Final report

Project code: B.FLT.4011

Prepared by: Michael Burchill, Sienna Blanckensee, Christine Killip
Weather Intelligence Pty Ltd

Date published: 31 May 2021

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Cattle Heat Load Toolbox 2019 to 2021

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The Cattle Heat Load Toolbox (CHLT), developed by Katestone and now operated by Weather Intelligence (a Katestone Company), alerts feedlot operators of impending adverse weather conditions that could lead to excessive heat load in feedlot cattle.

The toolbox is web based and provides access to weather and heat load forecasts out one week as well as risk assessment programs. The service is underpinned by 20 years of research into cattle heat load funded by Meat & Livestock Australia (MLA). This service provides useful and practical information to help feedlot operators manage heat stress in cattle through advanced warning of adverse conditions thus allowing operators time to undertake appropriate actions to mitigate the risk of heat stress.

The CHLT service has become an integral part of heat load management at Australian feedlots. The number of subscribers and feedlots that are registering for the service continues to grow every year with a significant increase since the new website was launched in October 2019. The service now has over 800 users and services 330 sites. Overall, the user base is satisfied with the delivery and performance of the service and see it as an integral part of their strategy to manage heat at their feedlot.

Executive summary

Background

The Cattle Heat Load Toolbox (CHLT), developed by Katestone and now operated by Weather Intelligence (a Katestone Company), alerts feedlot operators of impending adverse weather conditions that could lead to excessive heat load in feedlot cattle.

The service is underpinned by 20 years of research into cattle heat load funded by Meat and Livestock Australia (MLA). The CHLT service brings all this research together with a world class weather forecasting system to generate accurate and site specific forecasts across Australia. This service provides useful and practical information to help feedlot operators manage heat stress in cattle through advanced warning of adverse conditions thus allowing operators time to undertake appropriate actions to mitigate the risk of heat stress.

Objectives

The key objectives for the 2019-2021 season were to:

- Continue to provide the CHLT service 365 days of the year with seven day forecast for all parameters
- Develop a new website with a modern look, increased functionality and format that is compatible with mobile usage
- Upgrade of back-end data processing and storage
- Deliver CHLT refresher webinar.

All the above objectives were achieved.

Methodology

The toolbox is web based and provides access to weather and heat load forecasts out one week as well as risk assessment programs. Feedlot operators subscribe to the service free of charge and request a forecast for their feedlot. Subscribers also define risk alert levels suitable to their feedlot management and cattle type and condition through the Risk Assessment Program. Alerts are sent daily by email or SMS to designated recipients (e.g. site managers, veterinarians).

Results/key findings

The key achievements for the 2019-2021 season include:

- Reached the milestones of over 800 users and 330 sites
- Built and launched new website in October 2019 with new look, increased functionality and format that is compatible with mobile usage
- Delivered over 20,000 alerts via sms and e-mail during the heat season
- Preseason newsletter issued each year (see copy in Appendix A4 Preseason Newsletter)
- Delivered CHLT refresher webinar in November 2020 with over 50 registrations
- Completion of end of season survey in March 2020 (118 respondents) and 2021 (110 respondents)

Benefits to industry

The CHLT service has become an integral part of heat load management at Australian feedlots. The number of subscribers and feedlots that are registering for the service continues to grow every year with a significant increase (35% increase in the number of users and a 20% increase in the number of feedlots) since the new website was launched in October 2019. Overall, the user base is satisfied with the delivery and performance of the service and see it as an integral part of their strategy to manage heat at their feedlot. The upgrades to the service made at the beginning of the 2019-2020 season were well received by most users and have resulted in a stable system capable of managing the increased traffic and data load.

Future research and recommendations

The success of the overall system depends on the underlying research to determine a robust assessment of heat risk. The current model is extremely sensitive to the assumptions and small changes in meteorological conditions. Using the AHLU with distinct cut off values can also lead to a reduction in measured reliability. Continued research into refining assumptions and methods of presenting risks is recommended. User feedback identified thunderstorm forecasts, multi-model forecasts and probabilistic rainfall forecasts as the most desirable additional features to the system.

Table of contents

Tables

Figures

1 Project objectives

The Cattle Heat Load Toolbox (Fig. 1) was developed to assist in warning feedlot operators of impending adverse weather conditions that could lead to excessive heat loads for feedlot cattle. The objectives of the project are to:

1. Provide a daily forecast of heat load to the Australian feedlot sector, incorporating:
    a. Continuous monitoring of infrastructure to ensure the security and continued provision of the service.
    b. Timely update of the forecasts, plus review of forecast delivery and performance on a daily basis.
    c. Ongoing integration of new subscribers into the HLDN, plus regular checks with existing users to ensure everything is functioning correctly.

2. Undertake upgrades to the service and ancillary aspects of the CHLT to:
    a. Website and backend upgrades and additions that are required to keep the service running and maintaining a high level of user satisfaction and functionality.

2 Service use

A total of 800 subscribers, 331 user sites (328 feedlots and 3 abattoirs) are currently registered for the CHLT (Fig. 1). This is a 35% increase in the number of users and a 20% increase in the number of feedlots since the new website was launched in the beginning of the 2019-2020 season.

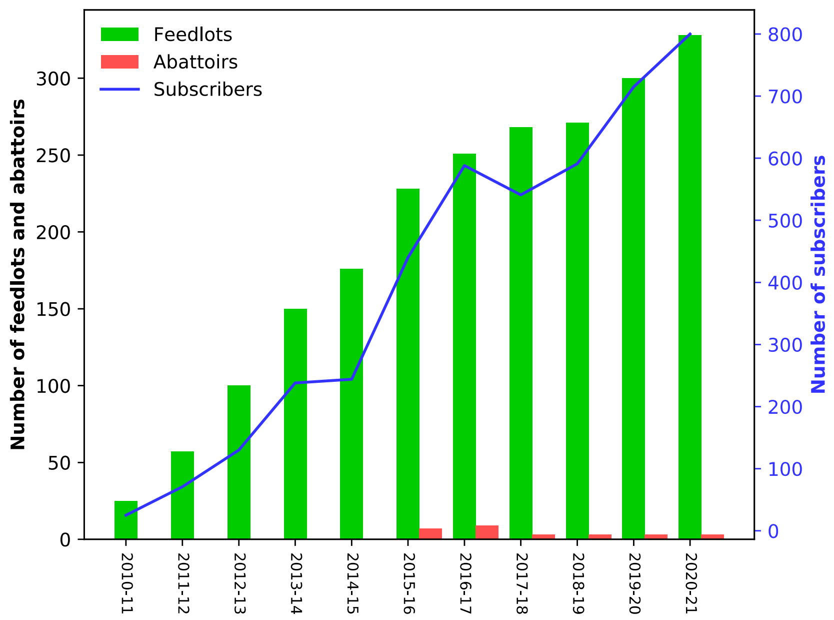


Fig. 1 Uptake of the CHLT service since its launch in 2010-*2011*

There are now 74 feedlots participating in the Heat Load Data Network (HLDN), shown in Fig. 2. The HLDN integrates the onsite weather station data into the CHLT system every hour (if the data is available), initialising the predicted AHLU from the measured data. However, most sites upload the weather data every 4, 6 or 24 hours. HLDN data is also displayed on the feedlots CHLT My Site page. The observations of the current day are proceeded by the forecast for the balance of the day. The user can also check the observations for the last 7 days and the forecast for the next 7 days (including the current day). The facility to download all observations as a file is also available.

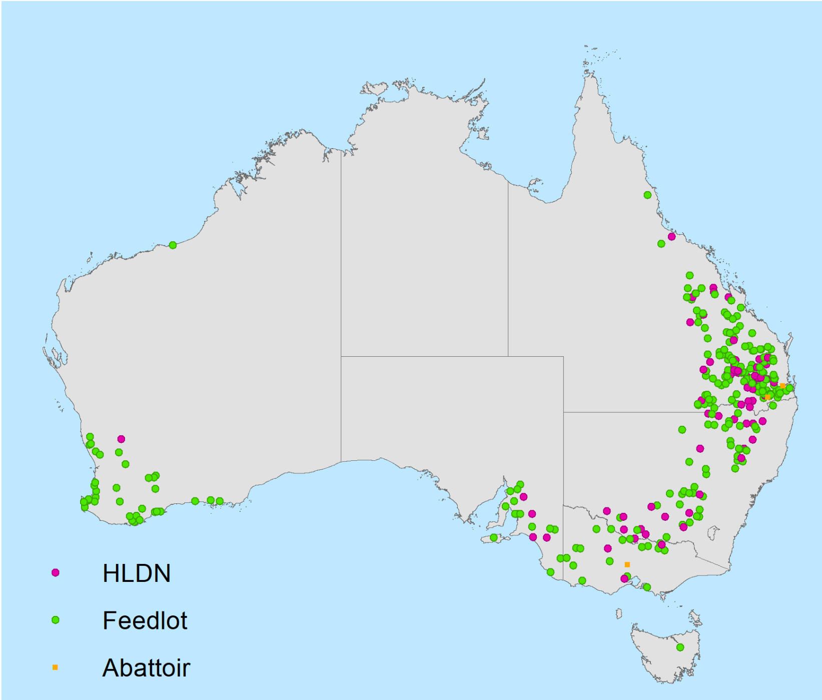


Fig. 2 Location of subscriber feedlots and HLDN participants

3 Methodology

3.1 Forecasting service

3.1.1 Overview

There are three parts to a successful early warning system:

1. Accurate weather forecast
2. Appropriate triggers that are relevant to the local climate and represent conditions that are conducive to heat stress in lot fed cattle
3. Communication of the warnings via an appropriate media

The following schematic presents an overview of the CHLT system (Fig. 3). The blue areas represent the global input from weather stations and models. These data are not gathered or generated directly by Weather Intelligence. The purple represents the local weather forecast, generated by Weather Intelligence every day. The red box indicates the areas of research that need to go into developing a robust system. The grey box represents the input from feedlot weather stations (HLDN). And finally, the delivery of the information is represented in green and shows the web site and alerts.

3.1.2 The weather models

The two weather forecasting models utilised by Weather Intelligence are an implementation of the Weather Research and Forecasting – Advanced Research and Weather (WRF-ARW) model (K-WRF), as a primary forecast, and the Australian Digital Forecast Database (ADFD), as a backup system.

The Weather Intelligence implementation of the WRF model (K-WRF) is initialised daily producing a 7-day forecast at an hourly time step. The modelling domain extends from 105°E to 160°E and 8°S to 45°S encompassing a significant portion of the oceans to better resolve the generation of tropical weather systems. The resolution of the model is 12 km, meaning that data is generated at 12 km spacing over a 23,436,000 km^2 area. K-WRF receives its initial and boundary conditions (IBCs) from the GFS model, which already contains data assimilated from the World Meteorological Organisation's (WMO) Australian monitoring sites, as well as satellite and upper air soundings. The model also incorporates a detailed land surface model that accounts for soil type, moisture content, porosity and vegetation type and density.

The ADFD operates continuously as an alternative weather forecasting product. It contains the official BOM weather forecast elements produced from multiple models and they are controlled by the Bureau's operational meteorologists. As for K-WRF, ADFD covers a 7-day period and provides hourly data. The ADFD has a horizontal grid resolution of 3 km for Victoria and Tasmania, and 6 km for the remainder of Australia. Unlike K-WRF, ADFD does not make solar radiation data available to the public, therefore a clear-day assumption is considered to estimate solar radiation.

In the event of a K-WRF failure, the ADFD forecast is utilised for the morning forecast. This includes the website update and alerts and the source of forecast is also noted on the website.

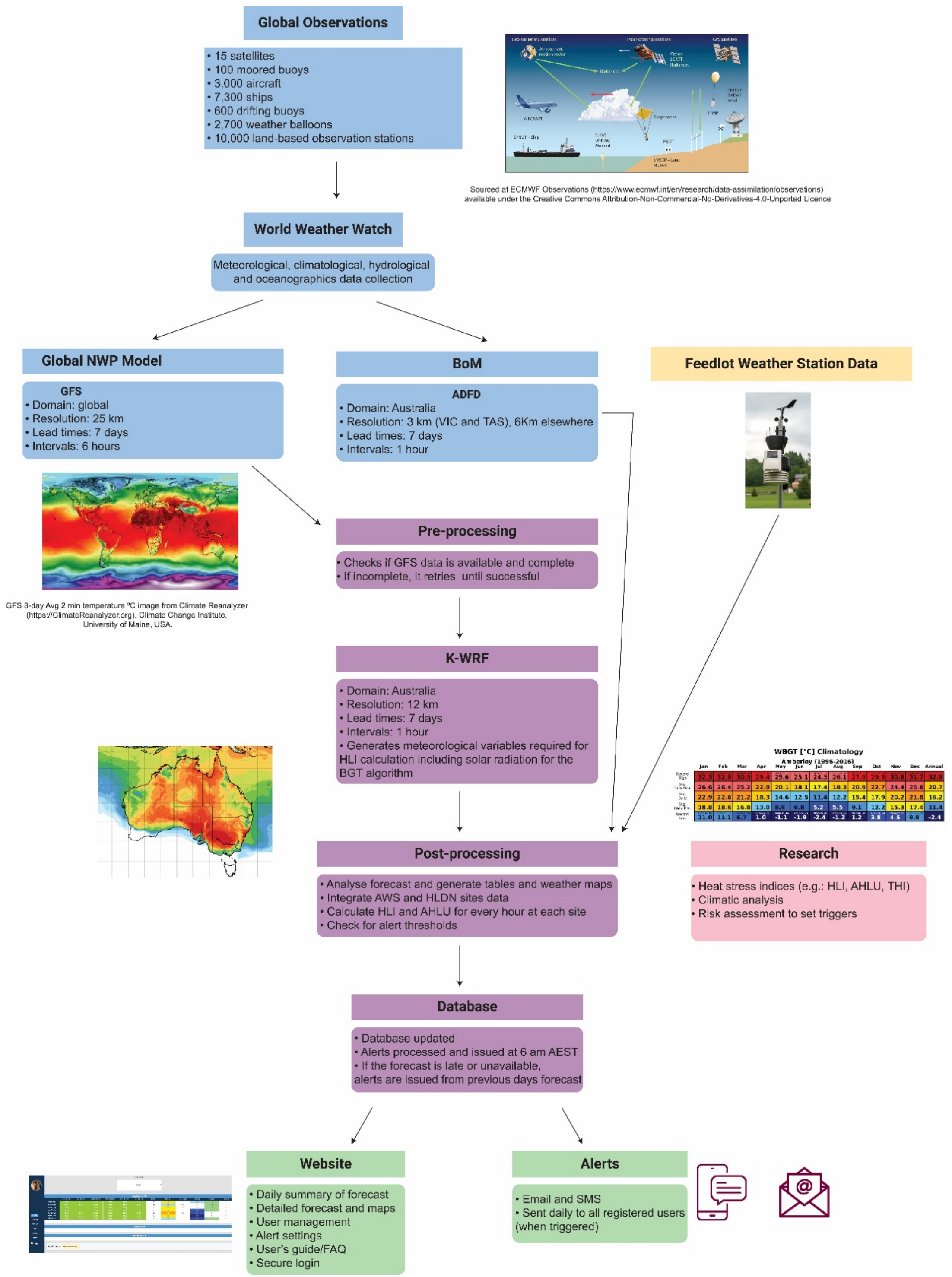


Fig. 3 Overview of the current process to deliver a forecast to CHLT

3.1.3 Heat load

There are many climatic conditions that may predispose feedlot cattle to high body heat loads, including:

- A recent rain event

- A high ongoing minimum and maximum ambient temperature
- A high ongoing relative humidity
- An absence of cloud cover with a high solar radiation level
- Minimal air movement over an extended period (4-5 days)
- A sudden change to adverse climatic conditions

It is usually a combination of some of these conditions that leads to an excessive heat load event, which may result in cattle deaths if conditions persist for a few days.

The calculation of HLI requires Relative Humidity (RH) expressed as a percentage, Wind Speed (WS) in m/s and Black Globe Temperature (BGT) in °C. HLI is calculated as a composite of HLI_{low} and HLI_{high}, with a weighting factor determined as a function of the difference in the calculated BGT and a threshold of 25°C (Gaughan et. Al 2002). A blending function was introduced as a result of an analysis of data over time, wherein it was evident that large jumps in HLI could occur under some circumstances when the BGT passes through 25°C – for example from 24.9°C to 25.1°C (B.FLT.0357).

In equation form, HLI_{LOW} and HLI_{HIGH} are calculated as follows, noting that exp is the exponentiation function:

$$HLI_{low} = 1.3 * BGT + 0.28 * RH - WS + 10.66$$

$$HLI_{high} = 1.55 * BGT + 0.38 * RH - 0.5 * WS + exp\,\exp(2.4 - WS) + 8.62$$

The weighting factor is calculated and used as:

$$FRAC_{high} = \frac{1.0}{\left(1.0 + e^{-\frac{BGT - 25.0}{2.25}}\right)}$$

$$HLI = \left(FRAC_{high} * HLI_{high}\right) + \left(\left(1 - FRAC_{high}\right) * HLI_{low}\right)$$

It is also worth noting that if any calculation of HLI yields a value less than 50, this value must be set to 50, as the dissipation of heat does not increase below this point.

The use of BGT in calculating the HLI, rather than ambient temperature, takes into account radiation effects as well as air temperature. Although sensors for measuring BGT exist, these are not included as part of the standard weather station and must be ordered from a suitable supplier. In the absence of measured BGT, a quantified relationship between BGT, ambient temperature (T) and solar radiation (SR) can be used. Here solar radiation can either be a measured value or a calculated value.

BGT can be calculated from T and SR using the following equation (noting that log is the logarithm function using base-10):

$$BGT = 1.33 * T - 2.65 * \sqrt{T} + 3.21 * \log(SR + 1) + 3.5$$

Accumulated Heat Load Units (AHLU) has been developed to give some indication of the amount of heat that is accumulated by an animal when it is exposed to environmental conditions that are above its ability to maintain thermo-neutral conditions.

For every hour that an animal is above its threshold HLI value, it will gain heat. This additional heat load accumulates over time and is reflected as an increase in body temperature. It is a normal physiological response for animals to gain heat during the day and dissipate this accumulated heat to the environment at night. If the animal cannot dissipate this accumulated heat overnight, the animal carries a heat load into the following day.

This makes the animal more susceptible to the effects of subsequent heat load. The three aspects that determine the potential for excessive heat load in feedlot cattle include time, intensity, and the opportunity to dissipate heat.

The following variables are required to calculate the AHLU:

- the HLI,
- upper (UL) and lower (LL) limit of the thermal neutral zones, and
- interval (in hours) between successive HLI estimates (Δt).

LL is fixed at 77, while UL is a variable dependent on the HLI value at which stock begins to accumulate heat. This depends on the stock characteristics, location, and management practices including mitigation measures.

The equation for calculating AHLU is as follows:

$$AHLU_{current} = AHLU_{previous} + BALANCE$$

If the HLI is less than LL ($HLI \ \leq 77$), then the heat is dissipated at half the rate of accumulation (the difference between HLI and LL). If the HLI falls between the LL and UL, then heat is neither dissipated nor accumulated. If the HLI is greater than UL, heat is accumulated.

In equation form, the $AHLU_{current}$ is calculated as:

$$HLI \leq 77 \; yields \rightarrow \; AHLU_{current} = AHLU_{previous} - \Delta t * \frac{77 - HLI}{2}$$

$$77 < HLI < UL \; yields \rightarrow \; AHLU_{current} = AHLU_{previous}$$

$$HLI \geq UL \; yields \rightarrow \; AHLU_{current} = AHLU_{previous} + \Delta t * (HLI - UL)$$

AHLU values do not go below zero. If any calculation results in an AHLU value below zero, it is set to zero.

Sites connected to the HLDN are initialised from AHLU calculated from data collected at local AWS, which theoretically would result in a more accurate AHLU forecast. The same holds true for BOM sites. Sites which do not have an integrated AWS are initialised from the previous day's AHLU forecast.

3.1.4 Delivery

3.1.4.1 Forecast generation

The sequence of steps that must be completed for the forecast to be delivered (as outlined in Fig. 3); from data retrieval and pre-processing to forecast computation and post-processing is monitored between the hours of 6 am and 9 pm, 7 days a week.

Once the forecast is generated a daily checklist is completed. These checks include but are not limited to:

- Successful completion of NWP system
- Successful processing of site data
- Alerts triggered successfully and delivered
- Website updated with most recent forecast.

3.1.4.2 Website and database administration

The CHLT system is administered and maintained by a system administrator. The system administrator maintains the integrity and security of the cloud-based infrastructure. There are three nodes within the HPC facility that require administration and maintenance:

1. Computational node - Core activities are data retrieval, pre-processing and forecast computation
2. Database node - Core activities are post processing, data storage and data availability to the web server
3. Web node - Core activities are website delivery, user information management, web security

The system administrator also maintains the CHLT website including:

- Registering new subscribers
- Checking their coordinates are valid
- Configuring site specific forecasts in the model
- Maintaining of the CHLT web site and associated databases
- Maintaining e-mail and SMS alert functions
- Daily monitoring and maintenance of computer systems including weekends and holidays
- Online and phone support for registered users during regular office hours (8 am to 5 pm)
- Maintenance and update of the FAQ page.

3.1.4.3 Onsite AWS integration

The Heat Load Data Network (HLDN) allows feedlots to send their weather station data to our servers and include these data in their site-specific forecast for the AHLU. To date 74 sites are operational.

The AWS integration requires continuous monitoring of data quality, as spurious data entering the system can adversely impact the prediction of risk and degrade confidence in the system. The integration step involves calculating the AHLU for all thresholds from the onsite data and initialising the predicted AHLU from the last available time step in the observations.

An automated data quality check is initiated at the integration step that flags spurious data and issues an internal alert to manually quality assure the offending dataset. Our experience indicates that the spurious data is either due to damage to the sensor, i.e. lightning strike, or changes to the data format following a system update by the AWS provider.

3.1.4.4 Alerts

The alerts, for a user selected HLI Threshold value, used in the system are:

- AHLU event today: AHLU > 50 units for today
- AHLU event tomorrow: AHLU > 50 for tomorrow and AHLU = 0 for less than 6 hours
- Extended AHLU event: AHLU > 50 units for more than 3 consecutive days
- Incomplete night time recovery: AHLU = 0 for less than 6 hours for more than 3 consecutive days in 7 day forecast period
- Rapid HLI change: change in HLI > 40 units over 4 hours

Alerts are processed every morning during the period 1 October – 31 March and issued around 6.30 am AEST.

3.2 RAP

The Risk Analysis Tool (RAP) was developed in 2005 for the purpose of obtaining the risk profile of a heat event for the Australian Feedlot industry. The risk that is calculated by the RAP consists of the probability of occurrence of specific heat events at the specified site (All BOM weather station sites). These heat events are classified in terms of their duration (in days) and the daily maximum AHLU value. The classifications are: Medium Risk, (AHLU between 21 and 50), High Risk (AHLU between 51 and 100) and Extreme Risk (AHLU greater than 100). For example, the probability of Extreme Risk events of three day duration is one event in two years. The output is displayed to the user with no interpretation of the acceptability of the predicted risk level.

The RAP is available for anyone to use on the Cattle Heat Load Toolbox website.

No changes have been made to the RAP in the 2019-2021 season.

4 Success in meeting the milestones

The CHLT was operational for the full season with alerts sent out daily from 1 October 2019 to 31 March 2020 and from 1 October 2020 to 31 March 2021. The key achievements for the 2019-2021 season include:

- Upgrade of back-end data processing and storage
- Consultation with feedlots during the design process of new website
- Launched new website in October 2019 with new look, increased functionality and format that is compatible with mobile usage
- Daily update of website 365 days of the year with new seven day forecast for all parameters
- Daily delivery of alerts via sms and e-mail during the heat season
- Preseason newsletter issued each year (see copy in Appendix A4 Preseason Newsletter)
- Delivered CHLT refresher webinar November 2020 (over 50 registrations)
- Supplied content for ALFA newsletters
- Delivered monthly reports during the heat season
- Completion of end of season survey in March 2020 (118 respondents) and 2021 (110 respondents)
- Participated in MLA Heat Load Modelling and Strategy workshop February 2019
- Supported ALFA at Beef Australia May 2021

The following sections present a summary of the season including:

- General climatic conditions and heat load
- Delivery of alerts
- Web site statistics
- An overview of the performance of the forecasts, and
- Feedback from the users via the end of season survey.

4.1 Season overview

4.1.1 Weather and climate review

4.1.1.1 Temperature and rainfall 2019-2020

2019 was Australia's warmest year on record (the national observational dataset commences in 1910). Australia's area-averaged mean temperature for 2019 was 1.52˚C above the 1961-1990 average. Both maximum and minimum temperatures were warmer than average, leading to the 1st and 6th -warmest on record, respectively. Regarding rainfall, nationally averaged rainfall for 2019 was 277.6 mm, 40% below the 1961-1990 average, making it the driest year for Australia for the record spanning 1900 to present (Fig. 4 left).

Focusing on the 2019-2020 season (from October 2019 to March 2020), temperatures were above average for the majority of Australia (Fig. 5). Nationally, summer 2019-2020 was the second warmest summer on record, with the Northern Territory and all states except Tasmania and Victoria in the top ten warmest summers on record. The hottest day on record averaged across Australia occurred on the 18th December 2019, peaking at 41.88˚C, which was also in the hottest December on record for Australia. December 2019 was also the driest on record and observed the highest accumulated Forest Fire Danger Index (FFDI) for Australia.

These hot, dry conditions were resultant of one of strongest positive Indian Ocean Dipoles (IOD) and a persistent negative phase of the Southern Annular Mode (SAM) from September to December. These two phases and a slow moving high created highly favourable scenario for hot dry conditions across the continent. The lack of any early wet-season rain also contributed to heat build-up in the northern tropics. Through December, heat waves moved through the country with a wind change on the 30-31st December moving through south-eastern Australia, resulting in some of the most significant fire weather conditions for the summer. These conditions led to one of the worst fire seasons on record for Australia.

Comparing rainfall of the 2019-2020 season to the previous season (2018-2019), a dramatic decrease is observed across northeast of Australia, and southeast NSW, whereas a significant increase occurred in some areas of northwest Australia and southern Queensland/northern NSW (Fig. 4 right).

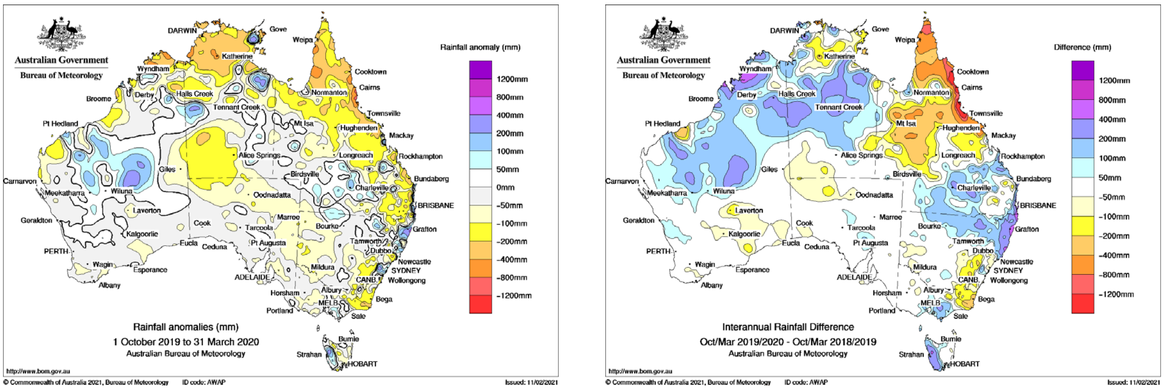


Fig. 4 Rainfall anomalies during the 2019-20 season (left) and the difference between October 2019 - March 2020 season and October 2018 – March 2019 (right)

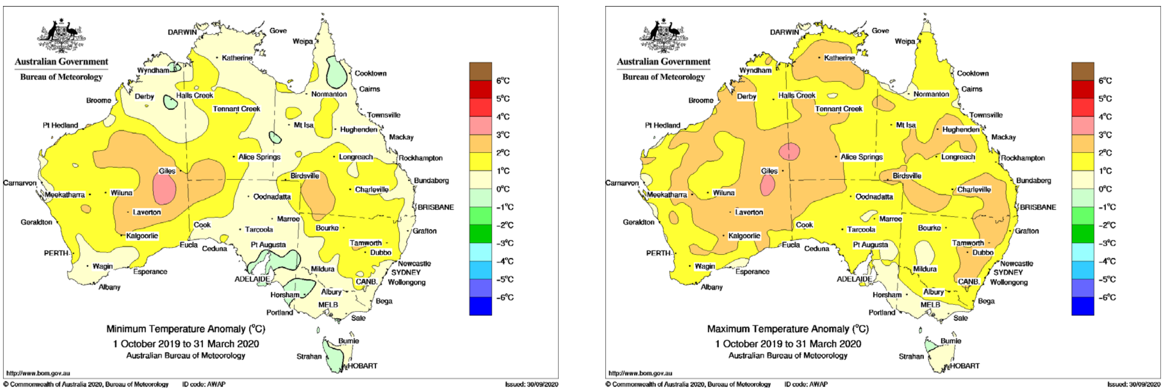


Fig. 5 Minimum (left) and maximum (right) temperature anomaly during the 2019-20 season

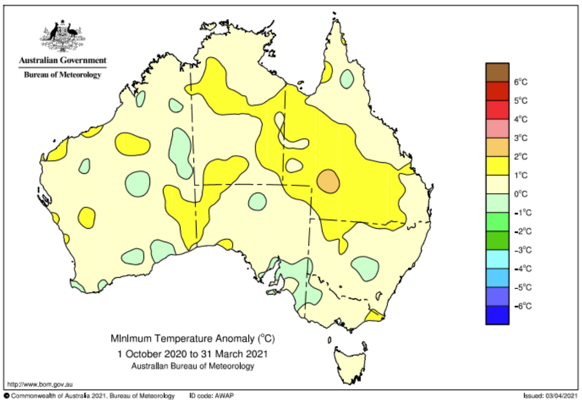
4.1.1.2 Temperature and rainfall 2020-2021

2020 was Australia's fourth warmest year on record (the national observational dataset commences in 1910). Australia's area-averaged mean temperature for 2020 was 1.15˚C above the 1961-1990 average. Both maximum and minimum temperatures were warmer than average, leading to the 8th - and 4th -warmest on record, respectively. Regarding rainfall, the national average for 2020 was 483.3 mm, 4% above the 1961-1990 average, making it close to average overall for Australia for the record spanning 1900 to present.

Focusing on the 2020-2021 season (from October 2020 to March 2021), temperatures were slightly above average with mean temperatures 0.06˚C above average. Nationally, summer 2020-2021 saw mean minimum temperatures above average at 0.39˚C and mean maximum temperatures below average at -0.28˚C (Fig. 6). These below mean values were observed in inland eastern Western Australia. However, they were above average for areas of south-west Queensland and between Rockhampton and Fraser Island. Rainfall this summer was 29% above the average nationally and was the wettest observed since 2016-2017 with December 2020 being the third wettest December on record (since 1900).

These average temperatures and increased rainfall were the result of the La Niña phase of the Pacific Ocean. This phase created a highly favourable scenario for enhanced precipitation across eastern and Northern Australia. There were also four named tropical cyclones that made landfall and four unnamed significant tropical lows that resulted in widespread rainfall to northern Australia. Finally, a cold front and low-pressure trough resulted in tropical moisture over southern NSW and Victoria.

Comparing rainfall of the 2020-2021 season to the previous season (2019-2020), a dramatic increase is observed across north, central and southeast Australia, whereas a decrease occurred in some areas of central Western Australia and the coast of eastern Queensland (Fig. 7 right).



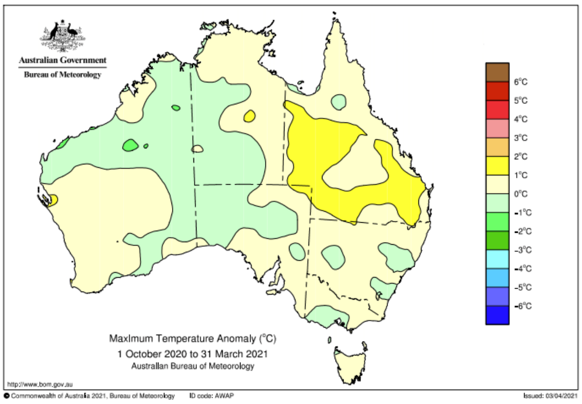
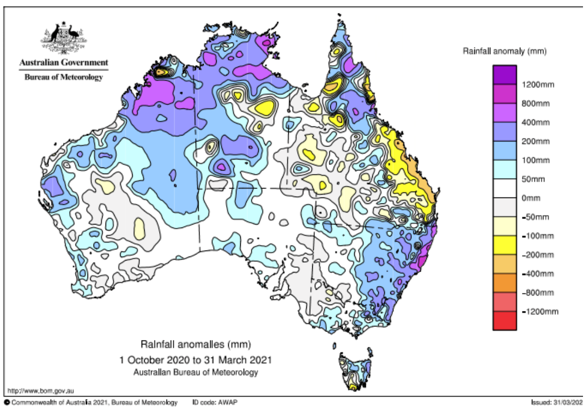


Fig. 6 Minimum (left) and maximum (right) temperature anomaly during the 2020-21 season



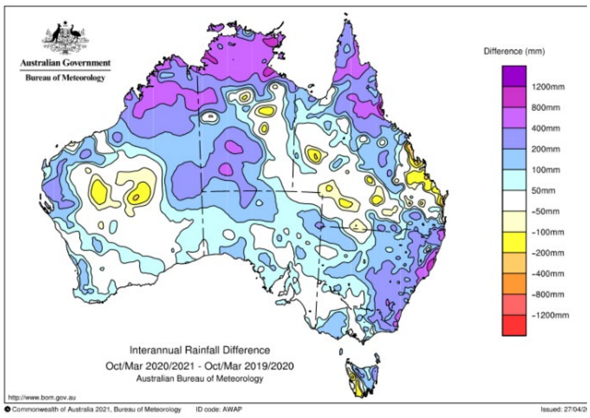


Fig. 7 Rainfall anomalies during the 2020-2021 season (left) and the difference between the 2020-2021 season and the 2019-2020 season (right)

4.1.1.3 Climate drivers

Australia's weather is influenced by many climate drivers. A brief description and their impacts on the 2019-21 seasons are given here.

El Niño-Southern Oscillation

El Niño-Southern Oscillation (ENSO) is arguably the most important global climate pattern affecting extreme weather conditions. It is characterized by two phases: warm phase (El Niño) and cold phase (La Niña). An El Niño event occurs when sea surface temperatures in the central and eastern tropical Pacific Ocean become substantially warmer than average, and this causes a shift in atmospheric circulation. As a result, the heavy rainfall that usually occurs to the north of Australia moves to the central and eastern parts of the Pacific basin. Therefore, an El Niño event is usually associated with drier conditions over eastern parts of Australia. Conversely, the enhanced trade winds during La Niña events lead to cooling of the central and eastern tropical Pacific Ocean and heavy rainfall can occur to the north of Australia.

In order to monitor ENSO events, two main indices are utilized: Niño-3.4 and SOI, measuring changes in the ocean and the atmosphere, respectively. The Niño-3.4 index refers to the observed sea surface temperatures within a region of the central and eastern equatorial Pacific, whereas SOI takes the difference of atmospheric pressure between Darwin and Tahiti.

Since January 2019, the SOI began a decline, resulting in fluctuating El Niño and neutral conditions for the remainder of 2019 and the summer of 2019-2020. SOI values began to rise throughout 2020 resulting in a La Niña phase for the 2020-2021 summer (Fig. 8).

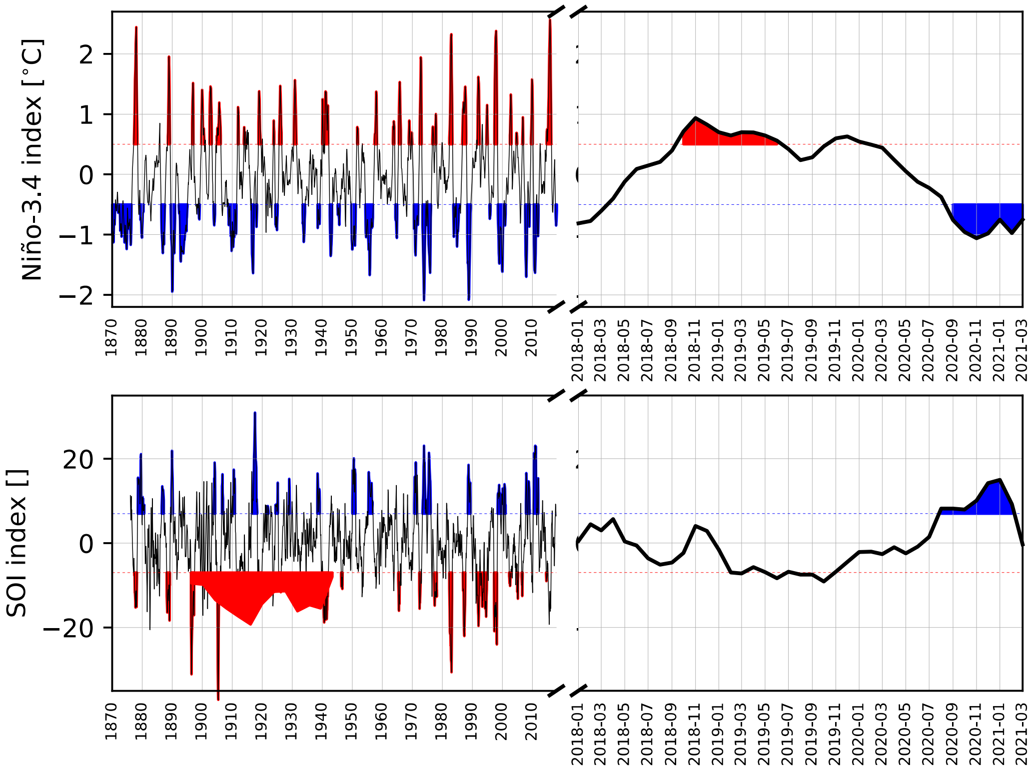


Fig. 8 Time series of Niño-3.4 index and SOI, Red (blue) shaded areas indicate El Niño (La Niña) events. Data source: NOAA and BOM

Indian Ocean Dipole

Indian Ocean sea surface temperatures impact rainfall and temperature patterns over Australia. Sustained changes in the difference between sea surface temperatures of the tropical western and eastern Indian Ocean are known as the Indian Ocean Dipole (IOD). Being one of the key drivers of Australia's climate, IOD can have a significant impact on agriculture since the events generally coincide with the winter crop growing season. Neutral IOD phase means that water from the Pacific flows between the islands of Indonesia, keeping seas to Australia's northwest warm. Positive IOD phase, i.e. with cooler than normal water in the east and warmer than normal in the west, implies less moisture than normal in the atmosphere to the northwest of Australia, resulting in less rainfall and higher than normal temperatures over parts of the country during winter and spring. However, negative IOD phase, i.e. with warmer than normal water in the east and cooler than normal in the west, leads to above-average winter-spring rainfall over parts of southern Australia.

A positive IOD event began in in the middle of 2019, with positive IOD values rapidly increasing throughout the second half of 2019, peaking at ~2.2°C in October 2019 before decaying to neutral conditions by January 2020. This highly positive IOD phase is linked with reduced rainfall to northwest Australia. The Dipole Mode Index (DMI) remained neutral through 2020, with the exception of a brief negative phase in August 2020, which resulted in the IOD having little influence on Australian climate from January 2020-March 2021 (Fig. 9).

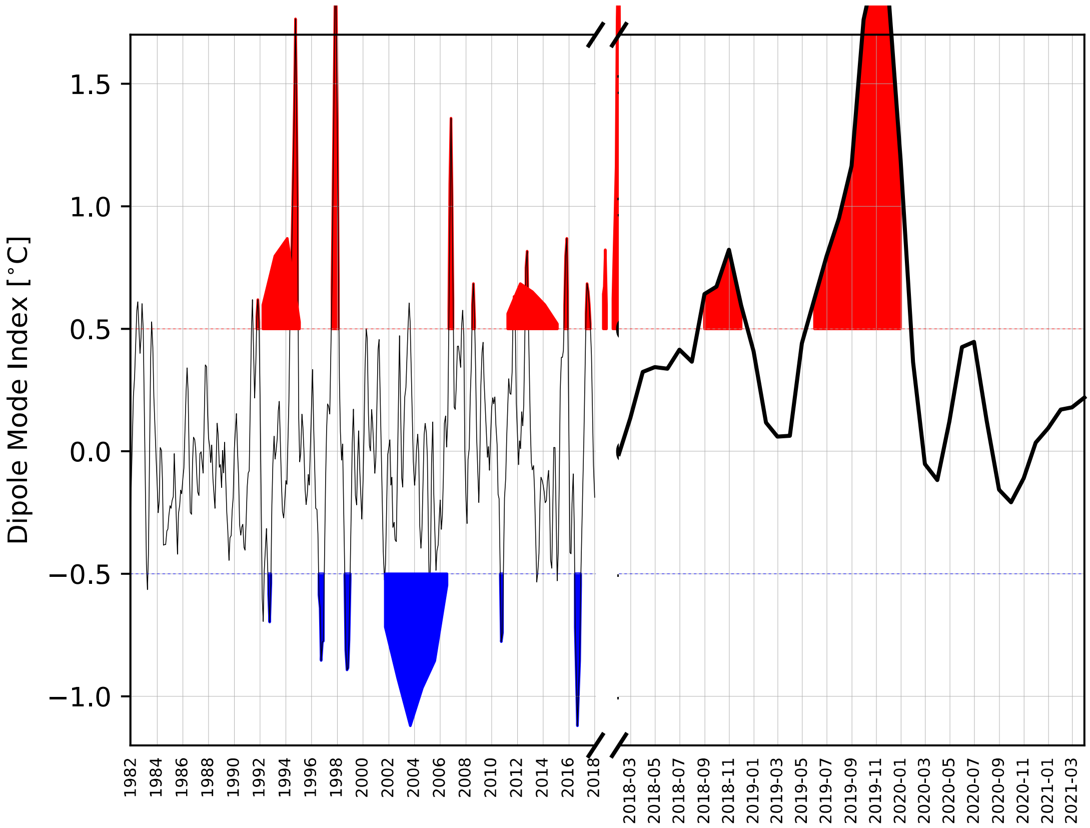


Fig. 9 Time series of Dipole Mode Index. Red (blue) shaded areas indicate positive (negative) IOD events. Data Source: NOAA

Southern Annular Mode

The Southern Annular Mode (SAM) describes the north-south movement of the westerly wind belt that circles Antarctica, dominating the middle to higher latitudes of the southern hemisphere (Ho et al. 2012). The changing position of the westerly wind belt influences the strength and position of cold fronts and mid-latitude storm systems, and it is an important driver of rainfall variability in southern Australia. In a positive SAM event, the band of westerly winds contracts towards Antarctic. This results in weaker than normal westerly winds and higher pressures over southern Australia, restricting the penetration of cold fronts inland. Conversely, a negative SAM indicates that the band of westerly winds expands towards the equator. This shift in the westerly winds leads to more low-pressure systems over southern Australia.

A high negative SAM dominated during the 2019-2020 season. This might explain the decreased rainfall observed in southeast and eastern Australia.

A high positive SAM has dominated during the 2020-21 season. This might explain the increase in rainfall to southeast and eastern Australia as a result of increased onshore flow (Fig. 10).

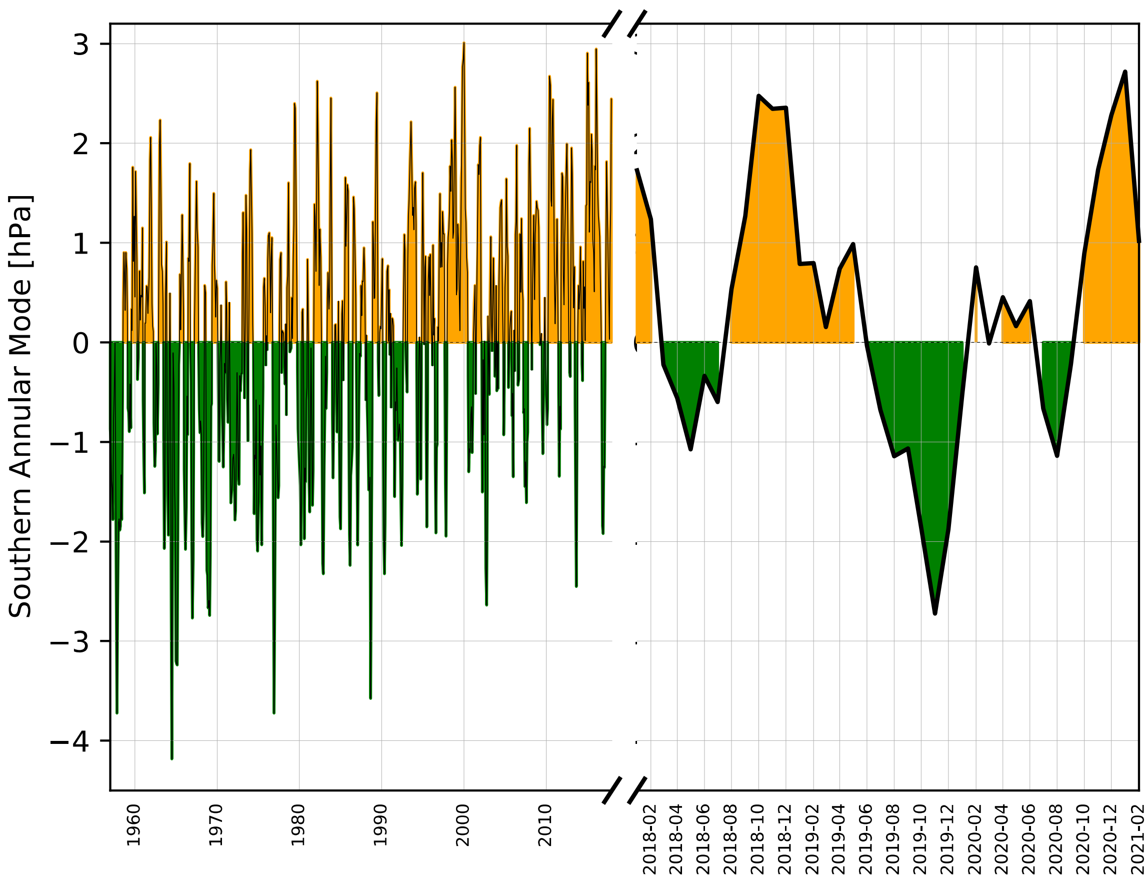


Fig. 10 Time series of Southern Annular Mode

4.1.1.4 Tropical cyclones 2019-2020

There were 8 Tropical Cyclones (TC) during the forecast period within the Australia region, which is below the long-term average (10 TCs), although only 5 had an effect upon the Australian mainland

(Table 1). Only TC Gretel impacted feedlot sites, in particular, those located on exposed sections of north QLD's east coast experiencing increases in rainfall and windspeed.

Table 1 Tropical cyclones in the Australian region between October 2019 and March 2020

Date	Name	Category	Region
4-8 Jan	Blake	1	WA
5-18 Jan	Claudia	3	WA
3-9 Feb	Damien	3	NT, WA
21 Feb – 1 Mar	Esther	1	WA, NT
10-14 Mar	Gretel	1	QLD

4.1.1.5 Tropical cyclones 2020-2021

There were 6 Tropical Cyclones (TC) during the forecast period within the Australia region, which is below the long-term average (10 TCs), although only 4 had an effect upon the Australian mainland (Table 2). All of these cyclones impacted North Queensland. Hence, feedlot sites in far North QLD experienced an increase in rainfall due to these events.

Table 2 Tropical cyclones in the Australian region between October 2020 and March 2021

Date	Name	Category	Region
1-6 Jan	Imogen	1	NT, North QLD
16-19 Jan	Kimi	2	North QLD
25 Jan – 1 Feb	Lucas	2	NT, North QLD
25 Feb – 5 Mar	Niran	5	Far North QLD

4.1.1.6 Heat load

The daily average HLI anomaly[1] derived from observations at the 17 benchmark locations (Section 4.1.4.1) for the 2019-2020 season is shown in Fig. 16. Most of the sites exhibit, as expected, some fluctuations of HLI between above and below average throughout the 6-month period. However, sites in QLD and NSW (Fig. 11) show above average HLI values in January and February, whereas the rest of the benchmark locations display HLI values close to climatology.

The weekly average of the daily maximum HLI derived from observations for all sites is presented in Fig. 12. For most of the sites, HLI peaks between late-January and mid-February. QLD sites reached peak HLI in late February in comparison to mid latitude sites reaching their peak in late January. Not surprisingly, Yanco, Hay, and Griffith had similar maximum HLIs due to their proximity. The peak HLI values for this season were also less defined than the 2018-2019 season, with values consistently above the previous year for most sites. This is representative of the climatology of this summer with record high temperatures and low rainfall.

[1] The HLI anomalous values are calculated by subtracting the monthly climatology to the actual value. In order to smooth the data, 6-day moving averages are shown.

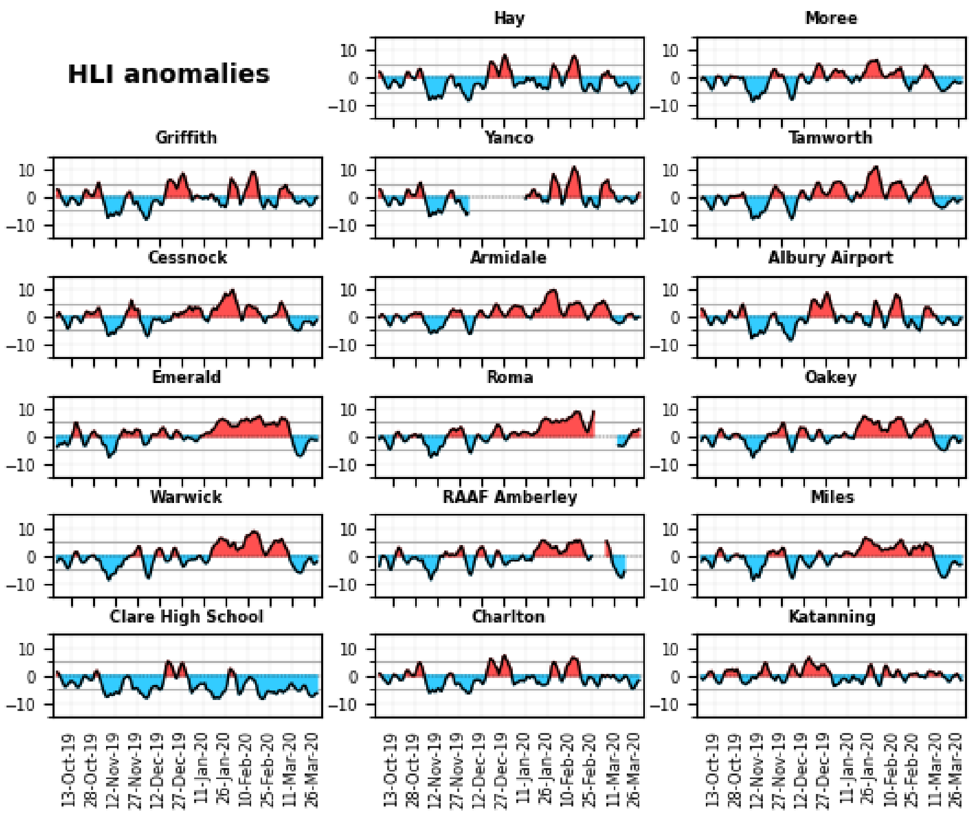


Fig. 11 Daily average HLI anomaly for the 17 benchmark locations during the 2019-2020 season. Note that red (blue) shades are used to denote higher (lower) HLIs values than usual

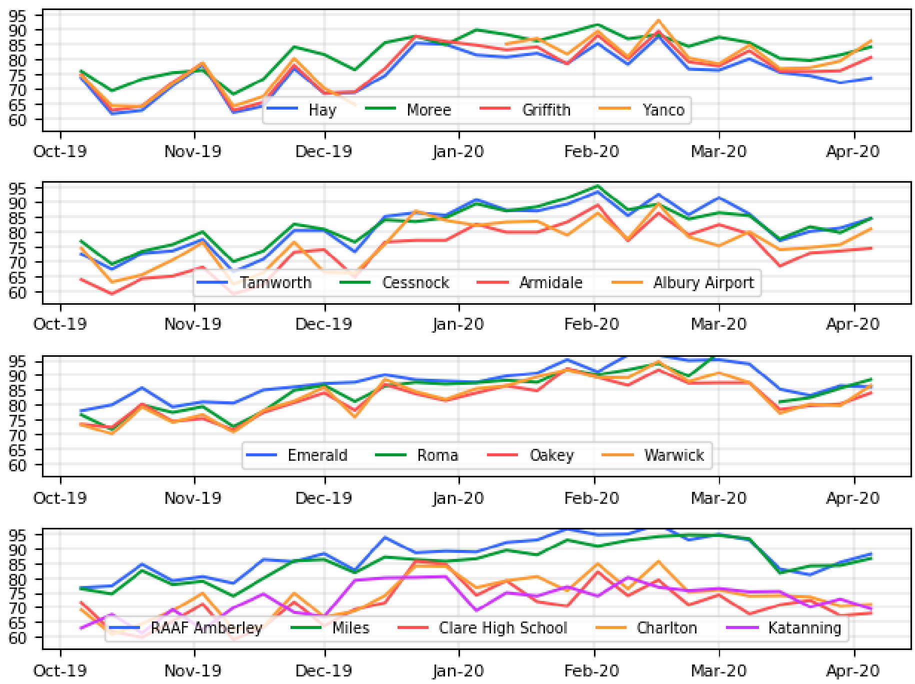


Fig. 12 Weekly average of daily maximum HLI for the 17 benchmark locations during the 2019-2020 season

The daily average HLI anomaly[2] derived from observations at the 17 benchmark locations for the 2020-2021 season is shown in Fig. 13. Most of the sites exhibit, as expected, some fluctuations of HLI between above and below average throughout the 6-month period. However, sites in QLD and NSW (Fig. 13) show below average HLI values from January to late February. Clare High School HLI values are also noteworthy, presenting below average from the start of December through to the end of March. This is resultant of the milder conditions observed this season from La Niña conditions in the Pacific Ocean.

The weekly average daily maximum HLI derived from observations for all sites is presented in Fig. 14. Most sites observed lower peaks than the previous summer season. Most sites also present no distinct, sharp peak in HLI with relatively consistent values across the summer. A noticeable feature from this summer is a dip in HLI during the middle of December (less pronounced in QLD). This is likely the result of increased wind, precipitation and reduced temperatures due to slow moving, tropical, low pressure system and a trough near the southern QLD coast.

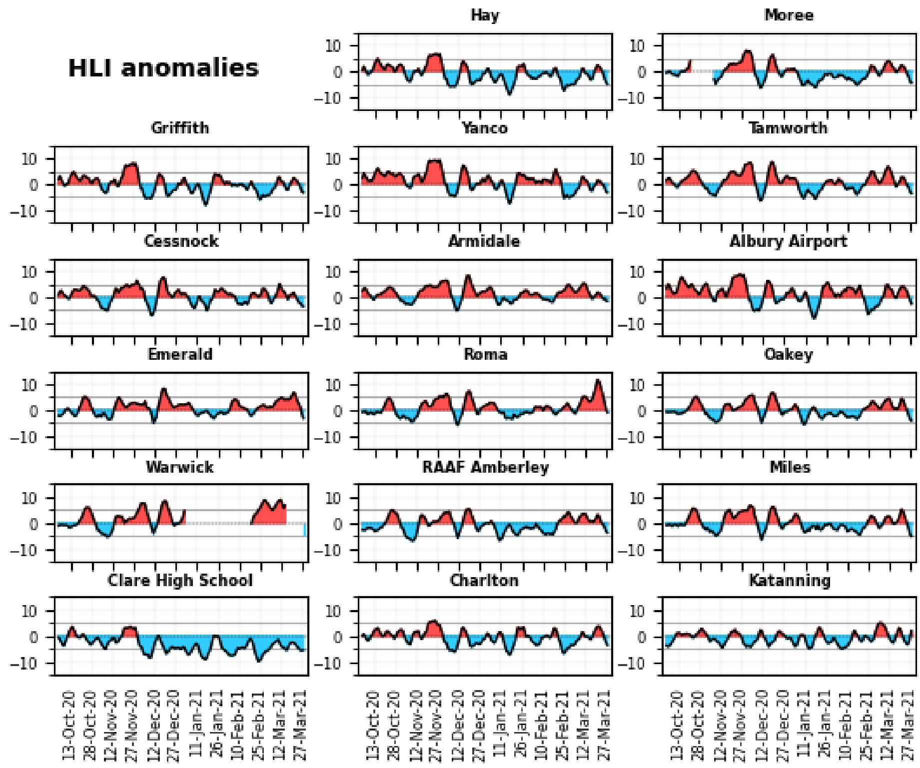


Fig. 13 Daily average HLI anomaly for the 17 benchmark locations for the 2020-2021 season. Note that red (blue) shades are used to denote higher (lower) HLIs values than usual.

[2] The HLI anomalous values are calculated by subtracting the monthly climatology to the actual value. In order to smooth the data, 6-day moving averages are shown.

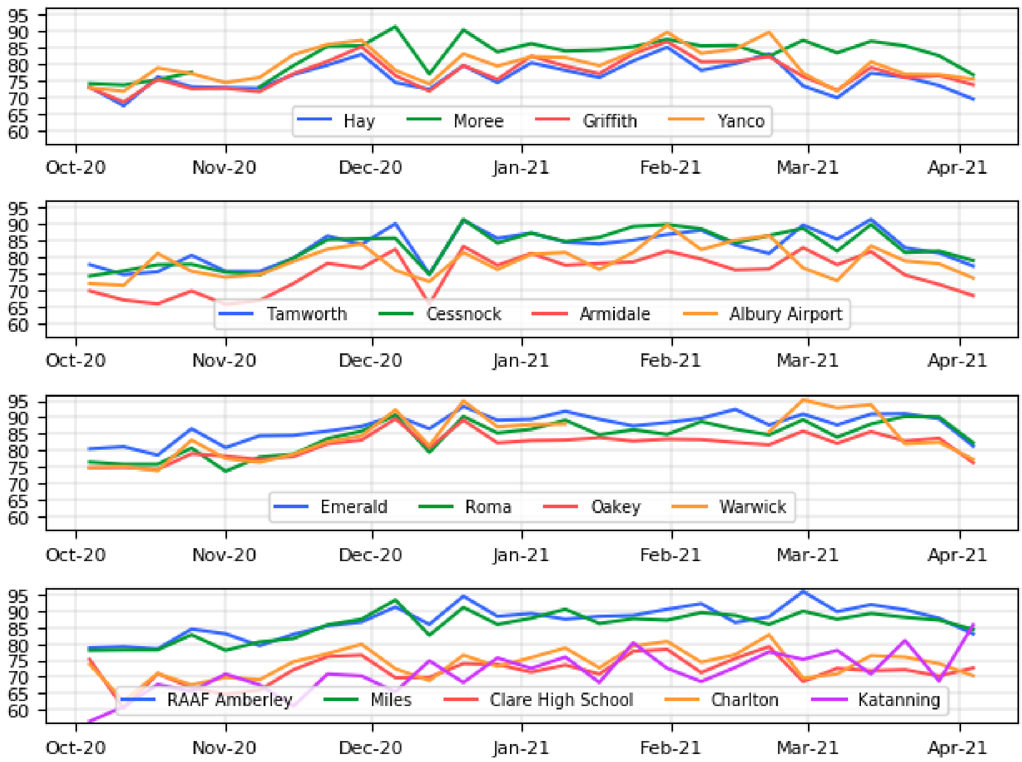


Fig. 14 Weekly average of daily maximum HLI for the 17 benchmark locations for the 2020-2021 season

4.1.2 Automated alerts

A total of 14,071 emails and 6,007 SMS alert messages were issued during the 2019-2020 summer forecast period, with a peak number of email and SMS alerts sent in February (Fig. 15). A total of 5,804 emails and 1,770 SMS alert messages were issue during the 2020-2021 summer forecast period, with a peak number of email and SMS alerts sent in December (Fig. 16). The significant reduction in the number of alerts sent is directly related to the contrasting weather conditions experienced during two seasons.

The breakdown of alerts by type for each month is also shown in these figures. Alerts for extended AHLU event and for today-tomorrow comprise most of the alerts. For Rapid HLI change, there were only 80 and 3 alerts for 2019-2020 and 2020-2021 respectively, representing less than 1% of total alerts.

The incomplete night time recovery alerts were triggered 3,341 times in the 2019-2020 season, in comparison to 912 times in the 2020-2021 season.

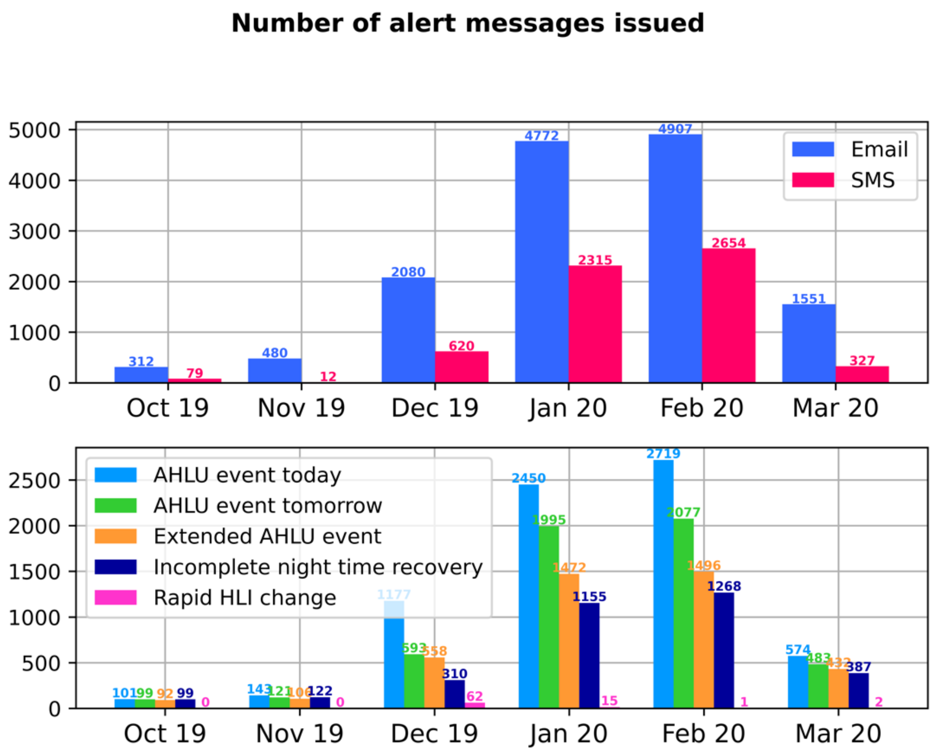


Fig. 15 Number of alerts sent by alert and notification types during the 2019-2020 season

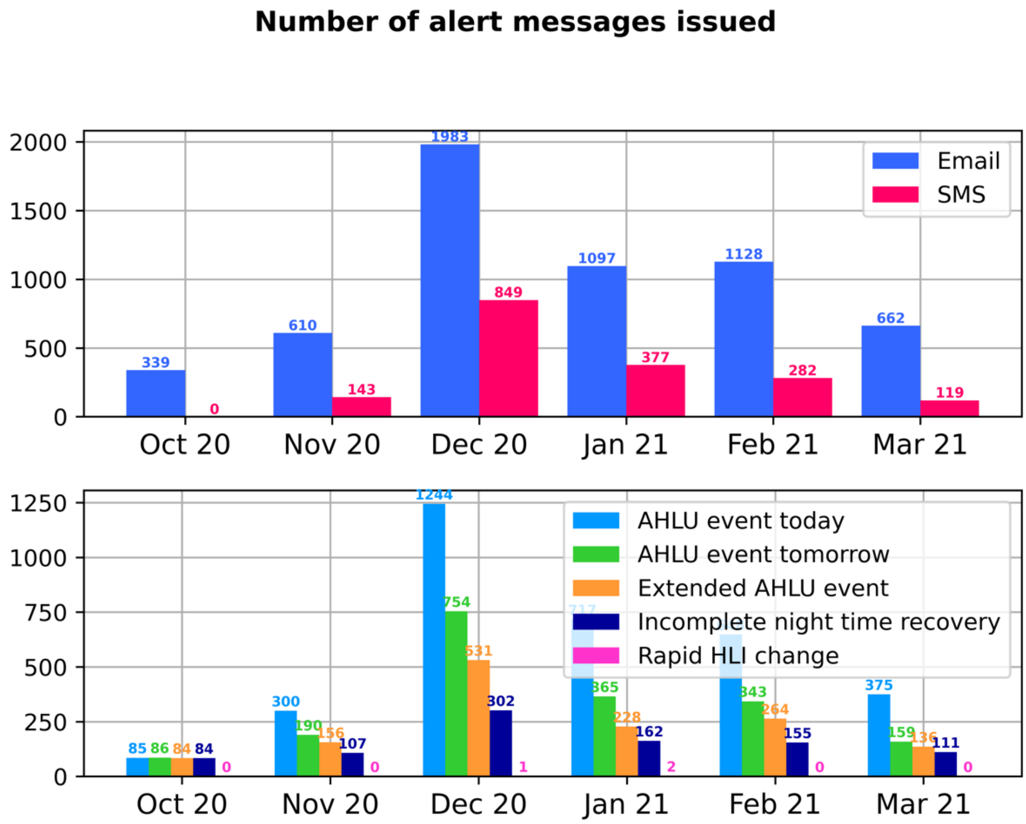


Fig. 16 Number of alerts sent by alert and notification types during the 2020-21 season

4.1.3 Web site statistics

The distribution of the CHLT website traffic by state is shown in Fig. 17 for 2019-2020. Queensland accounts for 56% of the site overall traffic, followed by NSW (20%) and VIC (14%). The remaining 10% is made from the other states and territories. The number of users (unique users of the website) increased from 1,735 during the 2018-2019 season to 2,268 during the 2019-2020 season, representing an increase of 31%.

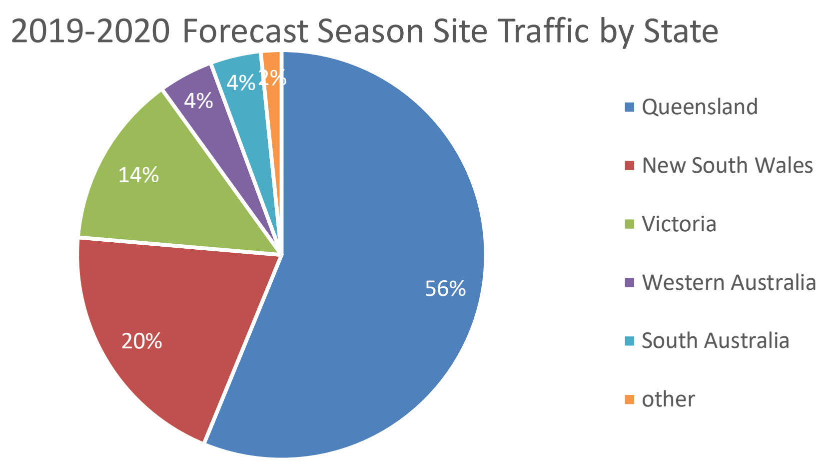


Fig. 17 CHLT website traffic by state during 2019-2021 season

The distribution of the CHLT website traffic by state is shown in Fig. 23 for 2020-2021. Queensland accounts for about 50% of the site overall traffic, followed by NSW and VIC. The number of users decreased from 2,268 during the 2019-2020 season to 1,833 during the current season, representing a decrease of approximately 20%. This could be a reflection of the relatively benign heat conditions experienced for the season, compared to the previous season.

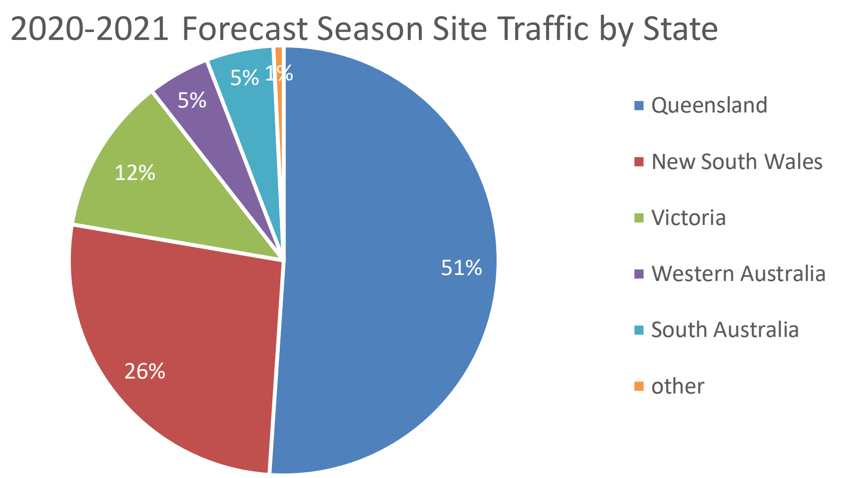


Fig. 18 CHLT website traffic by state during 2020-21 season

The top 10 webpages for 2019-2020 are shown in Table 3. The “My Site” and “Homepage” are the top two web pages. This is to be expected as they are the landing pages for the public and subscribers accessing the http://chlt.katestone.com.au/. The “Toolbox” is the next most visited page. The “Help”, “Glossary”, “Website tour”, “RAP calculator”, and site specific pages represent less than 2% each.

Table 3 Top 10 webpages as percentage of site traffic

Web page	% Site Traffic 2019-2020	% Site Traffic 2020-2021
/my-site/	47	46
/	16	15
/toolbox/	12	15
/weather/	7	6
/manage/	4	3
/my-site-summary/	2	2
/help/	2	2
/glossary/	2	2
/website-tour/	2	1
/rap-calculator/	1	1

Fig. 19 and Fig. 20 show the distribution of devices accessing the CHLT website. Most users (~75%) access the service from a desktop computer. The access from mobile phones/tablets remains at around 24%.

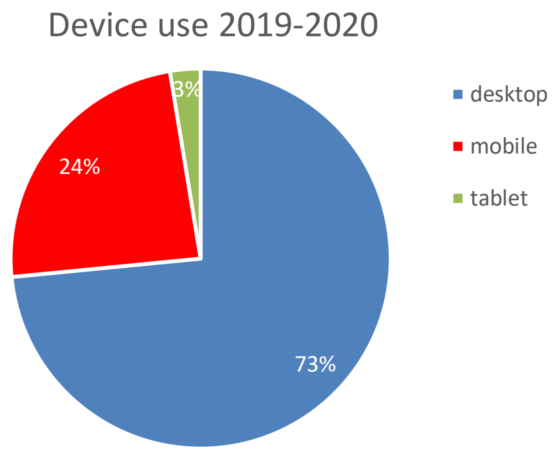


Fig. 19 Distribution of devices accessing the website (2019-2020)

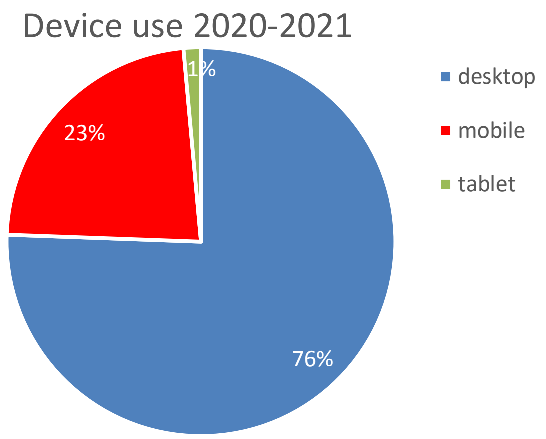


Fig. 20 Distribution of devices accessing the website (2020-2021)

4.1.4 Service performance

4.1.4.1 Benchmark locations

The performance of the forecasting service has been assessed each season against 17 benchmark locations. Most of these sites have been included in the forecast service since its inception and provide a good measure of the forecast's performance over the years. Fig. 21 and Table 4 describe the benchmark locations.

Table 4 Geographical information and WMO code of the benchmark locations analysed

Site Name	Lat	Lon	WMO code	State
Hay	-34.54	144.83	94702	NSW
Moree	-29.48	149.84	95527	NSW
Griffith	-34.24	146.06	95704	NSW
Yanco	-34.62	146.43	95705	NSW
Tamworth	-31.07	150.83	95762	NSW
Cessnock	-32.78	151.33	95771	NSW
Armidale	-30.52	151.61	95773	NSW
Albury Airport	-36.07	146.95	95896	NSW
Emerald	-23.56	148.17	94363	QLD
Roma	-26.54	148.77	94515	QLD
Oakey	-27.4	151.74	94552	QLD
Warwick	-28.2	152.1	94555	QLD
RAAF Amberley	-27.62	152.71	94568	QLD
Miles	-26.65	150.18	95529	QLD
Clare High School	-33.82	138.59	95667	SA
Charlton	-36.28	143.33	94839	VIC
Katanning	-33.68	117.6	94641	WA

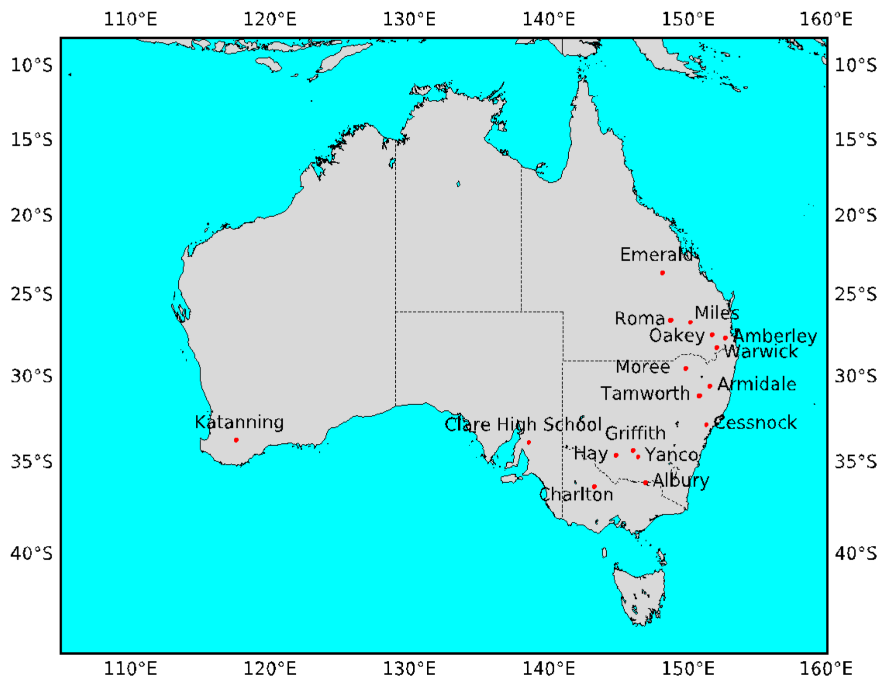


Fig. 21 Map of the 17 benchmark sites

4.1.4.2 Results

The HLI and AHLU performance analysis is presented in the following sections. A description of the statistical measured used to assess the performance of the system are in Appendix A1.

Heat Load Index

Fig. 22 shows the progression of the forecast performance since the 2005-06 season for the 17 benchmark locations. In particular, it represents the Root Mean Square Error (RMSE), which is the average magnitude of the forecast error with being 0 the perfect score. As expected, the 1-day lead time RMSE has always been lower than that for the 3-day lead time although their difference was much higher during the first years in contrast to more recent years.

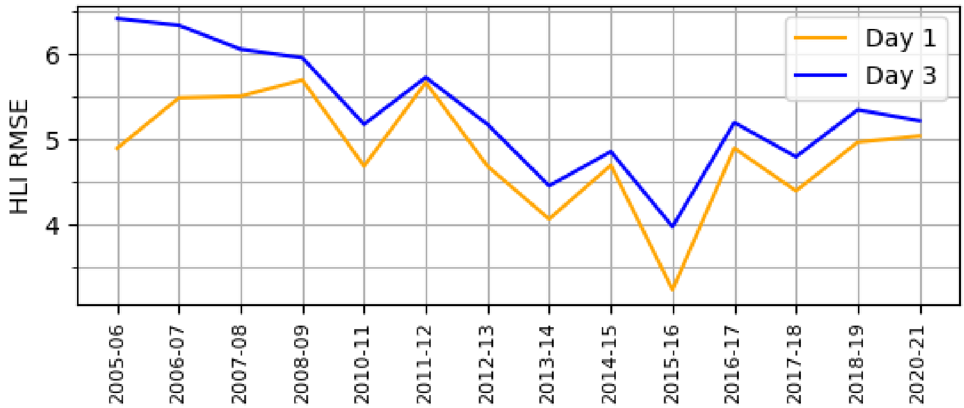


Fig. 22 HLI RMSE averaged seasonally (from 1-Oct to 31-Mar) and across the 17 benchmark sites throughout 14 seasons

To further verify the model performance, the following continuous scores have been considered:

- Mean Absolute Error (MAE): measures the average magnitude of the errors without considering their direction, as RMSE, but it is not a quadratic scoring rule. Rather, MAE is a linear score, which means that all the individual differences are weighted equally in the average. Both the MAE and RMSE can range from 0 to ∞, and they are negatively-orientated scores (i.e., the lower values, the better).

- Mean Error (ME): indicates the average direction of error. It is not a measure of the correspondence between forecasts and observations, as such it is possible to get a perfect score (0) for a bad forecast if there are compensating errors.

- Bias (BIAS): compares the average forecast magnitude to the average observed magnitude. As ME, it does not measure the correspondence between forecasts and observations, and therefore errors can cancel out.

- Correlation Coefficient (CC): measures the linear association between forecast and observation. Visually, the correlation measures how close the points of a scatter plot are to a straight line. Ranging from -1 to 1, the CC is positive when higher forecast values tend to be associated with higher observed values whereas CC is negative when higher forecast values tend to be associated with lower observed values.

- Refined Index of Agreement (rIOA): this index, developed by Willmott et al. (2011), indicates the sum of the magnitudes of the differences between the model-predicted and observed deviations about the observed mean relative to the sum of the magnitudes of the perfect-forecast and observed deviations about the observed mean. A value of rIOA of 0.5, for example, indicates that the sum of the error-magnitudes is one half of the sum of the perfect-model-deviation and observed-deviation magnitudes. Thus, rIOA is a measure of how well each time step (hour) performance is compared to the average of the observations.

In the most recent year, the first 5 days of the forecast exhibit similar values of RMSE followed by a gradual increase to 7-day lead time (Fig. 23a). This decrease in model efficiency with increase in lead time can be explained by increase in uncertainty. We point out that RMSE puts greater influence on large errors than smaller errors, but it does not indicate the direction of the deviations.

The MAE indicates that the average difference between the forecast and the observed HLI is from roughly 4 units for 1-day lead time to 5 units for 7-day lead time (Fig. 23b). Furthermore, the fact that RMSE indexes are not much larger than MAE indexes (only 1-2 HLI units), suggests a similar magnitude error in the forecast. In other words, very large errors are unlikely to have occurred. The overall negative values of ME (Fig. 23c) along with a general BIAS < 1 (Fig. 23d) imply that HLI tends to be under-forecast.

Consistent with the results described above, the very high CCs represent positive and very strong correlation between forecast and observed values, with decreasing, although still strong, performance as lead times increase (Fig. 23e). Finally, the close values of rIOA to 1 indicate a very good agreement between the variation of predicted and observed values at different time steps (Fig. 23f).

Overall, the performance of the operational forecasts in predicting the HLI on an hour-by-hour basis is good. We found that forecast skill is good out to 5 days.

It is also worth noting that as the data is paired in time the forecast can be an hour or two behind or ahead of the environment, causing a disparity in the dataset where the observed HLI is higher than predicted at any given hour. This can be caused by the movement of weather features, such as a trough, across the monitoring point. For instance, the model may move the trough over a region at 7 am, whereas in reality the trough crossed that point at 9 am. These small variations at the hourly scale can cause large variations in the HLI. In this aspect, a review of daily AHLU via the contingency tables (as presented in the following section) overcomes some of the minor discrepancies by interpreting hourly data.

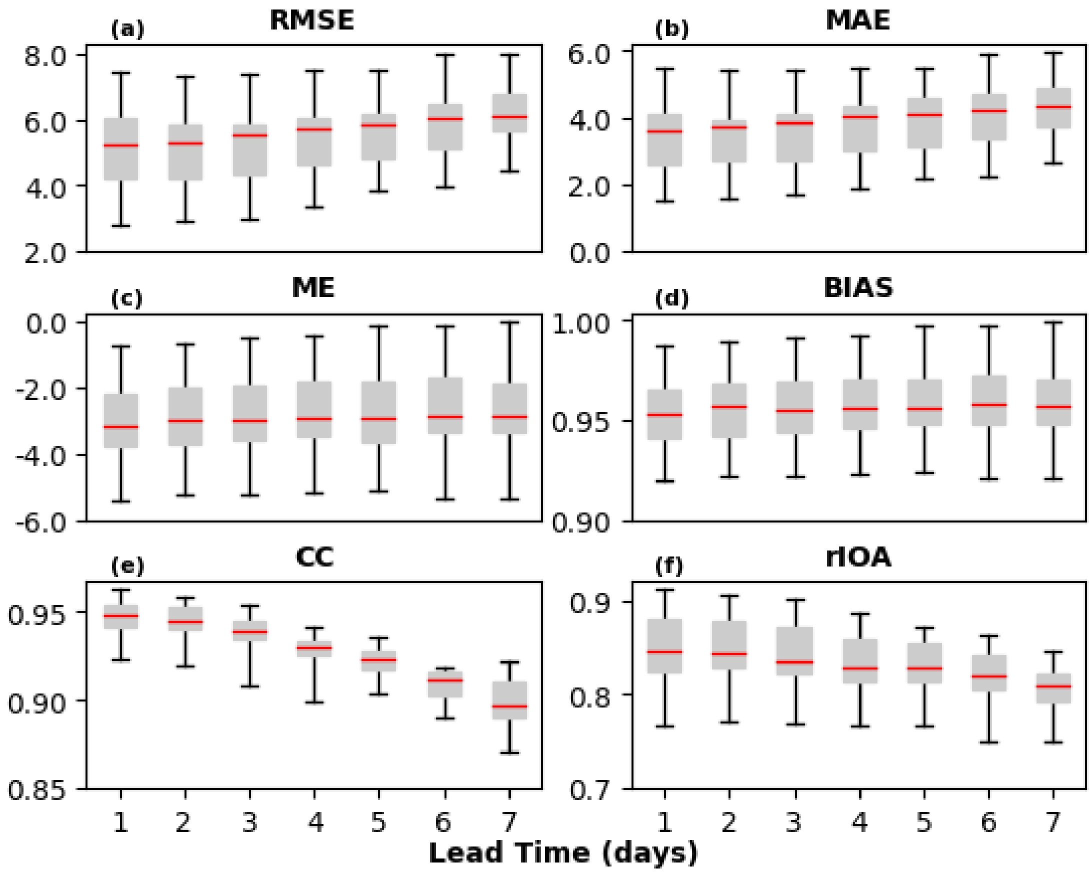


Fig. 23 Box plots comparing several continuous verification methods and statistics of HLI forecast averaged across the 17 benchmark sites for the 2020-2021 season. The bottom and top of the box show the 25th and 75th percentiles, respectively; the red line represents the median and the lower and upper whiskers are the minimum and maximum, respectively.

Accumulated Heat Load Units

A number of categorical statistics of AHLU contingency tables are analysed in this section. Among the metrics, the contingency table (Wilks, 2006) is extensively used in evaluation studies. The contingency table metrics describe whether forecast AHLU hits or misses the observed AHLU and leads to false forecasts relative to observations.

Table 5 Contingency table. A perfect forecast system would produce only "hits" and "correct negatives", and no "misses" or "false alarms"

	Observed: YES	**Observed: NO**
Forecast: YES	hits	false alarms
Forecast: NO	misses	correct negatives

Based on the contingency table (Table 5), several metrics are defined as follows:

- Accuracy: gives an indication of what fraction of the forecasts were correct. Ranging from 0 to 1, 0 means no skill and 1 is the perfect score.

- Bias (or frequency bias): measures the ratio of frequency of forecast events to the frequency of observed events. Therefore, it indicates whether the forecast system has a tendency to underforecast (BIAS<1) or overforecast (BIAS>1) events. The bias ranges from 0 to infinite, with 1 being the perfect score.

- Probability of Detection (POD) or hit rate: answers the question what fraction of the observed "yes" events were correctly forecast? The POD is very sensitive to the climatological frequency of the events and it is a good measure for rare events. The POD ranges from 0 to 1; 0 indicates no skill and 1 is a perfect score.

- Probability of false detection (POFD) or false alarm rate: answers the question what fraction of the observed "no" events were incorrectly forecast as "yes". The FAR ranges from 0 to 1 where 0 is a perfect score.

- False Alarm Ratio (FAR): indicates what fraction of the predicted "yes" events did not occur (i.e., were false alarms). As for POD, FAR is very sensitive to the climatological frequency of the event. FAR ranges from 0 to 1, where 0 is a perfect score.

- Threat Score (TS) or critical success index: indicates how well the forecast "yes" events correspond to the observed "yes" events. Thus, it can be thought of as the accuracy when correct negatives have been removed from consideration. It depends on climatological frequency of events, with poorer scores for rarer events.

Fig. 24 to Fig. 27 show the above metrics including all benchmark locations for the forecast season for 1-day through to 6-day forecast AHLU. Above each figure is displayed the number of correct forecasts (hits and correct negatives) followed by the number of incorrect forecasts (misses and false alarms) for each lead time and risk level. The data is not presented for AHLU92 and AHLU95 due to the lack of events.

The results for each AHLU threshold and category show a varied range of forecasting accuracy and reliability in predicting the correct category. Because of the nature of the derivation of the AHLU (with distinct cut offs) and the methods used to assess the categorical forecasts, it is difficult to draw many meaningful conclusions.

The following points can be made from review of Fig. 24 to Fig. 27:

- The accuracy for all categories and forecast lead times are high for the season (>85%)
- The probability of detection (POD) of an event is >80% for AHLU80 (High and Extreme) for a 1-day lead time, decreasing to 50-60% 2-6 days out. Noting that the number of false alarms for High and Extreme events is less than 10% out to 3 days, this means that a feedlot manager can confidently make a decision up to 3 days ahead of a High or Extreme event forecast. However, the rate of underprediction means that at 3 days out there is a 40% chance of a High or Extreme event not being forecast.
- The accuracy and reliability of the forecast for a Medium event is lower, even at one day ahead forecast period. This is likely to be related to relatively smaller AHLU band, with a Medium event triggered by a forecast AHLU between 20 and 50, while a High event corresponds to an AHLU forecast between 50 and 100.
- The forecast performance for an AHLU83 is different from the AHLU80 threshold, with much lower probability of detection of an Extreme event beyond 2 days but similarly good predictions for High events.
- There are fewer High and Extreme events for the AHLU86 category. The rate of a correctly forecast High event is greater than 90% one day out, decreasing to around 60% for 2-3 days ahead. The rate of false alarms for high events is less than 10% for a 2 day ahead forecast and

0% for Extreme events out to 5 days lead time. However, the forecast overpredicts the number of High events beyond 3 days lead time.

- There are insufficient High and Extreme events for the AHLU89 category to come to any meaningful conclusions. For a Medium event the forecast is reliable with a 3 day ahead time horizon. Beyond day 3 the forecast overpredicts the frequency of a Medium event.

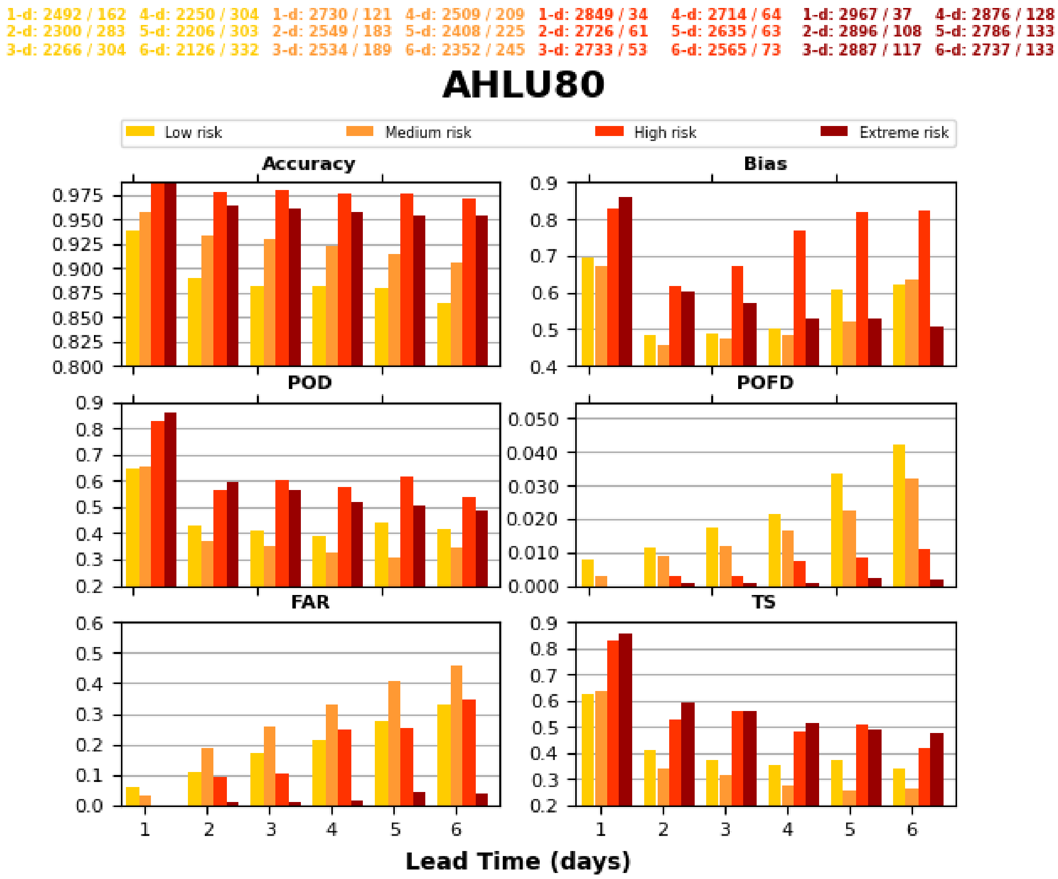


Fig. 24 Measures derived from the AHLU80 contingency table across the benchmark locations

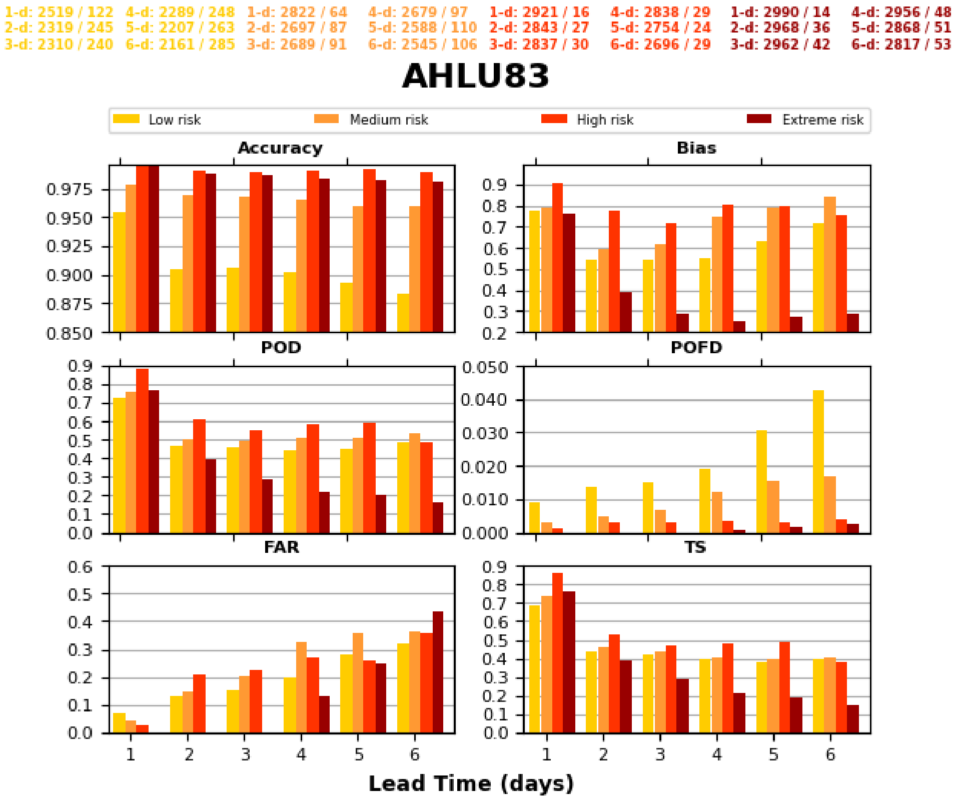


Fig. 25 Measures derived from the AHLU83 contingency table across the benchmark locations

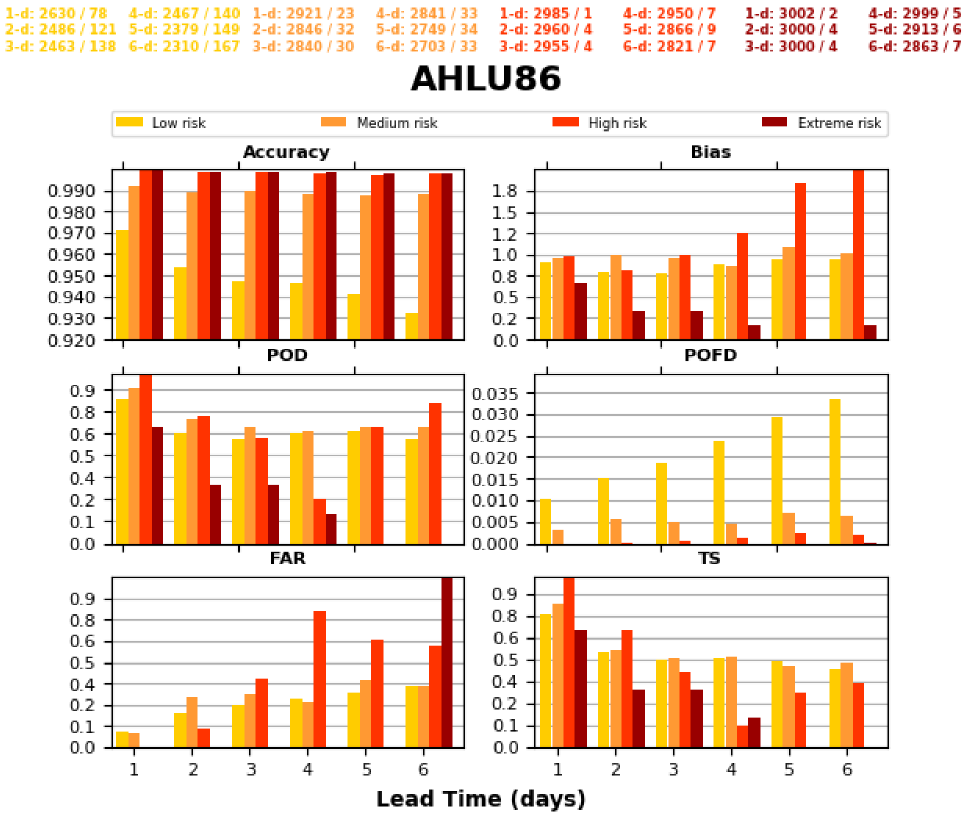


Fig. 26 Measures derived from the AHLU86 contingency table across the benchmark locations

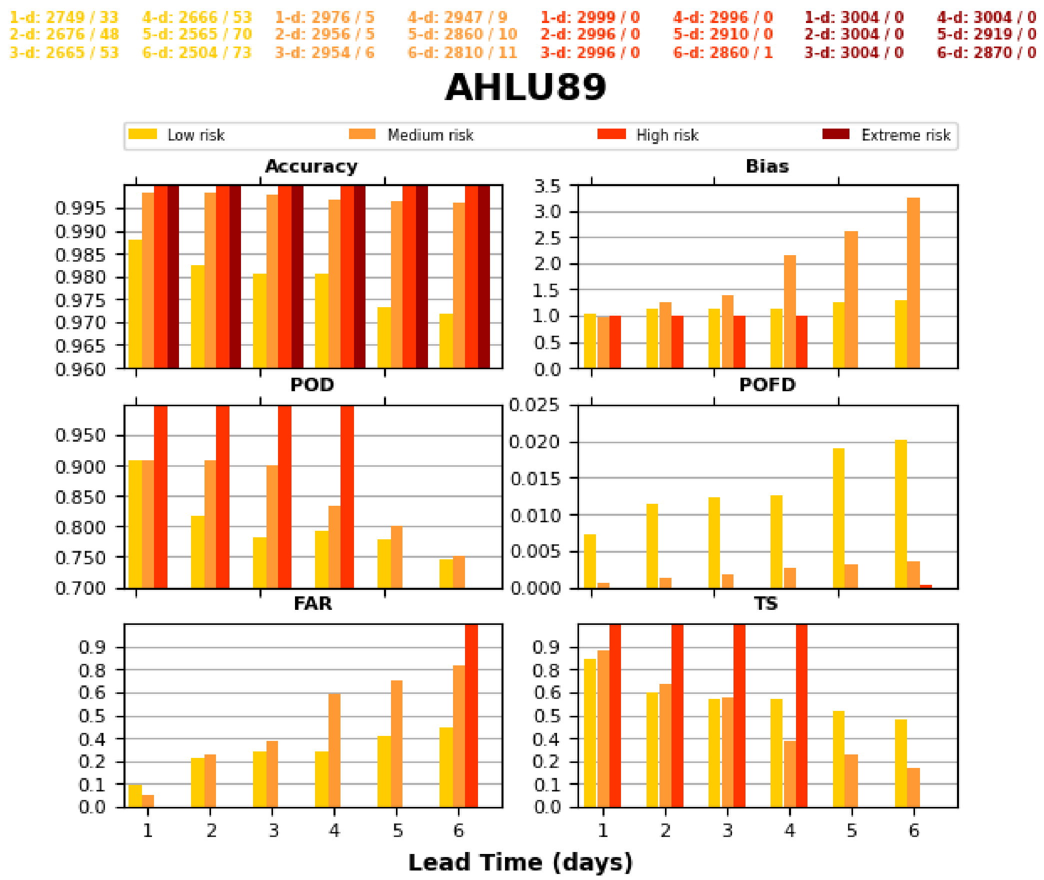


Fig. 27 Measures derived from the AHLU89 contingency table across the benchmark locations

4.1.5 User survey

At the end of each season, a survey is sent out to all CHLT subscribers. The subscribers were invited to comment on the accuracy of the forecast and other aspects of the service.

The March 2020 survey received 118 responses with the full detail of the survey results presented in Appendix A2. The key outcomes from the March 2020 survey are indicated below:

- Just over half of respondents (55%) indicated that they use the CHLT website almost every day during the hot season. A further 26% of respondents indicated that they use the website only when there was a heat wave.
- Half of the participants perceived moderate risk of heat stress in their feedlot animals during this season, and a further 17% perceived high risk.
- Considering the customers who have contacted Katestone at some point this season, all but three are very happy with the level of service they received from Katestone team this season.
- A large proportion of respondents 94% find the tools available on the CHLT website and alerts system helpful for better management of their feedlot.
- A large proportion of respondents indicated that they would like to be notified by SMS (25%) or e-mail (48%) if data is missing for more than 24 hours, while 27% indicated that they were happy to manage missing data themselves.

- Regarding the redevelopment of the CHLT website, 38% of respondents indicated that they found it hard to navigate initially but find it ok now that they are used to it, while 44% of respondents indicated that they like the new site and can find what they are looking for. 14% of respondents indicated that they were still finding it hard to find what they are looking for and/or would like some training.

The March 2021 survey received 111 responses and the full details can be found in Appendix A3. The key outcomes from the March 2021 survey are indicated below:

- Almost half of respondents use the CHLT website almost every day during the hot season. Approximately one-quarter check on the website only when there is a heatwave or when they have received alerts.
- 92% of respondents were feedlot owners, operators or staff, with vets, consultants, welfare officer, processor and business analyst among the remaining respondents. Of the vets and consultants, the most common number of feedlots to manage is 11-50.
- The most common feedlot sizes are 10,000+ and 1,000-5,000.
- The majority (69%) of respondents are responsible for making heat load decisions.
- In an extreme heat load event, the most common (49%) number of staff needed to respond is 2-5.
- Risk to heat load this season saw a decrease compared to 2019-20, with only 2% of respondents believing they were at high risk compared to 20% last year.
- Most (85%) respondents use panting score, and most believe it is a good indicator, with mentions that it is best used in conjunction with other indicators.
- 97% of respondents believe they have adequate resources to manage heat, with some requesting more accurate alerts and forecasts.
- A quarter of respondents have experienced financial loss in the last 5 years due to extreme heat events. These respondents believe heat load management training, more information, acting early, more accurate forecasts and increasing shade would have helped in these cases.
- 97% of respondents found CHLT tools and alerts very helpful or helpful some of the time in managing heat.
- More than three quarters of respondents found the forecast very accurate to accurate most of the time.
- Approximately half (55%) of respondents recalculate the HLI threshold each season or every day, with 37% recalculating when something changes, or appears wrong.
- The most useful elements provided by the CHLT service are the forecast, HLI calculator and being able to incorporate site weather station data.
- The most useful elements respondents would like to see added to CHLT are thunderstorm forecasts, BOM radar maps, video tutorials on improving heat load management, video tutorials on how to use CHLT, probabilistic rainfall forecast and the ability to see multi model forecasts.
- 79% of respondents were satisfied with customer service or did not contact us this season.
- Some comments were made on improving AHLU calculation accuracy, training on how to use CHLT and starting the season earlier.

5 Conclusions

The CHLT service has become an integral part of heat load management at Australian Feedlots. The number of subscribers and feedlots that are registering for the service continues to grow every year with a significant increase (35% increase in the number of users and a 20% increase in the number of feedlots) since the new website was launched in October 2019. Overall, the user base is satisfied with the delivery and performance of the service and see it as an integral part of their strategy to manage heat at their feedlot.

The upgrades to the service made at the beginning of the 2019-2020 season were well received by most users and have resulted in a stable system capable of managing the increased traffic and data load.

The 2019-20 season saw above average temperatures and lower rainfall totals in comparison to 2020-21. This most recent season was mild due to La Nina phase in the Pacific Ocean with lower maximum temperatures and higher rainfall totals.

The HLI anomalies showed a cooler start to the 2019-2020 season with below average conditions across most of the sites for October and November. From January to the end of February 2020 the HLIs were up to 10 units above average at most of the benchmark locations. The 2020-2021 season showed an almost opposite pattern with higher anomalies found early and late in the season.

The contrasting seasons were also reflected in the change in website traffic and less than half the number of alerts sent in the 2020-2021 season compared to 2019-2020, when over 20,000 alerts were issued during the season.

The forecast performance for prediction of HLI was comparable to the last five years. The volatility of the HLI algorithm has been shown in previous studies (B.FLT.0392), indicating that a near perfect forecast can still produce an error of 5 to 7 HLI units, which is similar to the RMSE for a 3-day forecast.

The reliability of the service to predict the correct risk category for different AHLU thresholds is mixed and highlights the problems with using the AHLU with distinct cut off values. The rarity of events also makes the ability to draw meaningful conclusions challenging. For the lower AHLU threshold value of 80, the rate of detection of a High or Extreme event is >80% for a 1-day lead time, decreasing to 50-60% 2-6 days out. However, the very low rate of false alarms for these events, means that a feedlot manager can confidently make a decision up to 3 days ahead if a High or Extreme event is forecast.

The success of the overall system depends on the underlying research to determine a robust assessment of heat risk. The current model is extremely sensitive to the assumptions and small changes in meteorological conditions, which is reflected in the forecast performance for the AHLU categories for the range of HLI threshold values.

The support from users and positive feedback obtained during the surveys indicates that either the users are comfortable with the errors or have developed a good understanding of how the system can best be used to help them manage the cattle under their care. Notwithstanding this, we see there are definite areas for improvement to support the goal of acceptable animal welfare through early warning of adverse weather conditions, such as refining the input assumptions to the system and the communication of risk. User feedback identified thunderstorm forecasts, multi-model forecasts and probabilistic rainfall forecasts as the most desirable additional features to the system.

6 Bibliography

B.FLT.0357, Katestone Environmental Pty ltd 2010a "Upgrade to the feedlot cattle heat load forecast service".

B.FLT.0392 Milestone 5.2, Katestone Environmental Pty ltd 2016 "Evaluation of alternative forecast service performance"

Bureau of Meteorology, 2017, "Seasonal Climate Summary: Australia in summer 2016-17", www.bom.gov.au/climate/current/season/aus/summary.shtml accessed: April 27 2017.

Carbonell L. T., and Coauthors, 2013: Assessment of the Weather Research and Forecasting model implementation in Cuba addressed to diagnostic air quality modeling, Atmospheric Pollution Research, Vol. 4, Issue 1, p. 64-74

Emery C, Tai E and Yarwood G, 2001, "Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes" Prepared for the Texas Near Non-Attainment Areas through the Alamo Council of Governments, By ENVIRON International Corp, Novato, CA.

Gaughan J, Goopy J and Spark J, 2002, "Excessive Heat Load Index for Feedlot Cattle", University of Queensland.

Ho M., A. S. Kiem, and D. C. Verdon-Kidd, 2012, "The Southern Annular Mode: a comparison of indices", Hydrology and Earth System Sciences, Vol. 16, 967-982.

Skamarock, W. C., and Coauthors, 2008: A description of the Advanced Research WRF version 3. NCAR Technical Note NCAR/TN-475+STR, 113 pp

Wilks, D. 2006, "Statistical Methods in the Atmospheric Sciences", 2nd ed., 627 pp., Academic, Burlington, Mass.

Willmott, C. J., S. M. Robeson, and K. Matsuura, 2012: Short communication: A refined index of model performance, *Int. J. Climatol.* **32**, 2088-2094

Appendix

A1 EVALUATION PARAMETERS

Methods for forecasts of continuous variables:

- Root mean square error: $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$
- Mean absolute error: $MAE = \frac{1}{N}\sum_{i=1}^{N}|F_i - O_i|$
- Mean error: $ME = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)$
- (Multiplicative) bias: $Bias = \frac{\frac{1}{N}\sum_{i=1}^{N} F_i}{\frac{1}{N}\sum_{i=1}^{N} O_i}$
- Correlation coefficient: $r = \frac{\sum(F-\bar{F})(O-\bar{O})}{\sqrt{\sum(F-\bar{F})^2}\sqrt{\sum(O-\bar{O})^2}}$
- Refined index of agreement:

$$rIOA = \begin{cases} 1 - \dfrac{\sum|F_i - O_i|}{2\sum|O_i - \underline{O}|}, & when \sum|F_i - O_i| \leq 2\sum|O_i - \underline{O}| \\ \dfrac{2\sum|O_i - \underline{O}|}{\sum|F_i - O_i|} - 1, & when \sum|F_i - O_i| > 2\sum|O_i - \underline{O}| \end{cases}$$

Methods for dichotomous (yes/no) forecasts:

- Accuracy: $Accuracy = \frac{hits + correct\ negatives}{total}$
- Bias: $Bias = \frac{hits + false\ alarms}{hits + misses}$
- Probability of detection: $POD = \frac{hits}{hits + misses}$
- Probability of false detection: $POFD = \frac{false\ alarms}{correct\ negatives + false\ alarms}$
- False alarm ratio: $FAR = \frac{false\ alarms}{hits + false\ alarms}$
- Threat score: $TS = \frac{hits}{hits + misses + false\ alarms}$

A2 2020 CHLT SURVEY SUMMARY

At the end of the 2019-2020 season, a survey was sent out to all CHLT subscribers. The subscribers were invited to comment on the use of, and satisfaction with, the forecast and other aspects of the service. The survey received a total of 118 responses.

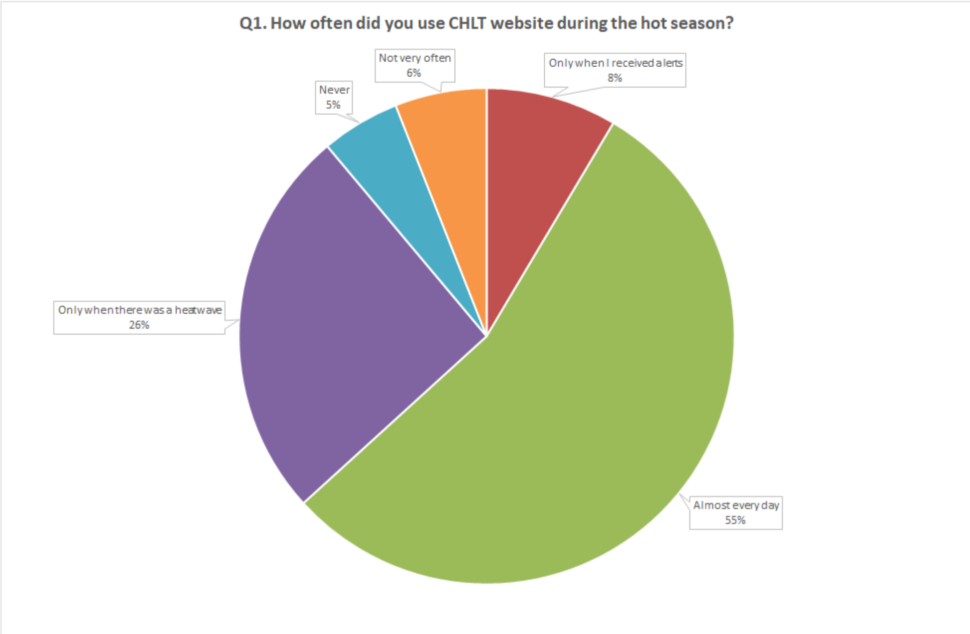


Fig. A2.1 Responses to question 1 of the end of season survey

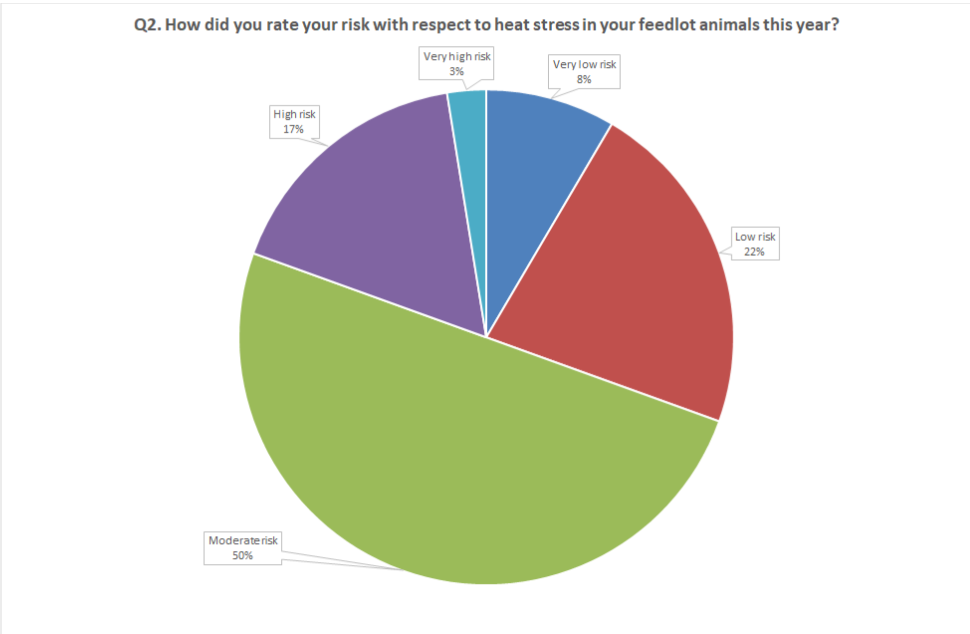


Fig. A2.2 Responses to question 2 of the end of season survey

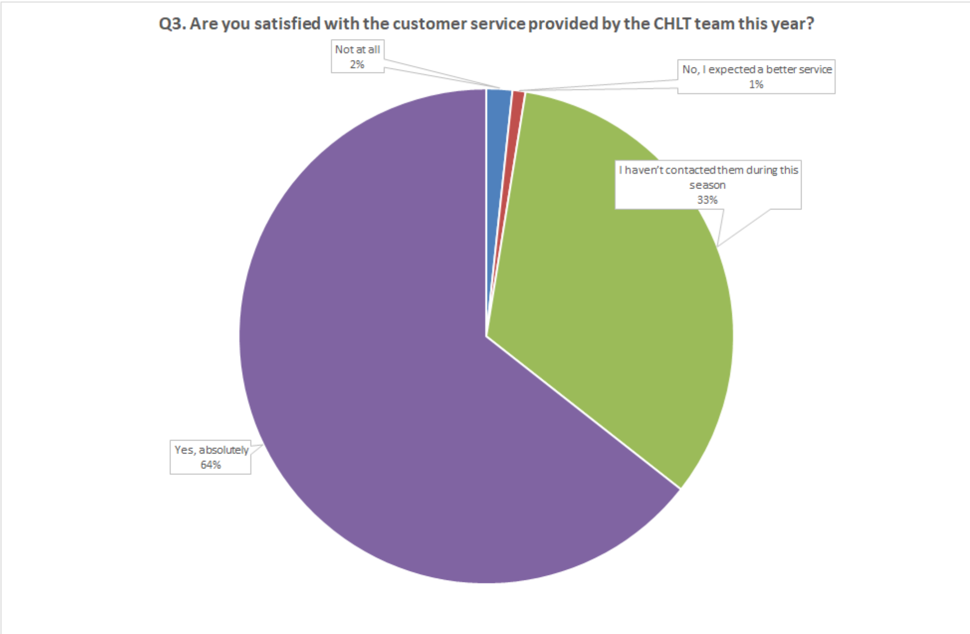


Fig. A2.3 Responses to question 3 of the end of season survey

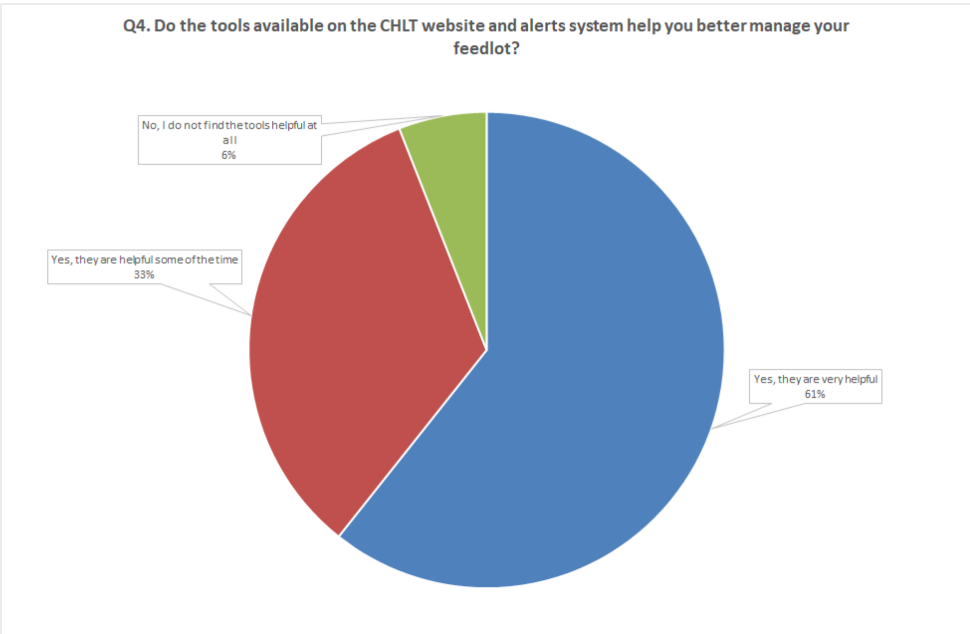


Fig. A2.4 Responses to question 4 of the end of season survey

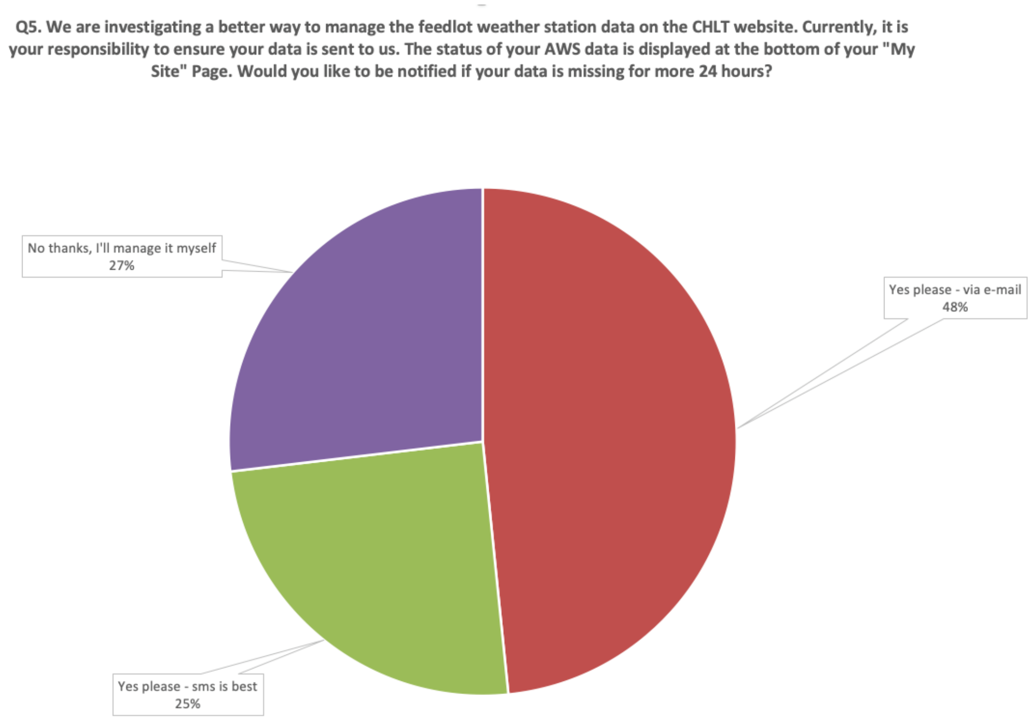


Fig. A2.5 Responses to question 5 of the end of season survey

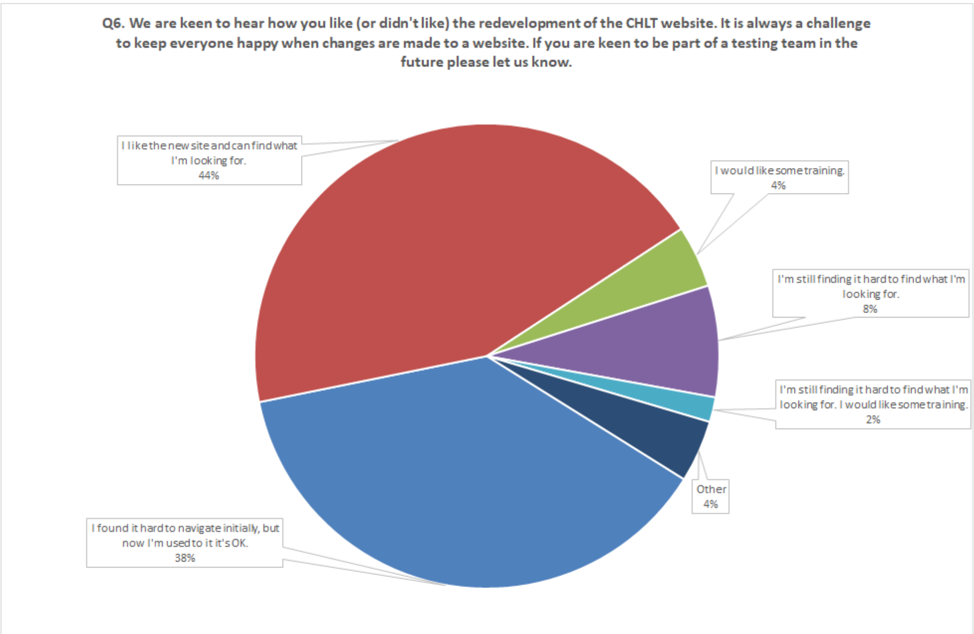


Fig. A2.6 Responses to question 6 of the end of season survey

Table A2.1 Additional comments of the end of season survey.

Q6. We are keen to hear how you like (or didn't like) the redevelopment of the CHLT website. It is always a challenge to keep everyone happy when changes are made to a website. If you are keen to be part of a testing team in the future please let us know. Other responses:		
Answer Options		**Response Count**
Comments:		15

Number	Comments:
1	Not as user friendly.
2	We do not use the website as it does not relate to our area and Tasmania is extremely low risk for heat.
3	Absolutely terrible. 1 person in this office can just interpret it. The old format was definitely much better. ALFA have discussed this with me along with vets and nutritionists, and we have all agreed and joke about how bad it is. I did contact Katestone re this and was completely underwhelmed with the response I received. Pointless contact and a complete was of mine and others time.
4	Still find the old layout better. New layout is 'pretty'.
5	I found it hard to navigate initially, but now I'm used to it it's OK.
6	I thought the new format made it simpler to see the total AHLU's that were predicted for each day ion the forecast. the old display. The information was made clearer in the current display than in previous years as it did not have a summary of daily AHLU's, HKI max and min for each day.
7	Long loading time compared to last website.
8	We are a privately owned & operated feedlot and have managed heat loading with commern sence without needing to access a website.
9	As a very small feedlot that had no stock on feed this past season we did not use the website at all.
10	I found it hard to navigate initially, but now I'm used to it it's OK.
11	Presentation of data and ease of access/use is significantly improved this year.
12	Was a bit hard to work out what had occurred in previous 24 hours.
13	I found it hard to navigate initially, but now I'm used to it it's OK.
14	Have calibrated data with cattle observations.... getting the hang of it in our circumstance. Grower not finishing ration.
15	Soft climate heat not an issue.

Q7. If you have specific feedback that might help us improve the delivery of the information, please let us know.:		
Answer Options		**Response Count**
Comments:		13

Number	Comments:
1	Where we are we had periods of extreme conditions lasting weeks. However, there were days that conditions were milder but the CHLT website did not reflect this.
2	Need to develop a max level for AHLU (e.g. 120 - 150), so that it does not keep accumulating during hot weather. Some sites got to well over 1000 ahlu which is nonsensical and confusing for the user. they actually start to ignore the site which is not desirable.
3	Really did not like the new change to the website this year, felt it was very confusing and did not use the site as much as i would have liked to because of this.
4	Go back to the old format, which was legible, sensible and easy to follow. Not all feedlot employees are rocket scientists!! so don't create a complex matrix for them to interpret. Basic, clear, common sense.
5	Make it an app, would make it quicker and easier to use.
6	Information delivery was good with no issues however this season did have higher Humidity than other seasons. At this feedlot we had issues with humidity levels at 80 plus % that was not hitting the AHLU triggers. I think the equation needed to factor the humidity at higher levels when it gets over 60%. Cattle displayed pant scores of 2.5 without the trigger being hit creating an alert a couple of times. the alert did come but the cattle had been hot for a few hours. the riverine also has very dry summers and this season was different to what we have usually seen.
7	It's like any website, You have to use it to become familiar but then it's very useful . Thankyou.
8	All good thank you.
9	Please keep it simple. some staff find it difficult at times.thanks.
10	The feedlot is in a black spot area and are not in the generation the spend time on electronic devices.
11	Your service covered all the queries we had through the summer.
12	Good job guys, thank you for everyone's help.

13	I found the forecast a lot more consistent this year with the hot dry conditions forecast very well and there appeared to be higher numbers forecast for humid conditions which was reflected in the cattle.

The main points from the end of season survey are indicated below:

- Just over half of respondents (55%) indicated that they use the CHLT website almost every day during the hot season. A further 26% of respondents indicated that they use the website only when there was a heat wave.
- Half of the participants perceived moderate risk of heat stress in their feedlot animals during this season, and a further 17% rated as high risk.
- Considering the customers who have contacted Katestone at some point this season, everyone, except for three, are very happy with the level of service they received from Katestone team this season.
- A large proportion of respondents (up to 94%) find the tools available on the CHLT website and alerts system helpful for a better management of their feedlot whereas only 6% do not find the tools useful.
- A large proportion of respondents indicated that they would like to be notified by SMS (25%) or e-mail (48%) if data is missing for more than 24 hours, while 27% indicated that they were happy to manage missing data themselves.
- Regarding the redevelpemnt of the CHLT website, 38% of respondents indicated that they found it hard to navigate initially but find it ok now that they are used to it, while 44% of respondents indicated that they like the new site and can find what they are looking for. A further 14% of respondents indicated that they were still finding it hard to find what they are looking for and/or would like some training.
- Additional comments relating to the satisfaction with the redeveloped CHLT website as well as any specific feedback to help improve the delivery of information are provided in

- Table **A2.**.

Overall, the survey results indicate that the large majority of users are well satisfied with the service provided by Weather Intelligence this season. However, we received some comments that help us to determine the weaknesses of CHLT so that we can improve the product for the next seasons.

A3 2021 CHLT SURVEY SUMMARY

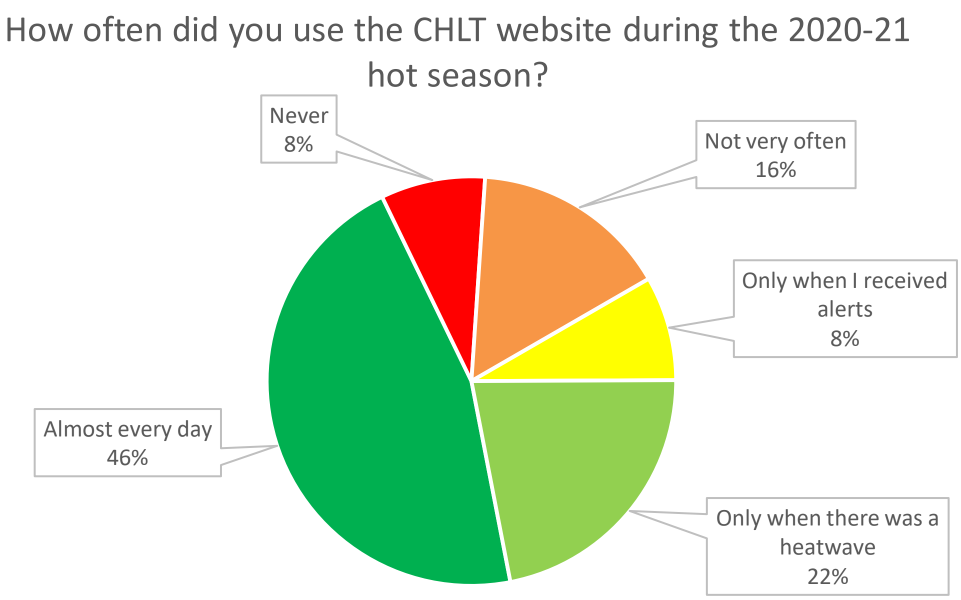


Fig. A3.1 Responses to question 1 of the end of season survey (2020-2021)

Of those who said they never use CHLT (9 respondents):

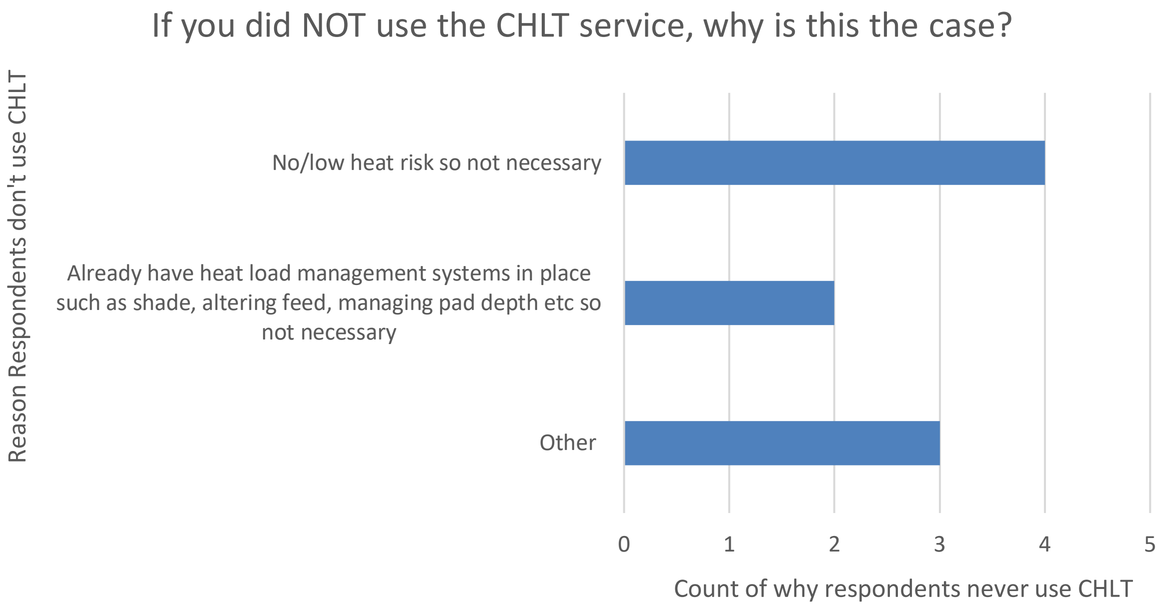


Fig. A3.2 Responses to question 2 of the end of season survey (2020-2021)

Comments from those who chose "Other":

- No longer have cattle / operate a feedlot
- Only have cattle in cooler months / in shaded paddock

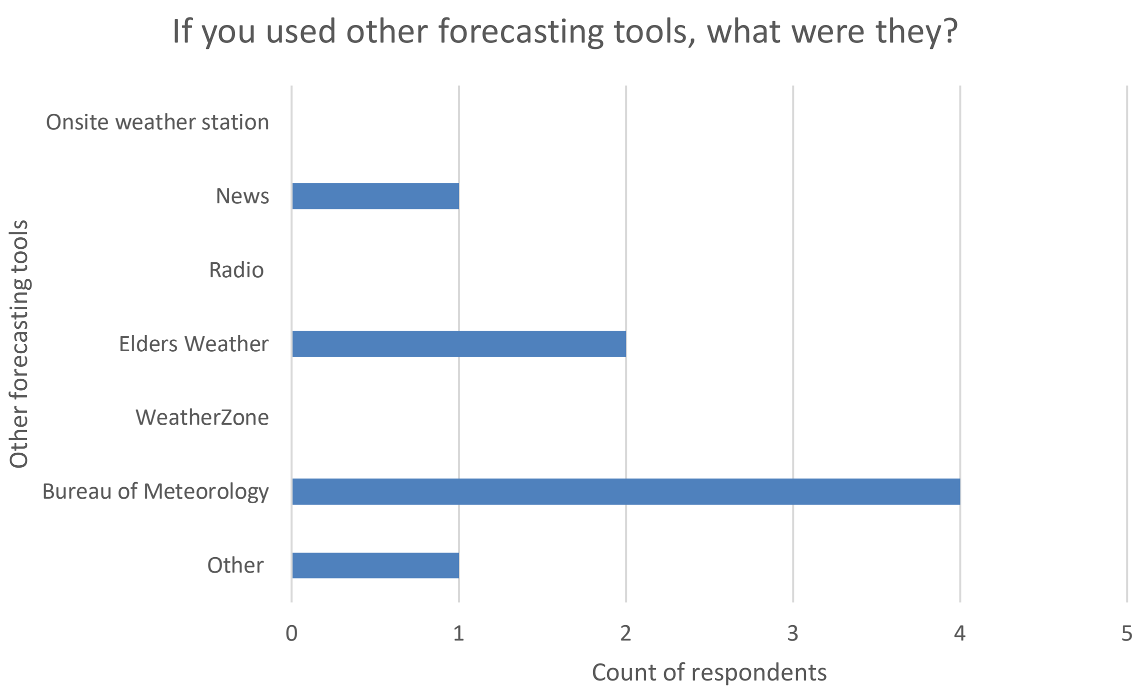


Fig. A3.3 Responses to question 3 of the end of season survey (2020-2021)

The respondent who chose “Other” does not have cattle anymore.

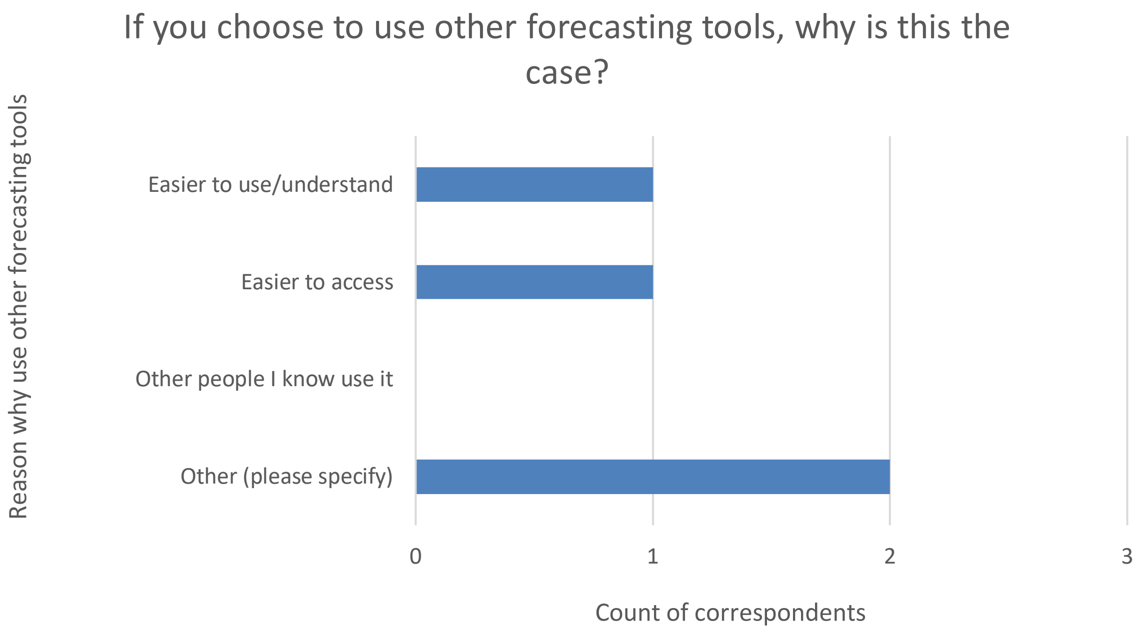


Fig. A3.4 Responses to question 4 of the end of season survey (2020-2021)

Comments from those who chose “Other” (2 respondents):

- Question not applicable
- Finds news sufficient for weather as have paddocks with shade

The remaining graphs are from respondents who do use CHLT (111 respondents):

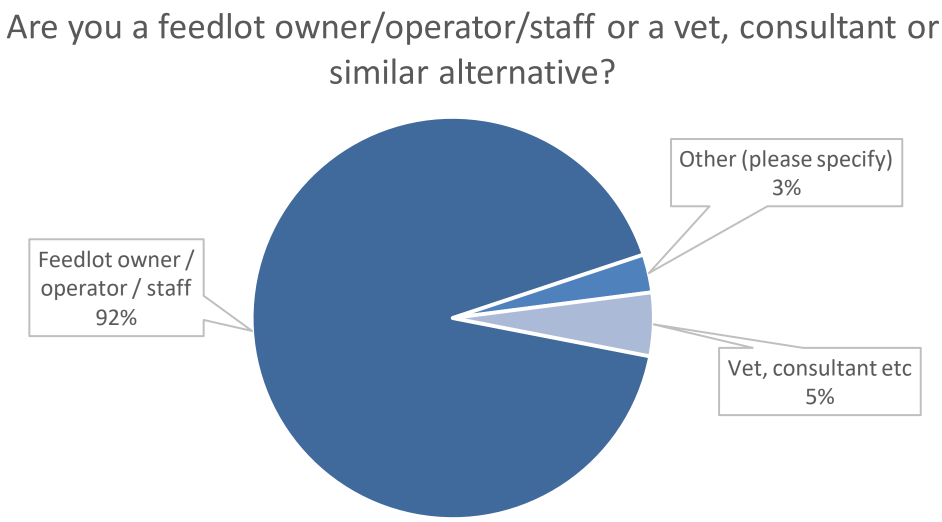


Fig. A3.5 Responses to question 5 of the end of season survey (2020-2021)

Comments from those who chose "Other":

- Headstockman/Animal welfare officer
- Grainfed Business Analyst
- Processor
-

Of those who said they are a vet, consultant etc (5 respondents):

1. How many feedlots do you help manage?

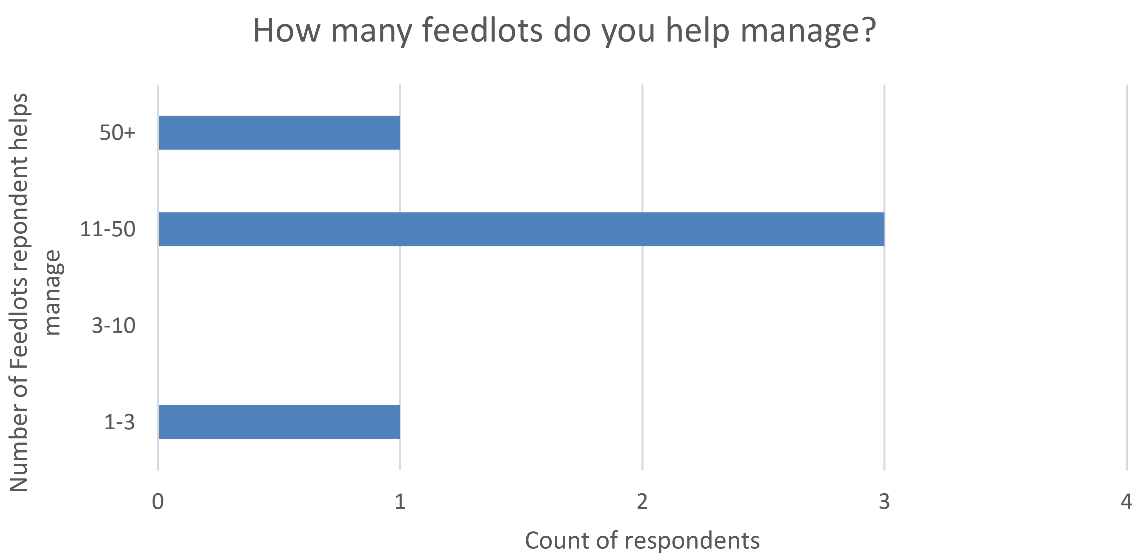


Fig. A3.6 Responses to question 6 of the end of season survey (2020-2021)

Of those who said they are a feedlot owner/operator/staff or other (96 respondents):

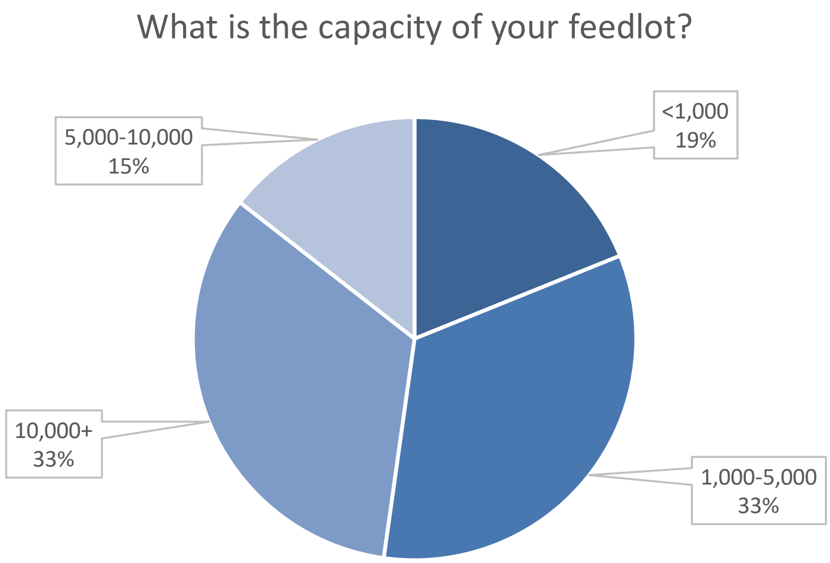


Fig. A3.7 Responses to question 7 of the end of season survey (2020-2021)

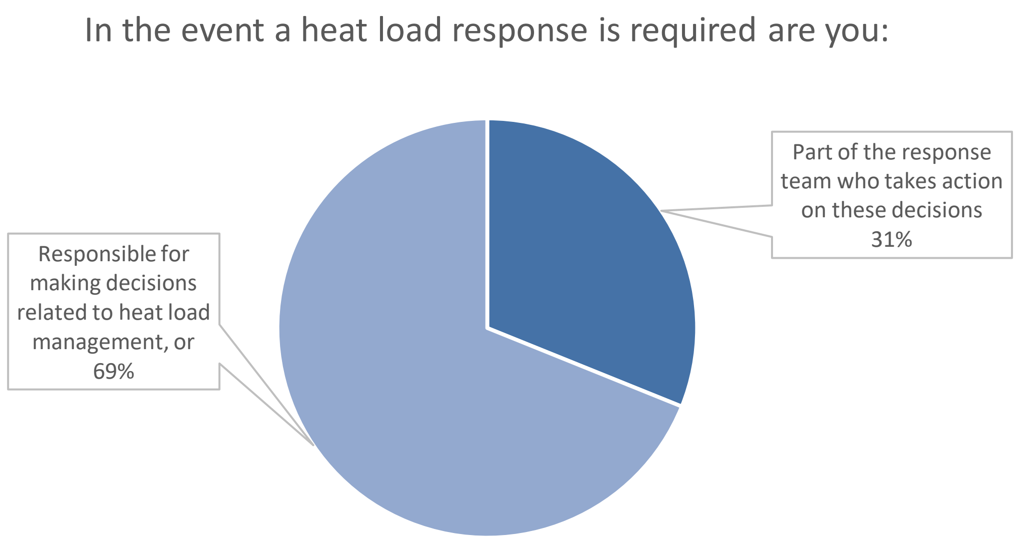


Fig. A3.8 Responses to question 8 of the end of season survey (2020-2021)

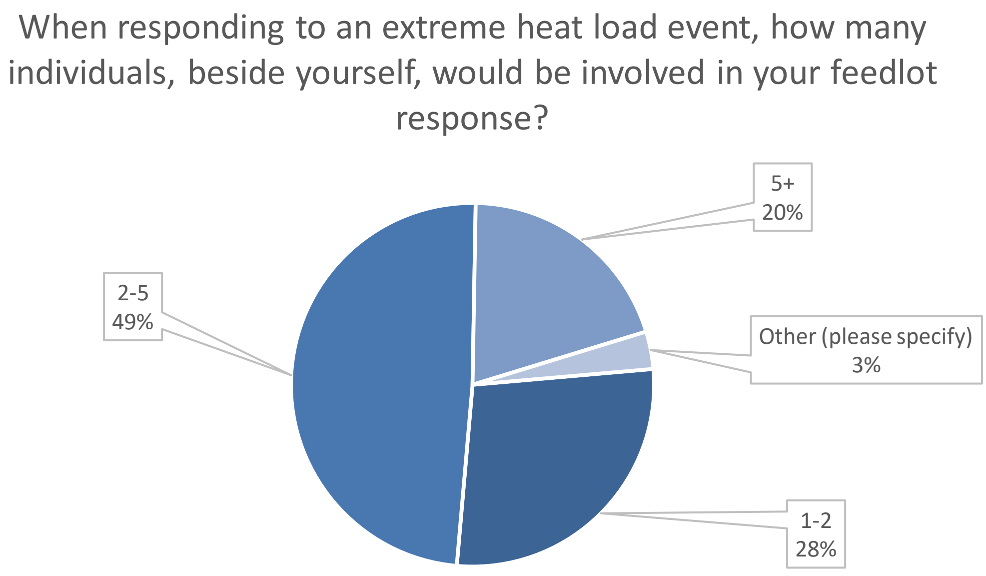


Fig. A3.9 Responses to question 9 of the end of season survey (2020-2021)

Comments from those who chose "Other":

- All staff at the feedlot
- 10+

The following questions were answered by everyone who uses CHLT (101 respondents):

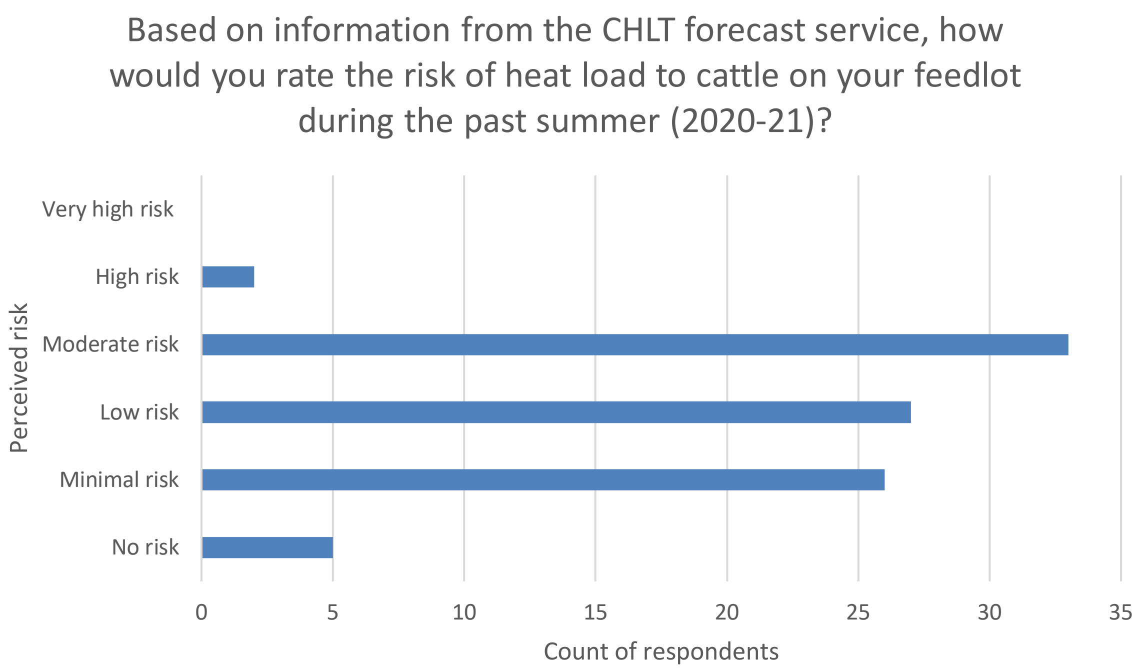


Fig. A3.10 Responses to question 10 of the end of season survey (2020-2021)

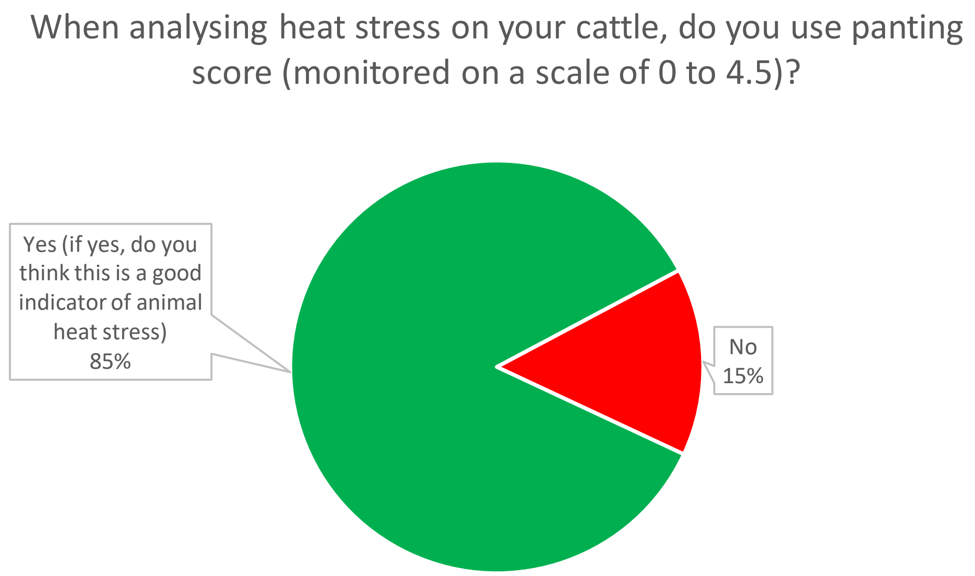


Fig. A3.11 Responses to question 11 of the end of season survey (2020-2021)

Some comments from those who think it is a good indicator:

- Most respondents (~79%) believe it is a good indicator
    - Highlights how cattle coping with conditions
    - Best indicator available
    - Assists target specific pens
    - Easy for staff to understand
- Some respondents (~10%) believe it is good, but best used with other indicators
    - Combine with food and water intake
    - Combine with breaths per minute
    - Influence by breed type
- The remaining respondents (~11%) generally found panting score moderately helpful with common responses below:
    - Sometimes accurate / reasonable / generally good
    - Show's if animal is experiencing heat stress, does not help prevent it
    - Not completely, but a good tool for early detection
    - Cattle never displayed signs of heat stress, even on hottest day

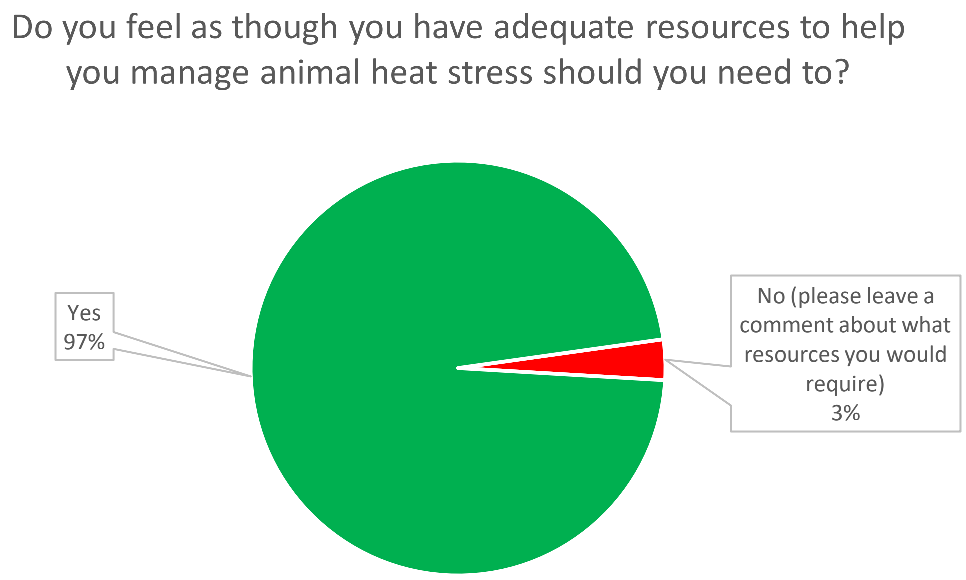


Fig. A3.12 Responses to question 12 of the end of season survey (2020-2021)

Some comments from those who don't feel they have adequate resource and would require more:

- More accurate forecasting
- Improved accuracy of alerts

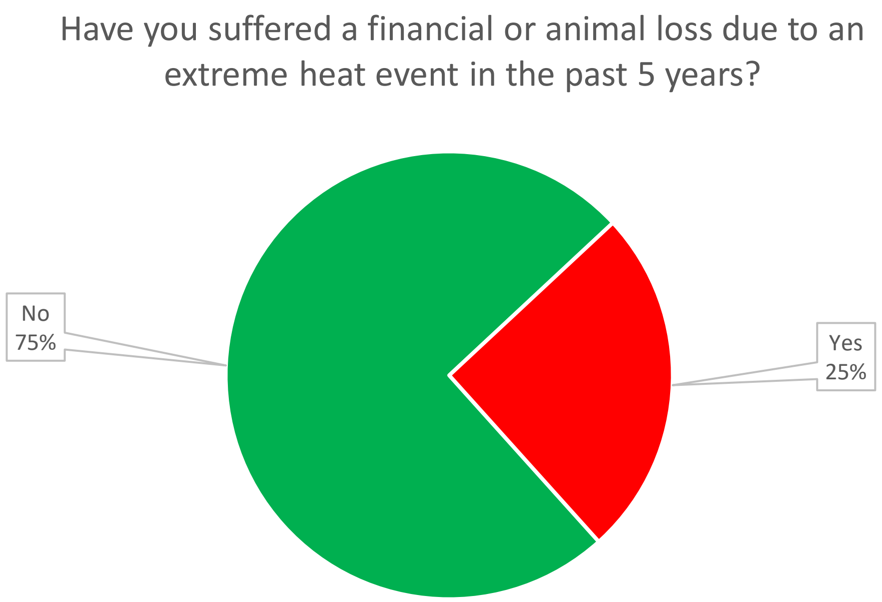


Fig. A3.13 Responses to question 13 of the end of season survey (2020-2021)

Of those who have had financial loss in the last 5 years (28 respondents):

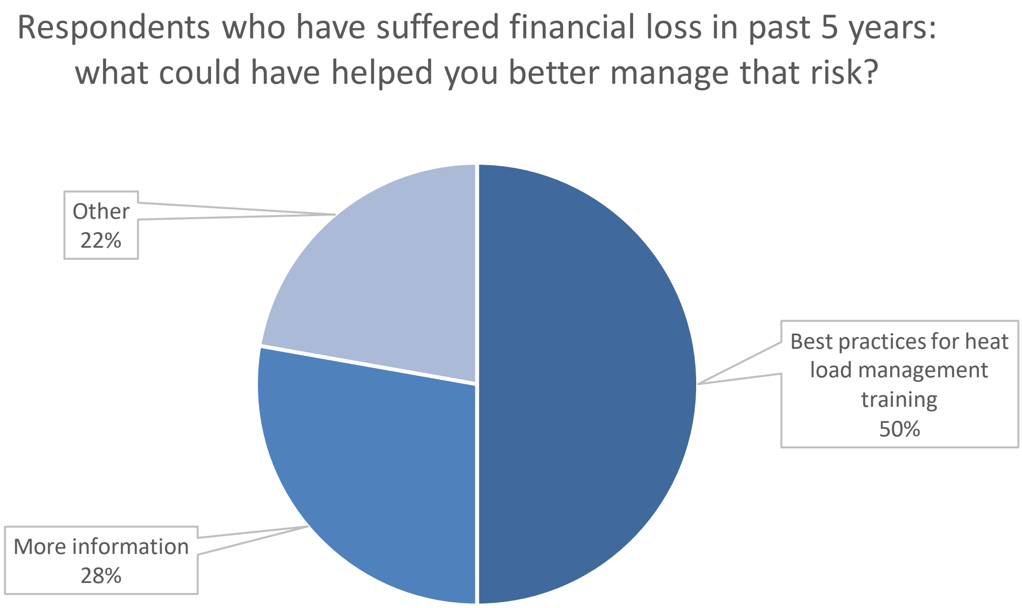


Fig. A3.14 Responses to question 14 of the end of season survey (2020-2021)

Comments from those who chose "Other":

- Due to unique event
- More accurate forecasts
- Not accepting cattle at start of heat event
- Act early
- Increasing shade
- Taking humidity into account

The following questions were answered by everyone who uses CHLT (101 respondents):

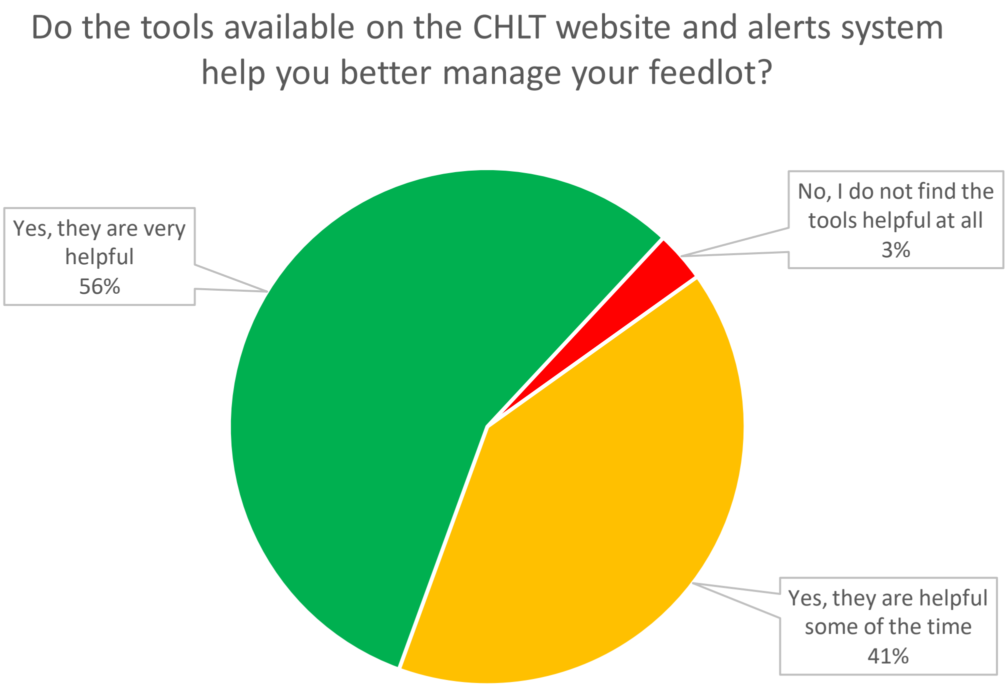


Fig. A3.15 Responses to question 15 of the end of season survey (2020-2021)

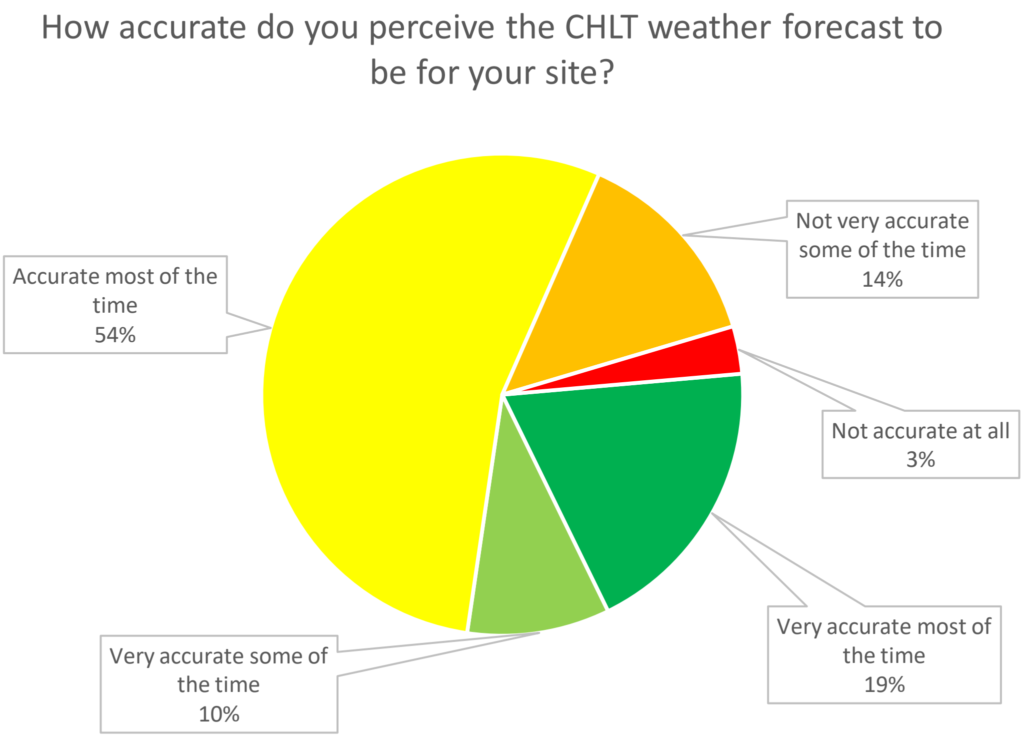


Fig. A3.16 Responses to question 16 of the end of season survey (2020-2021)

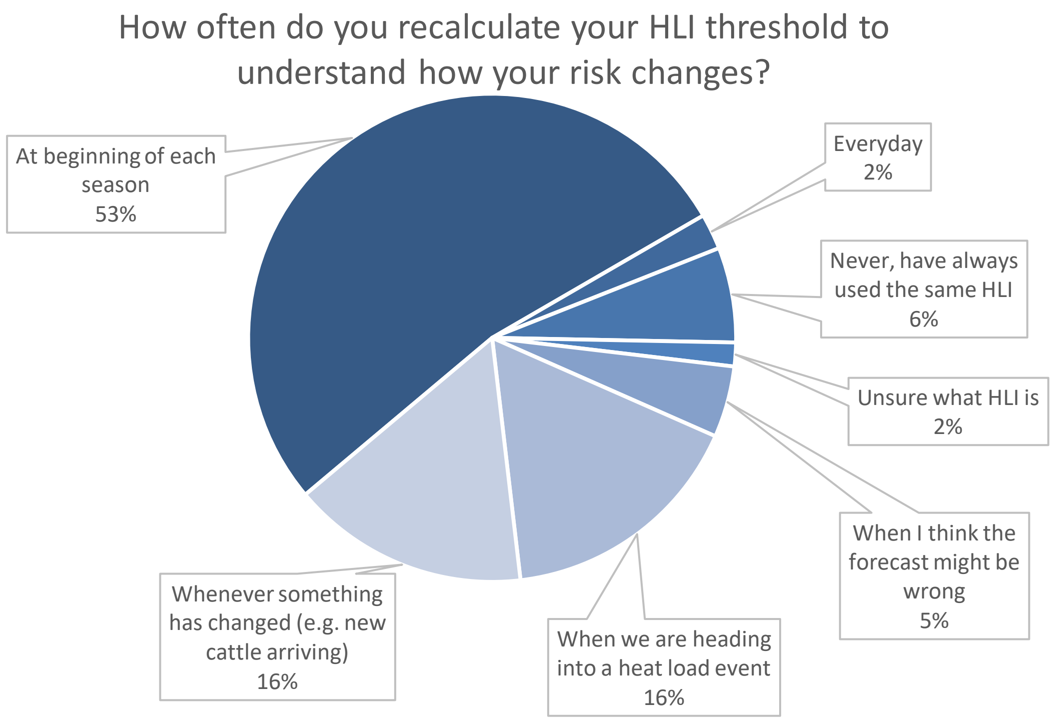


Fig. A3.17 Responses to question 17 of the end of season survey (2020-2021)

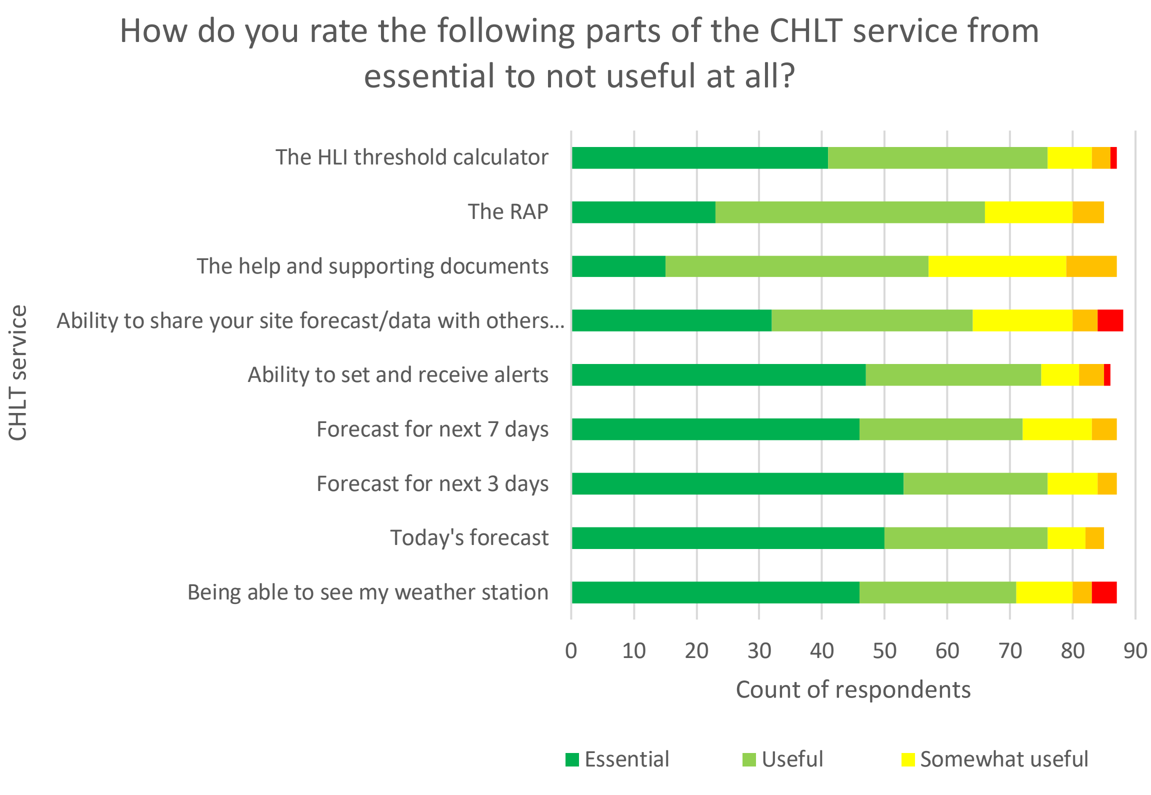


Fig. A3.18 Responses to question 18 of the end of season survey (2020-2021)

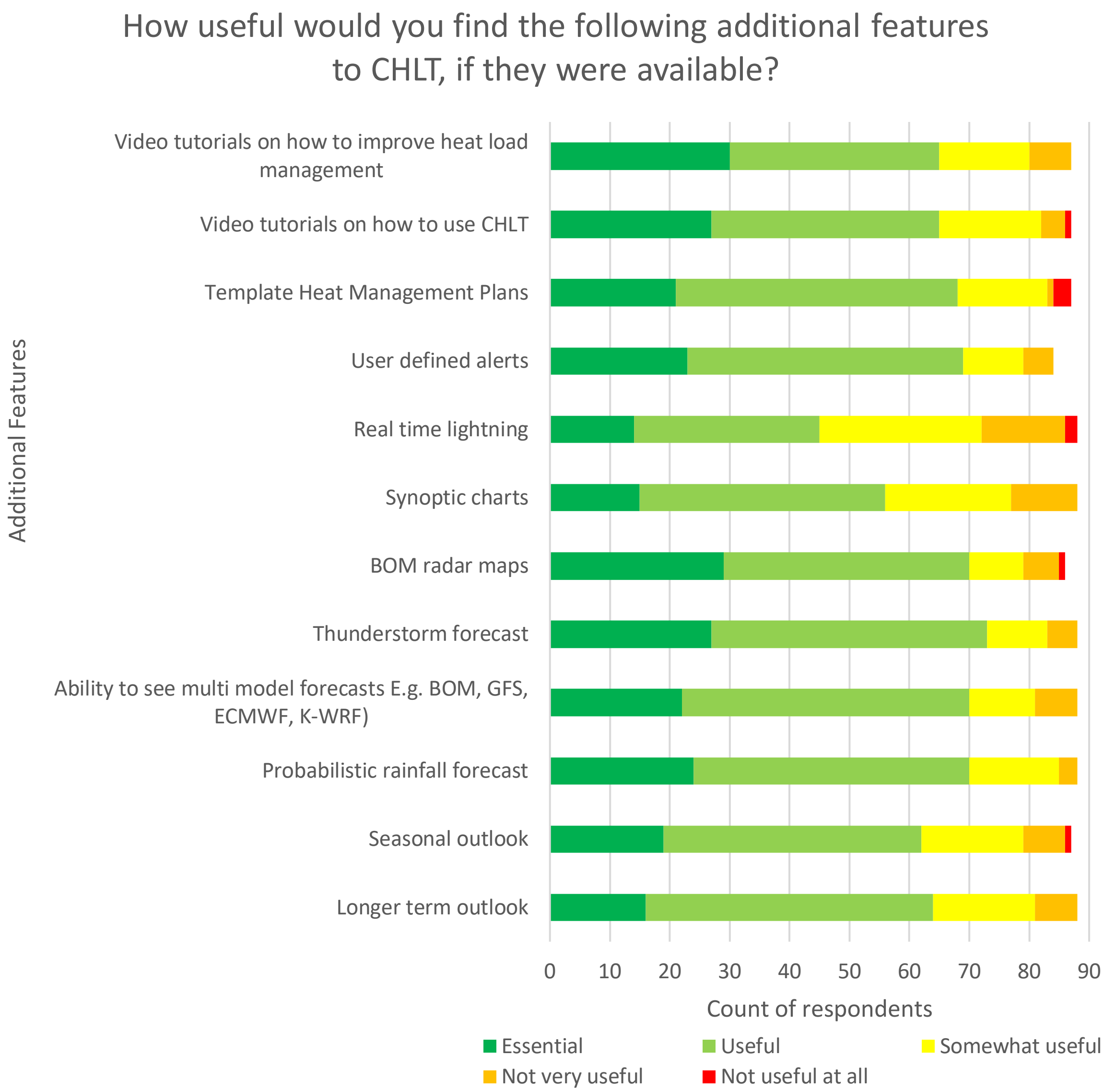


Fig. A3.19 Responses to question 19 of the end of season survey (2020-2021)

20. If there is anything that you would change on the CHLT website, what would it be?

- Most respondents (~86%) did not answer this question or answered no
- Some comments from the remaining respondents (~14%):
    - Improve/simplify layout of the website
    - Improve humidity and rainfall forecasting
    - Create a mobile app
    - Add extra alerts
    - Create training manuals for new staff
    - Training for website capabilities e.g. adding weather station, looking at observations
    - Reduce / increase number of alerts
    - Improve AHLU calculation to prevent runaway AHLU

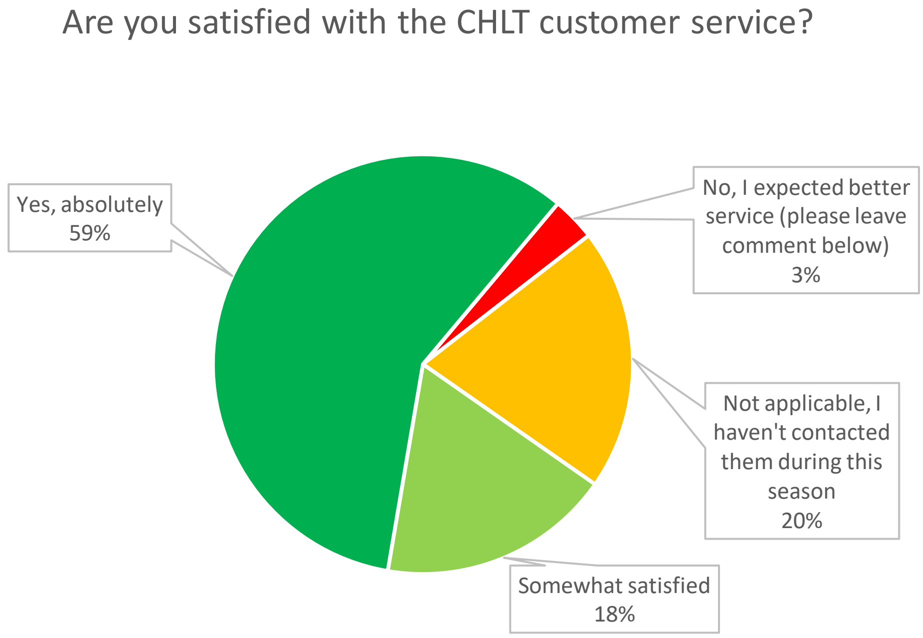


Fig. A3.20 Responses to question 21 of the end of season survey (2020-2021)

Comments from those who chose “No”:

- Appears to be a problem with the AHLU calculation, was informed that there is nothing they can do to fix it (Note: This calculation is currently being fixed)
- I made a query about cumulative rain record being misreported and Michael B said it could be fixed. Matter not finalised and still not working.

22. Additional comments for the end of season:

- CHLT is very useful
- Start alert season earlier for Central Queensland
- Weather and forecasts do not reflect each other sometimes
- Feedlot located in cooler location, CHLT not relied on heavily
- Improve AHLU calculation
- This year was mild, so extreme heat events occurred less often
- Longer term rainfall forecast

A4 Preseason Newsletter

17/05/2021 CHLT 2020-21 Season Newsletter

Subscribe | Past Issues | Translate

View this email in your browser

Get Ready for Summer

Drought, bushfires, floods and a global pandemic since the last time we spoke! What more can be thrown at us? A cyclone or two? These are certainly challenging times, but together we can support each other, build resilience, and come out the other side with a new outlook on life.

As the hot season has just started, your SMS alerts are now active again. The e-mail alerts are also active and have been operational all winter. As always, it's a good time to review your heat management strategies, ensure that all essential staff has active CHLT accounts (and can log in!), check your weather station and make sure it's uploading correctly to CHLT and have a heat management meeting with all your staff to keep everyone up to date with your procedures and how to identify heat stress in animals.

In this newsletter we have compiled a few things that might interest you:

- A brief outlook at the seasonal forecast for summer
- A summary of the 2019/20 season
- Latest survey responses
- The new ALFA Shade hub
- Upcoming webinars and workshops

https://mailchi.mp/2f4645c21d0c/chlt-2020-21-season-newsletter?e=[UNIQID] 1/8

We hope you are now all familiar with the changes made to the CHLT website last season. If you are looking for more information or would like a refresher before the hot weather arrives, please either contact the team at info@chlt.com.au or join us for an informative **Webinar on Friday 27 November at lunchtime.**

Keep safe and cool
Christine and the CHLT team

What is the weather doing?

The outlook for the summer (as issued by BOM 5/11/2020) is mixed for maximum temperature with some areas with a high chance of exceeding median maximum temperatures (see red areas on map) and some areas with a low change (see blue areas on map). However, the outlook for above-median minimum temperature is generally very high over the entire continent. This reflects the higher availability of moisture (humidity) which can also be seen in the higher chance of rainfall over most parts.

The tropical Pacific is in a La Nina phase and this is likely to last through summer and perhaps longer. La Nina typically brings higher than average summer rainfall across Eastern Australia. It is also expected to generate average or slightly above average number of cyclones and an earlier start the cyclone season (first cyclone is likely to cross the coast in December rather than in January). Significant heat events have occurred in the past following the passage of a cyclone or tropical low.
Overall the climatic risk this season is for above-average heat stress conditions.

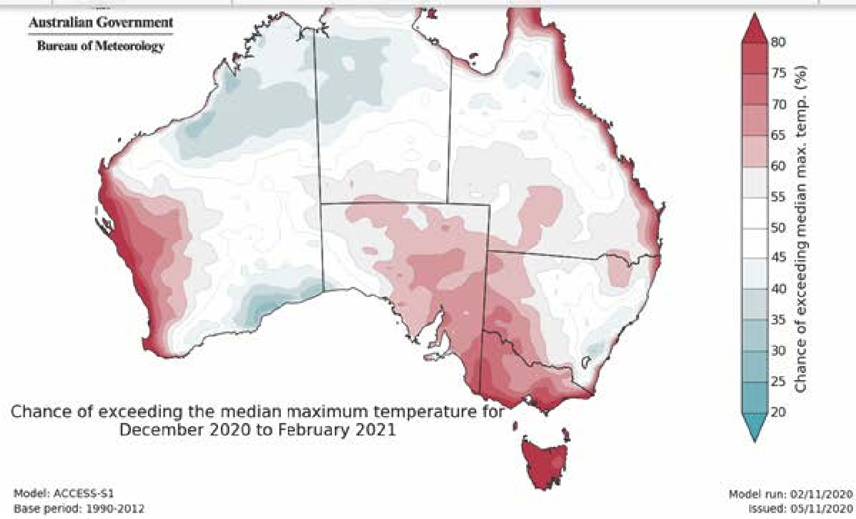


Figure 1. Chance of exceeding the median maximum temperature for December 2020 to February 2021

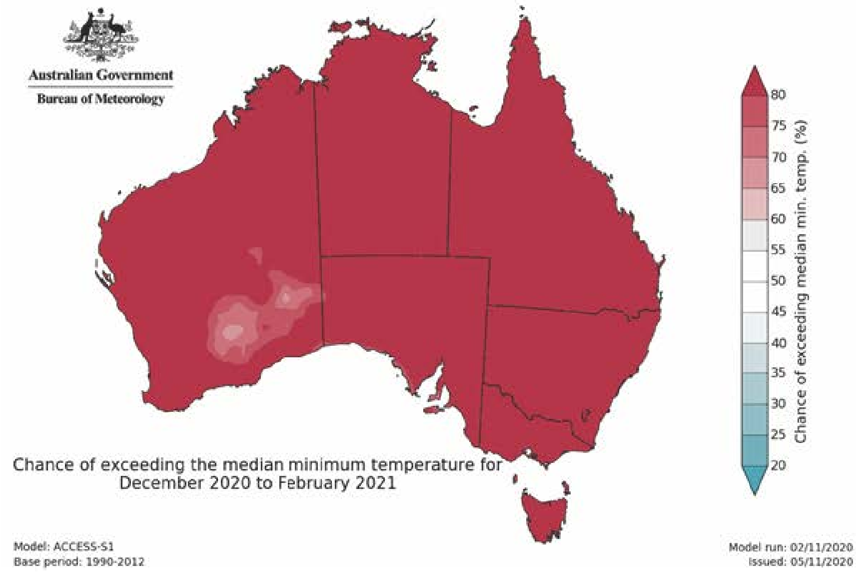


Figure 2. Chance of exceeding the median minimum temperature for December 2020 to February 2021

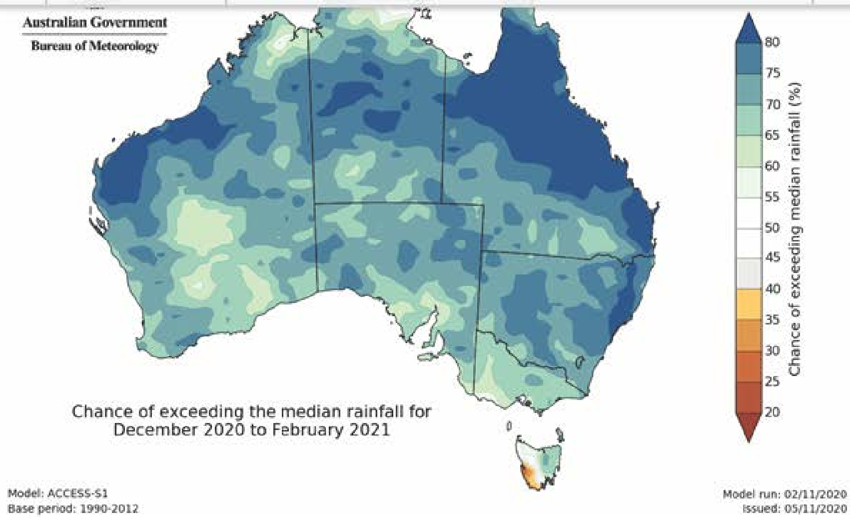


Figure 3. Chance of exceeding the median rainfall for December 2020 to February 2021

ALFA Shade hub

ALFA has been very busy compiling the information from many years of research and coming up with a one-stop-shop for all the information you could possibly want to understand shade in feedlots.

- How will it benefit you and the animals whose welfare you are responsible for (productivity and welfare benefits)?
- Design and construction advice
- Where to get finance to fund your development
- Shade manufacturers
- Case studies, research, and lots more!

Click here for more information: https://www.feedlots.com.au/shade

Review of Last Summer

The Weather

Last summer was another hot one with most parts of Australia recording very much above-average temperatures for the season (see below figure). As you all know temperature is only one part of the puzzle when it comes to heat stress. The figure showing large parts of Australia with lower than average vapour pressure indicates the lower risk of heat stress due to reduced humidity, which was also reflected in the very low levels of rainfall.

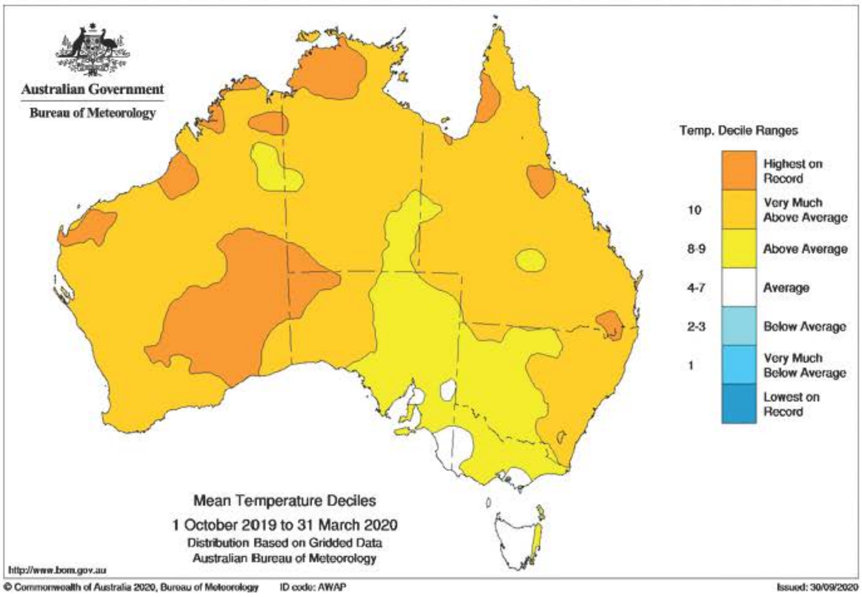


Figure 4. Median temperatures deciles - October 2019 - March 2020

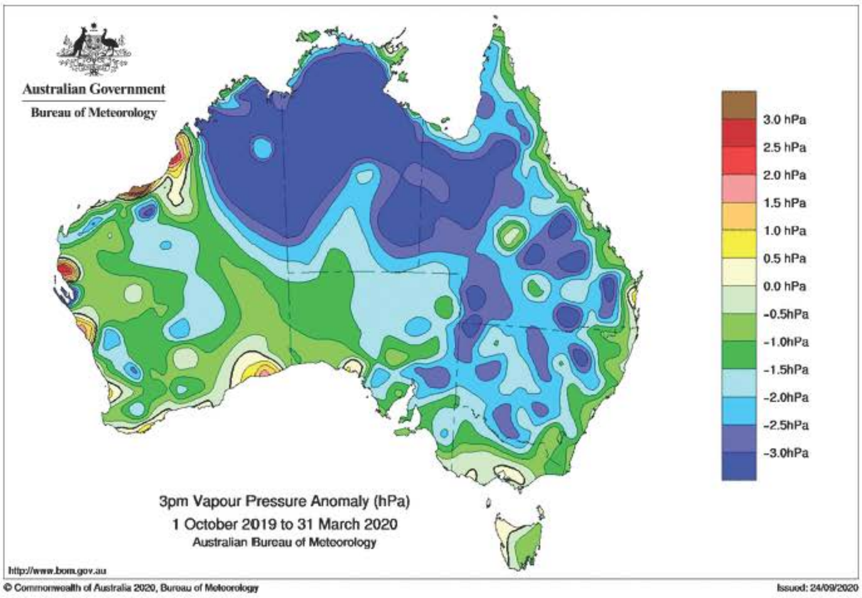


Figure 5. Vapour pressure anomaly - October 2019 - March 2020

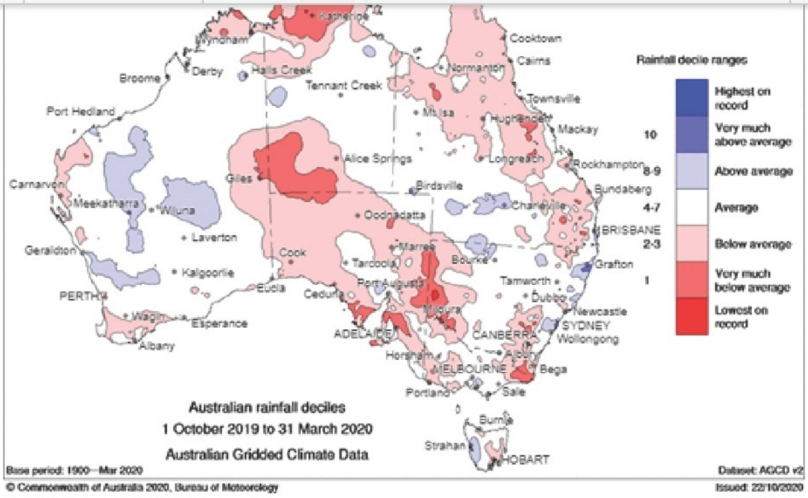


Figure 6. Australian rainfall deciles - October 2019 - March 2020

Alerts sent

Last season, we sent 70% more email alerts and 92% more SMS than in the 2018-19 summer season. In total, almost 20,000 alerts were sent to CHLT subscribers during the 2019-20 season.

Number of alert messages issued

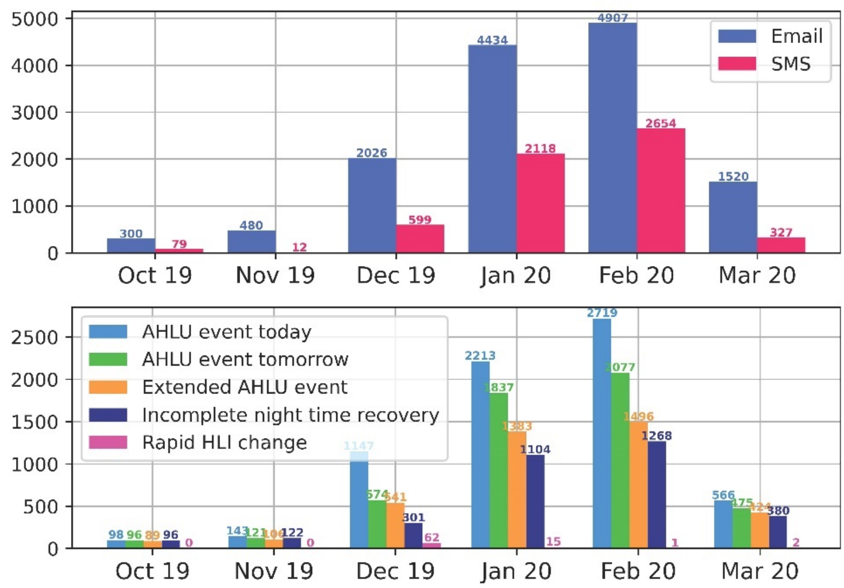


Figure 7. Number of alerts messages issued by Email and SMS - October 2019 - March 2020

End of 2019-20 season survey

At the end of last season, a survey was sent out to all CHLT subscribers. We greatly appreciate your information and feedback provided. Here are some key messages:

- 94% of the respondents perceive that the CHLT website and alerts system help them better manage the feedlot during the hot season.
- More than 50% checked the CHLT website almost every day.
- 82% found the new CHLT website to attend to their expectations during the summer season.

Some of the respondents mentioned that they would benefit from some training. **So, we are running a webinar to give you a refresher on how to use the website tools.**

Events

- ALFA Animal welfare workshops – online sessions. A very interesting one is the Unlocking the benefits of shade webinar that will happen on the 16th of November at 12 pm (AEST).
- Register here: https://www.feedlots.com.au/workshops
- CHLT refresher by the Weather Intelligence/Katestone team on 27 November 2020. Register here.

Thanks for your support and stay safe this summer
Your CHLT team

Time to introduce the team!!
Christine Killip, Dush Wimal, Michael Burchill, Trent Hennessy, Frank Quintarelli, Plistina Almeida

CHLT is powered by Weather Intelligence and brought to you by: