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IMPORTANCE OF HEAT STRESS ADAPTATION FOR NEW ZEALAND DAIRY CATTLE

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SUMMARY
An analysis was undertaken to explore the potential impacts of increased frequency of heat stress events on New Zealand dairy production systems, with subsequent consideration of the implications for current breeding strategies. Based on current forecasts, the expected impact of climate change will increase the frequency of heat stress events. However, it is unlikely that the expected impacts of heat stress require major deviations from current practices and breeding objectives based on unmitigated impacts on milk production and the trade-offs associated with mitigation.

INTRODUCTION
Anthropogenic climate change represents a key threat to global agricultural industries and food production systems via increased temperatures, changes in rainfall patterns, more frequent extreme weather events, and exposure to new pests and diseases. Given the importance of the dairy industry to the New Zealand economy, understanding the impacts of climate change on domestic dairy production is of national significance.

Increased frequency of hot weather could adversely affect the dairy industry via increased milk production losses due to heat stress. When exposed to hot conditions, cattle reduce dry matter intake to reduce production of metabolic heat, and partition energy into heat dissipation behaviours at the expense of production (Gaughan, Sejian, Mader, & Dunshea, 2019). Consequently, hot and humid weather is frequently associated with reductions in milk production because of heat stress.

This paper explores the long-term climate change forecasts across key New Zealand dairy regions to estimate the potential impact of increased heat stress and implications for current breeding objectives.

MATERIALS AND METHODS
Dairy production occurs across all New Zealand regions, albeit with the largest concentrations of dairy cow numbers occurring in Waikato (23%) and North Canterbury (14%) (LIC and DairyNZ 2018). With Waikato located in the north-western section of the North Island, and North Canterbury on the eastern coast of the South Island, these locations were selected as case studies in order to represent geographically diverse locations.

NIWA, the National Institute of Water and Atmospheric Research, produces long range climate change forecasts for key New Zealand locations. Changes in the frequency of heat stress events for both Waikato and North Canterbury were obtained using NIWA datasets. Climate comparisons occurred between a historical average from 1970 to 2015 as a baseline and forecast future climate in 2090.

NIWA climate change forecasts were configured using three Representative Concentration Pathways scenarios (RCPs) – RCP2.6 (low), RCP4.5 (low-mid), and RCP8.5 (high)- representing hypothetical pathways for the accumulation of greenhouse gases within the earth's atmosphere. These pathways broadly represent conservative (RCP2.6) through to extreme (RCP8.5) levels of climate change impacts on temperature and rainfall. Across each RCP scenario an average of six different global climate models was used to forecast changes in the number of annual 'hot days' above 25C (NIWA, 2019).

New Zealand dairy cattle have been reported to possess a threshold associated with the onset of heat stress over a Temperature Humidity Index (THI) range of 68 to 74 (Bryant *et al.* 2007). Based on prevailing levels of relative humidity in both regions, this heat stress threshold overlaps neatly with a temperature of 25C whereby the THI value at 50% relative humidity is 72, and at 80% relative humidity the THI value is 75. Consequently, the forecast annual 'hot days' frequency was used as a proxy for the expected annual frequency of days exceeding heat stress thresholds.

Regional milk solid production data was sourced for Waikato (358kg per cow per annum) and North Canterbury (413kg per cow per annum) from LIC and DairyNZ (2018). Future 2090 production levels were forecast by adjusting these baseline production levels to account for current genetic trends in milk solid production (National genetic progress of 2.15kg per year for milk solids). Consequently, future production was estimated to be 504kg per cow per year in Waikato, and 582kg per cow per year in North Canterbury.

Berry *et al*. (1964) established a formula for the prediction of milk production impacts due to heat stress: Decline in milk production (kg/d) = -1.075 - 1.736 x NL + 0.02474 x NL x THI, where NL is normal milk production (kg/d) during exposure to temperatures between 10 to 18 °C. NL was derived from the previously reported regional milk solid production forecasts.

Forecasts of current and future levels of milk loss attributable to heat stress were estimated using the above formula to determine daily losses at indicative THI values of 75 and 80. Annual losses were derived by multiplying these daily losses by the expected 'hot day' frequency for each RCP scenario. Due to the uncertainty surrounding average THI values across future 'hot days', a conservative average THI value (THI 75) and extreme average THI value (THI 80) were adopted.

RESULTS AND DISCUSSION

Table 1. displays forecast changes in the forecast frequency of hot days (days exceeding heat stress thresholds) for each location under the three climate change RCP scenarios.

Table 1. Forecast change in annual hot days under climate change

	Current annual hot days	Forecast hot day frequency		
		RCP2.6 (low)	RCP4.5 (mid)	RCP8.5 (high)
Waikato	30	40	60	100
North Canterbury	35	40	50	70

Table 2. displays estimated milk production losses associated with the increased frequency of hot days and subsequent heat stress effects.

Table 2. Forecast annual milk solid production losses in year 2090 attributable to heat stress

	Average THI on 'Hot Days'	Current annual milk solid loss	Forecast annual losses in milk solid production (2090)		
			RCP2.6 (low)	RCP4.5 (low-mid)	RCP8.5 (high)
Waikato	75	2.1kg (0.6%)	5.3kg (1.0%)	7.9kg (1.6%)	13.2kg (2.6%)
Waikato	80	7.2kg (2.0%)	14.9kg (3.0%)	22.3kg (4.4%)	37.2kg (7.4%)
North Canterbury	75	4.2kg (1.0%)	8.2kg (1.4%)	10.2kg (1.8%)	14.3kg (2.5%)
North Canterbury	80	12.0kg (2.9%)	20.7kg (3.6%)	25.9kg (4.5%)	36.3kg (6.2%)

Current heat stress losses are approximately 0.5% to 2.0% of annual production in Waikato and 1% to 2.9% in Canterbury. Under the more moderate RCP scenarios, expected milk solid loss attributable to heat stress is proportionally similar to current losses after accounting for expected genetic progress in milk solid production (2.15kg per year) to 2090. Under the most extreme RCP scenario (RCP8.5), losses increase up to 7.4% of expected 2090 milk solid production in Waikato and 6.2% in Canterbury.

To provide perspective, under the most extreme THI and RCP scenario (RCP8.5 & THI80), additional heat stress losses will amount to 14% of expected genetic progress (at current genetic trends) for milk solid production for North Canterbury farmers, 21% of expected genetic progress for Waikato farmers.

Mitigation of expected heat stress impacts on milk production could be undertaken via selection for heat tolerance. Research undertaken by Garner *et al*. (2016) and Nguyen *et al*. (2016) has led to the development of a genomic-based heat tolerance ABV for Australian dairy cattle to facilitate selection for improved heat tolerance.

The Australian heat tolerance ABV is moderately to strongly antagonistically correlated to milk production traits (r_g = -0.75 to the milk production index). In the absence of a very strong economic signal for improved heat tolerance it is likely that limited genetic progress will be made due to the relationship between heat tolerance and current key production traits. Diversion of index selection emphasis toward heat tolerance could also affect future genetic progress for production traits to an extent that is equivalent to the expected heat stress impacts.

Based on our analysis of forecast heat stress impacts it is likely that insufficient economic incentive will exist to warrant the inclusion of a heat tolerance trait within the New Zealand dairy breeding objective.

Some genetic mitigation of heat stress could be justified to mitigate potential impacts on cow fertility. The scale of potential impacts was on conception rates was not explored within this study and is more difficult to quantify and predict. Mitigation could be achieved by revising the index economic values for fertility based on potential conception rates under future climatic conditions as opposed to the development of a new trait. This would increase selection emphasis on fertility as a means of offsetting expected adverse heat stress impacts.

Further options for genetic mitigation could include development of homozygous ‘slick’ sires. The ‘slick gene’ represents an adaptive mechanism utilised by Senepol beef cattle, a tropically adapted Bos Taurus beef breed originating from Central America. The ‘slick gene’ represents a single gene haplotype located on chromosome 20 that produces a short, sleek coat and enhanced sweating capacity (Dikmen *et al*. 2014). However, validation is required of the heat tolerance benefits within a humid, pastoral environment with low evaporative cooling potential.

CONCLUSIONS

The forecast impacts of climate change on the frequency of heat stress events do not warrant significant genetic adaptation strategies for New Zealand dairy farmers. Farmers are encouraged to understand the expected level of adaptation challenge they will face into the future and make rational and objective decisions about the relative importance of adaptation within a genetic context. Trading off significant differences in production for greater heat tolerance would be unwarranted in most New Zealand dairy regions under the climate change forecasts contained within this paper.

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