Integrated Marine Observing System

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IMOS Fishing Vessels as Ships of Opportunity (FishSOOP)

Real time Quality Assurance and Quality Control

Practice Manual

Version 1.0
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NCRIS National Research Infrastructure for Australia An Australian Government Initiative

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IMOS acknowledges the Traditional Custodians and Elders of the land and sea on which we work and observe, and recognise them as Australia's first marine scientists and carers of Sea Country. We pay our respects to Aboriginal and Torres Strait Islander peoples past and present.

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Content

1. EXECUTIVE SUMMARY

The Fishing Vessels as Ships of Opportunity Program (FishSOOP) is a sub-Facility within Australia's Integrated Marine Observing System (IMOS) for oceanographic data collection using fishing vessels as Ships of Opportunity, run through the Sydney Institute of Marine Science (SIMS) and the University of New South Wales (UNSW), Sydney. FishSOOP operates in collaboration with the international Fishing Vessel Observation Network (FVON). This document outlines the recommended data quality assurance (QA), and data quality control (QC) procedures developed for FishSOOP. Detailed documentation is provided of QA and QC, including pre-deployment, during-deployment and post-deployment checks, and the quality control methods that are applied in real time, automated and delayed mode to ensure rigorous data collection, processing and archival of the de-identified data. FishSOOP uses ZebraTech Moana temperature and pressure sensors, in conjunction with communication deck units, also developed by ZebraTech, thus focusing the FishSOOP dataset on temperature, depth, time and position data ranging from tropical to polar waters. Details of data processing in Amazon Web Services and archival are also provided.

2. INTRODUCTION

FishSOOP has been recording ocean subsurface temperature and depth data in the waters around Australia since 2021 (Lago et al., 2025), building on the New Zealand Moana Project which was instigated by Prof M. Roughan in 2017. This document outlines the processes ensuring rigorous collection of research quality ocean temperature data from fishing vessels as Ships of Opportunity. This document also provides essential information regarding the data pathway and data QC for data users.

An important distinction between FishSOOP data compared to data from other ocean observing programs (Van Vranken et al., 2023) is that the sensor deployment method and positional information varies by fishing gear type (e.g drifting longline or bottom trawler), making it critical to document metadata and follow a rigorous methodology for QA and QC both within the FishSOOP sub-Facility, and across other programs to ensure intercomparison and compatibility of the data.

All data from FishSOOP is openly accessible on the Australian Ocean Data Network (AODN, www.aodn.org.au) both through their portal (https://portal.aodn.org.au/ and THREDDS server (https://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-FishSOOP/catalog.html) and is licenced under a Creative Commons Attribution 4.0 BY licence.

3. INSTRUMENT AND PLATFORM

3.1 MoanaTD and Deck Unit system

FishSOOP uses ZebraTech's Moana temperature and pressure sensors and communication deck units, available from https://www.zebra-tech.co.nz. Currently there are three sensor models specifically designed to collect data in the upper ocean at varying pressure thresholds: the Moana TD200 for waters down to 200 m, the Moana TD1000 for depths down to 1000 m, and the Moana TD2000 for depths down to 2000 m. The deck unit is an essential part of the system that is required for gps position and communication.

3.2 Purpose

The ZebraTech Moana sensors and deck units were designed during the Moana Project (under Roughan's leadership) through a partnership between ocean scientists and ZebraTech. Oceanographers proposed the desired sensor specifications to ensure they were fit for purpose. The main purpose is operational decision making and real time ocean modelling efforts. The sensors have a resolution of 0.001°C and an accuracy of 0.05°C (Table 1.) and were not designed to be climate quality. In the spirit of continual technological improvement, feedback is provided continuously to support the ongoing improvement of the system. Sensors were designed to be completely autonomous, requiring no human intervention after installation, ensuring ease of use by the fishing community. They are light weight, cost effective and with the ability to be attached to any fishing gear.

3.3 Design Overview and Detailed Design

3.3.1 MoanaTD Sensor

For optimal battery durability, the Moana sensors are designed to record temperature and pressure at 1-meter depth intervals down to 200 meters (note this is every 2 meters for the Moana TD2000), and at 4-meter intervals for depths greater than 200 meters. If depth does not change by more than these thresholds for a new measurement (e.g. when stationary on a pot or trap), data is recorded every 5 minutes to save memory and battery.

Moana sensor specifications and requirements	
Temperature Range	-2 °C to 36 °C
Temperature Accuracy	0.05°C
Temperature Resolution	0.001 °C
Temperature Response Rate	1 second
Pressure accuracy	0.5% of rated pressure range
Battery life and calibration duration	2 years

Dimensions	145mm long x 40 mm diameter (TD200 and TD1000) 181 mm long x 60 mm diameter (TD2000)
Weight with protective tough jacket	346g (TD200 and TD1000) 583g (TD2000)
Weight in water with protective tough jacket	100g (TD200 and TD1000) 157g (TD2000)
Memory capacity	31,146 data records (~ 100 days at 5 min sampling).
Communication range	30 meters

Table 1. *ZebraTech Moana sensor specifications.*

The MoanaTD sensors continuously record background atmospheric pressure to establish a baseline, which allows the sensors to be triggered and begin recording when changes from this baseline are detected. This allows the Moana sensors to automatically start recording temperature and pressure upon entering the ocean (to a depth of 1-2m) from a relatively small pressure change. The Moana sensor also contains a depth dependent real-time wave filtering algorithm that is applied to data between the surface and 35m water depth to reduce the impact of pressure changes due to surface waves on data collection frequency.

MoanaTD sensor layout and specifications can be seen in Table 1 and Figure 1.

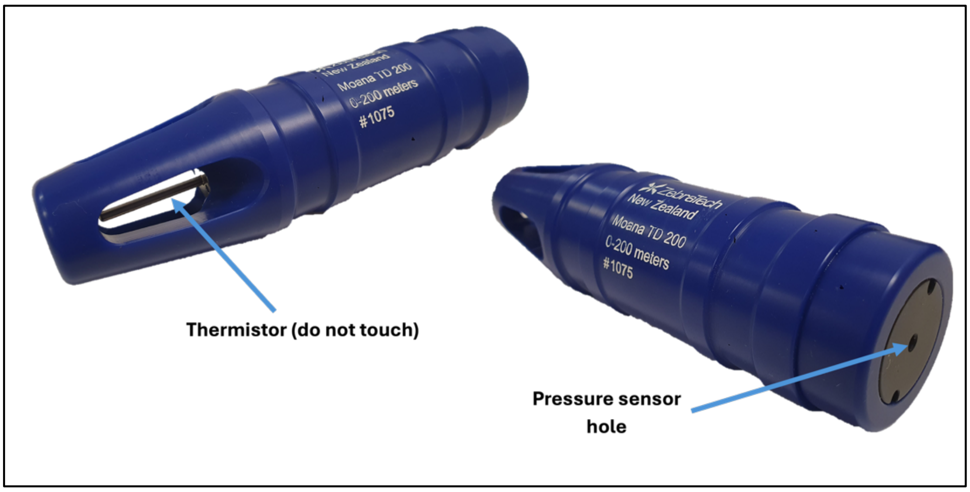

Figure 1. *Figure showing MoanaTD sensor layout. A detailed description of the sensor specifications can be found in Table 1.*

3.3.2 Moana Deck Unit

While the MoanaTD sensor can measure and record temperature and pressure internally and autonomously, the deck unit is essential for positional information and for data transmission. It is the deck unit that allows the temperature pressure collection system to be run completely autonomously from the vessel operating systems with little human intervention. The deck unit is fundamental to the success of the program and autonomous data delivery on a wide scale.

The deck unit records the timestamped position using its internal GPS receiver. Once the MoanaTD comes out of the water and sends a datafile to the deck unit via Bluetooth, the deck unit matches the position with the temperature data from the sensor using the timestamp. It combines the data in a single file before sending, using either the cellular network, or the vessel Wi-Fi.

Data can also be offloaded directly from the MoanaTD sensor to a phone app via Bluetooth, but in this case the data bypasses the IMOS data delivery pathway.

Deck unit specifications and layout can be seen in Table 2 and Figure 2.

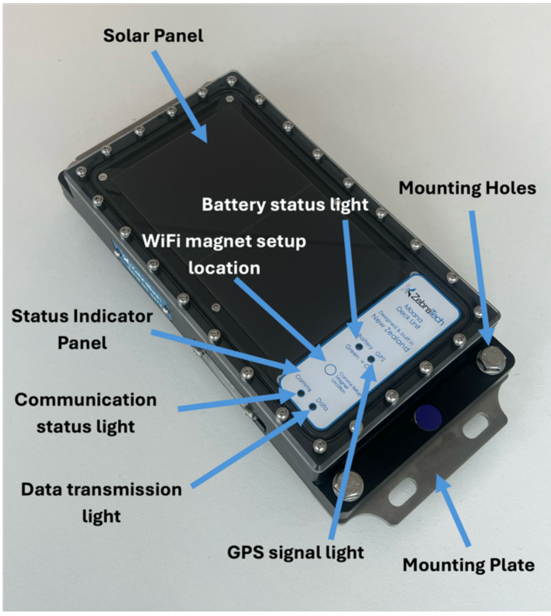

Figure 2. *Figure showing deck unit and basic layout. A detailed description of the deck unit specifications is presented Table 2.*

Deck unit specifications and requirements	
Battery endurance without solar charge	4 weeks
Power sources	Solar and USB-C
Data Transmission	Cellular and/or Wi-Fi
Position accuracy	15.4 m with 95% confidence
Position logging rate	15 seconds
Memory capacity	8GB
Weight	1.62 kg
Dimensions	270 mm L x 130 mm W x 43.75 mm D

Table 2. *ZebraTech deck unit specifications.*

3.4 Deployment

3.4.1 Pre-installation lab-based sensor checks

Prior to sending equipment for installation on a vessel, it is best practice to test the communication between the MoanaTD sensor/s and deck unit. If using cellular network (not Wi-Fi) for communications, the deck unit is required to be fully charged before inserting an activated SIM card. Once a sim is inserted, or the unit is connected to Wi-Fi, the GPS light on the unit will flash green if there is GPS reception, indicating the unit is ready for a communications test.

To test communication between the deck unit and the sensor, the sensor needs to offload data. This can be simulated in the lab by increasing pressure on the Moana pressure sensor to simulate submersion in water. This can be achieved by putting the sensor in a pressurised chamber, or by using a syringe to push air into the hole in the base of the Moana sensor, which is connected to the internal pressure sensor. Whilst pressure is increased, the sensor will collect data as if it is submerged underwater. When the pressure is released, the collected data should automatically transfer to the deck unit (Data light on the unit will illuminate blue during the transfer period). If external communications are active the data will then be transferred from the deck unit to the ZebraTech cloud server, and forwarded to the UNSW-IMOS cloud server. The data file also contains the last calibration date of the Moana sensor as well as its battery level, both of which are needed for pre-deployment checks (Table 3).

Pre-deployment check	Method
Deck unit battery level	Fully charge the deck box battery.
Communication between sensor and deck unit	Increase pressure on the sensor and check deck unit receives a raw data file (blue light).
Communication between deck unit and cloud server	Confirm data file has been received in the FishSOOP cloud server.
Calibration	In the raw data file, check the last calibration date. The data is assumed good for 2 years post-calibration.
Moana battery level	In the raw data file, the nominal voltage is 3.6V, battery levels under 3V are unreliable.

Table 3. *Pre-deployment sensor and communication checks and method.*

For the setup of the sensor/s, first the geographical region of operation as well as the type of fishing gear on which the sensor(s) will be mounted must be taken into consideration. The geographical region of operation will inform on the best method for communication (Wi-Fi, satellite or cellular) and installation, whilst the type of fishing gear on which the sensor(s) will be mounted will inform on the best attachment method and ultimately determine the quality control procedures.

3.4.2 Deck unit communications

If the geographical region of operation and/or home port of the vessel has cellular reception, the cellular network may be used for data transmission. The ZebraTech deck units are optimised to use an Internet of Things (IoT) SIM card. One such example is Hologram which uses the local cellular network in more than 190 countries. It is important to check the coverage in the intended country of operation and the home port of the vessel to ensure communication with the deck unit and therefore transmission of the data is possible. Hologram coverage can be checked at: https://www.hologram.io/coverage/.

If using a local cellular network with another SIM card, ensure compatibility and test communications within the region. This may require communication with ZebraTech.

If desired (or required in the absence of sufficient cellular network coverage), and provided the vessel has accessible Wi-Fi onboard, the deck unit can be setup to communicate via the vessel Wi-Fi. However, firstly the deck unit can be configured to access the internet with an SSID (network identifier) on a password protected network. The MAC address of the deck unit can be provided as a unique identifier of the deck unit so that it can be 'whitelisted'. However, it cannot access a network that requires a user sign in as well as a password. Furthermore, the deck unit requires a 2.4 GHz Wi-Fi signal, so the Wi-Fi may need to be split into a 2.4 GHz and 5 GHz band for the deck unit to successfully connect.

3.4.3 Deck unit Installation

The location at which the deck unit is installed must allow it to:

a. Have a clear sky view for solar charging and GPS reception
b. Be within 20-30 meters of the working deck where the sensors come on board
c. Have a clear line of sight with the working deck where the sensors come on board
d. Be within range of the vessel Wi-Fi (if applicable)

Examples of mounting locations are shown in Figure 3.

Figure 3. *Example of installation locations for the deck box.*

When installing the deck unit:

a. The O-ring on the deck unit side panel should be lightly greased and tightly sealed
b. The SIM card should be inserted with gold connections face down and the triangle to the back (if using cellular communications)
c. The Wi-Fi SSID and password should be setup (if using Wi-Fi communications) as per the technical manual
d. Should be turned on (battery and GPS lights should flash green)

For lower latitudes (< ~25° latitude), to prevent overheating, the deck box should be installed at a 45° angle (Figure 3). When overheating, the deck boxes with serial numbers from 5413 and higher have a thermal control where charging stops to prevent damage (Moana TD and Deck Unit Technical and Operation Manual).

After installation, regular cleaning of the plexiglass over the solar panel might be necessary for continued charging (e.g. bird poop might accumulate).

When the Moana sensor comes back on deck following submersion, a direct line of sight with the deck unit for at least 30 seconds is required to offload data. This means that, for example, gear that is kept in the hull of the ship between deployments is required to stay on deck at least 30 seconds after the Moana sensor has exited the water. A longer time period may be required if the Moana sensor was in the water for an extended period of time (i.e. weeks) as the data files will be larger and thus slower to transmit.

For more detailed installation instructions, refer to the installation guides available on the IMOS FishSOOP website: https://imos.org.au/facility/ships-of-opportunity/fishing-vessels-as-ships-of-opportunity

3.4.4 Post-Installation - Pre-deployment checks

Once the deck unit is installed on the vessel, communication between the sensor(s) and deck unit should be tested with a test cast to ensure adequate placement of the deck unit. The test cast should be taken in the location where the sensor will be returned to the vessel following usual fishing operations, to check it is within range of communications (< 30m, from the deck unit). If communications are successful, data should be transferred onto the deck unit from the sensor(s), transmitted to the ZebraTech Cloud server and then pushed to the in the FishSOOP cloud server.

The serial numbers of the sensor(s) and deck unit combination must be recorded and provided to the UNSW-FishSOOP team, as well as the deployment (fishing) method, which influences the data quality. The type of information that is essential for the metadata database is presented in greater detail in Section 6.

An installation checklist is provided to ensure consistency in the installation process (Appendix 1 - Installation Check list) and is particularly useful when external collaborators or participants are required to install the sensors independently.

3.4.5 Protective 'Tough Jackets' for the Sensors

The MoanaTD can be inserted into different attachment and protective housings (Figure 4). These are meant to facilitate attachment onto different types of gear for deployments, and to protect the sensor against shock, crushing pressure, etc. They are all designed for the MoanaTD to fit perfectly within the housing whilst still allowing proper water flow around the thermistor and pressure reading by the pressure sensor (Figure 1). Note that the Moana TD2000 sensor is designed within its own embedded attachment and protective housing and does not have additional attachments.

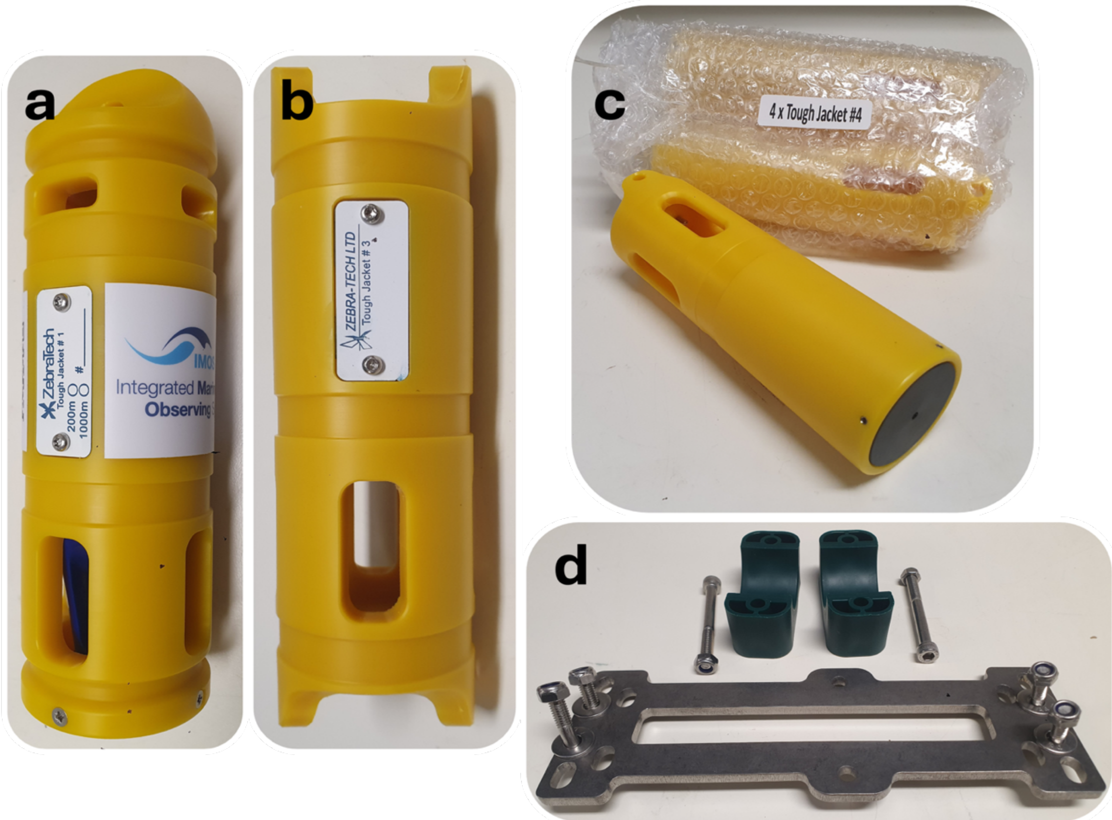

***Figure 4** Attachments and protective housings for the Moana TD200 and Moana TD1000. (**a**) Tough Jacket #1 for purse seining applications; (**b**) Tough Jacket #3, the most versatile option suitable for various gear types; (**c**) Tough Jacket #4 designed for longlining; (d) Attachment option for use with pots and traps.*

3.4.6 Mounting the Moana Sensor on Fishing gear

The installation method and hardware utilised to attach the Moana sensor is highly dependent on the type of fishing gear it is attached to. A wide variety of different mounting hardware is available from the manufacturer to accommodate different fishing types.

Below are installation instructions for different types of fishing gear. In all cases, it is most important that the sensor has sufficient and unrestricted water flow across the temperature probe, that it is securely fastened with at least 2 attachment points and is protected from significant shocks, twists, rubbing or catching.

3.4.6.1 Trawl

The Moana sensor is attached to the trawl trap door in tough jacket #3 using metal saddle clamps. The saddle clamps fit in the grooves of the tough jacket and are screwed onto the trap door of the trawl (Figure 5). If trawl door mounting is not suitable (e.g. if mounted against the side of the vessel), the Moana sensor can be attached to a line on the net using the tough jacket #3 attachment points (Figure 6).

Photo credit: ZebraTech

Figure 5. *Moana sensor attached to trawl door using tough jacket #3 and brackets.*

Photo credit: ZebraTech

Figure 6. *Alternate attachment for trawl, directly to net using a lead rope.*

3.4.6.2 Anchor

The Moana sensor, in a tough jacket, can be attached to the anchor of a vessel if the risk of gear loss is too high or if the fishing method leads to high uncertainty in the position variable (Figure 7).

Photo credit: ZebraTech

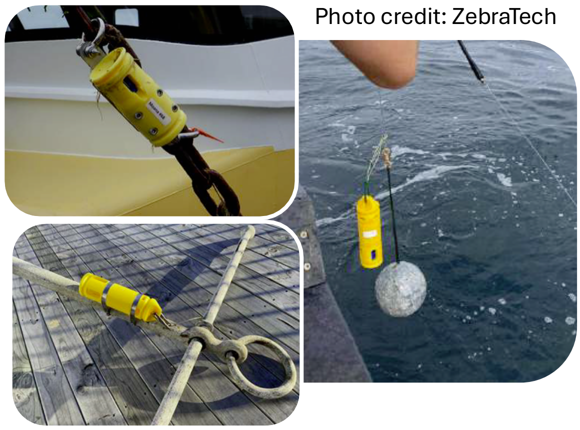

Figure 7. *Moana sensor attached to anchors using either tough jacket #3 or tough jacket #4.*

3.4.6.3 Long Lining

For long line operations, the sensor is attached to the backbone/mainline via a shark clip which attaches to the sensor in tough jacket #4 via dual monofilament leads (Figure 8). The shark clip is then attached to the middle of a set.

Photo credit: M. Roughan

Photo credit: Fishwell

Figure 8. *Moana sensor in tough jacket #4 attached to a shark clip / clasp which can then be attached to the middle of a set on a longline.*

3.4.6.4 Netting

The Moana sensor can be clipped onto any net using the tough jacket #3 via the attachment points (Figure 9). It can also be weaved into the net using the same attachment points on the tough jacket #3 (Figure 9).

Photo credit: ZebraTech

Photo credit: Fishwell

Figure 9. *Moana sensor in tough jacket #3 directly attached to a net or woven in.*

3.4.6.5 Purse Seine

For purse seine operations, the sensor is mounted in tough jacket #1, inserted into a net bag, and attached on the net ~50cm above the lead line (Figure 10).

Photo credits: Moninya Roughan

Figure 10. *Fitting of the Moana sensor on a purse seine net using tough jacket #1 in a net bag, ~50cm above the lead line.*

3.4.6.6 Dredge

Given the nature of dredging, to avoid sediment / debris accumulation around the sensor which could block water flow and therefore impact on data collection, it is best to attach the Moana sensor at the top of the dredge, over the structural beam of the frame, using the tough jacket #3 (Figure 11). After mounting, following a few sets, it is critical to check that the sensor has not accumulated debris around the probe (Figure 11). If accumulation of debris has occurred, the sensor should be cleaned and moved to ensure proper water flow.

Figure 11*. Moana fitted on the top of a dredge using tough jacket #3.*

3.4.6.7 Squid Jig

It is not recommended to attach the Moana sensor on a line that is likely to be damaged by predatory fish to avoid loses. If there is an underwater light, the Moana sensor can be attached to that line using a Stauff clamp, metal plate and U-bolts (Figure 12).

Photo credit: Fishwell

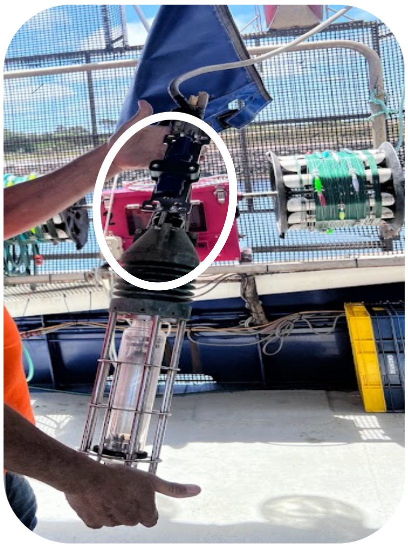

Figure 12. *Moana fitted on the underwater light for squid jigging using the metal plate and Stauff clamp.*

3.4.6.8 Pots and traps

The pot and trap attachment for the Moana sensor consist of a Stauff clamp fixed onto a metal plate with U-bolts which can then be mounted on a pot or trap (Figure 13). The plate can be attached to the interior of pots and traps, however if the trap does not allow good waterflow (fully enclosed), the Moana sensor should be installed on the outside.

Photo credit: ZebraTech

Photo credit: Fishwell

Photo credit: WRL

Figure 13. *Moana sensors fitted to pots and traps using mounting plate and clamps designed for pots and traps, or sturdy cable ties for attachment to wooden pots.*

3.4.5.9 Fishing rods and hand reels

For deployment on a fishing rod or hand reel, the Moana Sensor, in tough jacket #4, is securely attached to the end of the line (Figure 14). A 300g lead weight is attached below the sensor using 40 lb monofilament to ensure the sensor sinks appropriately and to allow the lead weight to reach the seafloor first, minimizing the risk of the sensor snagging and being lost (Figure 14). The lead weight and monofilament strength should be increased if strong currents are present.

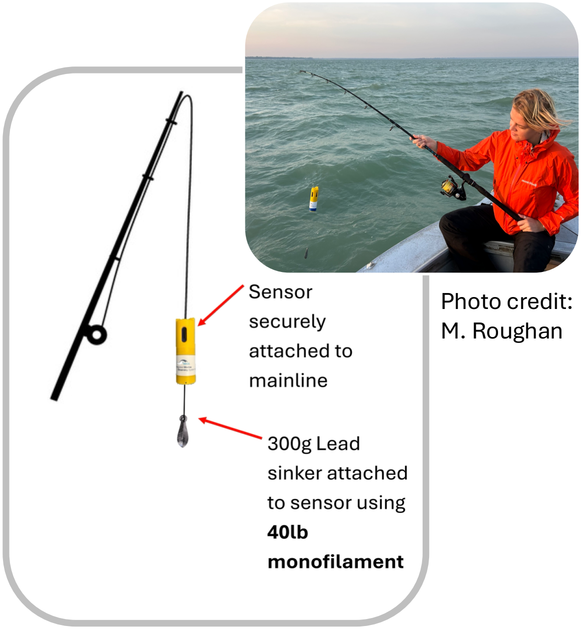

***Figure 14**. Moana sensor mounted to fishing rod schematic and photo.*

3.5 Method for Data Collection

The data collected during deployment is transmitted to the deck unit after the MoanaTD sensor exits the water. It is automatically offloaded via Bluetooth to the deck unit ensuring a hands off approach. The GPS position of the data is recorded on the deck unit which stays on the vessel. The deck unit continuously records GPS location and when the sensor offloads data to the deck unit it automatically processes files received to incorporate historical position information using the timestamp to match with each of the datapoints received from the Moana sensor. The deck unit then uploads the datafiles to the ZebraTech cloud server using either the cellular or Wi-Fi network in near real time.

3.5.1 Data Delivery

The data collected by the MoanaTD sensor is automatically sent via Bluetooth to the deck unit on the boat upon retrieval from the water (**Error! Reference source not found.**). The data is then sent to the ZebraTech cloud server where the data is automatically directed to the FishSOOP (UNSW) cloud server (currently hosted on Amazon Web Services). When a file is received in the FishSOOP cloud server it triggers automated QC routines for evaluation for each datapoint. The QC-ed data is automatically saved in anonymised IMOS compliant NetCDF files in the FishSOOP cloud server (Appendix 2 – IMOS data file format). From there, the data are delivered to three locations as shown in **Error! Reference source not found.**:

a) The participants who collected the data via Email
b) The Global Telecommunications System (GTS)
c) The AODN and other open access data portals as described below

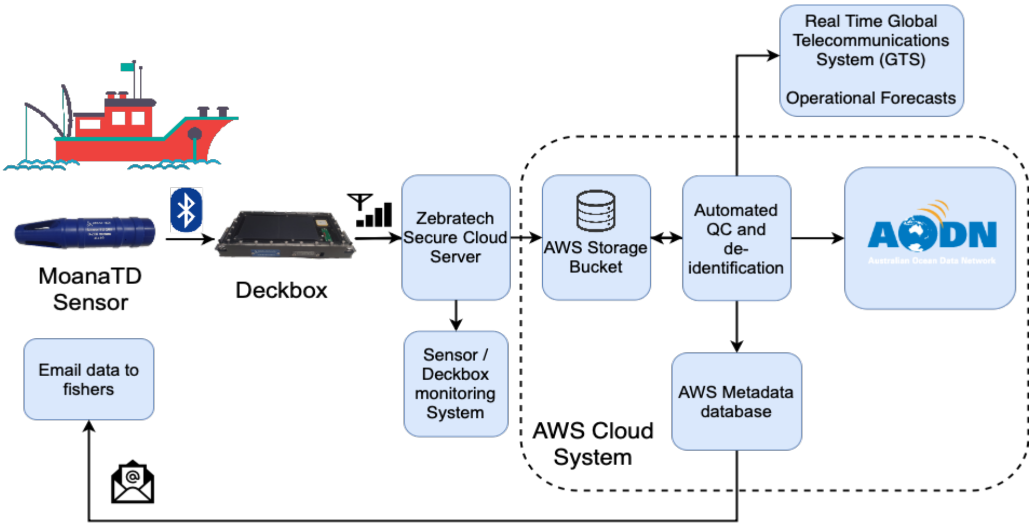

Figure 15. *Dataflow for the FishSOOP sub facility from sensor to vessel to cloud using Amazon Web Services cloud computing and then to the Global telecommunications system and the AODN. It is the intention that IMOS will ultimately be responsible for delivering data to the GTS. Data are also returned to the fisher via email.*

3.5.2 Data return to data collectors (Participants) via email

A fundamental part of the success of the FishSOOP is the notion of user-observers, where the data that is collected by participants is returned to participants first and foremost in an easily accessible format. The QC-ed data is converted into a csv file and presented in a plot showing both the temperature profile and the position of the cast. A personalised email for the corresponding vessel is automatically created and emailed to the participants in near real time, containing a figure and the data collected (as a csv file). The data pathway is automated, but there should not be the expectation that the service is operational 24 hours a day 7 days a week.

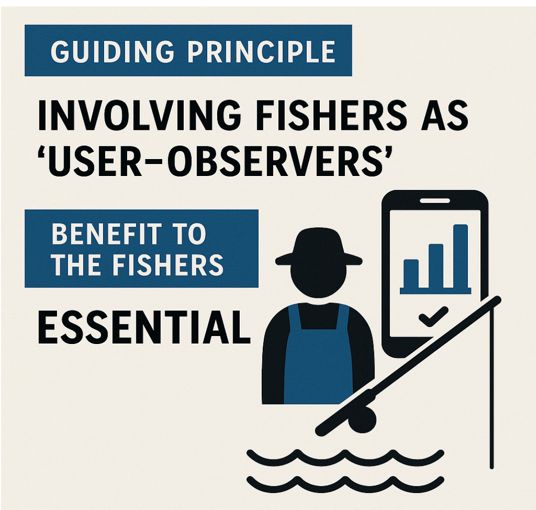

Figure 15. *FishSOOP Guiding Principle that recognises the fundamental importance of fishers as data users and data collectors. Providing value to the fishers is an essential component of FishSOOP's success.*

Providing value to the fishers that collect the data is a fundamental guiding principle of FishSOOP (Figure 15).

3.5.3 Data archival open access data portal

The QC-ed data is converted to a standard IMOS Compliant NetCDF file (IMOS NetCDF conventions, 2021), following CF conventions, on the FishSOOP cloud servers (Appendix 2 – IMOS data file format). The files are then sent via FTP to the AODN servers for publication to the IMOS open access data portal (https://portal.aodn.org.au/). All data sent to the data portal is de-identified with no information about the vessel that collected the data. Data are also available on the AODN THREDDS server.
(https://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-FishSOOP/catalog.html).

3.5.4 Real time data delivery to the Global Telecommunications System (GTS)

Another essential part of the FishSOOP impact is delivery of the data in near real time to the Global Telecommunications System (GTS) for access by national weather agencies worldwide. The upcast at the end of each QC-ed data file is converted to specific BURF file format and sent in real time to the GTS through the Australian Bureau of Meteorology FTP server. The vessel information is made anonymous and inaccessible by end-users. Only the last upcast is sent as it is the most recent data and the data that has the most accurate position information across all types of deployments.

3.5.5 Cloud based data processing

The IMOS data processing is conducted on Amazon Web Services (AWS) as it is a useful tool with which to operate the variety of services required in one location (e.g data storage, metadata database, data processing, email services etc.) and allows transfer across platforms with different stakeholders (Figure 16). Due to its interdisciplinary nature, it is best to use a platform that can easily be linked to receive the data from the ZebraTech cloud server, process the data, and then transfer the QC'd data onward, e.g. to the AODN and GTS, to the fishing vessels, and other potential stakeholders. Furthermore, AWS allows for flexible scaling of resources as the number of vessels grows, and monitoring of infrastructure to track potential malfunction in real time.

The data flow has been built in AWS, with the raw data sent directly from the ZebraTech cloud server to a FishSOOP AWS storage bucket (Figure 16). The reception of data triggers the real time anonymisation and automated QC functions in AWS data processing. The resulting QC-ed data file is associated with its relevant metadata information and is emailed to the data collectors automatically. The files are converted into Climate Forecast Convention v. 1.6 (Eaton et al., 2011) compliant (NetCDF) files that conform to the IMOS standards (IMOS NetCDF conventions, 2021) and are sent to the AODN for data archiving (Appendix 2 – IMOS data file format). The last upcast from the data is also converted to BUFR file format and is sent to the Australian Bureau of Meteorology to be transferred to the Global Telecommunications System (GTS) in near real time for access by national weather agencies to aid ocean and atmospheric prediction.

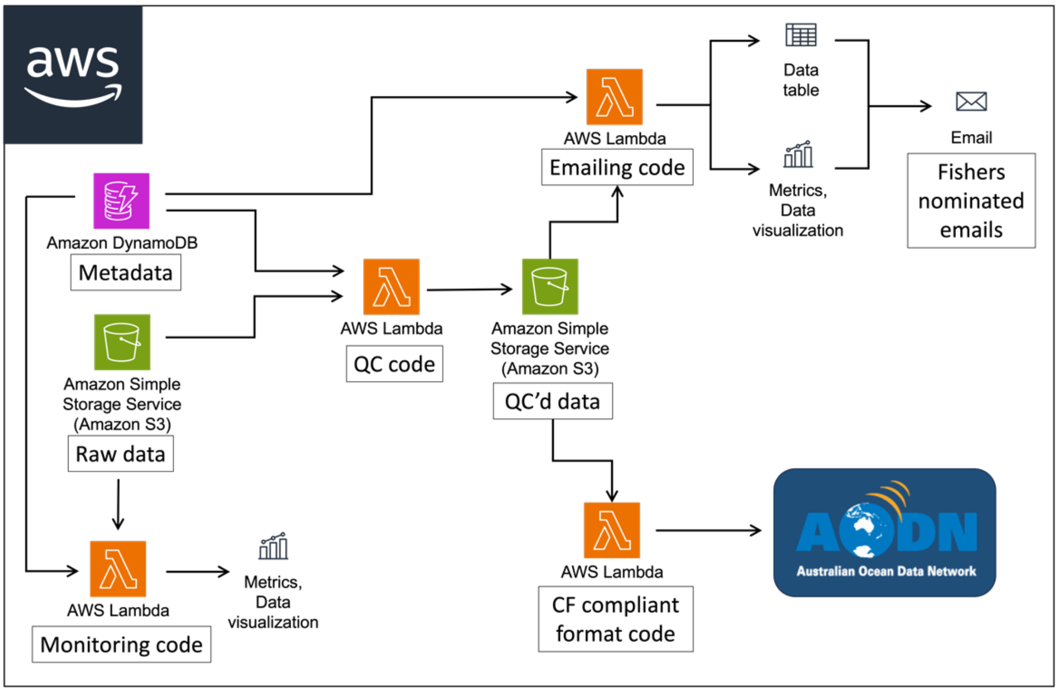

***Figure 16**. Dataflow structure in the FishSOOP cloud servers using AWS cloud computing.*

3.6 Calibration

It is a QA requirement that the MoanaTD sensors are recalibrated every 2 years (from date of manufacture). The MoanaTD sensors are returned to the manufacturer for replacement of their internal battery, re-calibration and testing. By design, the battery cannot be changed by the end user to ensure the integrity and water tightness of the sensor. The battery is replaced by the manufacturer during the 2 yearly recalibration procedure. The MoanaTD sensors are tested in a controlled environment for temperature and pressure within their operational range (Table 4) and the error within that range is calculated and eventually included in delayed QC (Section 3,13).

***Table 4**. Calibration test ranges.*

Sensor	Range
Temperature for TD200 and TD1000	3 °C to 36 °C
Temperature for TD2000	-1.8 °C to 36 °C
Pressure for TD200	1024 mbar to 21,000 mbar
Pressure for TD1000	1024 mbar to 101,000 mbar
Pressure for TD2000	1024 mbar to 201,000 mbar

The pressure recalibration is calculated using a linear adjustment between 2 points (from atmospheric to the sensor maximum range). The temperature recalibration uses 16 points, the difference in temperature at the test point is input into the Moana sensor during the calibration process. The MoanaTD sensor then interpolates between each of these points after measurement.

3.7 Uncertainties in observations

3.7.1 Geographic Position

Geographic position of the data is recorded from the internal GPS in the deck unit mounted on the vessel (there is no GPS in the sensor). Therefore, data from sensors attached to fishing gear that do not stay with the vessel (see Section 3.10.2) have a higher uncertainty on the geographic position. In this case, the position of the sensor is estimated as the average between deployment and recovery.

The GPS system used to track the vessel has a positional uncertainty of 15.4 meters at a 95% confidence level. This means that, 95% of the time, the actual position of the vessel is expected to be within 15.4 meters of the reported GPS location. When GPS data is recorded every second, this uncertainty can result in an apparent movement of up to 30 knots between two consecutive data points—even if the vessel hasn't moved that fast. Therefore, when interpreting the vessel's speed, it's important to consider that GPS error can add up to 30 knots to the actual speed. For example, if the vessel is traveling at 20 knots, the GPS data might suggest speeds as high as 50 knots due to this positional uncertainty.

It is worth noting that the uncertainty on the time variable also contributes to the uncertainty on the position because it is assigned to the data using the timestamp to match the GPS position with the data (see Section 3.7.4). That means that the distance the vessel travels within the time uncertainty is added to the uncertainty on the position. For a vessel travelling at a constant speed of 20 knots, this amounts to a maximum ~2.16km additional uncertainty on the last datapoint recorded in a more extreme case for our longest datafile.

3.7.2 Pressure

The pressure sensor has an accuracy of 0.5%. This translates to a 5 dbar uncertainty at 1000 dbar, and 10 dbar uncertainty at 2000 dbar. The depth is calculated from the pressure using the TEOS-10 method from the Gibbs Seawater Oceanographic Toolbox (IOC et al., 2010).

3.7.3 Temperature

The temperature sensor has an accuracy rating of 0.05°C. They are not designed for climate record but have an accuracy sufficient for weather forecasting and ocean monitoring purposes.

3.7.4 Time

The MoanaTD keeps track of the elapsed time since the first datapoint each time it starts recording. This elapsed time has an accuracy of 1 sec/day. When the data is sent to the deck unit, the timestamp is assigned from the first data point using the total elapsed time and the current GPS time, which itself has an accuracy of ±2 seconds. Each subsequent datapoint is then timestamped using the date and time of the first data point and the elapsed time since that first datapoint. That means that the uncertainty on the time variable depends on the elapsed time from the first data recording and the data offload onto the deck unit.

These uncertainties mean that for the average datafile received (13,735 seconds), the uncertainty for the first datapoint is 2.16 seconds and for the last datapoint 2 seconds. For the longest datafile received that passed QC, the uncertainty on the first datapoint was 106.1 seconds, whilst on the last datapoint it was 2 seconds. However, the uncertainty increases the longer the delay between the last recorded data point and its transfer to the deck unit, as the elapsed time counter in the MoanaTD continues to accumulate uncertainty at a rate of 1 second per day, even after the sensor stops recording temperature and depth, due to memory capacity being reached.

3.8 Standards Used

QC flag value	Meaning
0	QC not performed
1	Test passed; good data
2	Test failed, but probably still good data
3	Test failed, probably bad data
4	Test failed; bad data
5	Overwritten

Table 5. *IMOS standard QC flag values and their meaning.*

The quality control flags used align with the IMOS standard flags set 1 (Table 5; IMOS NetCDF Conventions version 1.4.2, 2021). The NetCDF files created for archival on the AODN follow the Climate and Forecast (CF) Metadata Conventions v.1.6 (Eaton et al 2011), and the IMOS NetCDF conventions (IMOS NetCDF Conventions version 1.4.2, 2021). These conventions ensure that each datafile contains sufficient metadata to be self-describing. A description of the IMOS file naming convention used and an example file format is presented in Appendix 2 – IMOS data file format.

3.9 Quality Assessment Methods

3.9.3 Data classification by fishing gear type

Gear Type	Category	
	Passive	Towed
Bottom Trawl		✓
Potting	✓	
Long Lining	✓	
Trawling		✓
Midwater Trawl		✓
Purse Seine Netting	✓	
Bottom Trawling		✓
Research		✓
Education		✓
Bottom Trawler		✓
Bottom Long Line	✓	
Danish Seining	✓	
Netting	✓	
Set Netting	✓	
Dredge		✓
Hand line		✓
Anchor		✓
Diving	✓	
Trolling		✓
Squid jig		✓

Table 6. *Classification of fishing gear types as passive or towed, which is essential meta-data for downstream processing.*

The data is classified by the type of fishing gear that it was collected on as this impacts the accuracy of the position data. The fishing gear types are classified as either 'passive' or 'towed' for the purpose of QC processing (Table 6). The 'towed' gear category is for gear which stays attached to the boat, thus the location recorded by the deck unit represents the location at which the temperature data is recorded by the sensor at all times. The 'passive' category is for gear which is not attached to the boat (e.g. a pot, trap or drifting long line that is deployed and left for a period of time), and therefore the location recorded by the deck unit is not necessarily always representative of the temperature sensor position. The position for 'passive' gear is calculated as the average between the first and last data 'good' reading (i.e. combined QC flag is 1 or 2; Table 5), which is assumed to be recorded at deployment and recovery, when the deck unit is at the same location as the MoanaTD sensor. If the first or last 'good' quality data reading is not near the ocean surface, the position cannot be calculated, and the data will fail the automated QC.

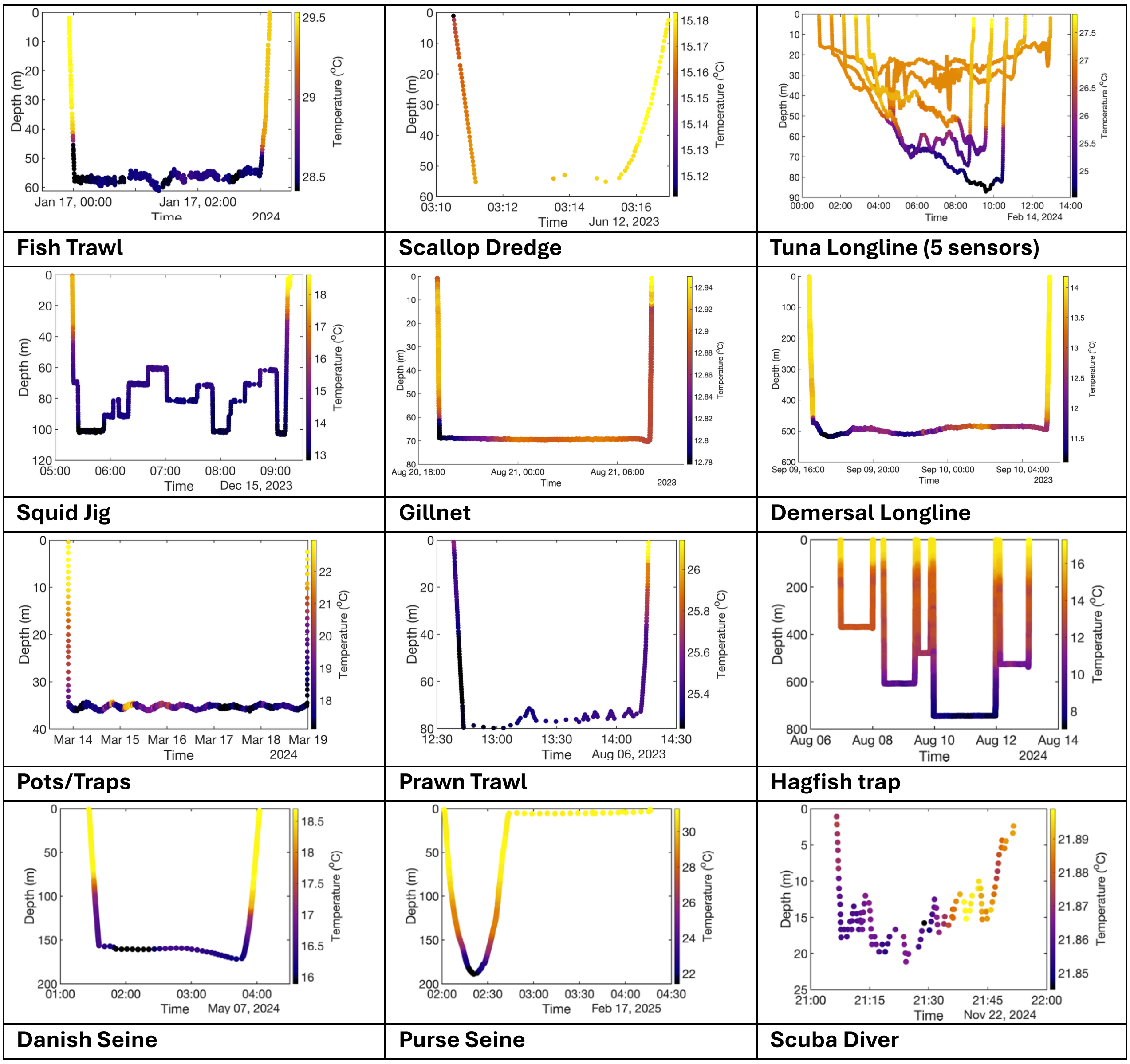

Figure 17. *Examples of different types of data profiles retrieved from the MoanaTD sensor attached to a range of fishing gear.*

The fishing style (and thus gear type used) impacts the sensor profile through the water column, i.e. how deep the sensor goes, how it moves vertically and how long it stays submerged in the water. Examples of different types of data profiles retrieved from the MoanaTD sensor attached to a range of fishing gear are shown in Figure 17

This complexity demands a robust QC system that works for the entire range of timeseries recorded. Therefore, for accurate automated QC processing, it is essential that measurements are associated with the correct deployment method and gear type from the metadata database.

3.9.4 Real Time Automatic QC

All observations are QC-ed automatically in real-time to provide high-quality, reliable data suitable for operational use. The automated QC code is run in AWS and is triggered when the data arrives in AWS from the ZebraTech cloud server. Standard temperature and pressure QC tests are based on the US Integrated Ocean Observing System (IOOS) Quality Assurance for Real Time Oceanographic Data (U.S. Integrated Ocean Observing System, 2020) and Argo quality-control procedures (Wong et al., 2020), and have been further developed in collaboration with the Fishing Vessel Ocean Observing Network (FVON, https://fvon.org/). All QC tests and the data flags are shown in Table 7 and Table 8. QC tests are applied to temperature, pressure, time and position, and are based on sensor specifications and fishing method. The QC code used is an improvement upon that provided by Jakoboski et al, (2023).

3.9.5 Quality Control Tests and QC Flags

The QC tests are run automatically, and each data point is given a QC flag as per the IMOS Standard Quality Control Flags (Table 7). QC flags are associated with each variable and are all included in the resulting data files (Table 8, Appendix 2 – IMOS data file format).

QC Test	Description	QC Flag Value(s)
Impossible Date	Checks that the observations are within a specific valid range (between January 1st, 2010 and offload date).	4
Impossible Location	Checks that the latitude is between -90 and 90, and longitude between -180 and 360.	4
Impossible Speed	Checks that the speed, calculated from data location, is less than 50 knots. The purpose of this test is to flag if the GPS location bounces outside its uncertainty range (95% variance within 15.4 m) and not to flag vessel speed (Section 3.7.1).	4
Timing Gap	If the observations are more than 60 minutes apart with less than 5 datapoints on either side of the gap, flag the smaller cluster of datapoints, usually due to splashes of water on the sensor while it is sitting on deck.	4
Global Range	Checks that the pressure and temperature variables are within their defined expected range and absolute range (See Table 7 below for ranges and flag values).	3: expected range 4: absolute range
Remove Reference Location	Remove data collected within a 5km radius of the ZebraTech facility location to account for test data that might have be acquired (and not offloaded) during the manufacturer's lab testing.	4
Spike	Flag spikes in the temperature and pressure data. The test uses a standard deviation threshold combined with a finite difference filter. If $\|-0.5\, x(i-1) + x(i) - 0.5x(i+1)\| > 3 \times$ standard deviation (for	3

	temperature or > 2 x standard deviation (for pressure), the datapoint x(i) gets flagged.	
Temperature Drift	Checks that all the temperature data within 0, 10, 20, 50, 100, 200, 400, 600, 1000 and 3000 depth bins have a standard deviation lesser than 2, 3.5, 3, 3, 3, 3, 2.5, 2.5, 1.5 respectively within the bin; and a difference between the largest and lowest temperature lesser than 7, 7, 8, 8, 7, 8, 7, 7, 5 respectively. These thresholds are empirical and have been taken from experience from damaged sensors. The intent is not to flag long term drift, which will be evaluated after recalibration, but rather malfunctioning sensors.	3
Stationary Position Check	If the fishing gear is passive, check that there are 'good data' (flag = 1) near the surface at the beginning and end of the set (i.e. the first and last "good data" needs to be in the top 10 dbar).	2: for towed gear class, 3: for passive gear class (Table 5)
Start and End Distance Check	For passive gear, checks that the distance between the first and last position for passive fishing gear is within an acceptable range. This is to flag data, in case of passive gear, that was not recovered exactly at the same place it was deployed as either failed but probably still good data (Flag=2 for >5 km) or failed and probably bad data (flag=3 for >50 km).	2: position uncertainty > 5km 3: position uncertainty > 50km
Test Cast	If data is within one day of installation, the maximum depth is less than 10m, and duration less than 10min, flag as a test cast. Data are returned to the fisher (for evidence the system works) but data are not sent to be archived. This is because water temperatures could be impacted by engine cooling water at the wharf.	No QC flag change associated

Table 7. *List of quality control tests applied for the automated QC.*

During the 'Stationary Position' check, the additional process of updating position for every individual measurement is specific to the passive gear types (Table 6). The global ranges (Table 8) are used to determine possible values (e.g. for position), or for the range in which the MoanaTD sensor is tested and calibrated (e.g. pressure and temperature). The lower limit has only one limit for both the absolute and expected range for pressure and temperature. Data outside the expected range will be given a flag=3, data outside the absolute range will be given a flag=4.

Variable	QC Test	Absolute/expected lower limit	Expected upper limit (sensor calibrated range)	Absolute upper limit
Pressure Moana TD200	Global Range	0	200	300

Pressure Moana TD1000	Global Range	0	1000	1500
Pressure Moana TD2000	Global Range	0	2000	2500
Temperature Moana TD200 and TD1000	Global Range	3	36	40
Temperature Moana TD20000	Global Range	-1.8	36	40
Latitude	Impossible location	-90	N/A	90
Longitude	Impossible location	-180	N/A	360

Table 8. *Ranges used for specific QC tests. The lower limit has only one limit for both the absolute and expected range. Data outside the expected range will be given a flag=3, data outside the absolute range will be given a flag=4.*

3.9.6 Automatic Fleet Monitoring

For the duration of the deployment of the MoanaTD sensors, some parameters require constant monitoring to ensure reliable and accurate data (Table 9). This is referred to as 'Fleet Monitoring'. The pertinent parameters have been setup for automatic monitoring, with alarm levels, in AWS (Figure 16) to ensure the data collection runs smoothly and errors are identified early.

Parameter	Diagnostic	Action
Calibration Date	Time since last calibration is checked with an automated alert when it gets close to the 2 year recalibration date. There is an alert at 180 days from the recalibration date, and an alert at 90 days.	Contact the participant and organise to trade of sensors. It might require logistics to switch the sensors while the vessel is at port.
Sensor battery voltage	The MoanaTD sensor battery voltage decreases non-linearly. Signs the battery is approaching end of life include high variation in voltage level, regularly sending data files that are either empty, with impossible data, and/or file naming number resetting to 1.	The sensor is then sent back to the manufacturer for recalibration and battery change.
Deck unit battery charge	The deck unit battery is recharged through solar power, so battery voltage is monitored for decrease in the charge which might indicate that the solar panel is not properly exposed to the sun. An automatic warning	Contact the participant to send a photo of the deck unit and its location to see if the solar panel is covered or in the shade. Ask the participant to clean or move the deck unit accordingly.

	is sent when the charge is less than 80% and an alert when the charge is less than 60%.	
Deck unit battery temperature	The battery capacity, as indicated by the battery voltage, might decrease with time or show high variability due to overheating. Both the battery capacity (in volts) and maximum temperature are monitored with an automatic alert when the deck unit internal temperature reaches higher than 60°C.	Inspect the battery capacity timeseries for high variability. If necessary, contact the participant to organise a replacement of the deck unit and send the overheated deck unit for servicing.
Deck unit communication	The deck unit sends a daily status report when in communication. Communication might be stopped because the vessel is out of cellular range (for those communicating on the cellular network). An automatic warning is set for 2 days since the last communication, and an alarm for 14 days since the last communication.	Check what is the usual duration of the offshore trips for this vessel and if the current duration since last communication falls within the norm. If not, contact the participant to update on vessel activity. If there are no explanation for the lack of communication, replace the deck unit and test in the lab. If there are still no communication in the lab, send for servicing.
Date data last sent	An automatic warning is set for 14 days since the last data files have been sent and an alarm for 30 days since the last data files have been sent.	This can indicate sensor malfunction, a flat battery, or a sensor lost. Contact the participant and ask if there were any recent deployment or loss. If the sensor was deployed and isn't lost, replace the sensor and send to manufacturer for servicing.

Table 9. *Parameters monitored and what to look for.*

3.9.7 Manual Fleet Monitoring

Daily visual data checks are undertaken by an expert oceanographer to detect data that has passed the automated QC process but could potentially be erroneous. Data are checked for unusual pressure changes and temperature profiles. Examples of data files that look spurious despite passing the QC tests are shown in Figure 18. This manual monitoring allows to both identify sensors that require replacing, and to further improve the automatic QC test to avoid such erroneous data passing the tests.

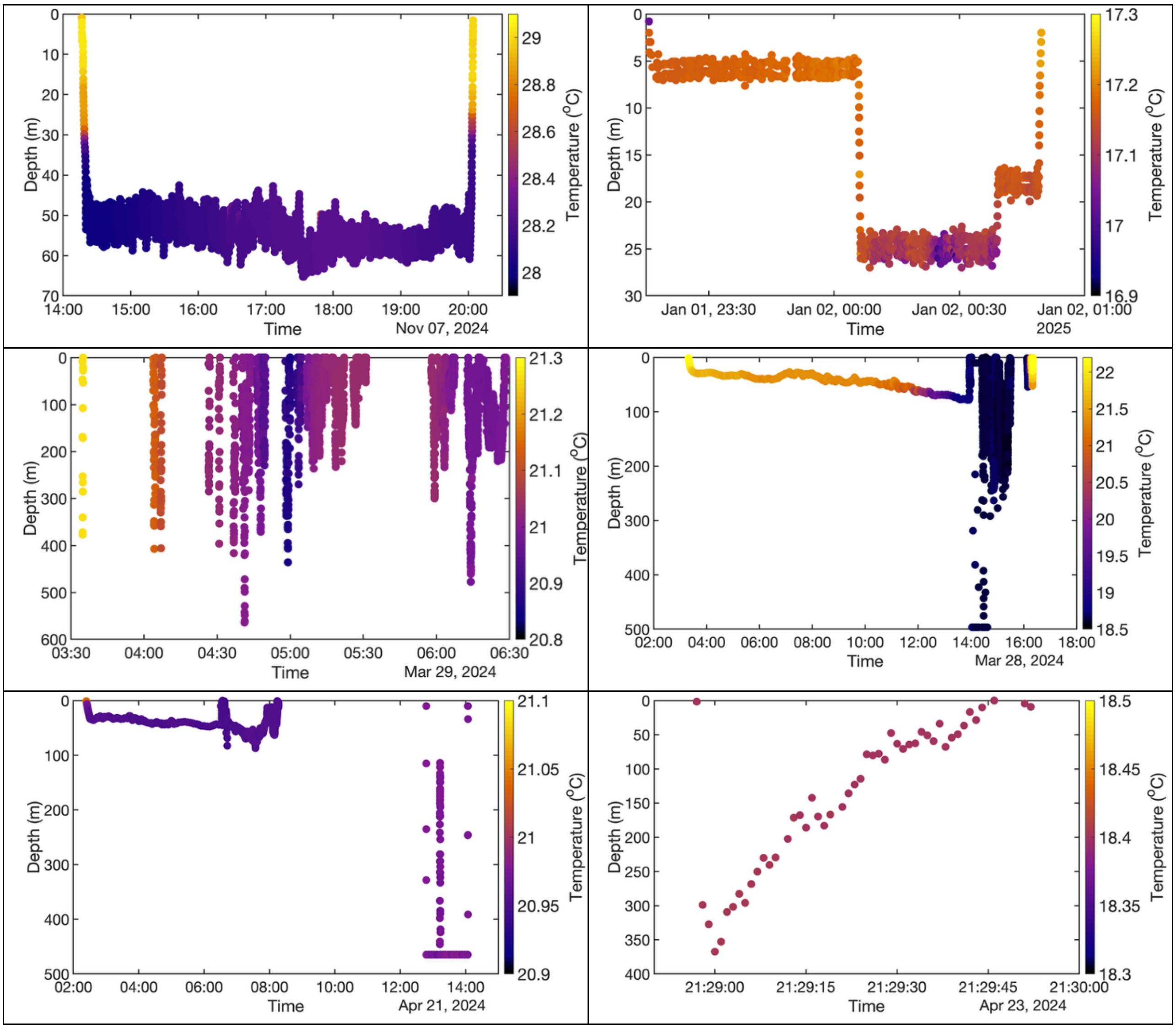

Figure 18. *Examples of different pressure temperature profiles that look spurious identified through either automated or expert QC.*

3.9.8 Diagnosing automated QC fail

Status files are created for each data file after it has gone through the automated QC process and an automated monitoring system is in place that sends an alert regarding files that have failed the automated QC. The system can also suggest the reason a data file might have failed the QC tests. For the files that failed one or more QC tests, the reason for the failure is investigated manually through the error message in the status file. The data is then either flagged as an unsalvageable file and archived in our private server (e.g. when a sensor sends data whilst not having been deployed or exhibit critical sensor failure). If the issue can be rectified, the data are re-run through the automatic QC tests and follows the usual data pathway from there. A list of common reasons that the data fails the automated QC are shown in Table 10, with the automated 'fail status message' and the suggested actions to be taken.

Fail status	Action
No valid time range in vessel metadata	Check vessel metadata, gear type needs to be assigned to a sensor and deck unit serial number starting from a given date or between a start and end dates. The date from the data file needs to be within the date range for the sensor serial number.
Multiple entries in vessel metadata for this serial number and time range	This sensor serial number is assigned to more than one vessel/deck unit/gear type for the date. Check the metadata and fix sensor association for specific date ranges.
Gear class unknown	Check gear class for 'typographical errors' and check if it exists in the current dictionary (Table 6).
Gear class calculation failed	This is a fail of the 'Stationary Position Check'. Check if there are 'good data' in the top 10m.
Could not calculate time range or serial number data	Check if the time data is missing and/or erroneous in the raw data file, and check the metadata if the sensor was assigned to a deck unit and vessel for the date of the data. If the sensor was not assigned.
Expected deck unit unknown	Check metadata entry for sensor serial number assignment to a deck box, vessel and gear type.
Deck units do not match	Data was offloaded and sent through a different deck unit serial number than the one in the metadata. This could have occurred as there was another deck unit in the vicinity, in that case we can't be sure of the vessel position in the file. Alternatively, the metadata entry needs to be fixed.
No Good Data (all QC Flags = 4)	Check the raw data file for empty or missing variables or check if the sensor sends erroneous data and requires to be replaced.
Apply QC Tests Failed	Check if the file is empty, or missing a variable, check code and dataflow.
Post-Processing Failed	Check dataflow permissions and code.
Save QC Flag Fail	Check dataflow permissions and code.

Table 10. *Automated QC monitoring system that identifies data that has failed QC and suggestions of the manual checks to fix the issue.*

3.9.9 Essential Metadata

Metadata regarding the fishing method is essential for data processing and quality control. When joining the IMOS FishSOOP program, the participant is required to fill-in a form, which collects all the metadata needed for the data files. For this purpose, an online 'jotform' has been used so that the data is automatically recorded into the metadata database.

At the minimum to pass through the QC process it is essential to know the fishing gear type on which the sensor is attached. Additionally, the sensor and deck unit serial numbers are required to match the sensors with the deck unit and vessel, maximum fishing depth is needed for sensor allocation (so as not to exceed pressure limits). Finally, the participants email address is required to send them their data (if they wish so) and contact details (for troubleshooting, recalibrating or recovery of sensors).

For effective program planning strategic gap filling and fleet monitoring (Section 4.4), the typical duration of the trip at sea, months actively fishing, and fishing zones/jurisdictions are required.

All the participant's metadata is kept private in a locked database only accessible through layers of security. However, as per the collaboration agreement (Section 3.10) signed by the vessel owner and / or skipper the anonymised, de-identified data collected, can be shared into public open access databases, i.e. the date and time, latitude and longitude, pressure (depth), and temperature, plus their associated QC flags. Private information is never shared.

3.9.10 Sensor inter-comparison

The MoanaTD sensors have been tested against industry leading benchmark ocean sensors in both regular cast situations (e.g. on a rosette) and in a deployment method comparable to fishing gear, such as a towed instrument (e.g. on an undulating towed body such as a Triaxus). For example, a comparison was conducted between data collected by a ZebraTech MoanaTD sensor and data from a co-deployed SeaBird CTD aboard the RV Investigator, both on a rosette and a Triaxus system. The analysis identified an issue with the Moana TD1000 sensors, which the manufacturer has since fixed for MoanaTD 1000m sensors manufactured or serviced after January 2024 (Figure 19). The TD1000 sensors serviced prior to this date have a reduced accuracy in their depth readings, but are still within acceptable user defined standards.

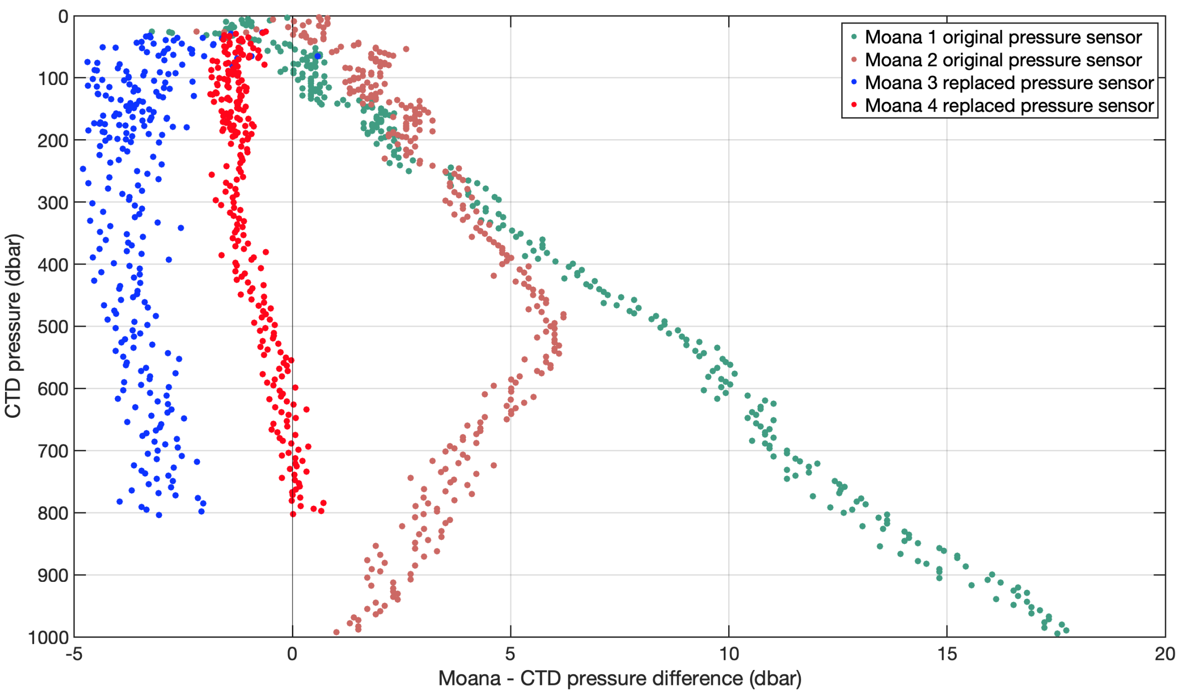

Figure 19. *Pressure sensor comparison between a Seabird CTD and two Moana TD1000s based on instrument timestamp. A time offset was applied such that the root mean square error in the top 300m of the downcast is minimised. The Seabird CTD pressure data is then interpolated onto the Moana TD1000 time datapoints and the error the difference is calculated. The plot shows two sensors with the original and new pressure sensors.*

Continuous intercomparison in different real environments, along with active communication and feedback with the manufacturer, provides further confidence that the sensors retain their level of accuracy through time and subsequent rounds of development. Other sensors which might be used in the future will also be required to go through the same level of scrutiny for ongoing improvement and evolution of FishSOOP.

3.10 Collaboration Agreement

It is essential to have a legal collaboration agreement in place with the participants to set terms of participation, the duration of the contract and the expectations from both parties as well as limits of liability.

The main terms defined in the agreement are:

a. to place the Moana temperature depth sensors and other scientific instruments of measurement such as the Cellular deck unit (**Scientific Products**) on marine vessels to collect and transmit in near real-time oceanographic temperature, pressure, geographical position, and time (**Project Data**) that will improve ocean modelling and forecasting to increase understanding of the oceanographic environment, and may be used to develop ocean data products.
b. exchanging Project Data collected using the Scientific Products via agreed methods and formats between UNSW, IMOS and Project participants and deliver de-identified **Project Data** to the publicly available Australian Ocean Data Network (**AODN**) under a Creative Commons Attribution 4.0 International Licence. Additionally, to gain feedback and understanding of collected data and the data available to the public on an open access basis (**Purpose**).

For ease of execution, we typically choose to have the fisher/ skipper agree electronically to the collaboration agreement within the metadata entry form. In some instances, this is done separately in either paper or electronic format, if good record keeping practices are in place for sensitive information.

The legal collaboration agreement that participants must agree with to participate in FishSOOP is shared through a link made available to participants with the legal agreement attached (Appendix 3 – Participant metadata collection form and vessel agreement

3.10.1 Special Cases

Sharing of the position data has been a concern in two small fisheries, so a degree of latency has been negotiated in a small number of participants for the sharing of the (position) data in the open access data portals. In this case the data follow the same QC path, but the files are not released until the end of the specified period (typically the end of that fishing season). In this case there is a modified vessel agreement. It is to be noted that participation in IMOS is contingent upon all data being made open access (anonymously) even if after a short delay.

3.10.2 Engagement

Information about FishSOOP should be provided to the vessel operators (through email, QR codes or with custom-made laminated sheets). This is to ensure consistent messaging, alleviate concerns about data sharing, provide some troubleshooting information, and to stimulate engagement with the data collectors. We also provide a monthly newsletter to maintain engagement in FishSOOP, share information on activities, data usage, and relevant stories. Finally, we performed a survey amongst all participants for insight into usability of the data returned to them, and receive feedback for improvement. FishSOOP is collaborative by nature, and as such engagement is essential for success.

3.11 International and Domestic Counterparts

The IMOS Fishing Vessels as Ships of Opportunity (FishSOOP) sub-Facility is a founding partner of the international Fishing Vessel Observation Network (FVON) which was established in 2020 after the 2019 Ocean Obs 19 conference. Links to both the domestic and the international network, as well as some of the international counterpart programs are below:

UNSW Oceanography & UNSW FishSOOP

https://www.unsw.edu.au/research/oceanography/fishsoop

FVON

https://fvon.org
https://github.com/collab-FVON/FVON-QCQA
(Van Vranken et al., 2020, Van Vranken et al., 2023)

FVON data can be accessed through the FVON ERDDAP:
https://erddap.fvon.org/erddap/tabledap/FVON_Profile_FV_NRT.html
and through EMODNET:
https://emodnet.ec.europa.eu/en/physics

International Programs

AdriFOOS (Italy)

https://www.irbim.cnr.it/en/inf-dettagli/adrifoos/
https://www.seanoe.org/data/00618/73008/
(Martinelli et al., 2016)

CFRF (USA)
www.cfrfoundation.org/

eMOLT (USA)
https://www.emolt.org

MetService Moana Project (New Zealand)
https://www.moanaproject.org/temperature-sensors
https://github.com/metocean/moana-qc
(Jakoboski et al., 2023, Jakoboski et al., 2024)

OBSERVA.FISH (Portugal)
https://www.researchgate.net/publication/330728204_OBSERVAFISH_Autonomous_Observing_Systems_in_Fishing_Vessels_for_the_Support_of_Marine_Ecosystem_Management

Ocean Data Network (USA)
https://oceandata.net/

Pacific Islands FVON (PI-FVON)
Pacific Community (SPC) is in the process of deploying sensors on 50 fishing vessels across fifteen countries in the western central Pacific in collaboration with IMOS Australia.

SFiN (Smart Fisheries Network) (Japan)
https://www.riam.kyushu-u.ac.jp/omg/sfin.html.ja

3.12 Known Issues

3.12.1 Deck unit over heating

Due to overheating of the deck units for vessels operating at low latitudes, the battery charging capacity has been limited by ZebraTech as a function of the maximum internal temperature in the previous 14 days for any deck units produced or serviced after September 2024 (Table 11).

Maximum daily temperature over the past 14 days	20	25	30	35	40	45	50	55	60	65	70
Solar charger disabled above this battery voltage	4.20	4.17	4.13	4.08	4.02	3.95	3.87	3.85	3.83	3.82	3.80
Solar charger enabled below this battery voltage Port mode disabled above this voltage	4.15	4.13	4.09	4.02	3.98	3.91	3.85	3.84	3.81	3.80	3.79
Port mode enabled below this battery voltage	4.08	4.04	4.00	3.95	3.91	3.85	3.82	3.80	3.78	3.77	3.75

Table 11. *Deck unit limited battery capacity as a function of the maximum internal temperature recorded in the previous 14 days in in °C. (Source: Moana Temperature and Pressure Sensor Moana Deck Unit Technical and Operation Manual v2.1).*

An example of an overheating deck unit is indicated by the erratic movement and overall decline in internal battery capacity, as shown by the blue line in the battery voltage plot in Figure 20.

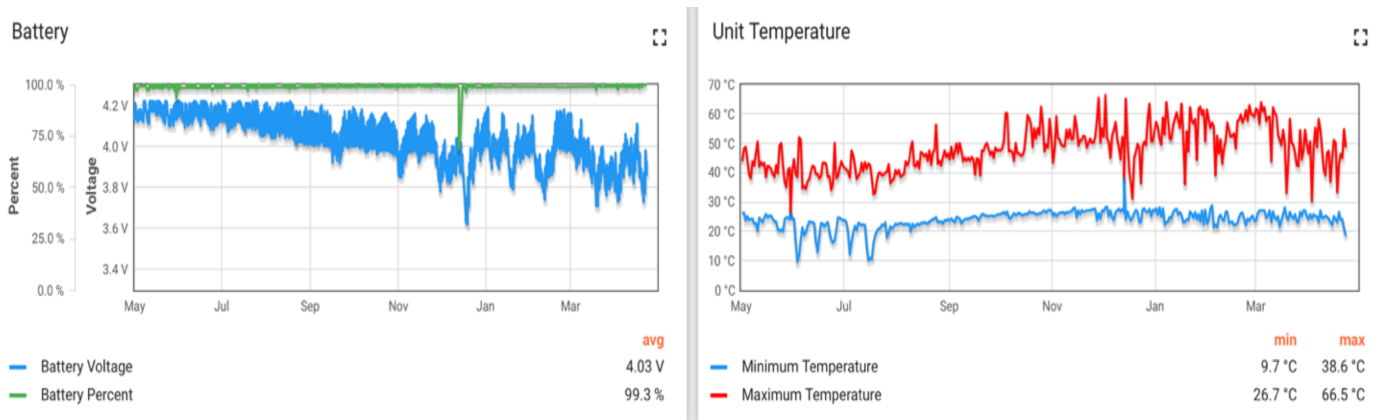

Figure 20. *Indication of an overheating deck unit and the impact on battery voltage.*

When the lithium battery of a deck unit has overheated, it might expand, causing the deck unit base to bow (Figure 22a and Figure 22b) and pose a risk of leaking toxic gases or igniting. The battery of the deck unit should then be drained down to lower than at least 30% whilst placed in a fire safe location such as in a flammable cabinet and/or a fire containment bag. To remove the battery, turn off the deck unit, and work on a non-flammable surface. The plexiglass cover needs to be removed first. To remove parts inside, use only manual precision tools while being mindful to not slip and possibly puncture through the battery. In case the battery might have leaked, wear nitrile gloves and safety glasses before proceeding any further. The solar panel needs to be pushed aside, and the circuit board disconnected before being also pushed aside to expose the plastic cover located over the battery (Figure 22c). The battery is located directly under that plastic cover. If the battery is swollen, the plastic cover might be under pressure, make sure you remove screws on both sides at the same time to avoid it snapping. Once the battery is removed, tape the connections to prevent short-circuiting (Figure 22d) and store in a fire containment bag, which itself should be placed in a smoke containment bag. The battery can then be safely disposed as chemical waste.

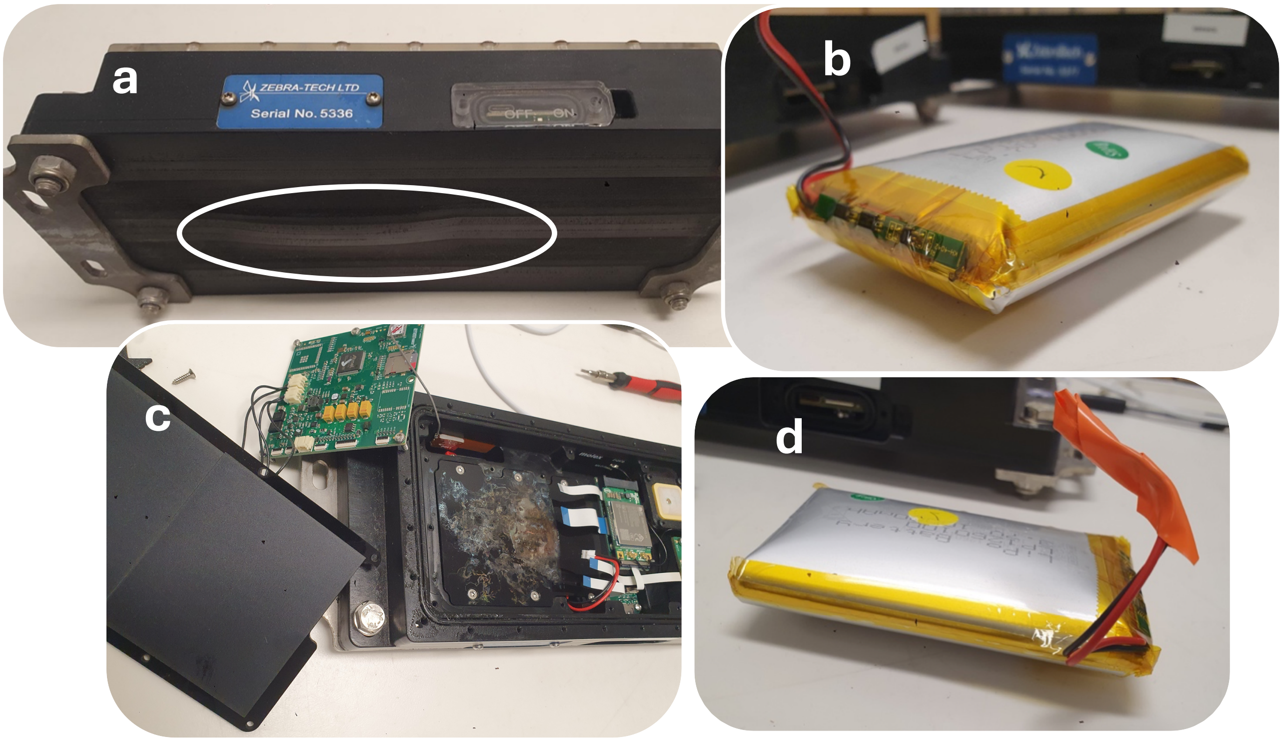

Figure 22. *Example of a deck unit where the lithium battery has overheated* ***a.*** *Deck unit with plastic bulging underneath, where the battery is located.* ***b.*** *Overheated swollen lithium-polymer battery.* ***c.*** *Deck unit opened to expose the plastic cover directly over the lithium battery with corrosion.* ***d.*** *Taped connections on the overheated battery.*

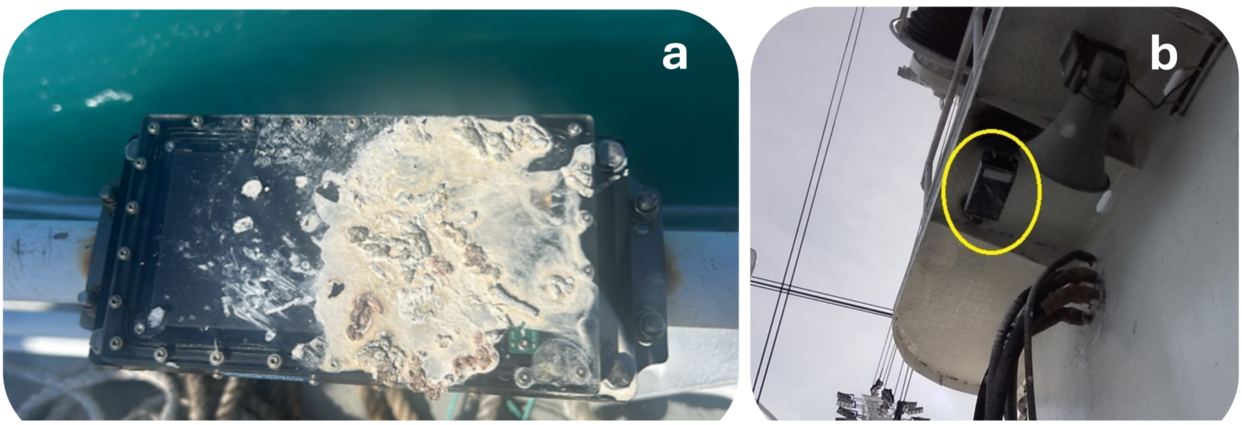

Figure 21. *Issues encountered with the deck unit impacting upon successful operation. Left, biofouling impacting operations of the solar panel. Right, deck unit mounted in the shade.*

3.12.2 Deck unit not charging

The solar panel on the deck unit must be routinely cleaned to reduce accumulation of residue (salt spray) and biofouling (Figure 21a) on the plexiglass cover, as these can impact battery charging functionality. Likewise, it is essential that the deck unit is mounted in a location exposed to the sun, not under a roof and/or facing downwards (Figure 21b), as this can greatly impact charging capacity.

3.12.3 Sensor Failures

Issues with the MoanaTD sensors have been observed as a result of poor placement. In one instance, the temperature probe within a MoanaTD sensor became bent during deployment whilst attached to a trap (Figure 23a), compromising the sensor's ability to collect accurate data. Additionally, when mounted in an inappropriate location on a dredge, organic matter can accumulate and significantly restrict water flow to the sensor (Figure 23b), again impacting data collection. These incidents highlight the importance of thoroughly testing the attachment method for the MoanaTD sensor across multiple deployments and routinely monitoring the condition of the sensor over time.

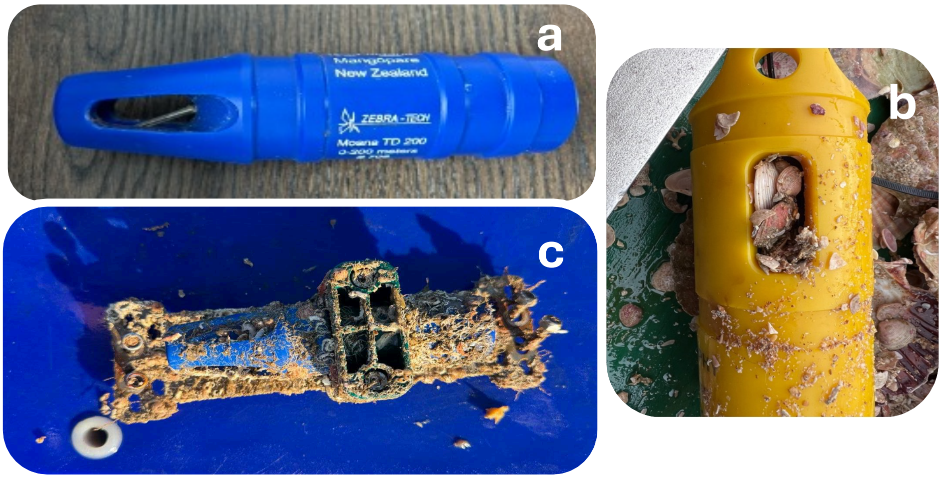

Figure 23. *Issues encountered with the MoanaTD sensors, include breakage and biofouling.*

3.12.4 Sensor Loss

The highest rates of MoanaTD sensor losses have occurred whilst attached to drifting long lines (~18% losses when deployed on drifting longlines); thought to be from shark interaction or pots and traps (~15% losses when deployed on pots and traps). However, the total losses amount to roughly 6% of total sensor deployments with very rare losses from other methods. Some participants forget to notify of losses, hence the importance of close monitoring on the data received by each vessel to identify losses. Whilst most sensors are not recovered after loss, it has occurred before where lost sensors attached to traps were found after 6-10 months (Figure 23c). The internal memory, however, could only record up to 31,146 data entries, which at a rate of 1 entry every 5 min, whilst at constant depth, lasted 3.5 months of the total period these sensors were submerged.

3.12 Training Materials and Contacts

Full installation instructions, installation checklists, travel information documents, and FAQ sheets all available from the IMOS FishSOOP website.
https://imos.org.au/facility/ships-of-opportunity/fishing-vessels-as-ships-of-opportunity

3.12.1 Feedback

Feedback on data formats, uptake, usage, and any issues or errors is always welcome. It can be sent via email to fishsoop@unsw.edu.au . We also actively seek feedback via stakeholder and end user workshops, the FishSOOP steering groups and the international FVON community.

3.13 Future development

As FishSOOP continues to expand in scale and capability, ongoing refinement of QA/QC protocols will be essential to meet emerging scientific, operational, and stakeholder needs. Future development will focus on improving QC, data delivery, adapting to unforeseen issues that might arise, and integrating new sensor technologies while maintaining consistency and compatibility with existing datasets for the long-term success and usability of the FishSOOP data stream.

3.13.1 Automated QC development

The implementation of a climatology test is necessary to catch sensors with a temperature offset, or generally out of normal range. The main consideration for the climatology test will need to be use a dataset accurate enough for coastal region over our whole operational domain.

For sensors attached to gears that do not stay with the boat, currently the position is set as a constant value that is averaged between the location at deployment and recovery. The position data will be improved by separating the position at deployment and at recovery from the position during the deployed phase, with different QC flag values for each of those phases. Additionally, a variable with a point by point uncertainty on the position will be included in a future version of the near real-time automatic QC process.

3.13.2 Delayed-mode QC

A key component of future QA/QC development within FishSOOP will be the implementation of a delayed-mode quality control process that incorporates the calibration data from the manufacturer, and broader contextual information. This will include applying re-calibration files to detect and correct any sensor drift or offset over time. In addition, data will be evaluated against surrounding available in situ measurements to identify outliers and flag values that fall outside expected environmental ranges. This multi-layered approach will enhance the reliability and scientific value of the dataset, particularly for retrospective analyses and data assimilation applications.

4 CONCLUSION

Since it's conception first as the Moana Project in 2017 in New Zealand, then as the FRDC trial in 2022-2023 in Australia, and now the IMOS-FishSOOP sub-Facility, the program has undergone rapid expansion resulting in the development of rigorous methodology for QA and QC. The checks in place pre, during and post deployment work to ensure data is collected, processed and delivered at a consistent, research quality standard. Given FishSOOP's early stage and its nature as both a crowdsourced initiative and a collaboration between multiple bodies, the QA and QC framework is continually evolving. This ongoing adaptation ensures alignment with both the sub-Facility's internal growth and the broader standards set by the IMOS community.

FishSOOP is working with stakeholders to ensure the data is provided in its most useful format for use by the participants, forecasters, modellers, and other scientists alike. Due to the nature of the sub-Facility, a high-level of engagement with the fishing community is essential for success. Therefore, the data needs to be returned in a format that benefits the fishing community directly (real time data delivery), and indirectly (improved ocean forecasts). Finally, open and continuous communication with stakeholders throughout the development of the data products is crucial to ensure the data is, and continues to be, relevant and valuable to the broader community.

5 ANNEXES

5.12 List of Figures

5.13 List of Tables

5.14 References

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Appendices

Appendix 1 - Installation Check list

IMOS FishSOOP Installation Checklist

Vessel Name

Date

Installed by

Deck unit number

Sensor number(s)

Installation form

- ☐ Online installation form completed with all details including:
  - ☐ Email addresses for the data delivery
  - ☐ Deck unit and sensor serial numbers

Deck unit – hardware check

- ☐ O-ring is present
- ☐ O-ring is greased sufficiently
- ☐ White switch is on the right (ON position)
- ☐ SIM card is inserted fully with gold contacts down and triangle to the left.
- ☐ Screws for the side door are screwed down tightly (O-ring flattened)

Comms & Test cast

- ☐ Two green lights evident (Battery and GPS)
- ☐ Sensor test cast conducted*
- ☐ Deck unit has communicated with the server (check dashboard - contact FishSOOP@unsw.edu.au if you don't have access)
  - ☐ Sensor/s have pinged to dashboard
  - ☐ Data received in FishSOOP email

Deck unit Mounting Location

- ☐ Suitable mounting location has been identified with the skipper / captain
  - ☐ < 20m from location where sensors come onboard
  - ☐ Clear view to the sky – GPS and solar charging,
  - ☐ Strong Wi-Fi signal (test with phone)
- ☐ Solution for mounting established (45° angle in the tropics preferred)

Sensor mounting

- ☐ Solution for sensor installation established
  - ☐ More than one attachment point
  - ☐ Net basket (so sensor does not snag)

Installation photographs

- ☐ Photographs of installation sent to fishsoop@unsw.edu.au
  - ☐ Deck unit and sensors in tough jackets, showing serial numbers
  - ☐ Deck unit mounted in place,
  - ☐ Clear side panel showing power switch to the right – ON
  - ☐ Sensor on net – showing attachment method
- ☐ We may want to use your photos in future material (e.g. instructions, reports etc.) – if you grant permission, please tick this box and write the name of the organisation/vessel which should receive credit:

(We welcome additional photos/videos of deployment at

any time)

Instructions

- ☐ Laminated copy of installation instructions held

****Once you have completed all steps, please send a copy of this form to fishsoop@unsw.edu.au ****

* Slowly lower the sensor into water (clear of any discharges or other disturbances) at a rate of ~1m/second to a depth between 2-10m. Leave for 1 minute, then recover at ~1m/second to communicate

Version 1 updated 10th Mar 2025

Figure 24. *Example of the FishSOOP instrument installation checklist.*

Appendix 2 – IMOS data file format

The filename follows the standards described in IMOS NetCDF File Naming Convention (2022) found here:
https://s3-ap-southeast-2.amazonaws.com/content.aodn.org.au/Documents/IMOS/Conventions/IMOS_NetCDF_File_Naming_Convention.pdf

The filenames contain 7 parts described in Table 12. Filename convention for each part. The filename part is described using the example provided. or the example file IMOS_SOOP-FishSOOP_TP_20250217T201507Z_FV01_1016.nc.

Filename part	Convention
IMOS	Data provider
SOOP	Facility
FishSOOP	Subfacility
TP	Raw data available in the file, here Temperature and Pressure
20250217T201507Z	Date in standard UTC format
FV01	File version, here for near real-time automatic QC
1026	Sensor serial number (no fixed number of digits)

Table 12. *Filename convention for each part. The filename part is described using the example provided.*

Below is an example of the content and format of a FishSOOP datafile following IMOS convention, this is for the example file
IMOS_SOOP-FishSOOP_TP_20250217T201507Z_FV01_1016.nc

Format:
    netcdf4
Global Attributes:
    project = 'Integrated Marine Observing System (IMOS)'
    title = 'FishSOOP data from Moana 1016 on a stationary type of fishing gear'
    institution = 'UNSW'
    Conventions = 'CF-1.6,IMOS-1.4'
    standard_name_vocabulary = 'NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table Version 29'
    cdm_data_type = 'Trajectory'
    data_mode = 'Near Real-Time'
    date_created = '2025-04-27T23:50:25Z'
    abstract = 'This NetCDF file contains data from the Zebratech Moana 1016 with a temperature and pressure sensors, deployed from a stationary type of fishing gear'

naming_authority = 'IMOS'
instrument = 'ZebraTech Moana TD200'
instrument_serial_number = '1016'
geospatial_lat_min = -33.7487
geospatial_lat_max = -33.7487
geospatial_lon_min = 151.3618
geospatial_lon_max = 151.3618
geospatial_vertical_min = 0.29787
geospatial_vertical_max = 44.7744
geospatial_vertical_positive = 'down'
time_coverage_start = '2025-02-13T19:48:40Z'
time_coverage_end = '2025-02-17T20:14:46Z'
data_centre = 'Australian Ocean Data Network (AODN)'
data_centre_email = 'info@aodn.org.au'
author = 'Lago, Veronique'
principal_investigator = 'Roughan, Moninya'
citation = 'The citation in a list of references is: \"IMOS [year-of-data-download], [Title], [data-access-url], accessed [date-of-access]'
acknowledgement = 'Data was collected in collaboration with fishing and other commercial and recreational vessels and we acknowledge their contribution. Any users of IMOS data are required to clearly acknowledge the source of the material derived from IMOS in the format: "Data was sourced from Australia's Integrated Marine Observing System (IMOS) - IMOS is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS)."'
disclaimer = 'Data, products and services from IMOS are provided "as is" without any warranty as to fitness for a particular purpose.'
license = 'http://creativecommons.org/licenses/by/4.0/'
file_version = 'Level 1 - Quality Controlled Data'
comment = 'Depth computed using the Gibbs-SeaWater toolbox (TEOS-10) v3.06 from latitude and pressure measurements from the Moana, which is referenced to the pressure of the sea surface at the start of the deployment event, 992 (mBar)'

Dimensions:
TIME = 1523
TRAJECTORY_ID = 1

Variables:
TRAJECTORY_ID
Size: 1x1
Dimensions: TRAJECTORY_ID
Datatype: double
Attributes:
long_name = 'trajectory identifier'
cf_role = 'trajectory_id'

TIME
Size: 1523x1
Dimensions: TIME
Datatype: double
Attributes:
standard_name = 'time'
long_name = 'time'
axis = 'T'
calendar = 'gregorian'
units = 'days since 1950-01-01 00:00:00 UTC'
valid_min = 21915
valid_max = 90000
comment = 'The valid_min is set to January 1st, 2010, dates before this time are flagged by the quality control impossible date test'
LATITUDE
Size: 1523x1
Dimensions: TIME
Datatype: single
Attributes:
_FillValue = -9999
ancillary_variables = 'LATITUDE_quality_control'
standard_name = 'latitude'
long_name = 'latitude'
units = 'degrees_north'
valid_min = -90
valid_max = 90
axis = 'Y'
reference_datum = 'WGS84 geographic coordinate system'
LATITUDE_quality_control
Size: 1523x1
Dimensions: TIME
Datatype: int8
Attributes:
long_name = 'quality flag for latitude'
standard_name = 'latitude status_flag'
quality_control_conventions = 'IMOS standard flags'
flag_values = [0 1 2 3 4 5 6 7 8 9]
flag_meanings = 'No_QC_performed Good_data Probably_good_data Bad_data_that_are_potentially_correctable Bad_data Value_changed Not_used Not_used Not_used Missing_value'
LONGITUDE

Size: 1523x1
Dimensions: TIME
Datatype: single
Attributes:
_FillValue = -9999
ancillary_variables = 'LONGITUDE_quality_control'
standard_name = 'longitude'
long_name = 'longitude'
units = 'degrees_east'
valid_min = -180
valid_max = 180
axis = 'X'
reference_datum = 'WGS84 geographic coordinate system'
LONGITUDE_quality_control
Size: 1523x1
Dimensions: TIME
Datatype: int8
Attributes:
long_name = 'quality flag for longitude'
standard_name = 'longitude status_flag'
quality_control_conventions = 'IMOS standard flags'
flag_values = [0 1 2 3 4 5 6 7 8 9]
flag_meanings = 'No_QC_performed Good_data Probably_good_data Bad_data_that_are_potentially_correctable Bad_data Value_changed Not_used Not_used Not_used Missing_value'
DEPTH
Size: 1523x1
Dimensions: TIME
Datatype: single
Attributes:
_FillValue = -9999
ancillary_variables = 'DEPTH_quality_control'
standard_name = 'depth'
long_name = 'depth'
units = 'm'
positive = 'down'
valid_min = -5
valid_max = 3000
coordinates = 'TIME LATITUDE LONGITUDE DEPTH'
axis = 'Z'

comment = 'Depth computed using the Gibbs-Seawater toolbox (TEOS10) v3.06 from the mean latitude in the data (or a default of -33 if no latitude was recorded) and pressure measurements from the Moana'
reference_datum = 'sea surface'

DEPTH_quality_control
Size: 1523x1
Dimensions: TIME
Datatype: int8
Attributes:
long_name = 'quality flag for depth'
standard_name = 'depth status_flag'
quality_control_conventions = 'IMOS standard flags'
flag_values = [0 1 2 3 4 5 6 7 8 9]
flag_meanings = 'No_QC_performed Good_data Probably_good_data Bad_data_that_are_potentially_correctable Bad_data Value_changed Not_used Not_used Not_used Missing_value'

TEMPERATURE
Size: 1523x1
Dimensions: TIME
Datatype: single
Attributes:
_FillValue = -9999
ancillary_variables = 'TEMPERATURE_quality_control'
standard_name = 'sea_water_temperature'
long_name = 'sea_water_temperature'
units = 'degrees_Celsius'
coordinates = 'TIME LATITUDE LONGITUDE DEPTH'
valid_min = -2
valid_max = 40
observation_type = 'measured'

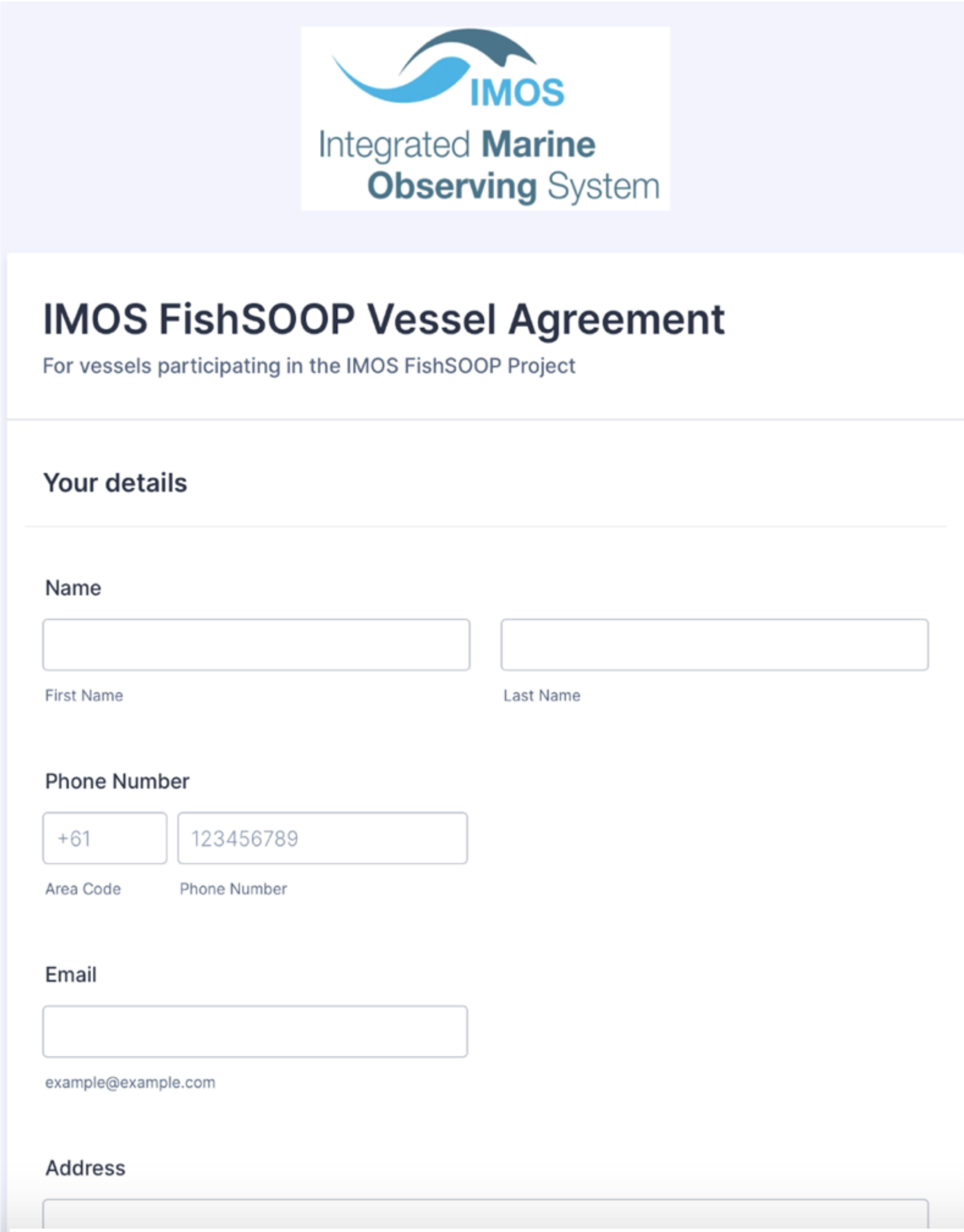
TEMPERATURE_quality_control
Size: 1523x1
Dimensions: TIME
Datatype: int8
Attributes:
long_name = 'quality flag for sea_water_temperature'
standard_name = 'sea_water_temperature status_flag'
quality_control_conventions = 'IMOS standard flags'
flag_values = [0 1 2 3 4 5 6 7 8 9]

flag_meanings = 'No_QC_performed Good_data Probably_good_data Bad_data_that_are_potentially_correctable Bad_data Value_changed Not_used Not_used Not_used Missing_value'

PRES
Size: 1523x1
Dimensions: TIME
Datatype: single
Attributes:
_FillValue = -9999
ancillary_variables = 'PRES_quality_control'
standard_name = 'sea_water_pressure'
long_name = 'sea_water_pressure'
coordinates = 'TIME LATITUDE LONGITUDE DEPTH'
units = 'dbar'
valid_min = -5
valid_max = 3000
comment = 'Measure from the Moana'

PRES_quality_control
Size: 1523x1
Dimensions: TIME
Datatype: int8
Attributes:
long_name = 'quality flag for sea_water_pressure'
standard_name = 'sea_water_pressure status_flag'
quality_control_conventions = 'IMOS standard flags'
flag_values = [0 1 2 3 4 5 6 7 8 9]
flag_meanings = 'No_QC_performed Good_data Probably_good_data Bad_data_that_are_potentially_correctable Bad_data Value_changed Not_used Not_used Not_used Missing_value'

Appendix 3 – Participant metadata collection form and vessel agreement



IMOS
Integrated Marine Observing System

IMOS FishSOOP Vessel Agreement

For vessels participating in the IMOS FishSOOP Project

Your details

Name

First Name

Last Name

Phone Number

+61

123456789

Area Code

Phone Number

Email

example@example.com

Address

Figure 25. *A screenshot of an example of the digital form used for participants or sensor installer to input required metadata for data processing and for participants to agree to the collaboration agreement.*