up by natural processes and erosion.

Spatial and Temporal Variability

At the regional scale, under the higher rainfall conditions of this part of the region, the remaining intact lagoons south of Walcha e.g. New Country Swamp, appear to develop vegetation that is more typical of *Carex* sedgelands, especially when they have been drained. Round Swamp was a *Carex appressa* sedgeland before it was impounded and Yarrowitch has *Carex* sedgeland in and near the drains but lagoon vegetation in other parts.

Differences due to size, depth and hydrology are apparent at the wetland scale. The small, shallow Wyanbah lagoon contained only 2 communities; drained or shallow lagoons often contain a species-poor version of Community 1. Larger and deeper intact lagoons feature more habitat diversity and several floristically distinct communities or zones may co-exist in the same wetland (Fig. 5).

The majority of lagoons (including all drained and shallow lagoons) are temporary, and hold water for only short periods each year or only in wet years. Only two the largest could be termed semi-permanent (Little Llangothlin, Llangothlin) and even these have been known to dry completely in severe droughts. The transect survey thus represents the vegetation of these sites at one point in time. Lagoon vegetation is highly dynamic, both within a growing season (Bell 1991), and over a number of years in response to changes in water depth and to water level history (Bell 2000). A drought may see that part of Llangothlin Lagoon, which in 1998 supported the *Utricularia australis – Nitella sonderi* community, covered with terrestrial plants such as *Conyza bonariensis* and *Persicaria* sp. Even where the species mix is the same, for example, in the edge Community 1, under some conditions, different species such as *Myriophyllum variifolium* (wetter) or *Hydrocotyle tripartita* (drier) may dominate. Many of the species respond to deeper water by altering growth-forms (Brock & Casanova 1997), but survive in dry sediments by means of seeds, tubers (*Potamogeton tricarinatus*) or dormant winter buds (*Utricularia australis*, *Aldrovanda vesiculosa*).

Because of temporal and within wetland variation, vegetation description in these, as in other dynamic systems, is problematic (Bell 2000). Although vegetation at the regional or whole wetland scale is appropriate for large-scale mapping (Benson & Jacobs 1994; Benson & Ashby 2000), broad descriptions ignore, of necessity, a wealth of detail that occurs at finer grains. Species richness, for example, varies strongly with depth (Figs 4 and 5). Thus though full wetland presence/abundance lists imply that all species co-exist, our study suggests that this is not always the case. At finer grains, differences among within-lagoon communities emerge that may be more important to the functioning of these systems than differences between lagoons.

Associations with other vegetation types

Seepage as a source of moisture is a feature of the lagoons whose catchments include basalt slopes or lunettes; the moisture in these areas is probably not static, but drains slowly through the soil, rather than ponding. Of the other two major wetland types in the Bioregion, the vegetation of these seepage areas (Communities 6 and 7) shares many species with the nutrient-rich *Carex* sedgelands, but few species (*Gonocarpus micranthus*, *Baloskion stenocoleum*) with the nutrient-poor and acidic bogs (Hunter & Bell 2007), and then only where granitic soils occur on margins. Under wet conditions, lagoons share few species with terrestrial communities, but opportunistic or weedy species, both native (*Asperula conferta*) and exotic (*Cirsium vulgare*) colonise damp mud during dry times.

Reservation and conservation issues

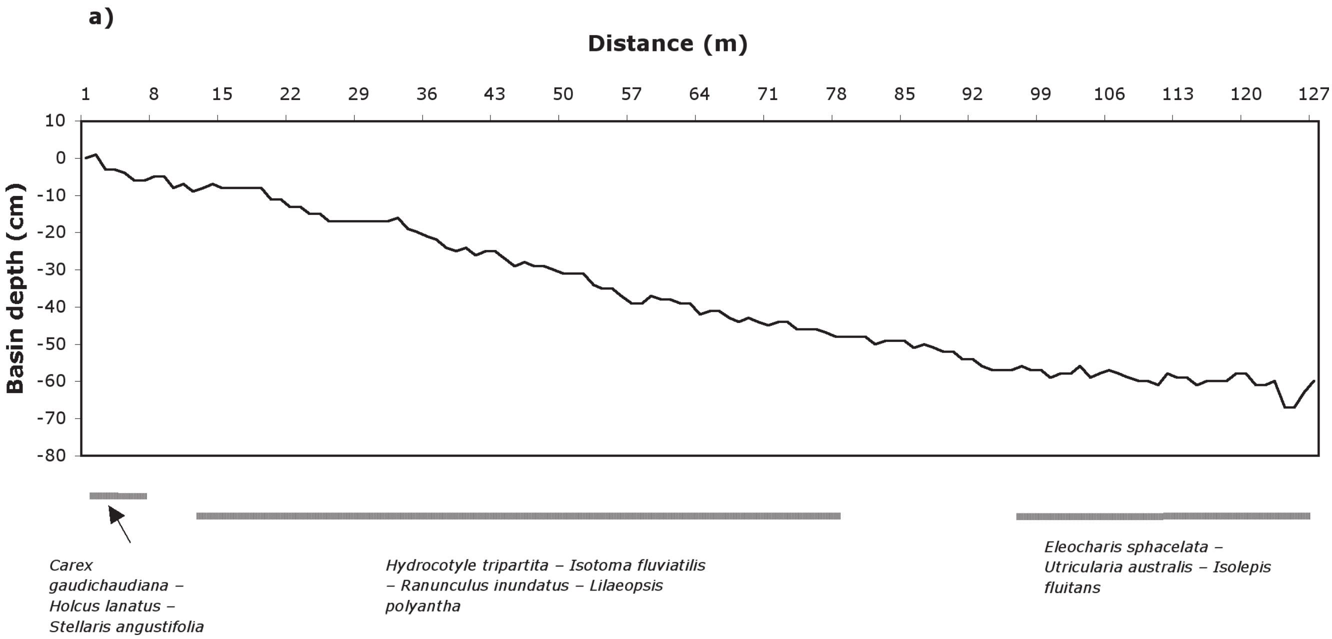
Lagoons on private property (85 %) are potentially vulnerable to damaging landuse activities; these usually involve some sort of hydrological disturbance. Since 1994 one site has been impounded, and dams excavated into the basins of two other sites. Impoundment has the potential to create a permanent reservoir and to literally ’drown’ all within-basin vegetation. An example of the vulnerability of these wetlands, and of landholder interactions is illustrated by recent events at Pinch Lagoon. Although the outlet of Pinch Lagoon has been lowered, there are drainage ditches along the lagoons margins, and sufficient water remains in the basin to support extensive wetland vegetation. The principal landholders value the fodder provided (mostly *Glyceria australis* with some *Eleocharis sphacelata*), and cattle frequently graze in deep water. The wetland drains into another property; where the owner partially filled in the drain, raising water levels in the lagoon, risking a reduction in *Glyceria* cover and reducing the value of the vegetation as fodder (*pers. com.*, Madge Sole, October 2006).

Although most lagoons are grazed, moderate grazing does not appear to have a deleterious affect on vegetation, except in those situations (Strahles, Blair Hill) where trampling in deep mud or peat in shallow basins destroys vegetation.

A low abundance of ‘true’ aquatic species such as submerged, floating and floating-leaved species is a feature of most lagoon communities. These species are most at risk from changing hydrology as few of them can survive prolonged absence of a water column, although the floating-leaved *Nymphoides montana* and *Potamogeton tricarinatus* can survive on damp mud for some time. Thus the communities most at risk of changes to hydrology are the deeper water Communities 2 to 5. Some species (*Eleocharis sphacelata*) persist in drained lagoons but seed production on dry soil is poor to absent. Other species may disappear altogether with a resulting reduction in the invertebrate and other faunal species that depend on that particular mixture of exposed water column and plant architecture.

Small lagoons and drained lagoons tell us what these wetlands could be like under severe hydrological changes. With a reduction in the duration of the inundation period, the small wetlands become an expanded edge community (Community 1). Where larger wetlands have been drained (Pinch, Saumerez Ponds), the distribution of edge species appears to have expanded to cover the whole wetland. However these shallow wetlands, as well as being the most abundant in the Bioregion, are valuable remnant systems as the species in them are usually strictly wetland species, and, as we have shown (Fig. 4), lagoon edges are more species-rich than other communities.

As with montane bogs (Hunter & Bell 2007), lagoons are at their northern limits in the New England Tablelands Bioregion and are thus susceptible to long-term changes in climate. Suggested impacts of climate change here are higher temperatures and increased rainfall seasonality (Hennessy et al. 2004). Dry periods are likely to be prolonged, and evapotranspiration will increase due to higher overall temperatures. Some lagoon species may disappear, to be replaced by more opportunistic species; the communities that require deeper sheltered water may be lost despite a store of viable diaspores in the sediments. The floating-leaved *Nymphoides montana* may be replaced by *Nymphoides geminata*, a plant of temporary wetlands (as has happened in part of Wyanbah Lagoon). The extensive (approx. 400 ha) *Eleocharis sphacelata – Potamogeton tricarinatus*



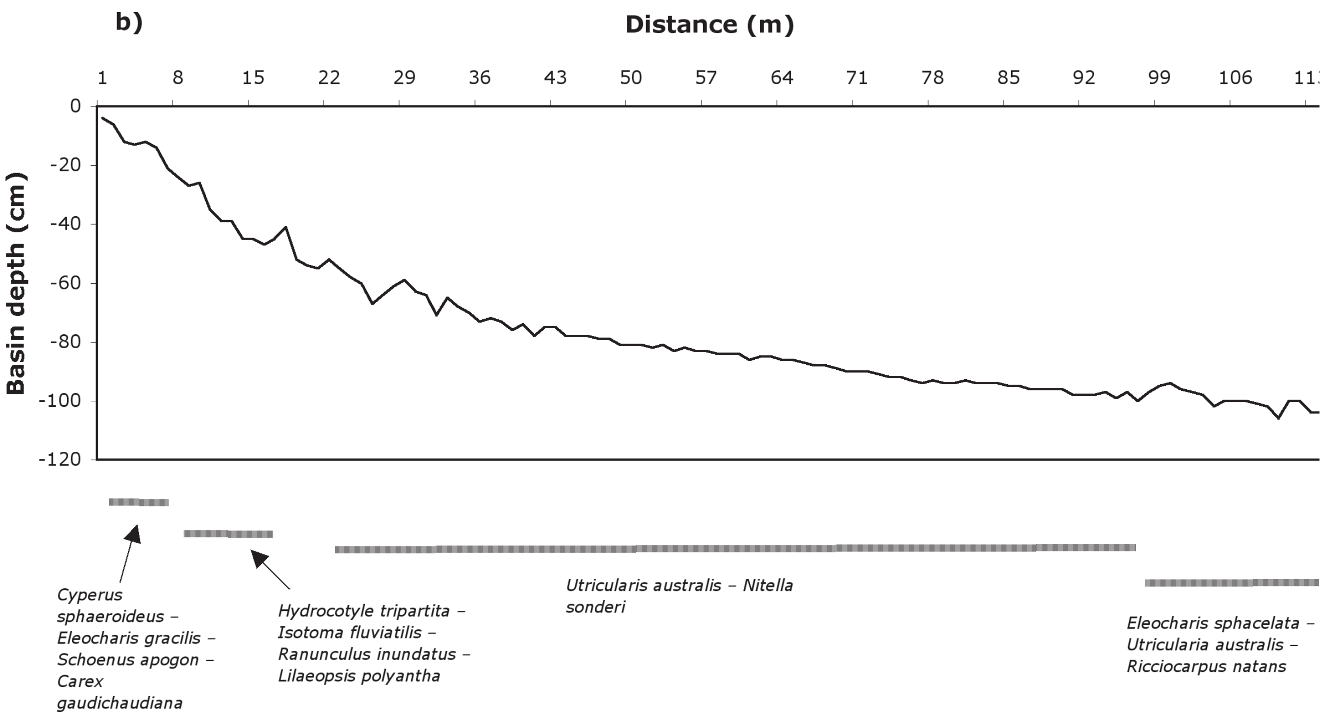


Fig. 5. Distribution of communities in two lagoons a) transect 3, Billybung, b) transect 4, Llangothlin (south end).

community of Llangothlin Lagoon could become more like the hybrid edge/deep community of Wyanbah and Saumerez Ponds with the loss of many plant and fauna species. Although seedbanks in these wetlands are long-lived (Brock 1997; Bell 2004), the potential impacts of prolonged dry periods on oospores, seeds and other propagules require investigation.

Management: retaining intermittence and semi-permanence

On geological time scales wetlands are temporary features of the landscape and have probably been slowly filling with sediment since the cessation of the active basin deflation period. Thus we need to be realistic about potential changes to these systems, particularly as we have no records of the sort of communities these basins supported before the beginning of sheep grazing in the Tablelands in the 1850s (Haworth 1994). We can, however, predict with some certainty what the present wetlands will become if drainage continues.

At shorter time scales, what is certain is that in these systems the diversity of habitat and species depends on the diversity of wetting and drying cycles (Brock et al. 1999). Restoring lagoon outlets to their original levels (Little Llangothlin Lagoon) should, in time, restore habitat diversity. The ditch and levee system, created in part of a large degraded lagoon basin to maintain bird habitat (Mother of Ducks Lagoon), is in fact, an artificial wetland, and may not be as successful. Although the original basin floor supported the weedy species *Juncus articulatus*, flooding that part of the basin within the levee did not appear to reduce the abundance of that species (Smith & Brock 1996). The reserve is now undergoing invasion by the native but weedy *Carex fascicularis*.

In 1998 a few plants of the exotic weedy species *Ranunculus sceleratus* appeared at the edge of Dangars Lagoon. By 2006, the population there was substantial, and scattered plants have appeared at Racecourse and Little Llangothlin Lagoons. This species, a coloniser of bare mud and dispersed by waterbirds, and is of particular concern to those wetlands where expanses of bar mud are common.

Rare or restricted plant species

There are 22 taxa of conservation significance in these wetlands. *Aldovandra vesiculosa* is currently listed as Endangered and *Arthaxon hispidus* as Vulnerable under the NSW *Threatened Species Conservation Act 1995*. Three taxa have been reported under the RoTAP criteria (Briggs & Leigh 1996): *Asperula charophyton* (3RCa), *Brasenia schreberi* (3RC-) and *Goodenia macbarronii* (3VC).

Three additional taxa are of significance:

Plantago sp. nov. The edge of Billybung Lagoon contains one of the only two known populations of *Plantago* sp. nov. (*pers. com.* Lachlan Copeland).

Eryngium sp. 'Little Llangothlin NR' (D.M. Bell 5 6), also known from the ACT, this species occurs within the Bioregion almost exclusively as small scattered populations on the margins or edges of lagoons (Billybung, Llangothlin, Edenglen, Thomas and South Head) with the biggest population at Billybung Lagoon.

Both the *Plantago* sp. nov. and *Eryngium* 'Uralla' (D.M. Bell NR 54142) display heterophylly; terrestrial forms have divided leaves, underwater forms undivided.

Leiocarpa sp. 'Northern Tablelands', although fairly common and widespread, also occurs almost exclusively on the margins of lagoons.

A further 14 species are considered as significant due to their being considered regionally uncommon, from depleted habitat or at or near their northern distributional limit (Sheringham & Westaway 1998). These taxa are: *Carex chlorantha*, *Carex tereticaulis*, *Crassula helmsii*, *Elatine gratioloides*, *Eleocharis atricha*, *Glossostigma diandrum*, *Isolepis fluitans*, *Isotoma fluviatilis* subsp. *borealis*, *Lemna trisulca*, *Lipocarpha microcephala*, *Myriophyllum simulans* (not seen in this survey), *Veronica serpyllifolia*, *Lilaeopsis polyantha* and *Juncus filicaulis*. Many of these species, e.g. *Lilaeopsis polyantha, Isotoma fluviatilis* subsp. *borealis* and *Isolepis fluitans,* are abundant and widespread in lagoons; it is the particular system that is rare in the landscape, so these species are generally not encountered in general surveys.

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Appendix 1: Floristic composition of lagoons of the New England Tablelands Bioregion.

Taxa found within the survey sites are scored according to their presence in each of the seven communities defined. Other taxa were found in previous surveys (Bell 2000) or opportunistically (Op) and therefore are not assigned to a specific community.
1 = *Hydrocotyle tripartita – Isotoma fluviatilis – Ranunculus inundatus – Lilaeopsis polyantha* herbfield
2 = *Eleocharis sphacelata – Potamogeton tricarinatus* sedgeland
3 = *Eleocharis sphacelata – Utricularia australis – Isolepis fluitans* herbfield
4 = *Utricularia australis – Nitella sonderi* herbfield
5 = *Eleocharis sphacelata – Utricularia australis –Ricciocarpus natans* sedgeland
6 = *Carex gaudichaudiana – Holcus lanatus – Stellaria angustifolia* sedgeland
7 = *Cyperus sphaeroideus – Eleocharis gracilis – Schoenus apogon – Carex gaudichaudiana* sedgeland

* = introduced in origin. Casanova (1993) was used for non-vascular species and charophyte nomenclature was verified by Michelle Casanova (*pers. com.*) Species life history types include: E: emergent; F: free-floating; FS: free-floating submerged, FL: floating-leaved; S: submerged; T: terrestrial.

Species	**Type**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Op**
Alismataceae									
Damasonium minus	FL								O
Amaranthaceae									
Alternanthera denticulata	E								O
Apiaceae									
Centella asiatica	E								O
**Daucus carota*	T								O
Eryngium sp. 'Little Llangothlin NR'	E							7	
Hydrocotyle peduncularis	E						6		
Hydrocotyle tripartita	E	1		3			6	7	
Lilaeopsis polyantha	E	1						7	
Asteraceae									
Ammobium alatum	T								O
**Aster subulatus*	E								O
Brachyscome graminea	E								O
Brachyscome radicans	E	1		3			6	7	
Calotis scapigera	E								O
Centipeda minima	E	1							
**Conyza parva*	E								O
**Conyza bonariensis*	E								O
**Cotula coronopifolia*	E								O
**Crepis capillaris*	E								O
Euchiton involucratus	E	1					6		
**Gamochaeta americana*	E	1					6	7	
*Hypochaeris glabra	E								O
**Hypochaeris radicata*	E						6	7	
**Lactuca serriola*	E								O
Leiocarpa sp. 'Uralla'	E						6		
**Leucanthemum vulgare*	E						6	7	
Pseudognaphalium luteoalbum	E								O
Solenogyne bellioides	E						6		
**Sonchus asper* subsp. *glaucescens*	E								O
**Taraxacum officinale*	E								O
**Tolpis umbellata*	T								O
**Tragopogon dubius*	T								O
**Xanthium spinosum*	T								O
Azollaceae									
Azolla filiculoides var *rubra*	F								O
Brassicaceae									
**Rorippa palustris*	E	1							
Cabombaceae		1							
Brasenia schreberi	FL	1							
Campanulaceae									
Wahlenbergia communis	T								O

Caryophyllaceae									
**Paronychia brasiliana*	E								O
Scleranthus biflorus	T								O
Stellaria angustifolia	E	1					6	7	
Characeae									
Chara corallina	S								O
Chara fibrosa	S								O
Chara muelleri	S				4				
Nitella cristata	S				4				
Nitella sonderi	S				4				
Nitella tasmanica	S								O
Clusiaceae									
Hypericum gramineum	T						6		
Hypericum japonicum	E	1					6	7	
Convolvulaceae									
Dichondra repens	E						6		O
Crassulaceae									
Crassula helmsii	E	1						7	
Cyperaceae		1						7	
Bolboschoenus fluviatilis	E								O
Carex appressa	E								O
Carex fascicularis	E								O
Carex gaudichaudiana	E	1					6	7	
Carex inversa	E						6		
Carex tereticaulis	E								O
Carex sp. 'Bendemeer' (D.M. Bell 296 & J.T. Hunter)									O
**Cyperus eragrostis*	E								O
Cyperus flaccidus	E								O
Cyperus flavidus	E								O
Cyperus gunnii subsp. *gunnii*	E								O
Cyperus sanguinolentus	E	1						7	
Cyperus sphaeroideus	E						6	7	
Eleocharis acuta	E	1					6		
Eleocharis atricha	E						6	7	
Eleocharis dietrichiana	E	1	2				6	7	
Eleocharis gracilis	E						6	7	
Eleocharis pusilla	E	1			4		6		
Eleocharis sphacelata	E	1	2	3		5			
Fimbristylis dichotoma	E								O
Isolepis cernua	E								O
Isolepis fluitans	E	1		3	4		6	7	
Isolepis habra	E								O
Isolepis hookeriana	E								O
Lipocarpha microcephala	E						6		
Schoenus apogon	E	1					6	7	
Droseraceae									
Aldrovandra vesiculosa	FS	1							
Drosera burmannii	E								O
Drosera peltata	E								O
Elatinaceae		1							2
Elatine gratioloides	E	1							
Eriocaulaceae									
Eriocaulon scariosum	E							7	
Fabaceae									
**Trifolium arvense*	T								O
**Trifolium repens*	E	1					6	7	
Gentianaceae									
**Centaurium tenuiflorum*	T								O
Geraniaceae									
Geranium solanderi var. *solanderi*	E								O
Goodeniaceae									
Goodenia macbarronii	E								O

Haloragaceae									
Gonocarpus micranthus	E						6		O
Haloragis heterophylla	E						6		O
Myriophyllum lophatum	E	1					6	7	
Myriophyllum variifolium	E	1	2	3	4	5	6		
Myriophyllum verrucosum	E								O
Hypoxidaceae									
Hypoxis hygrometrica	E							7	
Iridaceae									
**Sisyrinchium iridifolium*	E								O
**Sisyrinchium* sp. A	E								O
Isoetaceae									
Isoetes drummondii subsp. *anomala*	S								O
Juncaceae									
**Juncus articulatus*	E	1					6		O
Juncus australis	E	1						7	
Juncus bufonius	E	1						7	
Juncus filicaulis	E								O
Juncus fockei	E	1					6		
Juncus homalocaulis	E								O
Juncus subsecundus	E								O
Juncus usitatus	E								O
Juncus vaginatus	E								O
Lamiaceae									
**Prunella vulgaris*	E						6	7	
Lemnaceae									
Lemna trisulca	FS				4	5			
Spirodela punctata	F	1							
Wolffia australiana	E								O
Lentibulariaceae									
Utricularia australis	S	1		3	4	5			
Utricularia dichotoma	E	1						7	
Lobeliaceae									
Isotoma fluviatilis subsp. *borealis*	E	1		3			6	7	
Lythraceae									
Lythrum hyssopifolia	E								O
Malvaceae									
**Malva neglecta*	T								O
**Modiola caroliniana*	T								O
Marsileaceae									
Marsilea costulifera	FL								O
Marsilea hirsuta	FL								O
Menyanthaceae									
Nymphoides geminata	FL	1	2						
Nymphoides montana	FL	1	2	3					
Najadaceae									
Najas tenuifolia	S				4				
Onagraceae									
Epilobium billardierianum subsp. *cinereum*	E								O
Epilobium billardierianum subsp. *hydrophilum*	E	1					6	7	
Orchidaceae									
Microtis unifolia	E							7	O
Spiranthes sinensis subsp. *australis*	E						6	7	
Plantaginaceae									
**Plantago lanceolata*	T								O
Plantago sp. A	E								O
Poaceae									
Austrostipa inaequiglumis	E							7	
Amphibromus nervosus	E	1					6		
Amphibromus sinuatus	E	1		3					
**Anthoxanthum odoratum*	E						6		
**Briza minor*	T								O
Chloris truncata	T								O
Cynodon dactylon	E								O

Deyeuxia quadriseta	E								O
**Eleusine tristachya*	E								O
Eragrostis sp.	E							7	
**Festuca elatior*	E						6		
Glyceria australis	E	1	2	3			6	7	
Hemarthria uncinata	E	1					6	7	
**Holcus lanatus*	E	1					6	7	
Lachnagrostis filiformis	E	1					6	7	
**Lolium perenne*	T								O
Arthraxon hispidus	E							7	
**Panicum gilvum*	E								O
Panicum obseptum	E	1	2						
**Paspalum dilatatum*	E						6	7	
Paspalum distichum	E	1			4				
Pennisetum alopecuroides	E	1					6	7	
Phragmites australis	E							7	
Poa sieberiana	T								O
Sacciolepis indica	E							7	
Sporobolus creber	T								O
Sporobolus elongatus	T								O
**Vulpia bromoides*	T								O
Polygonaceae									
**Acetosella vulgaris*	E								O
Persicaria hydropiper	E	1							
Persicaria lapathifolia	E								O
Persicaria orientalis	E								O
Persicaria prostrata	E								O
**Polygonum arenastrum*	E								O
Rumex brownii	E								O
**Rumex crispus*	E	1							
Portulacaceae									
Neopaxia australasica	E						6		
Potamogetonaceae									
Potamogeton crispus	S				4				
Potamogeton ochreatus	S								O
Potamogeton tricarinatus	FL	1	2	3	4			7	
Ranunculaceae									
Ranunculus inundatus	E	1		3					
Ranunculus lappaceus	E						6		
Ranunculus pimpinellifolius								7	
**Ranunculus sceleratus*	E								O
Ranunculus sp. aff. *lappaceus* (D.M. Bell NE 54120)									O
Restionaceae									
Baloskion stenocoleum	E								O
Ricciaceae									
Ricciocarpus natans									
Rubiaceae									
Asperula charophyton	E	1					6		
Asperula conferta	E								O
Scrophulariaceae		1					6		O
Glossostigma diandrum	E								O
Gratiola peruviana	E								O
Limosella australis	E	1							
**Linaria pelisseriana*	E								O
Mimulus gracilis	E								O
**Veronica anagallis-aquatica*	E								O
Veronica serpyllifolia	E								O
Typhaceae									
Typha domingensis	E								O
Verbenaceae									
**Verbena bonariensis*	E								O
Violaceae									
Viola betonicifolia	E						6		