

A REVIEW OF CATTLE GRAZING EFFECTS ON LAKE MARGIN VEGETATION WITH OBSERVATIONS FROM DUNE LAKES IN NORTHLAND, NEW ZEALAND

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ABSTRACT

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Lake margin vegetation has become increasingly valued as a habitat for wildlife and as a moderator of sediment and nutrient inputs from surrounding catchments. This has encouraged action to exclude livestock from lake shorelines. Cattle grazing effects are reviewed in relation to natural grazing of lake margin vegetation. Direct consumption and trampling of plant biomass by livestock affects the structure, diversity, productivity, succession and nutrient dynamics of plant communities. In addition, livestock grazing may affect lake marginal vegetation and water quality by pugging and erosion of lakeshores, nutrient addition, bacterial contamination and promotion of weed invasion. Agricultural modification of surrounding catchments also causes many indirect effects such as increased nutrient runoff and changed hydrological regimes. However, low levels of grazing can result in beneficial changes in lake margin vegetation by reducing domination by tall rank species and increasing plant and habitat diversity. Observations of cattle grazing impacts on the lake margin vegetation of Northland dune lakes showed a graded range of effects dependant largely on grazing pressure. Ungrazed, agriculturally undeveloped shorelines were characterised by *Leptospermum scoparium* growing to the wetted margin, grading into an inshore zone of mixed sedges (*Baumea juncea*, *B. huttonii*, *Leptocarpus similis*, and *Eleocharis acuta*) to 0.3-0.8 m depth, an outer sedge zone of *Eleocharis sphacelata* to 1-2 m depth, then a sharp boundary into fully submerged communities of charophytes and *Potamogeton* spp. in deeper water. At sites subject to heavy grazing pressure inshore sedge communities were absent, leaving only a remnant outer zone of emergent *E. sphacelata* in water too deep to graze. Sites with light to moderate grazing pressure were associated with more open inshore sedge zones showing an increased diversity and abundance of short shallow-water species including *Myriophyllum*, *Potamogeton*, *Lilaeopsis*, *Juncus* and *Triglochin* spp., and in some areas the endangered species *Hydatella inconspicua*. It is concluded that although heavy grazing of lakeshores is clearly detrimental to marginal vegetation, low levels of grazing may be an appropriate management tool in areas of some lakes to promote more diverse inshore habitats for plants and wildlife.

KEYWORDS: Grazing effects - aquatic plants - native vegetation - endangered plants - *Hydatella inconspicua* - lake management - wildlife management - dune lakes.

INTRODUCTION

Farmed livestock have access to the shores of many New Zealand lakes. Increasingly, exclusion of stock from lakeshores and associated wetlands is being promoted as a desirable management action (eg. ARA 1983, Moore *et al.*, 1984, Davis

1985, Williamson & Hoare 1987, Buxton 1991). This is based largely on the importance of the vegetated margins of waterbodies as wildlife habitat and as moderators of nutrient and sediment transport from surrounding catchments.

The impacts of heavy grazing by cattle are often readily apparent along the shores of grossly

affected waterbodies and are commonly noted in descriptive wetland surveys (eg. Moore *et al.*, 1984, Glenny *et al.*, 1987, de Winton *et al.*, 1992). However, there have been few studies which document the effects of grazing on the marginal vegetation of lakes in New Zealand. Apart from studies by Keith (1961), Hoffman & Stanley (1978) and Whyte & Cain (1981) on North American lake and pond shores, most of the relevant studies published overseas relate primarily to grazing effects on stream banks and salt marshes. In New Zealand, Smale (1985) has discussed the conservation of wetlands in agricultural landscapes, and Maturin (1985) and Hicks & Howard-Williams (1990) have reviewed the need for and factors affecting grazing management of stream riparian strips. Williamson *et al.* (1990) have investigated the effects of riparian protection on the channel characteristics of grazed streams in Southland. Recently, Buxton (1991) has compiled a guide to the creation and management of wetlands in New Zealand. The present paper initially reviews the effects of natural and cattle grazing of lake margin vegetation, then presents observations on the effects of cattle grazing on dune lakes in the far north of New Zealand.

Moves to exclude or control stock access into riparian and marginal zones have occurred in other areas of the world, particularly along streams where grazing may significantly affect bank erosion, bed morphology and flow patterns (eg. White & Brynildson 1967, Kirsch 1969, Beeftink 1977, Platts & Wagstaff 1984, Platts & Rinne 1985, Armour *et al.*, 1991). Alternatively, in some areas controlled grazing has become regarded as an important management tool for the maintenance of desirable wildlife habitat (Bakker 1985, 1989, Looijen & Bakker 1987, Pehrsson 1988, Dijkema 1990, Burgess *et al.*, 1990, Andresen *et al.*, 1990). In these areas increased growth and litter accumulation leading to domination by tall rank species, with consequent reduction in species diversity, has commonly been observed after cessation of grazing. However, land-water ecotones in many of these areas have been subject to natural or agricultural grazing for centuries, whilst New Zealand's native vegetation has evolved in the absence both of small herbivorous aquatic mammals such as muskrats, beavers and nutrias, and until recent times of large ungulate grazers. Since

European colonisation of New Zealand, large numbers of introduced plant species have become naturalised in aquatic habitats (Howard-Williams *et al.*, 1987); most of which have evolved in the presence of mammalian grazing.

EFFECTS OF NATURAL GRAZING

In prehuman and early Maori times in the absence of mammalian grazers, now extinct birds such as the coastal and Mappin's moas (Atkinson & Greenwood 1989, Worthy 1990) and the native New Zealand goose and swan (Falla 1975), along with native wildfowl present today (particularly pukeko, paradise shelduck, grey duck, grey teal and coot) are likely to have grazed lake margin vegetation. In more recent times aquatic vegetation has been grazed both by native water fowl, and by naturalised species such as black swan, mallard and Canada goose (Falla 1975, Bisset 1976, Potts 1977, Williams 1981, Fordham 1983, Moore *et al.*, 1984).

Little is known of the effects of these species on lake-margin vegetation. Their grazing is likely to be more selective than that of ruminant mammals because their digestive systems are less able to cope with hard, cellulose-rich herbage (Wardle 1989). Significant grazing impacts on submerged plant biomass have been recorded by Jupp & Spence (1977), Kiorboe (1980) and Carter & Rybicki (1985); and black swan browsing commonly restricts *Egeria densa* and *Lagarosiphon major* growth to depths below 1 m in North Island lakes (Clayton in press, Howard-Williams & Davies 1988). High densities of visiting migratory birds such as snow geese have been found to effect primary production of emergent *Spartina* and *Scirpus* marshes in North America (Smith & Odum 1981, Giroux & Bedard 1987), but little is known of the effects of lower density resident populations. New Zealand water fowl are known to feed on the foliage of succulent herbaceous emergent species such as *Juncus articulatus* and *Rumex* spp., and on the young shoots of rushes, sedges and *Typha orientalis*. They also feed on a wide range of shallow-water submerged plants particularly *Potamogeton* spp., and on floating *Lemna* and *Spirodella*. The seeds and fruit of these species and those of *Polygonum*, *Alisma*, *Triglochin* and *Ottelia* are commonly consumed;

this being a major mechanism for their dispersal (see de Vlaming & Proctor 1968). Grazing impacts by native and naturalised phytophagous fish (eg. grey mullet and rudd respectively) are likely to be largely limited to submerged plant species; although adventive species with presently limited distributions (eg. grass carp) have the potential to graze lake margin vegetation (see Mitchell 1980). Herbivory by rodents may also be important particularly in the pre and post dispersal phases of seeds (Crawley 1983, Verkaar 1987). Lodge (1991) provides a thorough review of the importance of herbivory by aquatic organisms (particularly invertebrates) on aquatic macrophytes.

EFFECTS OF CATTLE GRAZING

Livestock usage of lake margins may be disproportionately high, particularly in seasonally hot dry climates, because they provide access to drinking water, a source of succulent vegetation, and a desirable microclimate (eg. evaporative cooling, shade, wallowing).

Cattle may directly affect marginal vegetation (see Ellison 1960, Reinold *et al.*, 1975, Meehan & Platts 1978, Holechek 1981, Crawley 1983, Kauffman & Krueger 1984, Platts & Raleigh 1984, Skovlin 1984, Belsky 1986) by:

1. Consumption of plant biomass, including selective grazing of palatable and accessible plant tissues and species, and defoliation (affecting production, reproduction, carbohydrate storage and litter accumulation).
2. Trampling of plants, including damage to underground rhizomes.
3. Pugging, compaction, erosion, and resuspension of lakeshore substrates.
4. Nutrient addition and bacterial contamination from dung and urine.
5. Creation of plant invasion microsites.
6. Introduction and dispersal of seeds and other plant propagules.

Modification of the surrounding catchment to a grazed pastoral landscape may also cause many indirect effects, particularly increased runoff of water, sediments and nutrients due to factors such as removal of protective forest and scrub cover and the application of fertilisers and pesticides (McColl & Hughes 1981).

Together these effects are likely to cause

changes in the abundance, productivity, structure, diversity and successional and nutrient cycling processes of lake margin plant communities, ultimately affecting:

1. The type and quality of habitat they provide for wildlife, eg. food sources, cover, shelter and shade for both birds and fish.
2. Their ability to store and process nutrient and sediment inputs from the surrounding catchments.
3. Their aesthetic qualities.

MEDIATING FACTORS

The effects of livestock grazing on lake margin vegetation are likely to be mediated by:

A. Agricultural factors:

1. The stock type and age; cattle, sheep, goats, deer and horses all exert different grazing and trampling effects.
2. The stocking regime, *ie.* the density, intensity and seasonal pattern of grazing pressure, the length and frequency of any spelling periods.
3. The presence of alternative water and food sources.

B. Environmental factors:

1. The lakeshore morphometry - its gradient and shape.
2. The exposure of shorelines to wind and waves.
3. The type of shoreline substrates - their texture and fertility.
4. The extent and periodicity of water level fluctuations.
5. Biogeography - *ie.* the plants, both indigenous and introduced, available to colonise the area and their colonisation potential, growth form, palatability, and tolerance of grazing.

These environmental factors act together to determine the morphology of the lakeshore formed, and the zonation patterns of the vegetation (Spence 1982, Keddy 1982, 1983, Weisner 1987, Coops *et al.*, 1991). They may also affect the palatability, accessibility and resistance of lakeshore vegetation to grazing influences. For example, periods of low water level may allow cattle access to vegetation which would be normally unavailable to them; coarse sandy sediments are less prone to pugging and resuspension than soft

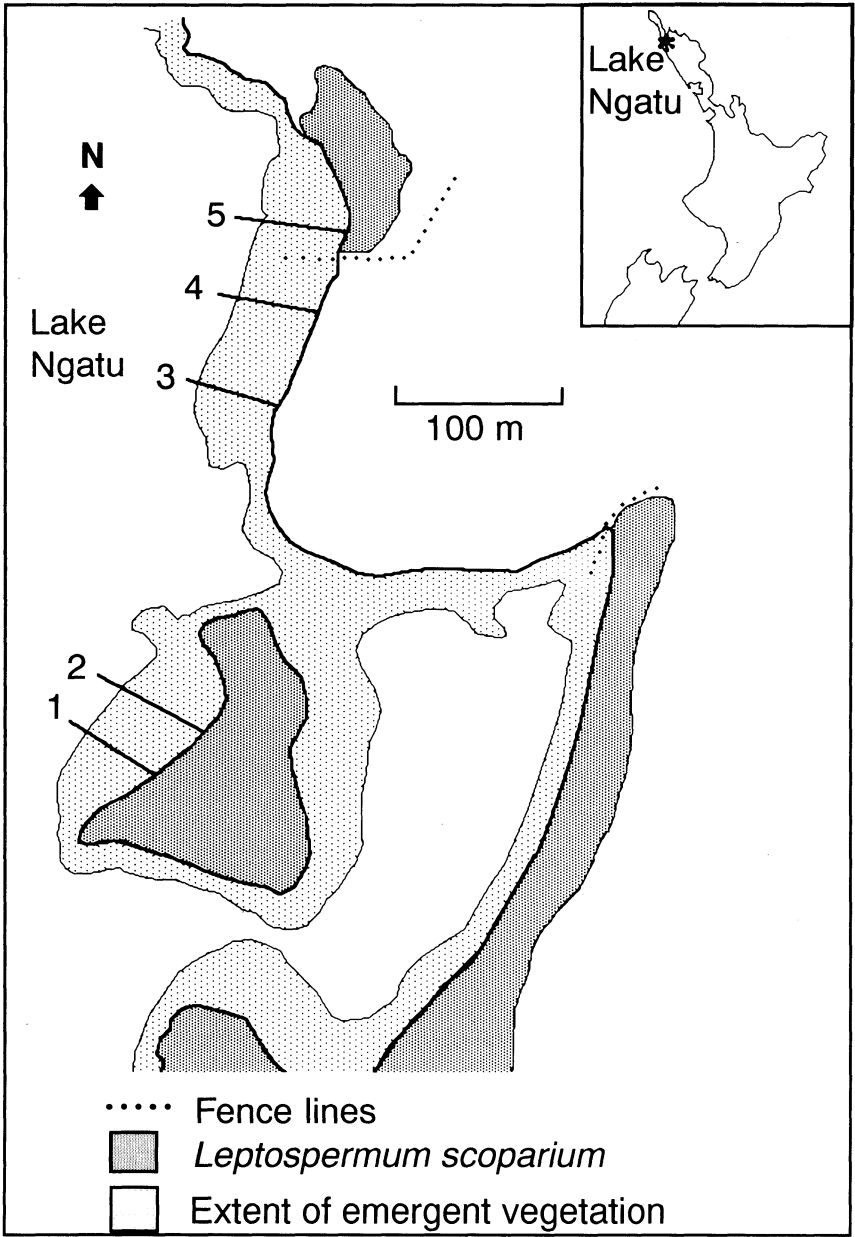


Figure 1: Map showing position of sample sites along the north-eastern shore of Lake Ngatu. Inset shows location of Lake Ngatu near Kaitiaki in the far north of New Zealand.

organic shores; and substrate fertility may affect both the palatability of the vegetation and its rate of regrowth after grazing impacts.

OBSERVATIONS FROM NORTHLAND DUNE LAKES

Numerous small dune lakes (most <1 km² in area) occur in fossil dune depressions along the western coast of Northland. Few have surface

inlets or outlets, being fed predominantly by groundwater inflows. The origins, general features and limnology of these lakes is discussed by Cunningham *et al.* (1953) and Cunningham (1957).

METHODS

General observations of cattle grazing effects were made in association with SCUBA surveys of

aquatic vegetation in 34 Northland dune lakes. Methodology and floristic details are summarised in Tanner *et al.*, 1986, 1988, and Wells *et al.*, 1988. Further detailed observations were made in December 1989 of grazed and ungrazed sections of Lake Ngatu, a 61 ha lake c. 10 km north of Kaitiāia, using a modification of the transect survey method described by Clayton (1983). Plant specimens have been deposited in the University of Waikato herbarium. Fig. 1 shows the placement of transect lines along the eastern shore of the lake. Ungrazed shorelines occurred on the island (sites 1 and 2) and within the recreational reserve protected by fences (site 5). The shore between these areas was grazed by cattle (sites 3 and 4). Water level records for the lake (Northland Catchment Commission pers. comm.) show a gradual rise of c. 1 m had occurred since early 1987. This had caused inundation of *Leptospermum* and pasture around the lake margins at the time of survey.

RESULTS

LAKE NGATU

The plant species recorded in grazed and ungrazed sites, their depth range, maximum and average covers are summarised in Table 1.

Along the ungrazed sections of the shore of Lake Ngatu (Fig. 2) *Leptospermum scoparium* intergraded into a mixed inner sedge zone of *Leptocarpus similis*, *Baumea juncea*, *B. huttonii* and occasionally *B. articulata*; with an outer zone of *Eleocharis sphacelata*. An understory of charophytes (*Chara fibrosa*, *C. corallina*, *Nitella pseudoflabellata*, and *N. leptostachys*) and the insectivorous bladderwort *Utricularia australis* occurred amongst the tall sedges.

The grazed sections of shore (Fig. 3) retained similar depth ranges and covers for the outer *Eleocharis sphacelata* zone, but with pasture to the waters edge and a relatively open inshore zone. The vegetation of this inshore zone included grazed sedge remnants and a modified assemblage of short-stature shallow-water submerged plants including *Juncus articulatus*, *J. bulbosus*, *Triglochin striata*, *Lilaeopsis novae-zelandiae*, *Myriophyllum propinquum*, *Potamogeton cheesemani*, *Schoenus maschalinus*, and in some areas *Hydatella inconspicua*; but the abundance of *U. australis* was reduced markedly. Nine species of

submerged plants were recorded in shallow water in each of the grazed compared to 3-4 in the ungrazed sites. It is likely that these additional species were excluded from many of the ungrazed sites by shading and the dense accumulation of litter noted beneath the taller sedge communities. The five adventive shallow water species noted (Table 1) were recorded only at the grazed sites.

GENERAL OBSERVATIONS

A range of impacts on marginal vegetation were observed in the dune lakes studied.

a) Ungrazed shores:

Characteristically the main structural vegetation of the lightly to moderately exposed, ungrazed shores of Northland dune lakes consisted of *Leptospermum scoparium* growing to the wetted margin (when this has not been cut or burnt), grading into an inshore zone of mixed sedges (predominantly *Baumea juncea*, *B. huttonii*, *Leptocarpus similis*, and *Eleocharis acuta*) to 0.3-0.8 m depth, an outer sedge zone commonly occupied by *Eleocharis sphacelata* to 1-2 m depth, then a sharp boundary into the fully submerged communities of charophytes and *Potamogeton* in deeper water.

b) Heavily grazed shores:

Heavy grazing was associated with the loss of tall-growing inshore sedge communities, leaving only the outer band of the emergent plant zone (Fig. 4). Erosion and fouling of the shoreline was often obvious above the water line. Below water level, shallow-water submerged plants such as *Glossostigma* spp., *Myriophyllum* spp., *Ruppia polycarpa*, *Juncus bulbosus* and *Ottelia ovalifolia* were often present forming variable low covers (<5%), despite numerous hoofmark depressions in the sandy substrates.

c) Lightly to moderately grazed shores:

On shorelines where grazing pressure appeared less intensive (eg. Fig. 5) remnants of the inner zone of mixed sedges were still present. The opening of the sedge canopy and reduction in litter accumulation by grazing was associated with a greater diversity of shallow-water submerged species, including the endangered species *Hydatella inconspicua* in some areas (Tanner *et al.*, 1988). Fig. 6 shows the impact of grazing

Table 1: Depth ranges, maximum and average covers (1, 1-5%; 2, 6-25%; 3, 26-50%; 4, 51-75%; 5, 76-95%; 6, 96-100%) for marginal aquatic plants (<2.5 m depth) recorded for grazed and ungrazed sites in Lake Ngatu. Depths given are those recorded at time of survey; lake level 1.96 m, Northland Regional Council.

Species	UNGRAZED								
	Profile 1			Profile 2			Profile 5		
	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.
EMERGENT¹									
² <i>Axonopus affinus</i> Chase	-	-	-	-	-	-	-	-	-
<i>Baumea articulata</i> (R. Br.) Blake	-	-	-	-	-	-	0.8-0.9	2	1
<i>B. huttoni</i> (Kirk) Blake	0.7-1.3	3	1	0.4-1.25	3	2	0.8-1	3	1
<i>B. juncea</i> (R. Br.) Palla	0.5-1.0	5	3	0.1-0.8	5	1	0-0.9	6	5
<i>Centella uniflora</i> (Col.) Nannf.	-	-	-	-	-	-	-	-	-
² <i>Cyperus tenellus</i> Linn. f.	-	-	-	-	-	-	-	-	-
<i>Eleocharis sphacelata</i> R. Br.	1-2.3	6	5	1.25-2.5	6	6	0.9-2.2	6	6
<i>Gleichenia dicarpa</i> R. Br.	0-0.3	3	1	-	-	-	-	-	-
² <i>Isolepis sepulcratis</i> Steud	-	-	-	-	-	-	-	-	-
² <i>Juncus articulatus</i> L.	-	-	-	-	-	-	-	-	-
<i>J. usitatus</i> L. Johnson	-	-	-	-	-	-	-	-	-
<i>Leptocarpus similis</i> Edgar	0-0.9	5	3	0.3-0.7	6	3	0.4 only	2	1
<i>Leptospermum scoparium</i> Forst.	0-0.7	5	4	0-0.7	5	4	0-0.4	6	5
<i>Schoenus mascalinus</i> Roemer et Schultes	-	-	-	-	-	-	-	-	-
SUBMERGED¹									
<u>Charophytes:</u>									
<i>Chara fibrosa</i> var. <i>acanthopitys</i> (A.Br.) Zanev	0.8-2.5 ³	6	3	0.6-2.5 ³	6	3	0.8-2.5 ³	6	3
<i>C. corallina</i> Kl. ex Willd, em. R.D.W.	-	-	-	-	-	-	-	-	-
<i>Nitella leptostachys</i>									
A. Br. em R.D.W.	0.8-2.5 ³	1	1	0.6-2.5 ³	1	1	0.6-2.5 ³	1	1
<i>N. pseudoflabellata</i> A. Br. em R.D.W.	-	-	-	0.7-1.25	1	1	0.8-2.5 ³	2	1
<u>Tracheophytes:</u>									
<i>Glossostigma diandrum</i> (L.) Kuntze	-	-	-	-	-	-	-	-	-
<i>Hydatella inconspicua</i> Cheeseman	-	-	-	-	-	-	-	-	-
² <i>Juncus bulbosus</i> L.	-	-	-	-	-	-	-	-	-
<i>Lilaeopsis novae-zelandiae</i> (Gand.) A.W. Hill	-	-	-	-	-	-	-	-	-
<i>Myriophyllum propinquum</i> A. Cunn.	-	-	-	-	-	-	-	-	-
<i>Potamogeton cheesemanii</i>									
A. Benn.	2.2 only	1	1	-	-	-	-	-	-
<i>Triglochin striata</i> Ruiz et Pav.	-	-	-	-	-	-	-	-	-
<i>Utricularia australis</i> R. Br.	0.7-2.3 ³	3	1	0.2-2.5 ³	4	2	0.4-2.5 ³	6	2
FREE FLOATING:									
<i>Azolla pinnata</i> R. Br.	-	-	-	-	-	-	0.3-0.5	1	1

Notes: ¹ life form categories are based on those predominant in present study; ² adventive species; ³ species continues to greater depths.

Table 1 (cont.)

GRAZED					
Profile 3			Profile 4		
Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.
0-0.1	1	1	0-0.2	1	1
-	-	-	-	-	-
1-1.1	2	1	0.4-1.0	2	1
0.9-1	2	1	-	-	-
0-0.35	1	1	-	-	-
0-0.1	2	1	0-0.2	2	1
1-2.25	6	5	0.9-2.2	6	5
-	-	-	-	-	-
0-0.1	3	2	0-0.2	1	1
0-0.3	4	2	0-0.4	4	3
0-0.4	2	1	-	-	-
0-0.85	5	3	-	-	-
-	-	-	-	-	-
0-0.35	2	1	0-0.4	3	2
0.7-2.5 ³	6	3	0.4-2.5 ³	5	3
-	-	-	0.6-1.0	2	1
0.7-2.5 ³	1	1	0.4-2.5 ³	1	1
0.7-1.0	2	1	0.4-2.5 ³	2	1
0.4 only	1	1	-	-	-
0.4-0.5	1	1	-	-	-
-	-	-	0.35-0.6	2	2
0.4-0.85	2	1	-	-	-
0.6-0.85	2	1	0.9-1	4	2
-	-	-	0.35-0.8	2	1
0.7-1	3	1	0.5-0.8	3	1
0.3 only	1	1	0.35-2.5 ³	1	1
-	-	-	-	-	-

(foreground) in comparison to an ungrazed zone behind the fence. Here low-growing shallow-water species including *Hydatella* were common in the open grazed zone but absent from the densely vegetated ungrazed zone.

DISCUSSION

Recent theories (Grime 1979, Huston 1979) and emerging evidence of vegetation dynamics (eg. Menges and Waller 1983; Day *et al.* 1988; Bakker 1989; Shipley *et al.* 1991) suggest that maximum species diversity occurs at moderate levels of environmental stress and/or disturbance. High levels of stress favour a small number of stress tolerant long-lived species while high levels of disturbance favour fast growing opportunistic ruderal species. Conversely low levels of both these factors in relatively homogeneous environments can lead to exclusion of all, but the few (or one) most competitive species. Grazing is a form of disturbance which is amenable to management. Its effect on vegetation will be dependent on its frequency, intensity and scale.

The Northland dune lakes illustrate some of the range and types of grazing effects which may occur along lake shores. They also show that although heavy grazing is detrimental to marginal plant communities, low levels of grazing may modify the structure of the vegetation and enhance its diversity. There is an increasing need for active and passive management to protect the conservation values of New Zealand's remaining natural areas, particularly in small and highly modified reserves (see Norton 1989). Wardle and Johnson (1989) have emphasised the need to carefully define the objectives of such natural vegetation management which may include: maintenance of high species diversity, protection of native communities or vulnerable species, maintenance of seral or "climax" communities, or management as wildlife habitat for specific species (eg. bitterns or white bait spawning) or for recreational pursuits such as bird-watching or hunting.

A high proportion of lake-margin emergent species have basal meristems and extensive underground storage tissues making them relatively tolerant of episodic grazing. Low levels of grazing may be beneficially managed in a number of the Northland lakes to promote open inshore habitat for endangered species such as *Hydatella incon-*

UNGRAZED

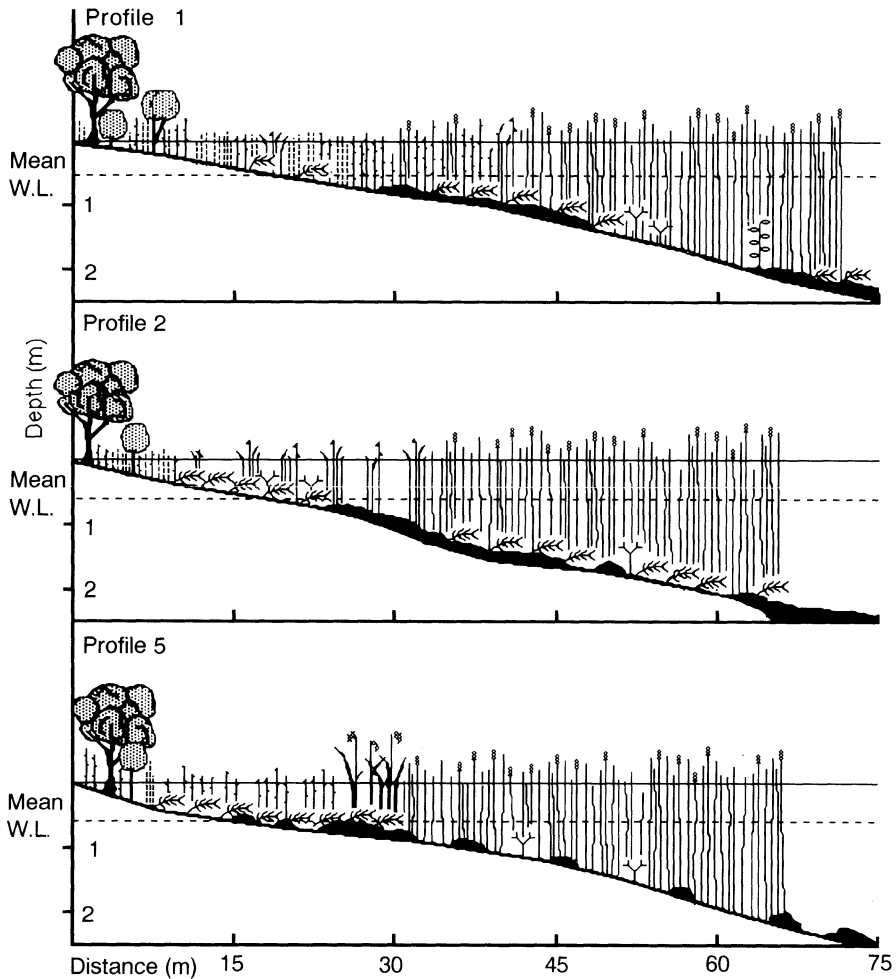


Figure 2: Profiles of ungrazed marginal vegetation along the north-eastern shores of Lake Ngatu. Species symbols as for Fig. 3.

spicua (see Tanner *et al.*, 1988). Such management may be more appropriate for sandy-shored dune lakes since softer-shored lakes would be more susceptible to pugging and erosion. Grazing may also be useful in the control of invasive adventive species such as *Glyceria maxima* and *Paspalum distichum* (see Thomas *et al.*, 1981, Middleton *et al.*, 1991).

Grazed sections of shoreline may be used, in conjunction with habitat manipulations such as water level fluctuation and herbicide applications, to increase habitat diversity for wildfowl (eg. Bakker 1985, 1989; Williams & Ogle 1987; Looijen

& Bakker 1987; Pehrsson 1988, Dijkema 1990). Keith (1961) reported enhancement of waterfowl habitat along the shorelines of prairie potholes after periodic cattle grazing. Reduction of dense *Typha* stands resulted in increased mallard and lesser scaup production. Andresen *et al.*, (1990) concluded that light grazing (0.5 cattle ha⁻¹) was the best management practice for nature conservation purposes in northern German salt marshes. Free grazing of large areas enhanced both species diversity and differences in vegetational structure by creating a pattern of heavily grazed patches with short turf and lightly grazed areas with accumu-

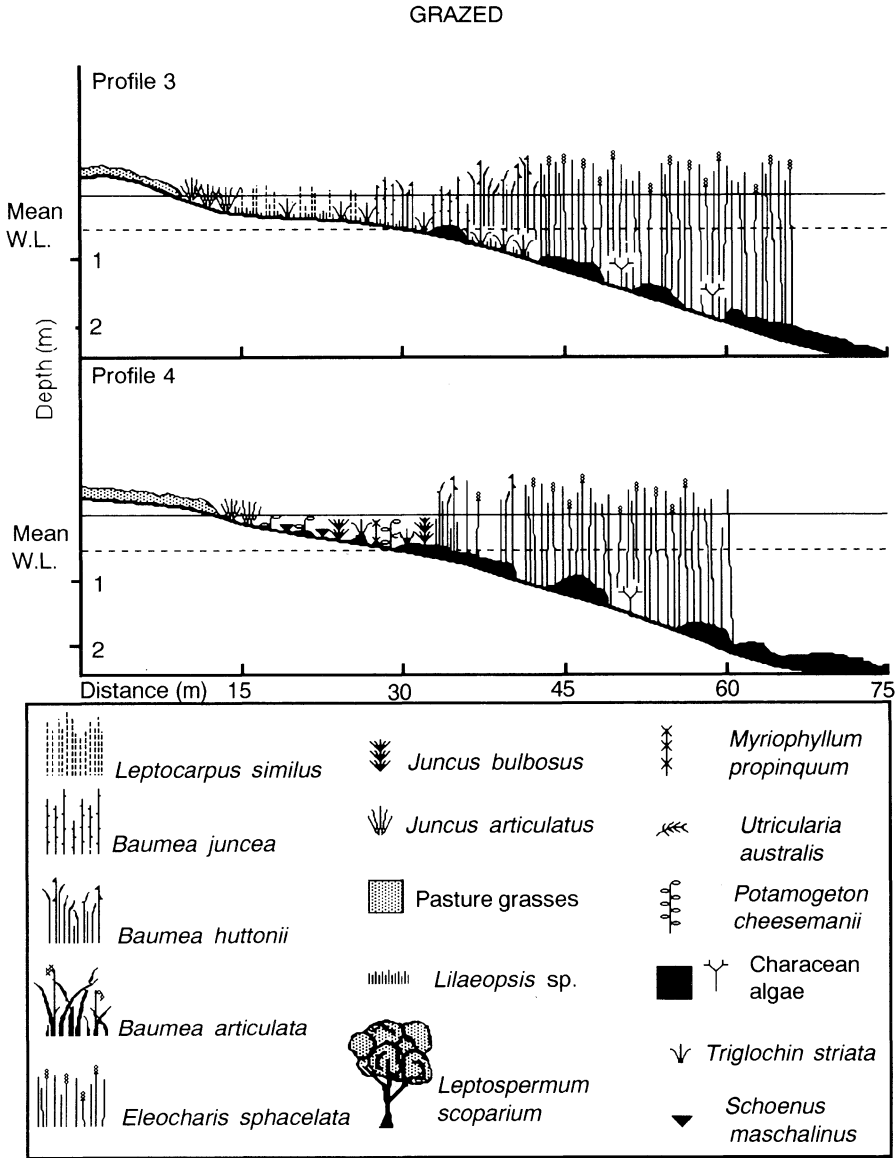


Figure 3: Profiles of grazed marginal vegetation along the north-eastern shores of Lake Ngatu.

lated litter providing rich habitats for invertebrate communities. Whyte & Cain (1981) concluded that stable waterfowl habitat in small Texan ponds could best be protected by fencing at least half of their shorelines. Gjersing (1975) and Mundinger (1976) found reduced stocking rates and restoration were sufficient to provide adequate shoreline vegetation to support productive waterfowl habitat in Montana reservoirs.

Studies are required to determine appropriate

grazing management guidelines for New Zealand lake margin vegetation; including the grazing frequency, intensity and scale appropriate for specific vegetation types and management objectives. For instance, Wardle & Johnson (1989) suggest cattle grazing management for habitat enhancement is only appropriate to eutrophic swamps, considering the impacts in oligotrophic swamps and peat bogs to be predominantly negative. Glenny *et al.*, 1987 describe cattle-grazing damage to high coun-

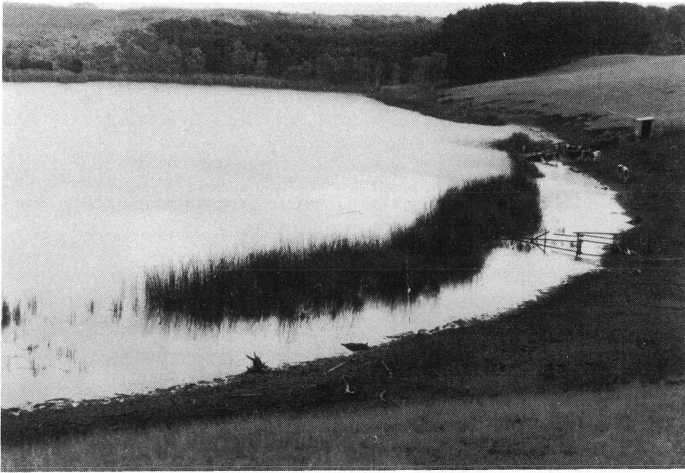


Figure 4: Effects of heavy cattle grazing during summer drought, on the shores of Lake Kahuparere (North Kaipara). Only the outer deep water stands of tall emergents (*Schoenoplectus validus*) remain. Inshore sedge communities have been removed by grazing and trampling, so that only a sparse cover (<5%) of short-growing submerged species remain.



Figure 5: Effects of light-moderate cattle grazing on the shores of Lake Ngatu (near Kaitaia). The outer *Eleocharis sphacelata* community remains little effected, while the inner mixed sedge zone (*Baumea huttoni*, *B. juncea*, *Leptocarpus simulus*) has been opened up by grazing, allowing the growth of moderate covers (20-60%) of short shallow-water species.



Figure 6: The north-eastern shore of Lake Rotokawau (near Kaitaia) showing the open inshore grazed zone (foreground) and contrasting ungrazed zone (behind fence). The more open cover and reduced litter accumulation in the grazed zone has allowed the growth of a diverse short shallow-water plant community, including the endangered species *Hydatella inconspicua*.

try wetland and lake margin vegetation near Lake Coleridge, but consider light grazing by sheep to be a less harmful and potentially desirable management practice around tarns in tussock catchments. It is also important to identify critical times (eg. wildfowl breeding seasons or periods of low water levels; see Hoffman & Stanley 1978, Kauffman & Varra 1983), and the types of vegetation and shore characteristics where grazing may result in undesirable effects. For example, Kirsch (1969) found reduced waterfowl nesting densities and nest success in grazed areas in North Dakota due to reduced protective cover, disturbance of breeding pairs, and greater accessibility to predators (foxes).

In addition to effects on plant and animal communities the long-term consequences of grazing practices on shoreline morphology, water quality and rates of eutrophication must be considered. Lake margin vegetation is important in intercepting both surface and subsurface nonpoint pollution flowing into lakes, promoting settling of solids, decomposition of organic compounds, and the uptake, immobilisation and transformation of nutrients and pesticides.

Buxton (1991) suggests that fencing of wetlands should be undertaken as a matter of course, irrespective of the objectives of management, to enable proper control of grazing. As costs for fencing and provision of alternative water supplies are in the order of NZ\$10 000/km, I believe it is important to gain an improved understanding of the effects of grazing in land-water ecotones to enable prioritisation of those requiring either complete or partial retirement from grazing, those where present or modified grazing regimes are acceptable, and those where controlled grazing is possibly a useful management tool. Alternatives to complete exclusion of stock from margins such as partial fencing along the most susceptible shores (Whyte & Cain 1981), provision of gravelled access lanes to the lake or alternative water sources also require evaluation.

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