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Effects of Providing Clean Water on the Health and Productivity of Cattle

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June 2012

Report for Northland Regional Council

Client report number: RE400/2012/346

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1. EXECUTIVE SUMMARY

- This report reviews national and international published scientific literature and shows the following:
- Animals grazing riparian areas can affect water quality, stream channel morphology, hydrology, riparian zone soil properties, vegetation and aquatic and riparian wildlife.
- Best management practices to exclude livestock from riparian areas include livestock exclusion fencing and providing an off-stream water source, however, this practice is often expensive and unpractical.
- The aim of this report was to investigate the value of providing a reticulated stock water supply from a high quality source compared to direct access to natural or man-made water sources on livestock health and productivity.
- Water intake is closely related to feed intake and thus animal productivity. Cattle are sensitive to the palatability of water and prefer to drink clean water without contamination.
- It was found that the provision of an off-stream clean water source may be beneficial for production particularly in conditions that are not stressful (e.g. no climatic stress and appropriate feeding conditions), however, there are only a few studies that have explored this topic.
- No studies in New Zealand have been carried out regarding potential positive effects of providing clean water from an off-stream water source to cattle.
- Water provided in off-steam sources should always be of high quality and freely available. Many of the factors that influence the survival and proliferation of bacteria in natural aquatic ecosystems have parallels in cattle water troughs. Factors, such as the nutrition content of the water, exposure to sunlight, cleaning management, trough design, and air temperature are all likely to influence the quality of the water.
- Cattle management should consider water quality together with forage conditions and resources such as shade and shelter in order to achieve optimal production.
- Further research regarding cattle utilization of riparian areas, the effects of providing off-stream water sources, and the effects of clean, palatable water in New Zealand conditions is warranted.

2. BACKGROUND

Habitat selection and use by animals is dependent on the availability of resources that the animals require to meet their nutritional and comfort needs (Mysterud & Ims 1998). Riparian areas (the interface between land and a river or stream) are of high value to cattle as they often provide food, water and shelter from inclement weather conditions. In many parts of the world, including New Zealand, there are concerns that cattle grazing in riparian areas may affect water quality by contamination with nutrients, pathogens and sediments, as well as affecting stream channel morphology, hydrology, riparian zone soil properties, vegetation and aquatic and riparian wildlife (reviewed by Belsky *et al* 1999). These changes are mainly caused by animals tramping and depositing excretions in and near the waterways. Animal manure is a source of bacteria, nitrogen and phosphorous that affects the water quality, therefore, reducing manure deposits in the stream and riparian area is desirable, especially since excretions are highly correlated with time spent in one location (White *et al* 2001; Haan *et al* 2010). The majority of literature investigating the effects of livestock grazing riparian zones has been carried out in North America in regions that differ in a range of environmental conditions. However, there are also a number of New Zealand studies exploring this issue. Most overseas studies have shown a negative impact of grazing (e.g. Kauffman *et al* 1983; Belsky *et al* 1999) or little or no impact (Buckhouse & Gifford 1976; Gary *et al* 1983) on riparian systems. In New Zealand, reports have shown that increased farming intensity may result in greater nutrient enrichment of waterways (Vant 1999; Parkyn *et al* 2002) and contamination by microbes (Vant 2001; McBride *et al* 2002; Nagels *et al* 2002). Contamination of water ways may lead to reduced water quality which in turn may lead to decreased productivity. A comprehensive New Zealand report prepared for MAF Sustainable Farming Fund (MAF SFF Project 03/001 2004) investigated the impact of water quality on livestock productivity and it was concluded that issues of microbial contamination and contamination with high concentrations of particular minerals or other contaminants of water were the primary concern from an animal health perspective. However, the potential positive effects of providing a clean water supply on animal productivity have not been extensively studied.

The aim of this report was to investigate the value of providing a reticulated stock water supply from a high quality source compared to direct access to natural or man-made water sources on livestock health and productivity. This was carried out by reviewing existing national and international literature published in scientific journals.

The review does not go into depth about the different aspects of water properties and general guidelines regarding water quality as this has been extensively covered in the MAF report (MAF SFF Project 03/001 2004). Instead, the focus of this review is to understand how and why animals use different water sources and the effects of clean, palatable water on cattle water consumption and subsequent productivity. The focus is on literature that has been peer-reviewed in scientific journals. However, reference to non peer-reviewed reports and guidelines is given where the scientific evidence is limited.

3. CATTLE UTILISATION OF RIPARIAN AREAS

Riparian areas often provide attractive resources to cattle, such as highly palatable forages, water, shade and shelter. The favourable micro-environment in riparian areas cause grazing cattle to spend disproportionate amounts of time within the area, resulting in overgrazing and accelerated stream bank erosion (Belsky *et al* 1999). Utilisation of riparian areas will vary with season due to the availability of forage and environmental conditions (Parsons *et al* 2003). Cattle will seek favourable micro-climates in inclement weather and access to water is not only essential for animal production (below), it is also important to cattle to assist cooling in summer (e.g. Legrand *et al* 2011). Increased heat load, caused by a combination of air temperature, relative humidity, air movement, and solar radiation, increases body temperature and respiration rate, and can reduce the feed intake and, consequently, milk and meat production (Hahn 1999; Ominski *et al* 2002; West 2003). Schütz *et al* (2010) demonstrated that dairy cattle in the Waikato region in New Zealand spent more time around a water trough in warm weather, and in particular when they had no access to shade. Similar findings have been shown in beef cattle, where animals were more likely to be observed in stream or in riparian zones in increasingly warm weather (Haan *et al* 2010). Animals sensitive to heat may be even more inclined to use water as cooling. For example, cattle grazing endophyte-infected tall fescue in warm weather may experience difficulty in dissipating heat (Al-Haidary *et al* 2001) and may spend more time in stream water to help regulate their body temperature.

Cattle will also use the vegetation in riparian areas as protection against inclement weather. Shade is an important resource to cattle (Schütz *et al* 2010) that is readily used when given access to it and beneficial in terms of alleviating negative effects of increased heat load (Roman-Ponce *et al* 1977; Valtorta *et al* 1997). Cows will spend more time in shade as ambient air temperature and solar radiation increase (Kendall *et al* 2006; Tucker *et al* 2008; Schütz *et al* 2009; Schütz *et al* 2010) indicating that shade becomes more important in warmer environmental conditions. Similarly, cattle will seek protection against inclement winter weather, particularly in strong winds and during heavy or persistent rain (Houseal & Olson 1995; Vandenheede *et al* 1995; Redbo *et al* 2001).

It is clear that there are many different reasons for why cattle spend time in riparian areas, the access to shade and shelter, food and water being important factors. Therefore, the natural behaviour and needs of cattle should be taken into account when designing different management practices to protect riparian environments.

4. WATER CONSUMPTION AND EFFECTS OF WATER RESTRICTION ON ANIMAL PERFORMANCE

Water intake is closely related to feed intake in both beef (Brew *et al* 2011) and dairy (Stockdale & King 1983) cattle and it is thus essential to provide palatable water to livestock to sustain productivity. Factors that affect voluntary water intake include animal factors, such as milk yield (Dahlborn *et al* 1998; Meyer *et al* 2004) and body weight (Meyer *et al* 2004), as well as external factors, such as climate conditions (Blackshaw & Blackshaw 1994) dry matter content of the feed (Dahlborn *et al* 1998) and trough design (Pinheiro Machado Filho *et al* 2004; Teixeira *et al* 2006). It is therefore difficult to determine what water consumption levels are normal. Values reported in the literature range between 19 to 41 L/day depending on season for beef cattle (Hoffman & Self 1972; Ali *et al* 1994; Brew *et al* 2011), and 54 to 114 L/day for lactating dairy cattle (Muller *et al* 1994; Pinheiro Machado Filho *et al* 2004; Cardot *et al* 2008; Morris *et al* 2010) divided into 3 to 7 drinking bouts, on average (Jago *et al* 2005; Cardot *et al* 2008). Figures from New Zealand indicate that water intake of New Zealand Holstein-Friesian and crossbred cows in mid-lactation were 41 and 78 L/day depending on if cows were on pasture (daily maximum temperature was 21°C) or housed indoors (daily maximum temperature was 27°C, Morris *et al* 2010). Indeed, feeding management influences water intake; Overseas and New Zealand Holstein Friesian cows that were fed a total mixed ration (TMR) drank more often (5.2 times/24 h) than pasture fed cows (3.5 times/24 h) and had higher water intakes (TMR: 73 L/cow/day, grass: 53.7 L/cow/day, respectively, Jago *et al* 2005). Similarly, water consumption is affected by climate and increases in warm weather (Ali *et al*

1994; Bicudo *et al* 2003; Arias & Mader 2011), in particular if the animals have no access to shade (Hoffman & Self 1972; Muller *et al* 1994).

Water deprivation affects the health, behaviour and performance of cattle. Severe water restriction may decrease dry matter intake (Utley *et al* 1970; Little *et al* 1978), milk yield (Little *et al* 1978; Little *et al* 1980), body weight (Little *et al* 1980; Little *et al* 1984) and cause a change in behaviour, such as increased aggression around the water trough and less lying (Little *et al* 1980). From a regulatory and welfare perspective, in the New Zealand Animal Welfare Act 1999, managers of livestock in New Zealand are required to provide "proper and sufficient food and water" and "protection from, and rapid diagnosis of, any significant injury or disease, appropriate to the species, environment and circumstances and in accordance with both good practice and scientific knowledge". The Australia and New Zealand Environment and Conservation Council (ANZECC 2000) estimated water requirements for cattle to be, on average 70 L/day/cow for lactating dairy cattle, 45 L/day for non-lactating cattle, 45 L/day for beef cattle and up to 25 L/day for calves.

5. EFFECTS OF WATER QUALITY ON PERFORMANCE AND PRODUCTIVITY

Water for livestock can be sourced from surface water, such as streams and ponds, and/or groundwater. The quality of the water will be influenced by its source and contamination from abiotic and biotic factors as a result of either dissolved nutrients or direct deposition of urine or faeces containing nutrients and possibly parasites (Willms *et al* 2002). Groundwater may contain levels of dissolved salts, depending on the geology of the surrounding area, rainfall, vegetation and topography. Human activities around the water sources will also influence the water quality. There are several published guidelines for water quality, however with limited information of how these were formulated (MAF SFF Report 03/001 2004; ANZECC 2000). ANZECC developed 'trigger values', which are values at which there is minimal risk to animal health, however if levels are exceeded the risk to stock should be investigated (ANZECC 2000).

Water quality measurements usually include readings of different water properties, such as the salinity (mainly sodium chloride), hardness (mainly calcium and magnesium), pH, microbiological quality, algae, and nitrate and nitrite levels.

Although there seem to be general consensus that the water quality affects the palatability and water consumption of animals, there have been surprisingly few studies investigating the effects of water quality on livestock health and production. High salt contents can influence water and feed intake and subsequent growth rates (in Willms *et al* 2002), however, since high salinity is of little concern to New Zealand farmers (MAF SFF Report 03/001 2004), this topic is not further discussed. Potential effects of the hardness of the water were investigated in the 50's, but these studies showed no effect of hardness (190 and 290 ppm compared to 0 ppm) on dairy cow milk production, weight gain or water consumption (Graf & Holdaway 1952; Allen *et al* 1958). High nitrate levels in water are not common but may occur and are often associated with extensive use of nitrogen fertilisers and manures, intensive and livestock operations and can affect the quality and palatability of water (in Wright 2007).

Algae grow in troughs and other freestanding water, such as ponds. Although regular health warnings of algae blooms are issued to humans and dogs, there is only anecdotal evidence of stock poisoning due to algae blooms in New Zealand. During warm, sunny weather, there is a risk of algae bloom, which in turn may expose livestock to liver or neurotoxings produced by Cyaonobacterium spp. such as *Anabaena*, *Microcystis* and *Nodularia* (Zin & Edwards 1979). The toxic effects of blue-green algae have been clearly identified. However, the effect of subclinical doses of these toxins on animal productivity and water palatability is not well understood. There are also other water-borne microorganisms that can present significant health risks for cattle. The *Leptospira* family (can cause reproductive problems) and *Fusobacterium necrophorum* (can cause footrot and lameness) often use water and mud as a means of transfer (Wright 2007). In addition, cattle are commonly hosts to *Giardia* spp., *Cryptosporidium* spp, nematodes and other parasites that affect their health and that are spread in water. *Giardia* and *Cryptosporidium* cause diarrhoea in calves and lambs (Olson *et al* 1995; Olson *et al* 1997).

If livestock has direct access to waterways the risk of faecal contamination is high. In guidelines from (ANZECC 2000) it is stated that no livestock should consume water containing more than 100 (median value of number of readings over time) faecal coliforms per 100 ml water. In fact, cattle will avoid drinking water that is contaminated with faeces (0.05 mg/g water) when given a choice of clean water (Willms *et al* 2002). When the animals had no choice but to drink contaminated water, water consumption was reduced at manure concentrations above 2.5 mg/gram water whereas a reduction in feed consumption occurred at concentrations greater than 5 mg/gram water (Willms *et al* 2002). Similar findings were demonstrated by Holechek (1980) who reported a decrease in water consumption and weight gain of cattle drinking from a water source contaminated with faeces and urine.

There are to my knowledge only 2 studies published in peer-reviewed journals that have explored potential production benefits of providing clean water to livestock. Both studies were carried out in Canada with beef cattle managed on pasture. A summary of the most important findings from these 2 studies are presented in Figure 1 and 2. In a study by Willms *et al* (2002) the effects of clean water (water delivered to a trough from a well, river or stream), pond water pumped to a trough, or direct access to the pond on beef cattle productivity were studied in 2 separate experiments (yearlings and cow-calf pairs). The study was carried out for 2 months per year over 3 to 6 years. The clean water had fewer coliforms than the pond water, however, infections by pathogens and parasites (*Giardia, Cryptosporidium, Trichostrongylus*, or *Nematodirus* spp.) were similar between water treatments (Willms *et al* 2002).

They found that yearling heifers having access to clean water gained 23 and 20% (this was a trend only and not significant on the 5% level) more weight than those with direct access to the pond and having pond water pumped to a trough, respectively, but results were not consistent among years (Figure 1). Calves with cows drinking clean water, tended to gain 9% more weight than those with cows that had direct access to the pond (again, this was a trend only), however, cow weight and backfat thickness was not affected. The effect of water source treatment on weight gains of cows with calves was not significant although average weight gains were 13 and 25% more for cows drinking clean water than cows with direct access to a pond, or pond water in a trough. Cattle that had access to clean water spent more time grazing and less time resting than those that were offered water pumped to the trough from a pond or cattle that had direct access to the pond.

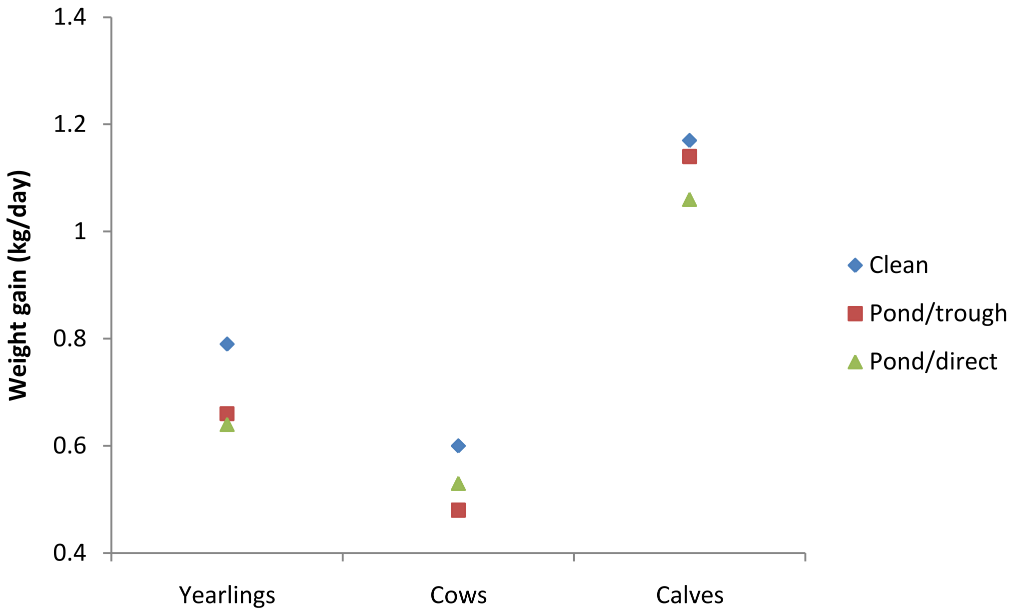

Figure 1. Effect of water supply on daily weight gains of yearlings (SEM: 0.09 kg/day), cows (SEM: 0.09 kg/day) and calves (SEM: 0.06 kg/day) over 3 to 6 years (2 months/year, data from Willms *et al* 2002). It was a tendency for calves with clean water to gain more weight than calves that had direct access to the pond (P=0.056). Yearlings with access to clean water tended to gain more weight than the other 2 treatments (P≤0.076).

Lardner and co-workers (2005) used water from the same source (a pond) to create 4 treatments: 1) treated water by aeration (allows plants and algae to decay under aerobic conditions therefore avoiding black, smelly water), 2) treated water by coagulation (removes impurities such as colour, turbidity, phosphorous and dissolved organic carbon) in combination with chlorine treatment, 3) pond water pumped to a trough, and 4) direct access to the pond, and studied the effects of these treatments on beef cattle in 2 separate experiments (yearlings and cow-calf pairs). Levels of *E. Coli* in the pond was reduced with increasing water quality treatment of the coagulated and aerated water, however the water treatment did not influence infection by Trichostrongyle, *Eimeria*, *Giardia/Cryptosporidium* or *Nematodirus* spp. in steers, cows or calves. Treated water improved weight gains by 9% over untreated water from the pond in 3 of 5 years (Figure 2). There was also an interesting effect of season, the steers with the treated water gained significantly more weight in the early part of the summer compared to the later part. Furthermore, steers that had access to aerated water tended to spend more time grazing and less time resting than steers that had direct access to the pond. However, these differences were not statistically different on the 5% level (Lardner *et al* 2005).

In the study by Lardner *et al* (2005), treated water had no effect of the weight gain of cows or calves. Water aerated and pumped to a trough in early summer tended to produce greater weight gains in calves than those drinking directly from the pond, however the difference was not significant on the 5% level. The authors suggested that seasonal conditions in the different years may have affected animal performance, and suggest that improving water quality will improve weight gain by 9-10% over a 90-day grazing period in years where forage availability and quality is appropriate for cattle production.

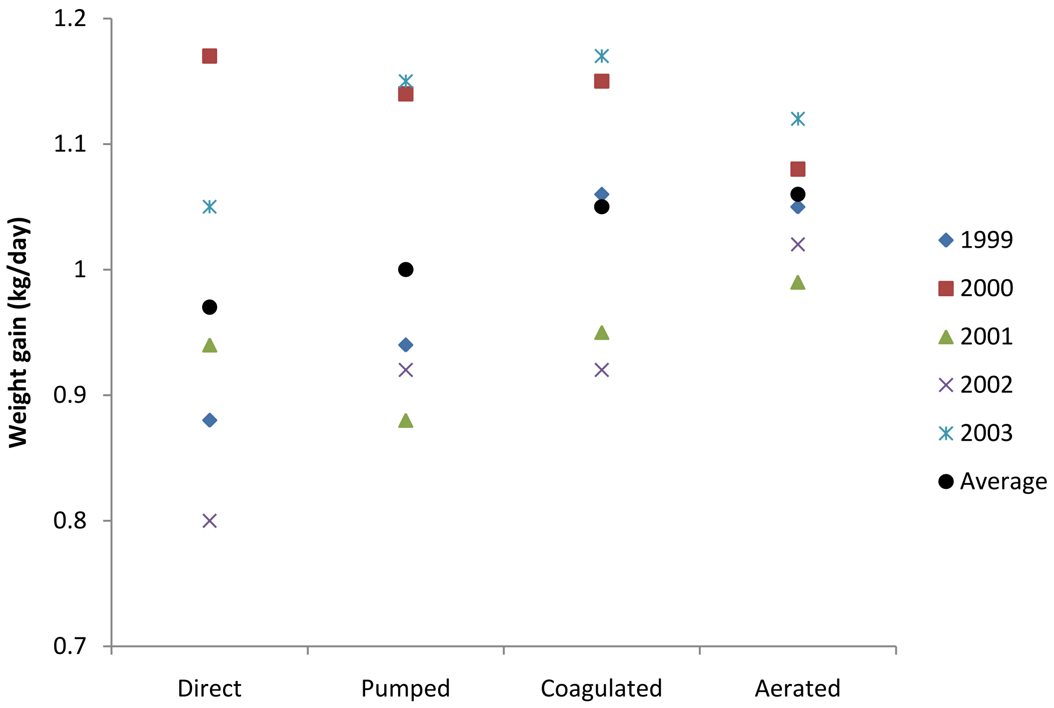

Figure 2. Effect of water treatment on average daily weight gain (kg/day, SEM: 0.013 kg/day) of steers managed on pasture over 5 years (n=11 steers/year, 76-106 days/year). The average weight gain over the 5 years was significantly higher in the Coagulated and Aerated treatments compared to the treatment where cattle had direct access to a pond (P=0.02). Data from Lardner *et al* (2005).

Furthermore, Porath *et al* (2002) demonstrated that the provision of off-stream water and trace-mineral salt improved weight gain in cows and calves by 11.5 kg and 0.14 kg/d, respectively, and the authors suggested that this management strategy may be effective in altering distribution patterns of cattle grazing a riparian meadow and its adjacent uplands.

In summary, the positive effects of drinking clean water seems to be caused by an increase in palatability and water intake (although water intake was not measured in the above mentioned studies), which consequently will lead to increased feed intake and improved animal performance (Willms *et al* 2002; Lardner *et al* 2005). However, production benefits will most likely only be observed in years where forage production and forage quality is adequate for livestock production.

6. EFFECTS OF PROVIDING AN OFF-STREAM WATER SUPPLY

As described above, riparian areas are attractive to cattle and if an unproportional amount of time is spent in these areas, this is likely to have undesired effects in terms of water quality and other stream and land characteristics. Beneficial or best management practices (BMPs) are methods and practices or combination of practices to prevent or reduce non-point source pollution to a level compatible with water quality goals (Miller *et al* 2011). Common BMPs that have proven to be efficient in reaching these goals include 1) fencing off the stream area (Owens *et al* 1996; Line 2003; Miller *et al* 2010), 2) rotational stocking (Sovell *et al* 2000; Haan *et al* 2010: Schwarte *et al* 2011), and 3) provision of off-stream water sources (Miner *et al* 1992; Godwin & Miner 1996; Sheffield *et al* 1997; Miller *et al* 2011).

Limiting cattle access to riparian areas may not only have benefits on the riparian environments, but may also provide other benefits, such as reducing exposure to parasites that are commonly occurring in New Zealand, such as liver fluke (Charleston *et al* 1990). Cattle do not get infected with liver fluke by drinking infected water, although the snail requires swampy conditions to survive and liberate cercariae that attach to plant material (Prof. Bill Pomroy, personal communication).

The most common practice in New Zealand to limit animal access to streams is to fence the stream area and provide some type of off-stream drinking water. However, this practice can be expensive and impractical in some regions, such as in hill country. Providing off-stream drinking water without resorting to stream bank fencing may be effective in reducing the negative effects grazing cattle can have on stream environments, however, not all studies have shown a positive effect of providing an off-stream water source. For example, the provision of an off-stream water source (minimum distance to the stream was 240 m) did not decrease the time cattle spend in the stream (Haan *et al* 2010) or improve water quality (Line 2003). Another study carried out in New Zealand conditions did not find any effect on stream use by beef cattle when a trough was placed at the top of a hill (150 m elevation) in the Waikato (Bagshaw *et al* 2008). Interestingly, trough use increased throughout the study, which could indicate that it took a while for the cattle to get habituated to the location of the trough (no previous habituation to the experimental setting was carried out). It is also possible that cattle were hesitant to walk up the hill to get access to the water as it has been shown that cattle prefer to lower elevation and flat areas (Bryant 1982; Dr. Keith Betteridge, personal communication).

Bagshaw *et al* (2008) suggested that forage availability influences stream/riparian areas use by beef cattle, and Bryant (1982) found that cattle used either a trough that was located 1.5 km from the stream, or a stream, depending on where they spent most of their time. These results show the importance of providing a water source in a suitable location, where cattle are likely to spend a high proportion of time, e.g. close to feeding areas and/or shade and shelter.

The effectiveness of providing an off-stream water source is also likely to be dependent on season. For example, the addition of an off-stream water source decreased the percentage of time cattle spent in the riparian area by 40 to 96% depending on season (Byers *et al* 2005). Haan *et al* (2010) demonstrated that cattle spent more of their time in the stream or streamside zone in unrestricted stream access pastures between May and August (Northern Hemisphere summer) compared to cattle with restricted access or rotational grazing. Animals were more likely to be in riparian zones with increasing heat load and the rate of increase was higher in animals that had unrestricted access to the stream. For each unit increase in air temperature, temperature-humidity index (THI) and heat load index (HLI, all are measures of heat load) in the unrestricted treatment, the probability of cattle being in the riparian zone increased by 12, 7 and 6%, respectively. Short-term provision of an off-stream water source did not influence the time spent in the stream.

In Georgia Piedmont in the USA, when the THI ranged between 62 and 72 (THI≥72 has historically been regarded as the threshold for thermal comfort in dairy cattle and equates to 25°C air temperature and 50% relative humidity, Igono *et al* 1992), the provision of water troughs outside the riparian zone tended (not statistically significant on the 5% level) to decrease the time spent in the riparian zones by 63% (Franklin *et al* 2009). When the weather became warmer (THI ranged between 72 and 84), the presence of a water trough did not influence the amount of time cattle spent in the riparian zone or in riparian shade (Franklin *et al* 2009).

In summary, the above presented studies suggest that water troughs placed away from unfenced streams may be effective in reducing the amount of time cattle spend in riparian zones when environmental conditions are not stressful. However, if there are attractive resources in the riparian areas, such as shade or forage, animals will spend more time in those areas.

Needless to say, and as shown above, cattle is sensitive to the palatability of water and water intake is closely related to feed intake, thus the water provided in off-steam sources should always be of high quality and freely available. LeJeune *et al* (2001) suggested that many of the factors that influence the survival and proliferation of bacteria in natural aquatic ecosystems have parallels in cattle water thoughts due to associations found between water quality parameters and ecological factors that were measured in intensive dairy systems in the USA. In the study, it was found that the water offered to cattle in troughs is often of poor microbiological quality and a major source of exposure of cattle to enteric bacteria (LeJeune *et al* 2001). Factors, such as the nutrition content of the water (by contamination of for example feed or faeces), exposure to sunlight, cleaning management, trough design, and air temperature are likely to influence the quality of the water (LeJeune *et al* 2001).

7. EFFECTS OF WATER TEMPERATURE ON CATTLE PERFORMANCE

Water provided in off-stream and reticulated sources may have different temperatures, depending on the source of the water, and this may influence animal productivity. The effects of water temperature have been extensively studied in both beef and dairy cattle, however not in New Zealand. Chilled drinking water (10°C vs. 27-28°C) reduced heat load by reducing body temperature and respiration rate (Stermer *et al* 1986; Wilks *et al* 1990) in warm weather (ambient temperatures in the studies ranged between 20 and 35°C), however the literature is not always consistent (Milam *et al* 1986; Stermer *et al* 1986; Baker *et al* 1988). Chilled drinking water has been shown to increase feed intake and milk production in dairy cattle (Milam *et al* 1986; Wilks *et al* 1990) and liveweight gains in beef cattle (Ittner *et al* 1951; Ittner *et al* 1954; Lofgreen *et al* 1975), however, there has also been reports of no effects on for example milk production (Baker *et al* 1988). When given a choice cattle seem to prefer to consume water close to ambient temperatures (Wilks *et al* 1990) and drink less chilled water (Ittner *et al* 1951; Lofgreen *et al* 1975; Lanham *et* *al* 1986; Baker *et al* 1988), although chilled water seems to be beneficial for production in the warm season.

Most of the literature described above was carried out in climates warmer than New Zealand. In cooler climates, the effect of chilled water may not be so clear or even reversed. For example, (Osborne *et al* 2002) found that water intake was 3 to 6% greater in all four seasons, and feed intake increased by 4.5% when cattle were offered heated water (30 to 33°C vs. 7 to 15°C) during summer (mean daily temperature was 21°C), however milk yield was greater when the cattle consumed the cooler (ambient) water in both spring and summer. In addition, under thermoneutral conditions (mean temperature was 15.3°C, and the range was 10 to 24°C), water consumption of lactating Swedish cows was lower when the cows were offered 24°C water than for 3, 10 or 17°C water. Water temperature did not affect dry matter intake but milk production was decreased when 3°C water was offered (Andersson 1985). It was hypothesised that feed energy required to warm water consumed may have depressed milk production. It is unclear whether water temperature would have an effect on production in New Zealand conditions.

8. CONCLUSIONS

It was found in this review that cattle are sensitive to the palatability of water and prefer to drink clean water without contamination. Water intake is closely related to feed intake and thus animal productivity. Providing off-stream water sources may be beneficial for production, this is most likely to be true in conditions that are not stressful for the animals (e.g. they are appropriately fed and have access to shade in warm weather). However, there have been surprisingly few studies investigating the effects of providing an off-stream water source of high water quality on livestock productivity. There has to my knowledge been no studies carried out in New Zealand to explore this topic. Water provided in off-steam sources should always be of high quality and freely available. Many of the factors that influence the survival and proliferation of bacteria in natural aquatic ecosystems have parallels in cattle water troughs and factors, such as the nutrition content of the water, exposure to sunlight, cleaning management, trough design, and air temperature are likely to influence the quality of the water in troughs. Further research regarding cattle utilization of riparian areas, the effects of off-stream water sources, and the effects of clean, palatable water in New Zealand conditions is warranted.

9. ACKNOWLEGEMENTS

I am grateful to Drs Keith Betteridge, Mairi Stewart and Mhairi Sutherland who provided helpful comments on the report and to Prof. Bill Pomroy at Massey University for providing useful information regarding liver fluke in New Zealand. The report was funded by the Northland Regional Council (Advice number 1051-NLRC142).

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