

Project Title	Coastal Local Observations Connection Hub (C-LOCH), supported by
Aim	C-LOCH is a proof-of-concept project to produce a roadmap for effective environmental monitoring for the benefit of aquaculture operators, statutory bodies, and coastal communities in Scotland.
Date & Duration	1 st February – 31 st December; 11 months

Partners

The Fishmongers' Company's Fisheries Charitable Trust (FCFCT)	Dr. Eleanor Adamson, Fisheries Programme Manager
Association of Scottish Shellfish Growers (ASSG)	Dr. Nick Lake, CEO
The Scottish Association for Marine Science (SAMS)	Dr. Kati Michalek (Senior PDRA Low-Trophic Aquaculture; Project lead) Marja van den Houten (Seaweed Farm Manager and Support Scientist) Dr. Alan MacDonald (Scientific Informatics Analyst), and Kieran Campbell (Senior ICT Systems Analyst) [in-kind]
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Scope

This document provides a summary of the C-LOCH project supported by the Fishmongers' Company's Fisheries Charitable Trust's (FCFCT) "Challenges in the Bivalve Shellfish Industry" grant.

Introduction

Coastal waters worldwide are experiencing challenges related to environmental pressures such as fluctuations in seawater temperature and salinity, increased pollution, and presence and spread of diseases. Scotland's highly productive coastal waters and strict quality regulations ensure the safety of Scottish seafood to consumers. However, these valuable marine environments are increasingly being shaped by climate-driven changes, most notably rising sea-surface temperatures (see Figure 1).

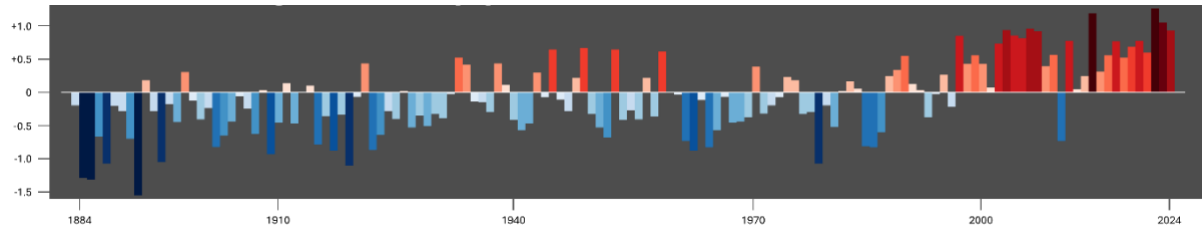


Figure 1 - Temperature change in Scotland. Relative to average of 1961-2010 [°C]. Source: University of Reading, #showyourstripes. <https://showyourstripes.info/c/europe/uk/scotland>.

Thanks to sustained monitoring efforts and global ocean observations via satellites, more data than ever is available on the state of our seas. Effective exploration of this information to create practical and timely knowledge for the diverse marine sector requires specialist data management, with outputs that are currently not readily accessible to end users.

The **Coastal Local Observations Connection Hub (C-LOCH)** aims to establish a user-driven monitoring network to record key physical parameters in long-term data series; starting with shellfish growing sites. Collected data will allow to identify relationships between growing conditions and crop performance that can directly be interpreted with more confidence by aquaculture professionals on the ground. In future, we further envisage it to serve as easy-to-use early warning mechanism ahead of the appearance of harmful blooms and pathogens adversely affecting the shellfish sector (see Discussion).

Deliverables

C-LOCH is a short-term project aiming to produce and/or lay the foundations for the following outputs:

- A standard protocol for location and deployment of monitoring devices;
- Provision of a structured route to participation for Growers;
- Incentivisation for standardised data collection; and

- Interface with existing open access data and the management of the Hub platform by SAMS

An overview of the project tasks and timelines is provided in Table 1.

Based on the findings, future refinement of systematic approaches to achieve long-term industry-managed data collection could be upscaled.

Methodology

C-LOCH aimed to provide an effective data collection and management system to foster cross-sector (shellfish producers, academia, regulators) communication and collaboration. The overarching incentive has been to address shared concerns and provide a proof-of-concept for community-driven monitoring programmes.

Table 1 – C-LOCH project timeline and progress.

<p>Preliminary Work (Feb – Apr 2025)</p>	<p>Market research: A high-level scoping search of commercial off-the-shelf (COTS) monitoring equipment was executed. A shortlist was drawn up where loggers were rated according to 10 criteria.</p>
<p>Establishment of Monitoring Network (since May 2025)</p>	<p>Several local contacts were approached in person and 3 have agreed to participate in the project. Site locations near the SAMS Seaweed farm were favoured for accessibility and comparison. Given the demonstrator intention of the project, variety of conditions to test the loggers was favoured over replicability.</p>
<p>Procurement and Supply of Environmental COTS (Jun/Jul 2025)</p>	<p>The preferred data logger selected from the scoping exercise have recently changed ownership, causing a price increase and a subscription obligation for data handling functions. A solution was identified to deal with these new circumstances.</p>
<p>Data Exploration and Management (since Aug 2025)</p>	<p>Project discussions have identified the most pragmatic way forward for data transfer, handling and management. Integration of C-LOCH data in HAB App underway.</p>

Case Study – Caledonian Oysters Company Ltd., Loch Creran

The Caledonian Oysters Company Ltd. were the first commercial shellfish grower to join C-LOCH. This family-operated business has been growing oysters (Pacific oyster *Crassostrea gigas*, and Native oyster *Ostrea edulis*) at their site Rubha Mor for 35 years, and over the years have kept close links to shellfish and aquaculture researchers at

SAMS. The growing area stretches along the shallow shorelines of Loch Creran and uses traditional intertidal cultivation methods with seawater trestles and trays being deployed from tables extending from the tidal high to low water mark (see Figure 2, left).

The first logger was deployed on the 30th of July 2025 during low tide, being securely attached to one bar of an oyster table, positioned approximately at the mid-water mark (HOBO ID: MWM) (Figure 2, right). The recording interval was chosen as every 30min, as this was found to maximise battery life on one hand and ensure meaningful coverage of locations that had more environmental variability on the other (i.e. high-water mark HWM). Two additional loggers followed, being deployed on the 9th of September 2025, responding to the growers expressed interest in recording temperature ranges and changes also at their lower and higher tidal deployment limits (HOBO ID: LWM and HWM for low and high-water mark, respectively). In particular, the LWM location was of interest as bio-hygiene sampling for *E. coli* is routinely performed at this farm location.



Figure 2 – Left: Oyster cultivation site Caledonian Oysters Company Ltd. (National Grid Reference: NM917407), Loch Creran. Showing deployment locations of three HOBO MX2202 data loggers (low-, mid-, high-water mark; LWM, MWM, HWM, respectively) for continuous recording of temperature. Right: First logger deployment (30/7/2025) from oyster table at mid-water mark.

Results

In the course over three months of continuous monitoring, we recorded a total temperature range from as low as -0.3°C to as high as 37.2°C being experienced by the on-growing oysters. As expected, oysters deployed higher up the shore experience a wider range of temperatures than those lower down (Figure 3, Table 2). This pattern reflects

tidal cycles, which leave high-shore oysters exposed to air for longer periods of time compared to low-shore oysters. Consequently, they are more frequently subjected to temperature extremes, including air frosts, hot spells, and heat waves.

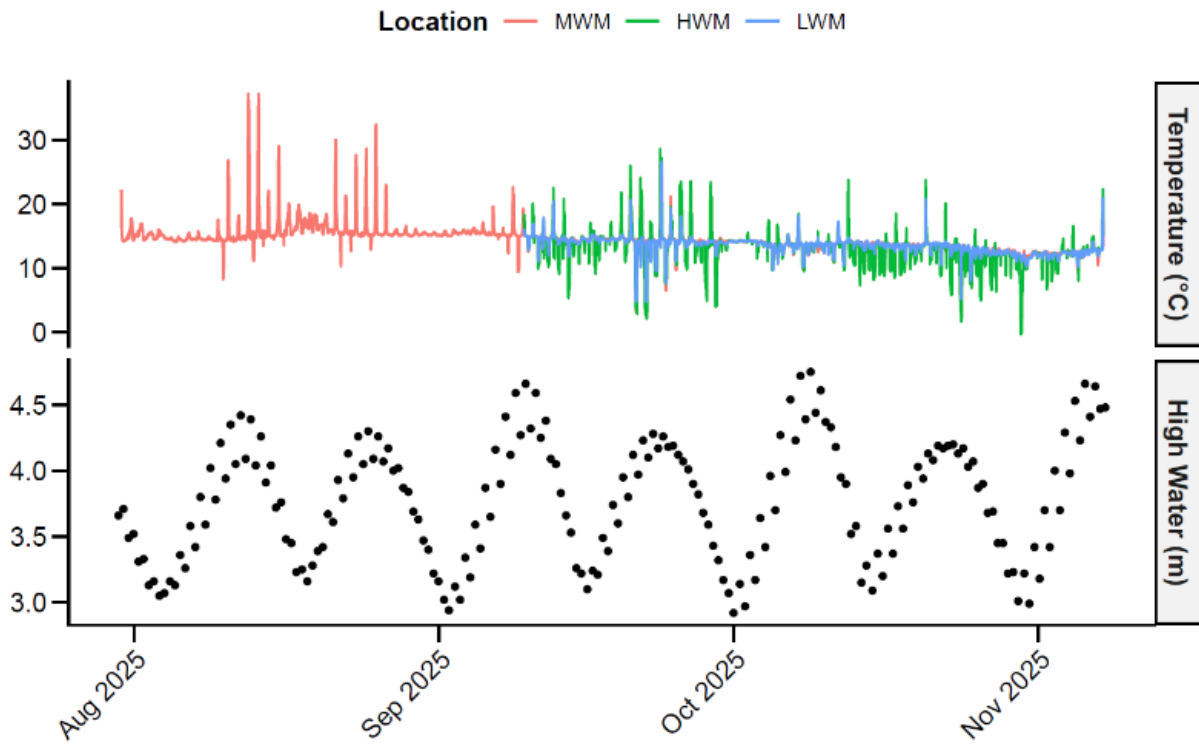


Figure 3 – Variation in Temperature over a 3-month period (30/7/ - 7/11/2025) at and across three different growing locations (LWM: low-water, MWM: mid-water, HWM: high-water mark) at Caledonian Oysters Company Ltd., Loch Creran. Also shown are the corresponding tidal high-water levels (Poltips-4, NOC, station: Port Appin).

Table 2 – Summary of temperature conditions (in °C) experienced at different locations at Caledonian Oysters.

Logger ID	Date of Deployment	Minimum (Min)	Maximum (Max)	Average (Mean)	Standard Deviation (SD)
LWM	09/09/2025	4.76	26.6	13.5	1.29
MWM	30/07/2025	2.49	37.2	14.4	2.07
HWM	09/09/2025	-0.346	28.6	12.9	2.66

This was also evident in data provided by John Barrington at Creran Oysters (C-LOCH site #2; 56° 32.183' N and 05° 20 202' W), who has been monitoring temperature conditions in the intertidal zone during summer to early autumn from 2020 onward.

Overall it remains important to consider that each site location and layout is different in terms of local bathymetry and hydrography as well as the extend and positioning of production infrastructure. These factors will also affect the deployment location of

environmental monitoring equipment. By way of example for Caledonian Oysters, recorded temperature data will partially contain readings in air rather than water; in particular for the high- and mid-water mark. However, with oysters being kept in closed trestles and thus experiencing the same conditions at the same time as the deployed monitoring equipment, this provides a realistic presentation of temperature ranges the on-growing crop is exposed to on any chosen timescale.

Discussion

One of C-LOCH’s aims was to provide an App that functions as an environmental monitoring tool with the ability to display alerts (e.g. push notifications) when environmental thresholds are exceeded.

SAMS had previously developed **HAB REPORTS**, an early-warning system for harmful algal blooms (HABs) for [desktop](#) and mobile ([iOS](#) and [Android](#)) applications. The HAB App provides a map-based visualisation of HAB toxin levels at Scottish shellfish farms using Google Map markers. Warming waters is one of the key factors influencing the appearance, frequency and severity of HABs and proliferation of other pathogens. Expanding the HAB REPORTS to incorporate additional environmental data enables end-users to decide earlier to take precautionary steps based on clear visualisation of real-time conditions (see Figure 4).

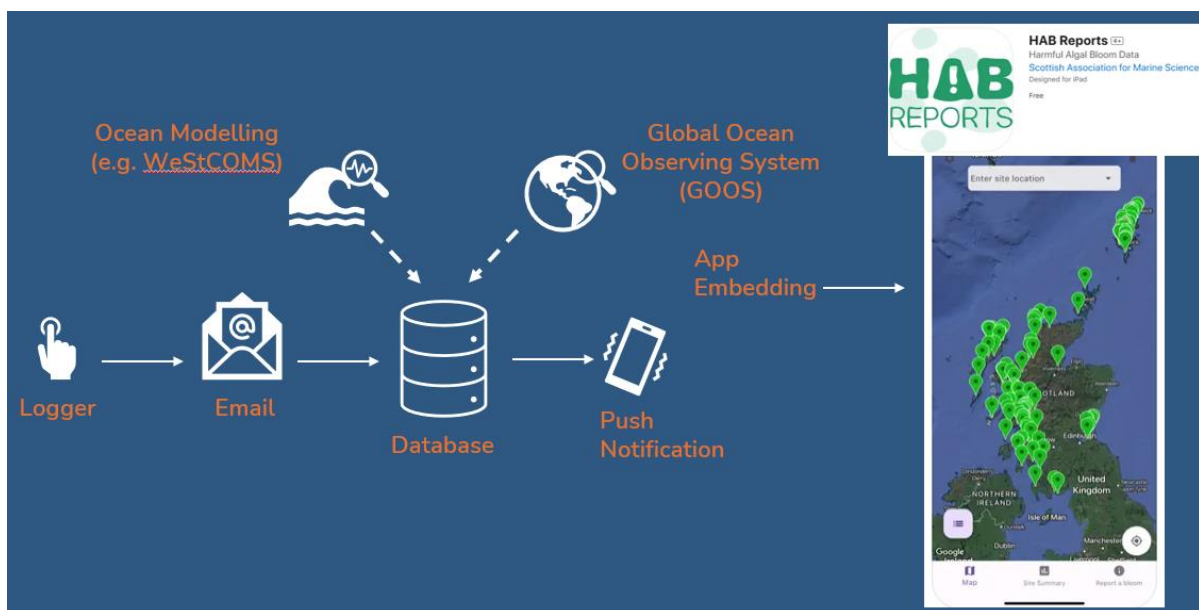


Figure 4 – Infographic depicting how multi-source and format information streams can be linked using SAMS Hab reports App.

To have the lowest threshold for people to participate in the network, the project team thought it was important to avoid any subscription obligation by creating a dedicated project data route that fed directly into the existing HAB App. This approach will also shield producers from the regular takeovers of COTS sensor suppliers and other market shifts in the future. The App can be used in **community network** or **private** mode, depending on the preferred user setting.

The following process description outlines how HOB0 data is generated, downloaded and fed into the existing HAB App pipeline.

System Description

Data ingestion:

- **HOB0 LOGGER** → EMAIL → DATABASE
Automated ingestion of stakeholder HOB0 logger data (Excel via email using **MSGGRAPH**) into **MySQL** on in-house servers.

Push notifications:

- A **Python** script will run every 5 minutes to: i) query the database, ii) check if any defined rules have been triggered (e.g. Temperature > X °C), iii) trigger the cloud messaging service from **Google Firebase** to send push notifications to users.

API:

- **Django REST API** feeds all data to the App and deals with login/authentication.

The App:

- The App is programmed in **Flutter**. At present it has a timeseries visualisation for Temperature and Light¹, latest records from various sites, graphs to allow easy monitoring of data, and a notification page (see Figure 5).

¹ Please note that recorded Light data was excluded from downstream processing due to biofilm developments on the sensor that falsify recorded light intensities if cleaning protocols are not followed.

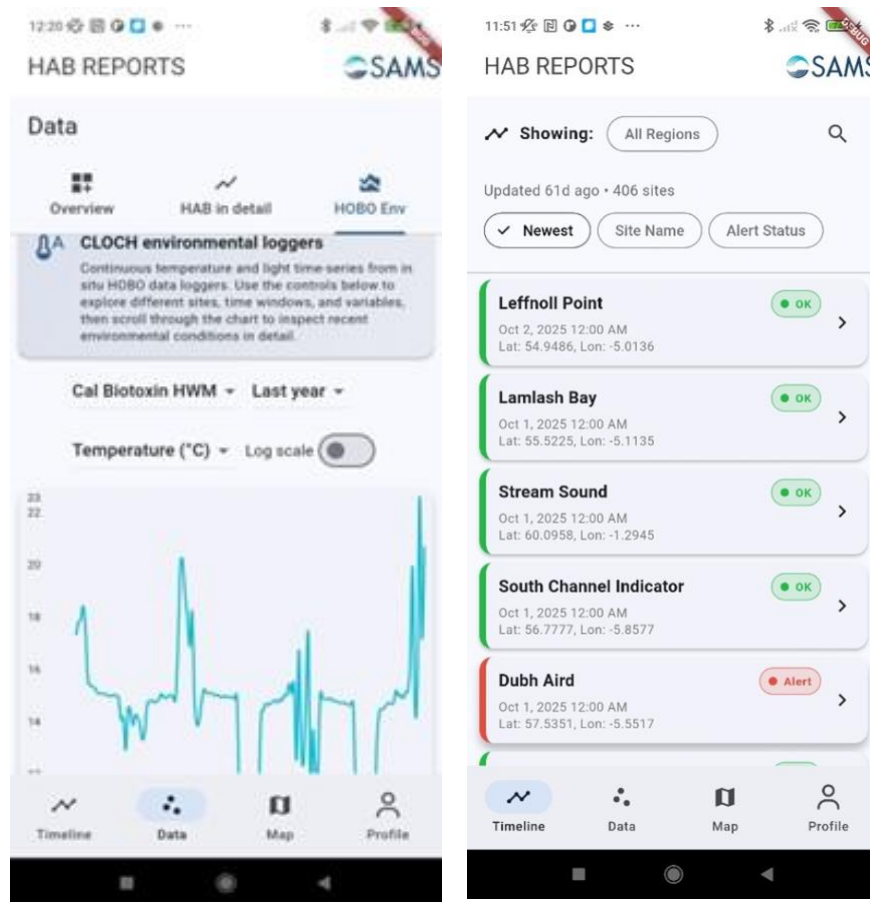


Figure 5 - Screenshot of integration of HOB0 derived data (left) and HAB alerts (right) in the HAB Reports App ©SAMS.

The focus has been on securing the delivery of the technical aspects of the project, leaving the social objectives (route to participation and incentivisation) to be explored fuller. In-person approaches have been effective in recruiting enough producers to make the project viable, and uptake remains ongoing.

At this stage, C-LOCH did not attempt to answer high-level questions considering underlying relations of coastal water dynamics, stress levels and product yield and quality, but rather to provide the outline of how a collaborative data network could look and function, and to identify how user experience could be enhanced by adding satellite-derived datasets to the App. Supported by SAMS, the network could grow through the agency and willingness of local growers to collaborate, with predictions becoming more precise and useful with every added participant.

Extensive field-based studies on the physical and biological features of sea lochs of western Scotland have been conducted by statutory nature conservation organisation during the late '80s and 90s (see: [Marine Nature Conservation Review: Sector 13.](#)

[Sealochs in west Scotland: Area summaries](#)). These historical data can now be brought into context of real-time Earth Observation data sets and field monitoring results to understand and predict where significant impacts of anthropogenic actions are likely to occur. Digital Elevation Models (DEM) using satellite-derived open-source datasets can be used to globally map and track the fluctuating and morphologically dynamic intertidal zone, helping to mitigate location-based risk. C-LOCH could be expanded to include more of these types of datasets.

Next Steps

The App is ready for user testing, and test builds could be released to project partners via **Google Play** (internal/closed testing) and **Apple TestFlight**. Feedback would be collected on data accuracy, App usability, and performance.

During and after the test phase:

- Identified issues will be resolved;
- Improvements will be made to data ingestion robustness, API performance and user experience;
- Alert logic will be refined to better incorporate logger-derived trends and thresholds;
- Clarity and consistency of in-App alerts will be evaluated and improved if necessary;
- Documentation and release notes will be prepared.

Once complete, the App can be released publicly on Google Play and the App store.

If the project is to be scaled up, it would be worth considering partnering up with the Copernicus Coastal Hub [National Collaboration Programme](#). The Copernicus Marine Service is the marine component of the European Union's Copernicus Programme. It provides free, open-access, and science-based information on the state of the Ocean at both global and regional scales. Funded by the EC and implemented by Mercator Ocean International, the service supports the implementation of EU policies and international legal commitments related to ocean governance. It also aims to meet the growing demand for reliable ocean knowledge across society and plays a key role in raising public awareness of marine-related issues by making complex information accessible to citizens all around the world.

The National Collaboration Programme's central aim is to boost user adoption and satisfaction while unlocking new possibilities for data and product applications, amplifying the impact of the Copernicus Marine Service.

The next open call for tender will be in January 2026, and an extended C-LOCH project would fit well with the scientific, economic and social goals and values. On one hand, the Copernicus Coastal Hub datasets would enhance the Apps visualisation and forecasting while on the other the C-LOCH network would provide ground-truthing/validation of Remote Sensing data, improve granularity, and add inshore data. Figure 6 demonstrates how the Copernicus data become thinner at smaller, more inshore scales. By way of example, the SAMS farm (Loch Linnhe) still shows values for all five selected parameters while sites in Loch Creran only show results for turbidity. With additional locally relevant models and datasets such as the **West Coast of Scotland Coastal Ocean Modelling System (WeStCOMS)** C-LOCH would provide a very useful tool for local aquaculture professionals.

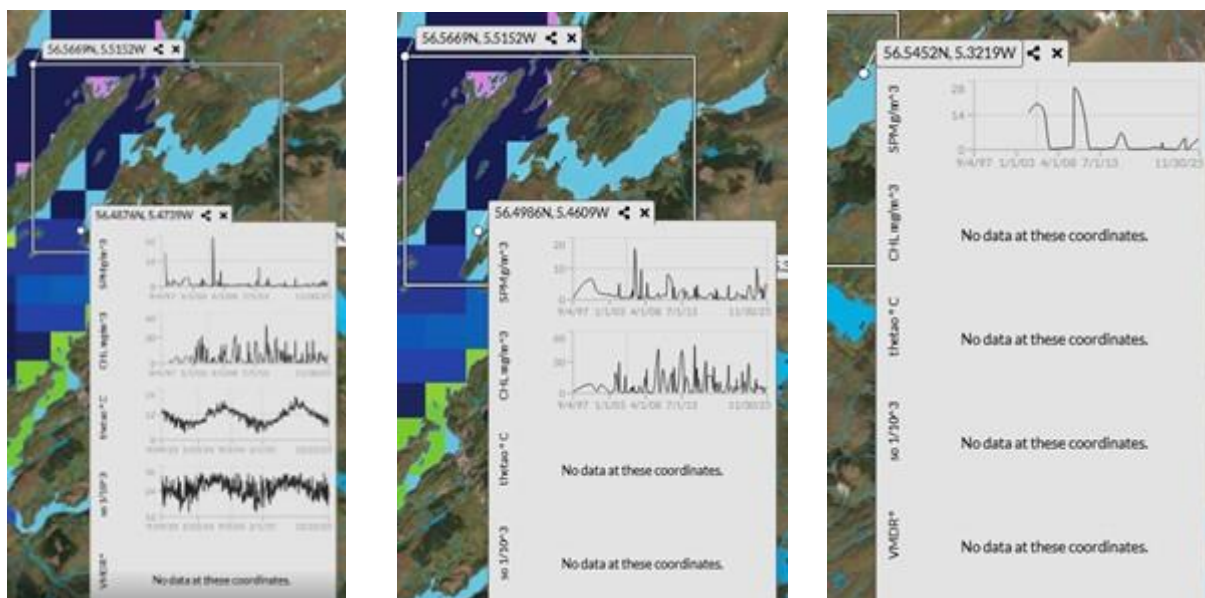


Figure 6 - Copernicus Coastal Hub database results for Turbidity, Chlorophyll A, Temperature and Salinity for, from left to right: SAMS site (Port a Bhuiltin, Loch Linnhe), Lochnell Oysters (Loch Linnhe), and Creran Oysters (Loch Creran).

Acknowledgements

Our thanks go out to all who provided data and information, and especially to the FCFCT panel for entrusting us with this pilot project. We hope that managers and shellfish farmers alike will find it useful to create growth and opportunities in the sector for superior product quality and environmental and economic sustainability.

ANNEX 1 - Data loggers SWOT analyses

Introduction

This document is a summary of a market research exercise in the context of the C-LOCH project for the Fishmonger's Company's *Challenges in the Bivalve Shellfish Industry* grant.

Early detection of changes in water quality and environmental conditions remain key concerns for coastal communities and shellfish producing businesses. Whilst relevant data sources are in parts available, they are often not accessible and/or limited regarding coverage (both for monitoring location and duration), resolution as well as data validation.

To overcome these barriers, the Coastal Local Observations Connection Hub (C-LOCH) aims to establish effective coastal partnerships using a service-based approach for environmental monitoring with shellfish producing sites at its core. C-LOCH will install environmental monitoring devices at shellfish sites across western Scotland. All data will be synthesised, analysed and put into context for the benefit of aquaculture operators, statutory bodies, and coastal communities in Scotland.

Method

A high-level scoping search (Annex 1) of sensors and data loggers was executed using search engines Google Scholar, Google and UHI scientific libraries. Scientific publications were limited to publications from 2020 onwards. A shortlist was drawn up and individual loggers were described in detail and rated according to 10 criteria (Table 1). Instruments that were considered too specialist for use by non-scientific/technical staff were not further considered and marked as “not suitable” for the purposes of the C-LOCH project.

Results

Currently available commercial off-the shelf (COTS) sensors have been mapped against a suite of criteria. Table A1 lists the attributes of logging instruments and how they are rated.

Table A2 provides the scoping exercise performed on environmental COTS.

Table A1 – Environmental COTS scoping summary, providing ratings for a list of operational and performance attributes.

Attributes	Rated				
	+++	++	+	-	--
Rating	+++	++	+	-	--
Cost	£50- 100	£100-250	£250-500	£500 - £1k	>£1k
Ease of use	V easy \longrightarrow V hard				
Deployment/ calibration/maintenance	5 min	10min	20 min	30min	>40min
Accuracy/drift	+/- 0.1% to +/- 5%				
Power consumption	One year – one month				
Service support	Responsive, high expertise service – automated				
Upgrade/repair	Easy, low/no extra charge \longrightarrow		not possible		
Adaptability and multi-use	Easy, low/no extra charge \longrightarrow		not possible		
Ruggedness and expected life	10+ years \longrightarrow		+/- 6months		
End of life/decommissioning	Return to manufacturer \longrightarrow		landfill		

Table A2 - Scoping exercise for environmental temperature loggers.

Instrument	HOBO data logger MX2201 (30m)	
Description	T measurements connect via Bluetooth Low Energy to smartphone via HOBO connect app.	
Manufacturer/supplier	Tempcon Instrumentation Ford Lane Business Park BN18 0UZ Ford, West Sussex Phone +44 (0) 1243 558270	
Price range	~£120	
Advantages	CE Marked, miniature, direct connect to phone with no extra hardware, easy to deploy and operate	
Disadvantages	Single parameter	
Links	https://www.onsetcomp.com/ https://www.tempcon.co.uk/data-loggers	
Overall rating	Cost	+++
	Ease of use	+++
	Deployment/ calibration/maintenance	+++
	Accuracy/drift	+++ V good /minimal

	Power consumption and autonomy.	Battery life 2 years typical with logging interval of 1 minute and Bluetooth Always Off enabled in software.
	Service support	+++
	Upgrade/repair	Multiparameter sensors and next generation available using same HOB0 connect platform
	Adaptability and multi-use	-
	Ruggedness and expected life	+++
	End of life/decommissioning	++ (could be recycled with small electronics)

Instrument	Gemini Tinytag Aquatic 2 TG4100	
Description	Miniature logger waterproof to 500m, suitable for longterm immersion.	
Manufacturer/supplier	Gemini Data Loggers designs and manufactures Tinytag in the UK and trades globally with a network of over 40 distributors. Gemini Data Loggers Uk Ltd. Scientific House Terminus Road, Chichester PO19 8UJ Phone +44 01243 813000	
Price range	~£200 (RS ComponentsLtd)	
Advantages	ISO 14001 and ISO9001 accredited company, data logger CE marked, miniature, easy to deploy. High visibility yellow casing. Low battery warning. Data is downloaded to the computer using a USB pad.	
Disadvantages	Single parameter, extra software licence and hardware (£35) needed (£75 together). T measurements downloaded via an inductive pad. User experience reported considerable drift and need for regular calibration.	
Links	https://www.geminidataloggers.com	
Overall rating	Cost	++
	Ease of use	++
	Deployment/calibration/maintenance	+++
	Accuracy/drift	+
	Power consumption and autonomy.	+++ Lid can be removed to enable user replacement of the battery
	Service support	+++
	Upgrade/repair	+++
	Adaptability and multi-use	-

	Ruggedness and expected life	+++
	End of life/decommissioning	+ (more waste including holding cases)

Instrument	Starmon mini/DST-centi-T	
Description	Small, high performing loggers for aquatic environments, suitable for short- and long-term oceanographic research.	
Manufacturer/supplier	Star-Oddi hf, Skeiðarás 12, 210 Garðabær, Iceland Aditech, Planet-ocean.co.uk	
Price range	~£120	
Advantages	Company also sells miniature multi parameter loggers.	
Disadvantages	Logger connects via USB A to USB mini-B cable to a PC. The SeaStar software for Windows is needed to operate the Starmon mini.	
Links	https://www.star-oddi.com/	
Overall rating	Cost	++
	Ease of use	+
	Deployment/ calibration/maintenance	+ (logger launch requires separate “communication box” connected to a PC)
	Accuracy/drift	+++ V good /minimal
	Power consumption and autonomy.	++++ Battery life 6.5 years (9)
	Service support	+++
	Upgrade/repair	Other products use different upload procedures
	Adaptability and multi-use	-
	Ruggedness and expected life	+++
	End of life/decommissioning	++

Discussion

Effective low-cost ocean observing systems should ideally comprise of a single instrument that can be easily integrated into multiple platforms. Its technical specifications should include miniaturisation, low power consumption, and easy integration into all types of oceanographic platforms. C-LOCH favoured single parameter COTS sensors for its ease of use and to provide a proof-of-concept for community-driven monitoring programmes. Single-parameter sensors are more economic than multi-parameter sensors while being limited in their monitoring capability.

The HOBO MX2201 is a Bluetooth enabled single parameter sensor from a whole suite of different models, all of which allow the site operator to upload recorded data via the HOBObconnect App to the associated platform HOBOLink.

Optical fibre sensors are worth keeping an eye on for future marine environment and marine structural health monitoring as they offer promising advantages including resistance to electromagnetic interference, durability under extreme temperature and pressures, high accuracy, light weight and small, high data transmission rate, and great flexibility. Of the few commercial options available, most are prohibitively expensive and require a level of maintenance that is outside the scope of this project and intended user group.

Table A3 – Scoping search using BOOLEAN string: “data loggers” (sensors) AND marine AND temperature OR salinity OR light, and marine AND “optical sensors” AND temperature OR salinity OR light, and organisation-wide consultation within SAMS

Instruments	Shortlist y/n	Links/comments
Atlas scientific	n	Not suitable
HOBO Water Temp Pro v2 U22-00	n	https://www.mdpi.com/2072-4292/12/7/1140
HOBO family	y	FRDC Final Report Design Standard
Greenspan	n	Electrical Conductivity Sensors EC-1000 salinity sensor Greenspan, Aus
Sontek Castaway CTD	n	£££ not suitable
EXO sondes/ YSI 600MS	n	£££
EnviteC	n	Not suitable
SeaPoint	n	Not suitable
Unilux (Chelsea technologies)	n	TriLux Low cost miniature chlorophyll sensors for early HAB detection

Seabird SBE56/SBE39/SBE37MicroCat Seabird scientific.	n	Accurate, stable, value for money for T. Used within SAMS for high precision deep measurements. Salinity is difficult and hard to measure reliably. Microcats difficult to get good data from, expensive and require regular calibration.
RBR tridente/quadrante/maestro	n	Not suitable
Valeport SWiFT	n	Not suitable
YOUNG 61302L	n	Not suitable
U24-002	n	£££
Cryo data logger	n	Not suitable
iButton	?	(0)1635 576801 phone enquiry
Smartfin	?	Enquiry sent
Gemini Tinytag	y	
ArLoc	n	Not commercially available?
Idronaut 305 Plus	n	Possibly suitable to be moored
STAR-Oddi	y	sensor drift over time may mean spend quite a lot of effort in cross-calibrating and correcting the data.
Soft Seaweed	n	Still quite experimental
NOSS NKE instrumentation	n	NOSS_UK3.pub
Campbell CR10	n	processor
Innovasea AquaMeasure	n	££££
OptiCal: Arduino data loggers combined with SAMS break out board and Cyclops7 sensor (Turner designs)	n	SAMS in house tested technology, logs for 6 months, communication via satellite, 4G or external instruments, includes GPS and clock.
Nanologger combination with SD card and open source platform Arduino	n	Less adaptable chip with less memory than the SAMS system

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<https://rbr-global.com/>

<https://rsaqua.co.uk/>

<https://www.tempcon.co.uk/>