Development of a temperature monitoring framework for Tasmania's seafood industry during marine heatwaves

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Acknowledgments

First and foremost, we would like to thank the commercial fishers that participated in the project and provided their data. We would also like to acknowledge Andrew Pender (IMAS) for the development, design, design testing and 3D-printing of the logger housings.

We would also like to acknowledge informative discussions with Seafood Industry Tasmania (SIT) and Natural Resources & Environmental (NRE) Tasmania in the framing of this project. NRE Tasmania also provided valuable insights into how this data could potentially be used to inform proactive management during Marine Heatwave events.

Executive Summary

Marine heatwaves can have devastating impacts on marine ecosystems, with a strong El Nino event forecast in Australia for the summer/autumn of 2023-24. Forecasts by CSIRO indicated sustained increases in water temperatures down the east coast of Tasmania with potential to significantly affect fisheries, aquaculture, and marine habitat. While sea surface temperature (SST) outputs from Bureau of Meteorology (BOM) and National Oceanic and Atmospheric Administration (NOAA) can provide information regarding broadscale patterns, missing is fine-scale, near-coastal and below surface information that is highly relevant to fisheries, aquaculture and marine coastal environments.

This project aimed to develop methods of collecting data at a scale and in locations that are relevant to fisheries in Tasmania. Methods were developed for both the deployment of instrumentation on fishing gear, along with R routines for efficiently and effectively presenting and reporting on the data. HOBO temperature loggers were deployed on commercial fishing gear from February to May 2024 to collect fine scale temperature data. Industries included the commercial Southern Rock Lobster, octopus and scalefish fisheries. Once the data was collected, it was cleaned and complied and used to compare to SST outputs for marine heatwave (MHW) monitoring.

Temperature data was collected across the state for the period from February to May 2024. Outputs in the form of letters containing the data they collected where provided back to participant fishers. This included a map of where the loggers were deployed, a per deployment temperature summary, the in-water temperature profile compared to seasonal averages and thresholds and overlapped on MHW classification plots. In addition, all data collected was developed into a spatially aggregated temporal summary to visualise the scope of data collected during the project.

These methods will be an essential tool for the management of fisheries in future MHW events, allowing for the tracking of temperature through the seafood supply chain and providing the framework to compile spatially and temporally robust datasets. End users of this data will be industry, researchers and government looking to better understand and manage MHW conditions as they become increasingly common into the future. Monitoring temperature through deployments with commercial operators will help to improve decision making for fishing locations, give marine farming better preparation around stock flows and allow for strategic decisions to be taken to adapt to changing environmental conditions. Overall, the method developed through this project fills an identified gap at a local level, which allows fishers to monitor temperature at industry-relevant and at a spatial scale that is indicative of fishing activities.

Should this method be used in the future there are a number of further R&D activities that could be explored. This include:

- An investment into loggers with a reduced time to environmental equilibrium
- Methods that will reduce the time-lag between capturing the data and providing the data to the fisher. These include:
  - Increasing efficiencies in data Quality Assurance/Quality Control (QAQC) and data collation through further development of R scripts (i.e. reduction in time from weeks to days).
  - A system that allows real-time or near real-time data collection from depth to be communicated directly to the fisher (i.e. reduction in time from weeks to hours or minutes).
- Methods that will decrease burden on the fisher to collect location data.
- Real time temperature monitoring of boat wells to complete supply chain temperature monitoring

Beyond the development of this method, there are several broader areas of research that this activity has highlighted as being of value in pursuing to better safeguard Tasmania's valuable marine industries from future, and likely more frequent, MHW events. Firstly, long term local data is needed to better inform industry and facilitate adaptive management by government. While SST estimates obtained from NOAA and NASA JPL satellite imagery are useful at understanding trends on a broadscale, our project highlighted the variability of these estimates with data collected from depth at local fishing grounds. This method allows for the collection of this data, which if continued in the long term, will aid fishers in making better decisions around fishing effort during MHW events and provide valuable data to ground-truth climate models at a local scale.

There are numerous marine industries within Tasmania that collect temperature data, although a thorough assessment of what is collected where and when has not been undertaken. Understanding what is already being collected across Tasmania's wild fisheries and aquaculture sectors could facilitate an industry-wide temperature data collation and collaboration framework during marine heatwave events. A system for sharing data between coastal industries could help to enable better response to MHW events across the Tasmanian seafood sector. This data may also be used to strengthen the capacity of predictive models and better understand the strengths and limitations of relying on broad-scale satellite data to inform decision making.

Adoption of the method more widely across the fishing industry may also help understanding how MHW events may also affect the productivity of Tasmania's marine ecosystem, beyond mass mortality. It is also an important part of an informed response. Shifts in productivity of coastal systems are more likely to cause subtle change over time; better understanding of how these changes may manifest are vital for ensuring a sustainable wild fisheries industry for future generations in the face of climate change.

Keywords

Marine heatwave, temperature logger, Southern Rock Lobster fishery, octopus fishery, sea surface temperature, temperature anomaly, fisheries-based deployments.

Introduction

Marine heatwaves (MHWs) are prolonged extreme oceanic warm water events that can severely impact marine ecosystems and the services that they provide (Holbrook et al. 2020). MHWs vary across temporal scales and can persist from weeks to years depending on the environmental drivers. They also vary across spatial scales and depth, in some instances isolated to an individual embayment, in others spanning multiple oceans (Holbrook et al. 2019). There are a range of inter-linked physical processes occurring at different temporal and spatial scales that bring about discrete and prolonged elevated temperature conditions (Smale et al. 2019, Holbrook et al. 2020). While there is inherent complexity around the processes that drive MHW events, evidence suggests that MHWs are becoming longer lasting and more frequent; a trend that is likely to accelerate under future climate change scenarios (Frölicher et al. 2018, Oliver et al. 2018a, Laufkötter et al. 2020).

The biological impact of MHWs on marine ecosystems is likely to be severe, with studies reporting negative impacts across a range of biological process and taxa, including critical foundation species such as corals, seagrasses and kelps (Smale et al. 2019). Most organisms function within certain temperature limits; rapid warming trends have increased the likelihood of exposure to temperatures beyond these limits (Smith et al. 2023). As such, case studies have documented widespread mortality, species range shifts and community reconfiguration associated with prolonged or severe MHW events, with effects seen at biological scales ranging from genes to ecosystems (Wernberg et al. 2013, Smale et al. 2019, Smith et al. 2023).

The impact of MHWs is likely to extend into fisheries, either directly through effecting the behaviour, ecological interactions, spawning, survival and distribution of commercially valuable species, or indirectly through alterations to food sources or habitat within the environment (Brown et al. 2021, Smith et al. 2021). Despite potential pathways of impact, the effects of MHWs on fisheries productivity are inconclusive in many cases, and likely to vary depending on the individual species and location (Cheung & Frölicher 2020). In the case of mass mortality, links between fisheries productivity and MHWs are relatively easy to determine, however the impact of sub-lethal effects are often confounded by other environmental changes and manifest over multiple years (Brown et al. 2021). Despite this, MHWs have been linked to a number of declines or changes to fisheries productivity, both in Australia (Caputi et al. 2016, Chandrapavan et al. 2019, Brown et al. 2021) and globally (Barbeaux et al. 2020, Free et al. 2023, Farchadi et al. 2024). Given the high socio-economic value of fisheries, a better understanding of effects of MHWs on fisheries, and how they might manifest across all aspects of productivity, catchability and supply chain is necessary to facilitate an adaptive management response to these events.

In Australia, MHW conditions have becoming increasingly common. South-eastern Australia is recognised as a climate-change hotspot with ocean warming occurring up to four times faster than the global average (Hobday & Pecl 2014, Pecl et al. 2014). MHWs have been predicted to occur increasingly off south-eastern Tasmania under most climate change scenarios (Oliver et al. 2018b). Forecasts by CSIRO indicated sustained increases in water temperatures down the east coast of Tasmania for the summer of 2023-24, with potential to significantly impact on fisheries, aquaculture, and marine habitat. Improved forecasting by CSIRO has provided industry and government with the opportunity to be better prepared, with the monitoring of ambient temperature a key component of this. While sea surface temperature (SST) observations from BOM and NOAA can provide information regarding broadscale patterns, missing is fine-scale, near-coastal and below surface information that is highly relevant to fisheries, aquaculture and marine coastal environments. While some industries monitor temperature as part of operations (e.g. salmon, oyster aquaculture), other industries are missing any fine scale information that may be of relevance to their operations.

Objectives

1. To develop a framework for collection of robust temperature data from depth along the east coast of Tasmania.
2. To validate the approach of rapid industry deployment of loggers to monitor temperature in MHW conditions for providing fine-scale variation in temperature.
3. Use the combined data to better understand how temperature data can inform fisheries management for future MHW events.

Method

HOBO temperature loggers & custom housings

Thirty-five HOBO MX2203 TidbiT water temperature loggers (Onset Computer Corporation, USA) were purchased to be deployed on commercial fishing gear around Tasmania during the summer/autumn of 2024. These loggers are compact, can be deployed up to 120 m depth and have a resolution of 0.01°C and an accuracy of ±0.2°C.

Prior to deployment, a custom 3D printed housing was designed to avoid damage to the deployed loggers in the field (Figure 1). The housing was comprised of two parts; a back plate and a front curved dome to house the logger. The two parts were secured together with two stainless steel screws. The housing was designed with features including a honeycombed dome to allow sufficient water flow past the loggers, and holes of different sizes to allow for flexible attachment options for different commercial fishing gear. The housing also had engraved on it 'IMAS' and a contact phone number, in case the housing and logger were lost while deployed.

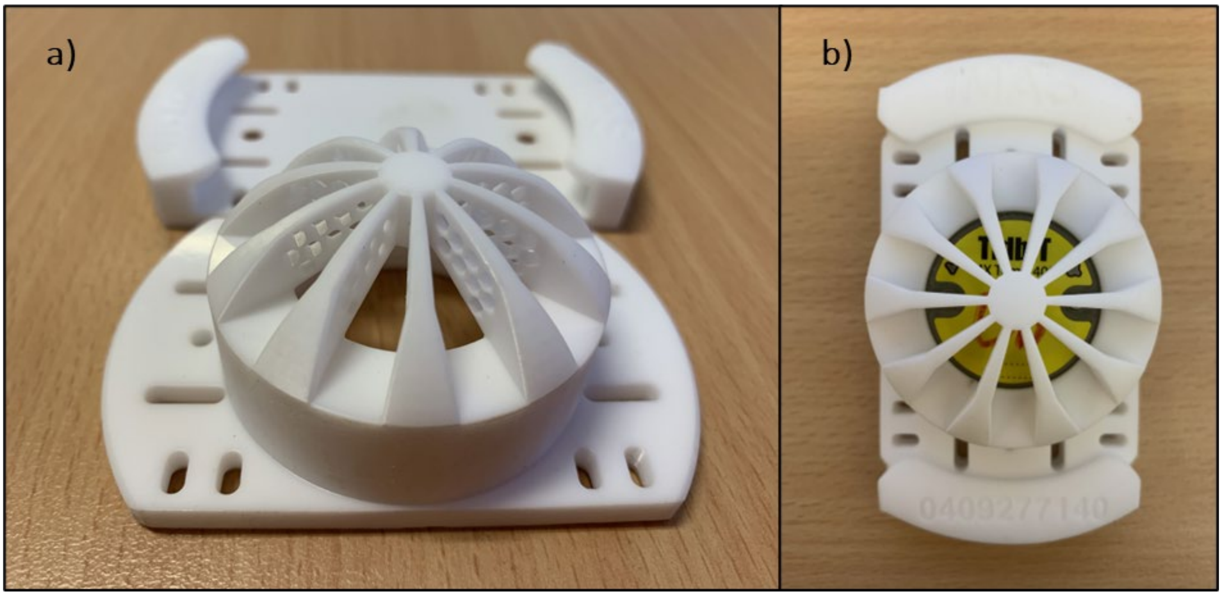

Figure 1. HOBO temperature logger housing, where a) shows the two-part housing and honeycombed dome, and b) shows the logger installed in the housing ready for deployment.

The HOBO loggers were also tested for accuracy prior to being deployed. All of the loggers were placed in a constant temperature water bath overnight, before placing a conductivity, temperature, depth (CTD) instrument in with them to validate their temperature readings. Loggers were found to have good accuracy, relative to both each other and the CTD.

Trial deployments

Prior to commercial deployment, the loggers were trialled during routine research sampling at IMAS. The loggers were first deployed on rock lobster pots in early February 2024 during the annual rock lobster sampling program at Crayfish Point Research Area, Taroona, Tasmania ("Fish Down"). Two loggers were cable-tied inside separate pots and deployed for a period of five days (Figure 2a). Data from this deployment indicated that the deployments on the pots were successful but that one minute temperature logging intervals were excessive to our needs. It was determined that the next deployment would trial five-minute logging intervals to see if that resolution would be sufficient.

A second trial deployment was conducted in late February during an undergraduate field trip to Maria Island, Tasmania (Figure 2b). Two loggers were again deployed on rock lobster pots, and another two were deployed on baited remote underwater video (BRUV) frames and on a conductivity, temperature, depth

(CTD) instrument. Data from these deployments indicated, as for the Crayfish Point deployments, that overnight deployments on rock lobster pots were successful, and that the five-minute temperature intervals were sufficient resolution. However, it also determined that the logger required time to equilibrate to ambient temperature once deployed in water. This period was approximately 30 minutes, meaning that data collected from the BRUVs (~30 minute deployments) and CTD (~10 minute deployments) were not accurate representations of the water temperature at the seafloor and are not suitable deployment methods for these particular temperature loggers.

Figure 2. Trial deployments at a) Crayfish Point Research Area showing the logger attached to the rock lobster pot, and b) during the Maria Island undergraduate field trip where students helped deploy the loggers during their rock lobster sampling project.

Commercial deployments

The HOBO temperature loggers were programmed with the following settings prior to being commercially deployed; five-minute temperature intervals, water detection on and data collection until either the logger memory was full, or the battery died. This balanced the battery life with data resolution needs. The water detect function allows the logger to log a timestamp at immersion and emersion. This function allows for easy detection of when the logger is deployed, and for the removal of air temperature data from deployment mean temperatures. These settings were programmed using the HOBOconnect software program (version 1.7.3 1508) via the loggers Bluetooth connection.

Along with the HOBO logger, commercial fishers were supplied a wheelhouse log sheet to collect information on deployment and retrieval dates and times, type of commercial fishing gear the logger was deployed on, maximum depth, and GPS coordinates of each deployment. Instructions for use were included in the letter sent with the equipment (Appendix 1).

Commercial fishers in the octopus, scale fish and Southern Rock Lobster industries were contacted and asked if they wished to participate in the study. Those that agreed and were going to be fishing in the months following contact were sent a HOBO logger, cable ties for attaching the logger to their commercial fishing gear, wheelhouse log sheets and return post pack. Fishers were instructed on what was required and asked to deploy the loggers during their commercial fishing operations over a short time period (weeks to a month). Once their fishing activities were complete, the loggers were sent back to IMAS for data download and analysis.

Data analysis & outputs

Once the loggers were returned to IMAS, the data was downloaded via HOBOconnect and the wheelhouse log sheets were translated into digital data. The temperature data was matched to its wheelhouse log before being cleaned and imported into a master data file for analysis. This included identifying when the logger was immersed (i.e. deployed), matching each in-water deployment to a set of GPS coordinates and depth, and including file and fisher details for inclusion in the master file for analysis. All cleaning and data manipulation was conducted using R (R Core Team 2023).

Once the data was cleaned and the master data file created, the data was used to create several outputs; an individualised letter to each participant commercial fisher that contributed data, an overview of all data collected during the project and an output for the Department of Natural Resources and Environment (NRE) Tasmania.

The individualised letter provided data back to the fisher to provide information on how their fishing grounds tracked for temperature compared to long term averages and SST profiles. This was presented as a series of maps and figures, with raw data made available on request. First, the GPS coordinates for the duration of the deployment were overlayed on a map to give a visual spatial assessment. The data for each deployment was then tabulated and summarised per deployment. This included the deployment number, deployment date, retrieval date, average, minimum and maximum deployment temperatures and depth recorded. Next, the full logger temperature profile was plotted with the long-term seasonal climatology of the area it was deployed in, including the 90th percentile temperature threshold. The seasonal climatology was constructed using NASA JPL's Group for High Resolution Sea Surface Temperature (GHRSST) satellite derived data provided by the IMAS Abalone team. The data was aggregated into daily SST measurements per Commercial Dive and Abalone Fishing Block. This data was fed into the 'heatwaveR' package (Schlegel & Smit 2018) to create the seasonal climatology for each fishing block using the 'ts2clm' function. This function provides both the seasonal average temperatures and the 90th percentile threshold temperatures, in this case per fishing block. This concludes the collected data summary for the fisher.

The next part of the letter providing information on the SST and MHW context in the area they were fishing while the logger was deployed. This analysis was also conducted using the 'heatwaveR' package (Schlegel & Smit 2018). As above, SST data from NASA JPL's GHRSST, complied and provided by the IMAS Abalone team, was used to construct seasonal and threshold climatology time series' (ts2clm() function). These timeseries were analysed to detect marine heatwave events based on published definitions (detect_event() function, Hobday et al. 2016). From here, the event_line() function was then used to construct a line plot of SST, climatology and threshold values for the area the fisher deployed the temperature logger. Overlaid on this plot were the average temperatures per deployment, to provide the fisher with information on the SST conditions they may have been fishing in as well as where their at-depth data compared to the sea surface temperature conditions in the area. This provided information in the context of whether the fisher was operating in warmer than normal SST conditions, but not necessarily MHW conditions.

Marine heatwaves have a classification system to simplify comparisons globally and to provide consistent terminology around the type of MHW event (Hobday et al. 2016, Hobday et al. 2018). For a warm water event to be classified as a MHW event, there are certain criteria that need to be met, including the temperature compared to seasonal threshold values (temperatures above the 90th percentile threshold) and its duration (five or more days above this threshold). Further, MHW events can be categorized based on the temperature exceedance of the local climatology for easier identification of the severity of potential biological impacts on the marine environment. This categorization includes Category I (Moderate), II (Strong), III (Severe) and IV (Extreme).

NRE Tasmania monitored the warm water event off Tasmania and provided categorization of MHW conditions for each Abalone and Commercial Dive Fishing Block based on two sea surface temperature datasets: NOAA's daily Optimum Interpolation Sea Surface Temperature (OISST) and NASA JPL's GHRSST.

The NOAA OISST dataset is at a 25 km resolution, while the NASA JPL dataset is at a 1 km resolution. Based on this monitoring, fisher data per deployment was matched to the MHW conditions for the area they were fishing in. this was displayed in a table with the deployment date, MHW classifications closest to that date from both NOAA and NASA datasets, the mean deployment temperature for the logger and the mean SST for that block from the NASA JPL data. This provided the information on whether the fisher was operating in an area with a MHW occurring at that time.

Once all data was received from fishers, analysis on the whole dataset was also completed. Based on the spatial and temporal spread of the data, monthly summaries were created for the areas that had loggers deployed in them. Temperature data was summarised per commercial abalone fishing block before being plotted on a map and compared to the average monthly SST from the NASA JPL data. From these two data sets, the difference between the sub-surface temperature was compared to the SST measurements to determine if the HOBO logger data was cooler or warmer relative to the SST in the area. From there, areas of interest were further explored, i.e. areas that had been classified as severe or extreme during the season.

The output for NRE included finer-scale spatial resolution information, not for public release due to confidentiality of fishing locations. The eventual aim is to have the data available at the block level through the IMAS data portal, with links to Tasmania's Marine Atlas, with this process occurring outside the limited project timeframe.

Results

A total of 24 trips where HOBO loggers were deployed were achieved during the project, between February and May 2024 (Table 1). Four of those deployments were during trials (Crayfish Point sampling and Maria Island undergraduate field course), and the rest on commercial fishing trips. Of the commercial deployments, three were on commercial octopus trips, one on a commercial scalefish trip and the remaining 16 on commercial Southern Rock Lobster trips. One logger failed as a result of water ingress; however some data was able to be retrieved from the logger.

A total of >70,000 temperature measurements were taken over >220 deployments, with most fishers deploying their logger multiple times on their equipment throughout a trip. Deployments lasted between 24 hours and 32 days, depending on the fishery. The maximum temperature recorded by the loggers was 19.9°C at 48 m depth north of Deal Island in the north-east of the state and the lowest temperature recorded was 12.2°C at 58 m depth near Sandy Cape on the north-west coast of Tasmania.

Table 1. All successful deployments of HOBO loggers during this project. The logger number indicates the unique logger identification number, the days deployed, the number of subsurface temperature measurements taken during those deployments, and the minimum and maximum recorded temperature of each trip. * indicates non-commercial (IMAS) deployments.

Logger number	Days deployed	Sub-surface measurements (n)	Minimum temp. recorded (°C)	Maximum temp. recorded (°C)
MHW#01	12	2613	16.2	17.6
MHW#01*	3	4223	17.5	18.3
MHW#02	1	349	18.2	19.1
MHW#02*	3	4183	16.9	18.1
MHW#03	32	9072	17.4	19.6
MHW#04	12	3451	18.5	19.9
MHW#12	7	1774	13.4	15.7
MHW#12	8	2087	14.5	15.9
MHW#13	22	3756	14.6	18.3
MHW#14	18	3857	12.2	17.4
MHW#18	16	4025	14.2	18.3
MHW#19	24	5058	16.9	17.9
MHW#21	23	4112	15	17.3
MHW#22	6	1348	14.9	17
MHW#23	9	2147	15.9	17.2
MHW#24	12	2659	15.6	17.1
MHW#25	7	1345	14.7	15.5
MHW#26	5	1308	16.3	17.4
MHW#27	9	2142	16.1	17.3
MHW#28	12	3172	16.2	17
MHW#29	7	1469	15.8	17.1
MHW#32*	3	735	18.6	19.7
MHW#33	17	4814	17.2	18.9
MHW#34*	3	788	18.8	19.4

Communication of data to fishers

Individual letters were created for each fishing trip a logger was deployed (see below). These included a general letter with information about their report, a map of logger deployment locations, the in-water temperature profile compared to seasonal and threshold temperature values, a temperature summary per deployment, the marine heatwave conditions during the deployment, and a summary of all data collected during the project (not shown in the letter below for brevity, Figures 4-7). Letters were sent to participants on the 24th of July 2024.

UNIVERSITY of TASMANIA

IMAS

Institute for Marine and Antarctic Studies

24 July 2024

Name
Address
SUBURB TAS 7XXX

Dear Fisher,

Thank you for participating in our FRDC- and NRE-funded project ‘Development of a temperature monitoring framework for Tasmania’s seafood industry during marine heatwaves’. The data you collected using the HOBO logger deployed on your commercial fishing gear has now been processed and the attached report generated. The outputs of this report include a map of the sites where you deployed the logger, a temperature summary for each deployment, a full in-water temperature profile for the duration of the deployments, as well as the temperature data you collected in the context of the marine heatwave conditions that may have been present during your fishing trip. Finally, there is a summary of all the data collected during this project. Please note that the data is aggregated by Abalone and Commercial Dive Fishing Blocks due to the data being collated and provided by the IMAS Abalone team. In future we hope to provide this at the Commercial Rock Lobster Fishing Block level.

This data is intended to be of use to the industry sector. If you have any thoughts on how this data may be interpreted in a way that is useful for you as a commercial fisher, please get in touch with Sam via phone (03 6226 8201) or email (Samantha.Twiname@utas.edu.au).

If you have any questions or queries about the project, please get in touch.

Thank you again,

Samantha Twiname, on behalf of the project team,

Dr Camille White, Dr Craig Mundy, Ben Quigley, Frances Seaborn and Dr Caleb Gardner

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Monitoring sub-surface ocean temperatures in Tasmania

HOBO logger deployment locations

Here is a map of the sites the HOBO logger was deployed during your fishing activities.

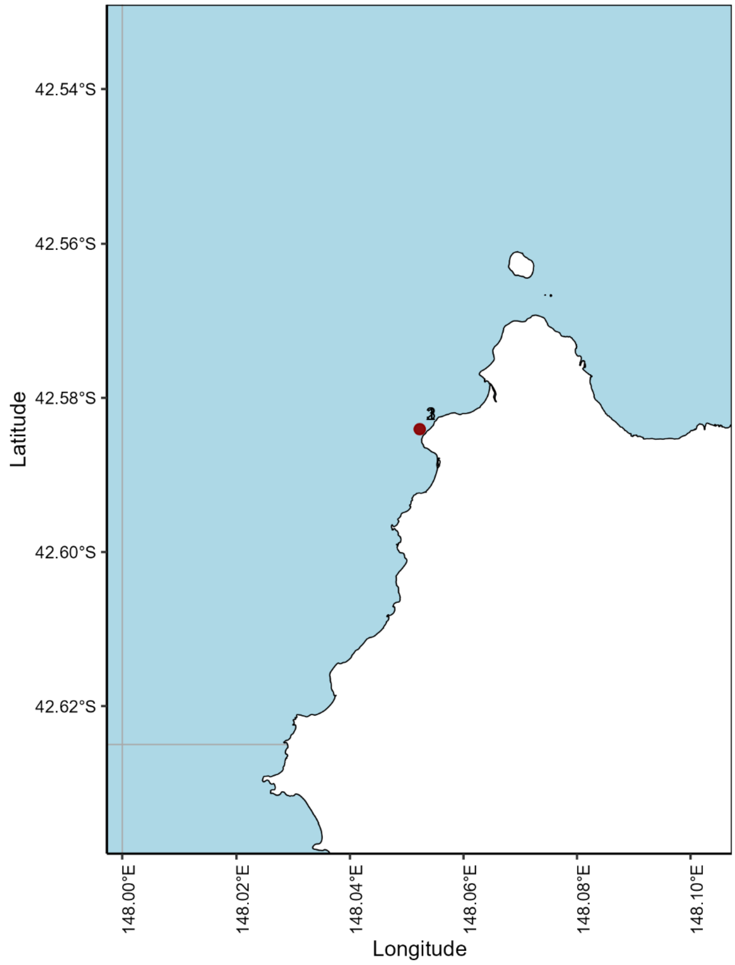


Figure 1. Sites of HOBO temperature logger deployment (red dots) with deployment number (ordered by deployment date). Grey lines indicate the borders of the Commercial Rock Lobster Fishing Blocks, and the black lines and 'AB' labels indicate the Abalone and Commercial Dive Fishing Blocks.

Sub-surface temperature profile

Here is the full sub-surface temperature profile for the deployed HOBO logger during your fishing activities. The seasonal average is the average temperature for the particular date calculated from long-term sea surface temperature data, in this case from the NASA JPL's Group for High Resolution Sea Surface Temperature (GHRSST) data. The 90th percentile temperature threshold indicates the limit where 90% of temperatures will normally fall below this value, with 10% of temperatures exceeding this value. Anything above this 90th percentile is considered anomalously warm.

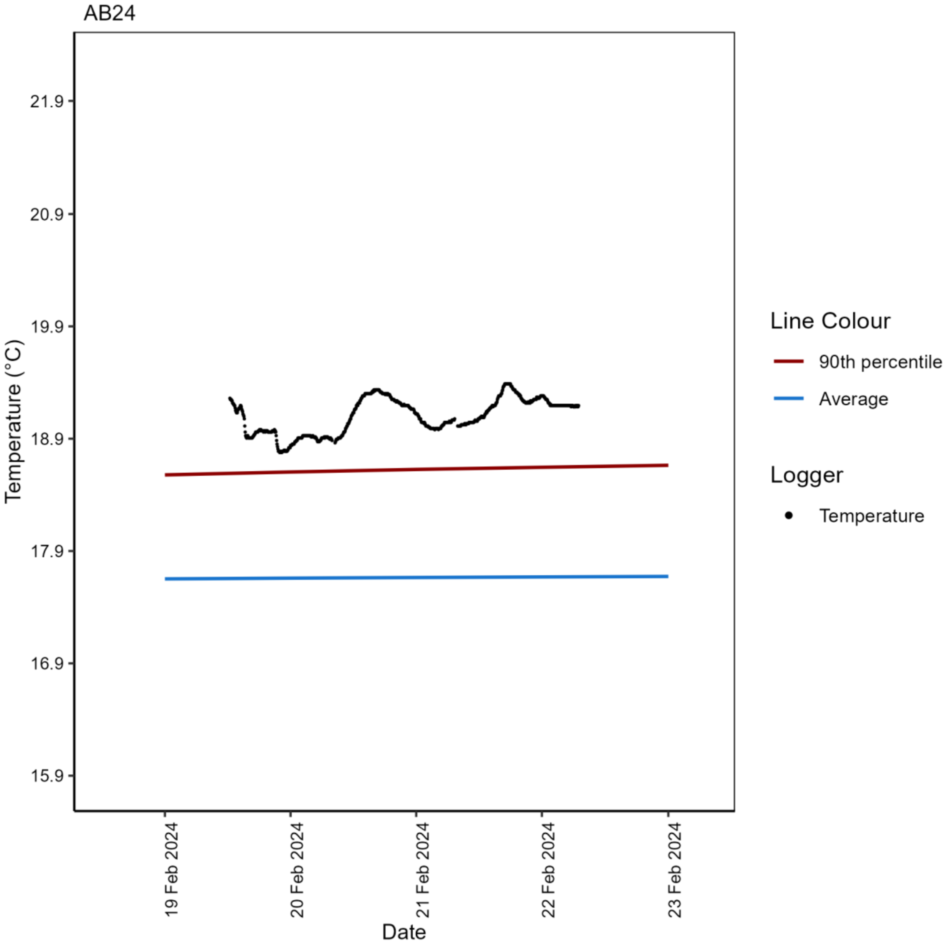


Figure 2. All subsurface temperature data collected by the HOBO temperature logger during deployment (black dots), compared to the long-term seasonal average temperature (blue line) and the 90th percentile temperature threshold (red line) for the region(s) you were fishing, as identified by the 'AB' code in the top left of the plot.

Deployment temperature summary

Here is the sub-surface temperature summary for each deployment of the HOBO logger during your fishing activities.

Table 1. Sub-surface temperature summary per HOBO logger deployment, including the deployment and retrieval dates, temperature metrics (in °C), and the depth the logger was deployed.

Deployment number	Deployment date	Retrieval date	Average temperature	Minimum temperature	Maximum temperature	Depth (m)
1	19/02/2024	20/02/2024	18.9	18.8	19.3	8.1
2	20/02/2024	21/02/2024	19.1	18.9	19.3	8.1
3	21/02/2024	22/02/2024	19.2	19.0	19.4	8.1

Comparing sub-surface temperature data to marine sea surface temperature data

Here is the average temperature per deployment during your fishing activities, compared to long-term seasonal average sea surface temperature (SST) and the observed SST of the region you were fishing in. The long-term seasonal average and threshold metrics were calculated using NASA JPL SST data, as explained above.

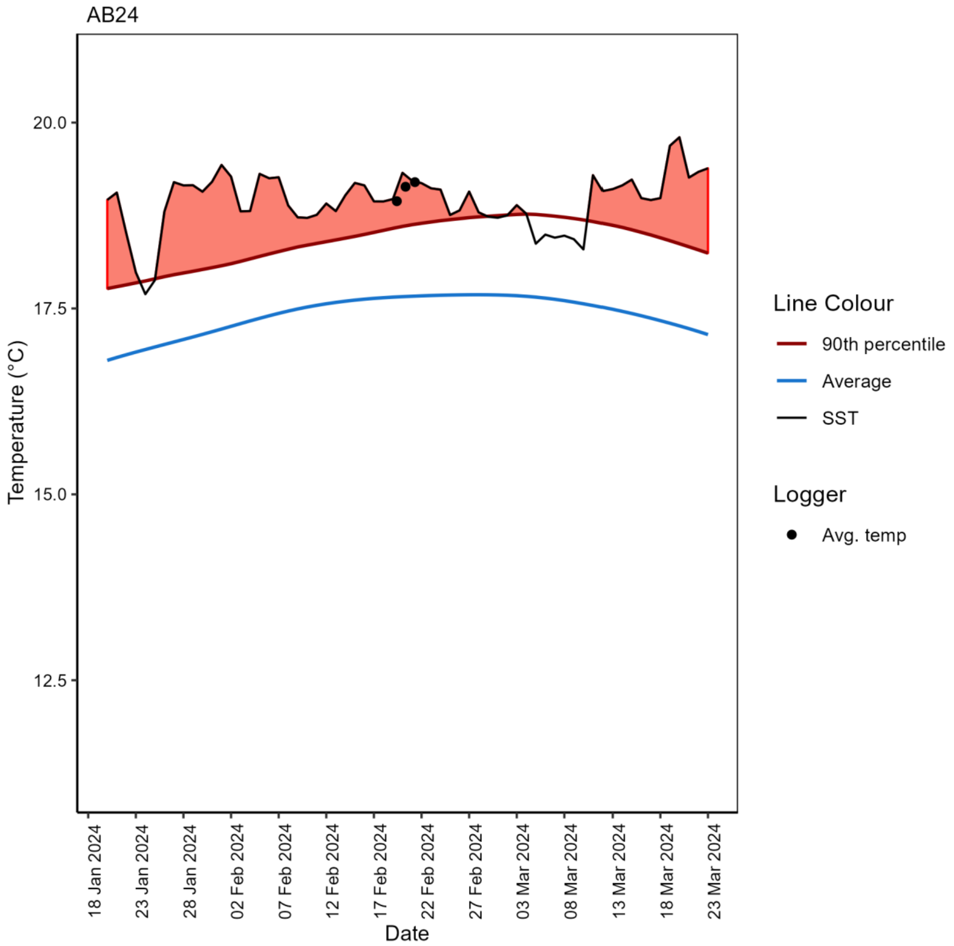


Figure 3. The average sub-surface temperature per deployment (black dots) compared to the long-term seasonal average sea surface temperature (blue line), the 90th percentile temperature threshold (red line) and the measured sea surface temperature (black line) for the region(s) you were fishing, as identified by the 'AB' code in the top left of the plot. The red shaded area indicates when the observed sea surface temperature is above the 90th percentile threshold temperature for the region.

Were you fishing in a marine heatwave classified area during the deployments?

Marine heatwaves are complex events, with a variety of impacts on marine environments. To be classified as a MHW event, there are certain criteria that need to be met, including the temperature compared to seasonal threshold values (temperatures above the 90th percentile threshold) and its duration (five or more days above this threshold). Further, MWH events can be categorized based on the temperature exceedance of the local climatology for easier identification of the severity of potential biological impacts on the marine environment. This categorization includes Category I (Moderate), II (Strong), III (Severe) and IV (Extreme).

NRE Tasmania monitored the warm water event off Tasmania and provided categorization of MHW conditions for each Abalone and Commercial Dive Fishing Block based on two sea surface temperature datasets: NOAA's daily Optimum Interpolation Sea Surface Temperature (OISST) and NASA JPL's Group for High Resolution Sea Surface Temperature (GHRSST). The NOAA OISST dataset is at a 25 km resolution, while the NASA JPL dataset is at a 1 km resolution.

Below is a table summarizing the MHW conditions in the fishing block(s) you were operating in while deploying the HOBO temperature logger. These are based on weekly categorizations where the data for the NOAA OISST and NASA JPL categories are taken from the closest date available from the NRE Tas Marine Heatwave (MHW) updates.

Table 2. Marine heatwave (MHW) classification for each HOBO logger deployment, using data from both NOAA and NASA JPL for the block location you were fishing in.

Deployment date	Location	Average logger temperature	NASA JPL SST	Temperature difference	NOAA OISST category*	NASA JPL category*
19/02/2024	AB24	18.9	19.0	-0.1	Strong	Normal
20/02/2024	AB24	19.1	19.3	-0.2	Strong	Normal
21/02/2024	AB24	19.2	19.2	0	Strong	Normal

*Data from the closest date available from the NRE Tas Marine Heatwave (MHW) update.

All data collected during the project

Here is a monthly summary of the data collected by all fishers during the project. The data is a monthly temperature summary for each Abalone and Commercial Dive Fishing Block where HOBO temperature data was collected. This is then compared to the monthly average temperature of the NASA JPL SST data for each of the same blocks. The difference in these temperatures was then calculated to determine if there were patterns in the sub-surface temperatures compared to the SST.

Using fisher data for monitoring MHW events

All of the HOBO logger data was summarised into a per-day averaged sub-surface temperature value per Commercial and Abalone Dive block (Figure 3). This figure shows the spatial and temporal coverage achieved by the project and the general temperature trends around Tasmania, with data collecting indicating warmer water on the north and east coasts and cooler on the south coast. To put this in context with sea surface temperature data used to monitor marine heatwaves, data for the same dates and fishing blocks from the NASA JPL GHRSST project were summarised and the difference between the sub-surface and sea surface temperatures calculated and presented at the same resolution (Figures 4-7). From this, we found that more often the HOBO logger sub-surface temperatures were cooler than the SST (blue shading in the temperature difference plots). However there are areas at time where the sub-surface temperature data exceeded that of the SST, in particular north of Flinders Island in March and around King Island in April.

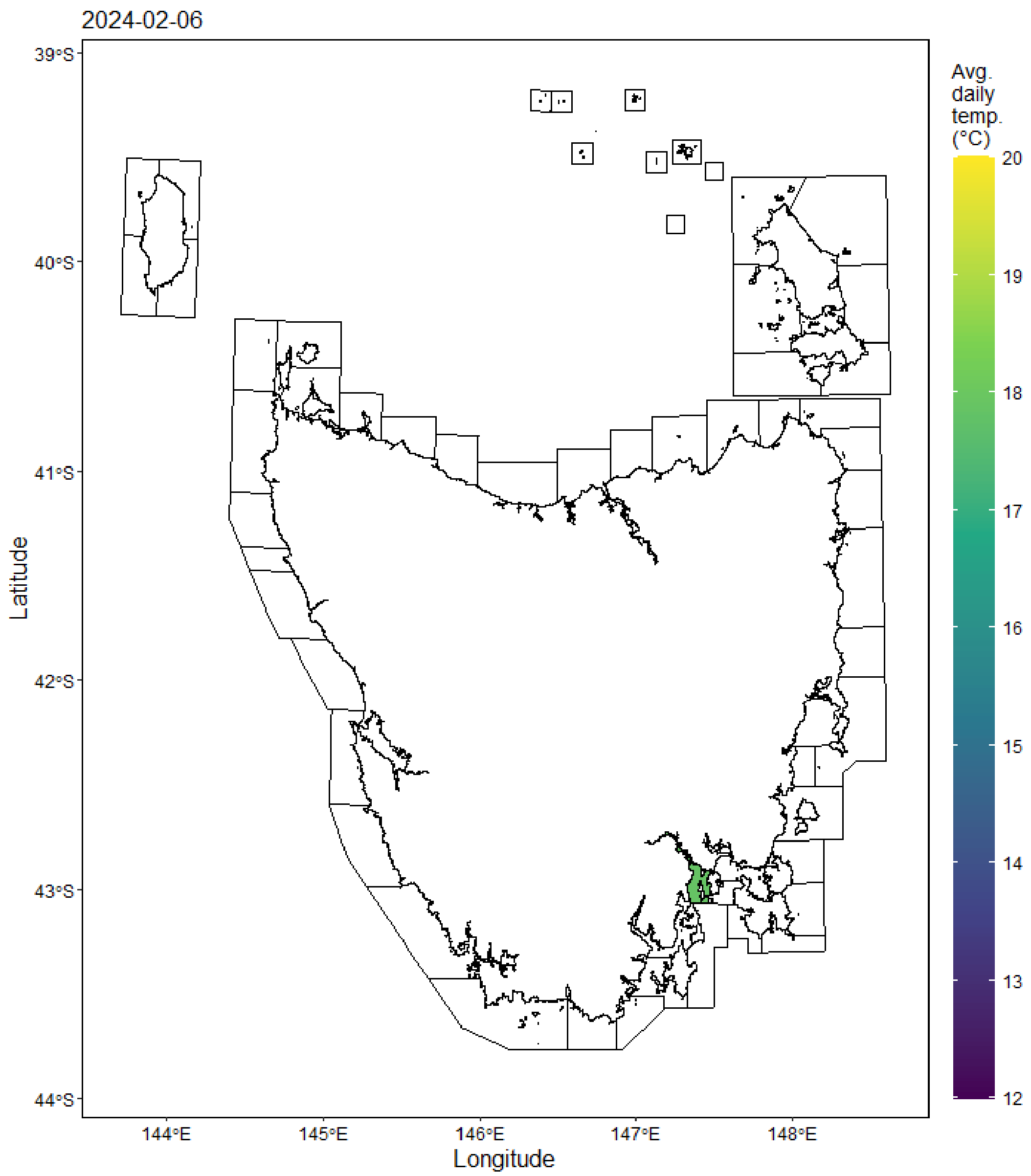


Figure 3. Spatially aggregated temperature data for all dates of logger deployments from March to May 2024. Temperature data is averaged per Commercial and Abalone Dive block per day.

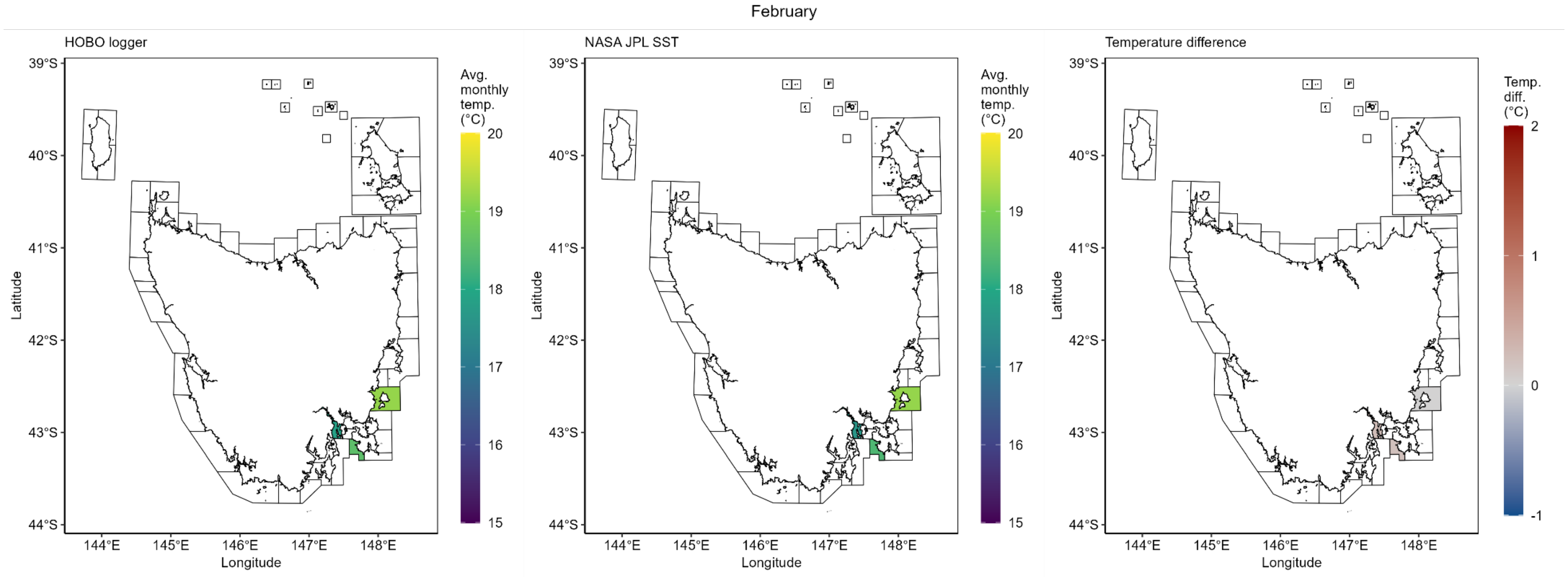


Figure 4. Temperature summary for February 2024, including the average monthly sub-surface temperature from the HOBO loggers deployed on fishing gear at depth (left), the monthly average sea surface temperature from NASA JPL GHRSST (middle) and the difference between the two temperatures (right), where red indicates warmer sub-surface temperatures than sea surface temperatures and blue indicates cooler.

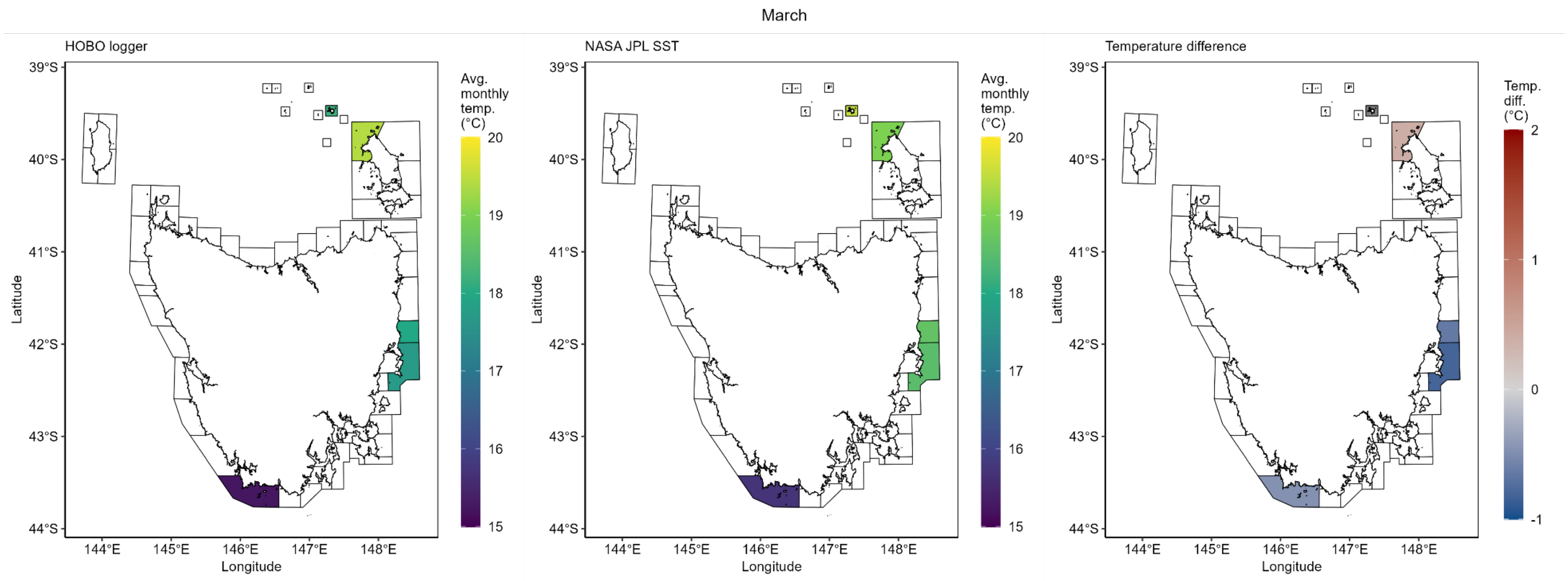


Figure 5. Temperature summary for March 2024, including the average monthly sub-surface temperature from the HOBO loggers deployed on fishing gear at depth (left), the monthly average sea surface temperature from NASA JPL GHRSST (middle) and the difference between the two temperatures (right), where red indicates warmer sub-surface temperatures than sea surface temperatures and blue indicates cooler.

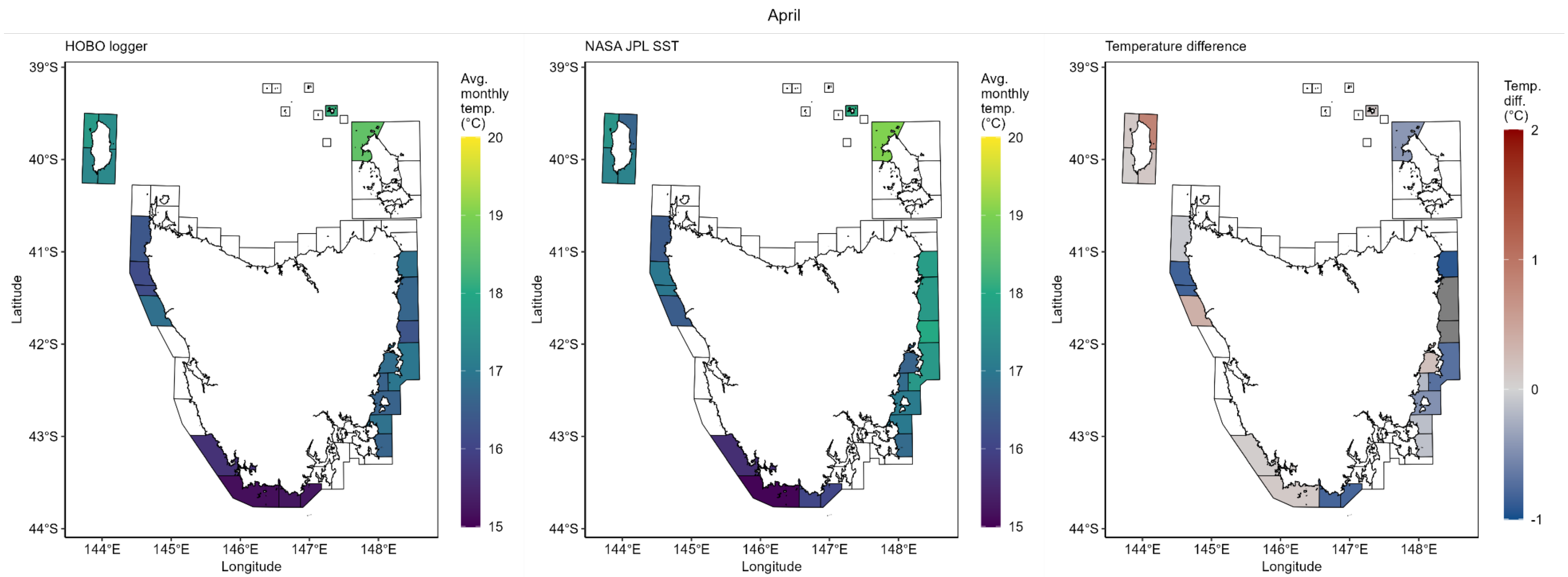


Figure 6. Temperature summary for April 2024, including the average monthly sub-surface temperature from the HOBO loggers deployed on fishing gear at depth (left), the monthly average sea surface temperature from NASA JPL GHRSST (middle) and the difference between the two temperatures (right), where red indicates warmer sub-surface temperatures than sea surface temperatures and blue indicates cooler.

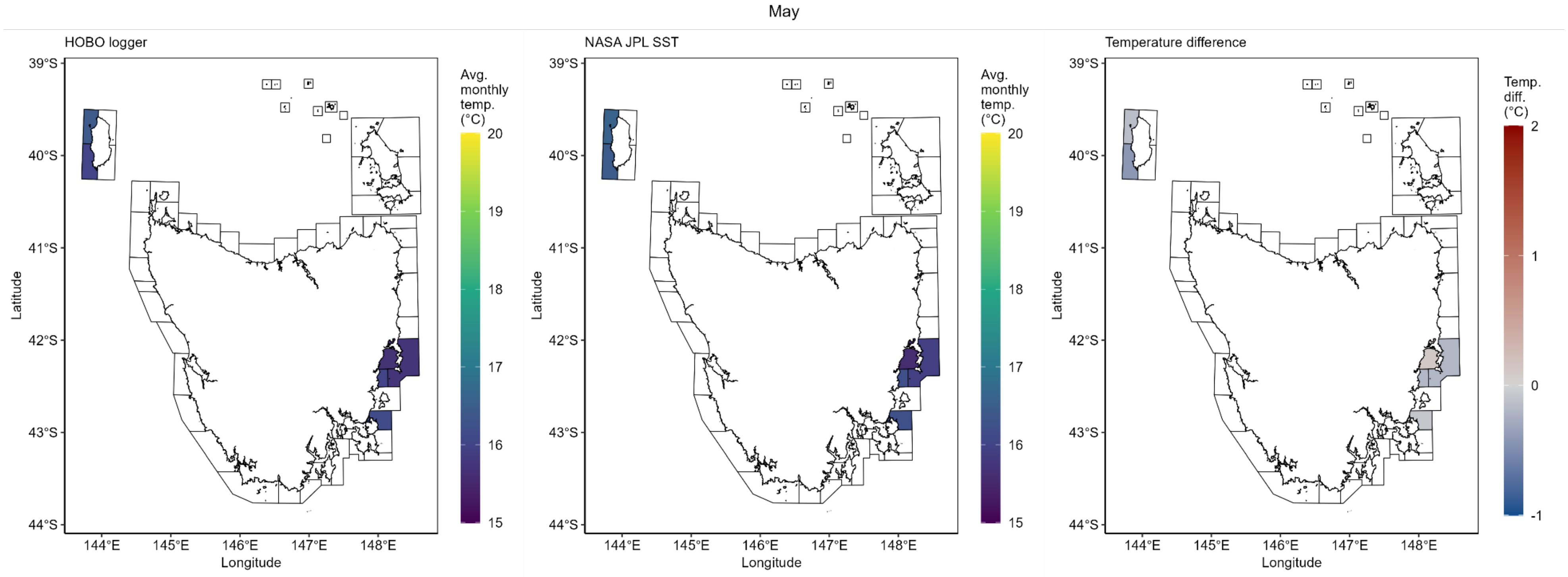


Figure 7. Temperature summary for May 2024, including the average monthly sub-surface temperature from the HOBO loggers deployed on fishing gear at depth (left), the monthly average sea surface temperature from NASA JPL GHRSST (middle) and the difference between the two temperatures (right), where red indicates warmer sub-surface temperatures than sea surface temperatures and blue indicates cooler.

Areas of interest were selected for finer temporal and spatial analysis, with the HOBO logger sub-surface data compared to the NASA JPL SST data and climatology. From the regional analysis above, north west King Island (block AB1) was identified as an area with higher sub-surface temperatures than sea surface temperatures. Data collected from HOBO loggers deployed on fishing gear at depth indicated that early April sub-surface temperatures were consistently higher than the 90th percentile temperature threshold and often higher that the NASA JPL SST in the area (Figure 8). Sub-surface temperatures appeared to drop from mid-late April.

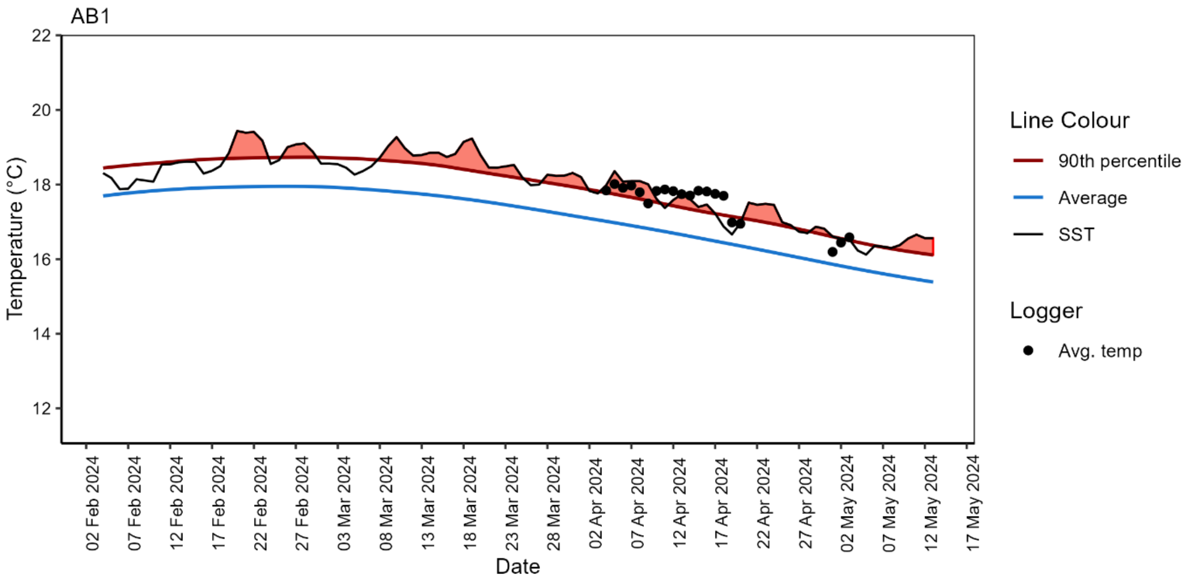


Figure 8. Temperature summary for Commercial Dive and Abalone Block 1 –North West King Island. The average sub-surface temperature per HOBO deployment (black dots) is compared to the NASA JPL long-term seasonal average sea surface temperature (blue line), the 90th percentile temperature threshold (red line) and the satellite derived sea surface temperature (black line) for the North West King Island area. The red shaded area indicates when the observed sea surface temperature is above the 90th percentile threshold temperature for the region.

In north-west of the state, a similar pattern was observed for north-west Flinders Island (AB37, Figure 9). The sub-surface temperatures were higher than both the SST and 90th percentile temperature threshold for late March before cooling in early April. Of note, trends around the 90th percentile temperature threshold were inverted when HOBO logger data deployed on fishing gear (black dots) were compared to the observed sea surface temperature data (black line) (Figure 9).

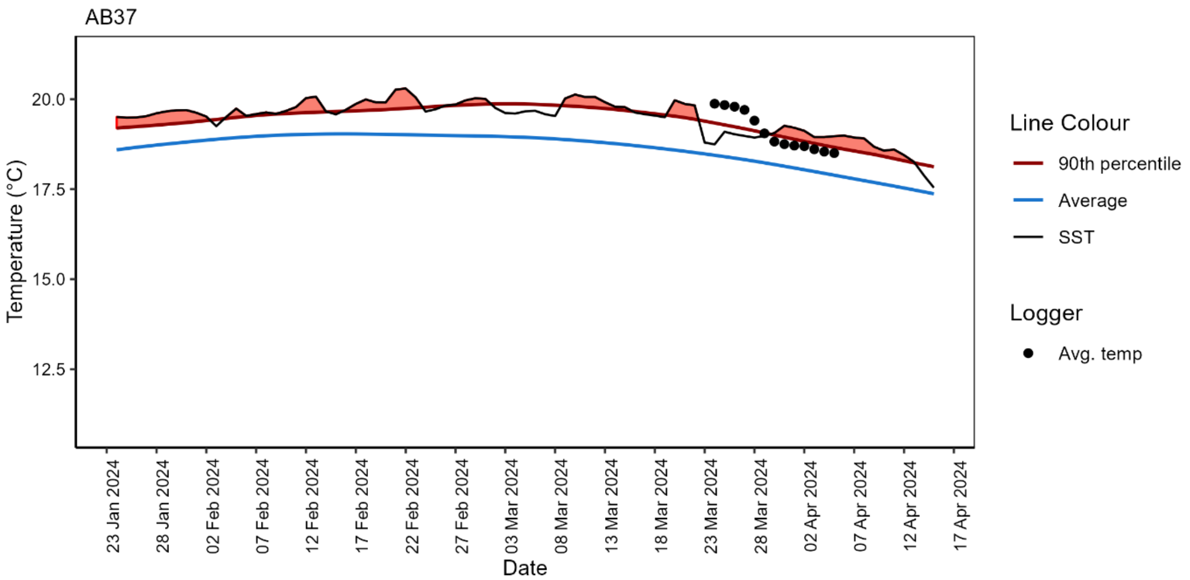


Figure 9. Temperature summary for Commercial Dive and Abalone Block 37 –North East Flinders Island. The average sub-surface temperature per deployment (black dots) is compared to the NASA JPL long-term seasonal average sea surface temperature (blue line), the 90th percentile temperature threshold (red line) and the satellite derived sea surface temperature (black line) for the North East Flinders Island area. The red shaded area indicates when the observed sea surface temperature is above the 90th percentile threshold temperature for the region.

Areas identified as being of concern through the NRE Tasmania MHW monitoring during the 2024 MHW event were also examined more closely. The SST of the coastal waters surrounding the Freycinet peninsula were regularly classified as being in MHW conditions by NRE Tasmania throughout February-April 2024. Due to most of the HOBO loggers being deployed after the highest temperatures of the season (February), the sub-surface temperature data collected inside of the AB27 block around Freycinet was generally lower than the 90th percentile temperature threshold and the SST in the area (Figure 10). While SST indicated conditions above the 90th percentile for most of April, the HOBO loggers deployed on fishing gear at depth suggested cooler conditions that sat between average and 90th percentile (Figure 10).

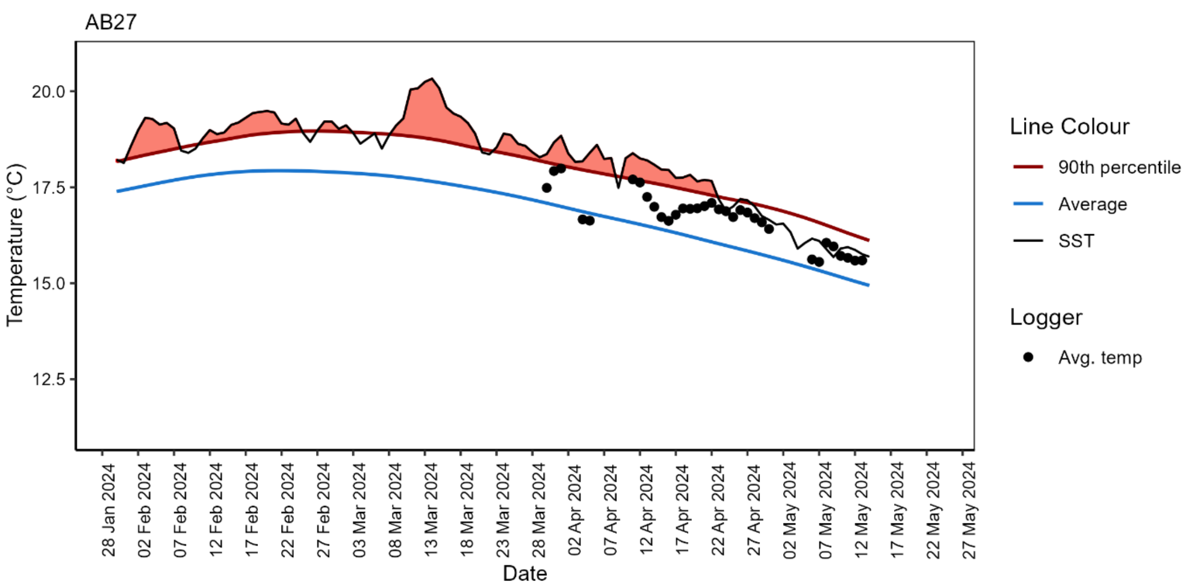


Figure 10. Temperature summary for Commercial Dive and Abalone Block 27 – Freycinet. The average sub-surface temperature per deployment (black dots) is compared to the NASA JPL long-term seasonal average sea surface temperature (blue line), the 90th percentile temperature threshold (red line) and the satellite derived sea surface temperature (black line) for the Freycinet area. The

red shaded area indicates when the observed sea surface temperature is above the 90th percentile threshold temperature for the region.

Fortescue Bay was also identified as an area of concern through MHW monitoring conducted by NRE Tasmania (AB22, Figure 11). While deployed later in the trial, the sub-surface temperatures were above the 90th percentile threshold but varied with regard to being above or below the SST for the area.

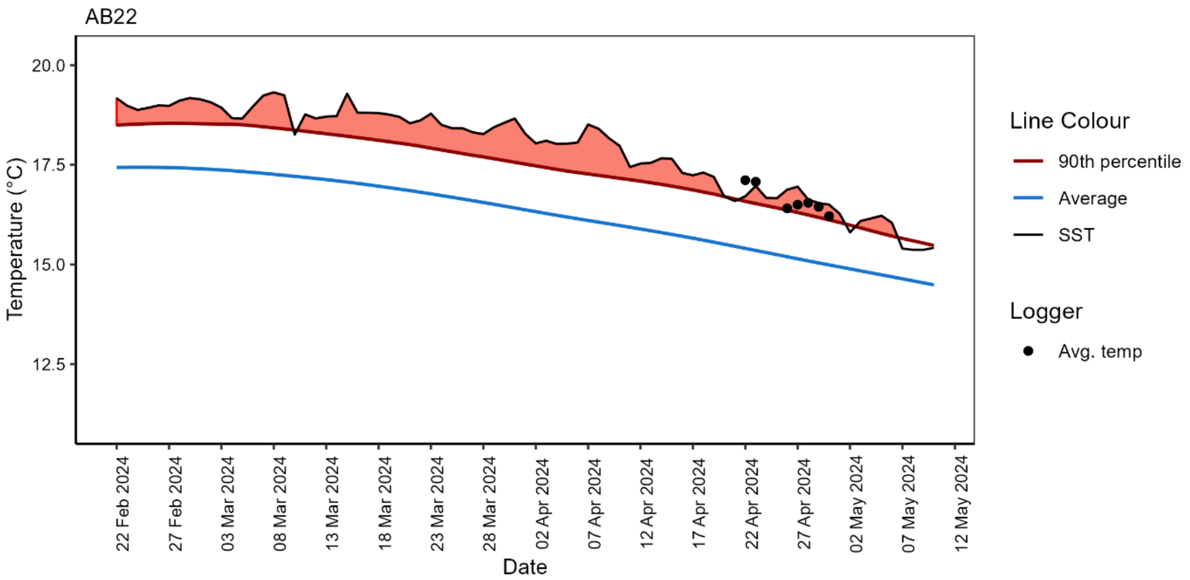


Figure 11. Temperature summary for Commercial Dive and Abalone Block 22 – Fortescue Bay. The average sub-surface temperature per deployment (black dots) is compared to the NASA JPL long-term seasonal average sea surface temperature (blue line), the 90th percentile temperature threshold (red line) and the satellite derived sea surface temperature (black line) for the Fortescue Bay area. The red shaded area indicates when the observed sea surface temperature is above the 90th percentile threshold temperature for the region.

Discussion

Through this project we were successful in purchasing and testing temperature loggers, designing and 3D-printing durable custom-designed housings, gaining positive uptake and deployment by constituents from Southern Rock Lobster, octopus and scalefish fisheries, and developing R routines to QAQC and interrogate data. While the short timeframe did not allow for extensive analysis of the data, the data collected did provide fine scale temperature data at depth across a large geographical area. The fisheries that had loggers deployed on their gear were all found to be suitable fisheries for deployments, where the logger was deployed for enough time that the data collected was of high quality. In this, we were successful in meeting the primary objective of this project.

The success of this trial was not without precedent, with temperature monitored through within-pot logger deployments focused on the lobster fisheries in both Canada and the United States (Tremblay et al. 2007, Manning & Pelletier 2009). In Canada, temperature loggers have been deployed in pots deployed off Nova Scotia for over 20 years, with 150 fishers participating in the project and up to 60 temperature loggers in the water at any given time (Tremblay et al. 2007). Data collected from pots allows fishers to better understand seasonal trends in their catch rates and evaluate whether changes in lobster condition during landing are related to temperature. More broadly, the fisheries data has been used to assess the coastal ocean climate, with particular reference to near-shore spatial variability (Tremblay et al. 2007). Similarly, the eMOLT program is a fisheries-based data collection system, that has collected temperature data from the mid-Atlantic NW shelf from 2001 through to the present (Manning & Pelletier 2009, NOAA 2024). In its inception, this program used small data loggers attached to the inside of lobster pots, not dissimilar to the loggers deployed through this project, where data was downloaded when fishers returned to shore. Over twenty years, this program has evolved to produce real-time data for uptake into temperature models across both lobster and trawl fisheries (NOAA 2024). At the beginning of the program the logger data provided the means to monitor environmental change at a spatial and temporal scale relevant to fisheries; over time the development of near real-time data platforms has allowed fishers to make informed modifications to their fishing practises while out at sea (Manning & Pelletier 2009, NOAA 2024). These examples provide an indication of the value data collected at spatial and temporal scales relevant to fishing activities, particularly where programs extend over decadal timeframes.

While our trial was relatively small scale compared to programs in northern America, one of the primary objectives of this program was to develop methods to analyse the data and develop outputs that were relevant to Tasmanian industry and state government. On evaluation, the data itself was found to be robust. During initial testing, loggers had high accuracy, both relative to other individual loggers, as well as the CTD unit deployed alongside. All but one of the loggers deployed were successful, with one logger failing due to water ingress. The data collected was of high resolution, had a broad geographical and depth range and was collected from fishers from multiple sectors across the three-month period deployment window. When developing methods for communicating data to fishers, we drew heavily on visual representation, using maps, graphs and colour where possible to provide information on where specific fisher data sat relative to ambient or long-term average conditions. While the time-lag between receiving a deployed logger and the fisher receiving their data file and interpretation letter back was not ideal (approximately 2-3 months), this window included the development of the R code and associated methods for generating outputs. With the R code now developed, it is expected that this time window could dramatically decrease should further logger deployments be undertaken in the future. Ideally, this time-window should be reduced to the point that the fisher has data in time to make decisions regarding upcoming fishing efforts; this should be possible with streamlining of process and outputs through optimisation of R code and associated data processing tools.

In terms of understanding the data collected from the HOBOs deployed on fishing gear relative to SST estimates from both NOAA and NASA JPL satellite data, we found that broad trends were similar, in that both SST estimates and HOBO data suggested that the MHW event persisted into early April, before normalising through May 2024. This is despite the comparatively patchy spatial coverage from the HOBO loggers deployed through this project. However, there was also deviation between the absolute values of the two measurements. As a general rule, SST estimates from satellite data were warmer than that recorded at depth by the HOBO loggers, although this was highly dependent on the region of interest. SST estimates from satellite data have become widespread for large-scale monitoring for MHW events and for ground-truthing modelling (Smale & Wernberg 2009, Stobart et al. 2016, Brewin et al. 2018). The advantage of SST from satellite data is the broad spatial scale for which it is possible to monitor, but the performance of this data in many coastal areas remains relatively untested (Brewin et al. 2018). Examining discrepancies of SST obtained from satellite against loggers deployed between 5 to 30 m depth in Tasmania and South Australia, Stobart et al. (2016) found that variation between the two measurements were not geographically consistent, and nor were there any meaningful correlations between site attributes. The need to understand these deviations at the site level was also suggested by our data, with deviations between in-situ data and satellite data inconsistent across the state, and even within a fishing block. While our capacity to assess deviations between HOBO data and satellite data would benefit from a larger dataset with greater spatial coverage, it highlights the clear need by the fishing industry to better understand how environmental conditions may vary at individual fishing grounds, in addition to broadscale SST trends.

Our third objective of using the combined data to better understand how temperature data can inform fisheries management for future MHW events is ongoing. Current results indicate that the data is of value to the sector as a whole, with potential for further applications for its use. Future considerations could include wider incorporation of logger monitoring into the fishing industry, with industry-wide access to data at a block level. Collaboration across multiple industries during MHW events, forming an integrated temperature monitoring framework, will give capacity for fishers to make evidence-based decisions around where to apply efforts. If this program could be supported beyond a pilot scale, long-term data, as seen in North America, creates greater opportunity for stakeholders to proactively use data in their decision-making (Manning & Pelletier 2009, NOAA 2024). For example, longer-term data collected from actual fishing grounds will allow for better understanding of how productivity may change relative to MHW events, as well as the opportunity to better understand the accuracy of models and satellite data for estimating temperature at depth and at fine scale resolution. This will allow for a more proactive approach to future MHW events, helping to safeguard marine industry into the future.

While this method was successful at a pilot scale, there are several concepts worth exploring further should there be an opportunity to develop this method. While the loggers used collected robust data, the stabilisation time of approximately 30 minutes would rule out deployment on industries such as the scallop dredge fishery, line-caught scalefish fisheries and scientific deployments of items such as BRUVs. An upgrade in the model of logger may alleviate this constraint, allowing the loggers to be deployed across a more diverse array of sectors, with potential for industries to co-inform each other. For fishers that rely on live catch to market, monitoring temperature and other environmental conditions in boat wells will help ensure temperature thresholds of individual species are not exceeded. Data pipelines could also be evaluated for efficiencies. In our method, the fisher needs to record location and depth of the logger deployment, with this data entered manually in post-processing. Automation of GPS and depth sounder data collection would increase this efficiency. The window between data collection and receiving the data is also problematic for fishers wishing for temperature data to inform decision-making while on-water. The last significant limitation is the lack of real-time data. The loggers required a manual download of the data once the deployments were complete. This meant that data was not available until the logger had been returned to IMAS, downloaded and processed. These limitations could be overcome with higher quality hardware. While cost will dictate the scale of improvements, temperature sensors that have a GPS unit and depth sensor included, as well as an automatic data download that is able to be transmitted in real time are all options that could be canvassed.

Overall, this project highlighted the potential for industry-based deployments of temperature loggers on fishing gear to provide robust data. While broad trends support those observed through SST temperature estimates provided by satellites, discrepancies at a local scale highlight the need for fishers to better understand the environment fluctuations of their local fishing grounds. Our data indicates that in situ loggers deployed as part of fishing operations is a valid option, and one that should be considered for future monitoring during MHW events.

Recommendations

This project developed a method that provided data that is relevant to both industry and government for managing activities during marine heatwave events. There are a variety of existing tools that managers have at their disposal, including SST predictions from CSIRO and BOM, along with NASA JPL satellite imagery that provides real-time estimates of SST. However, the majority of this data is at spatially broad resolution and limited to SST predictions or extrapolations, with very little information existing at depth. The method developed through this project fills an identified gap at a local level, which allows fishers to monitor temperature at industry-relevant and at a spatial scale that is indicative of fishing activities.

While this method has had preliminary success there are a number of limitations to what was developed under limited budget and short timeframe. Should this method be used in the future there are further R&D activities that could be explored. This includes:

- An investment into loggers with a reduced time to environmental equilibrium (i.e. approx. 5 minutes post-submersion), which will widen the range of activities through which loggers can be deployed.
- Methods that will reduce the time-lag between capturing the data and providing the data to the fisher. These methods could be simple and using current frameworks, or if further investment is available upscaling technology used to collect data to reduce the time-lag between data capture and data outputs becoming available.
    - If using current methods increased efficiencies in data QAQC and data collation through further development of R scripts (i.e. reduction in time from weeks to days).
    - A system that allows real-time or near real-time data collection from depth to be communicated directly to the fisher (i.e. reduction in time from weeks to hours or minutes).
- Methods that will decrease burden on the fisher to collect location data. An upgrade of technology to automate capture of GPS data would improve process.
- Real time temperature monitoring of boat wells. While this project aimed to investigate this in addition to collecting data on fishing gear, the logistics of deploying temperature loggers in live wells proved to be a hurdle that was too great to overcome with the limited budget and timeframe. However, this information is likely to be crucial in MHW events where mortalities to live animals may occur during the handling process.

Beyond the development of this method, there are two broader areas of research that this activity has highlighted as being of value in pursuing to better safeguard Tasmania's valuable marine industries from future, and likely more frequent, MHW events. Firstly, long term local data is needed to better inform industry and facilitate adaptive management by government. Numerous marine industries within Tasmania collect temperature data, although a thorough assessment of what is collected where and when has not been undertaken. Understanding what is already being collected across Tasmania's wild fisheries and aquaculture sectors is an important first step. Followed by this, facilitation of industry-wide temperature data collation and collaboration during marine heatwave events could enable an industry that is able to respond more quickly to MHW conditions in the future. This data may also be used to strengthen the capacity of predictive models and better understand the strengths and limitations of relying on broad-scale satellite data to inform decision making. Secondly, while extreme MHW conditions may cause mortality in fisheries, understanding how these events may also affect the productivity of Tasmania's marine ecosystems is also an important part of an informed response. Shifts in productivity of coastal systems are more likely to cause subtle change over time; better understanding of how these changes may manifest are vital for ensuring a sustainable wild fisheries industry for future generations in the face of climate change.

Extension and Adoption

This project provided numerous opportunities for extension. Participant fishers who deployed HOBO temperature loggers during their commercial fishing activities received a report with a summary of the data they collected (see letter in results section). Regular updates were provided to NRE Tasmania on the project, and their feedback sought on outputs that would be useful for them as managers.

The project was communicated to the general public through IMAS social media posts on Facebook (Figure 12) and through news articles in Seafood Industry Tasmania News. The project will be presented at the Australian Marine Science Association (AMSA) conference in Hobart in September 2024.

In terms of adoption, the pilot indicated that this is a good method for monitoring temperature on fishing grounds at local scale and at depth. It would be available to roll-out during the next MHW event as required.

Institute for Marine and Antarctic Studies - IMAS
24 May ·

Researchers have deployed temperature loggers off Tasmania's coastline to collect temperature data for commercial fishers, which will help the seafood industry better respond to marine heatwaves.

The trial program involved installing over 30 loggers on fishing gear around Tasmania between February and May to collect marine temperature data for commercial rock lobster, octopus and scalefish fishers.

"This project will allow us to develop temperature monitoring methods to help safeguard industry during future marine heatwave events, with data to be sent back to participating fishers to help them adapt their fishing practices to a changing climate," principal investigator and IMAS marine ecologist, Dr Camille White said. "We're also comparing this local data with broader sea surface temperature models.

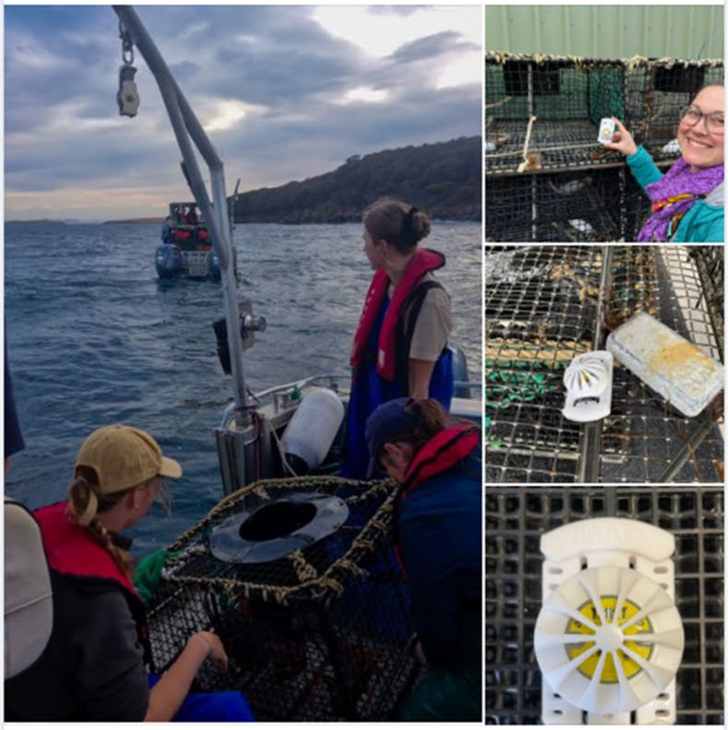
"Most marine temperature modelling and forecasting is restricted to surface waters. Through this project, we're collecting temperature data at fisheries-relevant depths and across productive fishing grounds. Understanding temperature data in these areas is a crucial first step to responding to extreme temperatures."

This research began at a time when Tasmania was enduring extreme marine heatwave conditions.

This project is supported by funding from the FRDC and Fisheries Tasmania.

📷: 1. Dr Samantha Twiname (middle) deploying a temperature logger inside a rock lobster pot off the Maria Island coast. (Photo: Joanna Schmid)
2. Dr Twiname with a temperature logger inside a 3D-printed housing.
3. Temperature logger attached to rock lobster pot.
4. Temperature logger (yellow) inside its housing.

University of Tasmania #imasresearch #marineheatwaves #climatechange



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Like Comment

Figure 12. Facebook social media post on 24 May 2024.

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Appendix 1

Letter provided to trial participants

20 March 2024

Name
Address
SUBURB TAS 7XXX

Dear Fisher,

Thanks again for your willingness to assist us in gathering temperature data during your fishing activities. This data will be very helpful for us, aiding our understanding of marine heat wave events and hopefully will aid in improving our readiness for present and possible future events around Tasmania.

We have enclosed a HOBO Temperature logger pack the following items:

- 1 x HOBO temperature data logger in housing.
- 6 cable ties for attachment to gear.
- 1 pre-paid post pack to return the housed logger around the end of Easter.
- Temperature logger data sheets to record the information below.

The logger is all set up and ready to deploy. Please attach to your gear where it will be the least disturbed. The logger will automatically record data, you do not need to do anything to initiate it.

Whenever you deploy the housed logger, can you please record the following information on the data sheet provided:

- Your name
- Logger number
- Deployment and retrieval date and time
- Depth
- GPS position (Note - exact position will remain confidential, anything published will be given as a fishing block location only).
- Deployment method (cray pot, octopus trap, gill net, long line etc.)

Any questions, please give me a call any time.

Kind regards,
Sam

Dr Samantha Twiname
Research Associate
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IMAS

Institute for Marine and Antarctic Studies

HOBO Temperature logger data sheet

Fisher name: mob: email:

Logger no.	Deployment method	Location	Deployment		Depth (m)	GPS Coordinates		Retreival		Notes
			Date	Time		Lat	Long	Date	Time	
#1	rock lobster pot	Eddystone Pt	15/2/24	06:15am	8	42.952	147.355	16/2/24	06:20am	DATA EXAMPLE