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Unrestricted dairy cattle grazing of a pastoral headwater wetland and its effect on water quality

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ABSTRACT

Unrestricted cattle access to pastoral wetlands can result in increased pollutant loads from agricultural areas. We quantified the time a herd of dairy cattle spent grazing a pastoral headwater wetland and its associated impact on water quality. Over a two year period a herd of ~220 dairy cattle rotationally grazed a paddock containing a permanently saturated pastoral wetland. Flow and turbidity were continuously monitored at a v-notch weir and baseflow and event samples were collected and analysed for TSS, *Escherichia coli* and various forms of N and P. Cattle were detected grazing the wetland paddock on 18 days by time-lapse cameras. Cattle only entered and grazed the saturated wetland area for 30–40% of the time and there were usually only a few animals in the wetland at one time. Cattle that did graze the wetland tended to remain near the edge. We attribute the low level of wetland grazing to the cattle recognizing the risk of entrapment in the deep (up to 2 m), boggy wetland soil. A measurable increase in pollutants (attributable solely to cattle generated disturbance) occurred only once. This occurred when a cow became entrapped in close proximity to the water quality monitoring location on a day when wetland flow was elevated. Exclusion of cattle from our study wetland by fencing is therefore unlikely to substantially improve downstream water quality. Further research is required to determine whether this is the case for similar wetlands in different environments.

1. Introduction

Unrestricted cattle access to streams and riparian areas can result in a number of adverse environmental effects, including degrading downstream water quality (Belsky et al., 1999; Davies-Colley et al., 2004; Vidon et al., 2008), damaging soils and vegetation and increasing erosion risk (Trimble and Mendel, 1995). Despite our understanding of the effects of cattle grazing within and near streams, few studies have specifically addressed the impact (particularly on water quality) of unrestricted cattle access to wetlands (e.g. McKergow et al., 2012). Wetlands within pastoral agricultural areas are particularly vulnerable if fences are not present to prevent cattle access. Farmers often view these wetlands as suitable areas for grazing and livestock water sources and typically there is little incentive to erect expensive fencing to exclude cattle.

Pastoral wetlands are common features in the hilly and undulating parts of New Zealand and have also been reported from other regions (e.g. Glenn and Woo, 1997; Merot et al., 2006). These wetlands (also known as flushes, valley bottom, seepage, or riparian wetlands), generally occur within the headwater areas of catchments and along the sides of streams. In many cases the wetlands are the result of infilling of ephemeral streams and are a legacy of large-scale catchment disturbance (see Zierholz et al., 2001). They are primarily fed by shallow subsurface flow that re-emerges via springs or seeps and their water content status may range between temporary dryness and permanent saturation. Although often small (<1 ha), they may represent a large proportion of headwater catchments and as they occur at the land–water interface they have the potential to attenuate contaminants being transported into waterways (Merot et al., 2006).

As found with streams and riparian zones (e.g. Smith et al., 1992; Trimble and Mendel, 1995; Collins and Rutherford, 2004) cattle with unrestricted access to these wetlands tend to be attracted to the water and presence of forage material. Collins (2004) used faecal pat numbers to confirm that cattle freely graze shallow wetlands (~0.3 m depth) but, probably due to the fear of entrapment, remain around the margins of deep wetlands (>1 m depth). Cattle access can adversely affect wetland biodiversity, reduce vegetation biomass, change plant composition, and deposit faeces and urine directly into water (Steven and Lowrance, 2011). Extensive cattle trampling can also entrain wetland material, resulting in increased fluxes of sediment and organic material entering streams. The pres-

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ence of large, heavy animals in wetlands can also damage soil structure and increase micro-topography, surface roughness and ponding (Bilotta et al., 2007).

The water quality impact of livestock grazing within riparian zones and streams has been the attention of considerable recent international research. Most studies have demonstrated that livestock exclusion from riparian areas can improve various measures of water quality including water clarity, suspended sediment, phosphorus, nitrogen and waterborne pathogens/faecal indicator bacteria (e.g. Belsky et al., 1999; Davies-Colley et al., 2004; Line, 2003; Line et al., 2000; McKergow et al., 2003; Sunohara et al., 2012; Vidon et al., 2008; Wilkes et al., 2013a,b). In terms of mitigating the effects of non-point source pollution sources, wetlands perform similar functions to riparian zones (EPA, 2005). In fact, in some circumstances riparian areas are considered to be wetlands themselves. Accordingly, one would expect the effects of livestock access to wetlands to be comparable to that of riparian zones. In New Zealand a wetland, as defined by the Resource Management Act 1991, '*includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions*' . Few studies have examined the water quality impact of livestock access to such areas and even fewer have assessed the impact of livestock grazing on permanently saturated pastoral wetlands. McKergow et al. (2012) detected cattle-induced increases in nitrogen (N) and turbidity at the outlet of a shallow permanently saturated pastoral wetland near Lake Taupo, New Zealand. They found that although cattle only spent 10% of the time in the wetland paddock they were responsible for 30% of the total nitrogen export (mostly as organic N). Collins (2004), also working in New Zealand found that unrestricted cattle access to a small, shallow permanently saturated wetland in Waikato hill-country contributed to high levels of faecal bacteria.

Here we examine the degree to which dairy cattle graze a permanently saturated pastoral wetland and what impact this grazing has on wetland water quality. It was hypothesized that episodes of cattle wetland grazing would be associated with increased fluxes of suspended solids, nutrients and faecal indicator bacteria (*Escherichia coli*). They key difference between this study and studies that have examined the impact of livestock grazing on saturated riparian areas is that here the wetland is not associated with a stream channel. This allowed the impact of livestock grazing of a saturated terrestrial area to be isolated from the impact of livestock-induced stream channel damage and wading disturbance

2. Materials and methods

2.1. Study site

The study wetland was located on a dairy farm near Kiwitahi in the headwaters of the Toenepi catchment in the eastern Waikato region, New Zealand (Fig. 1). The Toenepi catchment is a 15 km^2 sub-catchment of the Piako River (1440 km^2). The Toenepi catchment is intensively farmed and 75% of the catchment area is under dairy production with a stocking rate of ~3 cows ha^{-1} (Wilcock et al., 2006). The mean annual rainfall of the area is 1377 mm. The wetland catchment is dominated by Morrinsville clay soil (NZ Soil Classification: Orthic Granular Soil). The upper Toenepi catchment is hilly with ~80% of the area classified as either rolling or steep (>10% gradient); (Müller et al., 2010).

Rotational grazing is practiced on the dairy farm and the farm is divided into 33 individual paddocks (fenced pasture area for grazing) of between 1.0 and 3.1 ha. The herd of ~220 (Holstein Friesian) cattle are operated as one herd. The study wetland is located within a small (~1.9 ha) fenced paddock. As the wetland has no flowing surface water most of the time, drinking water is available to the herd from a water trough (groundwater bore source) within the paddock. The wetland paddock (with exception of the wetland itself) is steep (mostly exceeding 20°). The paddock is grazed for ca. one day every 40 days during winter and summer and ca. one day every 20 days during spring and autumn.

The wetland has an area of ~0.15 ha and an average slope of 3.5°. The permanently saturated wetland soil is composed largely of a mix of organic material and the clay-based soils eroded from the surrounding hillslopes. Sediment probe measurements indicated that within 1 m of the edge the saturated layer was generally between 0.5 and 1 m deep. Depths increased with distance from the edge, and were generally between 1 and 2 m in the centre of the wetland. The wetland vegetation is dominated by glaucous sweet grass (*Glyceria declinata*), with jointed rush (*Juncus effusus*), sedge (*Carex sp.*) and lotus (*Lotus pedunculatis*) also being present (Wilcock et al., 2012).

2.2. Site monitoring and laboratory analysis

The study site was monitored for the two year period between October 2011 and September 2013. Flow was measured at a natural constriction in the lower reaches of the wetland (Fig. 1) and the monitored catchment area was ~5.2 ha. Stage height was measured by a Unidata Hydrologger water level recorder (1 mm resolution) on a 30° v-notch weir and converted to flow. Continuous turbidity measurements (5 min intervals) were recorded by a Campbell Scientific OBS3 turbidimeter (nominal range 0–1000 nephelometric turbidity units (NTU)). An ISCO 3700 automatic water sampler was programmed to collect water samples behind the weir using both stage and turbidity triggers. The stage sampling trigger was activated when water level rose in response to rainfall events. The aim of the turbidity-based trigger was to initiate sampling in response to non-flow related (i.e. cattle activity) increases in turbidity. Low flow grab samples were collected during site visits approximately every six weeks. During the period between November 2012 and May 2013, the study site experienced exceptionally dry conditions (MPI, 2013). Consequently, no flow was recorded at the weir from early January 2013 through to May 2013. Despite this, the wetland remained wet and boggy during this time.

Once collected, samples were immediately placed in an insulated storage bin containing an ice slurry. Samples were delivered to the NIWA—Hamilton Water Quality Laboratory on the day of collection for grab samples and within 24 h for samples collected from the automatic sampler. Samples were analysed for *E. coli*, total suspended solids (TSS), turbidity, oxidized N (hereafter referred to as nitrate-N), ammonium-N, total nitrogen (TN), dissolved reactive phosphorus (DRP), total dissolved phosphorus (TDP) and total phosphorus (TP). Total organic nitrogen (TON) was approximated by subtracting nitrate-N and ammonium-N from TN. All ammonium-N, nitrate-N and DRP samples were filtered with a Millipore® syringe and filter holder containing a GF/C glass fibre pre-filter (47 mm diam., 1.2 μm pore size), and a Sartorius® cellulose acetate membrane filter (47 mm diam., 0.45 μm pore size). Details of all laboratory analyses and detection limits are presented in Table 1.

To document the duration and behaviour of cattle wetland grazing time-lapse digital cameras were positioned at two locations within the wetland catchment (Fig. 1). The upper camera surveyed the upper third of the wetland (referred to as the upper wetland) while the lower camera was positioned at the weir and surveyed the lower wetland (referred to as the lower wetland). The cameras took one photograph every five minutes during daylight hours. To calculate the time cattle spent grazing the wetland, it was assumed that each time an animal was recorded with more than their two front