:E,S

ISSN 0113-7492

continues in sequence
at the University of
nting research in the
ıt to New Zealand or
logy Department, and
ly acknowledged.

, Private Bag 4800, Christchurch,

y, Lincoln, New Zealand.
niversity of Canterbury,

1, Auckland, New Zealand.
Hutt, New Zealand.
Christchurch, New Zealand.
unedin, New Zealand.
hristchurch, New Zealand.
istchurch, New Zealand.
Christchurch, New Zealand.

NZ$ 20.00
NZ$ 14.00
US$ 14.00
NZ$ 5.00
US$ 5.00

epartment, University of

BIOSIS database), *Geo*
eralogical Abstracts and

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

C.C. TANNER

National Institute of Water and Atmospheric Research, Ruakura Agricultural Centre, Private Bag 3123, Hamilton, New Zealand.

(Received 2 April, 1992: revised and accepted 22 June, 1992)

ABSTRACT

Tanner, C.C. (1992). A review of cattle grazing effects on lake margin vegetation with observations from dune lakes in Northland, New Zealand. *New Zealand Natural Sciences* 19: 1-14.

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 mechanis
(see de Vlaming & Proctor
pacts by native and naturalis
(*eg.* grey mullet and rudd resp
be largely limited to subm
although adventive species w
distributions (*eg.* grass carp)
graze lake margin vegetation
Herbivory by rodents may al
ticularly in the pre and post
seeds (Crawley 1983, Verk
(1991) provides a thorough r
tance of herbivory by aquatic
larly invertebrates) on aquat

EFFECTS OF CATTI

Livestock usage of lake
proportionately high, particul
dry climates, because they pro
ing water, a source of succul
desirable microclimate (*eg.*
shade, wallowing).

Cattle may directly affect
(see Ellison 1960, Reinold *et*
Platts 1978, Holechek 19
Kauffman & Krueger 1984, P
Skovlin 1984, Belsky 1986) b

1. Consumption of plan
selective grazing of palatable
tissues and species, and defol
duction, reproduction, carbo
litter accumulation).

2. Trampling of plants,
underground rhizomes.

3. Pugging, compaction,
pension of lakeshore substra

4. Nutrient addition and
tion from dung and urine.

5. Creation of plant inva

6. Introduction and dis
other plant propagules.

Modification of the surro
a grazed pastoral landscape
indirect effects, particularly
water, sediments and nutrien
as removal of protective fores
the application of fertilis
(McColl & Hughes 1981).

Together these effects

ıtion of New Zealand, large
ıced plant species have become
tic habitats (Howard-Williams
of which have evolved in the
.alian grazing.

F NATURAL GRAZING

ınd early Maori times in the
ılian grazers, now extinct birds
and Mappin's moas (Atkinson
), Worthy 1990) and the native
: and swan (Falla 1975), along
vl present today (particularly
helduck, grey duck, grey teal
y to have grazed lake margin
e recent times aquatic vegeta-
l both by native water fowl, and
.es such as black swan, mallard
(Falla 1975, Bisset 1976, Potts
., Fordham 1983, Moore *et al.*,

of the effects of these species
:tation. Their grazing is likely
: than that of ruminant mam-
ligestive systems are less able
ellulose-rich herbage (Wardle
razing impacts on submerged
: been recorded by Jupp &
ɔrboe (1980) and Carter &
l black swan browsing com-
ria densa and *Lagarosiphon*
ıths below 1 m in North Island
press, Howard-Williams &
densities of visiting migratory
eese have been found to effect
ı of emergent *Spartin*a and
ı North America (Smith &
: & Bedard 1987), but little is
ts of lower density resident
ealand water fowl are known
ıge of succulent herbaceous
ıch as *Juncus articulatus* and
the young shoots of rushes,
ientalis. They also feed on a
ow-water submerged plants
geton spp., and on floating
lla. The seeds and fruit of
hose of *Polygonum*, *Alisma*,
ia 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

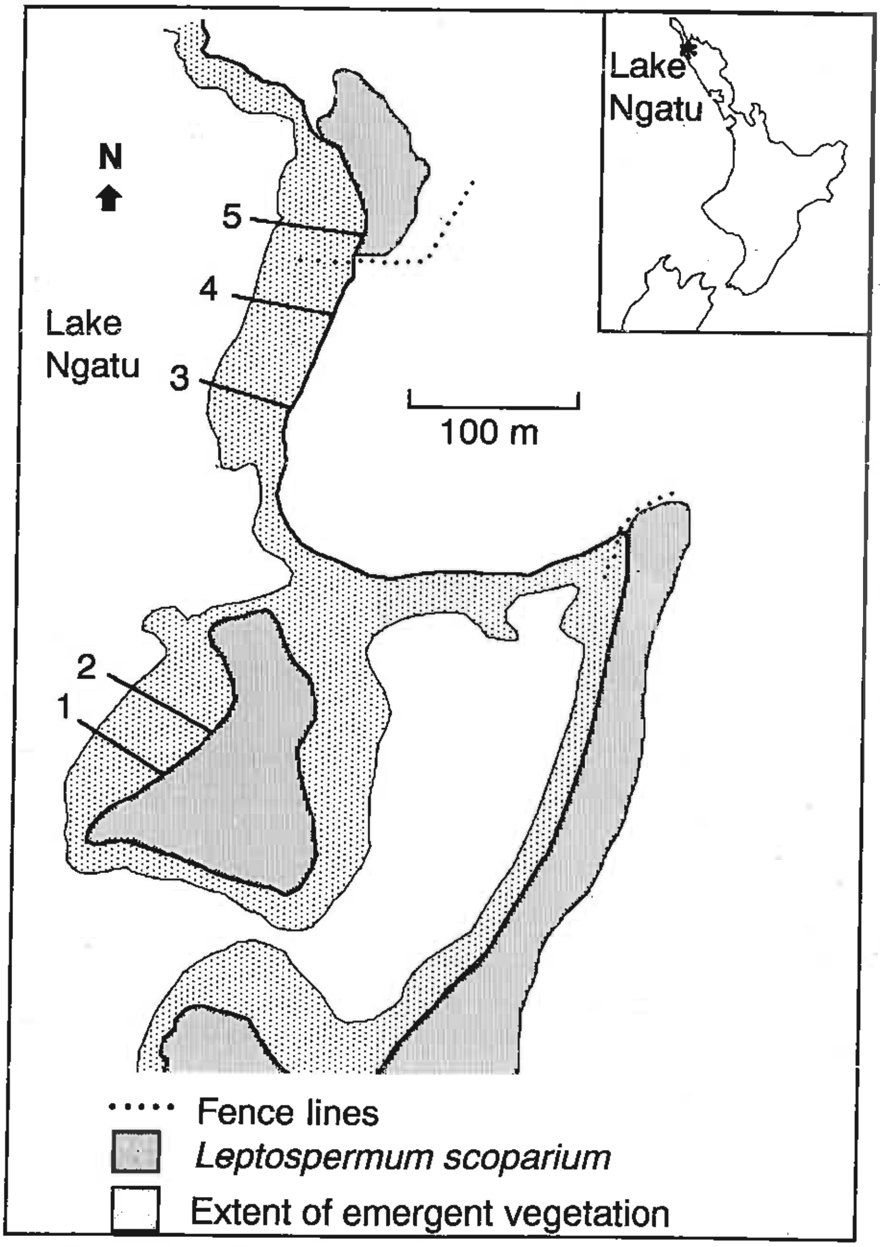


Figure 1: Map showing position of sample sites along the north-eastern shore of Lake Ngatu. Inset shows location of Lake Ngatu near Kaitaia in the far north of New Zealand.

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 Nc
Methodology and floristic de
in Tanner *et al.*, 1986, 1988, a
Further detailed observation
cember 1989 of grazed and
Lake Ngatu, a 61 ha lake *c.* 10
using a modification of the tra
described by Clayton (1983
have been deposited in the U
herbarium. Fig. 1 shows the p
lines along the eastern shor
grazed shorelines occurred c
and 2) and within the recre
tected by fences (site 5). The
areas was grazed by cattle (si
level records for the lake (N
Commission pers. comm.) sh
c. 1 m had occurred since e
caused inundation of *Leptosp*
around the lake margins at th

RESULTS

LAKE NGATU

The plant species recor
ungrazed sites, their depth ra
average covers are summaris

Along the ungrazed sect
Lake Ngatu (Fig. 2) *Leptos*
intergraded into a mixed inne
tocarpus similis, *Baumea jun*
occasionally *B. articulata*; wi
Eleocharis sphacelata. A
charophytes (*Chara fibrosa*,
pseudoflabellata, and *N. leptc*
sectivorous bladderwort *Utri*
curred amongst the tall sedge

The grazed sections of sh
similar depth ranges and c
Eleocharis sphacelata zone, bu
waters edge and a relatively
The vegetation of this ins
grazed sedge remnants and
blage of short-stature shallo
plants including *Juncus artic*
Triglochin striata, *Lilaeops*
Myriophyllum propinqu
cheesemanii, *Schoenus masch*
areas *Hydatella inconspicua*;
U. australis was reduced mark

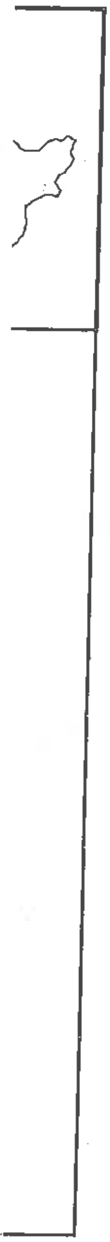


Figure 1: Map showing position of sample sites along the north-eastern shore of Lake Ngatu. Inset shows location of Lake Ngatu near Kaitaia in the far north of New Zealand.

being fed predominantly by
·s. The origins, general fea-
of these lakes is discussed by
l. (1953) and Cunningham

METHODS

ations of cattle grazing effects
ation 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 Kaitaia, 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 understorey 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 cheesemanii*, *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.

	UNGRAZED									GRAZED					
	Profile 1			Profile 2			Profile 5			Profile 3			Profile 4		
Species	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.	Depth range(m)	Cover Max.	Ave.
EMERGENT[1]															
[2]*Axonopsus affinus* Chase	-	-	-	-	-	-	-	-	-	0-0.1	1	1	0-0.2	1	1
Baumea articulata (R. Br.) Blake	-	-	-	-	-	-	0.8-0.9	2	1	-	-	-	-	-	-
B. huttoni (Kirk) Blake	0.7-1.3	3	1	0.4-1.25	3	2	0.8-1	3	1	1-1.1	2	1	0.4-1.0	2	1
B. juncea (R. Br.) Palla	0.5-1.0	5	3	0.1-0.8	5	1	0-0.9	6	5	0.9-1	2	1	-	-	-
Centella uniflora (Col.) Nannf.	-	-	-	-	-	-	-	-	-	0-0.35	1	1	-	-	-
[2]*Cyperus tenellus* Linn. f.	-	-	-	-	-	-	-	-	-	0-0.1	2	1	0-0.2	2	1
Eleocharis sphacelata R. Br.	1-2.3	6	5	1.25-2.5	6	6	0.9-2.2	6	6	1-2.25	6	5	0.9-2.2	6	5
Gleichenia dicarpa R. Br.	0-0.3	3	1	-	-	-	-	-	-	-	-	-	-	-	-
[2]*Isolepis sepulcratis* Steud	-	-	-	-	-	-	-	-	-	0-0.1	3	2	0-0.2	1	1
[2]*Juncus articulatus* L.	-	-	-	-	-	-	-	-	-	0-0.3	4	2	0-0.4	4	3
J. usitatus L. Johnson	-	-	-	-	-	-	-	-	-	0-0.4	2	1	-	-	-
Leptocarpus similis Edgar	0-0.9	5	3	0.3-0.7	6	3	0.4 only	2	1	0-0.85	5	3	-	-	-
Leptospermum scoparium Forst.	0-0.7	5	4	0-0.7	5	4	0-0.4	6	5	-	-	-	-	-	-
Schoenus mascalinus Roemer et Schultes	-	-	-	-	-	-	-	-	-	0-0.35	2	1	0-0.4	3	2
SUBMERGED[1]															
Charophytes:															
Chara fibrosa var. *acanthopitys* (A.Br.) Zanev	0.8-2.5[3]	6	3	0.6-2.5[3]	6	3	0.8-2.5[3]	6	3	0.7-2.5[3]	6	3	0.4-2.5[3]	5	3
C. corallina Kl. ex Willd, em. R.D.W.	-	-	-	-	-	-	-	-	-	-	-	-	0.6-1.0	2	1
Nitella leptostachys 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	0.7-2.5[3]	1	1	0.4-2.5[3]	1	1
N. pseudoflabellata A. Br. em R.D.W.	-	-	-	0.7-1.25	1	1	0.8-2.5[3]	2	1	0.7-1.0	2	1	0.4-2.5[3]	2	1
Tracheophytes:															
Glossostigma diandrum (L.) Kuntze	-	-	-	-	-	-	-	-	-	0.4 only	1	1	-	-	-
Hydatella inconspicua Cheeseman	-	-	-	-	-	-	-	-	-	0.4-0.5	1	1	-	-	-
[2]*Juncus bulbosus* L.	-	-	-	-	-	-	-	-	-	-	-	-	0.35-0.6	2	2
Lilaeopsis novae-zelandiae (Gand.) A.W. Hill	-	-	-	-	-	-	-	-	-	0.4-0.85	2	1	-	-	-
Myriophyllum propinquum A. Cunn.	-	-	-	-	-	-	-	-	-	0.6-0.85	2	1	0.9-1	4	2
Potamogeton cheesemanii A. Benn.	2.2 only	1	1	-	-	-	-	-	-	-	-	-	0.35-0.8	2	1
Triglochin striata Ruiz et Pav.	-	-	-	-	-	-	-	-	-	0.7-1	3	1	0.5-0.8	3	1
Utricularia australis R. Br.	0.7-2.3[3]	3	1	0.2-2.5[3]	4	2	0.4-2.5[3]	6	2	0.3 only	1	1	0.35-2.5[3]	1	1
FREE FLOATING:															
Azolla pinnata 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.)

(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-*

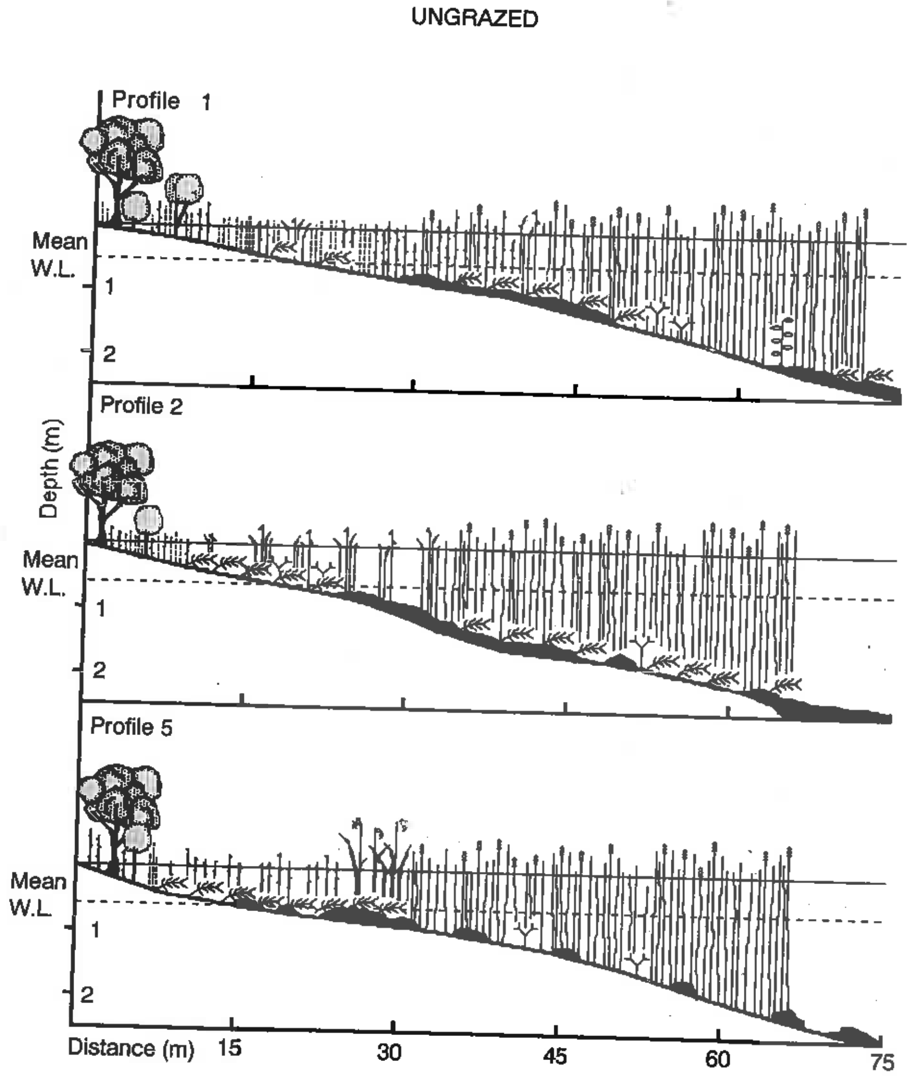


Figure 2: Profiles of ungrazed marginal vegetation along the north-eastern shores of Lake Ngatu. Species symbols as for Fig. 3.

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-

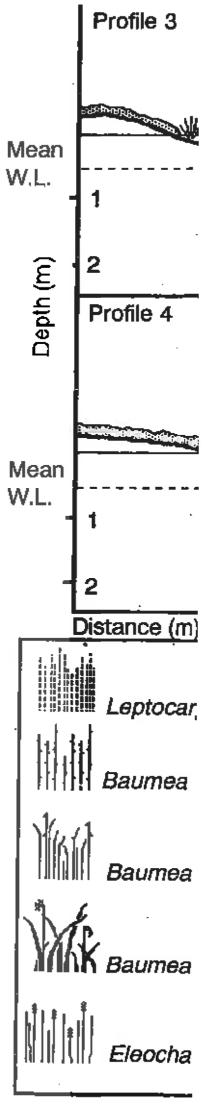
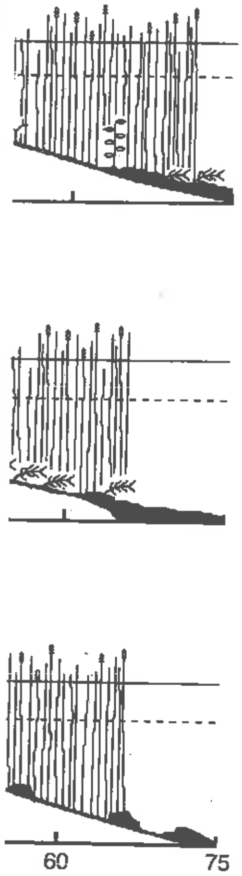


Figure 3: Profiles of grazed mar

lated litter providing rich ha
communities. Whyte & C
that stable waterfowl habita
could best be protected by
their shorelines. Gjersing (
(1976) found reduced sto
rotation were sufficient
shoreline vegetation to sup
fowl habitat in Montana re
Studies are required to



ke Ngatu. Species symbols as for Fig. 3.

?ehrsson 1988, Dijkema 1990). rted enhancement of waterfowl shorelines of prairie potholes le grazing. Reduction of dense ılted in increased mallard and ıction. Andresen *et al.*, (1990) ht grazing (0.5 cattle ha^{-1}) was ent practice for nature conser- northern German salt marshes. ge areas enhanced both species ences in vegetational structure n of heavily grazed patches with tly grazed areas with accumu-

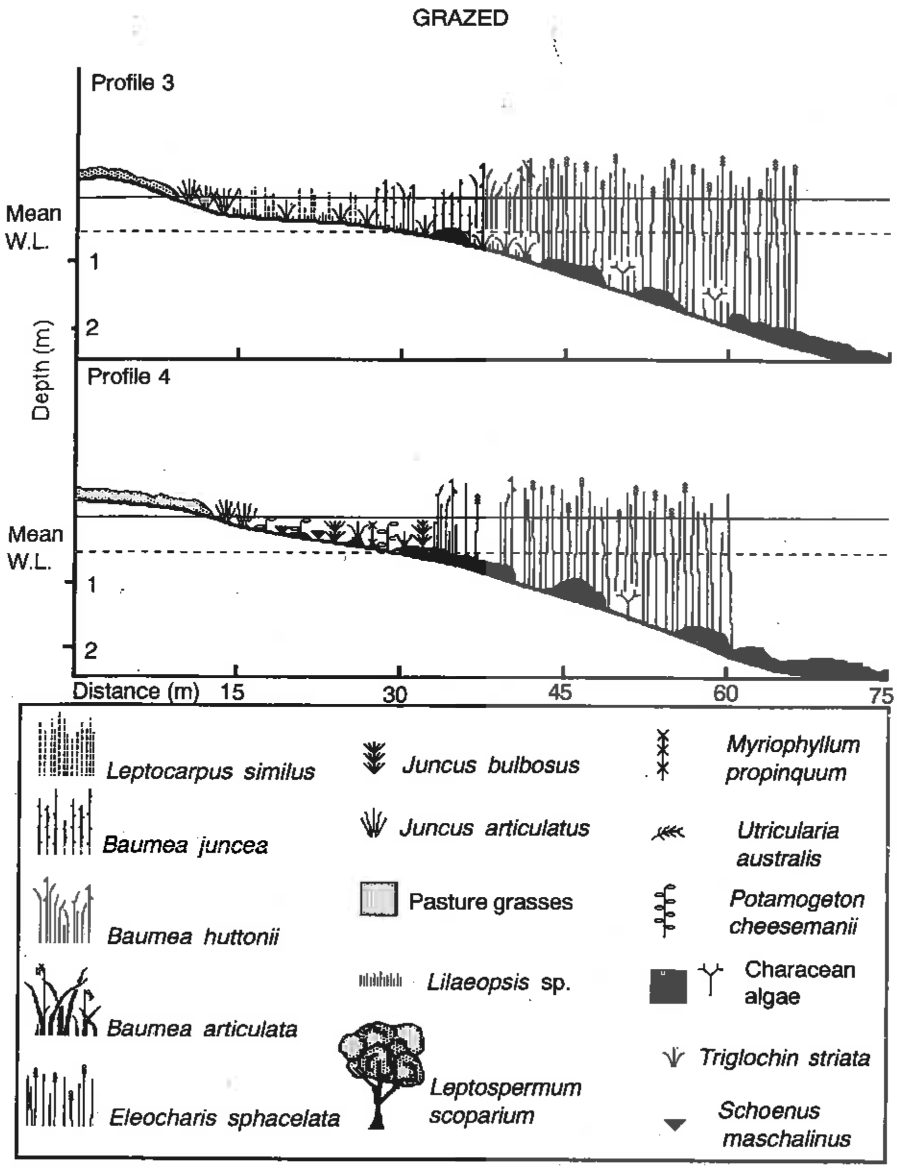


Figure 3: Profiles of grazed marginal vegetation along the north-eastern shores of Lake Ngatu.

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 rest-rotation 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-

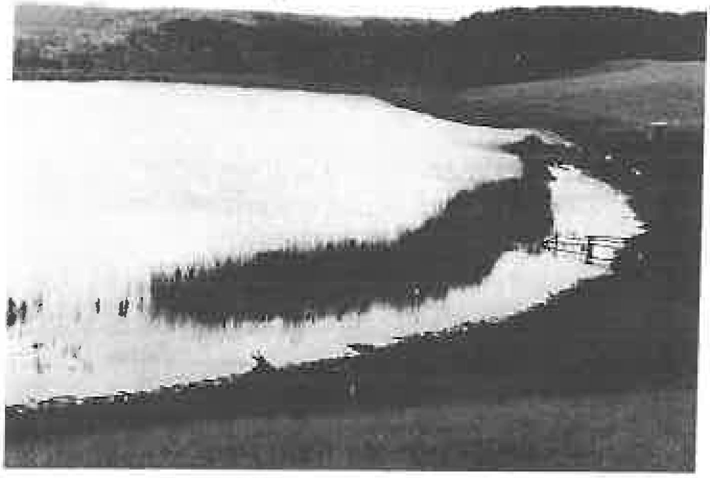


Figure 4: Effects of heavy cattle grazing during summer drought, on the shores of Lake Kahuparere (North Kaipara). Only the outer deep water stands of tall emergents (*Schoenoplectus validus*) remain. Inshore sedge communities have been removed by grazing and trampling, so that only a sparse cover (<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 mar
Coleridge, but consider l
be a less harmful and pc
agement practice arounc
ments. It is also importan
(*eg.* wildfowl breeding se
water levels; see Hoff
Kauffman & Varra 1983)
tion and shore characteri
result in undesirable effe
(1969) found reduced wa
and nest success in graze
due to reduced protecti
breeding pairs, and great
tors (foxes).

In addition to effec
communities the long-ter
ing practices on shorel
quality and rates of eutro
ered. Lake margin veg
intercepting both surface
pollution flowing into lak
solids, decomposition of
the uptake, immobilisatic
nutrients and pesticides.

Buxton (1991) sugge
lands should be undertak
irrespective of the object
enable proper control o
fencing and provision of a
are in the order of NZ$1
important to gain an im
the effects of grazing in
enable prioritisation of
complete or partial retire
where present or modifi
acceptable, and those wh
possibly a useful manage
to complete exclusion of
as partial fencing alon
shores (Whyte & Cain 1
elled access lanes to the
sources also require eval

ACKNOWLE

I am grateful to John
comments on the manus
with Rohan Wells, for as
fieldwork. Paul Cham
manuscript and an anon

re 4: Effects of heavy cattle grazing during summer drought, on the es of Lake Kahuparere (North ›ara). Only the outer deep water ds of tall emergents (*Schoenoplec- validus*) remain. Inshore sedge munities have been removed by ing and trampling, so that only a se cover (<5%) of short-growing ıerged species remain.

re 5: Effects of light-moderate grazing on the shores of Lake u (near Kaitaia). The outer *Eleo- s sphacelata* community remains effected, while the inner mixed zone (*Baumea huttoni*, *B. juncea*, ›carpus simulus) has been opened y grazing, allowing the growth of rate covers (20-60%) of short ›w-water species.

e 6: The north-eastern shore of Rotokawau (near Kaitaia) show- e open inshore grazed zone (fore- ıd) and contrasting ungrazed zone nd fence). The more open cover educed litter accumulation in the d zone has allowed the growth of a e short shallow-water plant com- y, including the endangered s *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.

ACKNOWLEDGEMENTS

I am grateful to John Clayton, both for helpful comments on the manuscript and in association with Rohan Wells, for assistance with preliminary fieldwork. Paul Champion critically read the manuscript and an anonymous referee provided useful comments. Mary de Winton ably drafted the diagrams and Sylvia Baker typed the manuscript.

REFERENCES

Andresen, H., Bakker, J.P., Bongers, M., Heydemann. B. & Irmler, U. (1990). Long-term changes of salt marsh communities by cattle grazing. *Vegetatio* 89: 137-148.

ARA (1983) Guideline: Rural catchment management. Upper Waitemata Harbour Catchment study, Auckland Regional Authority, Auckland.

Armour, C.L., Duff, D.A. & Elmore, W. (1991). The effects of livestock grazing on riparian and stream ecosystems (Draft American Fisheries Society position statement). *Fisheries* 16: 7-11.

Atkinson, I.A.E. & Greenwood, R.M. (1989). Relationships between moas and plants. In Moas, mammals and climate in the ecological history of New Zealand. (ed. M.R. Rudge) *New Zealand Journal of Ecology* 12 (Supplement): 67-96.

Bakker, J.P. (1985). The impact of grazing on plant communities and soil conditions on salt marshes. *Vegetatio* 62: 391-398.

Bakker, J.P. (1989). Nature management by grazing and cutting. Dordrecht, Kluwer Academic. Publ.

Beeftink, W.G. (1977). Salt marshes. In The Coastline (ed. R.S. Barnes), pp. 93-121. Wiley, London.

Belsky, A.J. (1986). Does herbivory benefit plants? A review of the evidence. *The American Naturalist* 127: 870-891.

Bisset, S.A. (1976). Foods of the paradise shelduck *Tadorna variegata* in the high country of North Canterbury, New Zealand. *Notornis* 23: 106-119.

Burgess, N.D., Evans, C.E. & Thomas, G.J. (1990). Vegetation change on the Ouse Washes wetland, England 1972-88 and effects on their conservation importance. *Biological Conservation* 53: 173-189.

Buxton, R. (1991). New Zealand's wetlands: A management guide. Department of Conservation and Environmental Council, Wellington.

Carter, V. & Rybicki, N.B. (1985). The effects of grazers and light penetration on the survival of transplants of *Vallisneria americana* Michx. in the tidal Potomac River, Marlyland. *Aquatic Botany* 23: 197-213.

Clayton, J.S. (1983). Sampling aquatic macrophyte communities. In *Biological methods for water quality surveys*. Soil and Water miscellaneous publication 54: AM/1-24 (ed. B.J. Biggs, J.S. Gifford & D.G. Smith). Ministry of Works and Development, Wellington.

Clayton, J.S. (in press). Major changes in the aquatic vegetation of shallow Waikato lakes over the last century. Paper presented at the special session on the botany of the Waikato, New Zealand Ecological Society Conference, August 1990, Hamilton.

Coops, H., Boeters, R & Smit, H. (1991). Direct and indirect effects of wave attack on helophytes. *Aquatic Botany* 41: 333-352.

Crawley, M.J. (1983). Herbivory, the dynamics of animal-plant interactions. Studies in ecology volume 10, Blackwell Scientific Publ., Oxford.

Cunningham, B.T. (1957). The coastal dune lakes. *Proceedings of the New Zealand Ecological Society* 5: 22-23.

Cunningham, B.T., Moar, N.T., Torrie, A.W., Parr, P.J. (1953). A survey of the western coastal dune lakes of the North Island New Zealand. *Australian Journal of Marine and Freshwater Research* 4: 343-386.

Davis, S.F. (1985). Effects of land development on aquatic ecosystems. *New Zealand Agricultural Science* 19: 156-164.

Day, R.T., Keddy, P.A., McNeill, J. & Carleton, T. (1988). Fertility and disturbance gradients: A summary model for riverine marsh vegetation. *Ecology* 69: 1044-1054.

de Vlaming, V. & Proctor, V.W. (1968). Dispersal of aquatic organisms: viability of seeds recovered from the droppings of captive kill deer and mallard ducks. *American Journal of Botany* 55: 20-26.

de Winton, M.D., Champion, P.D., de Lange, P., Clayton, J.S. & Wells, R.D.S. (1992). The aquatic vegetation of the lower Waikato lakes. Technical Report, National Institute of Water and Atmospheric Research, Hamilton.

Dijkema, K.S. (1990). Salt and brackish marshes around the Baltic sea and adjacent parts of the North Sea: Their vegetation and management. *Biological Conservation* 51: 191-209.

Ellison, L. (1960). Influence of grazing on plant succession of rangelands. *Botanical Review* 26: 1-78.

Falla, R.A. (1975). The bird fauna. In *New Zealand Lakes* (ed. V.H. Jolly & J.M.A. Brown), pp. 319-331. Auckland/Oxford University Press.

Fordham, R.A. (1983). Seasonal dispersion and activity of the pukeko *Porphyrio p. melanotus* (Rallidae) in swamp and pasture. *New Zealand Journal of Ecology* 6: 133-142.

Giroux, J.F. & Bedard, J. (1987). The effects of grazing by greater snow geese on the vegetation of tidal marshes in the St Lawrence estuary. *Journal of Applied Ecology* 24: 773-143.

Gjersing, F.M. (1975). Waterfowl production in relation to rest-rotation grazing. *Journal of Range Management* 28: 37-42.

Glenny, D., Fry, C., Stout, V.M. & Burrows, C.J. (1987). A biological survey of the lakes and other wetlands of the university endowment land at Lake Coleridge. Plant Science and Zoology Department report, Canterbury University, Christchurch.

Grime, J.P. (1979). Plant strategies and vegetation processes. Wiley, Chichester, England.

Hicks, B.J. & Howard-Williams, C. (1990). Development of guidelines for the management of streamside riparian strips. NZ Freshwater Fisheries miscellaneous report No. 59. MAF Fisheries, Rotorua.

Hoffman, G.R. & Stanley, L.D. (1978). Effects of cattle grazing on shore vegetation of fluctuating water level reservoirs. *Journal of Range Management* 31: 412-416.

Holechek, J.L. (1981). Livestock grazing impacts on public lands: A viewpoint. *Journal of Range Management* 34: 251-254.

Howard-Williams, C. & Davies, J. (1988). The invasion of Lake Taupo by the submerged water weed *Lagarosiphon major* and its impact on the native flora. *New Zealand Journal of Ecology* 11: 13-19.

Howard-Williams, C., Clayton, J.S., Coffey, B.T. & Johnstone, I.M. (1987). Macrophyte invasions. In *Inland waters of New Zealand* (ed. A.B. Viner) pp. 307-331. DSIR Publishing, Wellington.

Huston, M.A. (1979). A general hypothesis of species diversity. *Ameri*
101.

Jupp, B.P. & Spence, D.H.N
of macrophytes in a
Leven. II. Wave action
fowl grazing. *Journal o*

Kauffman, J.B. & Krueger
stock impacts on ripa
streamside manageme
review. *Journal of Rang*
438.

Kauffman, J.B. & Varra, M.
season cattle grazing
communities. *Journal*
36: 685-690.

Keddy, P.A. (1982). Quan
dients of wave energy
wave energy, substrate
line plants in Axe la
Botany 14: 41-58.

Keddy, P.A. (1983). Shore
Lake, Ontario: effects o
patterns. *Ecology* 64:

Keith, L.B. (1961). A stud
on small impoundme
Alberta. *Wildlife Mon*

Kiorboe, T. (1980). Distri
of submerged macropl
(Ringkobing Fjord, D
pact of waterfowl grazi
Ecology 17: 675-687.

Kirsch, L.M. (1969). Wa
relation to grazing. *Jo*
agement 33: 821-828.

Lodge, D.M. (1991). He
macrophytes. *Aquatic*

Looijen, R.C. & Bakker, J.
of different salt-marsh
cattle and geese. In *V*
and sea (ed. A.H.L. Hu
& J. Rosema), pp. 5
Dordrecht.

McColl, R.H.S. & Hughe
The effects of land u
review. *Water & Soil*
tion 23. Ministry of W
Wellington.

Maturin, S. (1985). The
riparian strips - a chall
and landscape archit
(NZ) 25: 27-29.

. Influence of grazing on plant rangelands. *Botanical Review*

5). The bird fauna. In *New* *;s* (ed. V.H. Jolly & J.M.A. 19-331. Auckland/Oxford Uni-

1983). Seasonal dispersion and pukeko *Porphyrio p. melanotus* swamp and pasture. *New* *al of Ecology* 6: 133-142.

dard, J. (1987). The effects of ater snow geese on the vegeta- marshes in the St Lawrence *ıal of Applied Ecology* 24: 773-

975). Waterfowl production in t-rotation grazing. *Journal of* *ment* 28: 37-42.

., Stout, V.M. & Burrows, C.J. logical survey of the lakes and s of the university endowment Coleridge. Plant Science and artment report, Canterbury ristchurch.

). Plant strategies and vegeta- . Wiley, Chichester, England.

ard-Williams, C. (1990). De- guidelines for the management iparian strips. NZ Freshwater ellaneous report No. 59. MAF orua.

tanley, L.D. (1978). Effects of n shore vegetation of fluctuat- reservoirs. *Journal of Range* 1: 412-416.

31). Livestock grazing impacts : A viewpoint. *Journal of Range* 4: 251-254.

C. & Davies, J. (1988). The ke Taupo by the submerged *garosiphon major* and its im- ve flora. *New Zealand Journal* 13-19.

C., Clayton, J.S., Coffey, B.T. .M. (1987). Macrophyte inva- *d waters of New Zealand* (ed.). 307-331. DSIR Publishing,

79). A general hypothesis of species diversity. *American Naturalist* 113: 81-101.

Jupp, B.P. & Spence, D.H.N. (1977). Limitations of macrophytes in a eutrophic lake, Loch Leven. II. Wave action, sediments and water fowl grazing. *Journal of Ecology* 65: 431-439.

Kauffman, J.B. & Krueger, W.C. (1984). Livestock impacts on riparian ecosystems and streamside management implications : A review. *Journal of Range Management* 37: 430-438.

Kauffman, J.B. & Varra, M. (1983). Effects of late season cattle grazing on riparian plant communities. *Journal of Range Management* 36: 685-690.

Keddy, P.A. (1982). Quantifying within lake gradients of wave energy : inter relationships of wave energy, substrate particle size and shoreline plants in Axe lake, Ontario. *Aquatic Botany* 14: 41-58.

Keddy, P.A. (1983). Shoreline vegetation in Axe Lake, Ontario: effects of exposure on zonation patterns. *Ecology* 64: 331-344.

Keith, L.B. (1961). A study of waterfowl ecology on small impoundments in south eastern Alberta. *Wildlife Monographs* 6, 88 pp.

Kiorboe, T. (1980). Distribution and production of submerged macrophytes in Tipper Grund (Ringkobing Fjord, Denmark), and the impact of waterfowl grazing. *Journal of Applied Ecology* 17: 675-687.

Kirsch, L.M. (1969). Waterfowl production in relation to grazing. *Journal of Wildlife Management* 33: 821-828.

Lodge, D.M. (1991). Herbivory on freshwater macrophytes. *Aquatic Botany* 41: 195-224.

Looijen, R.C. & Bakker, J.P. (1987). Utilisation of different salt-marsh plant communities by cattle and geese. In *Vegetation between land and sea* (ed. A.H.L. Huiskes, C.W.P.M. Blom & J. Rosema), pp. 52-64. W. Junk Publ., Dordrecht.

McColl, R.H.S. & Hughes, H.R. (eds) (1981). The effects of land use on water quality; a review. *Water & Soil Miscellaneous Publication* 23. Ministry of Works and Development, Wellington.

Maturin, S. (1985). The impact of grazing in riparian strips - a challenge for land managers and landscape architects. *The Landscape (NZ)* 25: 27-29.

Meehan, W.R. & Platts, W.R. (1978). Livestock grazing and the aquatic environment. *Journal of soil and water conservation* 33: 274-278.

Menges, E.S. & Waller, D.M. (1983). Plant strategies in relation to elevation and light in flood plain herbs. *American Naturalist* 122: 454-473.

Middleton, B.A., van der Valk, A.G., Mason, D.H., Williams, R.L. & Davis, C.B. (1991). Vegetation dynamics and seed banks of a monsoonal wetland overgrown with *Paspalum distichum* L. in northern India. *Aquatic Botany* 40: 239-259.

Mitchell, C.P. (1980). Control of water weeds by grass carp in two small lakes. *New Zealand Journal of Marine and Freshwater Research* 14: 381-390.

Moore, P.J., Ogle, C.C. & Moynihan, K.T. (1984). Habitat requirements of wetland birds in the Lake Wairarapa wetlands. Occasional publication No. 5, New Zealand Wildlife Service Wellington, Department of Internal Affairs.

Mundinger, J.A. (1976). Waterfowl responses to rest-rotation grazing. *Journal of Wildlife Management* 40: 60-68.

Norton, D.A. (1989). Management of New Zealand's Natural Estate. Occasional Publication No. 1, New Zealand Ecological Society, Christchurch.

Pehrsson, O. (1988). Effects of grazing and inundation on pasture quality and seed production in a salt marsh. *Vegetatio* 74: 113-124.

Platts, W.S. & Raleigh, R.F. (1984). Impacts of grazing on wetlands and riparian habitat. From: *Developing strategies for rangeland management* pp. 1105-1117. USA, National Research Council/National Academy of Science.

Platts, W.S. & Rinne, J.N. (1985). Riparian and stream enhancement management and research in the Rocky Mountains. *North American Journal of Fisheries Management.* 5: 115-125.

Platts, W.S. & Wagstaff, F.J. (1984). Fencing to control livestock grazing on riparian habitats along streams: Is it a viable alternative? *North American Journal of Fisheries Management* 4: 266-272.

Potts, K.J. (1977). Food of game ducks. *Wildlife - A Review* 8: 28-34.

Reinold, R.J., Linthurst, R.A. & Wolf, P.L. (1975). Effects of grazing on a salt marsh.

Biological Conservation 8: 105-125.

Shipley, B., Keddy, P.A., Gaudet, C. & Moore, D.R.J. (1991). A model of species density in shoreline vegetation. *Ecology* 72: 1658-1667.

Skovlin, J. (1984): Impacts of grazing on wetlands and riparian habitat: a review of our knowledge. From: Developing strategies for rangeland management. USA, National Research Council/National Academy of Science. pp 1001-1103.

Smale, S. (1985). Wetlands in the agricultural landscape. *The Landscape (NZ)* 25: 10-17.

Smith, T.J. & Odum, W.E. (1981). The effects of grazing by snow geese on coastal marshes. *Ecology* 62: 98-106.

Spence, D.H.N. (1982). The zonation of plants in freshwater lakes. *Advances in Ecological Research* 12: 37-125.

Tanner, C.C., Clayton, J.S. & Harper, L.M. (1986). Observations of aquatic macrophytes in 26 northern New Zealand lakes. *New Zealand Journal of Botany* 24: 539-551.

Tanner, C.C., Clayton, J.S. & Wells, R.D.S. (1988). The distribution, biology, habitat and conservation status of the endangered aquatic plants *Hydatella inconspicua* and *Myriophyllum robustum* in Northland; with recommendations for future management. Unpublished report to the Department of Conservation, Ministry of Agriculture and Fisheries, Hamilton.

Thomas, G.J., Allen, D.A. & Grose, M.P.B. (1981). The demography and flora of the Ouse Washes, England. *Biological Conservation* 21: 197-229.

Verkaar, H.J. (1987). Population dynamics - the influence of herbivory. *New Phytologist* 106 (Suppl.): 49-60.

Wardle, P. (1989). Grazing and management of natural areas: reintroducing an indigenous factor. In: *Management of New Zealand's natural estate* (ed. D.A. Norton), pp. 86-88. Occasional Publication No. 1., New Zealand Ecological Society, Christchurch.

Wardle, P. & Johnson, P. (1989). What is the role of disturbance as a management tool, especially for maintaining seral vegetation? Workshop report 3.3, New Zealand Ecological Society Symposium. In: *Management of New Zealand's natural estate* (ed. D.A. Norton), p. 96. Occasional Publication No. 1., New Zealand Ecological Society, Christchurch.

Weisner, S.E.B. (1987). The relationship between wave exposure and distribution of emergent vegetation in a eutrophic lake. *Freshwater Biology* 18: 537-544.

Wells, R.D.S., Clayton, J.S. & Tanner, C.C. (1988). Kai Iwi lakes study. Unpublished report to the Northern Regional Council, Ministry of Agriculture and Fisheries, Hamilton.

White, R.J. & Brynildson, O.M. (1967). Guidelines for management of trout stream habitat in Wisconsin. Department of Natural Resources Technical Bulletin 39, Madison, Wisconsin.

Whyte, R.J. & Cain, B.W. (1981). Wildlife habitat on grazed or ungrazed small pond shorelines in South Texas. *Journal of Range Management* 34: 64-68.

Williams, M.J. (1981). The duckshooter's bag: An understanding of New Zealand's wetland game birds. The Wetlands Press, Wellington.

Williams, M.J. & Ogle, C.C. (1987). Wildlife: Survey, problems and management. *In*: Vant, W.N. (ed), Lake Managers Handbook, Water and Soil miscellaneous publication No. 103, Wellington, Ministry of Works and Development for National Water and Soil Conservation Authority.

Williamson, R.B. & Hoare, R.A. (1987). Controlling nutrient loads and predicting resulting lake nutrient concentrations. *In*: Vant, W.B. (ed), Lake Managers Handbook, water and soil miscellaneous publication No. 103, Wellington, Ministry of Works and Development for National Water and Soil Conservation Authority. pp 172-182.

Williamson, R.B., Smith, R.K. & Quinn, J.M. (1990). The effects of riparian protection on channel form and stability of 6 grazed streams; Southland, New Zealand. Water Quality Centre Publication No. 19, DSIR Marine & Freshwater, Hamilton.

Worthy, T.H. (1990). An analysis of the distribution and relative abundance of moa species (Aves : Dinornithiformes). *New Zealand Journal of Zoology* 17: 213-241.

DRIFT OF A
MANGANUIATEAO

Science and Researc

Collier, K.J. & Wakelin
Central North Island, N

Drifting aquatic invertet
intervals between Janua
to mid-morning, mid-m
collected from 1 station
were taken in the drift.
(>10% of invertebrates
complete sets of samp
humeralis, Plecoptera a
between mid-afternoor
July (18-28 100 m^{-3}h^{-1}).
at 1-2 h periods for 24 h
were collected over 4 c
larvae in the drift we
comparable benthic sa
of Chironomidae larva
positive correlations w
trodes spp. We discus
including the potentia

KEYWORDS: aquat

INTROD

Drift, the downstrea
ganisms in the current, is
for invertebrate dispers
colonisation of denude
and anthropogenic di
Davies 1976, Minshall
1989, Doeg & Milledg
studies have shown tem
position and density of
densities generally occ
densities during winte
1972). Densities of dif