final report

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Development of indicative Temperature Humidity Index charts for northern Australia

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Executive Summary

This report has been completed as part of the P.PSH.0842 – Future Livestock Consultants 2 Program with co-investment with Meat & Livestock Australia. This is one of ten individual reports produced by a participating intern in the program, managed by Meridian Agriculture.

All ten interns participated in the two year networking, training and development program, including full time participation within an established livestock consulting business, regular connection with other interns and networking with industry leaders.

All interns were requested to submit a proposal for the development of an industry project that addressed a need within their client base and industry generally. A reference group approved the project topic and the interns subsequently completed the project and this resulting report.

Executive Summary

There is heightened interest in re-introducing *Bos taurus* genetics to northern Australia. This raises a trade-off between potential productivity and low adaptability. The interaction between climate and genotype was therefore investigated.

The factors which affect an animal's heat tolerance were identified in a literature review. These factors included whether the animal was *Bos taurus* or *Bos indicus*, its coat colour, and its coat length. The literature review also identified that the Temperature Humidity Index was the most appropriate heat stress index to use. Long-term climate data was downloaded from the BOM website for 57 Australian locations, with a focus on northern Australia. Monthly average maximum and minimum Temperature Humidity Index figures were generated from these data. CSIRO Temperature Humidity Index stress level thresholds for *Bos taurus* animals were used to categorise these data according to the level of heat stress they would cause.This information was overlaid on maps of Australia. Monthly images and .GIF files showing seasonal progession were generated.

Interpretation of the results found that it is very likely that the productivity of *Bos taurus* herds will be compromised by heat stress in locations where there is a monthly average minimum stress level recorded. These regions are Cape York, Gulf, Barkly, Top End, VRD, Kimberley, and Pilbara. The information found in the literature review, the maps generated, and the resulting interpretation will enhance producers' awareness of the heat stress issue, particularly with relation to *Bos taurus* cattle.

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1 Background

The first herds of cattle introduced into sub-tropical and tropical northern Australia were shorthorn *Bos taurus* breeds. However, early beef production in the region was characterised by poor adaptability and survivability. As a result, northern Australian beef production systems are currently dominated by *Bos indicus* and *Bos indicus/Bos taurus* composite genetics due to adaptability. Given current demand for *Bos taurus* breeds such as Angus, there is heightened interest in re-introducing these genetics to northern Australia. Consultants have encountered several producers looking to introduce black *Bos taurus* cattle into their production systems. This raises a trade-off between potential productivity and low adaptability. The interaction between climate and genotype was therefore investigated.

Whilst a considerable volume of research has been undertaken on managing heat (and humidity) load in Australian cattle, it has almost solely focussed on intensive dairy and feedlot systems. This project aims to apply some of the findings of this research to the distribution of genotypes across extensive northern Australian beef production systems.

The project arose after queries regarding the impact of coat colour on heat tolerance. Whilst conjecture remains over the details on the effect of coat colour on body temperature regulation in cattle, there is general consensus that darker coated animals have a lower heat load tolerance. Early research identified that rectal temperature was higher, grazing time and weight gain was reduced for dark red cattle compared with white cattle in warm conditions (Finch *et al.* 1984). The effect of coat colour was further highlighted when it was found that black cattle were 5.7 times more likely to die in a heatwave event that took place in the US (Busby and Loy 1997; Hungerford *et al.* 2000; Mader *et al.* 2001). Further studies confirmed that black Angus cattle had higher respiration rates, panting scores, hide temperatures, and more pronounced behaviour change such as shade seeking than cattle of dark red, tan, and white coat colours under similar conditions (Brown-Brandl *et al.* 2006a) . Other measures such as hide surface temperature and tympanic (inner-ear) temperature have confirmed lower levels of heat tolerance for darker coated cattle (Davis *et al.* 2003). These findings are attributed to lighter coloured cattle absorbing 40-50% less solar radiation than darker coloured animals (Lees 2016).

Although it is not used in this project, parameters developed for the Heat Load Index indicate the relative ability of different classes of stock to tolerate heat. Figure 1 shows that the relative effects on upper heat load threshold (the point at which heat begins to accumulate) are +3 for white cattle and +1 for red, with black being the reference level (86) (Gaughan *et al.* 2008; Lees 2016). It should be noted that purebreed type *Bos indicus* has a relative effect of around +10 over *Bos taurus* on the same index, indicating its higher relative importance in determining heat tolerance. Wagyu has a relative effect of +4, the same as a 25% *Bos indicus* content animal, indicated the higher heat tolerance of Wagyu among the black *Bos taurus* breeds (Gaughan *et al.* 2008; McCarthy and Fitzmaurice 2016). For this reason, the project focuses primarily on the difference in heat tolerance between *Bos taurus* and *Bos indicus* whilst acknowledging that factors such as coat colour and coat length also have an impact.

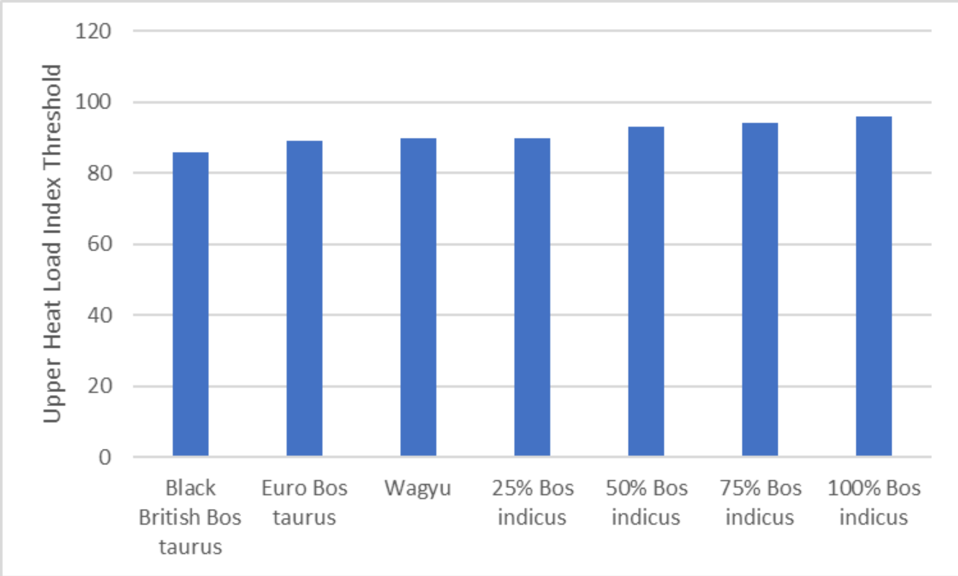

Fig 1: Upper Heat Load Index threshold (point at which cattle begin to accumulate heat load) for various genotypes, baseline level is 86 (adapted from Gaughan et al. 2008).

It should be noted that there is scope for adaption to stressful conditions within *Bos taurus* breeds. In Australia, this has been demonstrated by the development of a tropically adapted Shorthorn x Hereford Adaptaur line at Belmont Research Station, Central Queensland. The line was selected primarily for tick resistance and growth, which was most likely associated with increased heat tolerance (Prayaga and Henshall 2005; O'Neill *et al.* 2010; O'Neill and Swain 2015)

Several quantitative measures have been proposed to account for the combined effect of several environmental parameters, beyond solely ambient temperature, on the biological heat load of animals. One of the earliest proposed measures was the Temperature Humidity Index (THI) (Thom 1959). Initially developed to relate to human heat stress, it has been widely applied to dairy and feedlot cattle since the 1970s (Mader *et al.* 2006; Lees 2016). Humidity is combined with temperature because an animals' ability to dissipate heat away from the skin is affected by the humidity differential between the skin and the atmosphere. As such, at a constant temperature, an animal will be able to dissipate heat more effectively at lower humidity than it will at higher humidity. More recently, the Heat Load Index (HLI) which encompasses other environmental parameters such as wind speed and solar radiation has been developed and widely applied in Australian feedlots (Gaughan *et al.* 2008; McCarthy and Fitzmaurice 2016). As the additional parameters of wind speed and solar radiation are site (microclimate) specific and developed for a feedlot context, the simpler THI was chosen as a reasonable indicator.

2 Project Objectives

The project aims to:

- identify environmental limitations for the introduction of *Bos taurus* cattle in northern Australia.
- develop charts/maps which would inform producers on the suitability of *Bos taurus* genotypes in northern Australia.
- provide some interpretation around the resources developed.
- demonstrate the use of the Temperature Humidity Index as an indicator of a particular breed's suitability to a specific location.

3 Methodology

THI was calculated as follows: $THI = (0.8 * ambient\ T°C) + \left(\frac{Relative\ humidity\ \%}{100}\right) * (ambient\ T°C - 14.4) + 46.4$ (Mader *et al.* 2006; Lees 2016; MLA/LiveCorp 2018).There are other means of calculating THI using measures such as Dew Point Temperature instead of relative humidity. The above formula was chosen because of its recent use in determination of heat stress in Australian cattle (Lees 2016). To validate the formula used, the dew point formula was used for one site and the results generated for maximum THI were negligibly different to the relative humidity formula (R^2=0.99).

To calculate THI, climatic data was obtained from the Bureau of Meteorology climate data site (http://www.bom.gov.au/climate/data/). Daily minimum and maximum temperatures could be obtained as long as observations were recorded at a specific site. These files were downloaded and the excel Pivot Table function used to generate average daily minimum and maximum temperatures.

The average relative humidity data was more problematic to source as it was not available in the same format as temperature data. Monthly 9am and 3pm relative humidity averages were available. Therefore, average monthly 9am relative humidity was combined with daily minimum temperature and average monthly 3pm relative humidity with daily maximum temperature to produce average daily minimum and maximum THI. While the relative humidity data were not ideal, the approach taken gave the best possible estimate of relative humidity at the time of minimum/maximum temperature, and the results are sufficiently indicative to allow comparison between locations.

Daily average THI data were generated for 57 locations with the aim of including reference points across a wide range of regions. However, a large proportion of locations were in Queensland due to the scope and focus of the project. These data sets can be used to generate seasonal charts for specific locations such as those presented in Section 9.2. The THI figures were then aggregated on a monthly basis and these were loaded into the statistical software 'R' for further analysis and map development. This is because it was invisaged that mapping the THI across months rather than days would be a more accessible and meaningful extension tool for producers.

The data was classified based on CSIRO derived THI stress categories for *Bos taurus* animals presented in the MLA Veterinary Handbook (MLA/LiveCorp 2018). Other classifications of stress level against THI exist but were generated overseas and were not as recent (Hahn *et al.* 2009). The classification used is shown in Table 1. Monthly average minimum and maximum THI maps were then generated into 24 images, and two .GIF files were created illustrating the January to December progression of the maximum and minimum THI respectively.

Table 1: Stress categories based on Temperature Humidity Index (THI), applied in the mapping methodology for this project (MLA/LiveCorp 2018).

Temp			Relative Humidity (%)															
F	C	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
77	25.0						72	72	73	73	74	74	75	75	76	76	77	MILD
78	25.6		NO STRESS			72	73	73	74	74	75	75	76	76	77	77	77	STRESS
79	26.1				72	76	73	74	74	75	76	76	77	77	78	78	79	
80	26.7		72	72	73	76	74	74	75	76	76	77	78	78	79	79	80	
81	27.2	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81	
82	27.8	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82	
83	28.3	73	73	74	74	75	76	77	78	78	79	80	80	81	82	82	83	SEVERE
84	28.9	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84	STRESS
85	29.4	74	75	75	76	77	78	79	79	80	81	81	82	83	84	84	85	
86	30.0	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86	
87	30.6	75	76	77	77	78	79	80	81	81	82	83	86	85	85	86	87	
88	31.1	75	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88	
89	31.7	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	89	
90	32.2	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90	
91	32.8	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91	
92	33.3	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92	
93	33.9	79	80	80	81	82	83	84	85	86	87	88	89	90	91	92	93	VERY
94	34.4	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	SEVERE
95	35.0	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	STRESS
96	35.6	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96	
97	36.1	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97	
98	36.7	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97	98	
99	37.2	82	83	84	85	87	88	89	90	91	92	93	94	96	97	98	99	
100	37.8	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	100	
101	38.3	83	86	86	87	88	89	90	92	93	96	95	96	97	99	100	101	
102	38.9	86	85	86	87	89	90	91	92	96	95	96	97	96	99	101	102	
103	39.4	86	86	87	88	89	91	92	94	95	96	97	98	100	101	102	103	
104	40.0	85	86	88	88	90	91	93	94	95	96	97	99	100	101	103	104	
105	40.6	86	87	88	89	91	92	93	96	96	97	98	99	100	101	104	105	DEAD
106	41.1	86	88	89	90	91	93	94	95	97	98	99	101	102	103	105	106	CATTLE
107	41.7	87	88	89	91	92	94	95	96	98	99	101	102	103	105	106	107	
108	42.2	87	89	90	92	93	94	96	97	98	100	101	102	104	105	106	108	
109	42.8	88	89	91	92	94	95	96	98	99	101	102	103	105	106	107	109	
110	43.3	88	90	91	92	94	96	97	98	100	101	102	104	105	106	108	110	
111	43.9	89	91	93	94	95	96	98	99	101	102	103	105	106	107	109	111	

4 Results

The mapping output (Appendix 9.1) shows the category of stress (None, Mild, and Severe) by colour at the daily maximum and minimum THI for 57 locations in Australia for each month. Note that the sequence of maps by month is best presented in an animated (.GIF file) form in presentations or on webpages.

For simplicity, the number of days per year where at least mild stress would be expected to occur at the average minimum and maximum THI is presented (Figures 2&3).

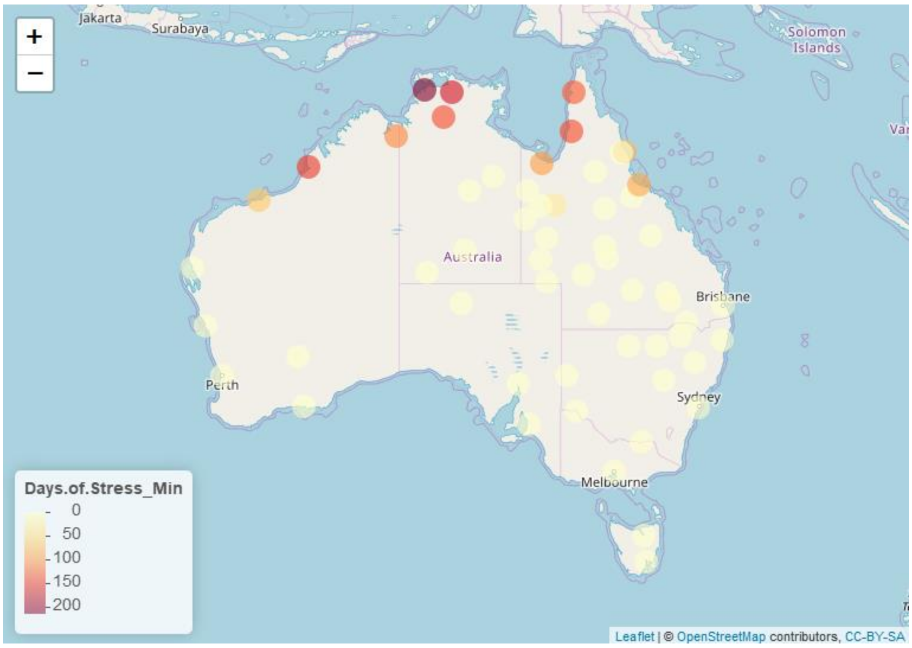

Fig 2: Map with location colours showing the number of days per year that at least mild stress would be expected at the average minimum THI.

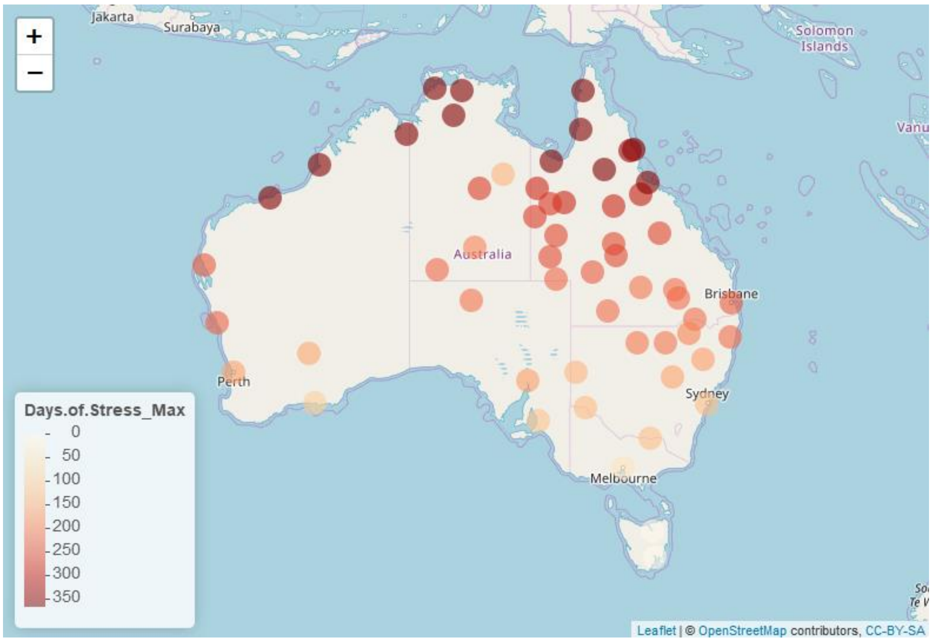

Fig 3: Map with location colours showing the number of days per year that at least mild stress would be expected at the average maximum THI.

5 Discussion

For *Bos taurus* cattle, the mapping output shows that the average daily maximum THI is likely to incur severe stress from December to February in all of Queensland, the Northern Territory, and northern Western Australia. Southern Australia experiences average maximum THI figures likely to incur mild stress throughout this period. Hobart is the only location with no period of any stress recorded.

The average monthly minimum THI maps show levels associated with mild stress from December to March for the Cape York, Gulf, Top End, Kimberley and Pilbara regions. This period stretches from October to April for northern Cape York and the Top End. No other regions show monthly average minimum THI figures associated with any level of stress and the entire country shows the no stress category over the winter months.

While the average monthly maximum THI maps illustrate the widespread nature of the heat stress issue, it is arguably the average monthly minimum THI maps which are more important in informing the distribution of cattle genotypes. This is due to the effect of accumulated heat load. If thermoneutral conditions are not reached overnight, then cattle accumulate heat load over several days. An extended period of hot nights is when most widespread heat stress fatalities are observed (Brown-Brandl *et al.* 2006b; Gaughan *et al.* 2008; Lees 2016).

It is therefore very likely that the productivity of *Bos taurus* herds will be compromised by heat stress in locations where there is a monthly average minimum stress level recorded. These locations are: Broome, Brunette Downs, Burketown, Cairns, Camooweal, Cloncurry, Darwin, Katherine, Kowanyama, Kununurra, Port Hedland, Townsville, Weipa. These locations comprise Cape York, Gulf, Barkly, Top End, VRD, Kimberley, and Pilbara. This finding is particularly significant for the Southern Gulf and Barkly as there has been interest in introducing black coated *Bos taurus* genetics in these regions.

This research and associated findings accounts for the effect of heat stress only. The presence of certain parasites, such as ticks, has historically had a significant bearing on the distribution of beef genotypes in Australia due to the parasite resistance of *Bos indicus* breeds. The distribution of tropical parasites is typically highly associated with hot and humid areas (Frisch and O'Neill 1998). However, the parasite issue must be considered in combination with climate. Further research should aim to incorporate the effect of parasite burden with climate and make recommendations based on this.

The application of the THI data was also limited by lack of information on how cattle, particularly *Bos indicus* breeds interact with this measure. Information generated in feedlot and dairy contexts had to be extrapolated for application in the extensive beef industry. There is an opportunity to research the relationship between THI and other climatic measures and stress levels in Australian beef genotypes. This would enable threshold THI levels for stress in different genotypes and/or coat colours to be identified.

Extension material from this project would most likely be a short explanation of the importance of considering adaptation when considering genotypes, the relative ability of different genotypes to tolerate heat, a short explanation of the THI, and the .GIF files displayed on a web page. This would better inform producers selecting genotypes in northern Australia.

The following project objectives have been addressed in this project:

- To develop charts/maps which would inform producers on the suitability of *Bos taurus* genotypes in northern Australia.
    - These have been developed and are best displayed on a webpage in .GIF format. They can also be displayed as stills, as in this report, and would be best presented as a poster in this format. More locations could be added if required. Charts were also generated as presented in Section 9.2.
- To provide some interpretation around the resources developed.
    - Information in this report, especially the literature review in Section 1 Background, and the analysis will form the basis for this material.
- To demonstrate the use of the Temperature Humidity Index as an indicator of a particular breed's suitability to a specific location.
    - The project effectively demonstrates and uses the THI to inform the possible distribution of beef genotypes.

6 Conclusions/Recommendations

Temperature Humidity Index can effectively be related to expected levels of stress felt by cattle. The THI can therefore be used to inform the suitability of a genotype to a particular location. It is very likely that the productivity of *Bos taurus* herds will be compromised by heat stress in locations where there is a monthly average minimum stress level recorded. These regions are Cape York, Gulf, Barkly, Top End, VRD, Kimberley, and Pilbara.

Future R&D should incorporate the effect of parasite burden and resistance as well as climate adaptation. The elucidation of relationships between THI and stress in more Australian beef genotypes would also be beneficial. Extension materials arising from this project should be information on climate adaptation associated with the .GIF files on a web page.

7 Key Messages

- Adaptation to climate should be a primary consideration when considering the introduction of new genotype to region, as significant productivity losses may occur as a result of unadapted genotypes.
- Cattle vary significantly in their tolerance to high temperature and humidity. The major factors to consider are *Bos indicus* vs *Bos taurus*, coat colour, and coat length.
- The relationship between climatic conditions and the level of heat stress incurred can be measured through indexes such as the Temperature Humidity Index.
- The most severe stress events occur when thermoneutral conditions are not reached for several nights and cattle accumulate heat load over several days and nights. This is why minimum THI can be used to inform the suitability of a location to a specific genotype.
- It is very likely that the productivity of Bos taurus herds will be compromised by heat stress in locations where there is a monthly average minimum stress level recorded. These regions are Cape York, Gulf, Barkly, Top End, VRD, Kimberley, and Pilbara.

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9 Appendix

9.1 Monthly Mean Maximum and Minumum THI Maps

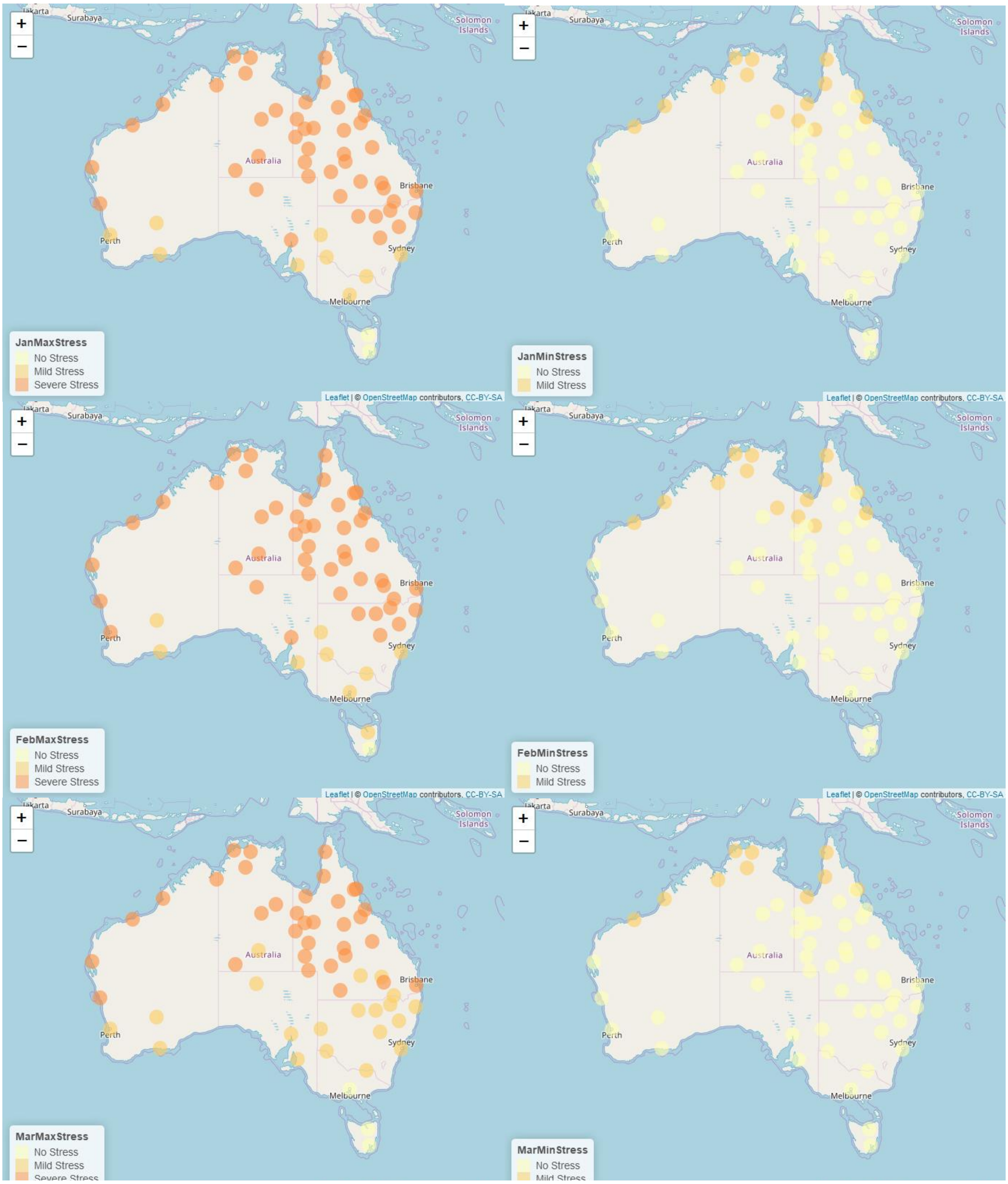


Figure 4: Jan-Mar average maximum (left) and minimum (right) THI values for 57 locations in Australia.

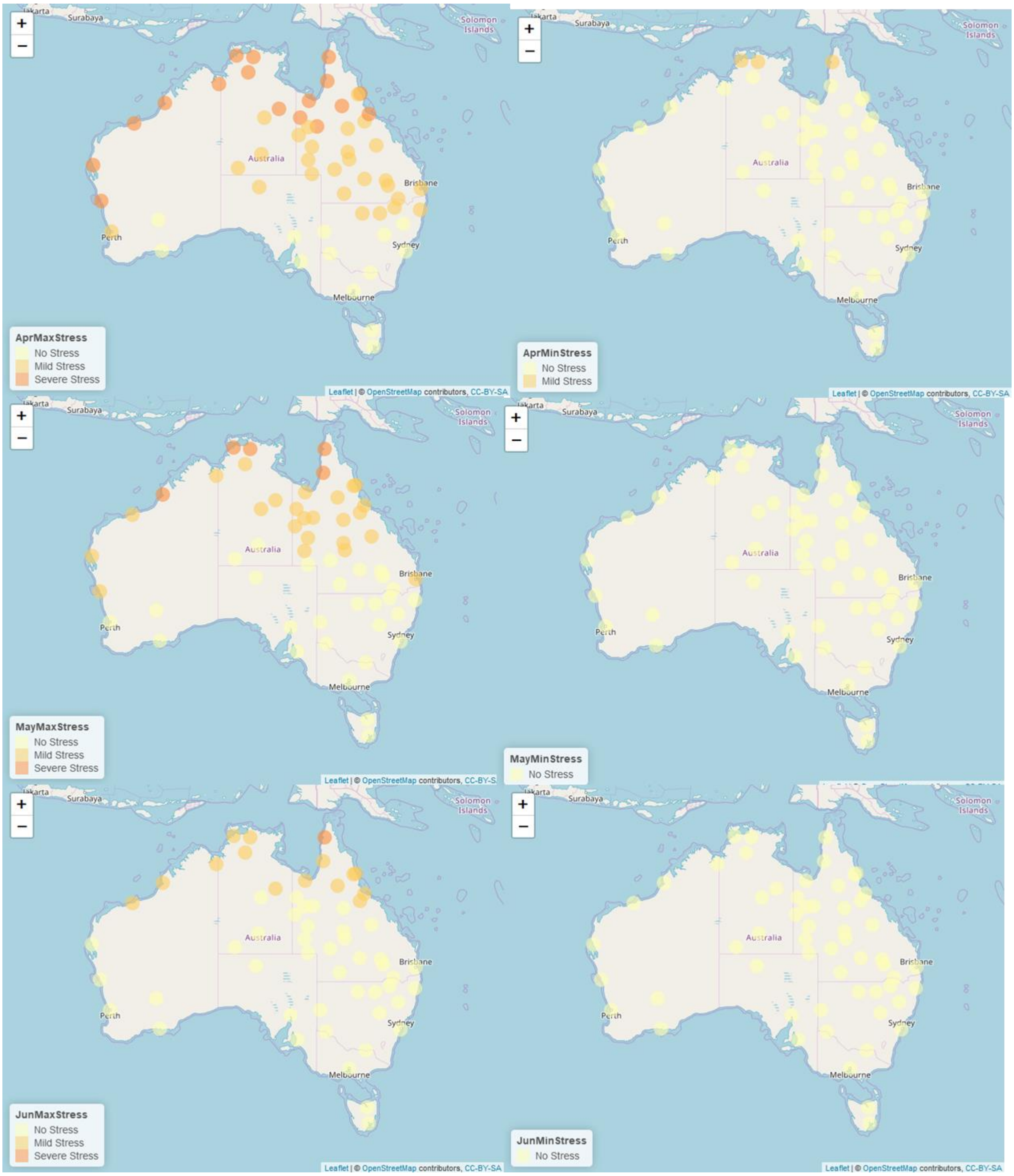


Figure 5: Apr-Jun average maximum (left) and minimum (right) THI values for 57 locations in Australia.

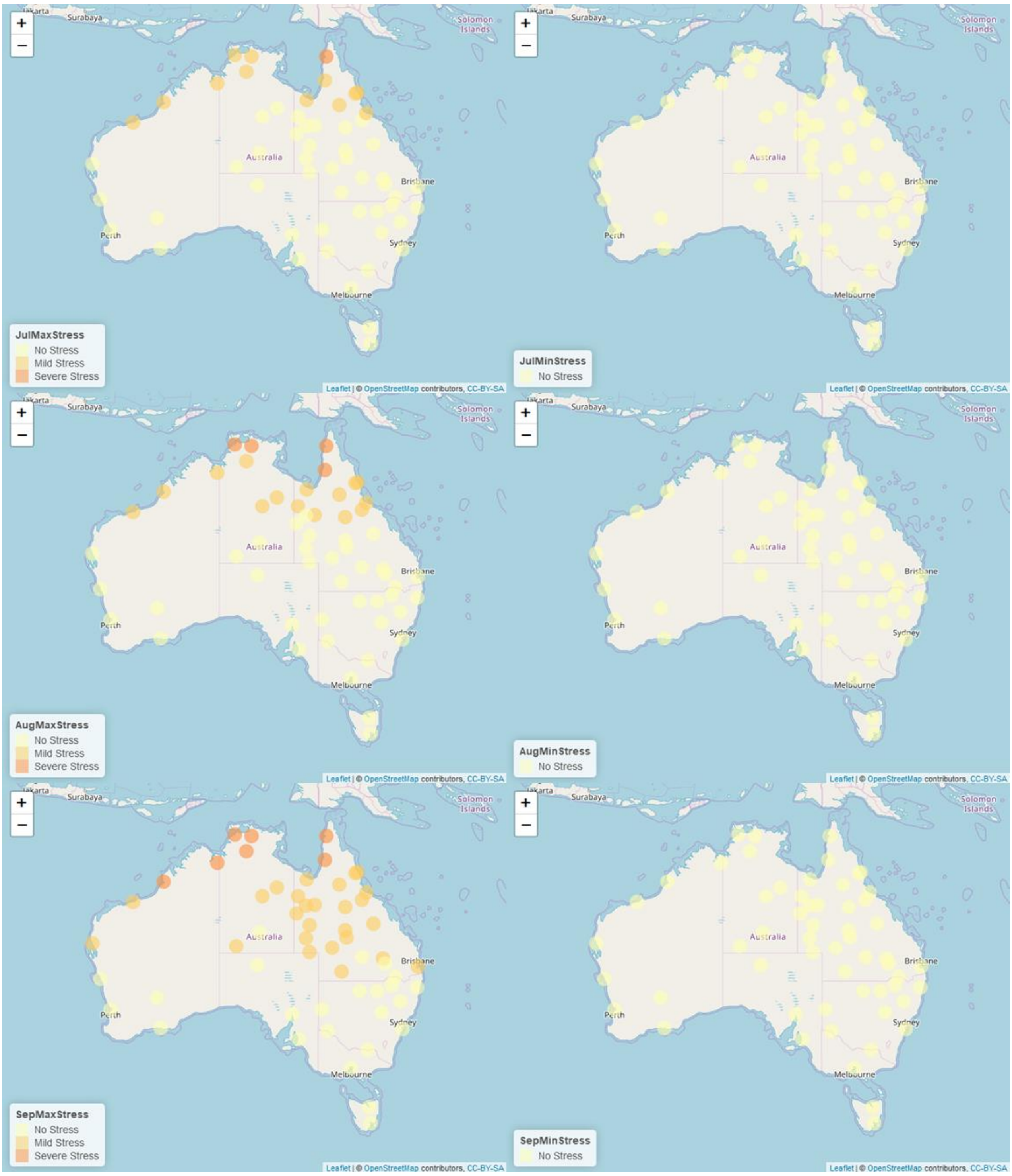


Figure 6: Jul-Sep average maximum (left) and minimum (right) THI values for 57 locations in Australia.

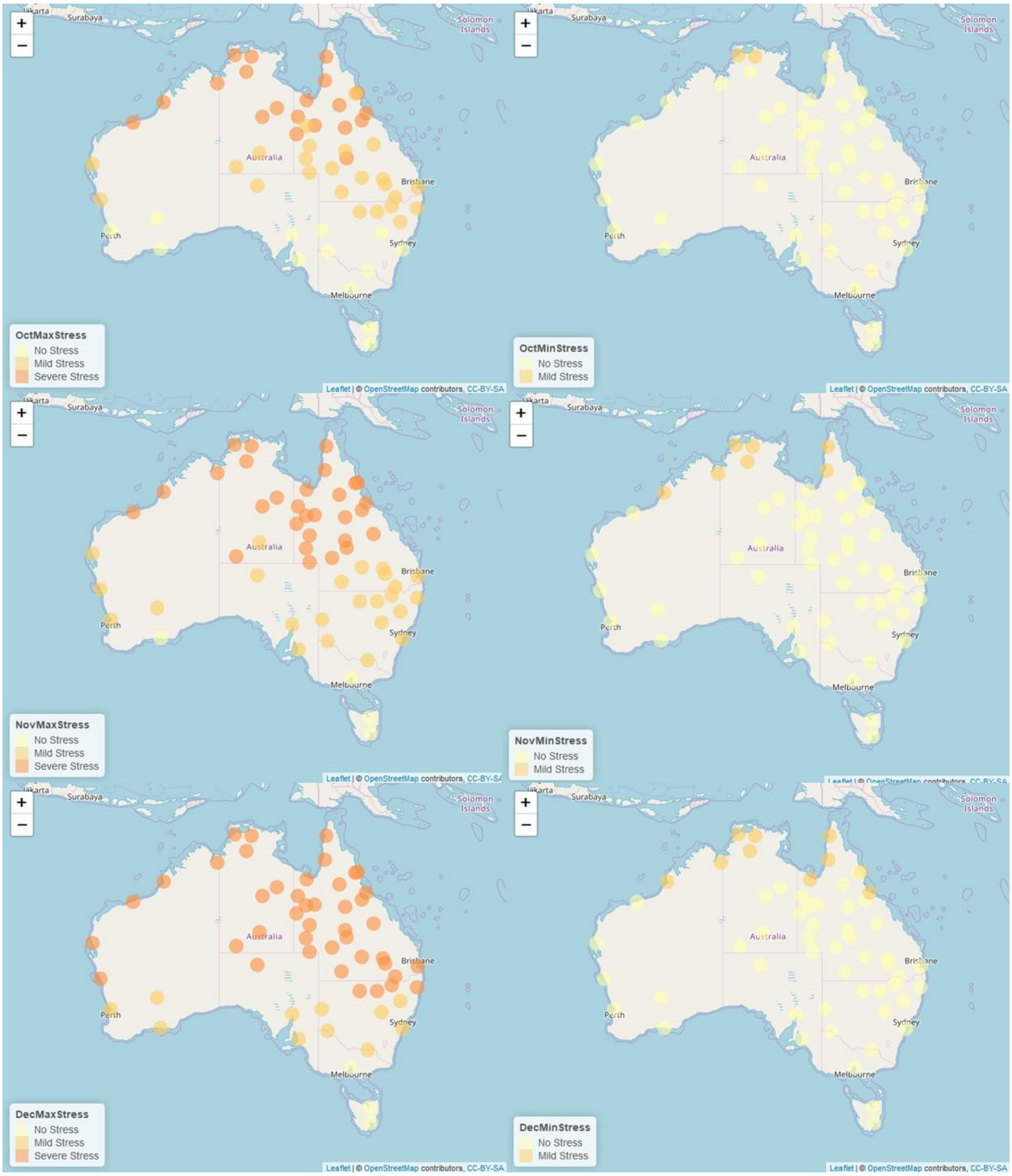
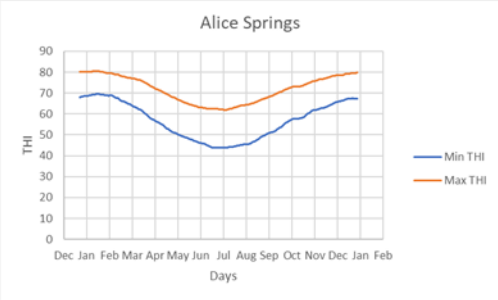


Figure 7: Oct-Dec average maximum (left) and minimum (right) THI values for 57 locations in Australia.

9.2 Example of Location Charts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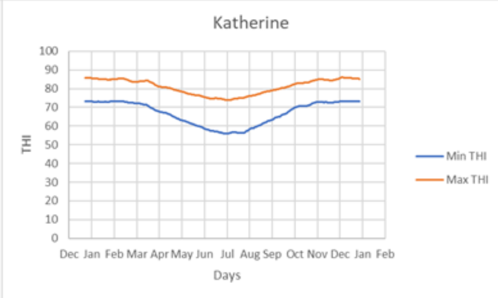
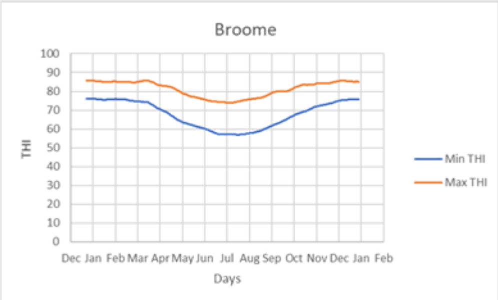
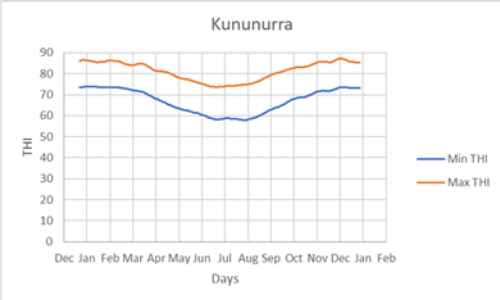
THI
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
Days
Min THI
Max THI


Katherine
THI
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
Days
Min THI
Max THI


Broome
THI
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
Days
Min THI
Max THI


Kununurra
THI
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Days
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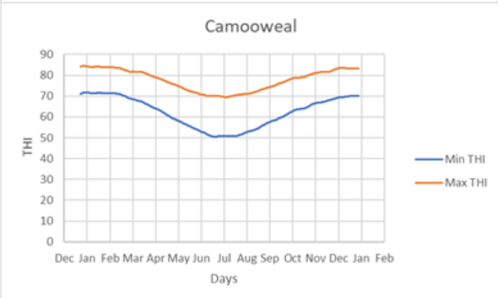
Max THI


Camooweal
THI
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Days
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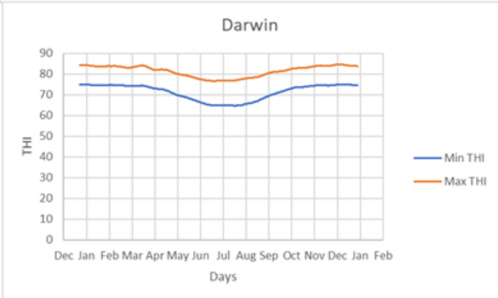
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Days
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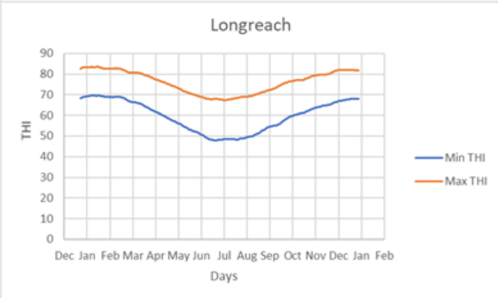
Max THI


Longreach
THI
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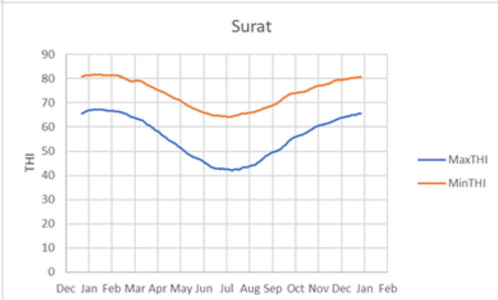
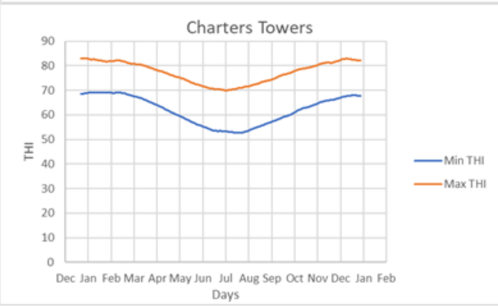
Days
Min THI
Max THI


Surat
THI
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
MaxTHI
MinTHI


Charters Towers
THI
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
Days
Min THI
Max THI