Water Temperature - Monitoring Results

Technical Report A - Annexure E

Report to: AECOM

AGL Gas Import Jetty Project

Water Temperature

December 2019

Technical Report – Monitoring Results

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Report to:
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1 Context for this task

AGL Wholesale Gas Pty Ltd (AGL) and APA are jointly proposing to develop a Liquid Natural Gas (LNG) import terminal at Crib Point in the lower north arm of Western Port. The proposal is for a floating storage and regasification unit (FSRU) to be permanently moored at Crib Point Jetty Berth 2, installation of LNG offloading facilities on the jetty and construction of a transfer pipeline between Crib Pt and Pakenham. AGL proposes to engage a contractor to supply and operate the FSRU facility, while APA will develop and operate the gas transfer pipeline.

A desktop assessment found that the project had the potential for significant impacts on Matters of National Environmental Significance as defined in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and potential impacts on listed flora, fauna and ecological communities under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act). The project was therefore referred to both the Australian and Victorian Governments. The Victorian Minister for Planning (the Minister) decided that based on the referral documentation an Environment Effects Statement under the EE Act was required. The Victorian EES process is an accredited assessment process under the EPBC Act.

The Minister issued scoping requirements (Ministerial Guidelines) for the EES in February 2018. The Ministerial Guidelines along with the EES referral documents were used to design technical studies that fulfil the requirements for the Environment Effects Statement.

The EES referral was used to identify the pathways by which the proposal may impact upon the Western Port marine ecosystem.

The primary impact pathway for plankton in Western Port is entrainment of plankton in the seawater used in heat exchangers and other processes onboard the FSRU. Seawater used in FSRU processes will be chlorinated to prevent marine growth developing within the pipework and heat exchangers. The EES process is assessing the maximum or worst-case project scenario that there is 100 per cent mortality of plankton in seawater entrained by the FSRU, at a rate of up to 450,000 m^3 per day. There are two secondary impact pathways for plankton, discharge of seawater at below ambient temperature and with residual chlorine.

This technical report provides the results of a 12 months seawater temperature logging at Crib Point.

2 Background

Western Por is a tidal embayment connected to Bass Strait by a large Western Entrance and a considerably smaller eastern entrance. Bass Strait waters mix into North Arm of Western Port with tidal oscillations firstly through the Western Entrance, and then via the Confluence Zone into Lower North Arm (Figure 1). Seawater temperature at Crib Point in Lower North Arm is the consequence of waters mixing from other areas of Western Port and with Bass Strait, and the local effects of heating and cooling in North Arm. These local effects include seasonal air temperatures, winds, insolation and the tidal inundation and exposure of the extensive mudflats in North Arm.

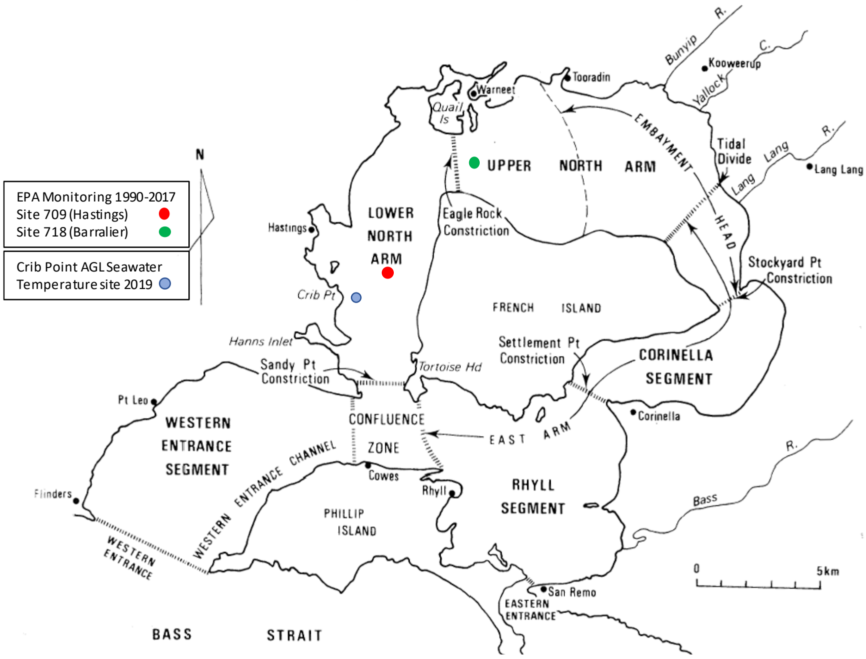


Figure 1. Regional segments described during the Western Port Environmental Study (Source Marsden 1979)

Freshwater inputs in the northeast of Western Port are relatively small and, while their sediment inputs are periodically significant, their effect on salinity and stratification is negligible. Seawater is mixed vertically through the water column throughout the Western Entrance and Lower and Upper North Arm and waters are considered marine rather than estarine. Previous studies and fortnightly water column measurements for the AGL project (see Appendix A) have shown that the water column at in Lower North Arm is unstratified with respect to temperature and salinity. Small vertical gradients in temperature may be apparent with temperatures up to 0.3^{o}C warmer at the surface relatively to the seabed in summer, but a thermocline (or layering) is never present. Most temperature differences in North Arm are therefore are due to horizontal spatial influences.

3 Long-term Bass Strait and Western Port seawater temperature

Bass Strait waters are generally considered to be oceanic as they are influenced by large scale metocean processes. Persistent westerly winds move water cool oceanic water from west to east through Bass Strait, while shorter duration easterly winds may move warm water from the East Australia Current into eastern Bass Strait. As a result, north-central Bass Strait water temperature range is approximately 6ºC over the year with a 10-year average maximum of 19ºC in February to a minimum of 13ºC in August and September (Figure 2).

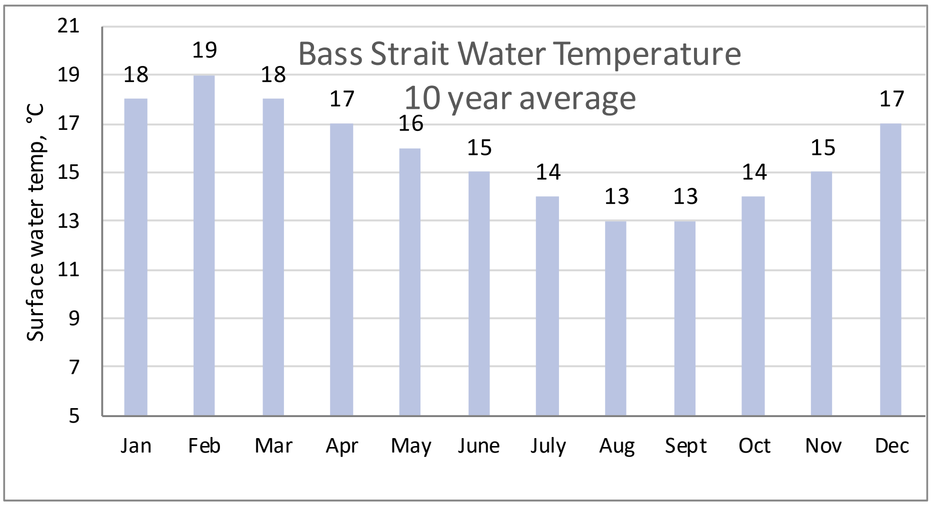


Figure 2. Bass Strait 10 year monthly average water temperature
(https://seatemperature.info/bass-strait-water-temperature.html)

Seawater temperature in Western Port is measured by EPA in the North Arm at sites in the main channel adjacent to Hastings and near the Eagle Rock Constriction (Figure 1). EPA data from these sites was available for the period 1990 to 2017. Average monthly surface water temperature measured at these sites from 1990 to 2017 are summarised in Figure 3 and Figure 4.

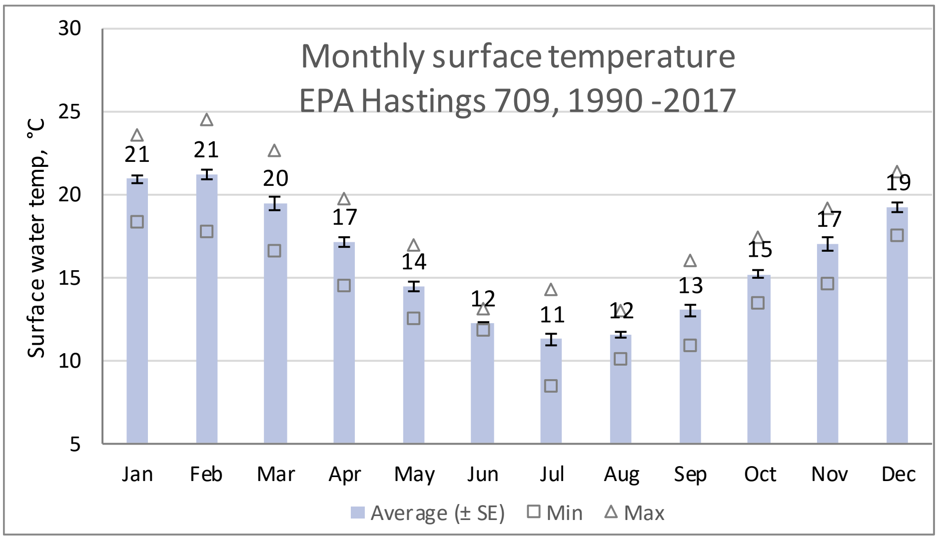


Figure 3. Monthly surface water temperature near Hastings 1990-2017
(Source EPA, see Figure 1)

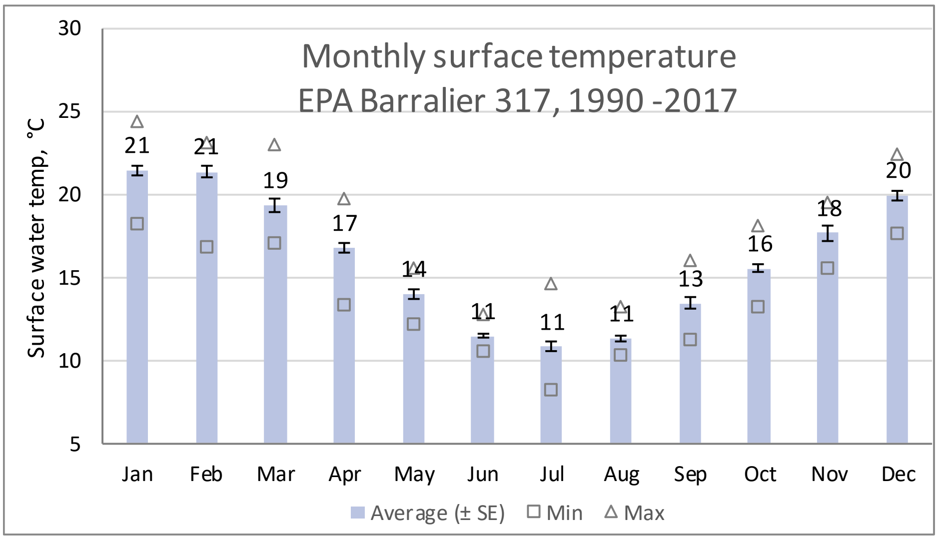


Figure 4. Monthly surface water temperature near Warneet 1990-2017
(Source EPA, Figure 1)

The data from North Arm monitoring sites show a similar annual pattern in average monthly temperature at the Hastings and Barralier Island (Eagle Rock) sites, with maximum temperatures of 21°C in January/February and minimum monthly temperatures in June, July and August of 11°C to 12°C. There is a similar temperature range at the two sites, which indicates relatively well mixed water over the 12 km distance between the two sites.

Comparison of the North Arm (Figure 3,Figure 4) and Bass Strait (Figure 2) monthly averages shows a similar seasonal pattern of highest temperature in February to lowest in August, but the North Arm waters show a larger annual temperature range: North Arm warms two to three degrees more than Bass Strait in summer and cools more than Bass Strait by one to two degrees in winter. This is due to the relatively shallow depth of North Arm and hence greater effect of surface heat exchange processes on water temperature.

The available EPA water temperature data were generally monthly, with an average of seven measurements per year over the monitoring period. More frequent and accurate data were required to assess the natural variation in seawater temperature at Crib Point. Thus a study was initiated to measure water temperature at Crib Point every 15 minutes over 12 months commencing January 2019. The records provide continuous temperature data for assessment of short-term variations that would naturally be experienced by marine biota in the locality of Crib point jetty.

4 Seawater Temperature Monitoring at Crib Point

The passage of seawater through a FSRU heat exchanger results in a temperature reduction of 7ºC from the incoming seawater temperature. At the lower temperature, the discharged seawater is approximately 5 per cent denser than the ambient seawater and therefore sinks towards the seabed where is dispersed by tidal currents and mixing.

Seawater temperature is a key influence on marine biological processes. Long term changes in seawater temperature affects the distribution and behaviour of marine biota, and localised, short-term variation can affect the distribution and behaviour of marine biota in the locality depending on the magnitude of the temperature change.

It was recognised that accurate and frequent seawater temperature data were required at Crib Point for input to the hydrodynamic and plume dilution modelling of the discharge from the heat exchanger and to inform interpretation of potential ecosystem effects due to temperature changes from short-term (for example hourly to 24-hourly) natural variations over a year. Hence, data loggers were installed at 1 m above the seabed at Berth 2, Crib Point Jetty in January 2019 (Figure 1).

4.1 Seawater Temperature Logger setup

As noted above, seawater from an FSRU heat exchanger operating on the open loop process (using seawater to heat LNG) is cooler than the ambient seawater and hence the seawater plume descends to the seabed. Seawater temperature at Crib Point was therefore logged at 1 m above the seabed.

Onset 'Hobo' U24-002-C conductivity sensor loggers with accuracy of 0.1ºC and resolution of 0.01ºC were used to autonomously log seawater temperature at 15-minute intervals at Crib Point.

A logger inside an HDPE canister, coated in antifoul paint was attached to a weighted galvanised chain hanging from the lattice walkway between Crib Point Berth 2 and the southern mooring dolphin. The logger was were recovered, cleaned, downloaded and reinstalled on a monthly cycle.

4.2 Data record

Monthly temperature data downloads were checked for continuity and consistency and added to an Excel database. Excel pivot tables were used to examine, analyse and summarise the water temperature record from Crib Point Berth 2 for presentation in this Chapter.

5 Seawater temperature variation at Crib Point

Daily mean, maximum, minimum bottom water temperature at Crib Point over the 2019 monitoring period is shown in Figure 5, together with daylength. Key features of the temperature record area summarised below:

- Strong seasonal variation in temperature with peaks of around 22ºC in late January early February 2019 and lowest temperatures around 11.5ºC in July and August 2019.
- Water temperature maximum lagged longest daylength by approximately a month in summer, and minimum temperature lagged shortest daylength by approximately a month in winter 2019.
- Short-term cyclic variations in temperature (over hours and days) are apparent in summer and winter which are due to the effects of heating in summer and cooling in winter of the mudflats when they are exposed to the atmosphere at low tides. Water running onto and off the mudflats is warmer in summer and colder in winter than the main body of water remaining in the channels
- Longer term cyclic variations (over weeks) are also apparent in the temperature record. These are due to the regular two-week cycle of spring tides, as well as episodic large scale (Bass Strait) sea level variations pushing extra Bass Strait water into Western Port.

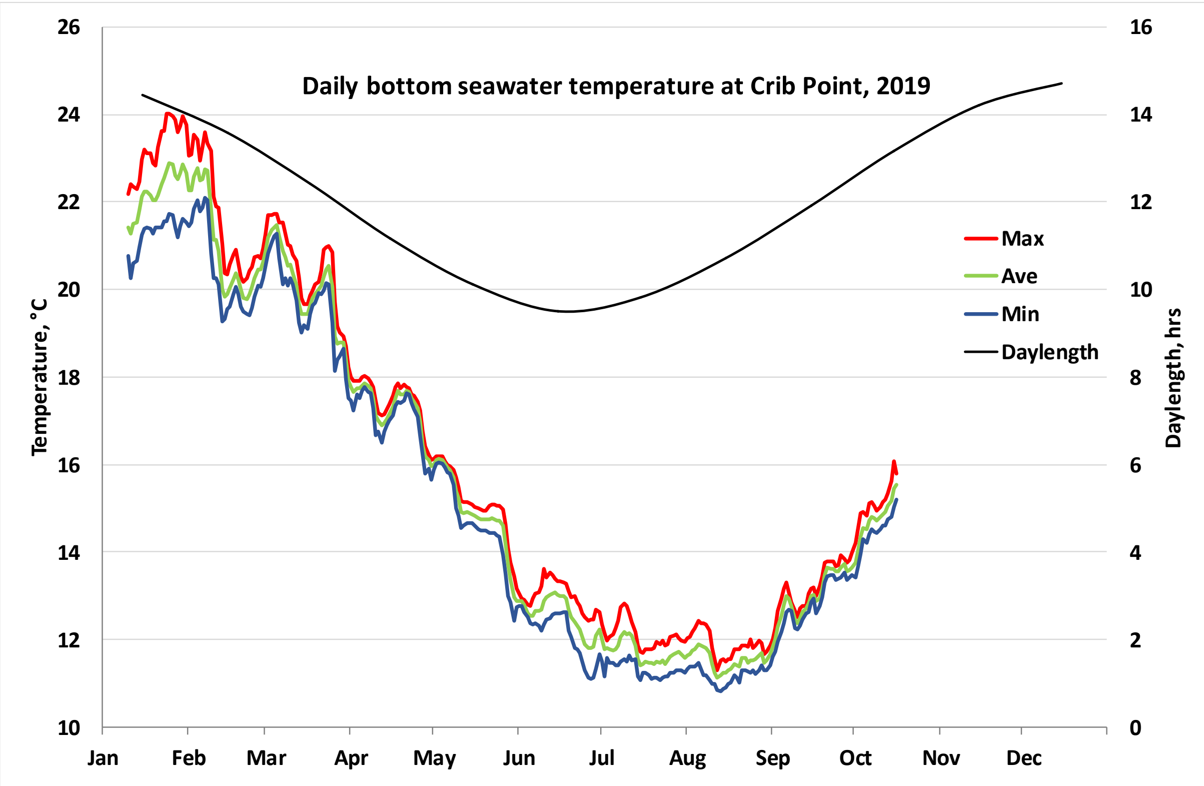


Figure 5. Annual daily temperature mean, minimum and maximum
(96, 15-minute temperature measurements per day)

5.1 Daily seawater temperature variation at Crib Point

The plot of daily mean, minimum and maximum water temperature (Figure 5) indicates the scale of daily variation in water temperature that is experienced by marine biota in the vicinity of Crib Point over the year. The magnitude of the daily variation over the monitoring period is shown in Figure 6.

The daily temperature range in water temperature can be 2.5ºC in mid-summer and less than 0.2 ºC in late autumn. Temperature ranges in the coldest months (July and August) also vary substantially.

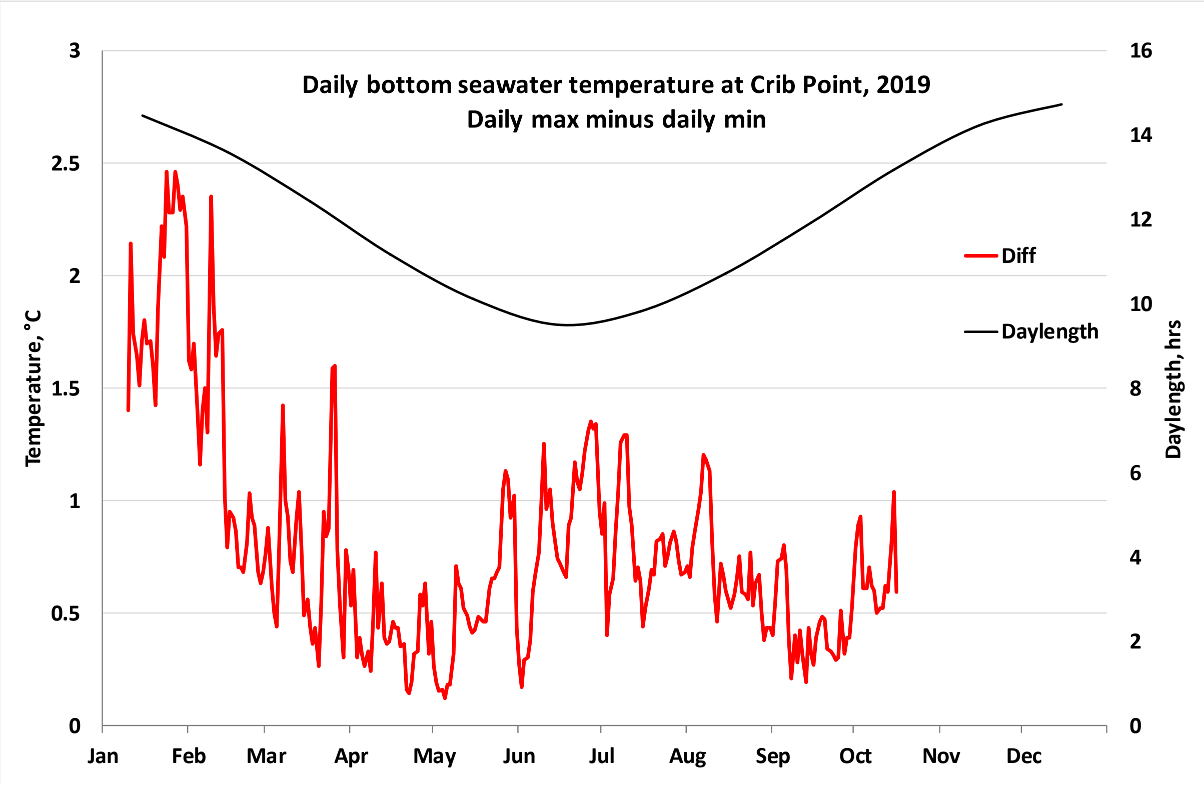


Figure 6. Daily temperature range (minimum to maximum in calendar day)

5.2 Short term variation in seawater temperature at Crib Point

The full data set of 15-minute temperature records were analysed to determine running 1-hour, 6-hour, 12 hour and 24 hour temperature range.

Figure 7 shows examples of 1-hour and 6-hour temperature ranges in February, April and August 2019 and demonstrates the large natural variability in bottom water temperature that occurred at Crib Point in those months.

The 1-hour variation shows the small-scale effect of tidal currents on water temperature due to such processes as solar heating and cooling, and mixing of water patches of different temperature. Figures showing 1-hour and 6-hour temperature variations for all months in 2019 are provided in Appendix A.

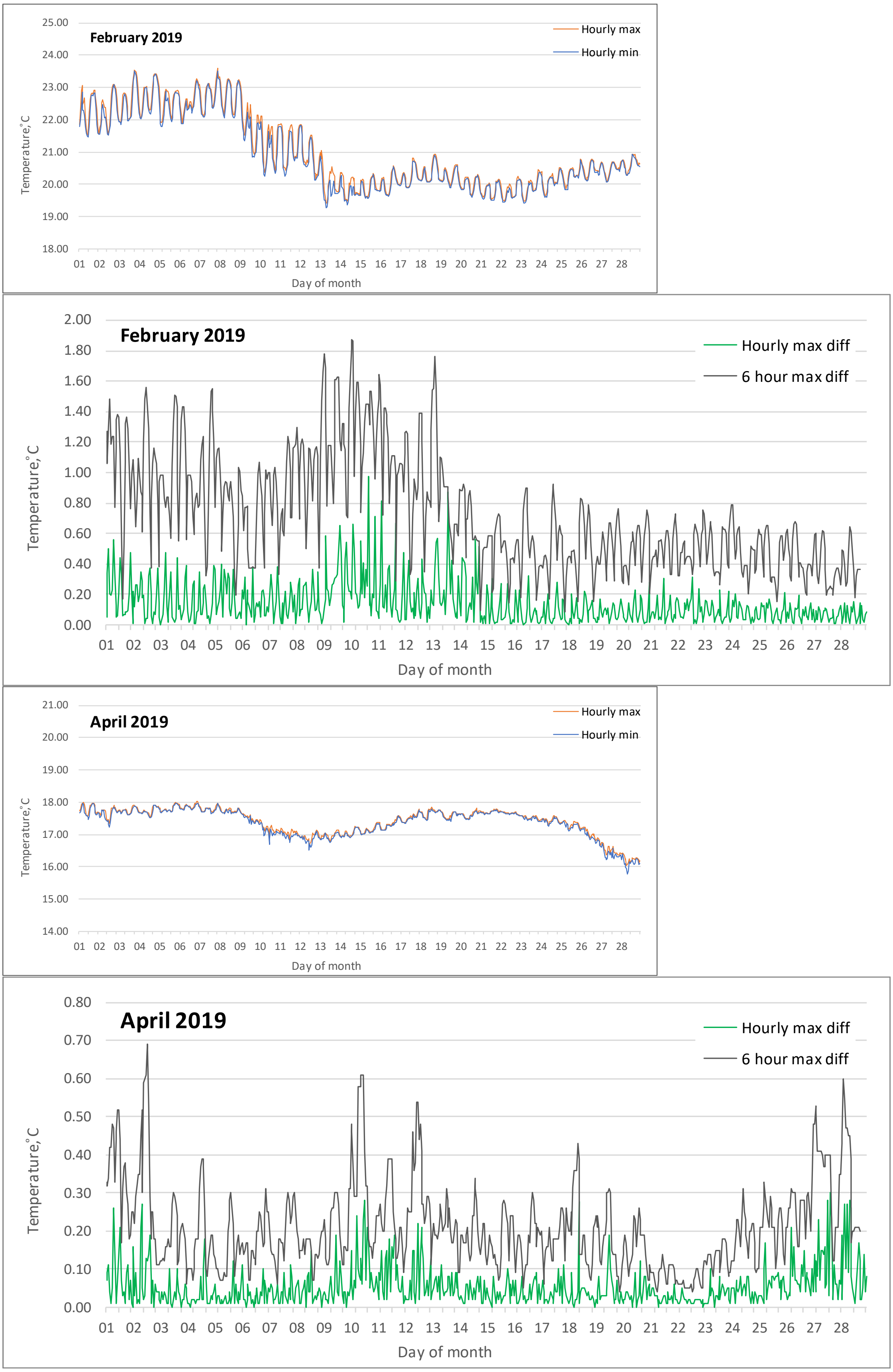


Figure 7. Examples of monthly short-term temperature variation

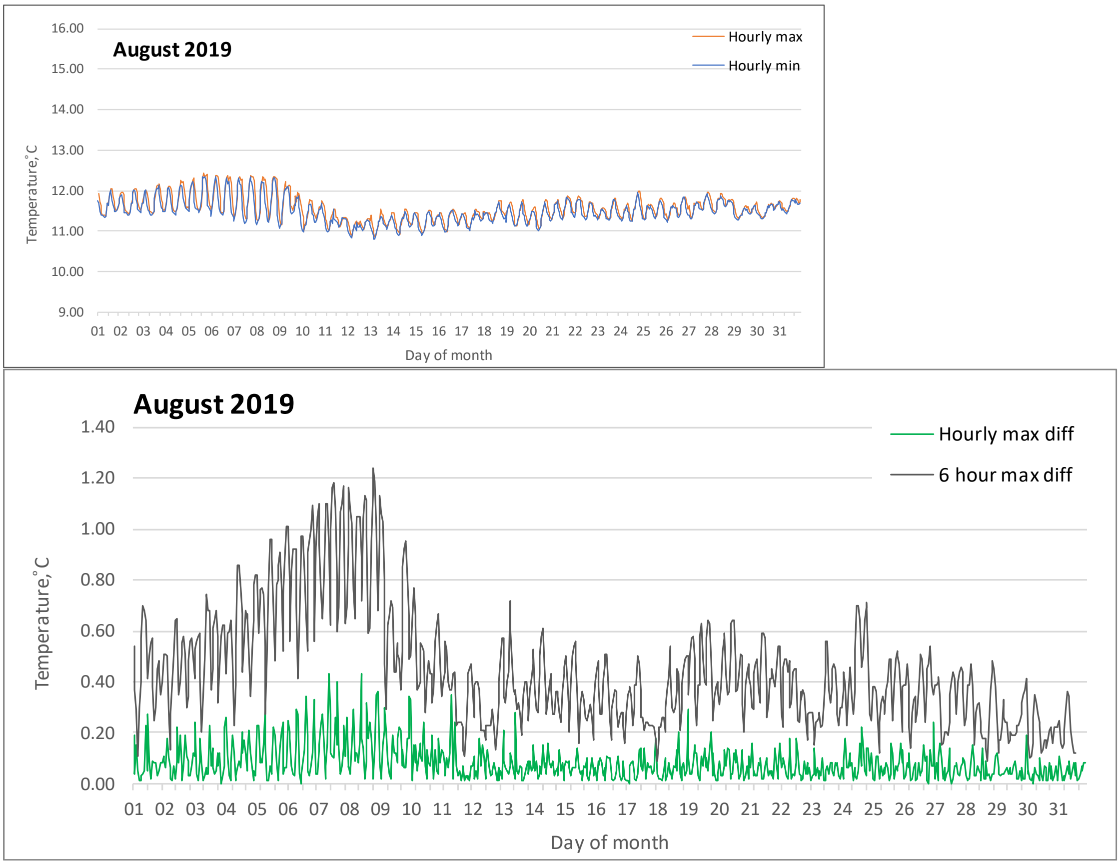


Figure 7. Examples of monthly short-term temperature variation (cont.)

5.3 Annual frequency of seawater temperature variations at Crib Point

Cumulative frequency of running 6-hour, 12-hour and 24-hour temperature ranges for all the full monitoring data record are shown in Figure 8, Figure 9 and Figure 10, respectively.

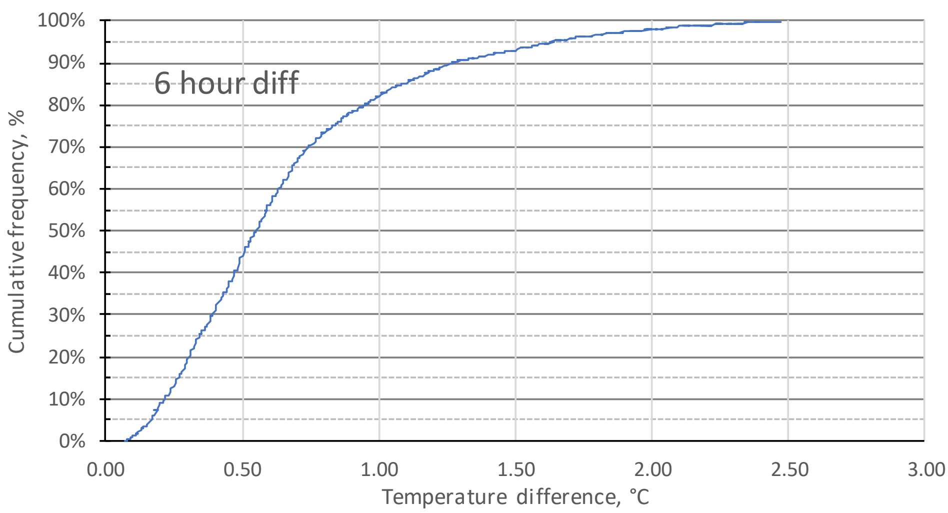


Figure 8. Cumulative frequency 6-hour, 12 month running temperature difference

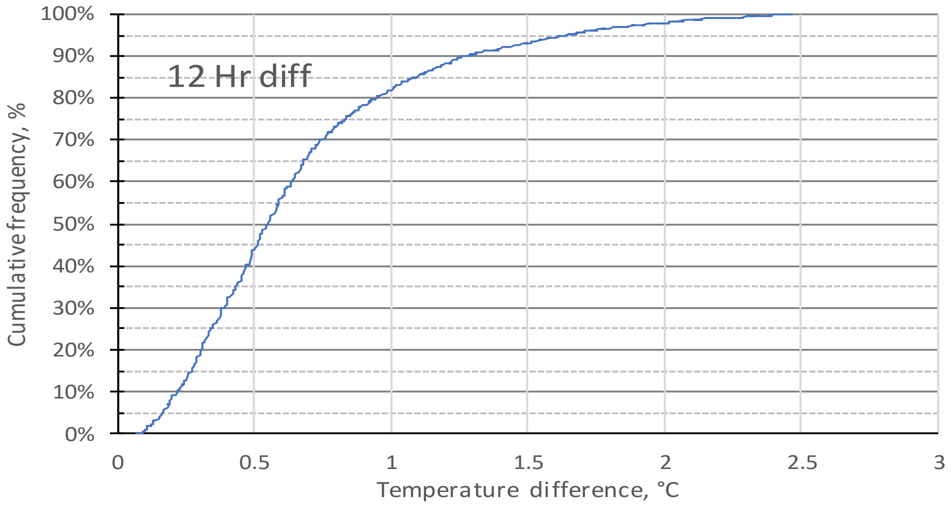


Figure 9. Cumulative frequency 12-hour, 12 month running temperature difference

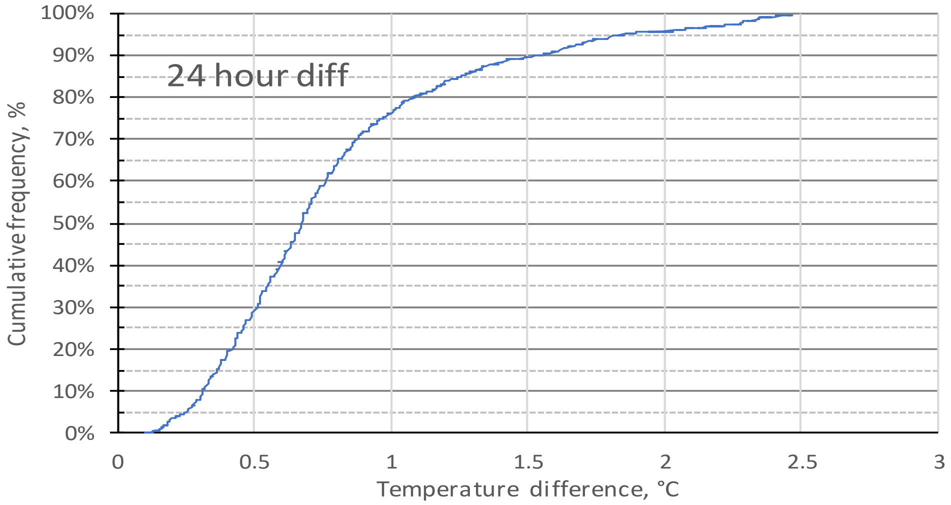


Figure 10. Cumulative frequency 24-hour, 12 month running temperature difference

The 25 percentile, 50 percentile and 75 percentile temperature changes for the various time periods are listed in Table 1. The table shows that there is negligible difference between the temperature variations over 6-hours (half tide cycle) and 12-hours (full tide cycle), and only a small increase in temperature variations over 24-hours compared to the shorter time periods.

Yet 1-hour temperature variations are much smaller in magnitude than 6-hour variations (as shown in Figure 7). Also, the EPA data shows a small variation in temperature over a 12 km length of North Arm. These results suggest that the short-term (6 to 12-hour) temperature variations are mostly related to diurnal variations related to solar heating and cooling n the shallower waters, and mixing of patches of water with different temperatures.

Table 1. Cumulative frequency 24-hour, 12 month running temperature difference

Range period	25 percentile	50 percentile	75 percentile	Interquartile range (25% - 75%)
6-hourly	0.34°C	0.55°C	0.83°C	0.5°C
12-hourly	0.34°C	0.55°C	0.83°C	0.5°C
24-hourly	0.46°C	0.67°C	0.96°C	0.5°C

6 Water temperature assessment guidance value

It is apparent from the data presented in the previous sections that all marine biota living in the North Arm ecosystem are accustomed to large seasonal temperature ranges and substantial short-term temperature variations at scales from six hours to 24 hours, weeks and months. The operation of the FSRU on water temperature will affect the magnitude of the variation in the vicinity of the discharge, but not the temporal pattern of the variation.

A meaningful guidance value of temperature change is needed to inform spatial scale presentation of modelled extent of the change in temperature so that the extent of the effect of the heat exchanger discharge on the marine ecosystem in the vicinity of Crib Point can be assessed. The guidance value would most practically be based on existing ambient temperature range, since all biota living in North Arm are resilient to this temperature regime. This guidance value would be conservatively informative for EIS assessment purposes, but would not as a regulatory limit, which would be established in consideration of a Works Approval.

6.1 Regulatory guidance

Environmental objectives for seawater water quality are regulated by State Environment Protection Policy (SEPP) “Waters” 2018 and also, from 2018, the online “Australian and New Zealand guidelines for fresh and marine water quality” (www.waterquality.gov.au). The Policy and the ANZ Guidelines provide guidance on physico-chemical stressors and toxicants for geographical segments of the State and nationally.

The Policy divides Victoria’s surface waters into Segments that are based on Beneficial Uses of the waters, regional water quality influences and existing ambient conditions. Crib Point is located in the *Entrances and North Arm* sub-segment of the *Western Port* Segment of Victoria’s surface waters.

Ramsar listed wetlands, such as Western Port, are included in Schedule B – Areas of High Conservation Value of the Policy. Additional environmental management measures are listed for such areas.

Environmental Quality Indicators and Objectives for Western Port are listed in Table 7 of the Policy. The table includes 25th and 75th percentile values for water quality objectives such as nutrients and certain physico-chemical indicators including salinity, dissolved oxygen and pH, but does not include water quality objectives for temperature. The ANZ Guidelines do not include physico-chemical stressors, but refer to “Fact Sheets” in ANZECC 2000.

The Fact Sheet for temperature in ANZECC 2000 discusses an 80 percentile upper temperature limits for heated water discharges in inland waters but does not discuss lower limits for any surface waters. ANZECC 2000 concludes with respect to water temperature: “The method used will depend upon the ecosystem type, the desired level of protection, and the availability of suitable reference systems and adequate data for these systems.”

6.2 Temperature guidance value for assessment in North Arm

The modelled thermal plume extent inputs are a 'temperature difference from ambient'. The model outputs are calculated based on cyclical hydrodynamic processes (monthly tidal cycles) irrespective of the ambient seawater temperature at a particular time of year. Hence, a single environmentally-based temperature difference from ambient will be most useful.

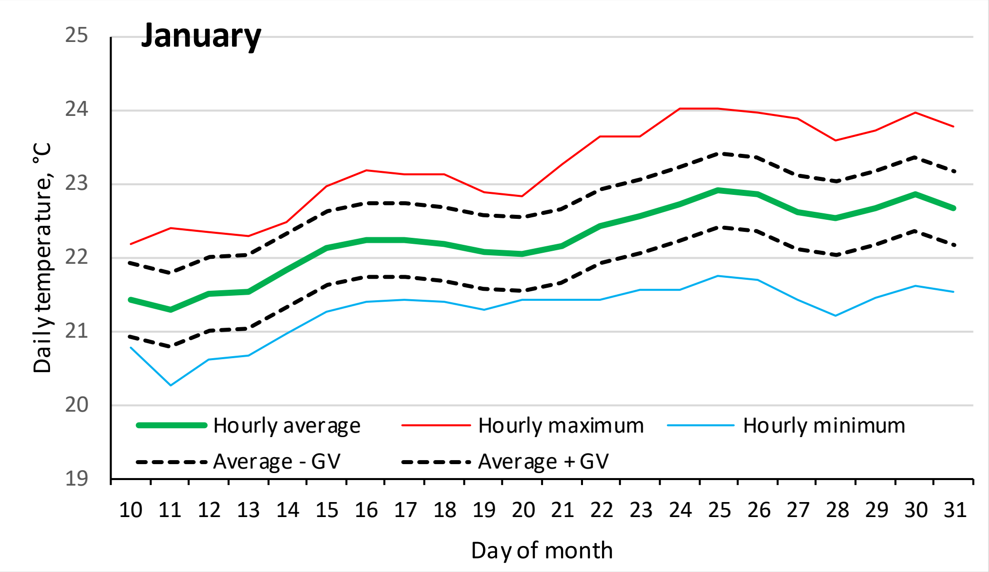
It is apparent from the above discussion that temperature guidance values should be developed to inform interpretation of modelled thermal plumes (cool and arm) extending from the operating FSRU.

- SEPP Waters 2018 specifies that 25th and 75th percentile values for some physico-chemical indicators in Western Port.
- The ANZ Guideline suggest that guidance values should be developed based on conditions in a "reference system".
- SEPP Waters 2018 states that objectives should be established by calculating 25th and 75th percentile values from a reference site.

The interquartile range in seawater variation of 0.5ºC over the year (25 percentile to 75 percentile as shown in Table 1) provides a metric that:

- is based on measured seawater variation at Crib Point over a twelve-month period
- includes high and low variation either side of the mean annual temperature
- is a useful representation of temperature variation experienced by biota in the water column and on the seabed in the channel in the vicinity of Crib Point
- allows transparent assessment of spatial risk to marine biota from thermal differences resulting from the FSRU heat exchanger discharge from month to month.

Examples showing a temperature variation guidance value of 0.5ºC guidance value added and subtracted from the measured daily monthly temperatures at Crib Point are shown in Figure 11 to demonstrate the transparency of the application of this value. These figures clearly show the proportion of the measured natural temperature range included in the Guidance Value and how it can be used as an informative, transparent tool in assessing temperature risk to the marine ecosystem at any time of the year to the modelled temperature differences. This 0.5ºC variation guidance value can conservatively informative of the resilience of marine biota in Western Port over 6- to 24-hour temperature variations for EES assessment purposes. However, a regulatory limit should be established separately in consideration of a Works Approval.


January
Daily temperature, °C
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24
23
22
21
20
19
Hourly average
Hourly maximum
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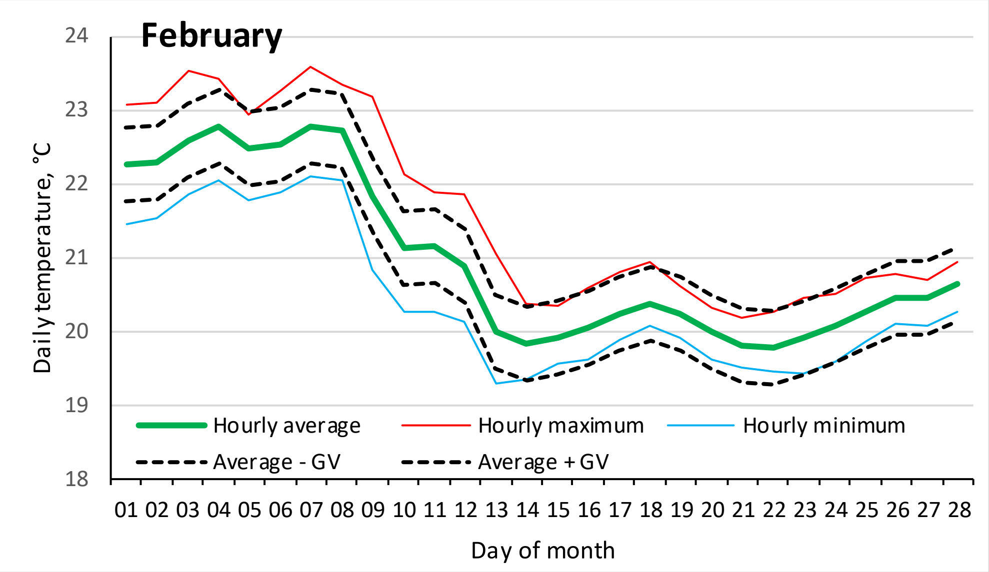
Average - GV
Average + GV
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Day of month


February
Daily temperature, °C
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19
18
Hourly average
Hourly maximum
Hourly minimum
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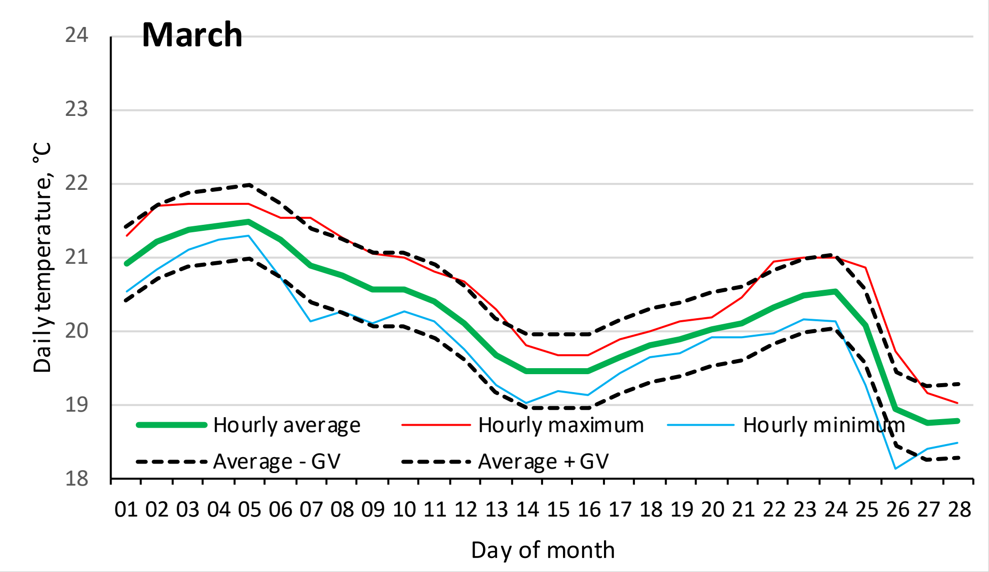
Day of month


March
Daily temperature, °C
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Hourly average
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Hourly minimum
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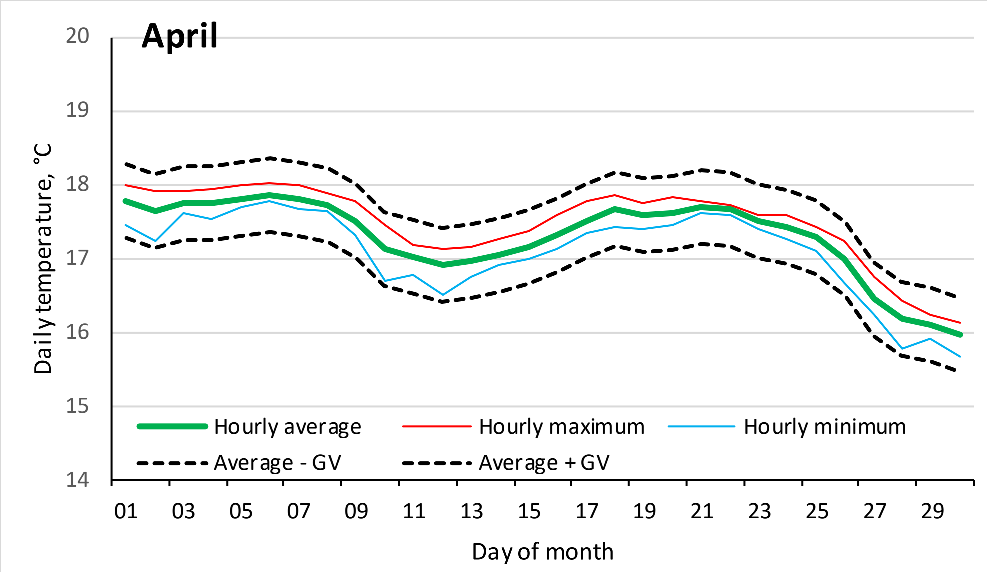
Day of month


April
Daily temperature, °C
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Hourly minimum
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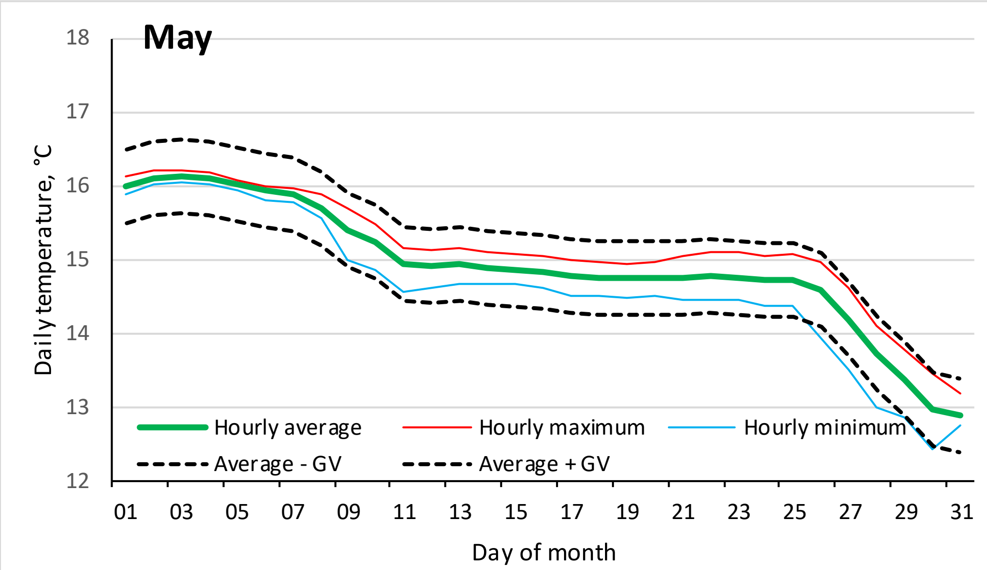
Day of month


May
Daily temperature, °C
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Hourly average
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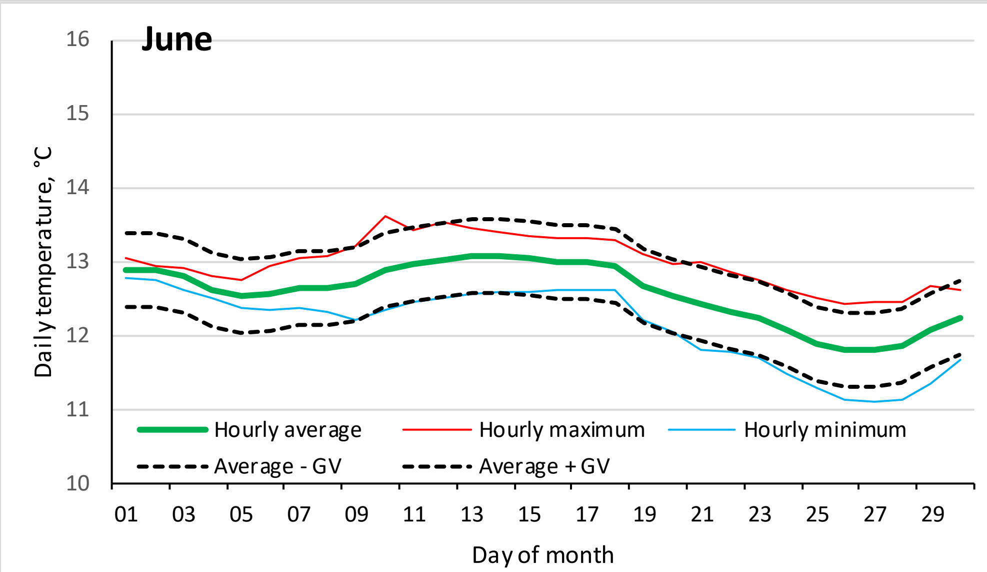
Day of month


June
Daily temperature, °C
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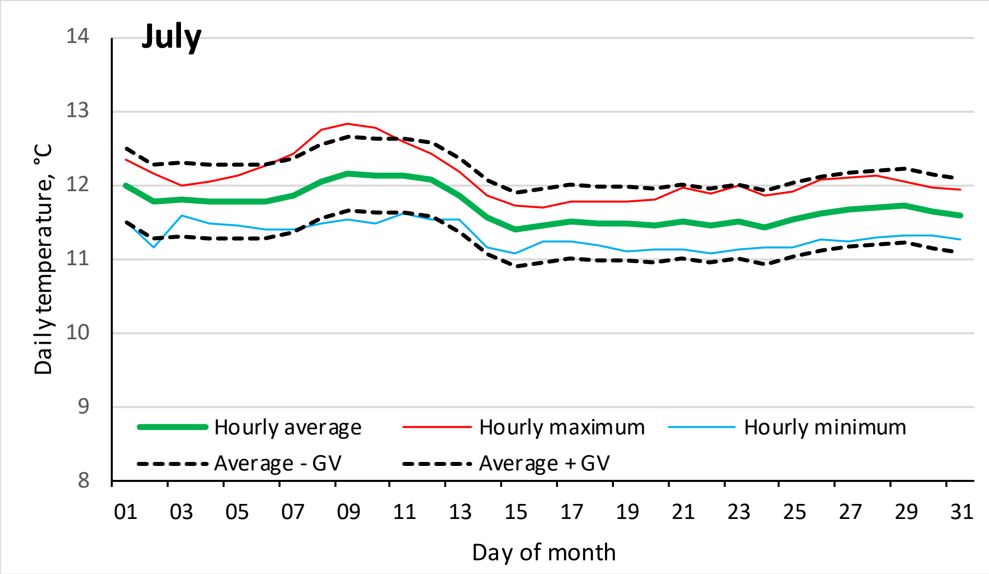
Hourly average
Hourly maximum
Hourly minimum
Average - GV
Average + GV
01 03 05 07 09 11 13 15 17 19 21 23 25 27 29
Day of month


July
Daily temperature, °C
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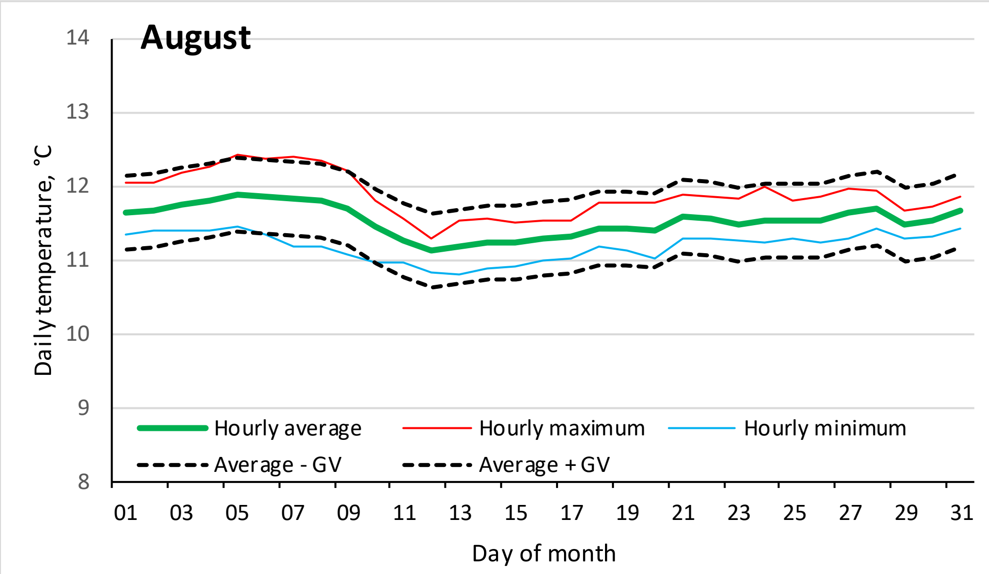
Hourly average
Hourly maximum
Hourly minimum
Average - GV
Average + GV
01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 31
Day of month


August
Daily temperature, °C
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Hourly average
Hourly maximum
Hourly minimum
Average - GV
Average + GV
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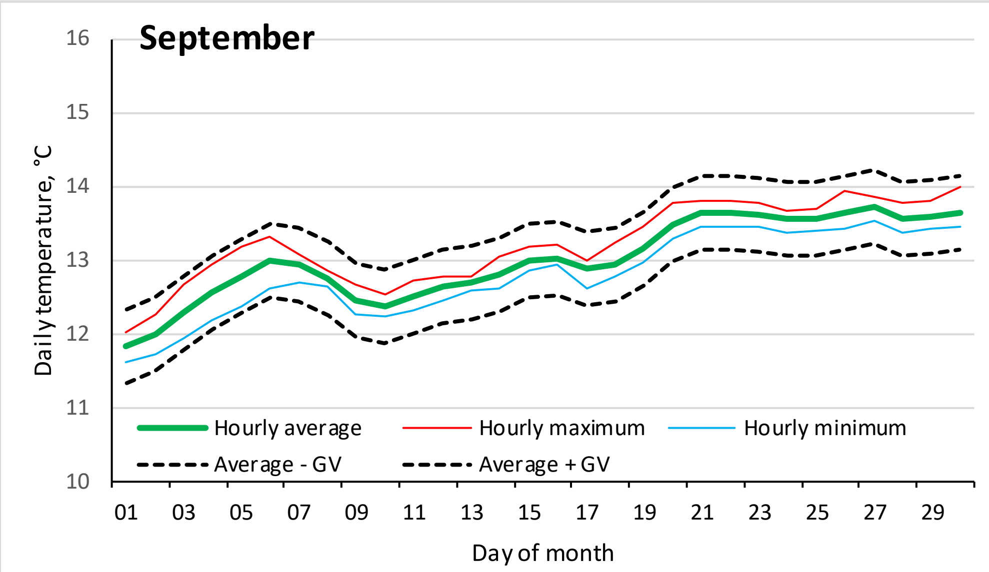
Day of month


September
Daily temperature, °C
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Hourly average
Hourly maximum
Hourly minimum
Average - GV
Average + GV
01 03 05 07 09 11 13 15 17 19 21 23 25 27 29
Day of month

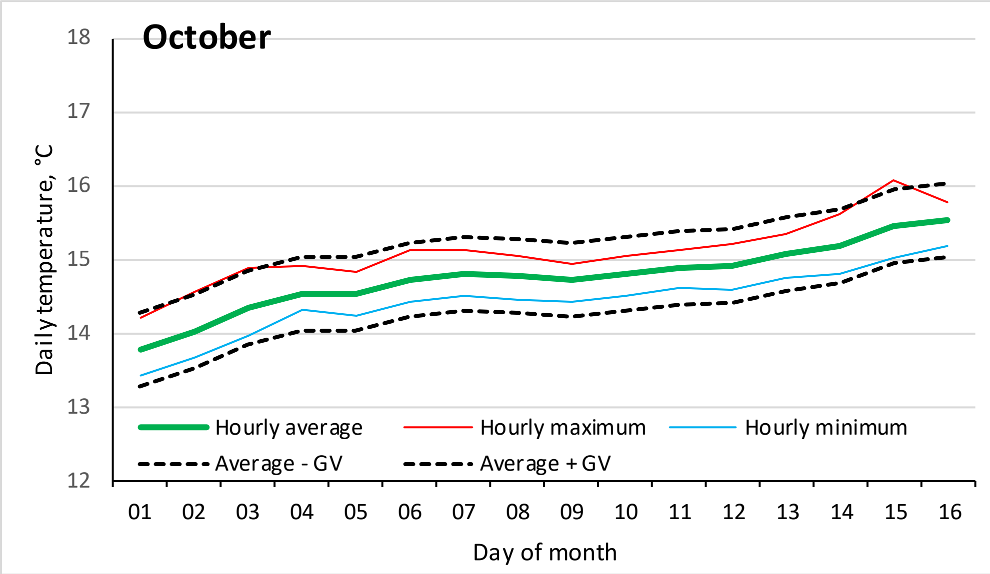


Figure 11. Temperature assessment guidance values for Guidance Values

7 Conclusion

Seawater in North Arm of Western Port follows the general pattern of water temperature in Bass Strait. However, water temperature in North Arm is strongly influenced by local insolation, radiation and evaporation of the extensive areas of shallow waters less than 10 m deep including the intertidal areas that are cyclically inundated and exposed. Water temperatures are consequently are 3ºC hotter in summer and 2ºC cooler in Winter than Bass Strait.

Water temperature was logged continuously at 15 minute intervals at 1 m above the seabed at Crib Point Jetty from January 2019. The record provides valuable information on short term seawater temperature variability that is used to demonstrate the degree of short-term seawater temperature variation that is naturally experienced by marine biota living in North Arm. The data also inform interpretation of the hydrodynamic modelling of the coldwater plume from the FSRU.

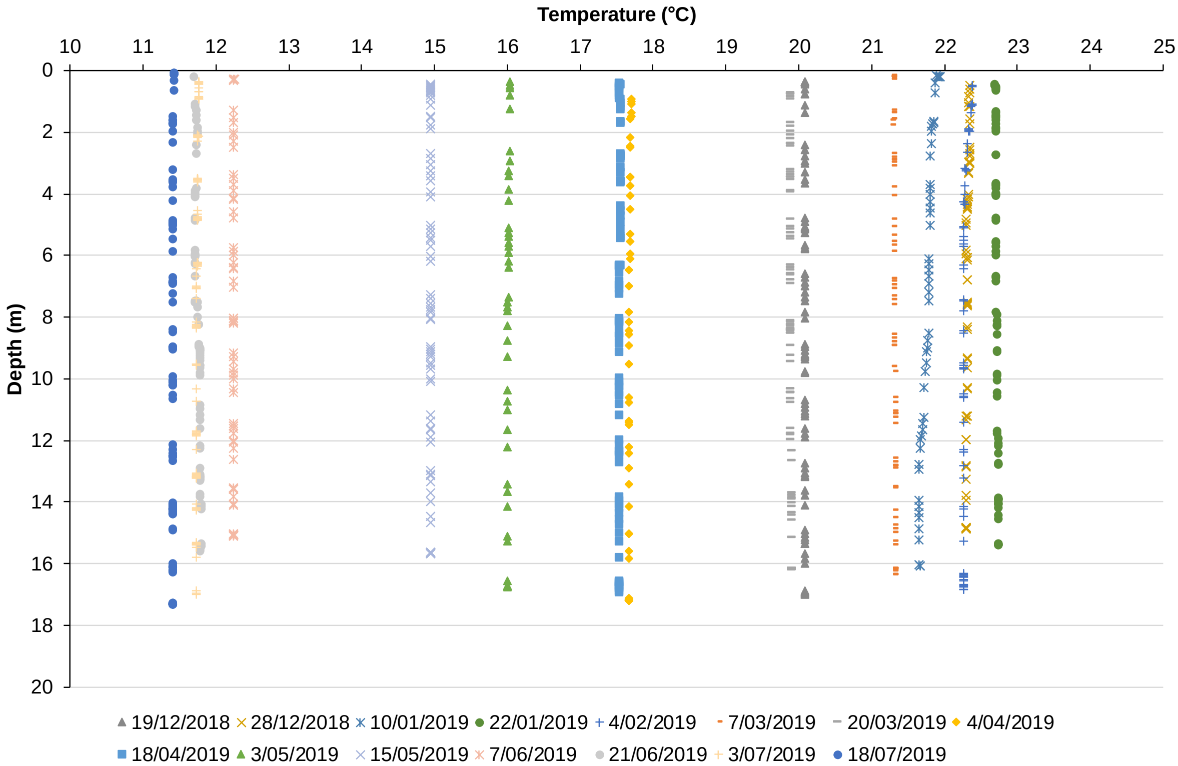
The temperature record shows that seasonal variation in North Arm seawater temperature peaks at around 22ºC in late January early February 2019 and drops to 11.5ºC in July and August 2019. Water temperature maximum lagged longest daylength by approximately a month in summer, and minimum temperature lagged shortest daylength by approximately a month in winter 2019.

Short-term cyclic variations in temperature (over hours and days) are apparent in summer and winter which are due to the effects of heating in summer and cooling in winter of the mudflats when they are exposed to the atmosphere at low tides. Water running onto and off the mudflats is warmer in summer and colder in winter than the main body of water remaining in the channels. The temperature record shows that all marine biota living in the North Arm ecosystem are accustomed to large seasonal temperature ranges of more than 10ºC and substantial short-term temperature variations of 0.1ºC to more than 2 ºC at scales from six hours to 24 hours.

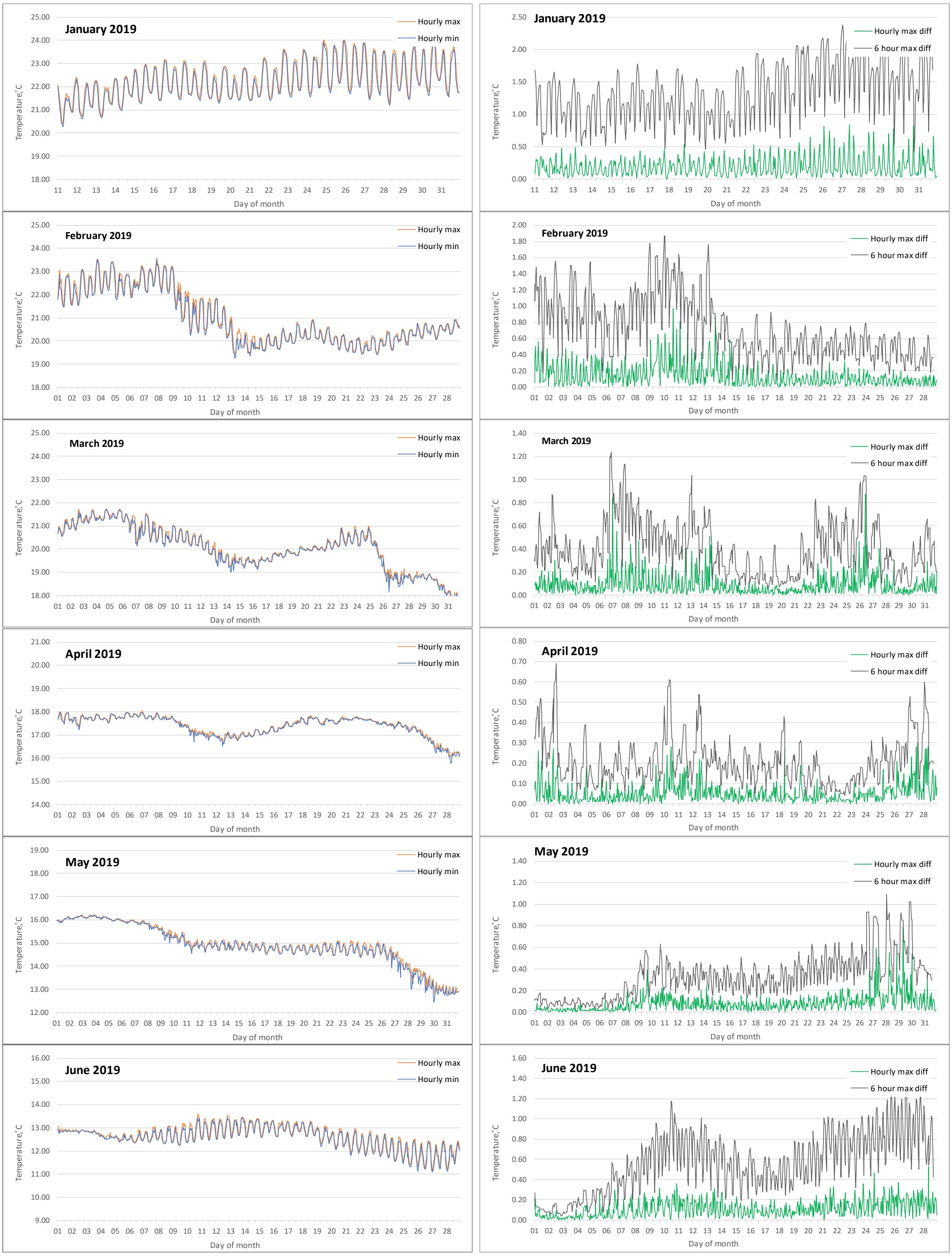
Longer term cyclic variations are also apparent in the temperature record at due to the regular two-week cycle of spring tides, as well as episodic large scale (Bass Strait) sea level variations pushing extra Bass Strait water into Western Port.

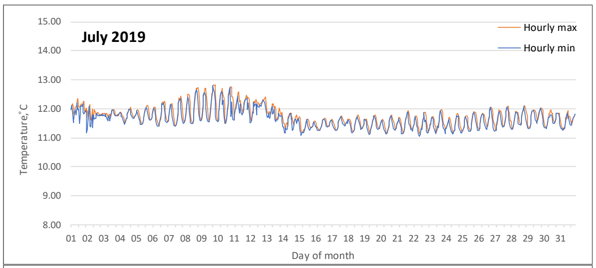
A meaningful guidance value of temperature change based on the measured natural variation of water temperature can inform interpretation of the modelled extent of the change in temperature in relation to the extent of the effect of the heat exchanger discharge on the marine ecosystem. It is proposed that measured interquartile range in seawater variation of 0.5ºC can conservatively informative of the resilience of marine biota in Western Port to natural temperature over 6- to 24-hour periods for EES assessment purposes. A regulatory limit should be established separately in consideration of a Works Approval.

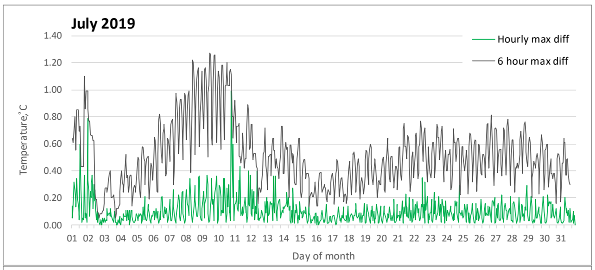
8 Appendix A. Seawater temperature profiles, Crib Point Jetty 2018_19

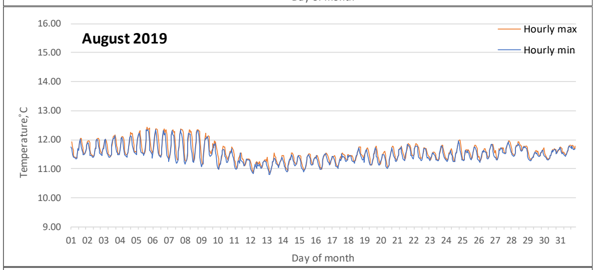


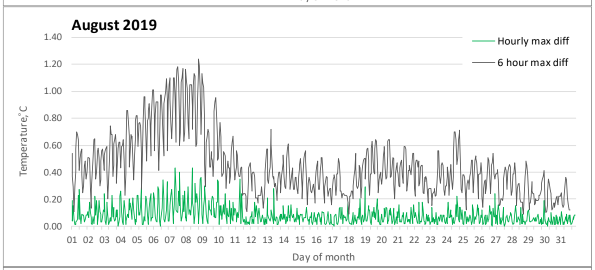
9 Appendix B. Monthly seawater temperature variation at Crib Point

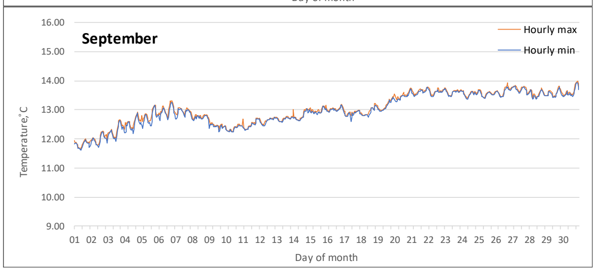


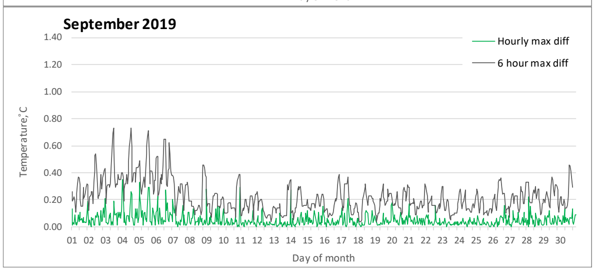

July 2019
Hourly max
Hourly min
Temperature,°C
Day of month


July 2019
Hourly max diff
6 hour max diff
Temperature,°C
Day of month


August 2019
Hourly max
Hourly min
Temperature,°C
Day of month


August 2019
Hourly max diff
6 hour max diff
Temperature,°C
Day of month


September
Hourly max
Hourly min
Temperature,°C
Day of month


September 2019
Hourly max diff
6 hour max diff
Temperature,°C
Day of month

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