Effects of Livestock Grazing on Wetlands: Literature Review

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Executive Summary

This report reviews the available scientific literature on the effects of livestock grazing in wetlands. It specifically identifies the effects of livestock grazing on the physical and biological components of estuarine, riverine and palustrine wetlands with the aim of providing preliminary guidelines for livestock grazing in these wetland types. Research gaps are then identified that could contribute to the development of more definitive wetland grazing guidelines.

The direct effects of livestock grazing include; the consumption of plant biomass, trampling of plants, including below-ground parts and soil, nutrient inputs and bacterial contamination from dung and urine and the introduction and dispersal of seeds and other propagules. The follow-on effects of these combined activities on the physical and biological components of wetland systems range enormously and can be difficult to predict.

The effects of the removal of plant biomass, depends on how species respond with some increasing biomass and reproductive output, others decreasing both and some decreasing biomass but increasing reproductive output. These changes to vegetative and reproductive output can alter species' population dynamics, with frequent changes in species composition that may lead to changes in the structure and function of vegetation communities. Adding complexity is the palatability of individual species and the feeding behaviour of different livestock species, which further alter community dynamics.

Removal of biomass usually in combination with the trampling of plants and soil frequently has deleterious effects on fauna. This can be due to damage of reproductive habitats (e.g., nest / burrow trampling, exposing spawning sites to desiccation and removal of mating perches and oviposition sites) and decreasing the spatial heterogeneity of vegetation, which reduces habitat diversity. However in areas that are densely vegetated particularly by only a few species, grazing may increase habitat diversity resulting in an increase in the abundance and diversity of fauna.

There is very little information on the effects of livestock grazing on water and soil quality in wetlands. A reduction in soil infiltration has been observed in several studies as a result of trampling and another study reported an increase in nitrates-N in heavily grazed fen soils from dung and urine inputs although ammoniacal-N was unchanged. A study of water turbidity and conductivity within 26 floodplain wetlands in Australia found that water quality was generally poorer under high intensity grazing than low intensity grazing.

There was no consistent pattern of effects within or across estuarine, riverine and palustrine wetlands. The lack of consistency is due to the wide variability of grazing effects. For this reason we recommend that the decision to allow grazing within estuarine, riverine and palustrine wetlands needs to be carried

out on a site-specific basis and led by well defined management objectives. Factors that should be taken into account when evaluating the use of grazing include;

- the palatability of individual species, their growth form and inherent vigour;
- level of disturbance experienced at the site;
- time elapsed since grazing commenced or was discontinued;
- stock type and stocking rate;
- grazing season, periodicity of grazing and length of grazing time.

The information required to assess many of these factors is scarce for New Zealand wetlands with only a handful of experimental studies having been conducted on a limited range of wetland types (e.g., lowland bogs, sub-alpine tarns, ephemeral swamps and floodplain terraces). Some guidance can be taken from the scientific evidence in other parts of the world however it needs to be interpreted within its natural context and the applicability to New Zealand conditions needs to be assessed (particularly the evolution of native species in the absence of mammalian browsers).

Research effort is best led by management objectives at a range of sites where wetland values are under threat. The choice of which wetland types to focus research efforts requires further investigation based on an evaluation of management priorities combined with an assessment of which wetland types are most likely to benefit from the effects of grazing.

1. Introduction

This review arose out of a workshop discussion at the Restoring Wetlands Forum in February 2004. The purpose of the discussion was to try and identify situations where grazing might have beneficial effects for a wetland as wetland managers struggle to cope with weed invasion and some farmers seek to continue with grazing practices they believe are beneficial to some wetland types. A handful of anecdotal examples were supplied by participants however many questions remained unanswered, particularly whether perceived beneficial effects were real and consistent across wetland types. The discussion continued amongst Regional Council staff interested in knowing more about the effects of livestock grazing to help landowners better manage wetlands as part of their role under the Dairying and Clean Streams Accord (Fonterra Co-Operative Group et al. 2003) leading to the commissioning of this review.

The specific objectives of this review were:

- To identify the effects of livestock grazing on the physical and biological components (e.g., soil, water, vegetation and fauna) of estuarine, riverine and palustrine wetlands.

- Provide some preliminary guidelines for livestock grazing in estuarine, riverine and palustrine wetlands.

- Identify research gaps that could contribute to the development of more definitive wetland grazing guidelines.

The literature review concentrated on papers and reports published in the last 15 years, which were located by searching science information databases and the web using appropriate search terms. These references were scrutinised for further key references, particularly seminal or review papers that much of the recent work is based on. As so little of the published information was from New Zealand, an email request for relevant information was circulated to the Department of Conservation Freshwater Group and the Local Government Ecologists Network (references that establish grazing effects in New Zealand wetlands are highlighted in Section 7: References).

The review initially looks at the scientific evidence of the effects of livestock grazing on the different wetland components before summarising these effects according to wetland types. Crucial to comparing studies is being able to standardise stocking rates of livestock. Where sufficient information is given stocking rates have been standardised to the ‘stock unit’ or ‘SU’ rate used in New Zealand where 1 SU is equivalent to 1 breeding ewe. Appendix 1 contains the conversion factors for converting different types of livestock (e.g., 1 dairy cow = 7 SU). In many instances only qualitative measures of grazing intensity are supplied i.e., ‘low’ or ‘high’ and in cases where quantitative measures are provided there appears to be no consensus on what stocking rates constitutes different levels of grazing intensity. In part this will depend on the livestock grazing capacity of the system and may or may not be known (e.g., wetland grazing guidelines for South Africa rely on a known carrying capacity of livestock in different bio-climatic regions; Wyatt 1997). For this reason, there has been no attempt to define different levels of grazing intensity and instead these have been reported verbatim.

2. Effects of livestock grazing

The direct effects of livestock grazing on ecosystems are well known and include (after Tanner 1992):

- consumption of plant biomass;
- trampling of plants, including below-ground parts and soil;
- nutrient inputs and bacterial contamination from dung and urine;
- introduction and dispersal of seeds and other propagules.

The follow-on effects of these combined activities on the physical and biological components of wetland systems are discussed below.

2.1 Vegetation

2.1.1 Biomass

Clary and Kinney (2002) looked at the effects of different grazing intensities on the total amount of biomass in a riparian wetland meadow in the USA. Clipping was used to simulate biomass removal and hoof imitators were used to simulate trampling at different grazing intensities. Root biomass was only affected at the heaviest grazing intensity (above ground parts reduced to 1 cm height, 3 times during summer) where it declined by 32.5%. Above ground biomass was affected under both moderate (clipped to 10cm once during summer) and heavy grazing intensities, with spring foliage growth up to 43% less on moderate treatment plots and up to 87% on heavy.

Several studies in wetlands have investigated the effect of how biomass removal can affect different wetland species. Matheson et al. (2002) simulate grazing by clipping a sward of *Glyceria declinata* in New Zealand. They found that both shoot and root growth were markedly reduced over the one month study period. In Australia, Crossle and Brock (2002) used clipping to stimulate grazing on a range of freshwater ephemeral wetland species in outdoor tanks. Three different responses to biomass removal were observed. In some species biomass and reproduction increased in response to clipping (e.g.,[1] *Centipeda minima, Lythrum salicaria*); in others both biomass and reproduction decreased (e.g., *Vallisneria gigantea*, *Myriophyllum variifolium*) and in the final group biomass decreased while reproduction increased (e.g., *Cyperus sanguinolentus*).

[1] Only species found in New Zealand are listed.

These changes to vegetative and reproductive output have the potential to alter species' population dynamics and potentially change the vegetation community. In many situations this may be deleterious if desirable species are eventually eliminated from the seedbank with consequences for restoration efforts. However there may be some situations where an undesirable species could be eliminated as occurred in Danish swamp meadows with the removal of hogweed (*Hercleum mantegazzianum*) by intensive sheep grazing (10 SU/ha) in 7 years (Anderson and Calov 1996). Conversely for undesirable species (in the context of New Zealand wetlands) that increase biomass and reproduction in response to biomass removal, such as purple loosestrife (*Lythrum salicaria)* and jointed rush *(Juncus articulatus)*, grazing would not be a suitable management tool.

2.1.2 Species richness and composition

Species richness is the number of species within a habitat and is often used as a measure of plant diversity. As species richness does not differentiate between indigenous and alien species, caution must be taken when using species richness as a measure of indigenous biodiversity. It was one of the most frequently measured variables in the grazing studies reviewed. Table 1 provides a summary of studies in different wetland types and the effect of grazing regimes on species richness.

Table 1: Summary of studies that measured species richness under different grazing regimes. '**-**' indicates a decrease in species richness with grazing and a '**+**' indicates an increase with grazing. Stocking intensities are given for studies where they have been reported. Where stocking rates have been included these have been converted to 'stocking units' or 'SU' using the NZ Agri-quality conversion factors (Appendix 1).

Wetland type	Grazing regime / intensity	Species richness	Citation
Saltmarsh (Holland)	cattle mod-high (1.3 – 1.7 animals / ha)	+	Bakker 1985
Lake shoreline (NZ)	cattle / low	+	Tanner 1992
	cattle / high	-	
Sub-alpine tarn (NZ)	cattle	+	Haines 1995 in Johnson 1998
Mire (UK)	cattle / high	+	Bullock & Pakeman 1997
Delta meadow	cattle	+	Jutila 1999
Seashore meadow (Finland)	cattle	-	
Lake turf (NZ)	cattle / horses	-	Champion et al. 2001
Riverine floodplain (France)			Touzard & Clement 2001
- abandoned grassland	simulated (herbicide)	-	
- mowed grassland	simulated (herbicide)	+	
Riverine floodplain (NZ)	cattle & sheep low (0.7 – 1.1 SU / ha)	+	Buxton et al. 2001
Ephemeral swamp (NZ)	cattle	+	Rebergen 2002

Species richness increased in almost as many studies as it was found to decline in. Usually an increase in species richness occurred when grazing reduced dominant species that were excluding less competitive species (e.g., Tanner 1992; Bullock and Pakeman 1997; Haines 1995 in Johnson 1998; Jutila 1999; Rebergen 2002). However if dominant species are not palatable or resistant to grazing then grazing may result in a decrease in species richness (Keddy 2000).

Species richness will also decline when trampling or over-consumption of certain species is sufficient to eliminate more species than are recruited (e.g., Jutila 1999; Champion et al. 2001). This has more often occurred under high intensity cattle grazing (e.g., Tanner 1992).

Different livestock species have different grazing behaviour and feeding preferences (Table 2) that may affect species composition. For example Menard et al. (2002) found that marshes grazed by horses were invaded by woody plants that horses wouldn't eat, whereas under cattle, woody plants were effectively controlled.

The intensity of grazing may also affect species composition. Looyen (1984 in Bakker 1985) found that under heavy grazing pressure (cattle at 1.6 animals / ha = 11.2 SU/ha), forage selection depends on the amount of newly produced biomass not on its' protein content and digestibility. Therefore under heavy grazing, species that have recently produced biomass are more likely to be impacted.

Trampling is also known to affect species composition, with some species being better adapted to compact soils (Wardle 1991) or requiring bare patches created by trampling to establish such as annual or stoloniferous species (Grevilliot and Muller 2002).

Table 2: Summary of reported feeding preferences and behaviour of livestock species.

Livestock species	Vegetation preferences	Grazing behaviour	Citation
Red deer (*Cervus elaphus*)	Prefer woody species with low foliar lignin. Prefer: *Hedycarya arborea*, *Phormium tenax*, *Ranunculus* spp. Avoid: *Dacrycarpus dacrydioides*, most ferns, *Carex coriacea, Juncus spp., Luzula* spp. *Uncinia* spp*., Corybas* spp., wirerush, *Potamogeton* spp., *Pratia angulata.*	Feed only within 2m of ground level. Attracted to water. Fence pace.	Forsyth et al. 2002 Forsyth et al. 2003 de Klein et al. 2003
Fallow deer (*Dama dama*)	Prefer woody species with low foliar lignin. Avoid: *Leptospermum scoparium*, most ferns, *Uncinia* spp.	Feed only within 2m of ground level. Attracted to water, will wallow. Fence pace.	Forsyth et al. 2002 Forsyth et al. 2003 Environment Southland 2000. de Klein et al. 2003
Goat (*Capra hircus*)	Prefer woody species with low foliar lignin. Prefer: *Cordyline australis.* Avoid: *Podocarpus totara*, most ferns, *Carex coriacea, Uncinia* spp.	Avoid water.	Forsyth et al. 2002

Livestock species	Vegetation preferences	Grazing behaviour	Citation
Horses (*Equus caballus*)	Prefer monocots. Prefer shorter grasses (<5cm). Avoid: woody species.	Will feed in water. Avoid plants contaminated by faeces or urine. Feed low to the ground. Consume 101- 215 g dm kg $LW^{0.75}$ day^{-1}.	Menard et al. 2002 Fleurance et al. 2001
Cattle (*Bos taurus*)	Prefer grasses 9-16 cm in height but eat most things including broadleaf and woody species.	Will feed in water (although varies with different breeds).	Grondman 1997
		Consume 46-119 g dm kg $LW^{0.75}$ day^{-1}.	Menard et al. 2002
Sheep (*Ovis aries*)		Avoid water.	Crawley 1983

2.1.3 Structure and function

The effects of livestock grazing on species composition have been found to ultimately affect the structure and function of wetland vegetation. Middleton (2002) found that sedge meadows that were recovering from cattle grazing structurally changed into a dense shrub carr while sedge meadows that had never been grazed had a different species composition to grazed meadows but were still similar structurally (i.e., they remained sedge meadows). It appeared that consumption of biomass and trampling of sedges, opened up the habitat allowing the shrub, *Cornus sericea* to invade. Cattle grazing also facilitated a short-term proliferation of subordinate species that prevented sedges from expanding as a result of the introduction of seeds and propagules and creation of bare patches. Once cattle were removed the shrubs expanded to become the dominant vegetation type.

Garnett et al. (2000) investigated whether light sheep grazing (0.016 – 0.16 SU / ha) had any effect on carbon accumulation in blanket bog and found there was no difference between grazed and ungrazed sites. The authors commented that this was not surprising given the very low grazing regime and that others had found no changes in above-ground biomass under this stocking density.

Grace and Ford (1996) found that grazing (simulated using clipping) combined with flooding reduced the ability of a freshwater marsh plant (*Sagittaria lancifolia*) to recover from saltwater intrusion whereas neither simulated grazing, nor salinity, nor flooding caused any long-term effect either singly or in pairwise combinations. These results suggest that the removal of plant biomass caused by grazing in combination with other stresses can be sufficient to have dramatic effects on some wetland plants. Sale and Wetzel (1983) also found that flooding of clipped *Typha* stands resulted in rapid decay of below-water biomass due to deprivation of oxygen to roots and rhizomes.

2.2 Birds

Several studies report variable effects of livestock grazing on wetland birds. The most commonly reported are the negative effects of trampling on nests (Beintema and Mueskens 1987; Popotnik and Giuliano 2000) and removal of vegetation biomass and structure, which degrade bird habitat values (Moore et al. 1984; Popotnik and Giuliano 2000). Two experimental studies in floodplain wetlands in the USA found that avian abundance and species richness increased in areas excluded from cattle grazing (Dobkin et al. 1998; Popotnik and Giuliano 2000).

Vegetation removal can however have beneficial effects on birds that rely on large areas of open water. In freshwater marshes in India and Costa Rica, cessation of cattle grazing lead to massive invasion of open water by emergent macrophytes (e.g., *Typha dominguensis*, *Paspalidium* spp.) that triggered substantial declines in waterfowl populations (McCoy and Rodriguez 1994). There is also some suggestion that light grazing on edges of open water can improve habitat for waterfowl and waders (Guthery and Stormer 1984; Buxton 1991).

The management of dense swards of kikuyu (Pennisetum clandestinum) using cattle grazing on Great Barrier Island opened up this vegetation and appeared to improve habitat usage by the endangered brown teal (*Anas aucklandica chlorotis*) (Barker 2004). Grazing was permitted outside of the teal nesting season and this promoted habitat for nesting, feeding and shelter in areas which were previously occupied by dense vegetation.

2.3 Invertebrates

There are very few studies that have investigated the effect of livestock grazing on wetland invertebrates. Hornung and Rice (2002) investigated the effects of cattle grazing on species richness of adult dragonflies in Canadian prairie wetlands. They found that species richness decreased with increasing grazing intensity. This relationship was attributed to the removal and trampling of vegetation necessary for mating perches, emergence and oviposition sites. In addition some species were found to be particularly sensitive to cattle grazing. One of New Zealand's large native dragonflies, *Uropetala oarovei*, is known to spend its larval stage in burrows in sub-alpine bogs (Winstanley and Rowe 1980) and may be particularly sensitive to cattle trampling.

In contrast to the results of Hornung and Rice (2002), Bullock and Pakeman (1997) anecdotally observed an enormous increase in the population of a rare damselfly in mire and wet heath in England, following an increase in cattle grazing intensity. No explanation was given for why this occurred.

Steinman et al. (2003) investigated cattle stocking densities on macro-invertebrates in modified freshwater wetlands in Florida. They found that cattle stocking had little impact on invertebrate community structure relative to prior pasture land use.

2.4 Fish

No studies were found in the overseas literature that had directly investigated the effects of grazing on fish populations in wetlands.

In New Zealand Mitchell (1991) has investigated the effects of cattle grazing on whitebait spawning grounds in a riparian wetland next to the Kaituna River in the Bay of Plenty. He found that inanga (*Galaxias maculatus*) preferred to lay their eggs within an exclosure and that survival rates were also significantly higher where cattle had been excluded. It is likely that poor survival of eggs in grazed pasture is due to the direct effects of trampling and consumption and indirectly as a result of biomass removal leading to desiccation and greater temperature fluctuations (Mitchell 1991; Mitchell and Eldon 1991). Mitchell and Eldon (1991) express concern that the common practice of intense rotational grazing of cattle on riverbanks is likely to have a greater impact than most other forms of grazing.

No-one has investigated the effects of livestock grazing on mudfish in New Zealand wetlands. However, during dry periods mudfish sometimes aestivate (i.e., become dormant in burrows) close to the soil surface (McDowall 1990). As livestock often access these wetlands as they dry out it appears likely that trampling by heavy livestock (e.g., cattle) may impact on mudfish by rupturing their ‘burrows’ causing desiccation.

2.5 Water quality

Jansen and Healey (2003) measured water turbidity and conductivity within 26 floodplain wetlands ranging from small ephemeral ponds to large billabongs that had known grazing regimes by sheep and cattle. The water quality measurements were converted to a sub-index score, which was compared between grazing intensities of wetlands. They found that in the first year of the study water quality scores were significantly lower in wetlands subjected to high intensity grazing (< 4 SU / ha / annum) but in the following year there was no significant difference between low and highly intensively grazed wetlands. The lack of difference in the second year appeared to be a result of a particularly dry season, which left many wetlands with only a shallow area of surface area that would have been prone to high turbidity even under low grazing intensities.

While in New Zealand there has been a lot of research that establishes the detrimental effects of livestock grazing on water quality in streams and lakes (see Parkyn et al. 2002 for a summary), few comparable studies could be found for wetlands. A study in Southland on the effects of livestock deer wallowing in a riparian wetland resulted in downstream concentrations of ammoniacal-N that were toxic to fish (Environment Southland 2000). In addition, Matheson et al. (2002) looked at how the nitrate buffering function of a riparian wetland might be affected by grazing using clipping in a microcosm study. They found that in the short-term (1 month) grazing did not affect the nitrate removal function. Although shoot N concentrations increased this was offset by decreased shoot biomass production.

2.6 Soil quality

While a number of studies have investigated the effects of livestock on soil quality in a range of ecosystem types, very few have been conducted in wetlands (e.g., Milchunas and Lauenroth (1993) reviewed 34 studies of which none occurred in wetlands). The few papers found are summarised below.

Amiaud et al. (1998) found that in old embanked salt marshes, trampling altered the soil structure (i.e., to a lamellar structure indicative of compaction) reducing soil infiltration and preventing salt from being leached from the soil. In ungrazed sites soil salinity decreased within 5 years of grazing being ceased.

Taboada et al. (1999) found that in riverine wetlands soil infiltration rates were much lower in cattle grazed areas than ungrazed. Soil structural stability also decreased in the grazed plots however this was due to grazing when soils were dry (trampling fractured and pulverised dry soil leading to smaller soil aggregates) rather than wet. They suggested that soil deterioration could be limited by reducing stocking intensities during dry periods.

Under heavy cattle and horse grazing, Van Hoewyk et al. (2000) found that calcareous fens had lower pH and higher NO_3^- levels, with no difference in ammonium between grazed and ungrazed sites. These results suggest that manure inputs were being nitrified and that although the fens were accumulating N, there may be some resilience to increase in potentially toxic ammoniacal N levels.

3. Effects of livestock grazing on different wetland types

The previous section explored the range of diverse effects of livestock grazing on different wetland components. In many instances the effects of grazing weren't necessarily detrimental leading to the question of whether there are some wetland types that are more resilient to livestock grazing or whether some conservation values (e.g., rare plants) could be effectively managed under specific grazing regimes. To attempt to answer these questions, effects that have been quantified in studies reviewed have been summarised in the following sections according to wetland types.

3.1 Estuarine wetlands

Estuarine wetlands are defined as partly enclosed by land but open to the sea, with evident tidal effects, or coastal land markedly affected by marine salt with salinity between 0.5 – 3 % (Johnson & Gerbeaux, in press). Table 3 presents a summary of the studies reviewed in estuarine wetlands and the different types of effects observed.

Table 3: A summary of the different effects of grazing on wetland components in estuarine wetlands. Where stocking rates have been included these have been converted to 'stocking units' or 'SU' using the NZ Agri-quality conversion factors (Appendix 1).

Wetland class / form	**Grazing regime**	**Vegetation**	**Fauna**	**Water and soil quality**	**Citation**
Saltmarsh (Holland)	cattle mod-high (7.2 – 9.35 SU / ha)	Increase in species richness.			Bakker 1985
Floodplain marsh (0.5 – 2% salinity) (NZ)	cattle (17.5 SU / ha) cashmere goats		Decrease in number and survival of whitebait eggs.		Mitchell 1991
Meadows of former saltmarsh (France)	not specified			Decrease in soil structure.	Amiaud et al. 1998
Delta marsh (Finland)	cattle	Increase in rarer species. Decrease in number of seedlings.			Jutila 2001
Seashore meadow (Finland)	cattle	Decrease in species richness. Decrease in total cover. Increase in rarer species. Decrease in dicot seedlings. Increase in monocot seedlings.			Jutila 1999 Jutila 2001 Jutila 2003

As expected from the discussion in section 2.1, the effects of grazing on estuarine vegetation was mixed. The increase in species richness observed by Bakker (1985) was due to consumption and trampling decreasing the amount of litter that was suppressing germination and restricting bare areas necessary for the colonisation of many species. Whereas there is no clear explanation for why species richness decreased in the studies of Jutila (1999; 2001; 2003) the increase in rare species was probably due to the increase in suitable habitat following the decrease in the smothering effects of the emergent *Phragmites australis.*

Jutila (2001) contends that the stocking rate for conservation purposes of seashore meadows and delta marshes would depend on the local conditions, habitat type and herbivore species. He suggests that a ‘rule of thumb’ for boreal seashore meadows would be to graze 1 cattle / ha (i.e., 7 SU / ha) during the summer and for coastal deltas 2 cattle / ha (i.e., 14 SU / ha) during summer.

High grazing intensity has major impacts on the survival of whitebait in spawning grounds that are located at the extreme waters edge of river floodplains and sometimes in non-tidal marshes on the edges of large lakes (Mitchell and Eldon 1991). In these areas Mitchell and Eldon (1991) recommend that stock are permanently excluded or if noxious weeds need to be controlled then at least temporarily excluded during spawning season (Jan-May).

3.2 Riverine wetlands

Riverine wetlands include those situated in river or stream channels, or immediately adjacent to watercourses or on deltas that are influenced by continuous or intermittently flowing water (Johnson and Gerbeaux, in press). Table 4 presents a summary of the studies reviewed in riverine wetlands and the different types of effects observed.

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Table 4: A summary of the different effects of grazing on wetland components on riverine wetlands. Where stocking rates have been included these have been converted to 'stocking units' or 'SU' using the NZ Agri-quality conversion factors (Appendix 1).

Wetland class / form	Grazing regime	Vegetation	Fauna	Water and soil quality	Other	Citation
Floodplain (Argentina)	cattle grazing low (7 SU / ha / yr)			Soil structural stability decreased temporarily during dry periods. Soil infiltration decreased.		Taboada et al. 1999
Floodplain meadow (USA)	Cattle Low (2.75 SU / ha)	Stem density, shrub cover and spatial heterogeneity all less than ungrazed plots.	Avian richness and abundance 1.5 – 1.6 times less abundant than ungrazed plots. No difference in nest success and density.			Popotnik & Giuliano 2000
Floodplain (NZ) Westland	cattle & sheep low (0.7 – 1.1 SU / ha)	Increase in species richness.				Buxton et al. 2001
Floodplain (Australia)	cattle & sheep mod (4-8 SU ha/ annum) high (>16 SU / ha / annum)				Excellent riparian condition.[2] Very poor riparian condition.	Jansen and Robertson 2001

[2] Riparian condition was assessed by field scoring of sub-indices which include; width and continuity of vegetation, vegetation cover, bank stability, aquatic woody debris, soil structure, terrestrial debris, regeneration of key species.

Wetland class / form	Grazing regime	Vegetation	Fauna	Water and soil quality	Other	Citation
Floodplain (France) - abandoned grassland - mowed grassland	 simulated (herbicide) simulated (herbicide)	 Decrease in species richness. Increase in species richness.				Touzard & Clement 2001
Floodplain meadow (USA)	simulated[3] moderate early summer (1 animal unit month (AUM) / ha) heavy season long (7.5 AUM / ha)	43% less above ground biomass. No change in root biomass. 87 % less above ground biomass. 32.5 % decrease in root biomass.		Soil surface depressed by ~ 3cm. Soil surface depressed by ~ 11.5 cm.		Clary and Kinney 2002
Floodplain (NZ) Westland	cattle moderate (12- 15 SU / ha)	More small and tall totara seedlings. Reduced gorse cover.				Miller and Wells 2003
Floodplain (Australia)	cattle & sheep low (< 4 SU / ha / annum) high (> 4 SU / ha / annum)		Frog species richness higher compared to high grazing intensities. Frog species richness lower compared to low grazing intensities.	Water quality better compared to high grazing intensities. Water quality poorer compared to low grazing intensities.		Jansen and Healey 2003

[3] Grazing simulated by different intensities of clipping, hoof impacts using a hoof imitator, and application of manure and urine.

Grazing of cattle and sheep at low-moderate stocking rates in riverine floodplains in Westland, New Zealand resulted in mostly beneficial effects for wetland vegetation (Buxton et al. 2001; Miller and Wells 2003) although it should be noted that at both study sites (Arawata and Whataroa Rivers) the vegetation communities were highly modified from grazing in the past and contained a high abundance of exotic species. The beneficial effects observed appear to be from livestock grazing reducing rank grasses and dense exotic herbs (e.g., *Holcus lanatus, Lotus pedunculatus, Ranunculus repens*) that had been overwhelming small native sedges (e.g., *Isolepis reticularis*), *Carex* species and preventing the regeneration of totara seedlings.

The effects of grazing on riverine floodplains in other parts of the world tended to be less positive with mixed effects on species richness, and major impacts on both below and aboveground biomass at high stocking rates. High stocking rates similarly had much worse effects on soil quality, water quality and overall wetland condition than low stocking rates.

Frog species richness decreases with increased grazing intensity probably as a result of changes in wetland habitat quality, particularly a decrease in the habitat structural complexity (from biomass consumption and trampling) increasing fish predation and reducing reproductive opportunities (Jansen and Healey 2003). Disturbance and alteration of vegetation structure also appears to affect bird species richness and abundance (Popotnic and Giuliano 2000) even at low grazing intensities suggesting that there are few situations where grazing of riverine floodplains would not have a detrimental impact on avian abundance.

3.3 Palustrine wetlands

Palustrine wetlands include all freshwater wetlands fed by rain, groundwater or surface water that are not directly connected to estuaries, lakes or rivers (Johnson and Gerbeaux, in press). Table 5 presents a summary of the studies reviewed in palustrine wetlands and the different types of effects observed.

Table 5: A summary of the different effects of grazing on wetland components in palustrine wetlands. Studies are listed in order of increasing fertility. Where stocking rates have been included these have been converted to 'stocking units' or 'SU' using the NZ Agri-quality conversion factors (Appendix 1).

Wetland class / form	**Grazing regime**	**Vegetation**	**Fauna**	**Water and soil quality**	**Citation**
Sub-alpine tarn (NZ)	cattle	Species richness increased.			Haines 1995 (Reported in Johnson 1998)
Swamp (Denmark)	sheep 8 SU/ ha / summer-autumn	Eliminated undesirable weed in 7 years. Species richness decreased leaving mostly grazing tolerant species.			Anderson & Calov 1996
Mire (UK)	cattle / low cattle / very high (175 - 483 SU / ha)	Species richness less than under high grazing pressure. Litter depth greater and less bare ground than under high grazing pressure. Species richness higher than low grazing pressure. Litter depth less and more bare ground than under low grazing pressure.	Substantial increase in abundance of rare damselfly.		Bullock & Pakeman 1997
Calcareous fen (USA)	cattle & horse grazing			Grazed sites had lower pH and higher NO_3^- levels.	Van Hoewyk et al. 2000

Wetland class / form	Grazing regime	Vegetation	Fauna	Water and soil quality	Citation
Ephemeral swamp (NZ)	cattle	Species richness greater under grazing, but initially increased once grazing was removed and then declined as wetland overtaken by a few exotic grasses.			Rebergen 2002
Prairie wetlands (USA)	cattle	Species richness decreased as grazing intensity increased.	Species richness of odonata decreased as grazing intensity increased.	Zinc, ortho-phosphates and ammonium in water were significantly higher at cattle grazed sites.	Hornung & Rice 2003
Low-mid altitude bog (Chatham Islands, NZ)	not specified	Species richness was greatest in most modified plots[4]. Plant height was shortest in most modified plots.		Peat moisture was lowest in most modified plots. Nutrients (N, P, K), pH, total C, and von Post index were highest in most modified plots.	Clarkson et al. 2004.

[4] Bog vegetation plots were ranked according to modification by stock and fire. A 3 point scale was used for stock modification: 0 = no visible stock damage, 1 = minor foliage browsing or trampling, 2 = medium-severe foliage browsing and/or trampling damage. The effects of fire have not been separated from those of stock.

The effects on soil and water quality observed by Clarkson et al. (2004) with peat decomposition clearly underway in sites most modified by livestock grazing make a convincing case for excluding livestock grazing from bogs in New Zealand. While species richness was greater in bogs that had been grazed by livestock this was partly because of an increase in small herbaceous plants many of which were exotic weeds (e.g., *Hypocheris radicata*, *Leontodon taraxacoides*, *Anthoxanthum odoratum and Holcus lanatus*).

The effects of extremely heavy cattle grazing (175 – 483 SU / ha) in UK mires met the management goal of preventing succession to woodland by opening up the vegetation, repressing scrub and encouraging low-growing plants with a subsequent increase in species richness which was not as successful under less intensive grazing (Bullock and Pakeman 1997). Heavy grazing in these mires also substantially increased the abundance of a rare damselfly.

The conservation goal of eliminating the unwanted hogweed in a swamp in Denmark was achieved under far reduced stocking rates (i.e., 8 SU / ha), however this amount of grazing pressure was too great for the remaining vegetation which was reduced to unpalatable monocots (Anderson and Calov 1996). At half the stocking intensity (i.e., 4 SU / ha) species richness was greater but hogweed could not be eliminated.

The other two New Zealand studies in palustrine wetlands (Haines 1996 in Johnson 1998; Rebergen 2002) are both wetlands where the indigenous vegetation is mostly comprised of low growing turf vegetation. In both cases, livestock were excluded to try and increase the cover of these turf species. Like the studies on NZ riverine wetlands, removal of grazing led to an increase in tall exotic grasses to the detriment of species richness and cover of the shorter, less productive indigenous species.

4. Potential guidelines for livestock grazing in wetlands

In most cases the grazing of wetlands in New Zealand is undertaken to provide food for livestock species where this is seasonally unavailable in more terrestrial habitats, rather than for any conservation benefit. However, the ability of cattle grazing to prevent succession to woody vegetation (e.g., alien willow species) and to control dense mats of sprawling alien species such as reed sweet grass (*Glyceria maxima*) and reed canary grass (*Phalaris arundinacea*) (pers. obs. of authors at Whangamarino Wetland, Waikato) means that cattle grazing can offer some conservation value. Likewise, sheep grazing has been found to help maintain a short turf that increases native vegetation species diversity (Haines 1996 in Johnson 1998).

Stock grazing is however frequently accompanied by deleterious impacts such as reduced soil infiltration from trampling and nutrient enrichment and bacterial contamination from dung and urine. There are often alternatives to grazing that provide similar benefits without these adverse effects. For example the targeted use of herbicides can selectively control problematic wetland species in New Zealand with no effect on native vegetation (Champion 1999) and mowing is frequently used in the Netherlands to maintain native plant species diversity of floodplain wetlands that would otherwise be reduced to only a few plant species (Grondman 1997). Turf communities at Whitiau Scientific Reserve near Wanganui have been managed by scraping away existing vegetation to promote endangered low-growing turf species (Johnson and Rogers 2003). Fire has also been successfully used to reduce wetland vegetation biomass in other countries (Garnett et al. 2000).

Others have tried to determine appropriate guidelines or frameworks for managing introduced herbivores for conservation purposes in ecosystem types in New Zealand based on far more comprehensive data on grazing effects than exists for New Zealand wetlands (e.g., Meurk et al. 1989; Buxton et al. 2002; Forsyth et al. 2003; Walker et al. 2003; Ewans 2004). In general they have concluded that the effects of grazing are so variable that grazing decisions should be based on conservation objectives specific to each site. This conclusion is also valid for this review.

Some general guidance can possibly be taken from wetland grazing studies conducted in other areas of the world but they need to be interpreted within their natural context and the applicability to New Zealand conditions then needs to be assessed. For example wetland systems in most other countries evolved in the presence of large browsing mammals and therefore benefits from livestock grazing may restore ecological imbalances that have developed in absence of wild browsing mammals (e.g., McCoy and Rodriguez 1994).

While New Zealand’s vegetation did not evolve in the presence of large mammalian browsers it did evolve in the presence of a wide range of herbivores (Rudge 1989). Most notable in wetlands would have been avian species known to consume wetland / aquatic vegetation. These would have included moas, native geese (*Cnemiornis* spp.), the extinct swan (*Cygnus sumnerensis*), NZ giant coot (*Fulica chathamensis*) and Hodgen’s waterhen (*Gallinula hodgenorum*) (Holdaway 1989). These grazing birds would impact on above-ground biomass, but not have the trampling impacts of heavy mammalian browsers especially cattle. The grazing impacts of introduced waterfowl (e.g., Canada geese, *Branta canadensis maxima*) and potentially smaller, lighter mammals (e.g., rabbits, hares and possibly sheep) are likely to be similar to the pre-human grazing situation.

Swamp vegetation, especially in riverine systems is highly dynamic and relies on disturbance through flooding as a ‘resetting’ agent (Howard-Williams 1991), allowing a greater diversity of early successional vegetation and natural regeneration. As a result of flood control schemes, many of New Zealand’s lowland swamp wetlands are now far less prone to extreme flooding events. Essentially grazing is another disturbance mechanism, but its substitution for reduced dynamism of the hydrological regime needs evaluation.

In each situation, the key desirable attributes of a wetland that require protection and the threats to those values and available methods of mitigation should be considered. If a wetland is currently modified by the impacts of mammalian grazing, then manipulation of stock type, stocking rate, grazing season, periodicity of grazing and length of grazing time should be considered as a means to achieve better management. Meurk (1989) also recommends that the palatability of individual species and their growth form and inherent vigour as well as the general level of disturbance should also be taken into account in site-specifc evaluations. If a wetland has not been grazed by stock, it would be unwise to begin grazing as a form of management.

5. Future research needs

Research priorities have previously been recommended for ephemeral wetlands based on a comprehensive review of current knowledge relating to ecosystem properties, threats and impacts (Johnson and Rogers 2003). They were:

1. What are the impacts of small hoofed animals (e.g., sheep) on freshwater turf plants, substrates and processes?

2. What are the possible benefits of appropriate intensity and timing of sheep and/or rabbit grazing as a management tool to minimise the competitive impact of naturalised weedy plants capable of overtopping and replacing native turf plants?

3. What are the impacts of cattle trampling, grazing and faecal matter on turf wetlands?

We consider these types of research priorities to be applicable to other wetland types. However we note that since grazing effects are so variable and site specific, research efforts are best led by management objectives at those sites where wetland values are currently under threat. We also recommend that another research need, related to (2) above is determining the value of grazing as a management tool in relation to alternative options (e.g. mechanical removal, herbicide application) that could achieve the same biodiversity / wetland conservation goals and with potentially less adverse effects.

The choice of which wetland types to focus research efforts on requires further investigation, based on an evaluation of management priorities combined with an assessment of which wetland types are most likely to benefit from the effects of grazing.

To achieve the above research objectives, appropriate sites need to be selected, an evaluation made of current grazing regimes and their impacts (on vegetation dynamics, associated fauna, use by waterfowl, hydrologic and edaphic conditions) followed by reassessments of the impacts under manipulated grazing regimes (e.g. exclosures / different livestock types / stocking densities).

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Appendix 1: Stock unit (SU) conversion factors

From AgriQuality New Zealand Ltd. and accessed at http://www.ew.govt.nz/enviroinfo/indicators/land/use/riv9/techinfo.htm.

Farm Type	Class	Stock Units (SU) or ewe equivalent
Dairy	Dairy Cows	7
	Dairy Replacements	4.25
	Other (bulls etc.)	5.5
Beef	Beef Cows	5.5
	Beef Dry	4.75
	Beef Replacements	4
	Other	5.5
Sheep	Breeding Ewes	1
	Sheep Dry	0.8
	Sheep replacements	0.7
	Other	0.8
Deer	Hinds	1.9
	Deer for Meat	1.8
	Stags for velvet	2.1
	Other	1.8