WELCOME

Application of Sensors in Precision Aquaculture

25 May 2021 | 10:00 - 12:20

Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION

access 2sea

STREAM

Agenda

10:00 **Welcome**
Hugh O'Sullivan, Waterford Institute of Technology
Dr Sara Barrento, Centre for Sustainable Aquatic Research (CSAR),Swansea University

10:05 **Setting the stage: what is precision aquaculture?**
Dr Sara Barrento, Centre for Sustainable Aquatic Research (CSAR), Swansea University

10:10 **Access2Sea: New Opportunities for More Competitive and Sustainable Blue Growth in the Atlantic Zone**
Dr Sara Barrento, Centre for Sustainable Aquatic Research (CSAR), Swansea University

10:15 **STREAM: Sensor Technologies for Remote Environmental Aquatic Monitoring**
Prof. Carlos Garcia de Leaniz, Centre for Sustainable Aquatic Research (CSAR), Swansea University

10:20 **Application of sensors for fish health and welfare in aquaculture**
Dr Sofia Teixeira, Tyndall National Institute, Ireland

10:35 **Overview of Printable Sensors**
Prof. David Gethin, The Welsh Centre for Printing and Coating (WCPC), Swansea University

10:50 **Shellfish Aquaculture and Sensor Deployment in the Southeast of Ireland.**
Brian O'Loan, Bord Iascaigh Mhara

11:05 – 11:20 BREAK

Agenda

11:20 **Coastal Monitoring Radar**
Paul Shanahan, National Maritime College of Ireland

11:35 **Aquaculture at the Centre for Sustainable Aquatic Research using sensors**
Paul Howes, Dr Pete Jones and Dr Josh Jones, Centre for Sustainable Aquatic Research, Swansea University

11:50 **Reverse engineering a machine vision solution for aquaculture**
Dan Rusu, Gyopár Elekes, faptic.xyz

12:05 **SeaLens technology to monitor 3D aquaculture in Wales**
Christian Berger, PEBL- Plant Ecology Beyond Land

12:20 **Closing Remarks**

Setting the stage: what is precision aquaculture?

Dr. Sara Barrento
Swansea University
Centre for Sustainable Aquatic Research

Application of Sensors in Precision Aquaculture

25 May 2021

Aquaculture

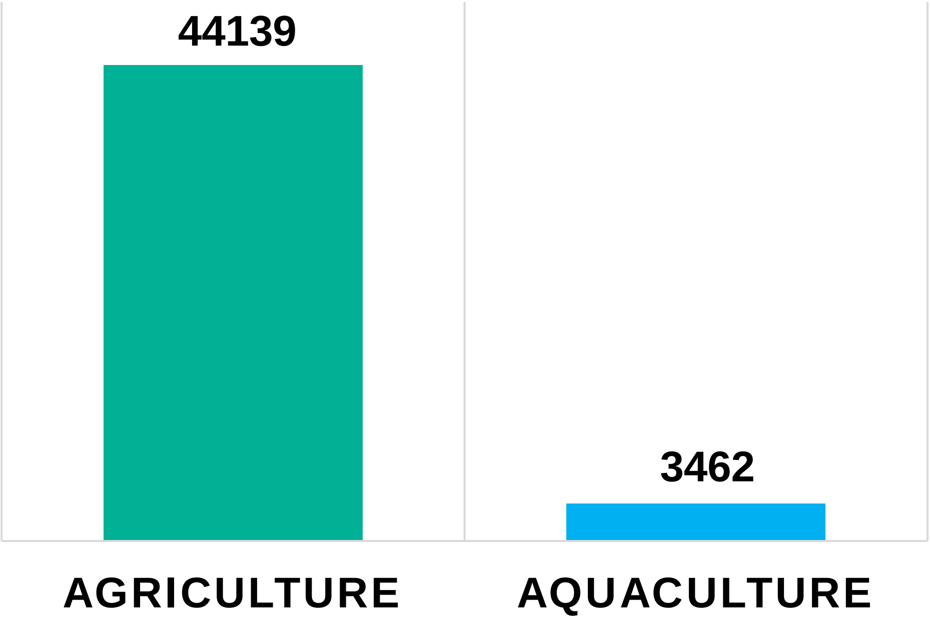
The farming of aquatic organisms

- Fish
- Molluscs
- Crustaceans
- Aquatic Plants
- Amphibians …

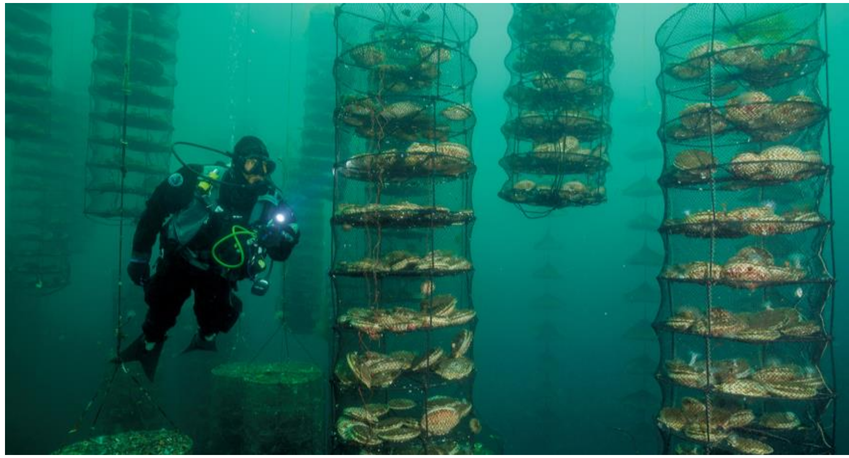
Precision aquaculture

The acquisition and interpretation of data about the aquatic environment and farmed species through sensors that can provide **decision support for farm operations**.

Precision farming is not a new concept



Number of Review articles, Research articles and Book chapters retrieved from Science Direct search **2015-2021**



Challenges

- Harsh environment
- Access can be impeded by weather
- Power and connectivity
- Large range of spatial scales

Precision Aquaculture

The motivation…

Farms are getting bigger and moving offshore	Pressure from consumers and regulators	New real-time sensor technologies

Precision aquaculture: the framework

DATA COLLECTION & INTEGRATION

Aquatic Environment
- Temperature
- Nutrients
- pH
- Salinity
- Pollutants

Species related data
- Biomass
- Behaviour
- Physiology

Existing data
- Weather
- Hydrography

DATA ANALYSES

Modelling and Insight
- Image analyses
- Species growth
- Forecasts

SUPPORT DECISION

- Feed management
- Harvesting schedule
- Veterinary intervention
- Early warning
- Risk analysis

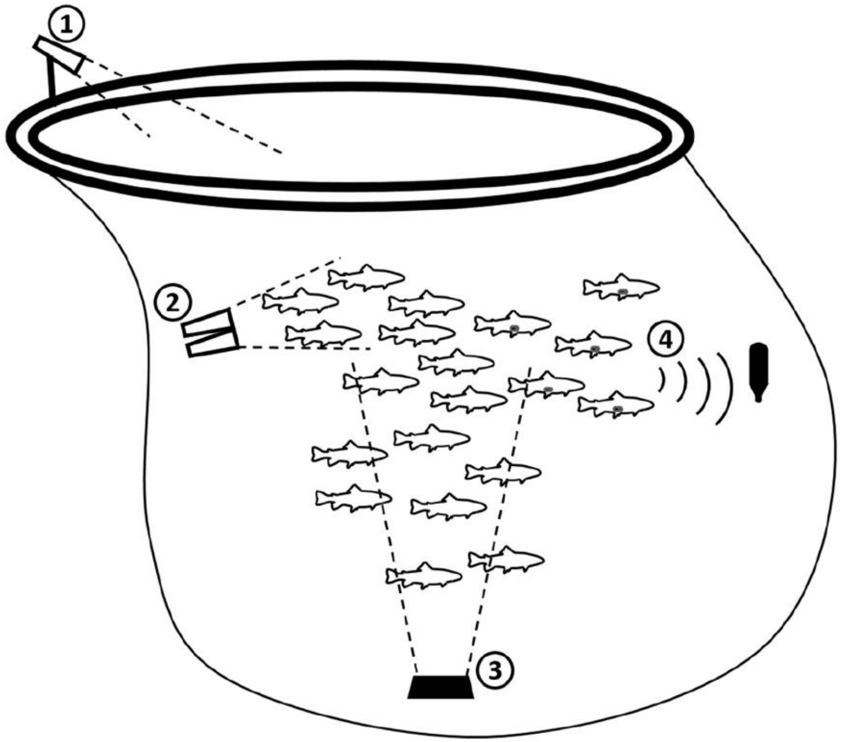
Observe

Interpret

Decide and act

Precision Aquaculture

What does it look like?



1 Surface camera
2 Stereo video
3 Sonar
4 Acoustic telemetry

5 - Water quality probes
6 – Local weather station
7 – Satellite-based monitoring

Real Time Monitoring

<u>Føre</u> et al. 2018
Biosystems Engineering
Volume 173, September 2018, Pages 176-193

Precision aquaculture: moving forward

Sensors need to be:

- robust
- low-cost
- capable of underwater and in-air wireless connectivity
- high level of Interoperability

Data Management

Models need to be robust

Security and sovereignty of data is critical to exploit technology in an ethical and commercially sustainable way.

Thank you

Dr Sara Barrento
s.i.barrento@swansea.ac.uk

Access2Sea: New Opportunities for More Competitive and Sustainable Blue Growth in the Atlantic Zone

Dr. Sara Barrento

Swansea University
Centre for Sustainable Aquatic Research

Application of Sensors in Precision Aquaculture

25 May 2021

Access2Sea aims

to improve the availability of the Atlantic shore for aquaculture SMEs

How?

By Enabling

- *business opportunities*
- *more sustainable operating environment*

Partners

UNITED KINGDOM

- Swansea University|Centre for Sustainable Aquatic Research

IRELAND

- Udarás na Gaeltachta (Agencia de Desarrollo)
- WestBIC

SPAIN

- CEEI Bahía de Cádiz (Lead Partner)
- CTAQUA

PORTUGAL

- CIIMAR – Marine and Enviromental Research
- Centre of the University of Porto
- Universidad de Algarve

FRANCE

- Investir en Finistère
- Technopole Quimper - Cornuaille

Access2Sea Products

An opportunities map for aquaculture in the "Access2Sea" Atlantic Coastal Region.

SPATIAL PLANNING

SOCIAL ACCEPTABILITY

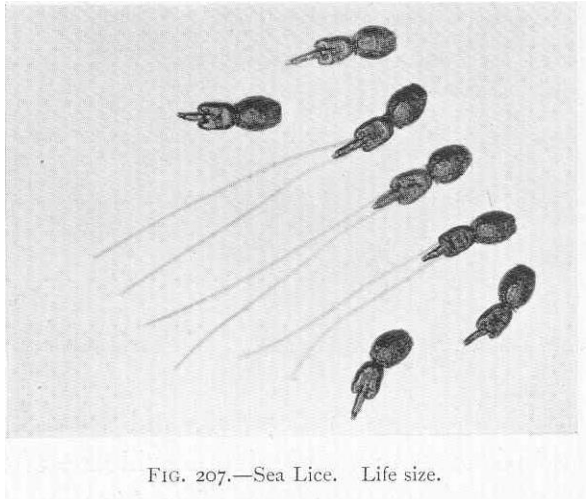
A Strategy to improve the acceptability of aquaculture

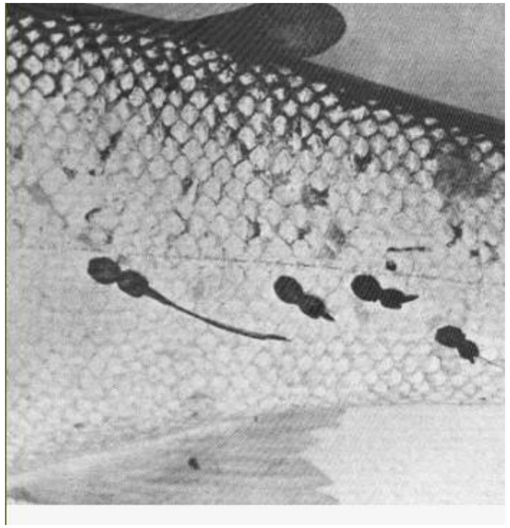
Business Model Guides and roadmap

BUSINESS MODELS

PILOT PROJECTS

Every year the salmon industry needs 50 million lumpfish to clean salmon off sea lice





Sealice are external parasites that feed on the skin and mucus of the Atlantic salmon

Sea lice impact salmon

- Growth
- Health
- Welfare

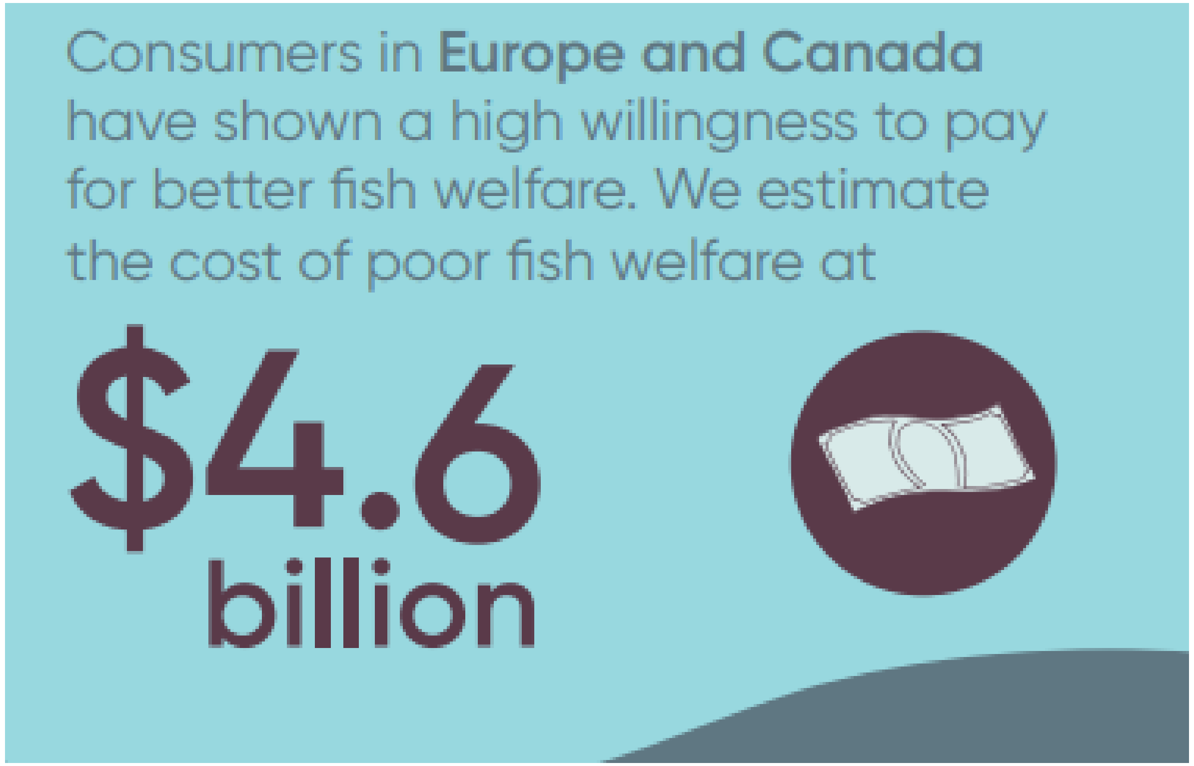
Studies suggest that lumpfish can reduce the use of anti-sea lice drugs by 80%

BUT

The salmon farming industry has been criticized for not doing enough to maintain the welfare of lumpfish.

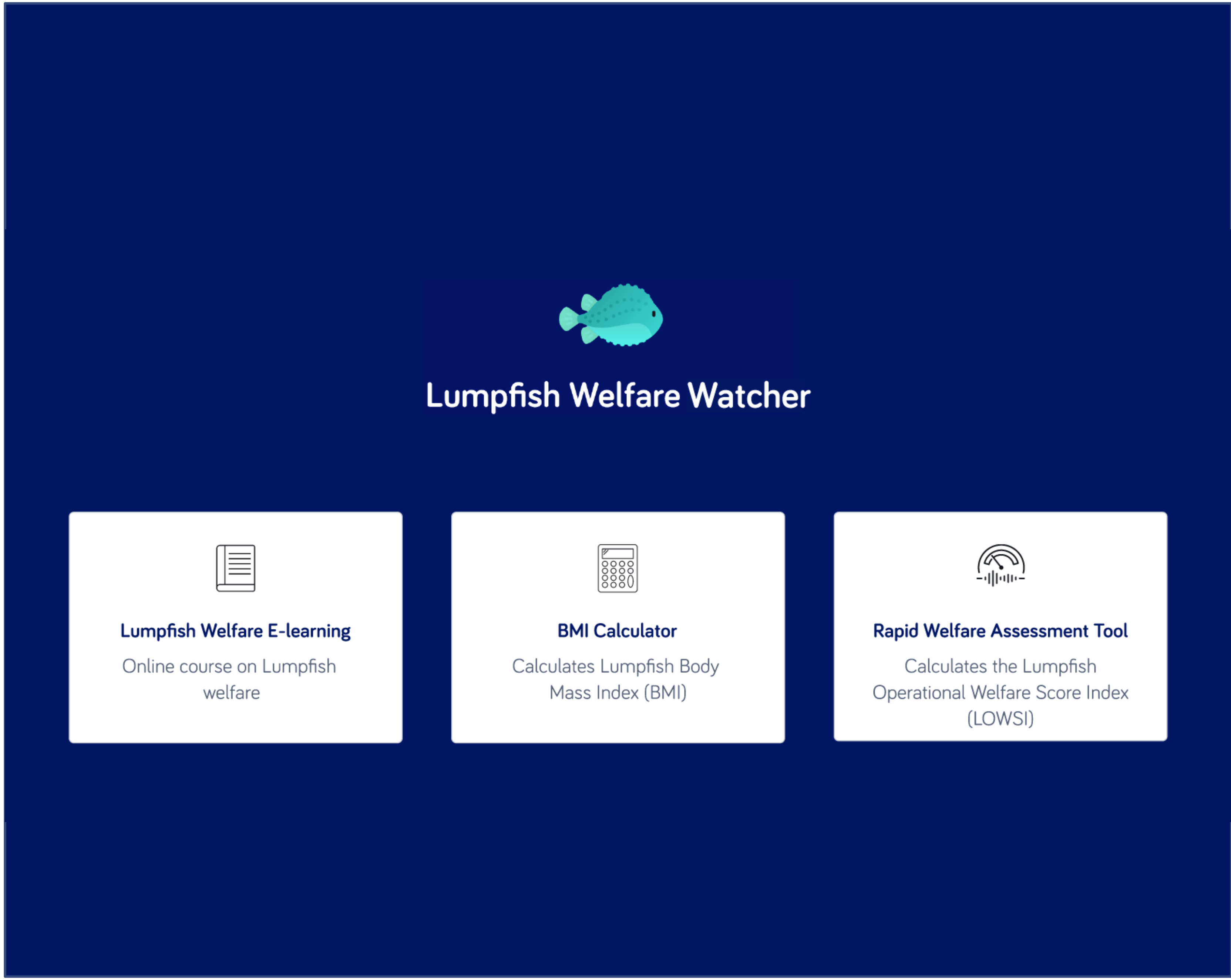
Concern among consumers prompted pressure groups to **discourage the use of cleaner fish until welfare standards are met**.

Lumpfish welfare
driving fish aquaculture social acceptability



Solutions

SU is developing technology to improve welfare practices. Fish farmers will be able to monitor and record the welfare of lumpfish and take remedial actions.



Lumpfish Welfare Tracker

Data analyses and support decision

Data

- BMI
- body height
- weight class
- fineness
- LOWSI

Summary results and welfare plan:

- Proportion of fish that are emaciated, underweight, normal or overfed
- Maximum mesh size that should be used to prevent lumpfish from escaping from sea cages
- Basic statistics descriptors
- Remedial actions

Thank you

Dr Sara Barrento
s.i.barrento@swansea.ac.uk

STREAM: Sensor Technologies for Remote Environmental Aquatic Monitoring

Prof. Carlos Garcia de Leaniz
Centre for Sustainable Aquatic Research (CSAR), Swansea University

Application of Sensors in Precision Aquaculture

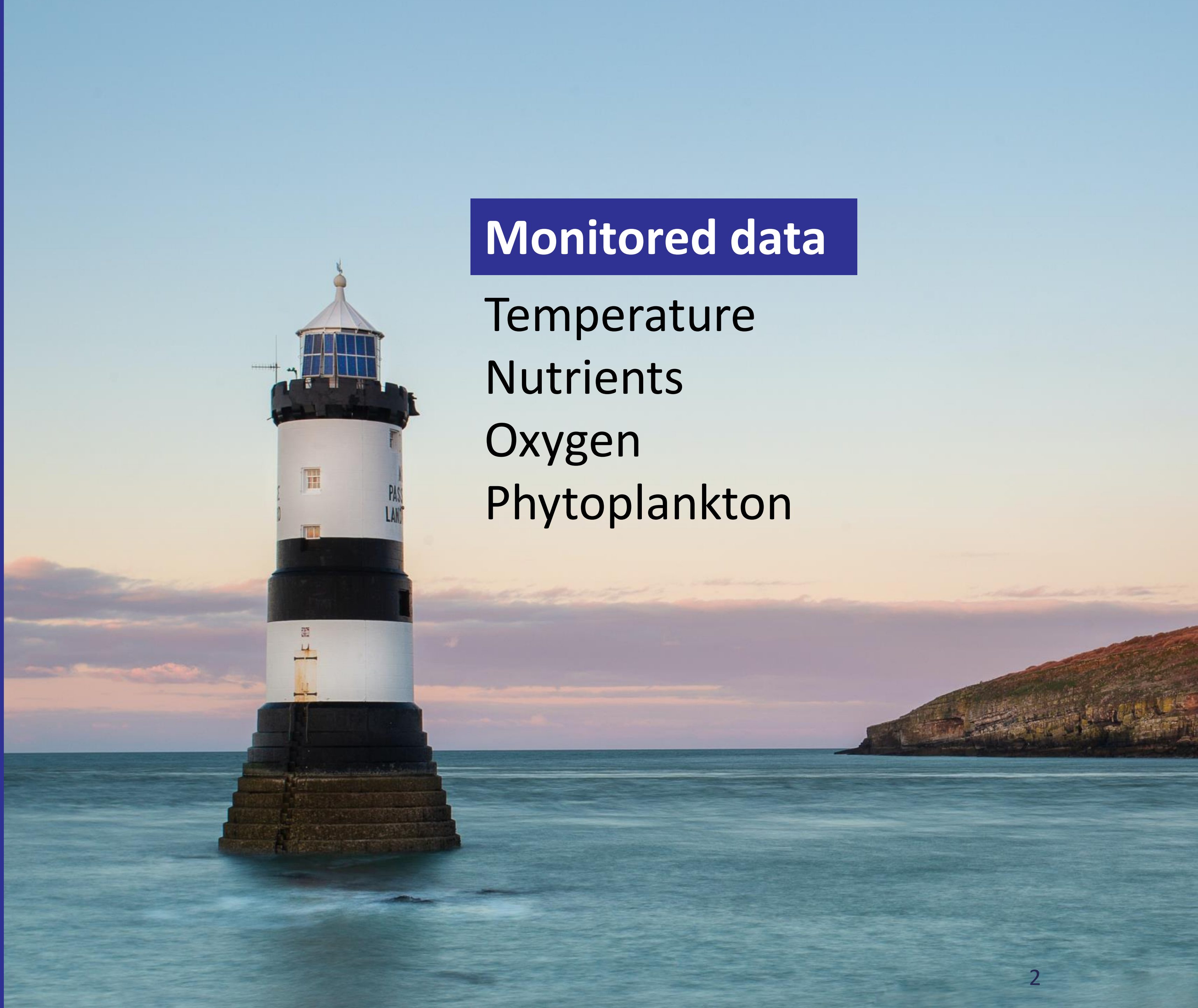
25 May 2021

STREAM

STREAM

Purpose:

to monitor the Coastal and Estuarine environment around both Ireland and Wales



Monitored data

Temperature
Nutrients
Oxygen
Phytoplankton

The Team

Waterford Institute of Technology

Waterford Institute of Technology

Waterford Institute of Technology (WIT) offers expertise in the development of optical sensors and electronic platforms for advanced sensor technologies through the smart systems development laboratory hosted within the **Pharmaceutical and Molecular Biotechnology Research Center (PMBRC).** The **Walton Institute** offers expertise in advanced data networking processing and storage.

Waterford Institute of Technology

- Dr Joseph O'Mahony
- Dr Peter McLoughlin
- Benyuan Yu
- Stephen Norton
- Hugh O'Sullivan
- Jerry Horgan
- John Ronan

Principal Investigator and Project Lead I WIT I PMBrc

Dr O'Mahony heads up the Smart Systems Development Lab where his research interests include organic electronics, scanning probe microscopy and nanosensing. He is responsible for developing the STREAM manufactured Optical Sensors.

Contact Dr Joseph O'Mahony

Munster Technological University

Munster Technological University (MTU) is a multi-campus technological university and the newest in Ireland. **The Mass Spectrometry Group** at MTU has a long-established background in analytical chemistry, with extensive experience and capability in the areas of elemental and toxicology analysis using techniques such as separation chromatography and mass spectrometry. **The Halpin Centre for Research and Innovation** undertakes maritime research for the **National Maritime College of Ireland (NMCI).** The centre is a key partner in Ireland's national effort to build a strong maritime sector.

Munster technological university

- Cormac Gebruers
- Dr Ambrose Fury
- Dr Naghmeh Kamali
- Paul Shanahan
- Mike Griew
- Brid Cripps

Head of CollegeI PI I NMCI

Cormac is the founding Manager of the HALPIN Centre. Cormac is a member of the NMCI College Senior Executive Team, of the MTU Research Ethics Committee and the MTU School of Graduate Studies Steering Committee.

Contact Cormac Gebruers

Swansea University

Prifysgol Abertawe
Swansea University

Swansea University is a research-led university that has been making a difference since 1920. The University community thrives on exploration and discovery.

The Welsh Centre for Printing and Coating (WCPC) offers state of the art laboratories at Swansea University's Bay campus, that are dedicated to the fabrication of the sensor technologies required by the STREAM operation. The WCPC is a university recognised research centre that has a strong track record in undertaking fundamental and applied research in printing, including graphics and functional materials. It is recognised Internationally and is seen as a World leader in this field.

Centre for Sustainable Aquatic Research (CSAR) delivers innovative impacts in the aquatic sciences and education sector and has been a Centre of Excellence since 2003. CSAR have the best facilities in Europe for applied and fundamental research on aquatic ecosystems and organisms from temperate to tropical and marine to freshwater environments. CSAR will be testing the sensor technologies in controlled recirculating aquaculture system.

Swansea University

- Prof. David Gethin
- Dr Ben Clifford
- Prof. Carlos Garcia de Leaniz
- Dr Sara Barrento
- Paul Howes
- Dr Josh Jones
- Dr Peter Jones

Professor in Engineering I Swansea University I WCPC

Professor Gethin is a mechanical engineer and the Co-founder and Co-director of the Welsh Centre for Printing and Coating. Professor Gethins research interests include powder forming with emphasis on tabletting; fundamental scientific work on high speed, high volume graphics printing processes and applied research in the field of polymer electronics with a future emphasis on biopolymers and biosensing devices.

Contact Prof. David Gethin

Work Packages

Work Package 1: Management and Governance

This work package establishes the management structures for the STREAM operation. STREAM will successfully meet its aims and objectives through careful coordination of the operation's activities which will be led by WIT in Ireland and SU in Wales.

Work Package 2: Specification

In the specification stage, the partners will confirm the specification of the operation and the location and scope of monitoring activity for each site in SE Ireland and Wales.

Work Package 3: Dissemination

In this work package we will develop the STREAM website; promote the project among Stakeholders, Coastal Communities and the General public.The key aim is to Build Awareness of Climate Change impacts and Disseminate the Scientific publications.

Work Package 4: Development of ICT enabled Sensor Technologies for Estuarine Monitoring

Within this work package the sensor and ICT technologies will be developed. SU will develop a range of physical and chemical sensor technologies that will be interfaced with the Wireless Communications System developed by WIT-NRG. Additionally, WIT will develop a suite of wireless enabled optical sensors for the monitoring of Harmful Algal Blooms in estuarine and coastal waters.

Work Package 5: Estuary Water Sampling & Precipitation Monitoring

In this work package partners will develop, deploy and test an innovative portable submersible adsorbent pumping platform to pre-concentrate marine bio-toxins and chemical contaminants in estuarine waters.

Work Package 6: STREAM Deployment

In this work package, sensor technologies will be deployed and modern ICT constructs such as sensor fusion and data fusion will be developed to minimize uncertainties in the returned data. These constructs will be developed further in Work Package 7 with the inclusion of data mining operation.

Work Package 7: Building capacity to respond to climate change impacts on the Irish Sea

This work package is focused on providing a predictor – response solution to climate change impacts, in this scenario the monitoring system acts as the predictor of events, these events are simulated in the laboratory and the response is scientifically determined for different scenarios.

How to collect environmental data?

Using affordable sensors

Commercial sensors

Develop new sensors

Test the performance of the STREAM developed sensors against the industry standard

Deployment

Deploy a temporally and spatially sophisticated array that will monitor the coastal and estuarine environment in high resolution.

Portal

Create an online portal where users can access live and archival data from these sensor systems.

Thank you

STREAM

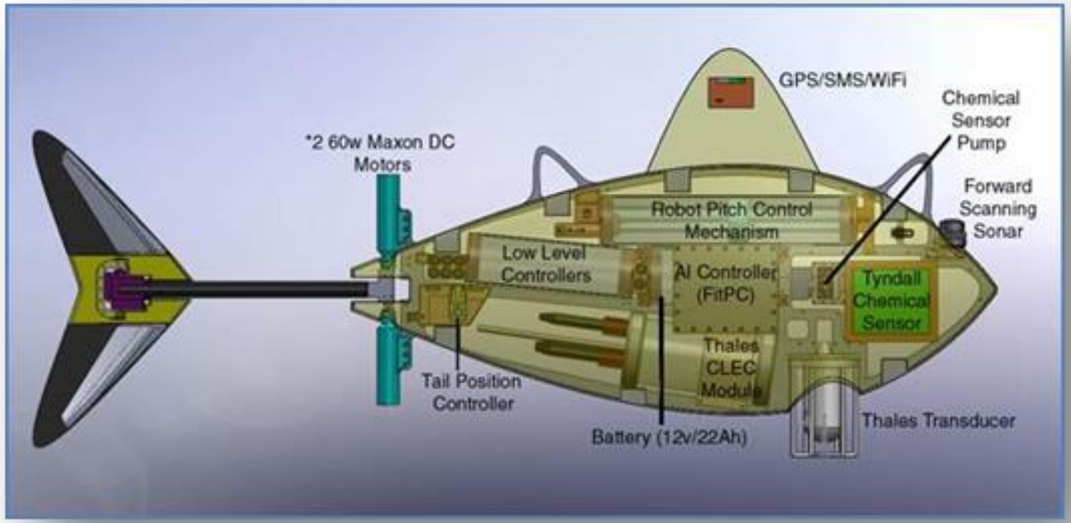
Application of sensors for fish health and welfare in aquaculture

Dr Sofia Teixeira

Tyndall National Institute, Ireland

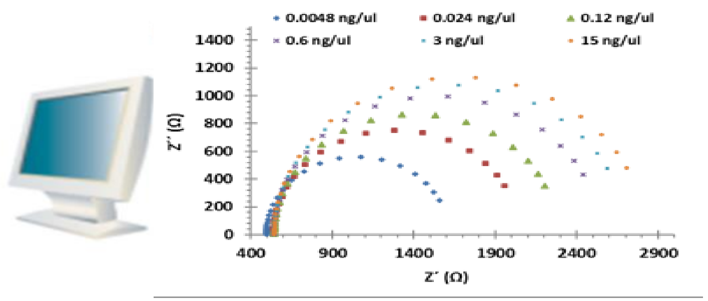
Application of Sensors in Precision Aquaculture

25 May 2021

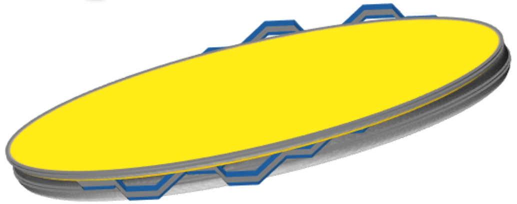


Flexible, label free

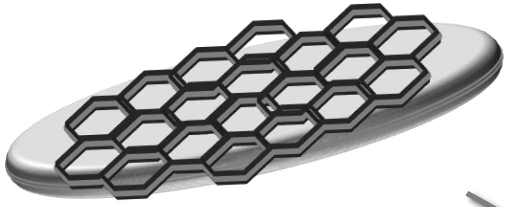
Electrochemical output



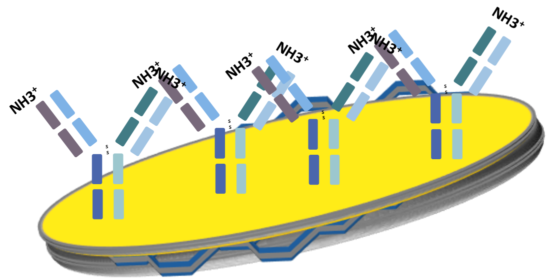
Surface Chemistry

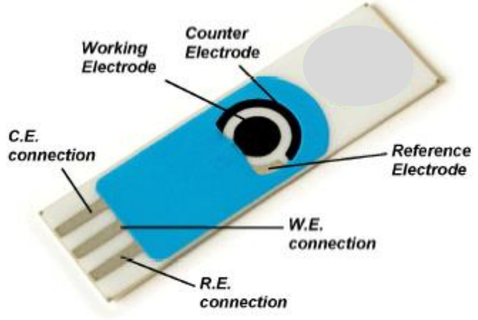


Materials

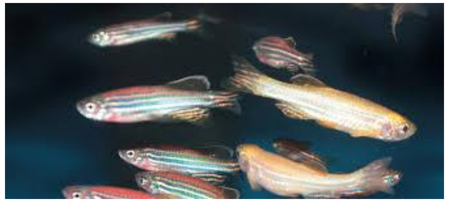


Bio-receptor

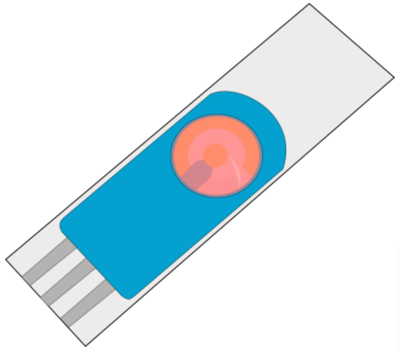




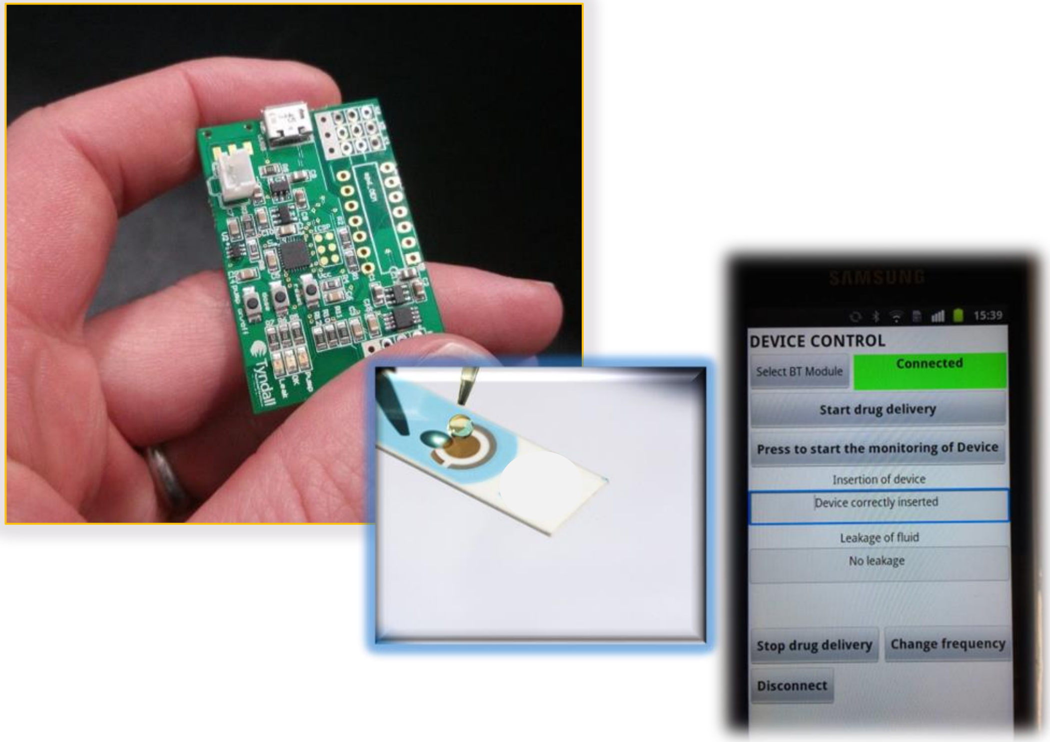
Quantification of Biomarkers

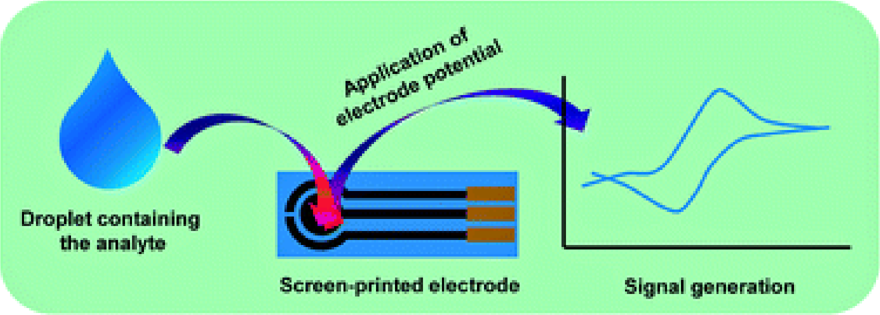


1. Identification of specific biomarkers



2. Biosensor development for objective biomarker selection



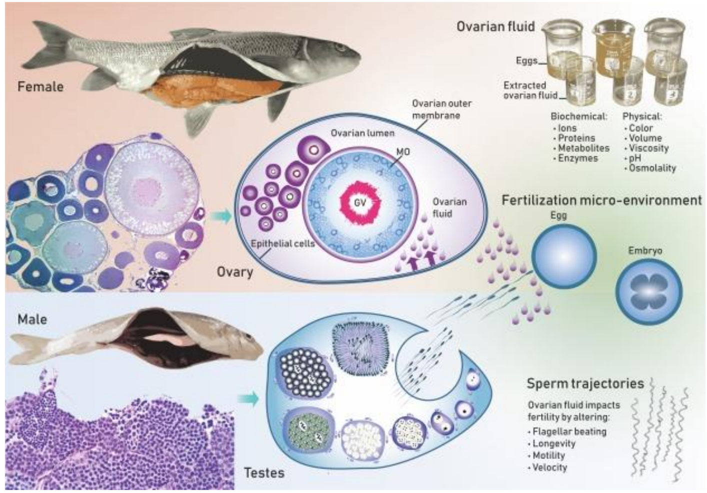


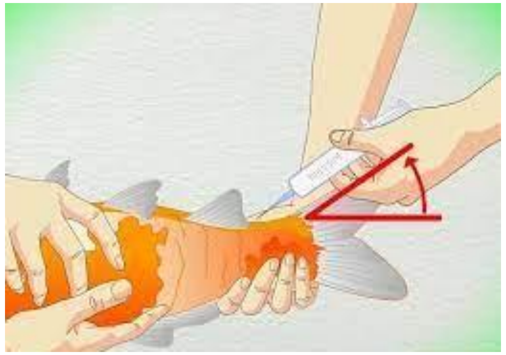
Biomarkers for…

SCREENING	DIAGNOSIS
Highly specific, minimize false positive and negative	Sensitivity, specificity, and accuracy
Easily detected without invasive procedures	Be prognostic of outcome and treatment
Cost effective	

Biomarkers for…

- Blood
- Urine
- Other body fluids
- Tissue samples



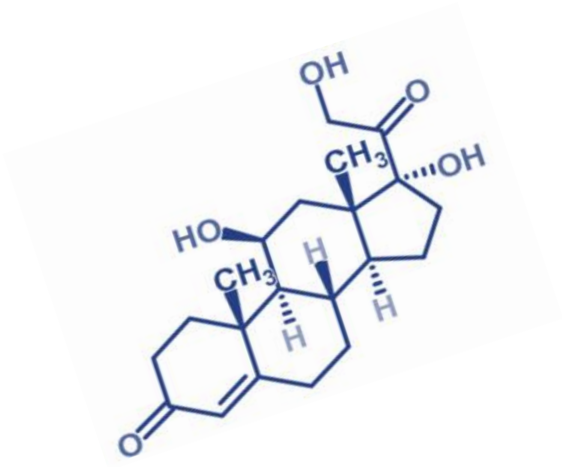


Cortisol

Exposure to causes of stress

Production and secretion of cortisol

from adrenal glands



Altered cortisol levels

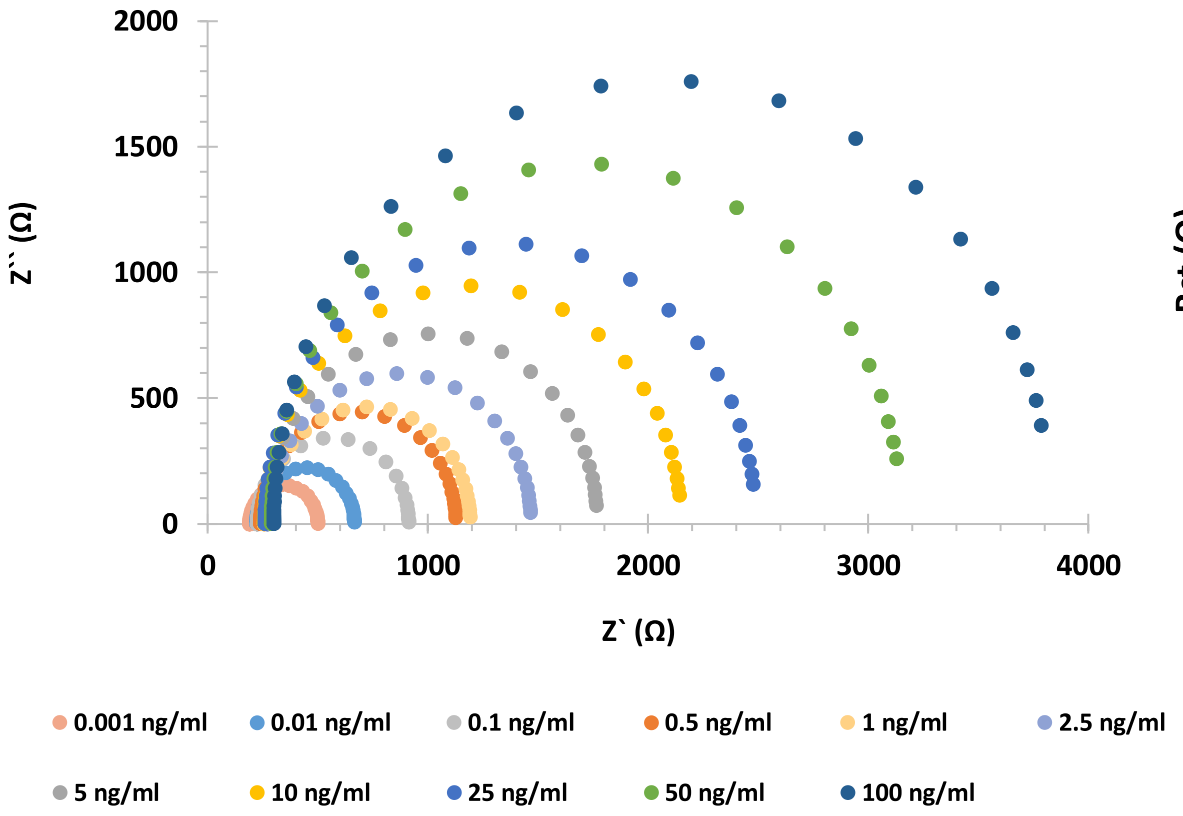
linked to a range of stress-related disorders.

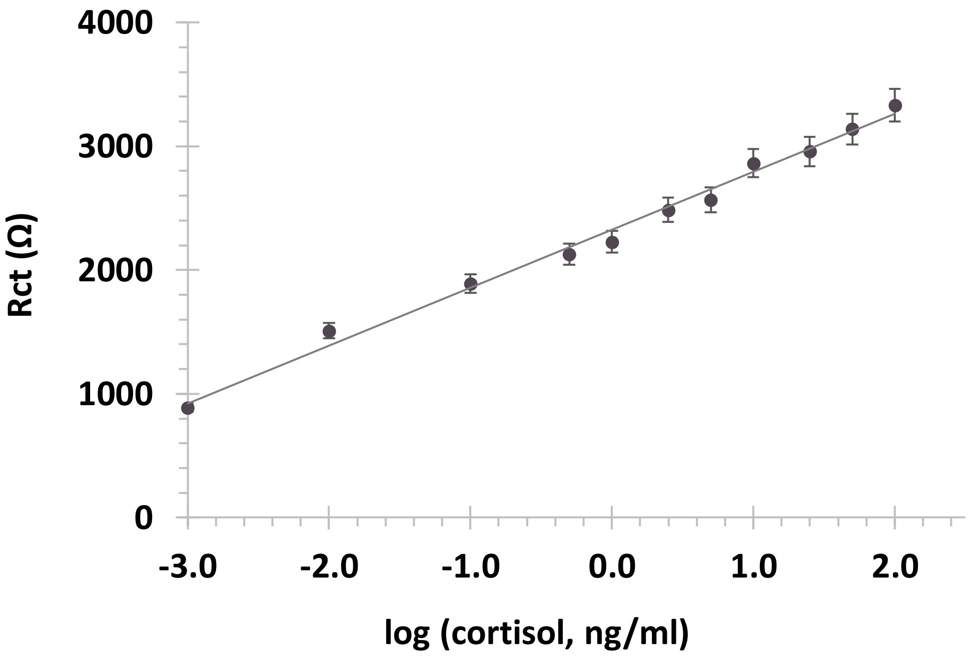
cortisol levels

10^{-7} – 10^{-6} M (high)

10^{-9} – 10^{-8} M (low)

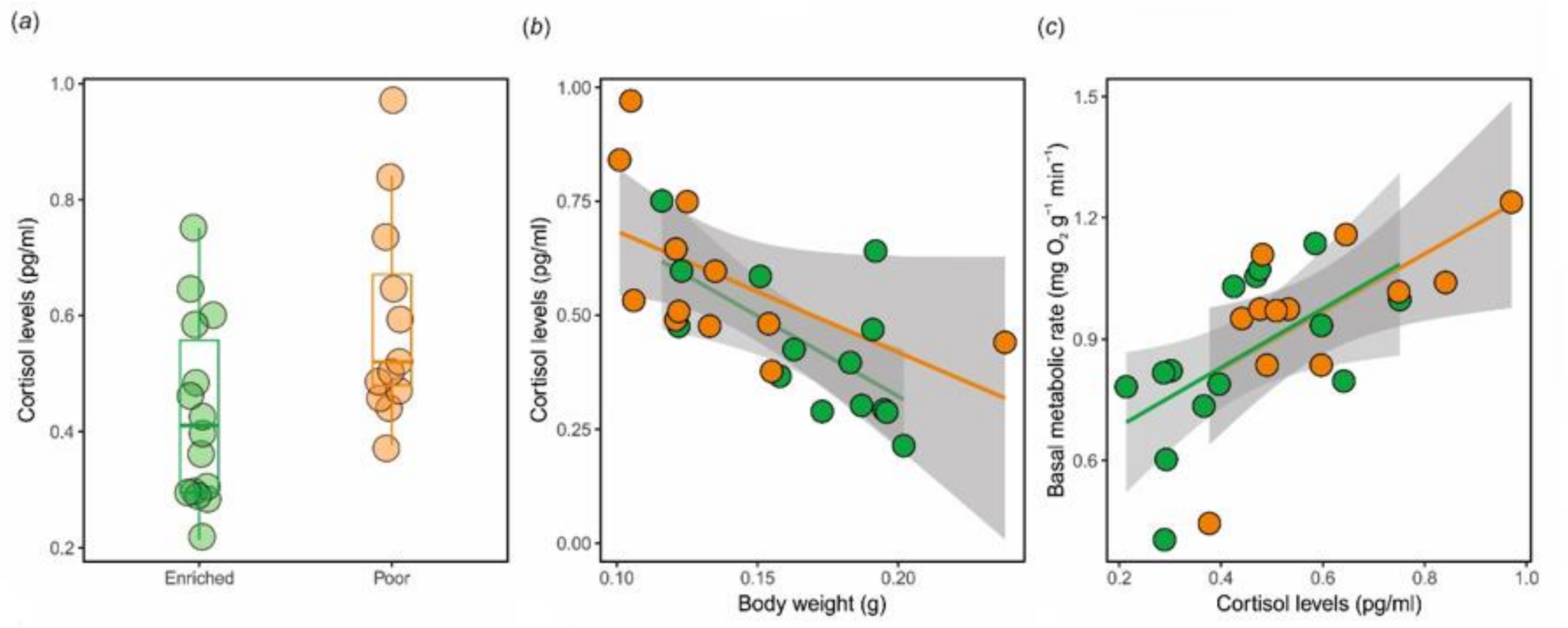
Analytical Response - Detection





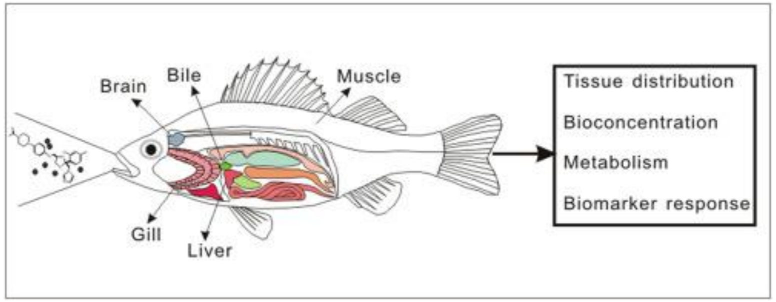
LOD = 0.005 pg/ml = 5fg/ml

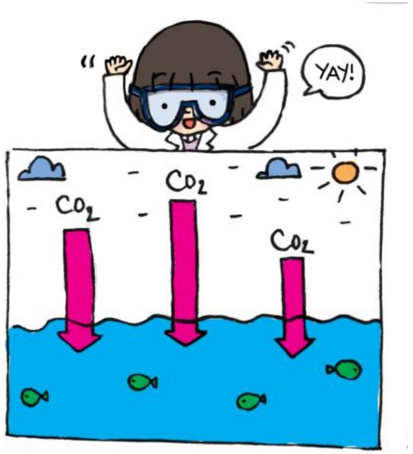
Analytical Response - Physiological and behavioural relationships

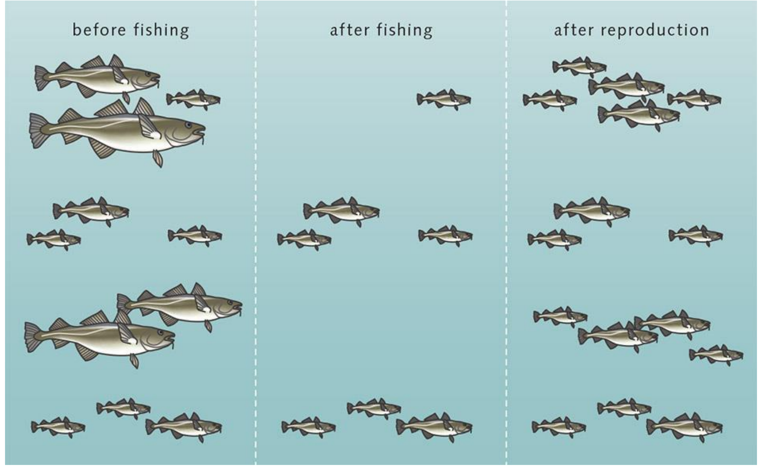


Applications on Welfare in Aquaculture

- ☐ Stress
- ☐ Immune Function
- ☐ Metabolism changes
- ☐ Natural Behavior
- ☐ Reproductive capacity
- ☐ Growth Changes



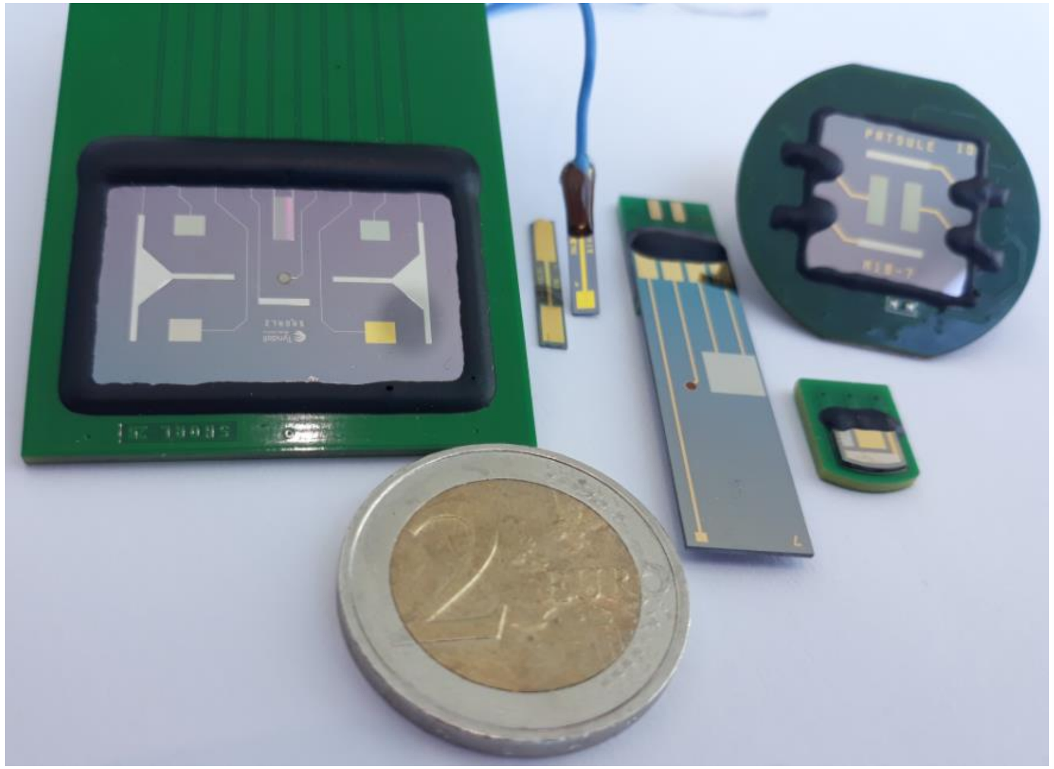


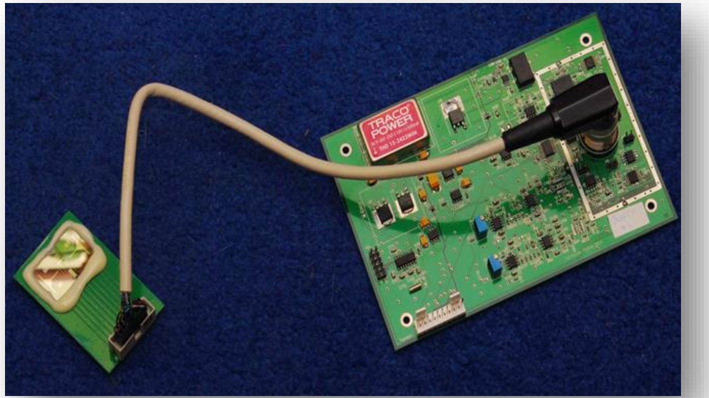


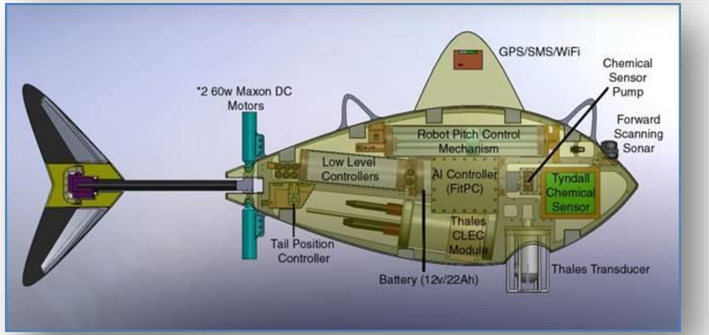
Smart Sensors for Wellness and Health in aquaculture

ENTERPRISE IRELAND

European Union
European Regional
Development Fund







www.roboshoal.com
FP7-ICT-231646

Acknowledgments

E-mail: sofia.teixeira@tyndall.ie
LinkedIn: https://www.linkedin.com/in/sofia-teixeira-690564b/
UCC website: http://research.ucc.ie/profiles/E024/sofia.rodriguesteixeira@ucc.ie

Overview of Printable Sensors

Prof. David Gethin

d.t.gethin@swansea.ac.uk

Swansea University

Welsh Centre for Printing and Coating (WCPC)

Application of Sensors in Precision Aquaculture

25 May 2021

Sensors for Aquatic Monitoring

Several commercial systems available to measure key parameters:

1. Temperature (5 - 25°C)
2. pH (6-10)
3. Salinity (0-50pss)
4. Dissolved oxygen (0-20mg/l)
5. Total dissolved solids (0-60g/l)
6. Dissolved organic matter
7. Chlorophyl (0-200µg/l)
8. Turbidity (0-3000NTU)
9. Ionic salts (Nitrates etc)
10. …….

EXO2 Sonde – courtesy Xylem Analytics

Values in brackets are typical, generally commercial sensors have a wider working range

Data Capture, Retrieval and Management

Several options available

- Hand held from the sonde
- Wireless transmission to a receiving portal
- Very large data volumes can be generated

Management

- Time trend displays
- Space variation displays
- ……….
- Big data analytics

The Need for Printable Sensors and Challenges

Commercial systems are accurate, but high cost

- Sonde + sensors – typically £20k
- Prevents widespread monitoring of aquatic environments

Printable sensors

- Offer potential for lower cost solutions
- Sensors to measure a range of parameters may be fabricated as an integrated system

Challenges

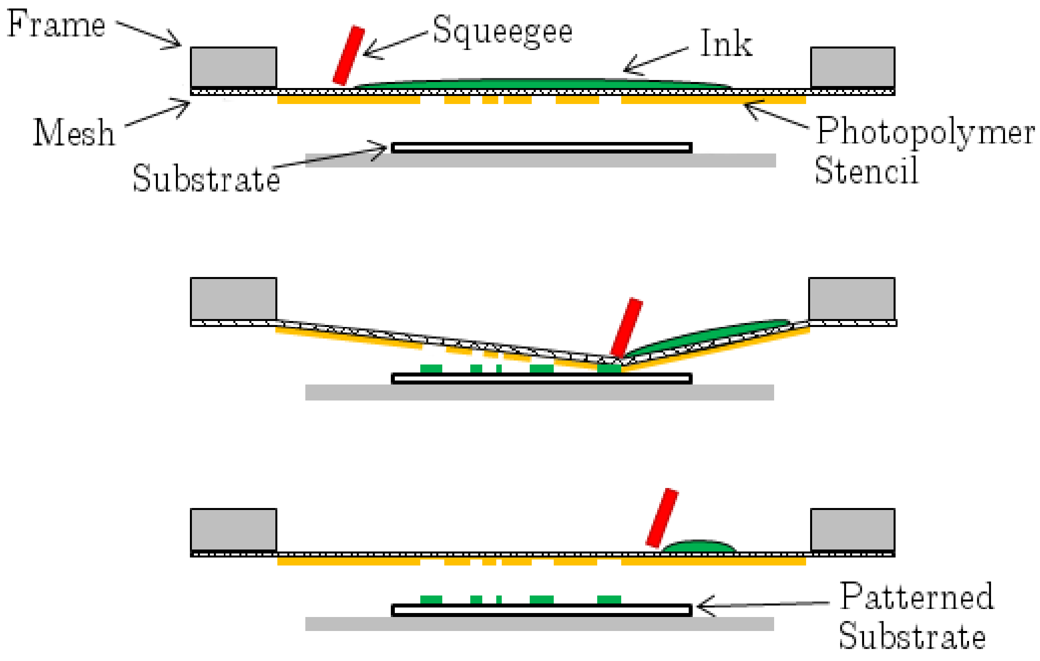
- Measurement accuracy – calibration against laboratory and commercial devices
- Survival in a harsh environment
- Working duration

Potential Printed Sensors

1. Temperature (5 - 25°C)
2. pH (6-10)
3. Salinity (0-50pss) – via conductivity
4. Dissolved oxygen (0-20mg/l)
5. Total dissolved solids (0-60g/l) – via conductivity and temperature

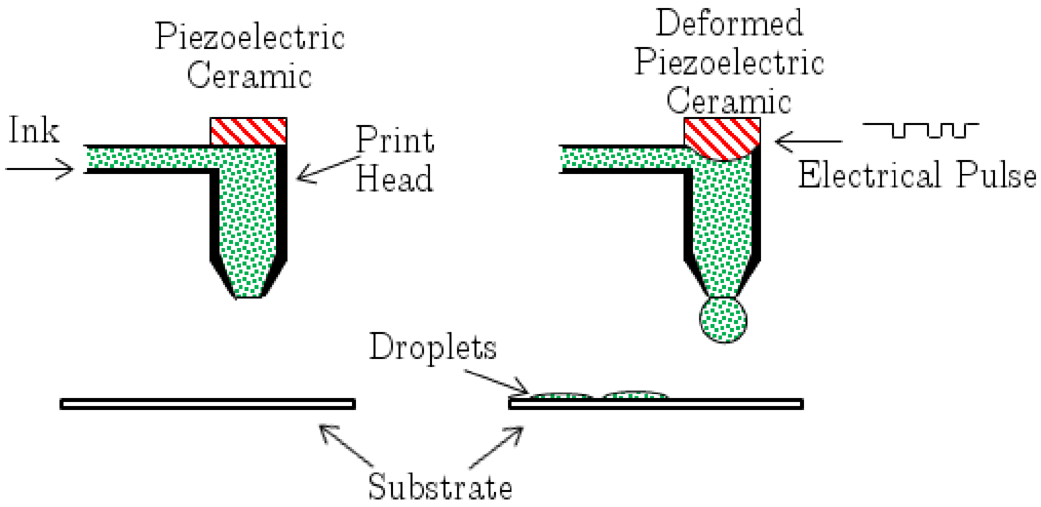
Remaining parameters may be measured by optical methods (being developed by Waterford)

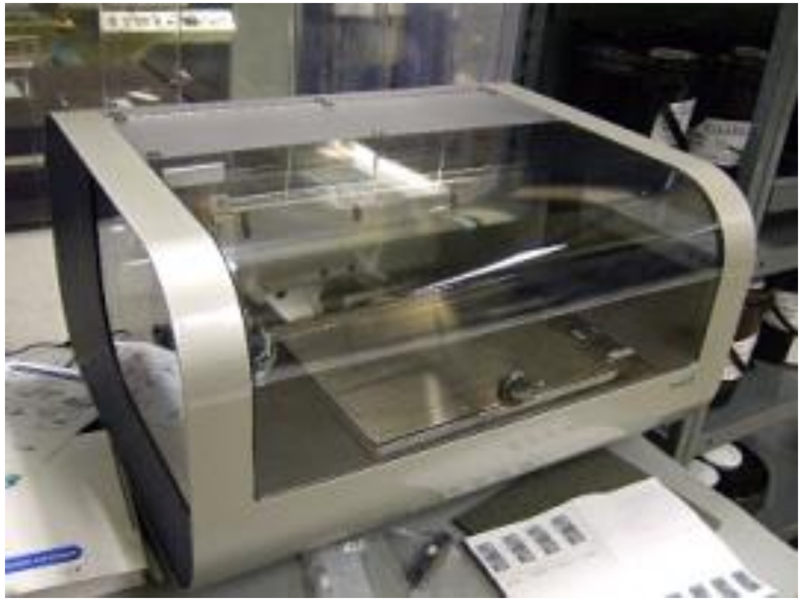
Potential Printing Methods - Screen



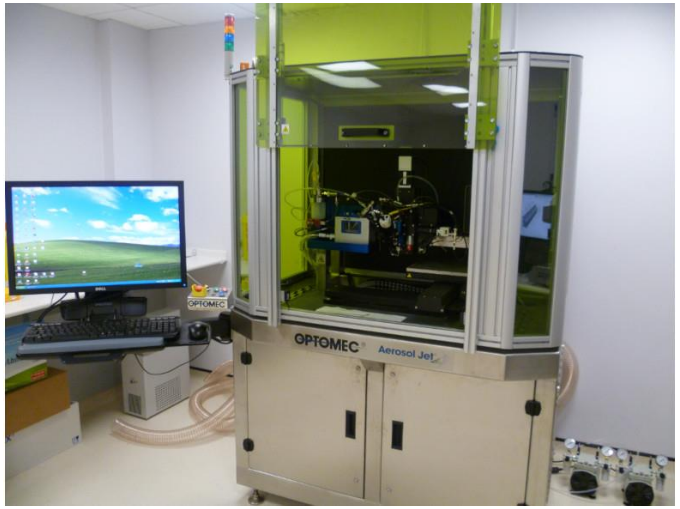
Screen is the principal process for sensor printing

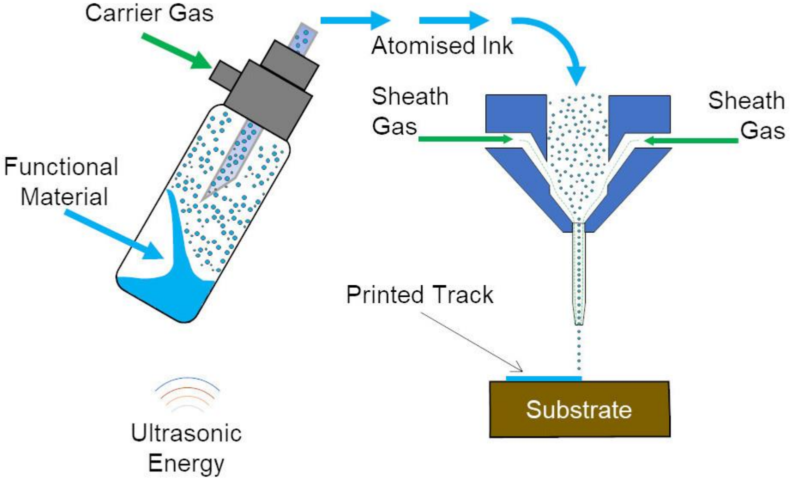
Potential Printing Methods - Inkjet

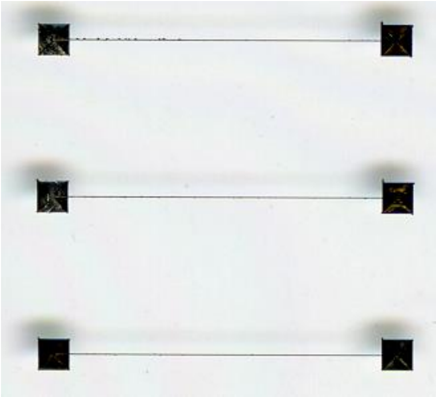


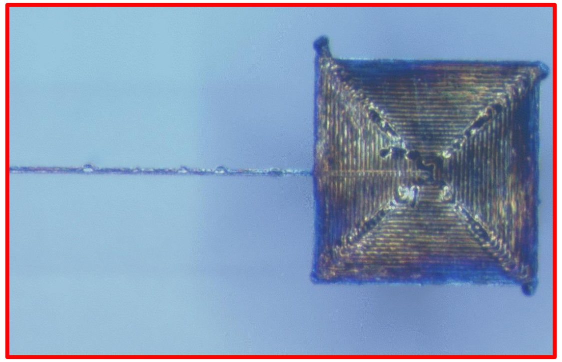


Potential Printing Methods – Aerosol Jet

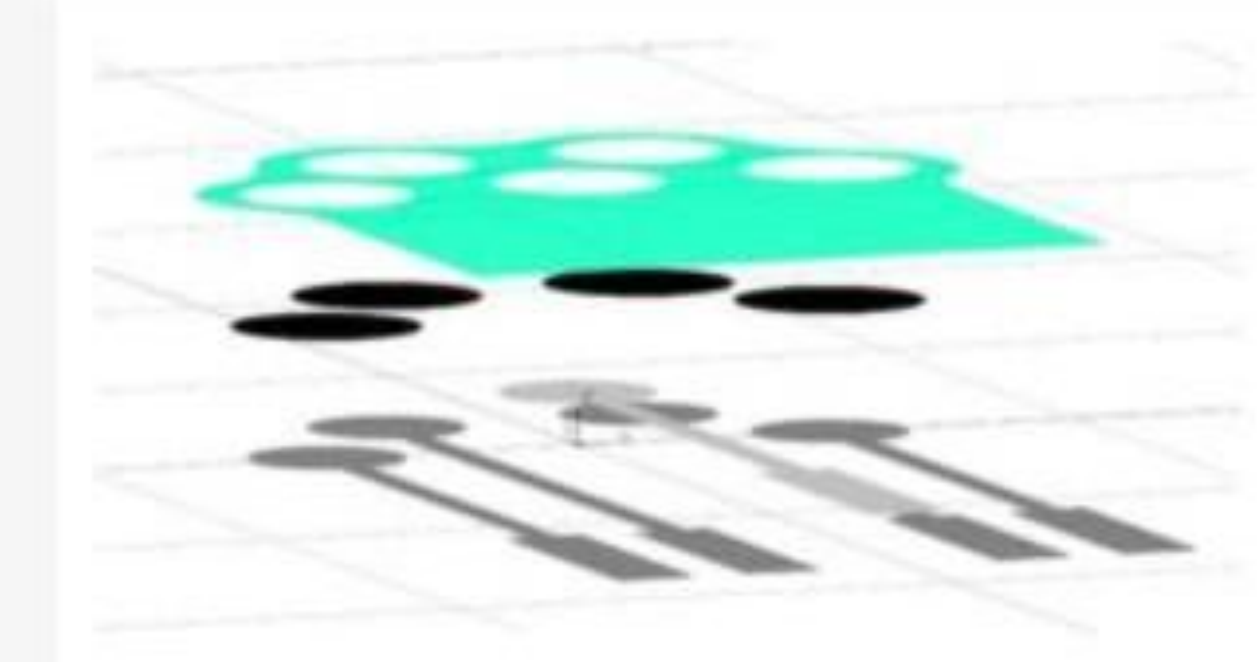


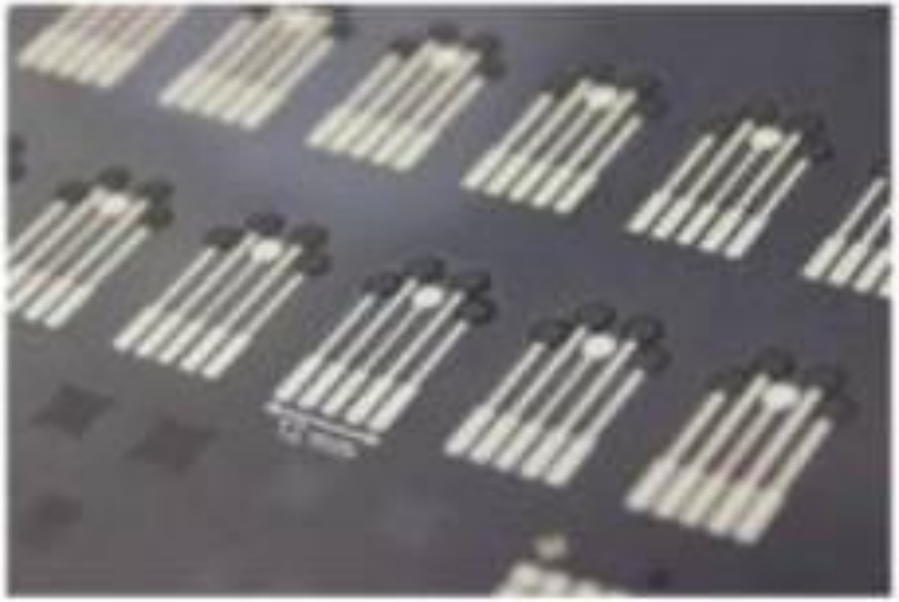




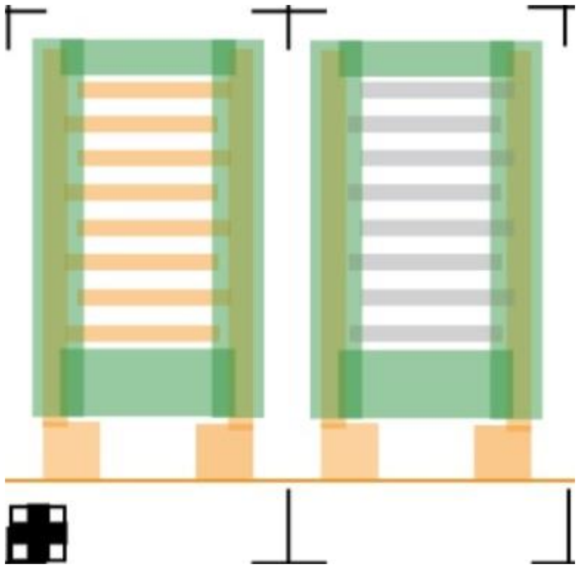


Fabricating a Sensor – multiple layers

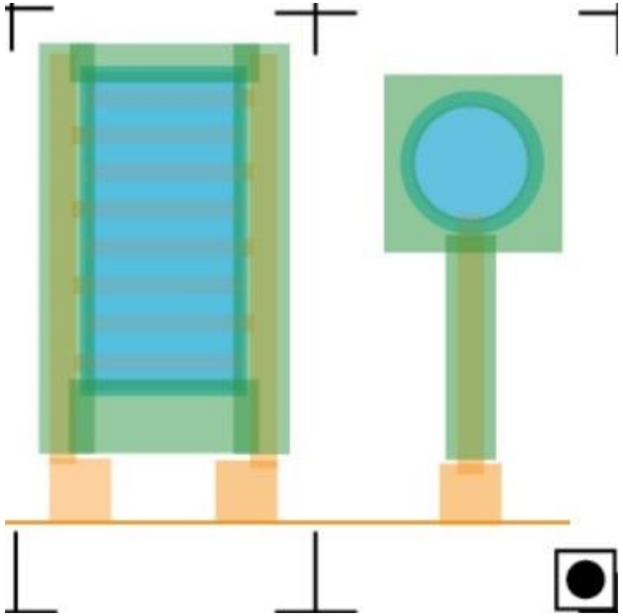




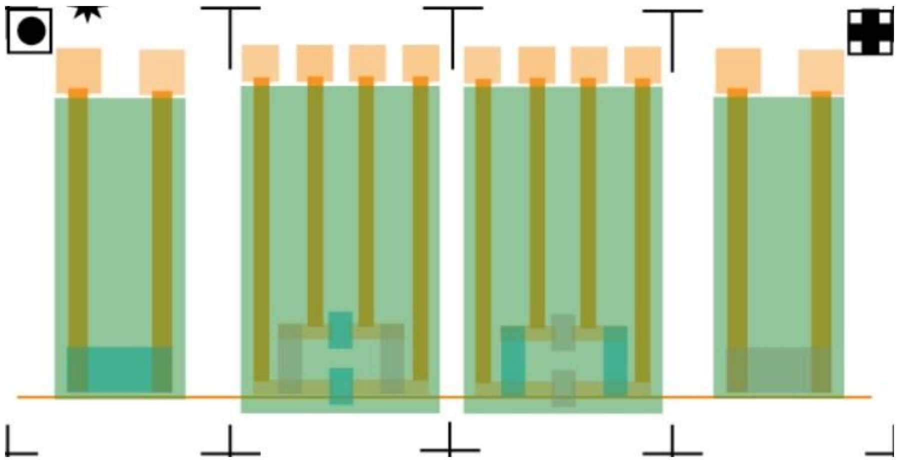
STREAM Sensors – Initial Study



Conductivity

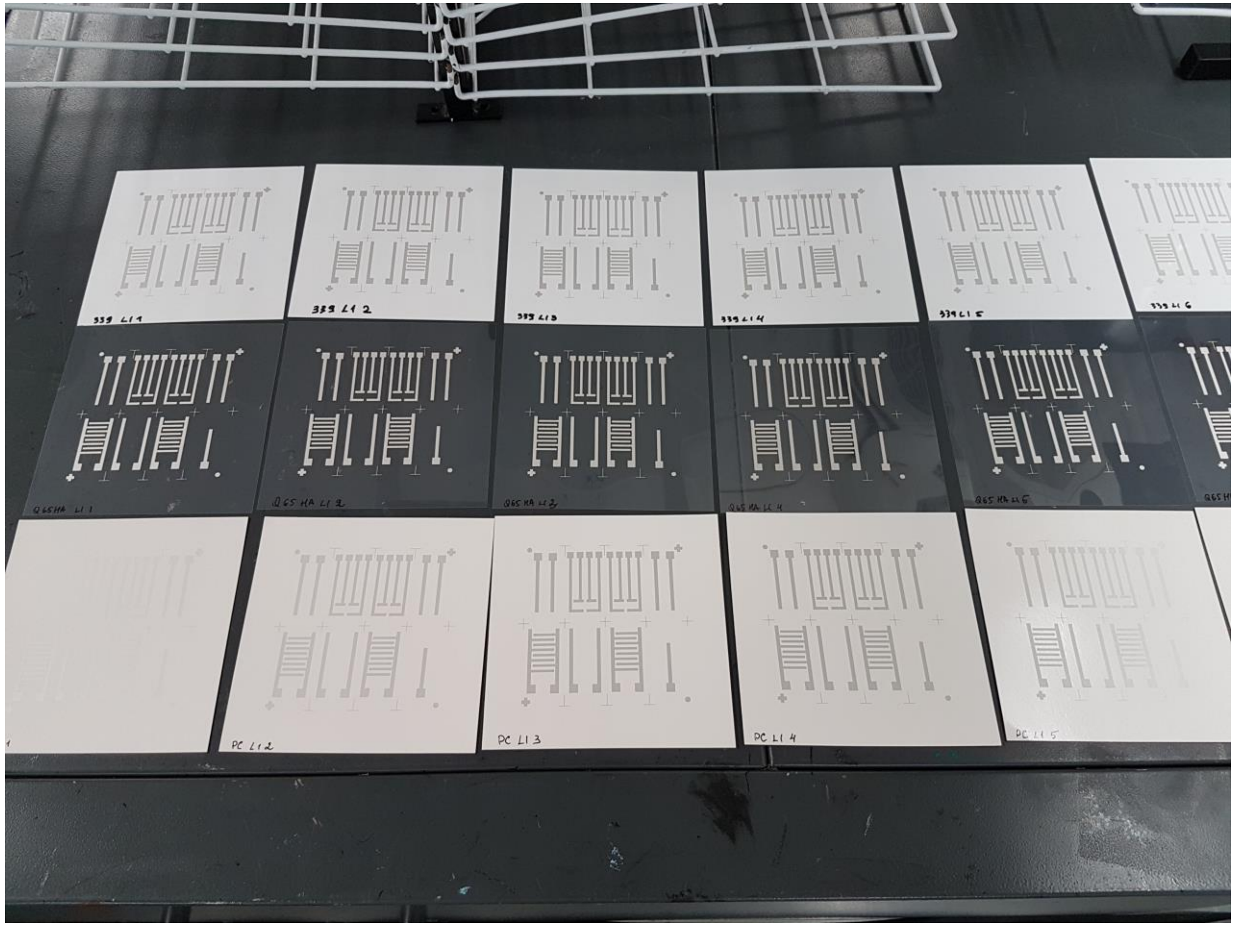


pH

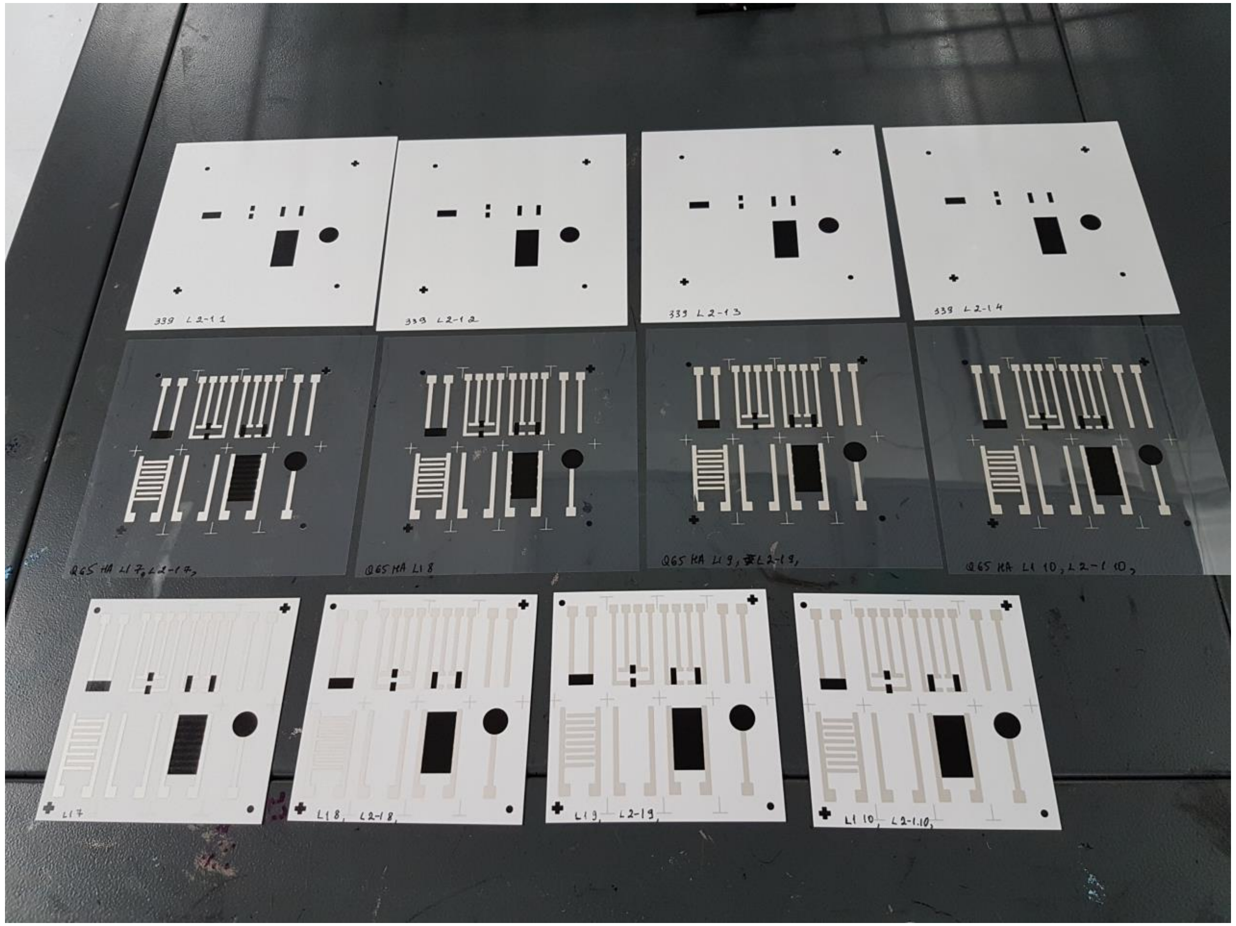


Temperature

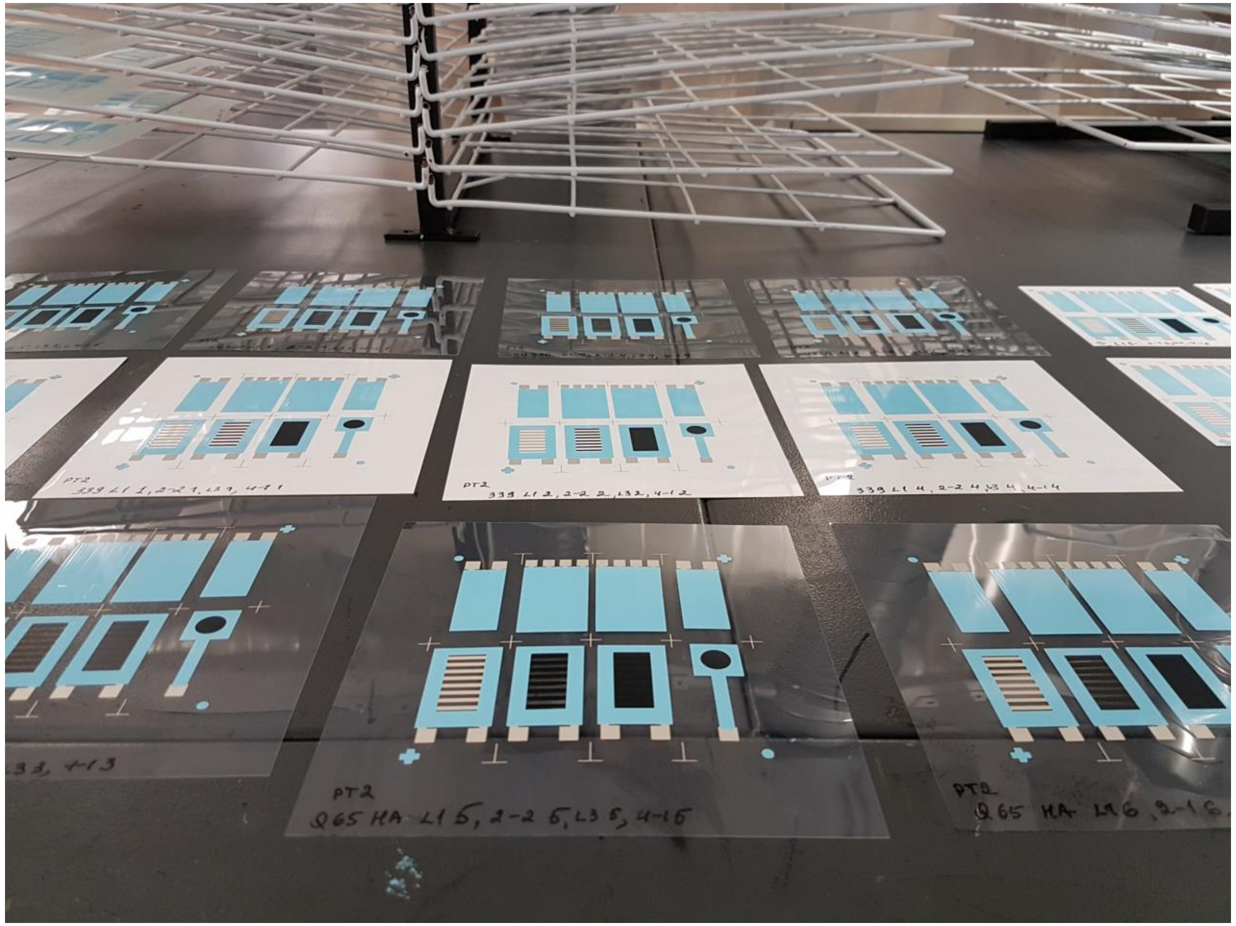
Silver Conducting Track Layer



Carbon PEDOT:PSS Sensing Layer



Dielectric/Protecting Layer



Next Steps

Testing, calibration and development

Design for deployment

COVID has impeded progress

Example Printed Potassium Sensor

Screen printed

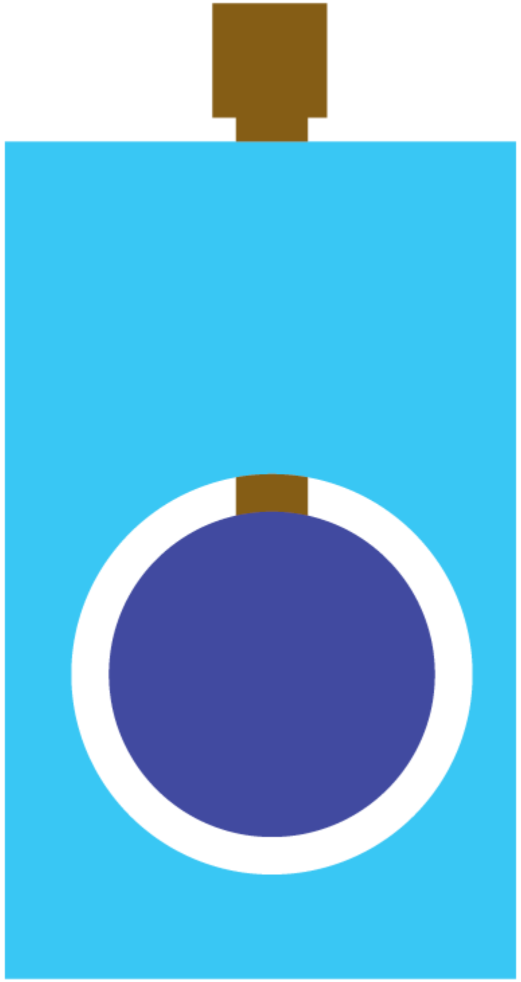
Conductor: 1 layer

Transducer: 1-2 layers

Insulator: 1-2 layers

Applied manually using a pipette

ISM: 1-2 layers

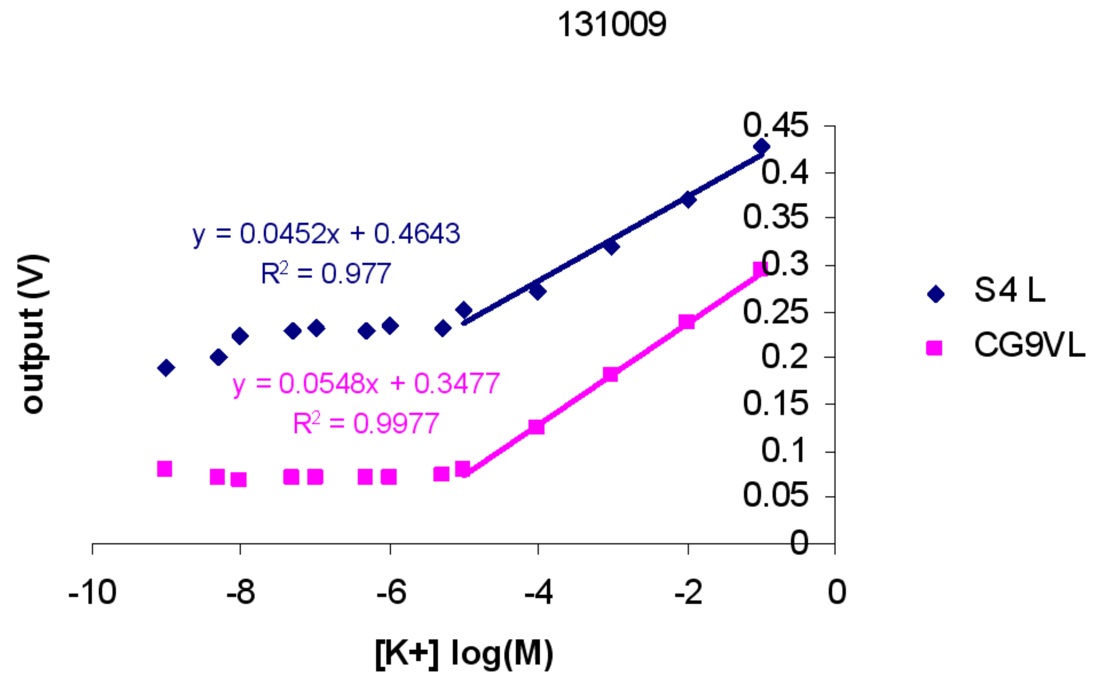


Example Printed Potassium Sensor

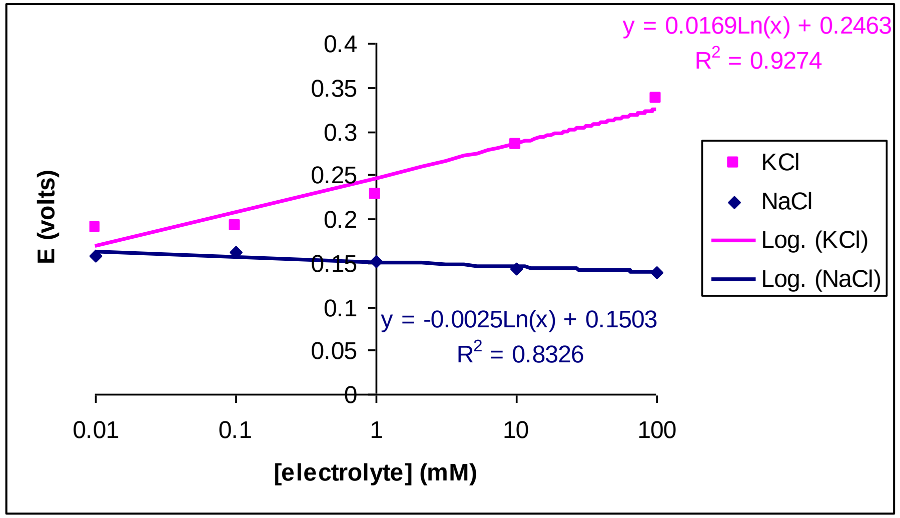
Sensitivity to K+: 55 and 45 (mV dec-1)

The lower limit of detection for both sensors is around 10 µM

Exhibit a near Nernstian response over a given and practical range of activity



Example Printed Potassium Sensor



Responds Potassium Ions only – does not respond to Sodium

Shellfish Aquaculture and Sensor Deployment in the Southeast of Ireland

Brian O'Loan

Bord Iascaigh Mhara

Application of Sensors in Precision Aquaculture

25 May 2021

BIM Ireland's Seafood Development Agency

Overview of Presentation

Southeast Shellfish Aquaculture Region

Value of Southeast Aquaculture

Range of Monitoring Work and Equipment Used

Monitoring constraints in each bay

Interesting Findings

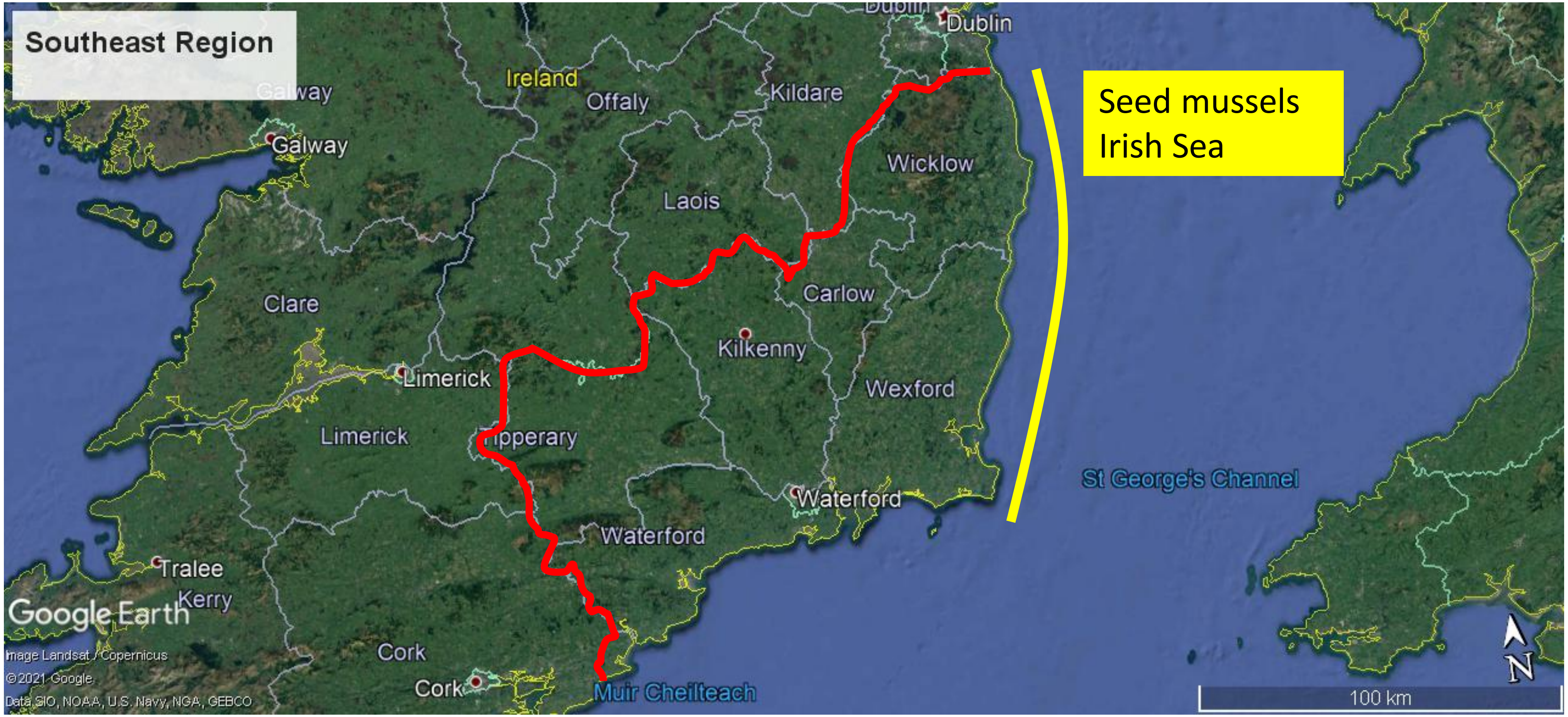
Performance of Monitoring Equipment

SE_Shellfish Industry Pressures and Concerns

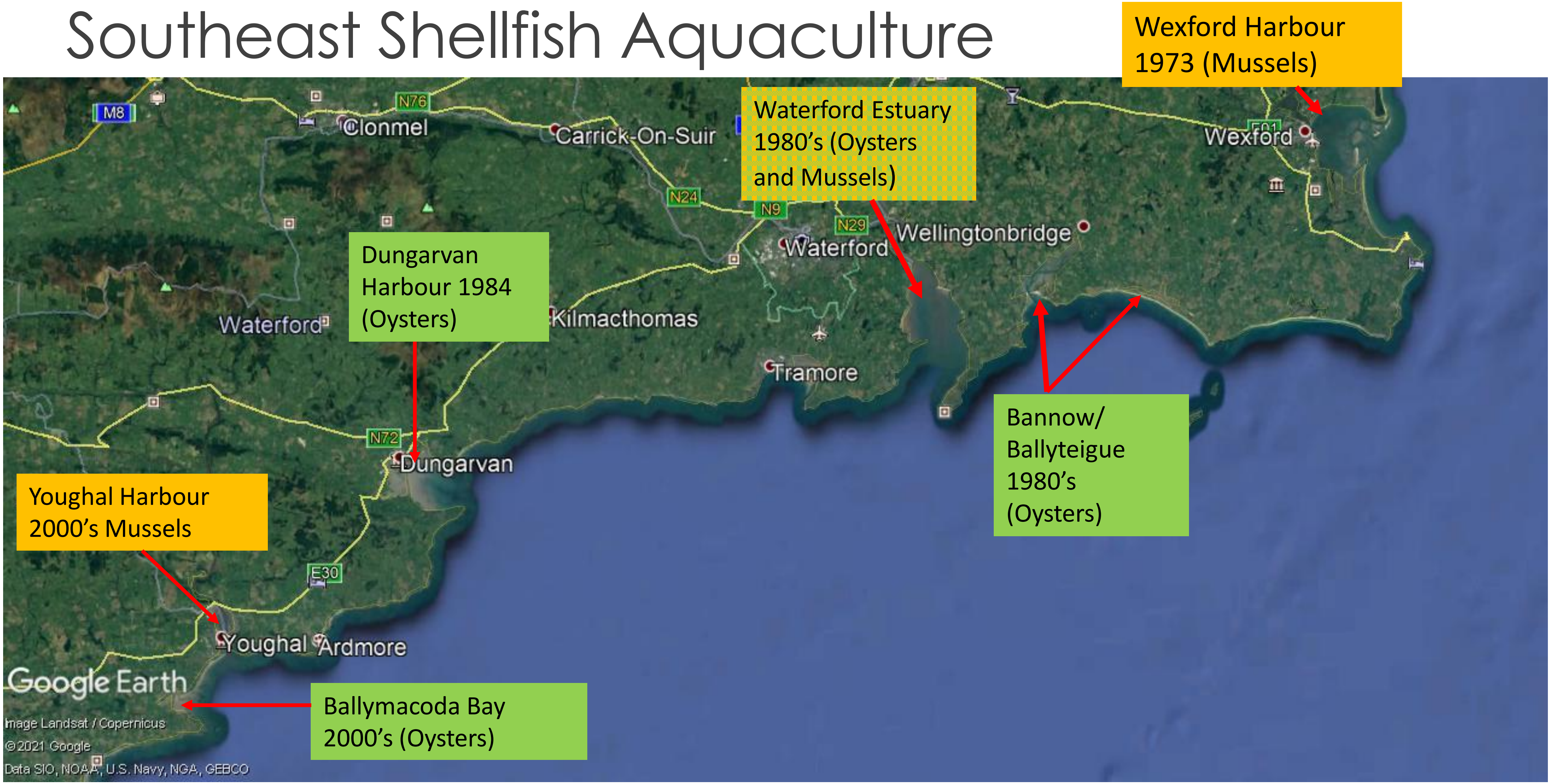
What the Industry (and I) would like in terms of Water Quality Sensors

Take Home Messages

Full Southeast Region



Southeast Shellfish Aquaculture



Wexford Harbour Mussels

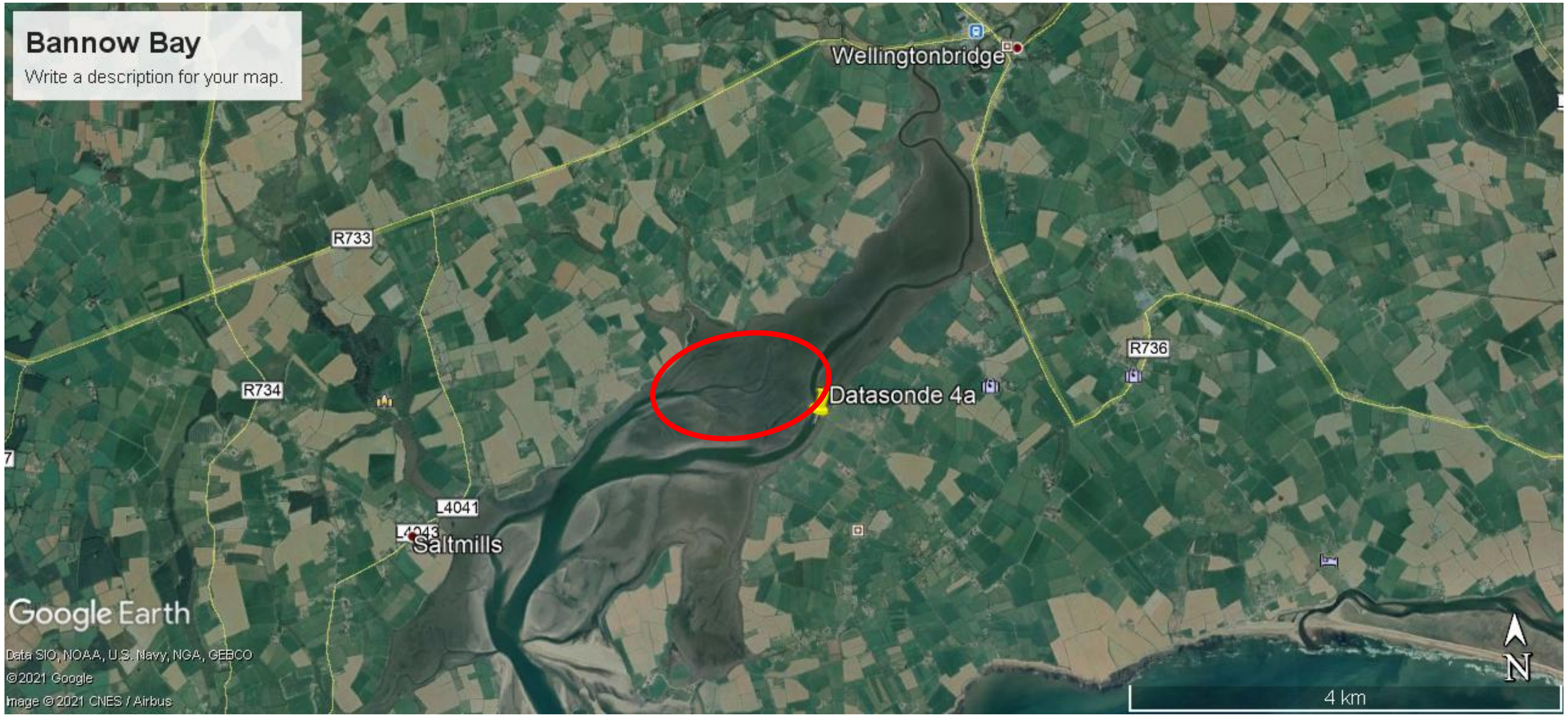
Subtidal Mussel Farming

Shallow/highly dynamic channels and sandbanks

Major town on shore

Major agricultural hinterland around the River Slaney

Bannow Bay (Oysters)



Soft substratum

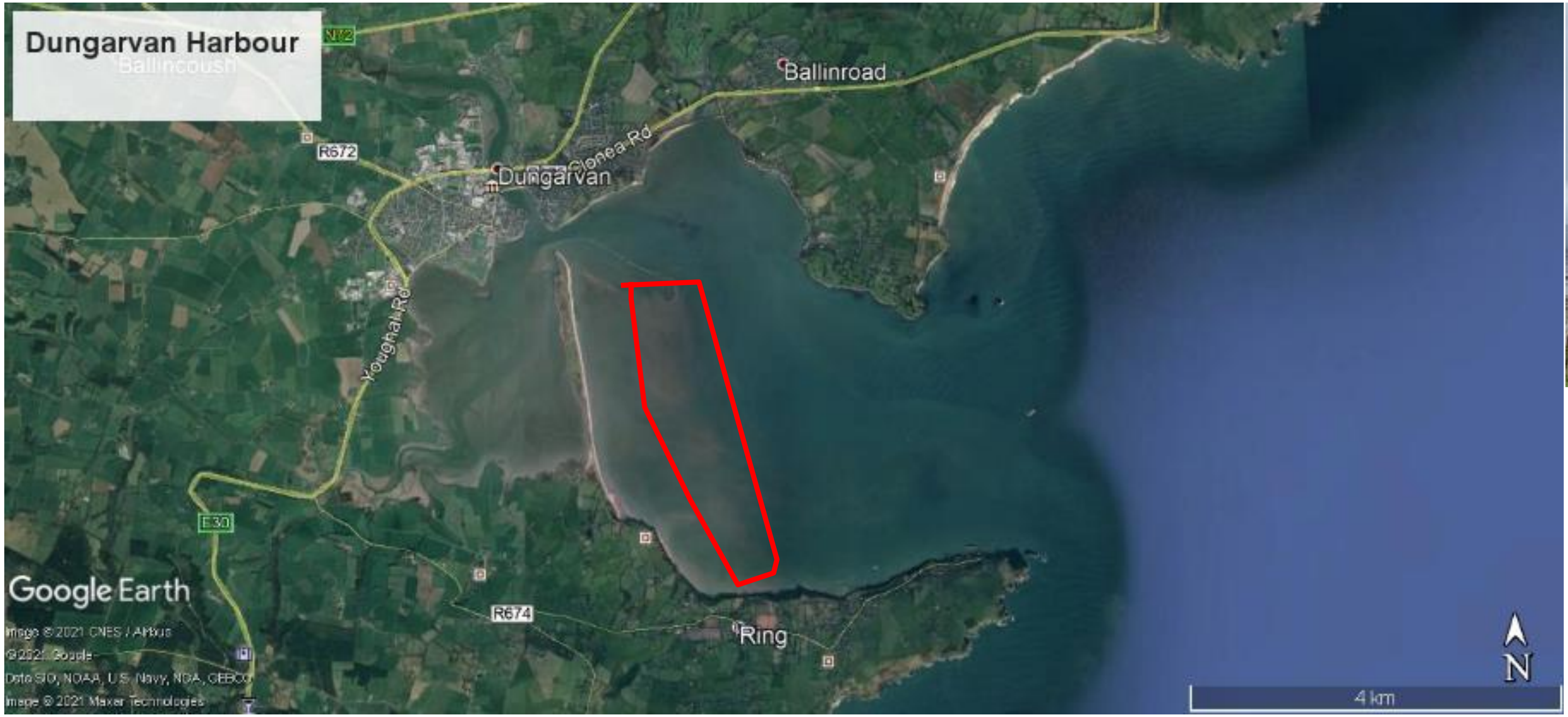
High productivity

Meaty oysters/world class

Flat bottomed Boat and Tractor access

Large agricultural catchment and several rural villages nearshore.

Dungarvan Harbour (Oysters)



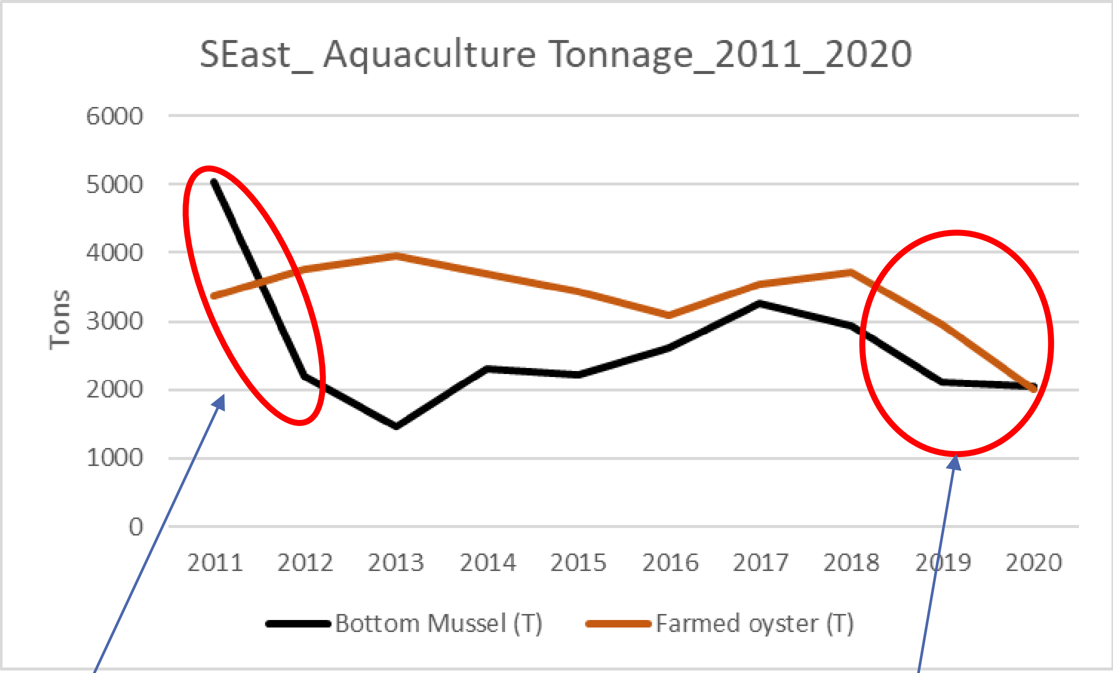
Intertidal Oysters/tractor only

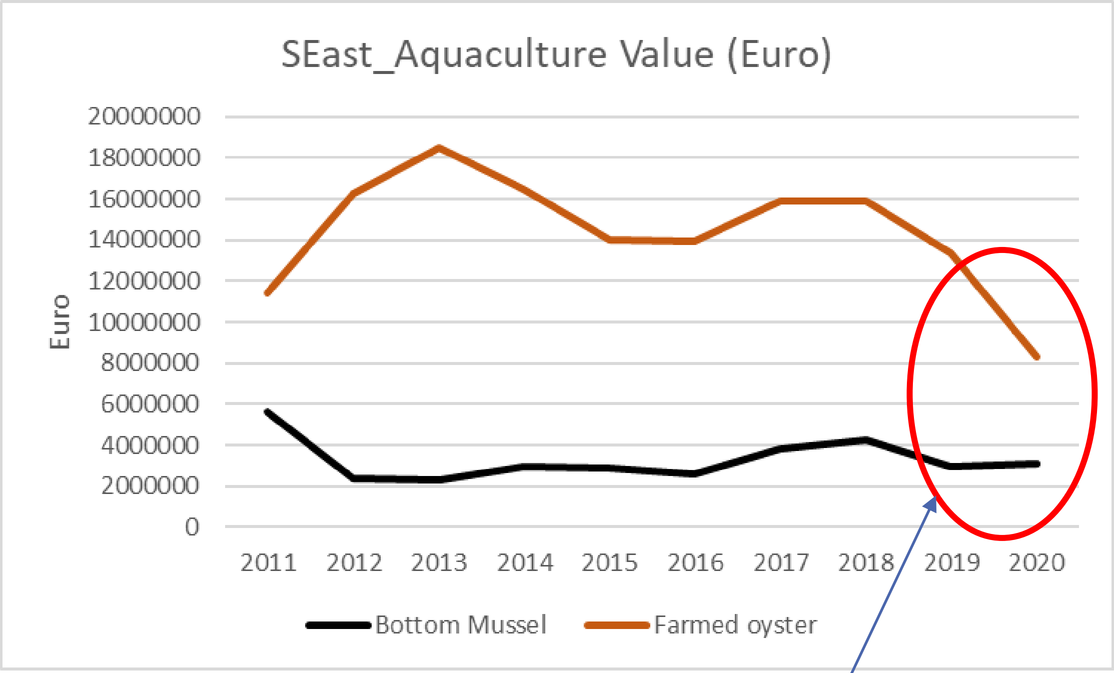
Largest oyster producing bay

Small town

Ideal substratum for oyster farming

Southeast Tonnage and Value (Mussels and Oysters)



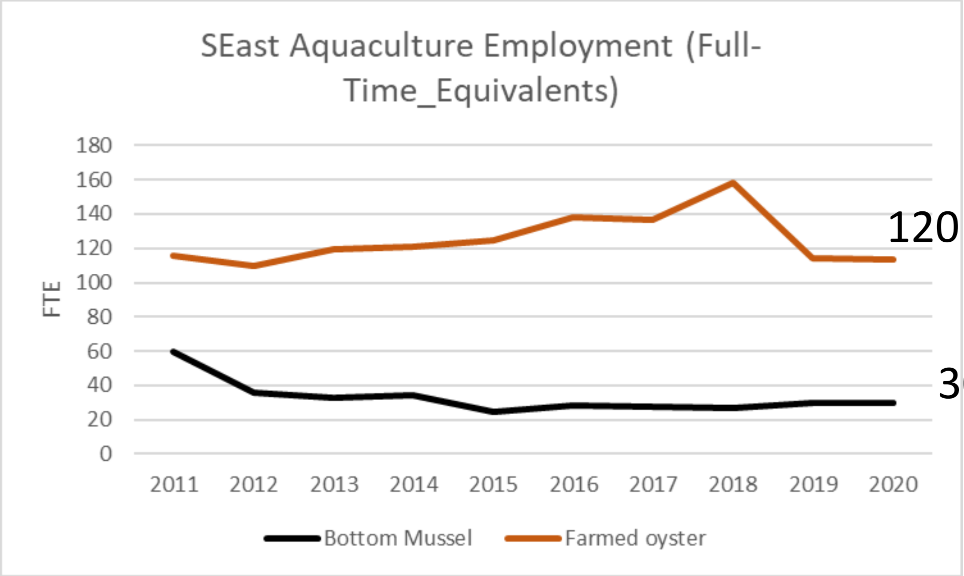


Drop in mussel seed supply from East Coast

Impact of pandemic and also oyster mortalities in some bays

Oysters sales affected more by pandemic than mussels. Also regional drop in oyster output due to mortalities in some bays

Employment_Full Time Equivalents and Production Units in the Southeast

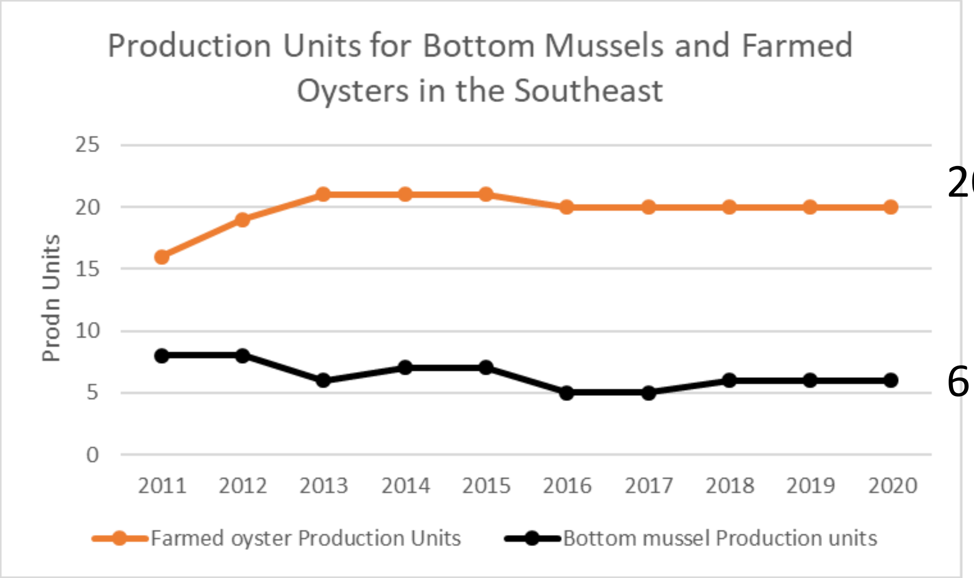


120

30

Currently the bottom mussel job impact is focussed close to Wexford Town.

Oyster industry jobs spread across the region.

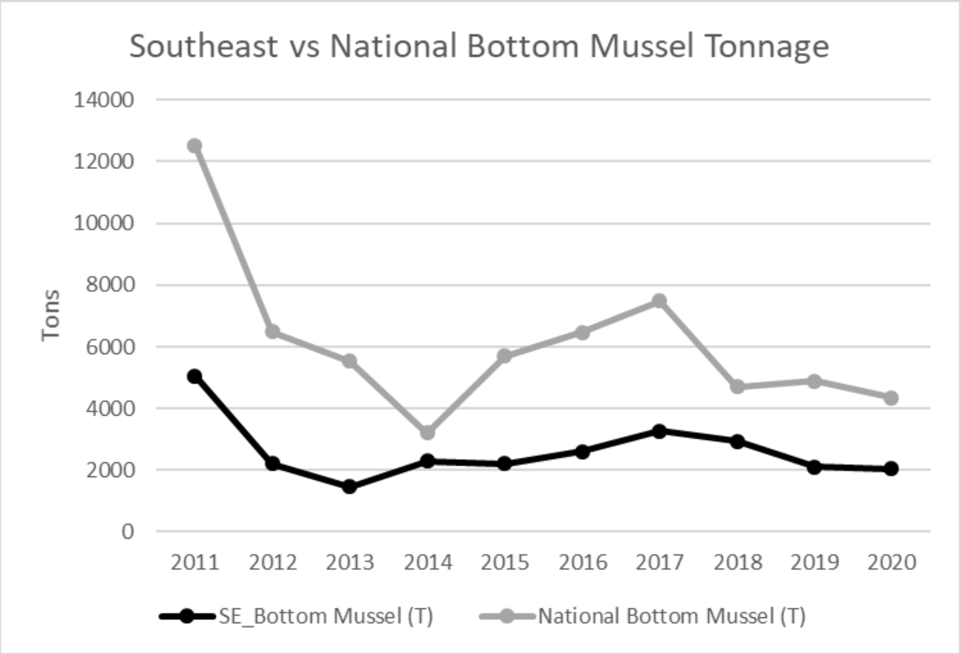


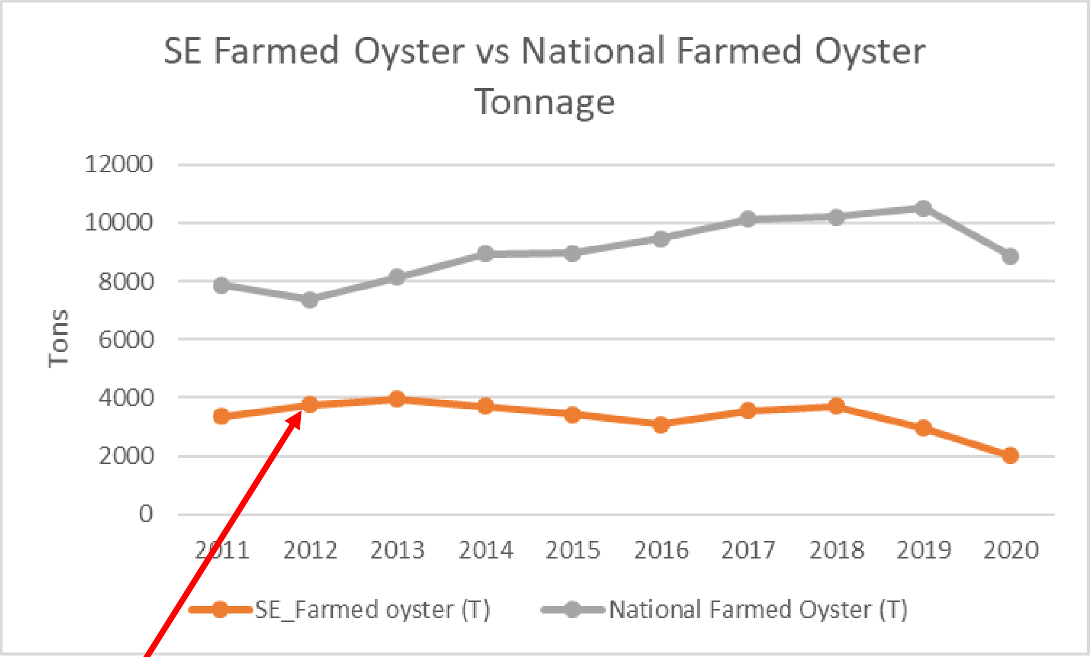
20

6

Jobs and production units relatively stable

Southeast Very Important Nationally for Bottom Mussels and Oysters

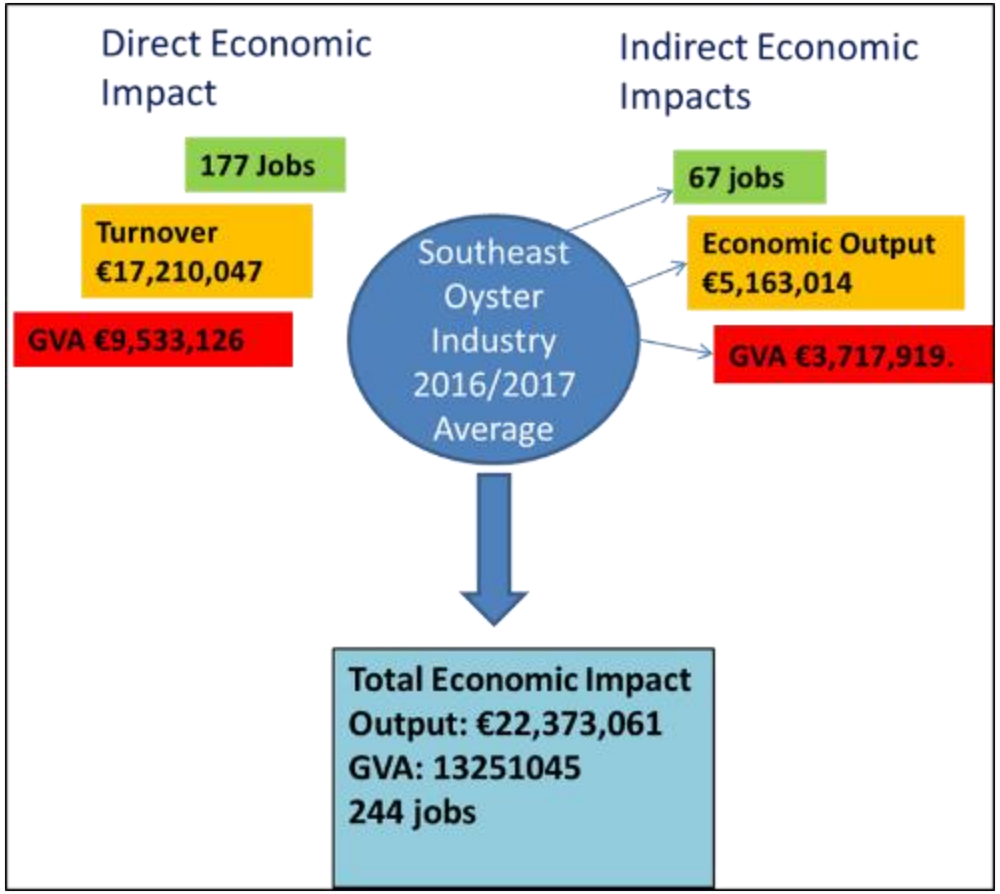




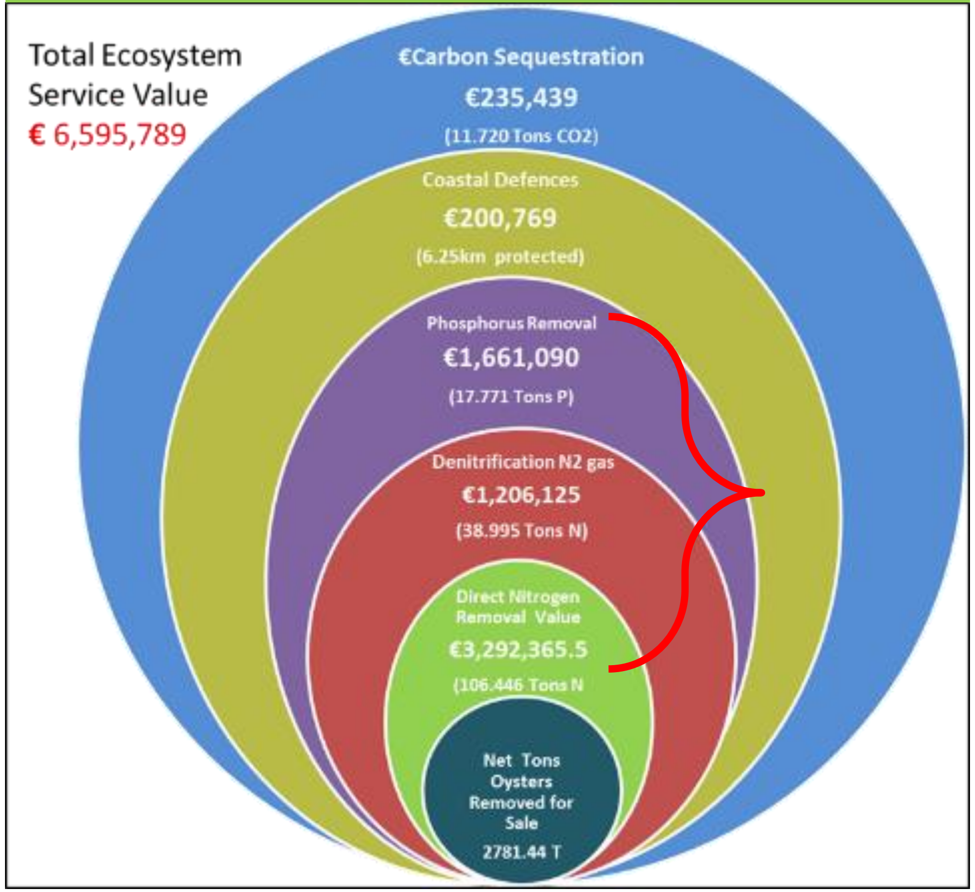
Wexford Harbour is a stalwart in the national bottom mussel industry (40% plus)

More than 50% at one point. Currently impacted by mortality and pandemic issues. Oyster production growing in other regions.

Additional Economic Value of SE Oyster Industry in 2016/2017
(Thesis for HDip in Aquabusiness)



Ecosystem Service Value



Range of Monitoring work in the region

Increasing cost and time

Small sensor on one producer’s farm

Multiple small sensors across oyster farms

Datasonde at one or multiple oyster farms

In farm currents with salinity and temperature.

Spot monitoring from boat (Datasonde or RCM 9 Current meter)

Bay scale hydrographic current meter deployments for hydrographic modelling

2 year full scale sampling and analytical programme with multiple monitoring sensors deployed across three bays and a team of academics! E.g. UISCE Project (Understanding Irish Shellfish Culture Environments)

Mostly summer monitoring at present in oyster areas affected by above average mortalities

UISCE Project Partners

National Oceanic & Atmospheric Administration (USA)
Suzanne Bricker

MarCon Computations International (IRL)
Alan Berry

AquaFact International Services (IRL)
Brendan O'Connor

Plymouth Marine Laboratory (UK)
Anthony Hawkins

Longline Environmental (UK)
Joao Ferreira

Great Eastern Mussels (USA)
Carter Newell

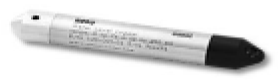
Blue Hill Hydraulics (USA)
John Richardson

Martin Ryan Institute (IRL)
Michael Hartnett & Declan Clarke

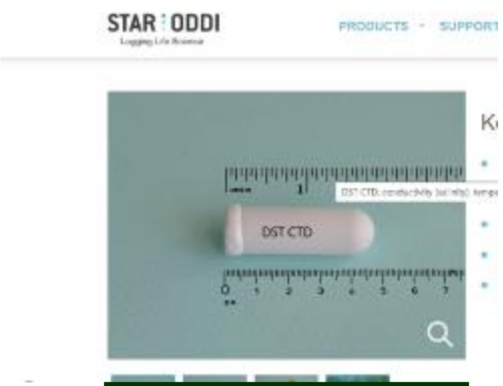
Compass Informatics (IRL)
Gearoid O'Riain

Plus three staff monitoring and sampling in the southeast and three BIM divers when needed.

Range of Monitoring Equipment Used



Hobo Water Level & Temp Loggers



Star Oddi CT and CTD's

Hydrolab Datasonde 5X's

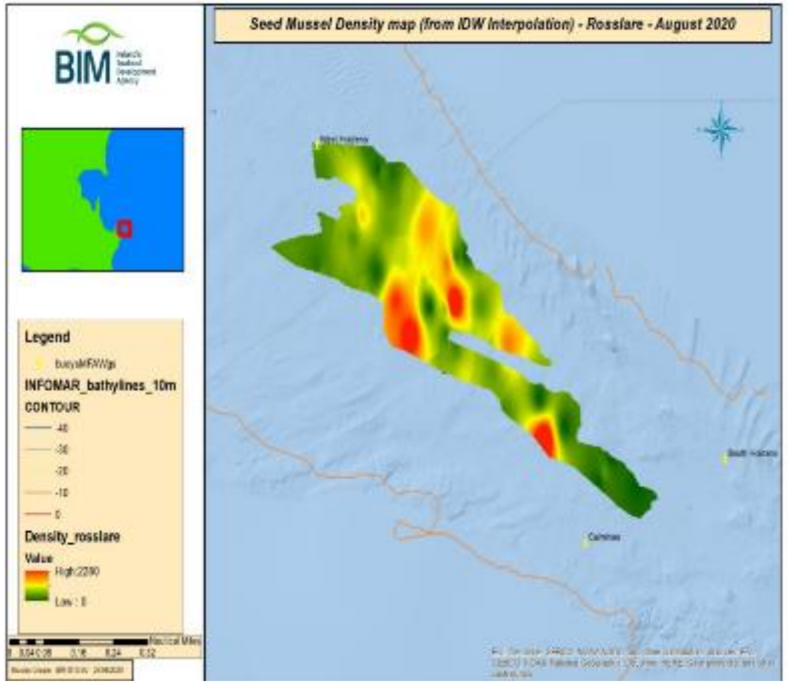
Aanderra RCM9's & Mooring Bases/Frames

Quad and trailer

Custom built filtration systems

GPS

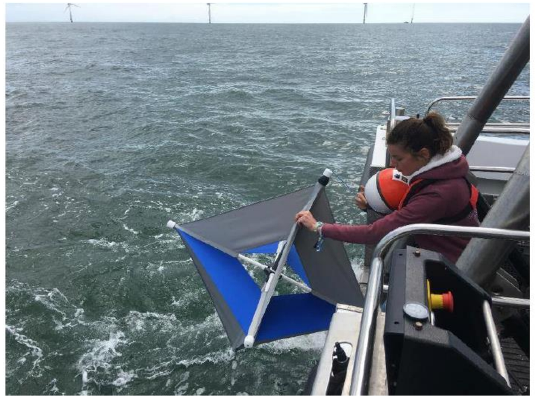
Additional Work in Region:
BIM Mussel Seed Survey/Bluefish Project



Side scan sonar seed mussel bed mapping Irish sea off Wicklow and Wexford Coasts

BIM survey vessel

Figure 29: MS 0007 deployment



Drogue mussel larval tracking

Exosonde and water sampling combined Bannow, Waterford Dungarvan

Monitoring constraints

Subtidal access to subtidal monitoring location. Divers. Health and Safety Red Tape

Anchorage

Exposure to air (pH)

Fouling (Algae, barnacles etc)

Foreshore licence/ Navigational issues

Boats (cost)/ access to shallow subtidal areas

Weather (Rough seas displacing instruments)

Budget

Length of deployment period/power

Limited telemetry options

Exposure of instruments and to accidental or deliberate damage

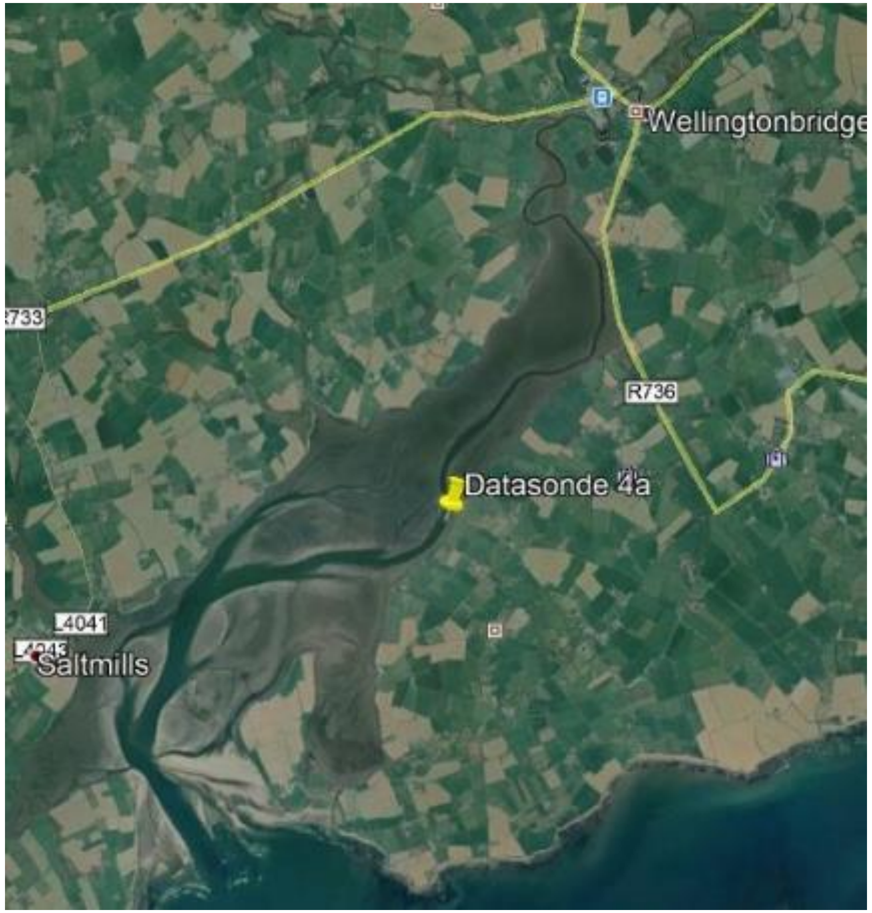
Size of production areas and widespread location of pressures.

Monitoring constraints

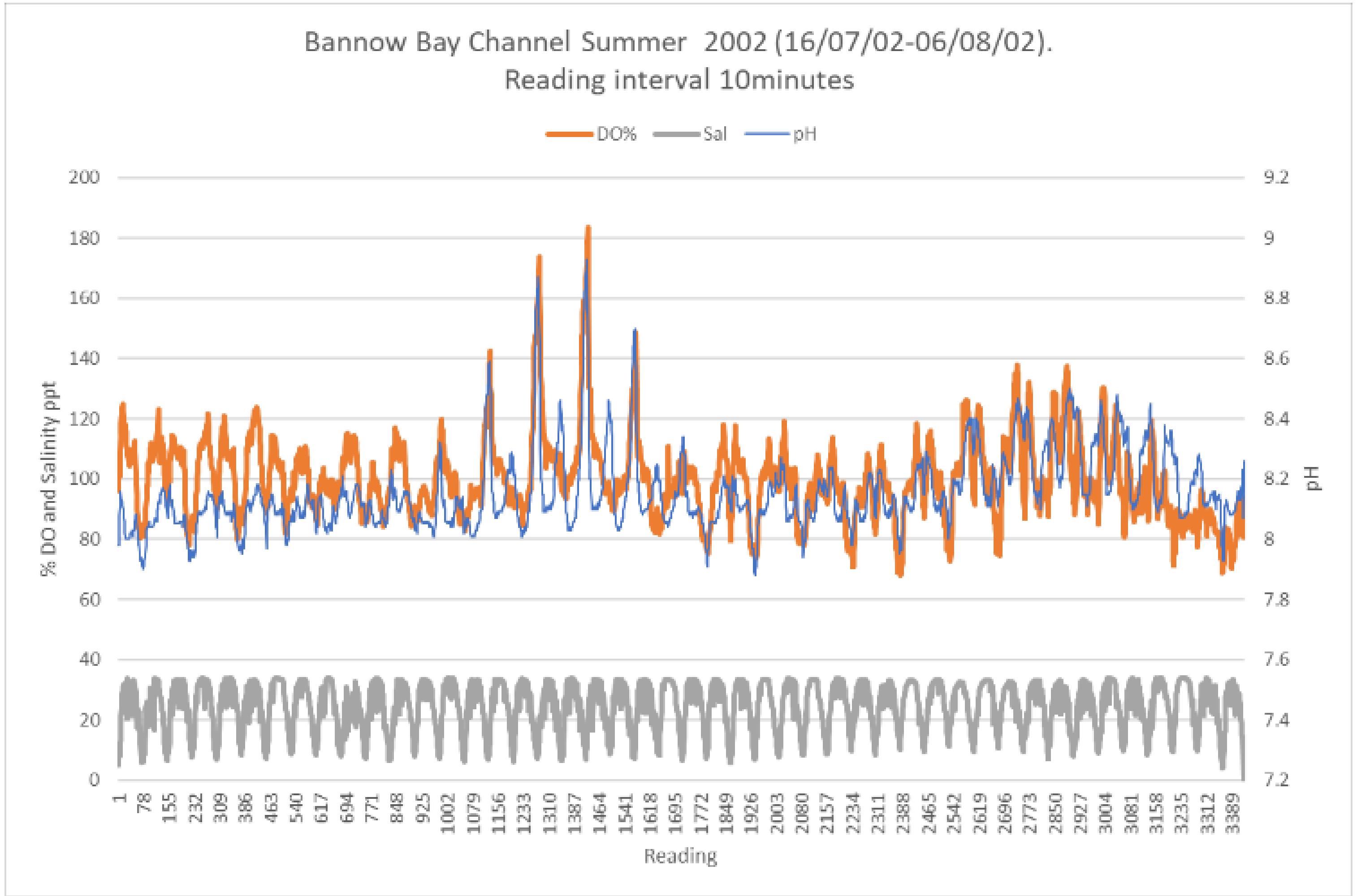
Interesting findings…..

•

First Sensor Deployment Bannow Bay 2002



Main Findings in Bannow Bay Summer 2002



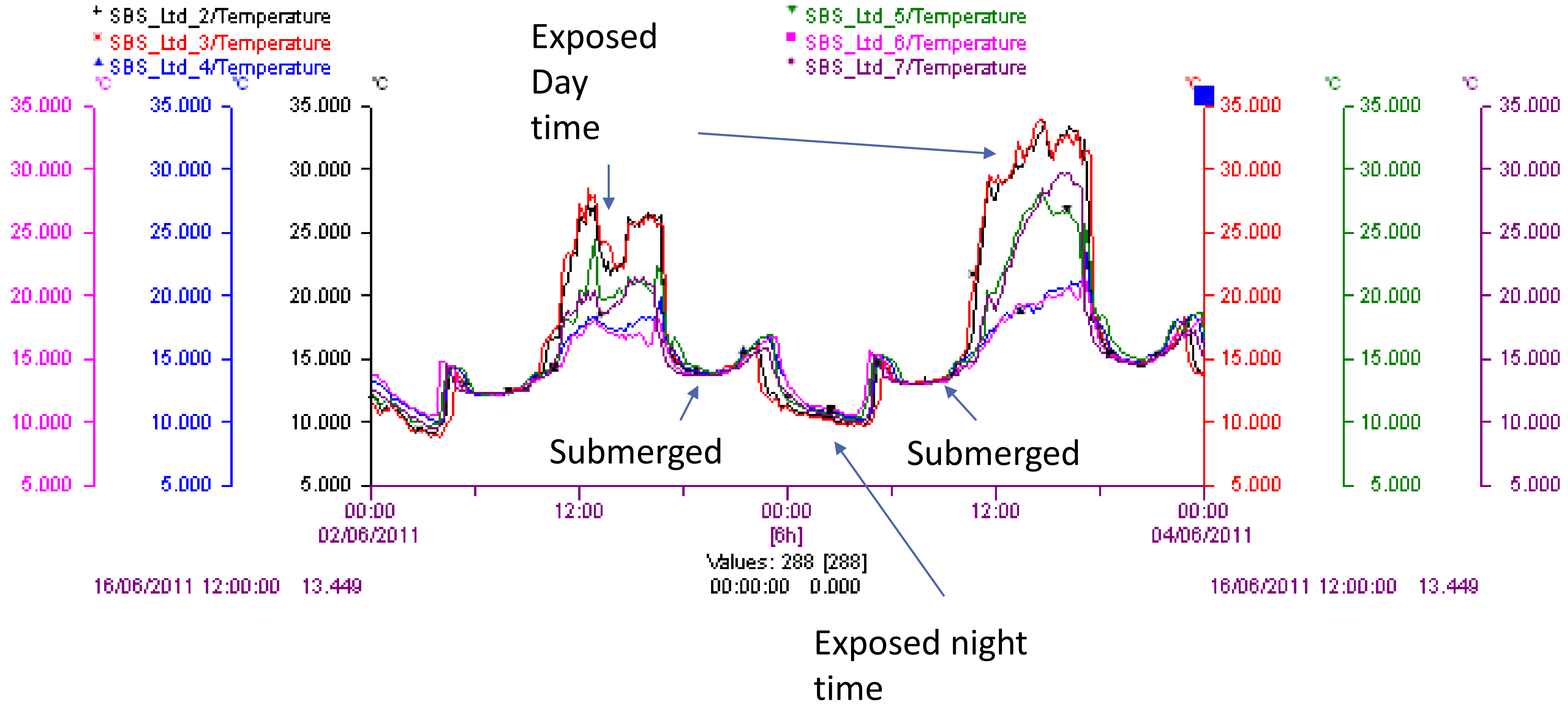
O2 and pH swings

Freshwater influence particularly on neaps

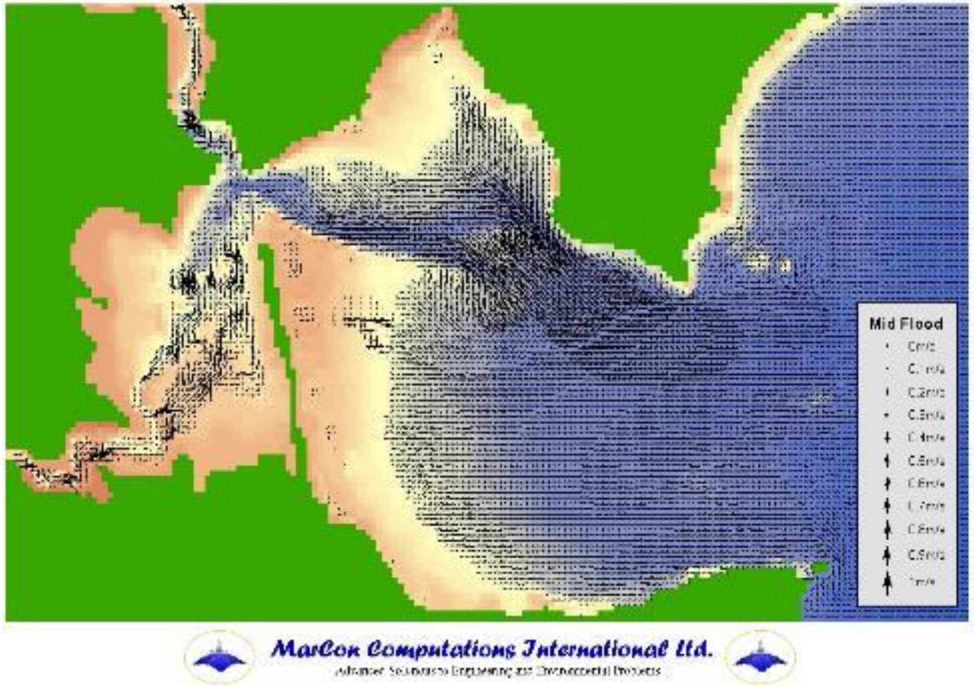
Applied for trial sites away from channel

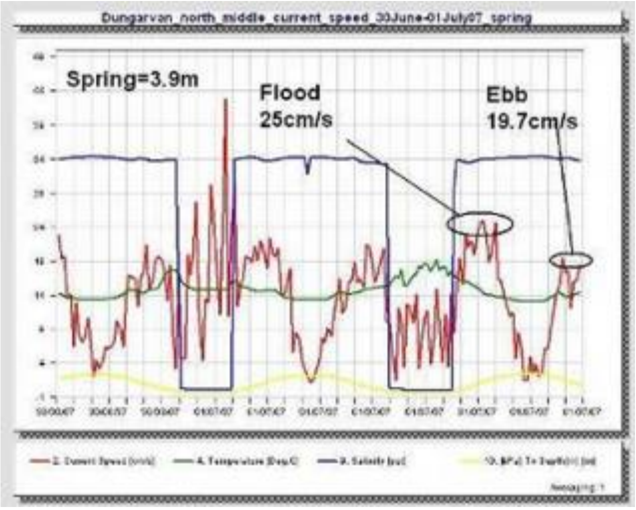
Trial sites successful and move oysters away from channel in summer-less mortality

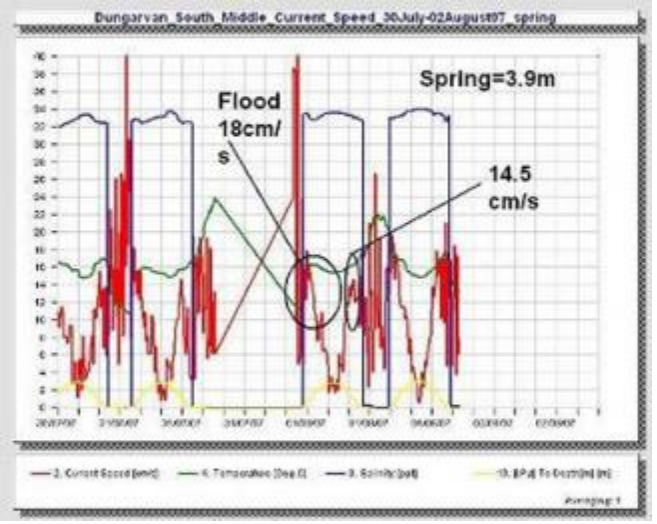
Temperature Data inside Oyster Bags Bannow Oyster Farm (2011)



Some Interesting Findings from UISCE project in Dungarvan Harbour (2008)

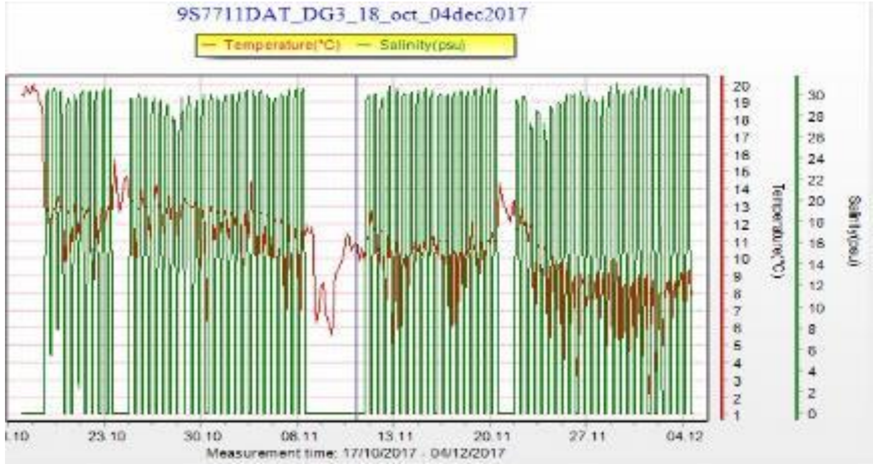


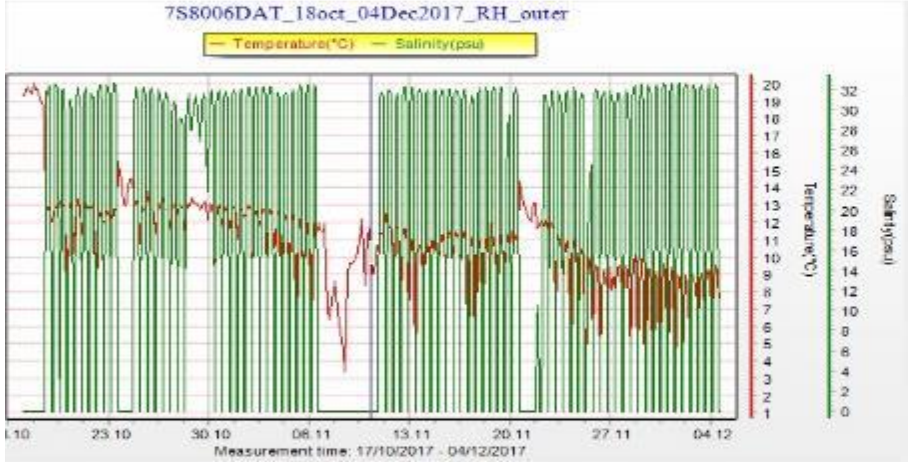


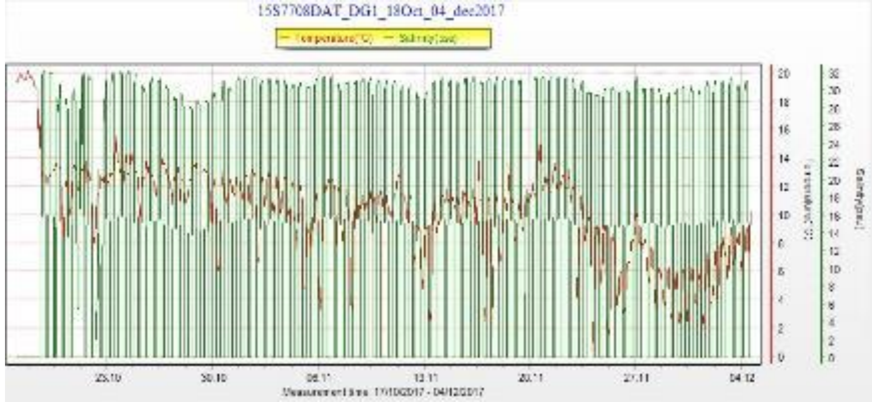


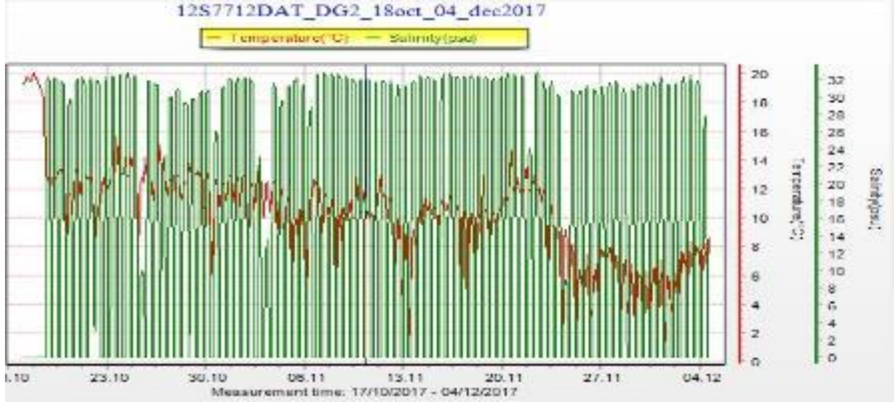
- Pulse of chlor a incoming tide- benthic diatoms from sandflats
- Seed oysters did better in the slower currents in southern sector
- Northern sector better for growout to market size

Zero Salinity Events Northern Edge of Dungarvan Production (Norovirus study 2017)



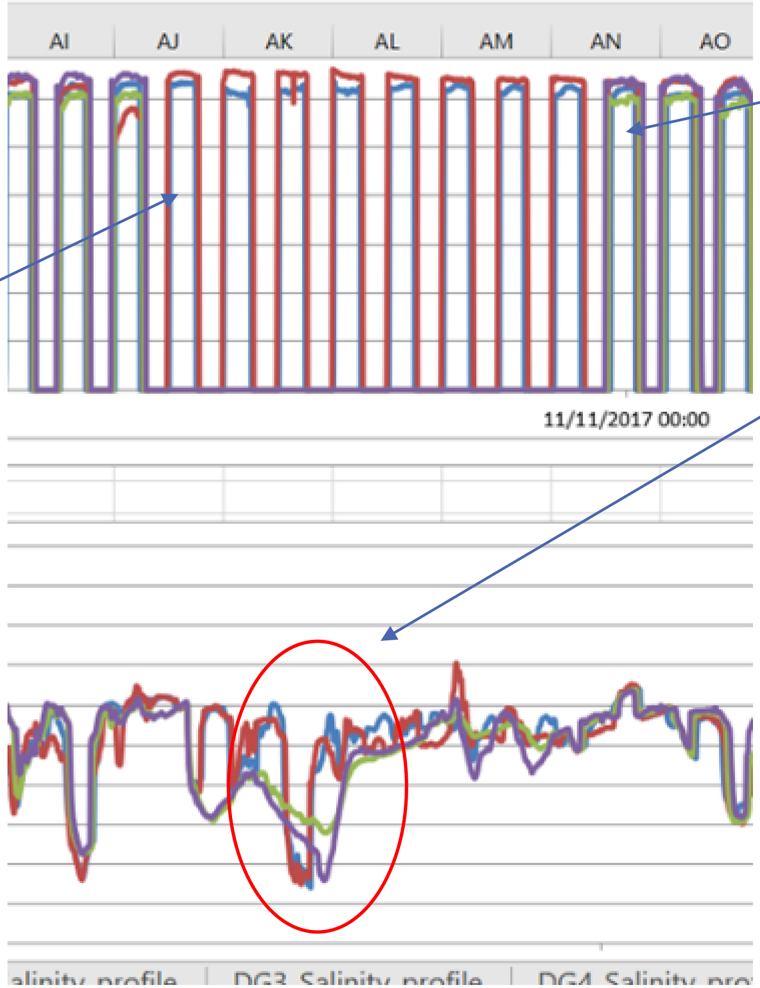






Comparison of Temperature during Zero Salinity event in Dungarvan North vs South

Northern sensors independently (400m apart) both commence recording zero salinity for several days and for similar periods.



Return to normal environmental conditions in northern flank

Both CT loggers in the north (green and purple lines) record temperatures sloping off and no clear exposed/submerged temp profile. Possibility they were covered in cool freshwater from the main channel coming from Dungarvan. Rainfall wasn't particularly heavy.

Performance of monitoring equipment

Tidbits, tide gauges- no issues, long life reliable, low cost- can be lost. Good value for money.

CT/CTD's- give more information, fairly reliable, can suffer from fouling/clogging and can get lost. Good value for money.

Datasondes (4a/5X's). Spikey chlorophyll data/error readings. DO fluorescence excellent. Fouling, critters living in the housing near sensors. Cost of units and calibration is high. Spot reading hand held unit very good. Power drain when sensor fails.

Current meters (Aandera). Extremely reliable data and robust (If only everything in life was as reliable!). Costly. Have had a tractor drive over one and a dredger drag one off its location. Can do spot readings from boat too with inline frame (not live readings).

Not Real Time Data. No alarms!

Pressures/Concerns

E. coli shellfish classification (B classification or better essential for industry) (Mussels and Oysters)

- WWTP's
- Stormwater Overflows
- Pumping Station failures
- Agriculture
- Septic tanks
- The combination of pressures will vary from bay to bay.

Norovirus levels more of a concern for oyster industry

- Human sources (WWTP'S, Stormwater Overflows, Pumping Station Failures), Septic tanks
- Sales to Asian lucrative markets depends on very stringent levels for Norovirus.
- Depuration required but sometimes Norovirus can be too high for depuration to work fully.

Excessive Mortalities

- Microbial Causes (Herpes, Vibrio)
- Algal blooms (Oxygen/Toxins)
- Unknown causes?

What the Shellfish Industry wants

Real Time Monitoring with alarms/notifications.

Year round monitoring but late spring to early autumn essential (I focus on June-September)

Better spread of monitoring locations (production areas are big)

More monitoring close to point pressures eg WWTP/Stormwater Overflows/Industrial Discharges

Different priorities for each bay e.g. Impact of Chlorine Produced Oxidants on ecosystem and turbidity monitoring.

Dissolved Oxygen crucial.

E. coli/Norovirus. Can sensors be developed to detect in the field?

Cheaper sensors.

3 Take home messages:

Requirement for monitoring shifting more towards **protection of shellfish**

Realtime data(preferably with notifications) is strongly desired by industry

Requirement for cheaper sensors and monitoring of new parameters over greater area

Thank you for your attention.

brian.oloan@bim.ie

https://bim.ie

Its time for the next generation of sensors

2002 Bannow

2021 Dungarvan

Coastal Monitoring Radar

Paul Shanahan

Halpin Centre for Research and Innovation

Application of Sensors in Precision Aquaculture

25 May 2021

STREAM MTU

Halpin

Deploying sensors

Pumping system

Coastal Monitoring Radar

Social media Platform

Department of Physical Sciences

Sampling & Testing Programme

Radar System

Low Cost Coastal Monitoring Solution

Accurate Local Weather Information

National Rainfall Radar

Disseminated on Social Media Platform

Halo-6 Radar

Simrad Halo-6 Pulse Compression Radar. Range 75m – 72nm

Yacht & Small Vessels

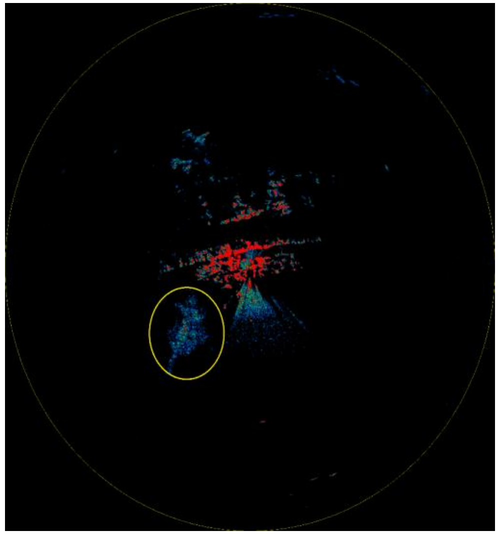
Weather & Bird Modes

Halo-6 Radar

Battery Powered

Wind and Solar Generation

Detecting rainfall at 35km



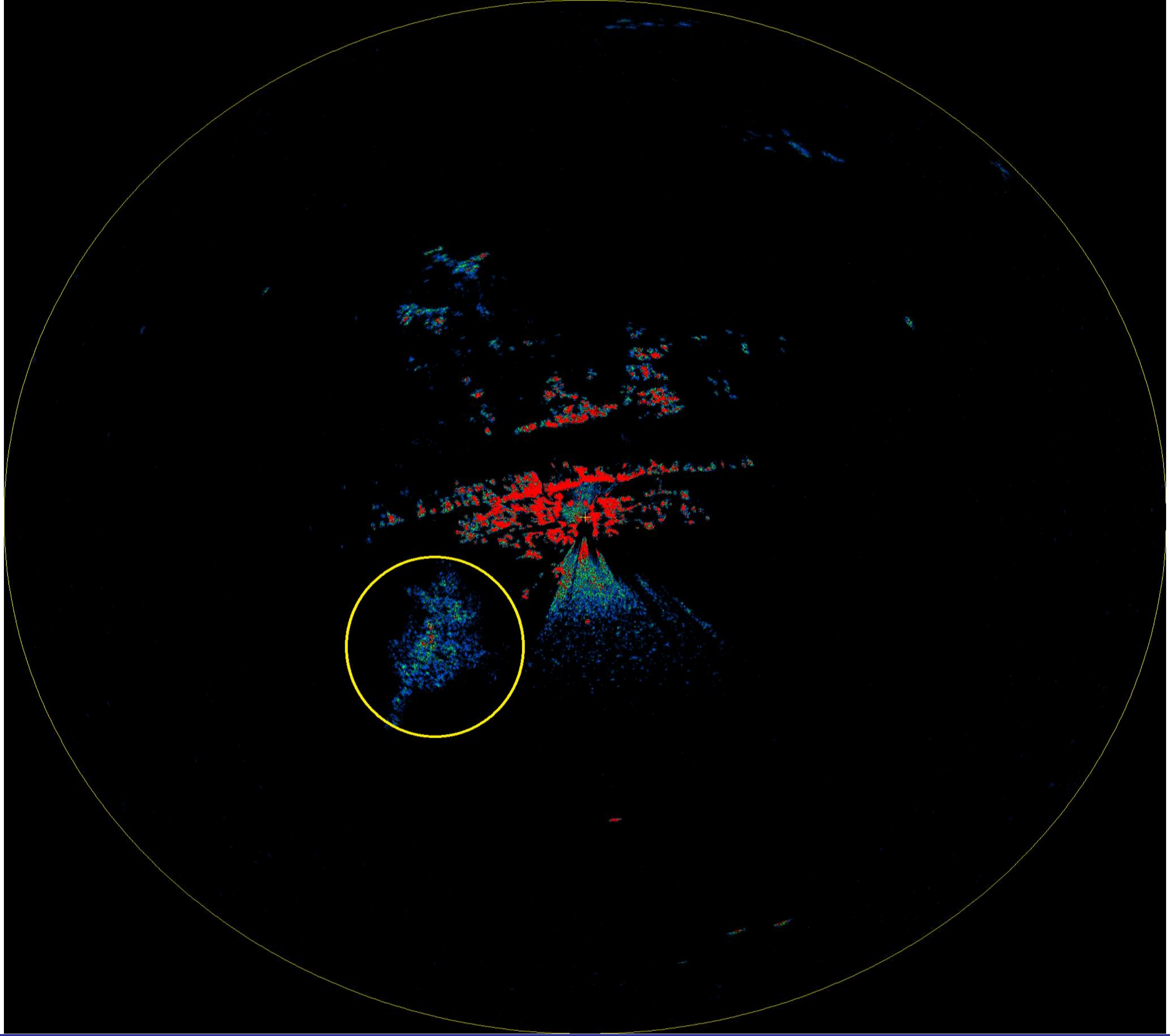
Radar Deployment Sites

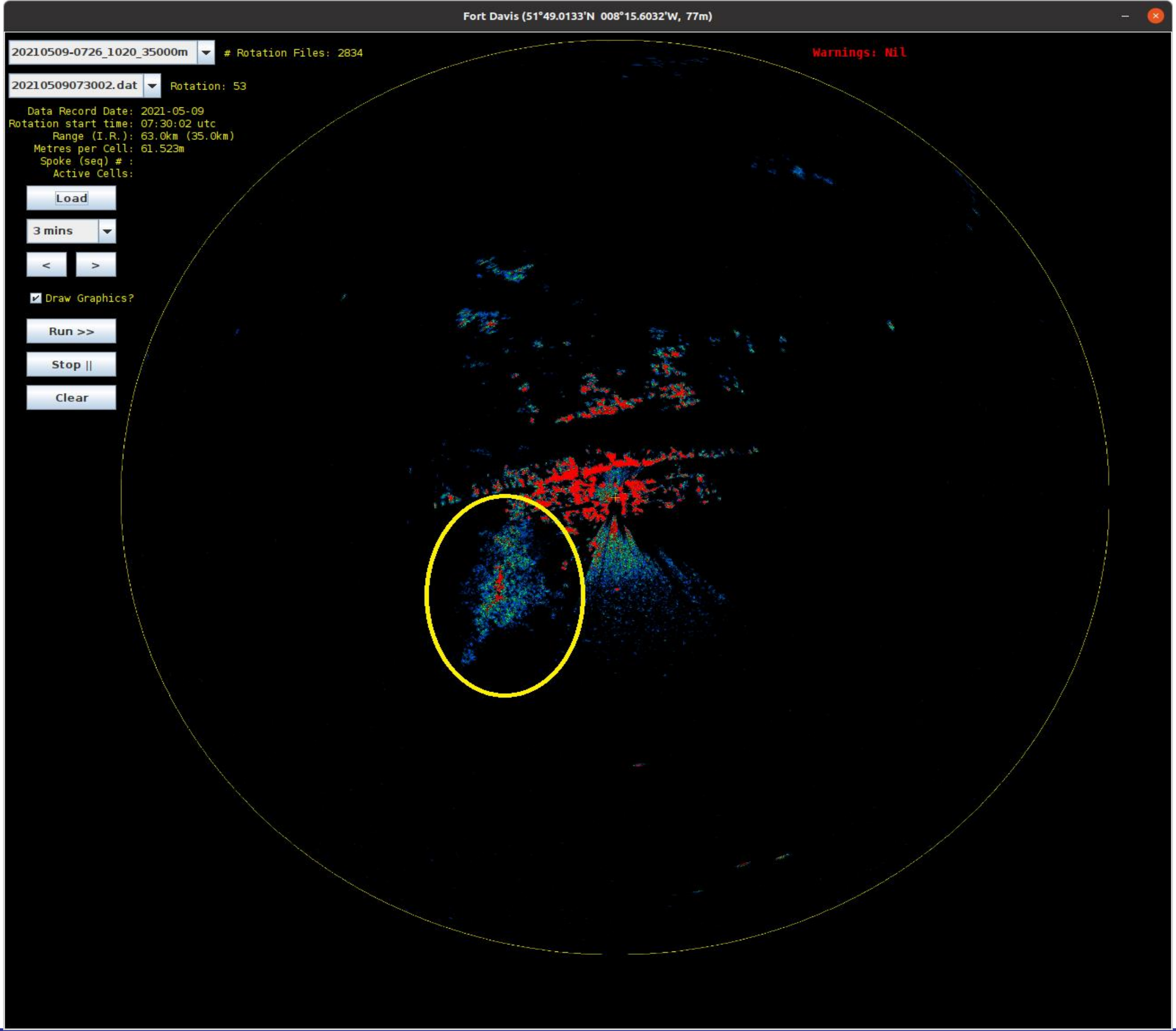
FT Davis Test Site (Cork Harbour)

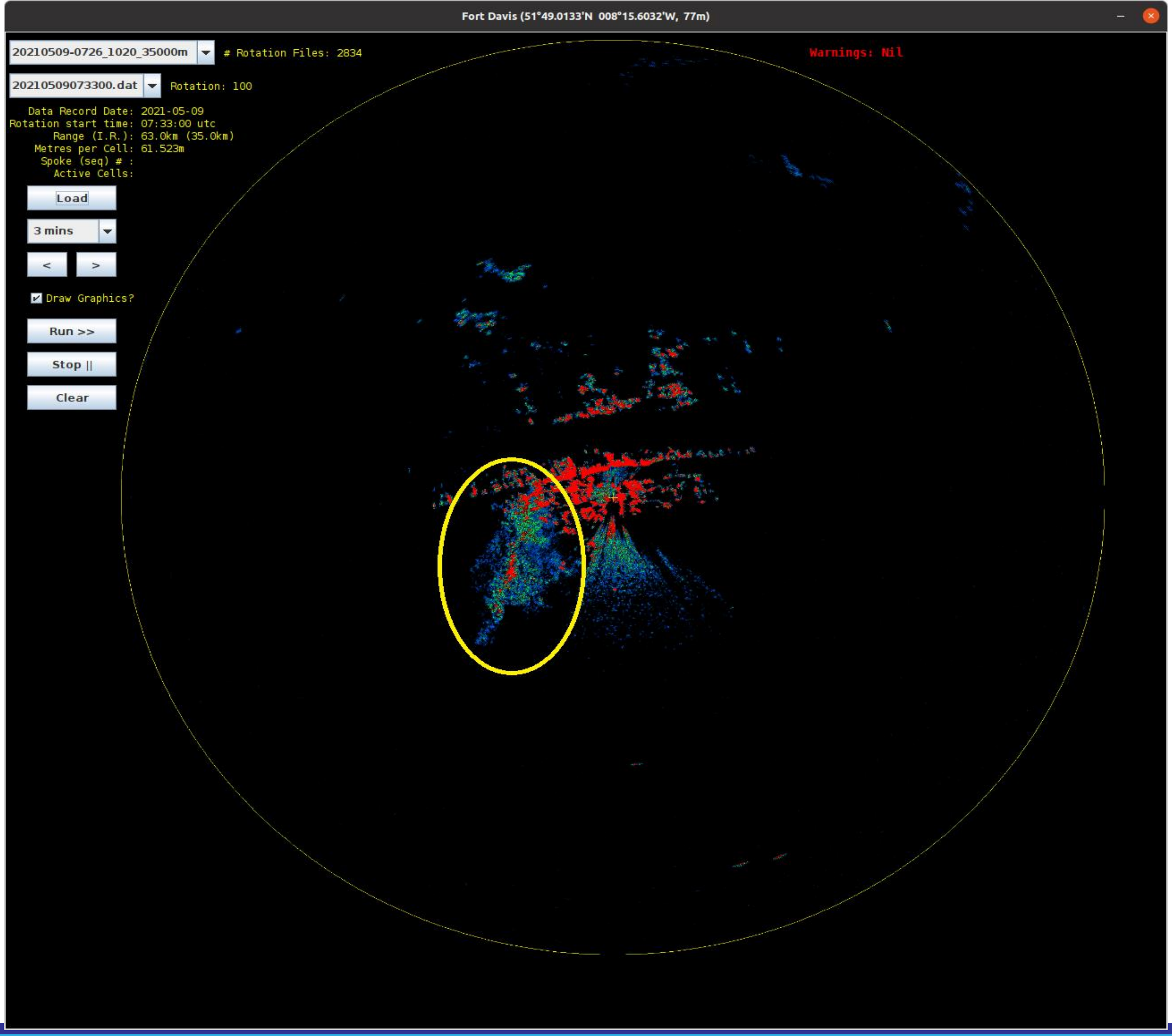
Kilmore Quay (2021)

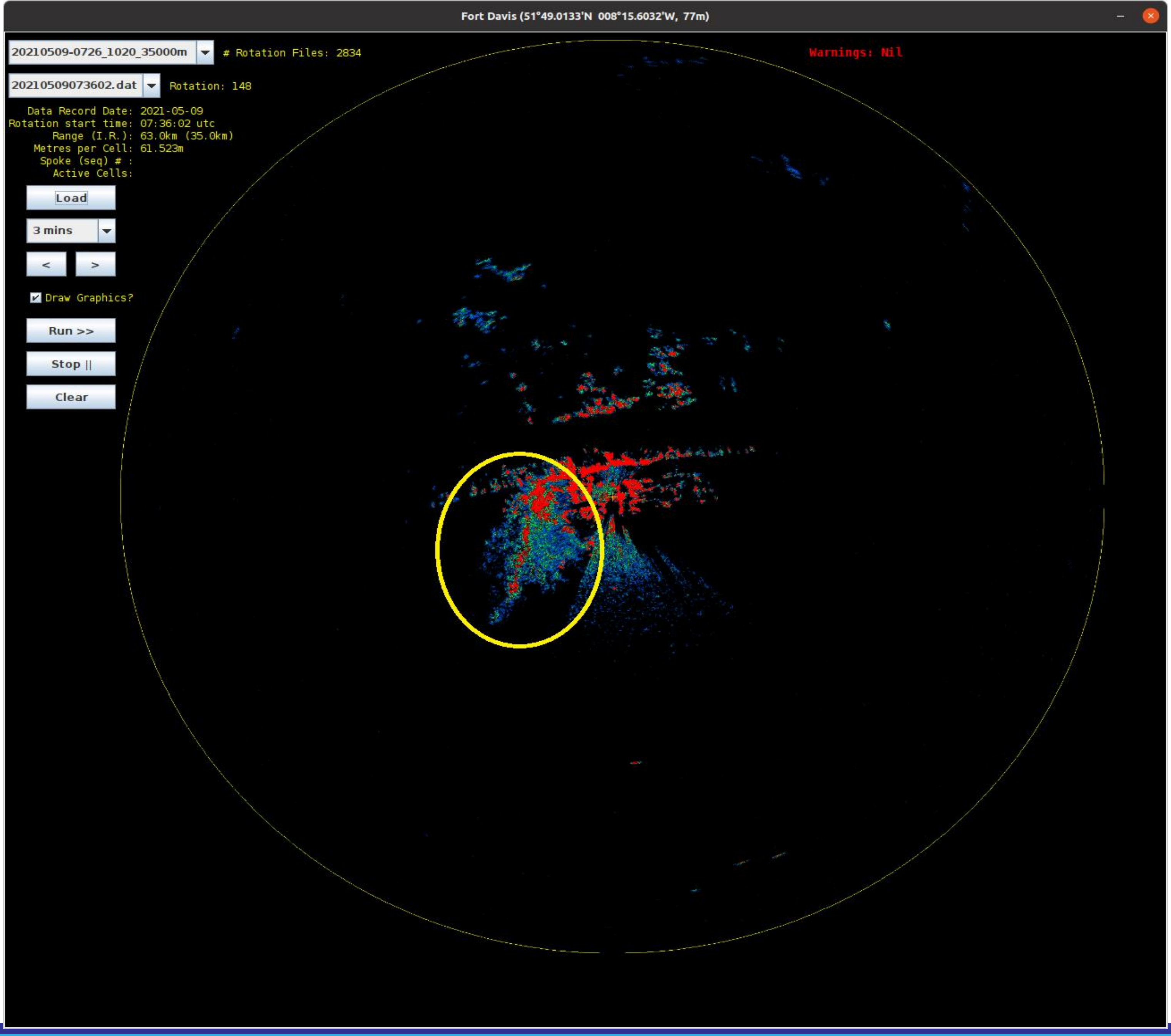
Swansea (2022)

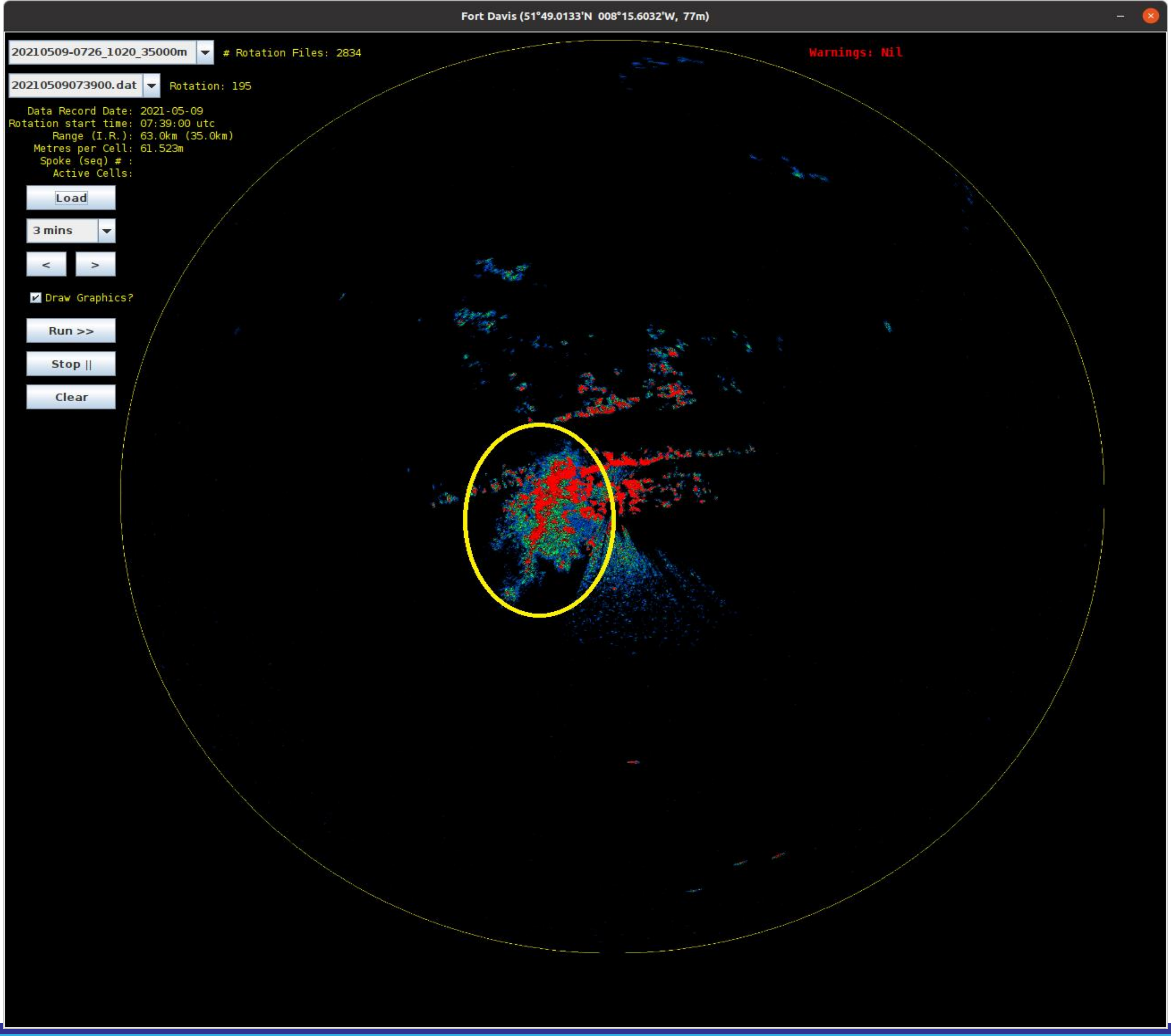
Other Deployments



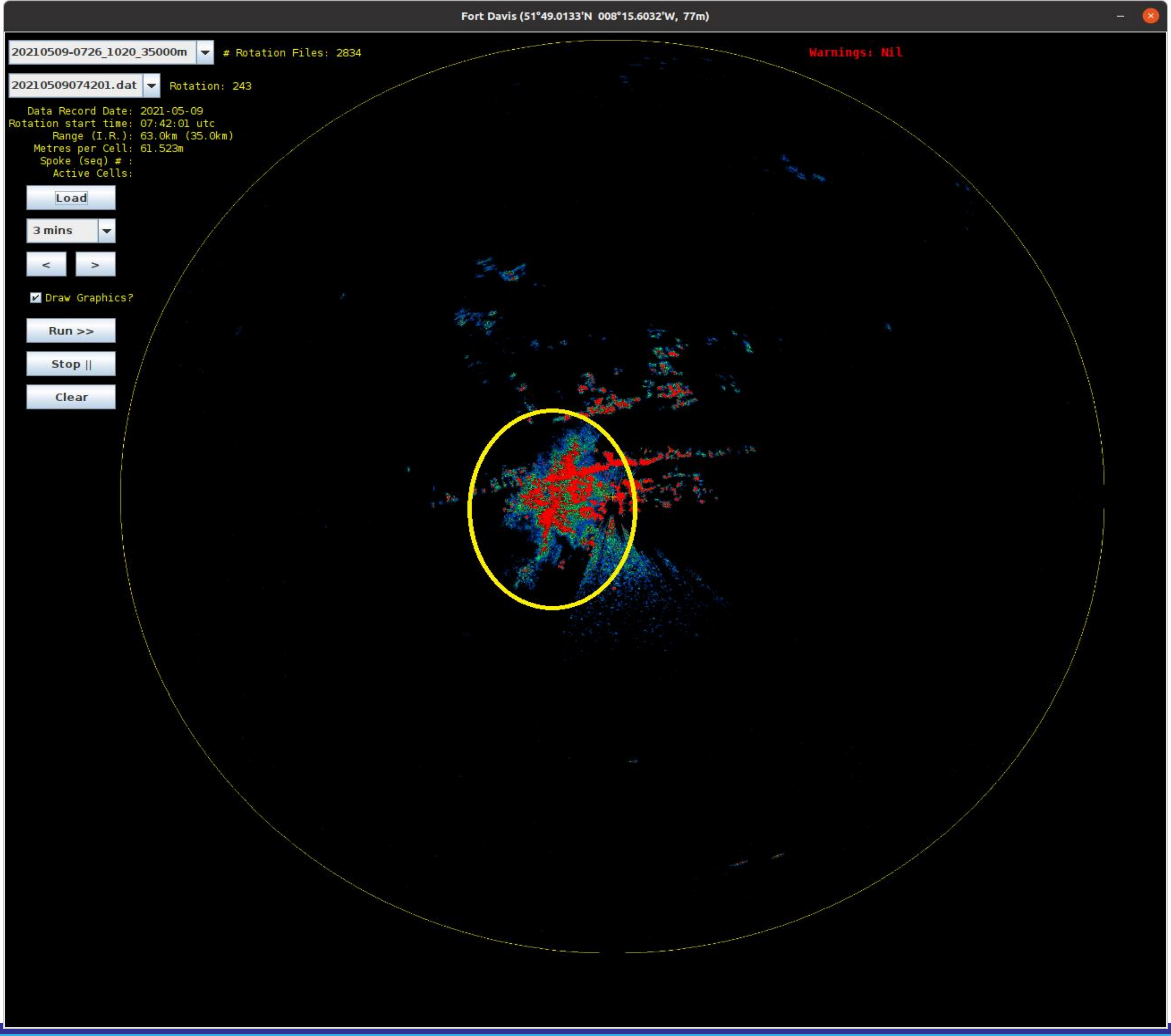

Fort Davis (51°49.0133'N 008°15.6032'W, 77m)
20210509-0726_1020_35000m
Rotation Files: 2834
Warnings: Nil
20210509073002.dat
Rotation: 53
Data Record Date: 2021-05-09
Rotation start time: 07:30:02 utc
Range (I.R.): 63.0km (35.0km)
Metres per Cell: 61.523m
Spoke (seq) # :
Active Cells:
Load
3 mins
<
>
Draw Graphics?
Run >>
Stop ||
Clear


Fort Davis (51°49.0133'N 008°15.6032'W, 77m)
20210509-0726_1020_35000m
Rotation Files: 2834
Warnings: Nil
20210509073300.dat
Rotation: 100
Data Record Date: 2021-05-09
Rotation start time: 07:33:00 utc
Range (I.R.): 63.0km (35.0km)
Metres per Cell: 61.523m
Spoke (seq) # :
Active Cells:
Load
3 mins
<
>
Draw Graphics?
Run >>
Stop ||
Clear


Fort Davis (51°49.0133'N 008°15.6032'W, 77m)
20210509-0726_1020_35000m
Rotation Files: 2834
Warnings: Nil
20210509073602.dat
Rotation: 148
Data Record Date: 2021-05-09
Rotation start time: 07:36:02 utc
Range (I.R.): 63.0km (35.0km)
Metres per Cell: 61.523m
Spoke (seq) # :
Active Cells:
Load
3 mins
<
>
Draw Graphics?
Run >>
Stop ||
Clear



Fort Davis (51°49.0133'N 008°15.6032'W, 77m)
20210509-0726_1020_35000m
Rotation Files: 2834
Warnings: Nil
20210509073900.dat
Rotation: 195
Data Record Date: 2021-05-09
Rotation start time: 07:39:00 utc
Range (I.R.): 63.0km (35.0km)
Metres per Cell: 61.523m
Spoke (seq) # :
Active Cells:
Load
3 mins
<
>
Draw Graphics?
Run >>
Stop ||
Clear


Fort Davis (51°49.0133'N 008°15.6032'W, 77m)
20210509-0726_1020_35000m
Rotation Files: 2834
Warnings: Nil
20210509074201.dat
Rotation: 243
Data Record Date: 2021-05-09
Rotation start time: 07:42:01 utc
Range (I.R.): 63.0km (35.0km)
Metres per Cell: 61.523m
Spoke (seq) # :
Active Cells:
Load
3 mins
<
>
Draw Graphics?
Run >>
Stop ||
Clear

Thank You

Contact Paul Shanahan paul.Shanahan@cit.ie

HALPIN
Centre for Research & Innovation at NMCI
Ionad um Thaighde agus Nuálaíocht ag NMCI

STREAM

MTU
Ollscoil Teicneolaíochta na Mumhan
Munster Technological University

EU Funds: Ireland Wales Programme 2014-2020

Tionól Réigiúnach an Deiscirt
Southern Regional Assembly

Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach

UNDEB EWROPEAIDD
EUROPEAN UNION
Llywodraeth Cymru
Welsh Government
Cronfa Datblygu Rhanbarthol Ewrop
European Regional Development Fund

Aquaculture at the Centre for Sustainable Aquatic Research using sensors

Paul Howes
Dr Pete Jones
Dr Josh Jones
Swansea University
Centre for Sustainable Aquatic Research

Application of Sensors in Precision Aquaculture

25 May 2021

Prifysgol Abertawe
Swansea University

Centre for Sustainable Aquatic Research
CSAR
Canolfan Ymchwil Dyfrol Cynaliadwy

Who are we?

Created with sustainability as a core principle in order to:

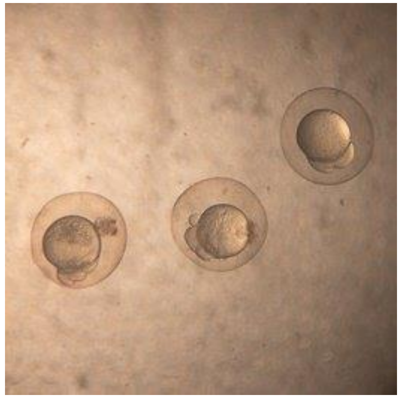
- Deliver unique training and research in aquatic science to enhance the student experience
- Deliver impactful and far-reaching research
- Provide meaningful support to industry, particularly in the areas of sustainable aquaculture, algal biotechnology and sector development

What do we do?

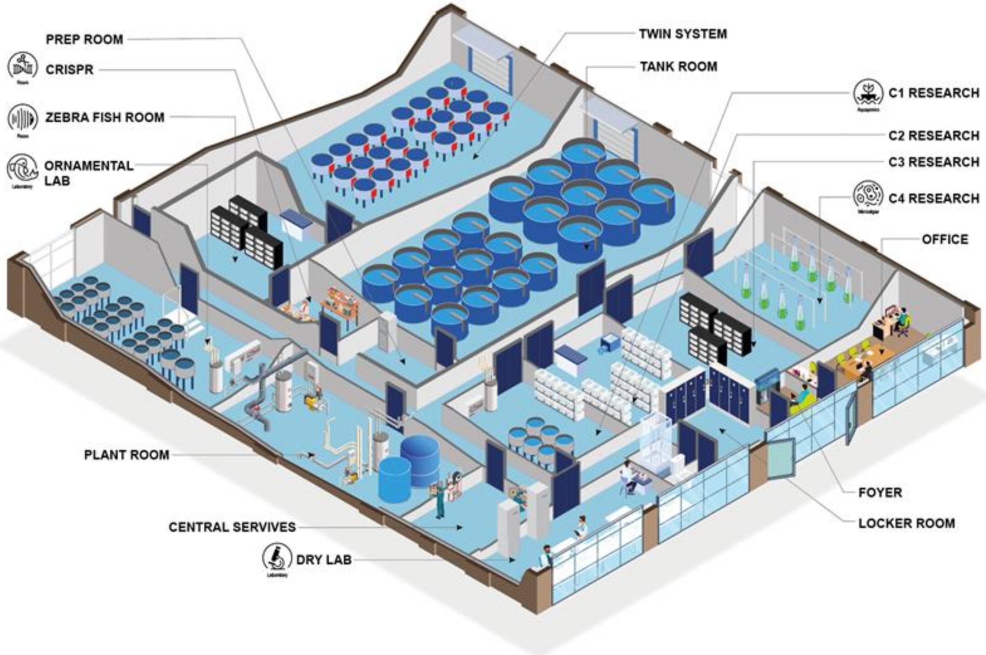
Areas of Expertise within CSAR:

- Welfare in aquaculture and aquatic research
- Larval culture
- Algal biotechnology
- Epigenetics
- Environmental impacts of aquaculture
- Ecosystem modelling
- ***Aquaculture hatchery technologies***






Facilities at CSAR



15 dedicated aquatic research laboratories including:

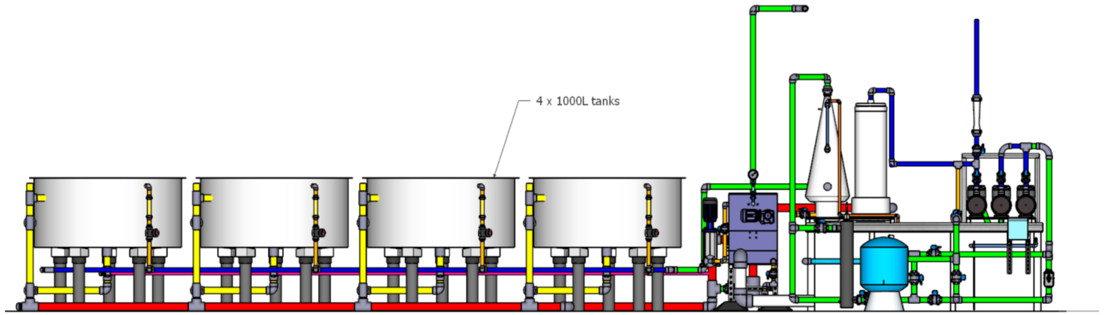
13 RAS systems ranging from 2m cubed to 60 meters cubed volume

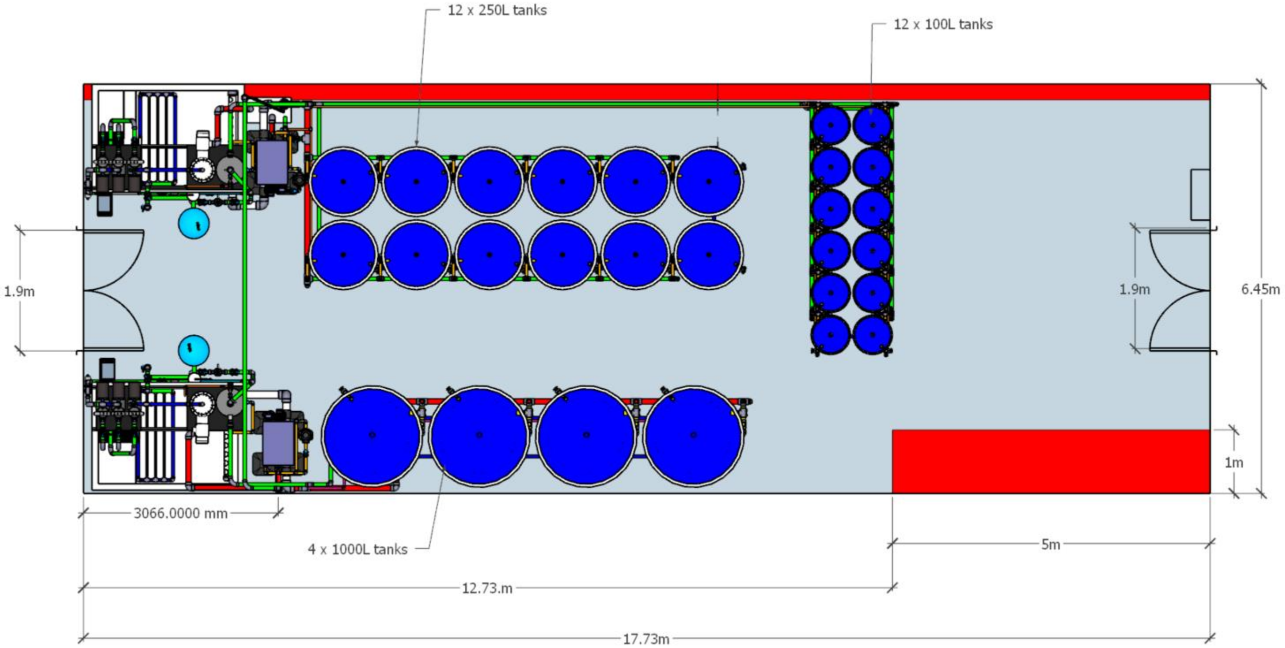
12 model RAS racks for laboratory fish

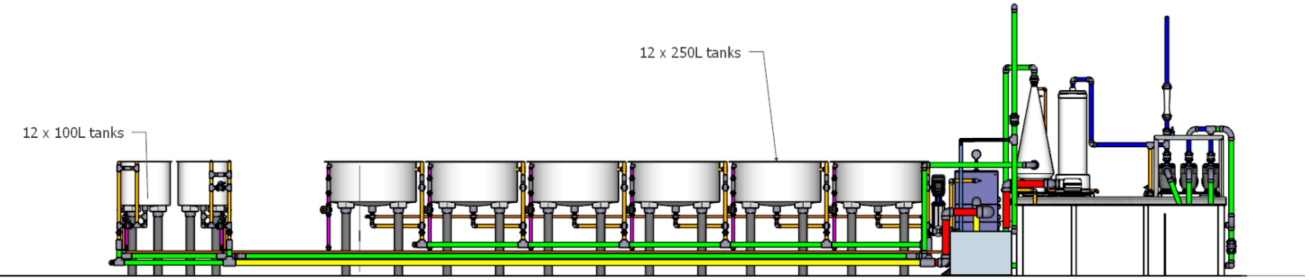
Temperature controlled from 8 - 30 degrees Celsius

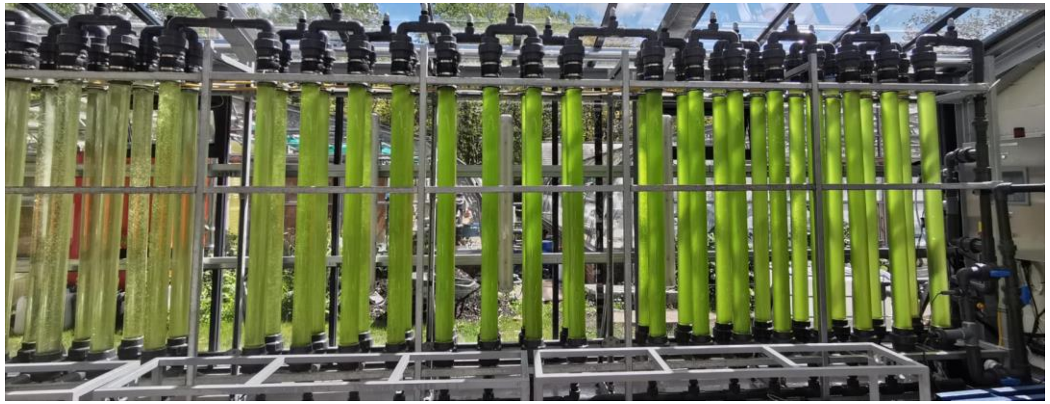
Wales Aquaculture Centre of Excellence – Wales ACE

Multi-Trophic Aquaculture at CSAR







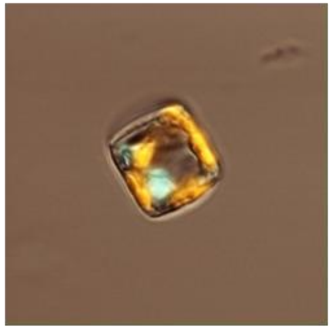


PBR from ALG-AD and EnhanceMicroAlgae INTERREG projects

Comprehensive suite of facilities for Algal Biotechnology

- 25+ master cultures
- 20 x 100L batch culture in a controlled environment lab
- 6 Biofences from 400l to 5000l



Paul Howes, Dr Peter Jones and Dr Josh Jones

Excellence in welfare = robust research data

NACWO

Monitoring fish
Staff training in humane killing listed in ASPA Schedule 1
Replacement, Reduction and Refinement (3 R's)

Fish Vet

Weekly visits from Vet (fish specialist)
Training staff on injection techniques, signs of ill health, histology and dissection
Collaborations with staff in the field of disease
Lumpfish Endoscopy

Animal welfare technician

Responsible for ensuring optimal rearing conditions for animals involved in trials and dissertations
Coaching researchers on animal husbandry
Setting up systems to provide high welfare standards

Sensor technology in CSAR for monitoring and controlling systems.

As with many RAS facilities, CSAR makes use of probes to monitor and adjust the following parameters:

- Air temp, Water temp
- Salinity
- pH
- Oxygen levels
- CO2 levels
- Ozone
- Flow rates
- Tank depth

In addition, all probes are linked to a central alarm system which includes hardware failure backup

How can the current sensor tech in the sector be enhanced?

Advancing sensor use for aquatic production

Incorporating sensors in the circular economy

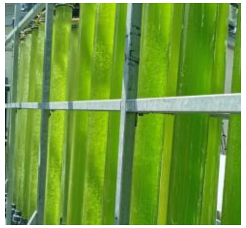
IMTA innovation for the circular economy

Sensor tech is to be incorporated at each trophic stage to optimise and monitor nutrient proportions.

Sensor tech

Feed formulation

Sensor tech



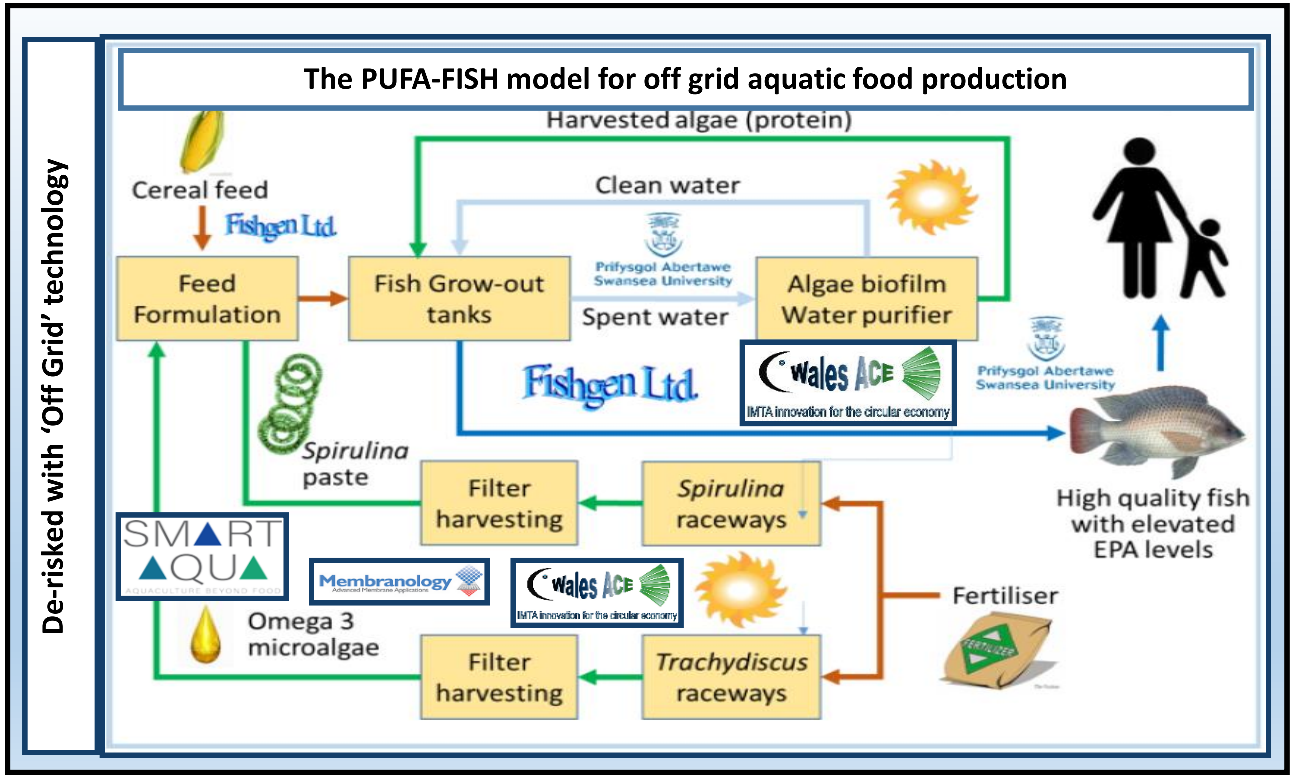
Sensor tech

Down Stream processing

Sensor tech

Incorporating sensors in LIC's/Marginal environments

Global Challenges Research Fund



Incorporating sensors in the Biophilic sector

Picton Yard Biophillic Development

- 22,000sqft Grade A Commercial Office Space
- 44 residential units
- New public event space
- Aquaponics Centre and vertical garden
- Public viewing aquarium
- The living building
- Energy capture materials

Funding **4.6 million** from Innovative Housing Programme **10.4 million** in private investment

Determining preference and avoidance thresholds for marine organisms

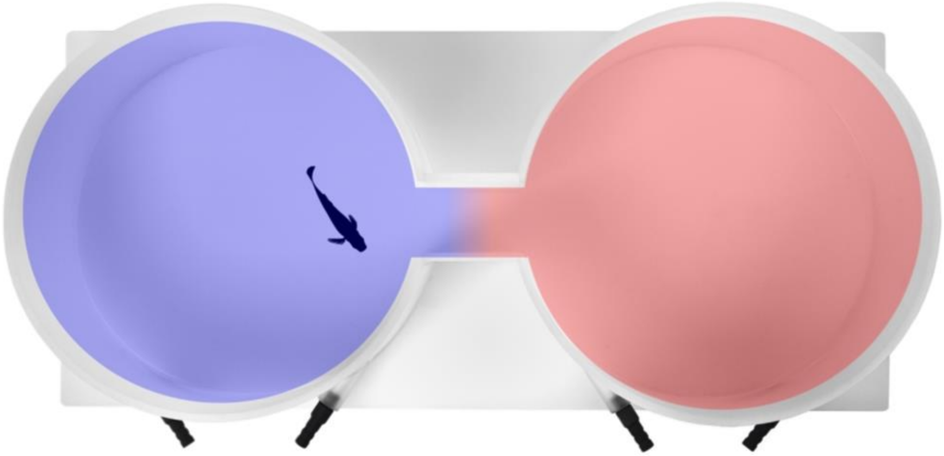
Shuttle box experiments

Allow choice experiments for fish and crustaceans

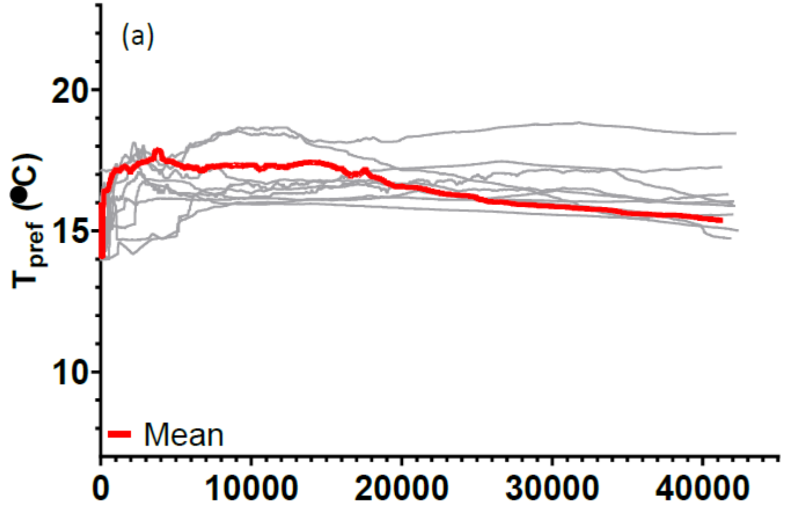
Can manipulate water quality parameters on each side independently

Organisms can detect differences at interface and can shuttle back and forth to control ambient conditions

Monitor movements with overhead camera

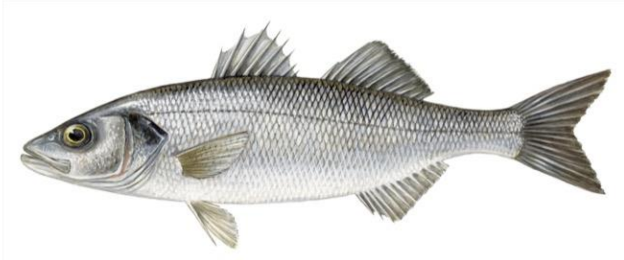


Source: loligosystems.com, 2021



Source: Harman et al., 2020

Determining preference and avoidance thresholds for marine organisms



Shuttle box outputs

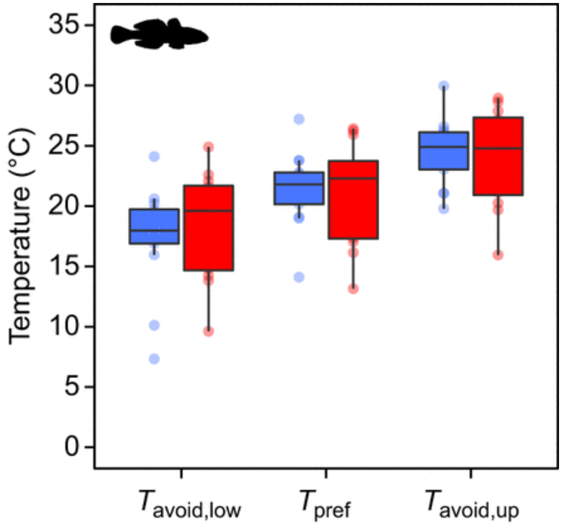
Sea bass (*Dicentrarchus labrax*)

Temperature, DO, pH, pCO_2, salinity

Preference and avoidance thresholds for a range of species

Can be used to identify areas with suitable water parameters for aquaculture

Predict how habitat suitability and species distributions are likely to change with predicted climate change



Temperature preference and avoidance temperature of round goby (Source: Christensen et al., 2021)

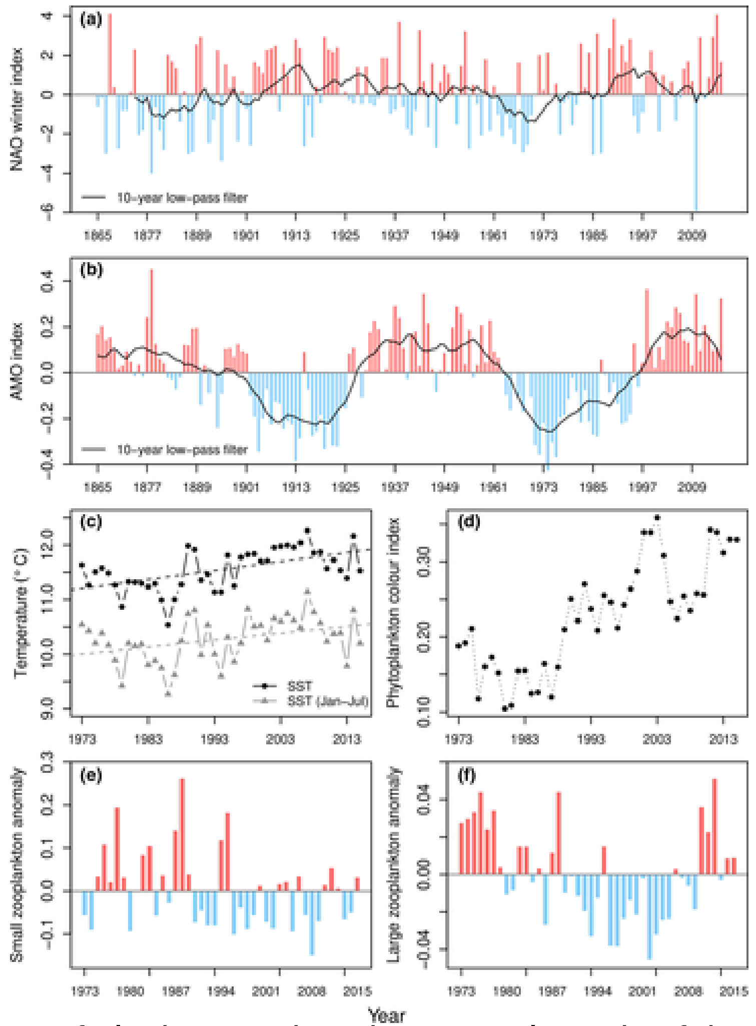
Mapping opportunities and challenges for aquaculture and fisheries

Historic suitability mapping

Dynamic Energy Budget theory (koijman, 2010)

Model historic aquaculture and fisheries suitability using:

Bathymetry, chlorophyll-a, current speed, temperature, pH



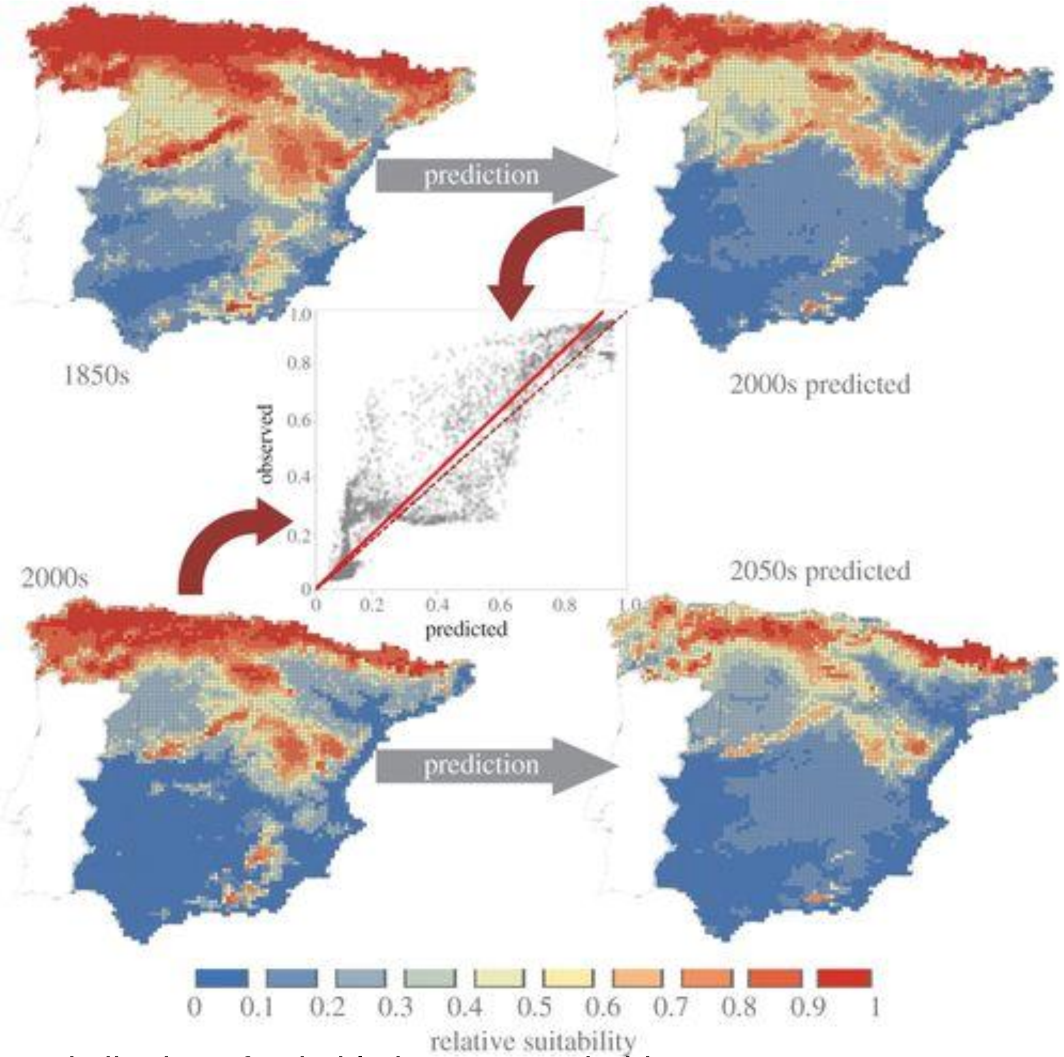
100 years of plankton and environmental trends of the Irish Sea (Bentley et al., 2020)

Mapping opportunities and challenges for aquaculture and fisheries

Current suitability

Validate historic distribution models using contemporary species distributions and environmental data

Cross reference these with mesocosm experiments

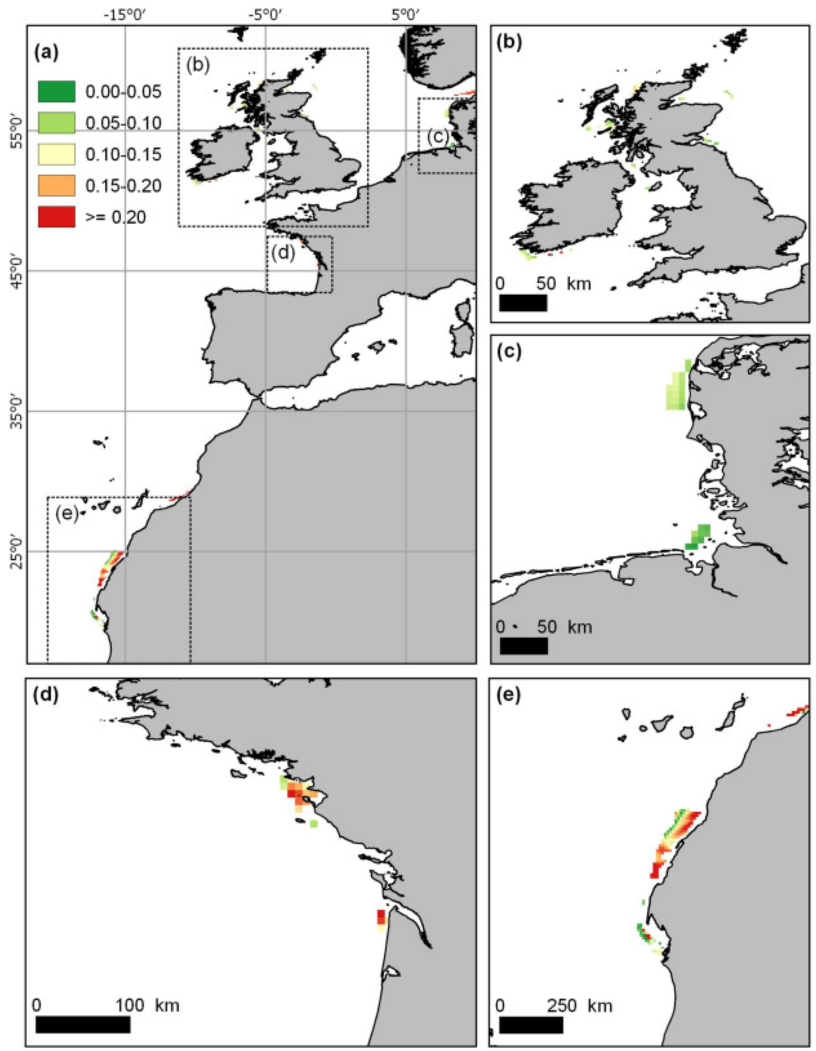


Distibution of suitable brown trout habitat (Clavero et al., 2017)

Mapping opportunities and challenges for aquaculture and fisheries

Suitability projections

Estimate impacts of climate change scenarios to assess future opportunities and challenges



Pacific oyster cultivation suitability under climate change scenarios (Palmer et al., 2021)

Reverse engineering: a machine vision solution for aquaculture

Gyopár Elekes

Data Scientist FAPTIC.xyz

Application of Sensors in Precision Aquaculture

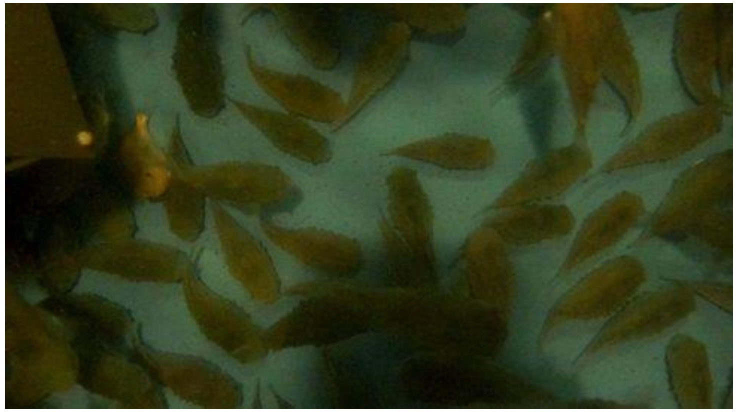
25 May 2021

Introduction

REVERSE ENGINEERING:

A MACHINE VISION SOLUTION FOR AQUACULTURE

- Machine Vision
- Industry questions
- In this presentation
  1. Where do the fish go?
  2. Can clinging and swimming behavior be identified?



1. Where do the fish go?

Start from:

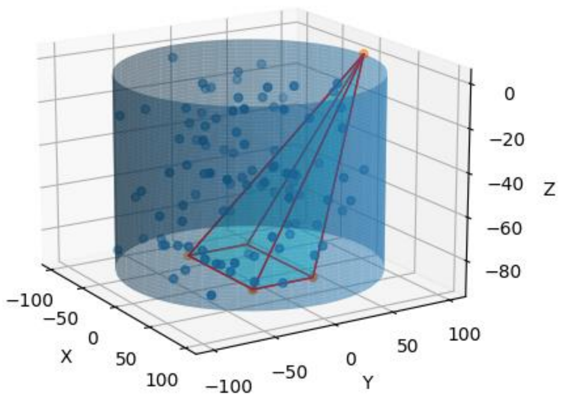
- visual representation

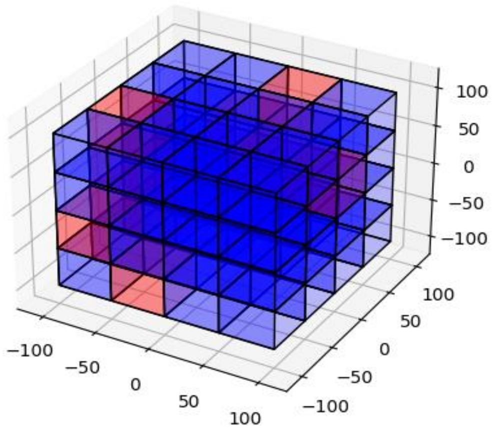
Gives insight:

- fish behaviour
- distribution in the water volume

Indicates:

- e.g. fish aggregating to the surface can suggest low oxygen level





The process in reverse:

7. record underwater videos and detect fish in frames

6. define the position of individual fish in 3D space - (x, y, z) coordinates

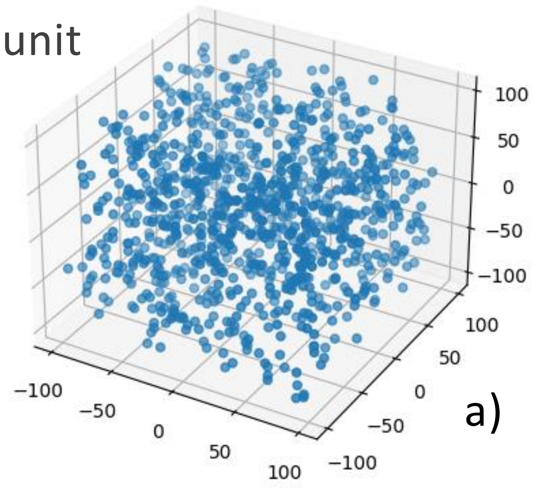
5. distribute the total volume in small units

4. calculate the number of fish inside unit volumes

3. calculate the average fish number in each unit

2. define a threshold for critical fish density

1. visualize the results



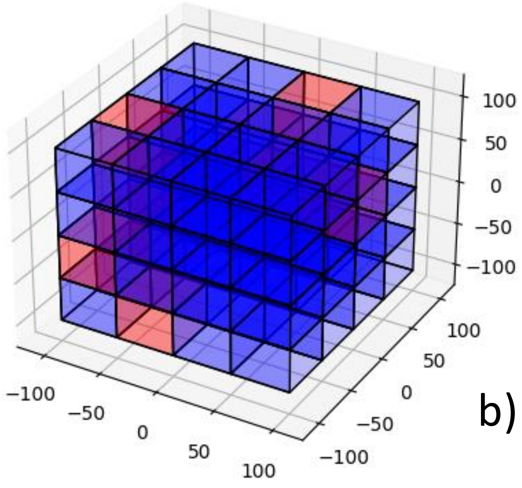


Fig. 1
a) Uniformly randomized position of 1000 fish in 200x200x200 m^3 volume.
b) Unit volumes, colored based on the number of fish in volume.
Red – high density-more fish, blue – low density – less fish

Employing machine vision

DETECT FISH

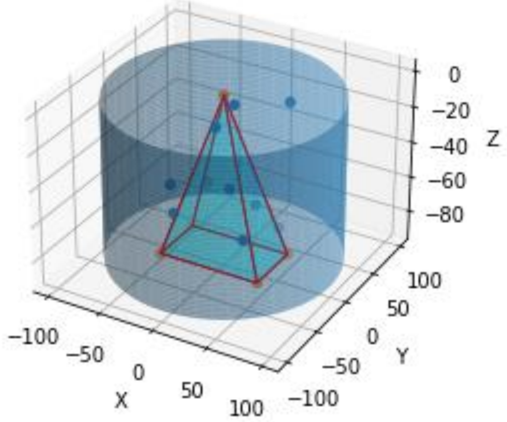
- AI - Deep Learning algorithms
- Fish position in the image 2D (pixel coordinates)

DEFINE POSITION IN 3D

Stereoscopic images are used in the recordings.

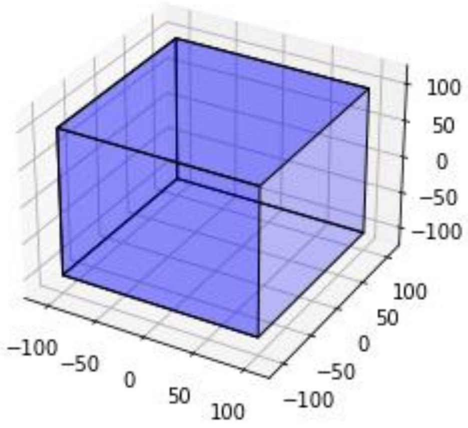
We can calculate the (x, y, z) coordinates of the detected fish.

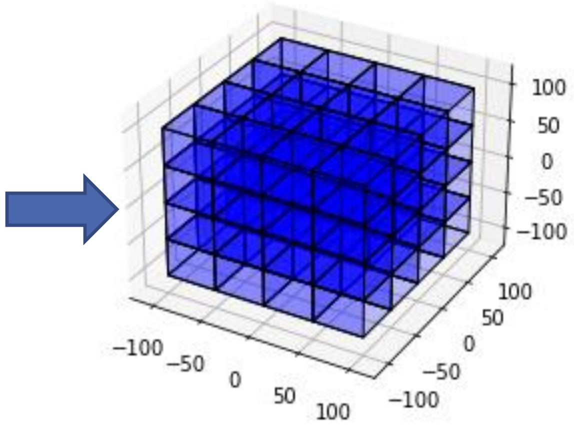
We can visualize the position of the fish inside the tank.



Simplifying the results

DIVIDE THE TOTAL VOLUME



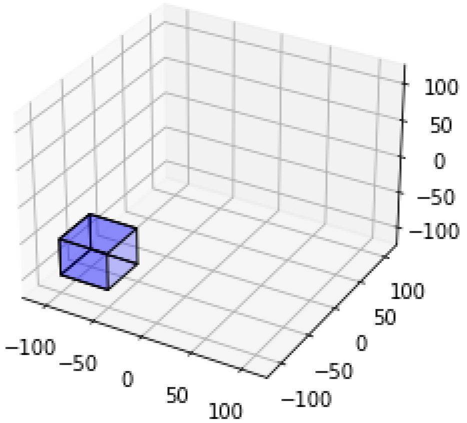


- distribute the total volume in small units – 50x50x50 m units

u_x, u_y, u_z = 50, 50, 50
units_x = int((x_max-x_min)/u_x)
units_y = int((y_max-y_min)/u_y)
units_z = int((z_max-z_min)/u_z)

FISH IN UNIT VOLUMES

- Unit volumes are determined by the coordinates of the vertices.



[[-100,-100,-100],
[-50, -100, -100],
[-50, -50, -100],
[-100, -50, -100],
[-100,-100,-50],
[-50, -100, -50],
[-50, -50, -50],
[-100, -50, -50]]

- The positions of the fish are known.

- Counting the number of fish, when its position is inside the unit volume
  (e.g. [25, 20, 36, 14, 22, …])

Simplifying the problem

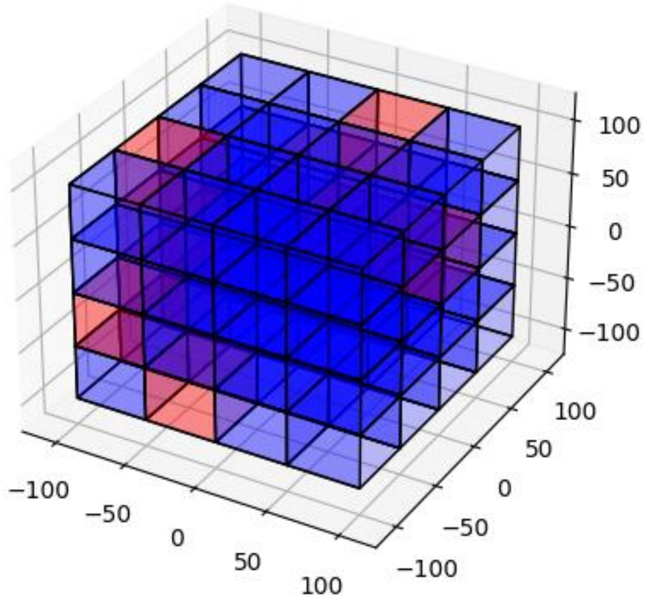
AVERAGE FISH DENSITY IN UNIT VOLUME

- save historical data about counts inside unit volumes

- calculate the average number for a given period (e.g. 20 min)

- mark visually if the number of fish is high in a specific part of the water

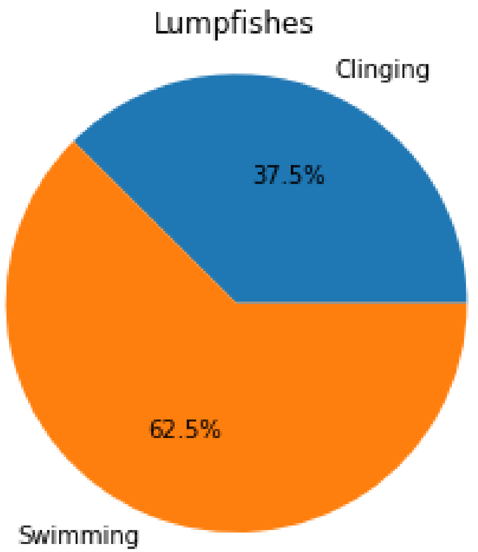
VISUALIZE THE RESULTS



2.Clinging and swimming behavior

What we want to see

- Blue – amount of fishes clinging represented in %
- Orange – amount of fishes swimming represented in %



The process in reverse:

7. record underwater videos and track fish in frames

6. define the initial position of fish where the centroid shows up

5. in next frames identify again the fish/fishes position and compare with previous one

4. fish swimming : compare new position of lumpfish

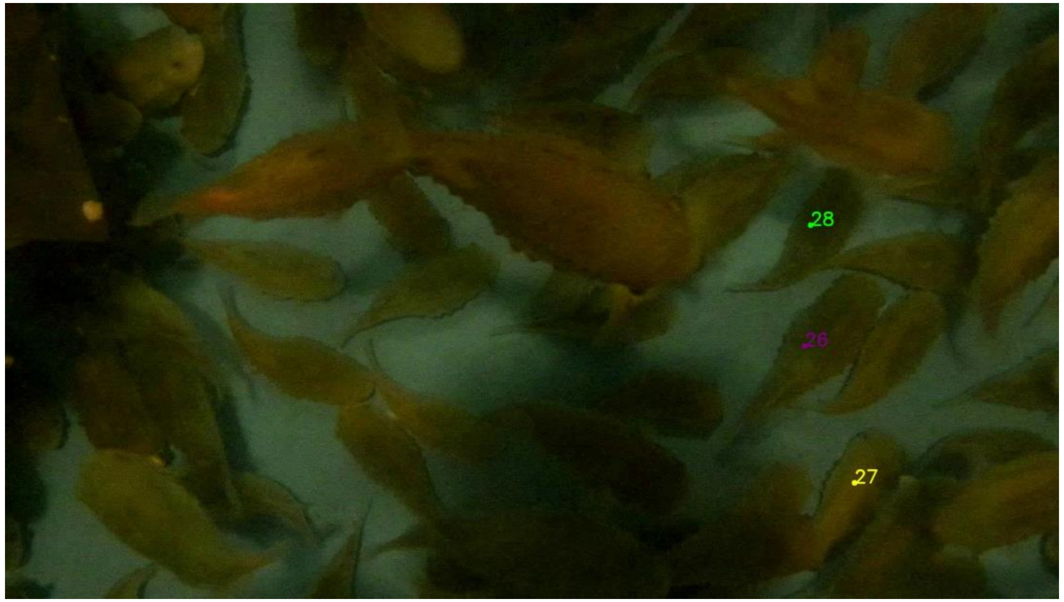
with last position , if not equal -> lumpfish moves

3. fish clinging : compare new position of lumpfish

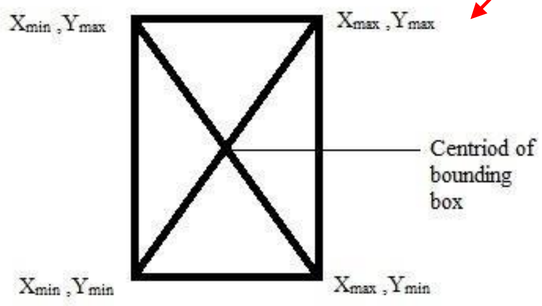
with last position , if equal -> lumpfish doesn't move

2. count fish swimming and fish clinging

1. visualize the results

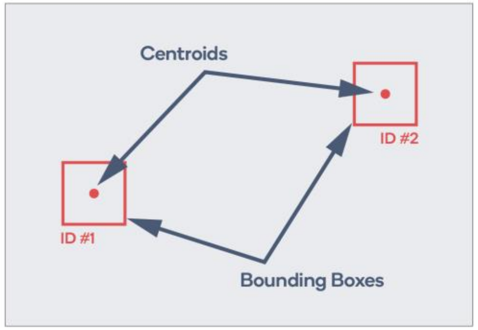


Fish detection

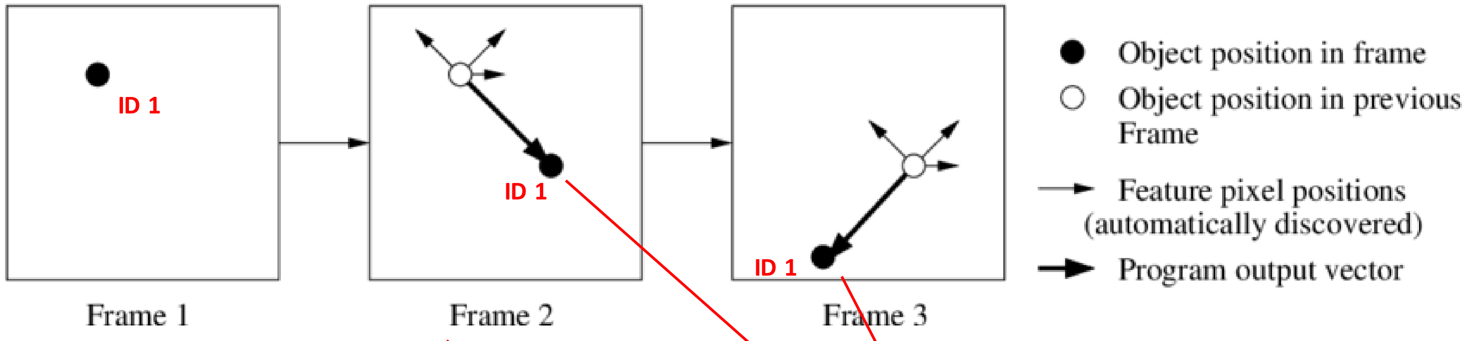


As input for tracking, we used the output of Deep Learning algorithm (detections of lumpfish)

Calculate centroid of each detection and give a unique id



Fish tracking



Apply Kalman filter [1] – predicts new position based on historical positions

Hungarian Algorithm[2] - validates if an object in current frame is the same as the one in previous frame

Output Detectron2 model → Kalman Filter → Hungarian Algorithm → Detect and track objects

Clinging vs swimming behaviour

Estimating behaviour types:

- Fish swimming:

  Previous position of fish detected is not equal to the new position.

- Fish clinging:

  Previous position of fish detected is equal to the new position.

Example for distinguishing behaviour:

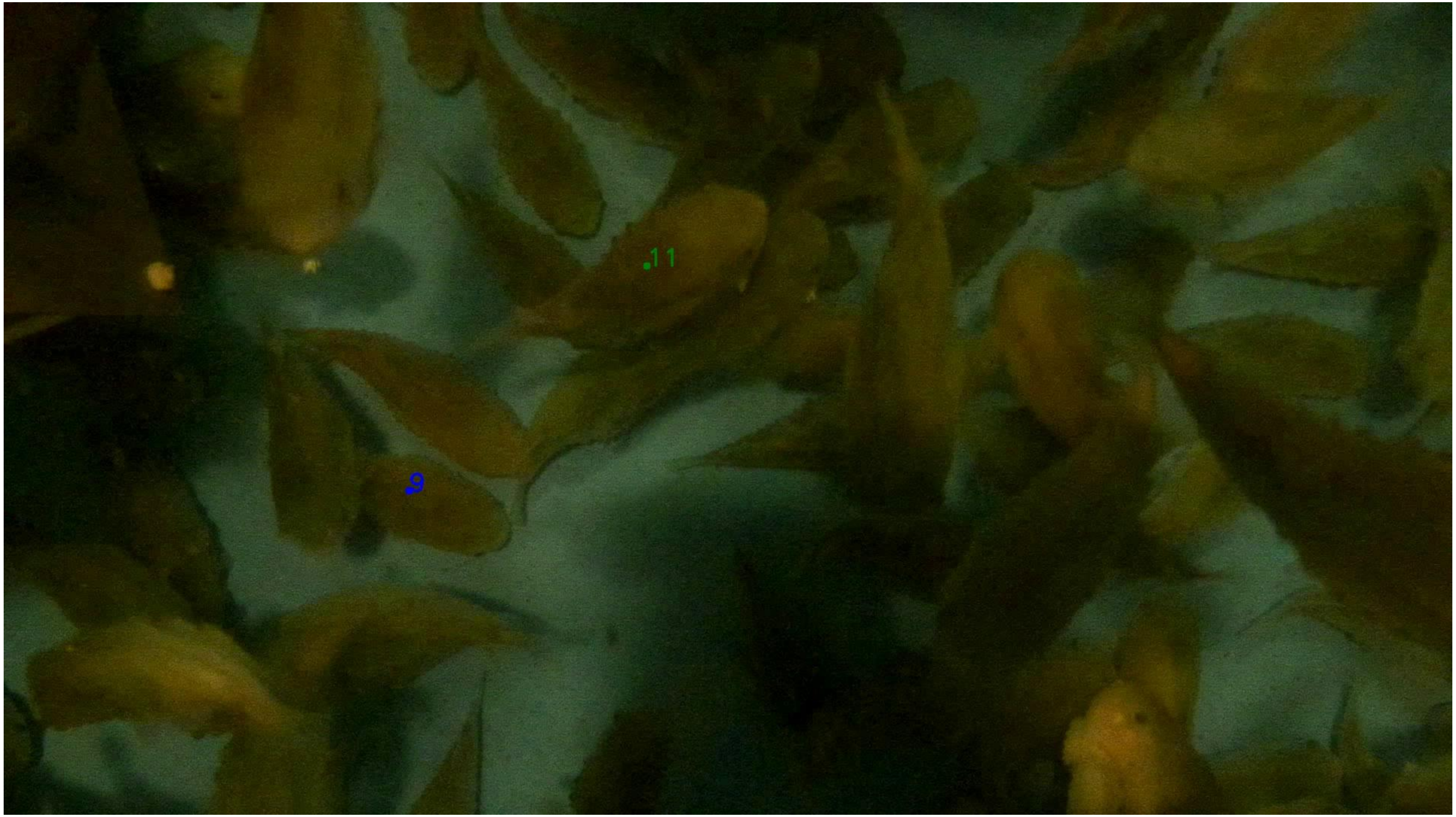
Lumpfish 9 : in initial frame was found at 28.33 pixels and next frames the same at 28.33 = lumpfish clinging

Lumpfish 11: in initial frame was found at 31.59 pixels and next frames at 25.74 = lumpfish swimming

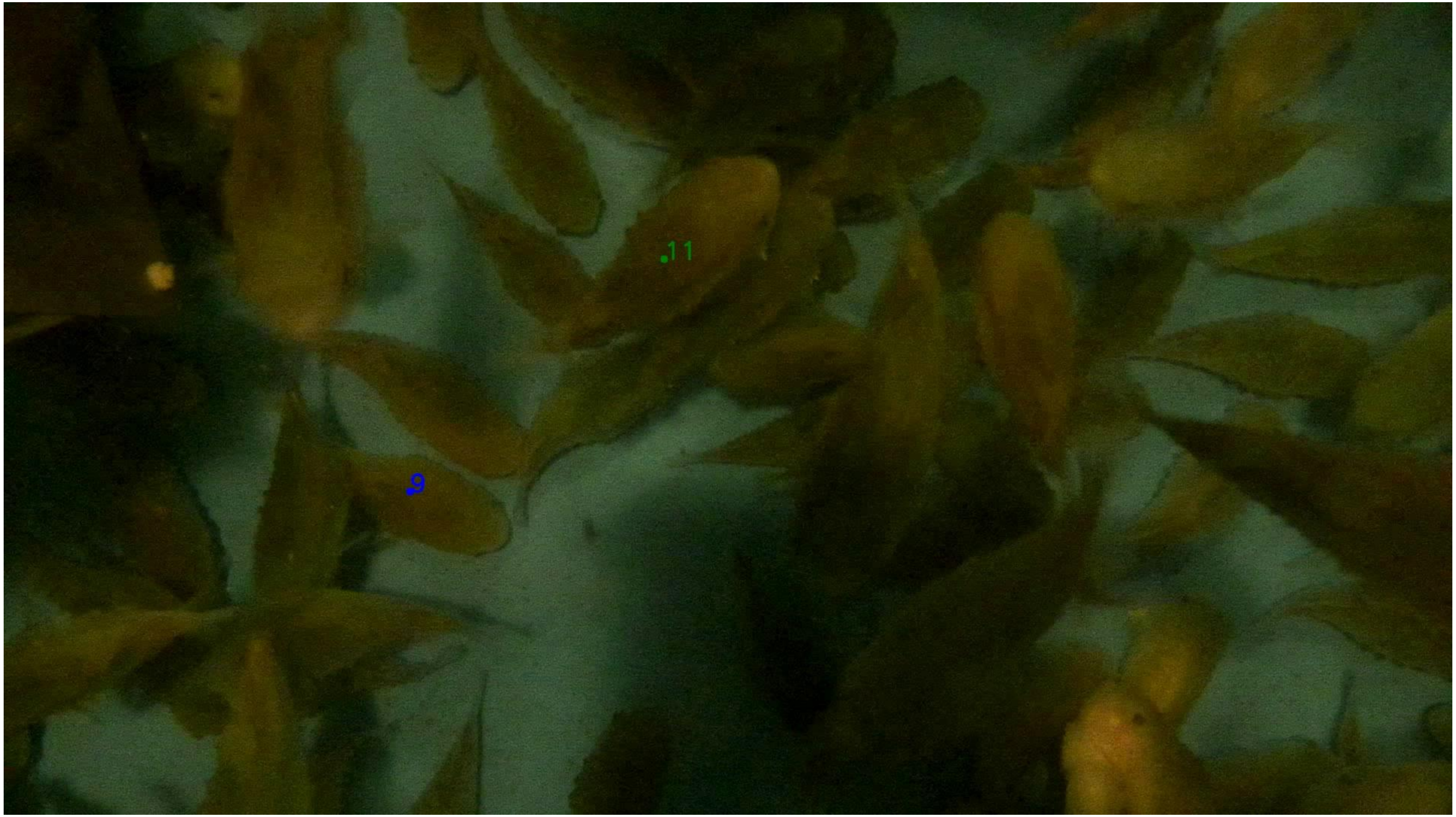
We represent an example in the following images.

Clinging vs Swimming

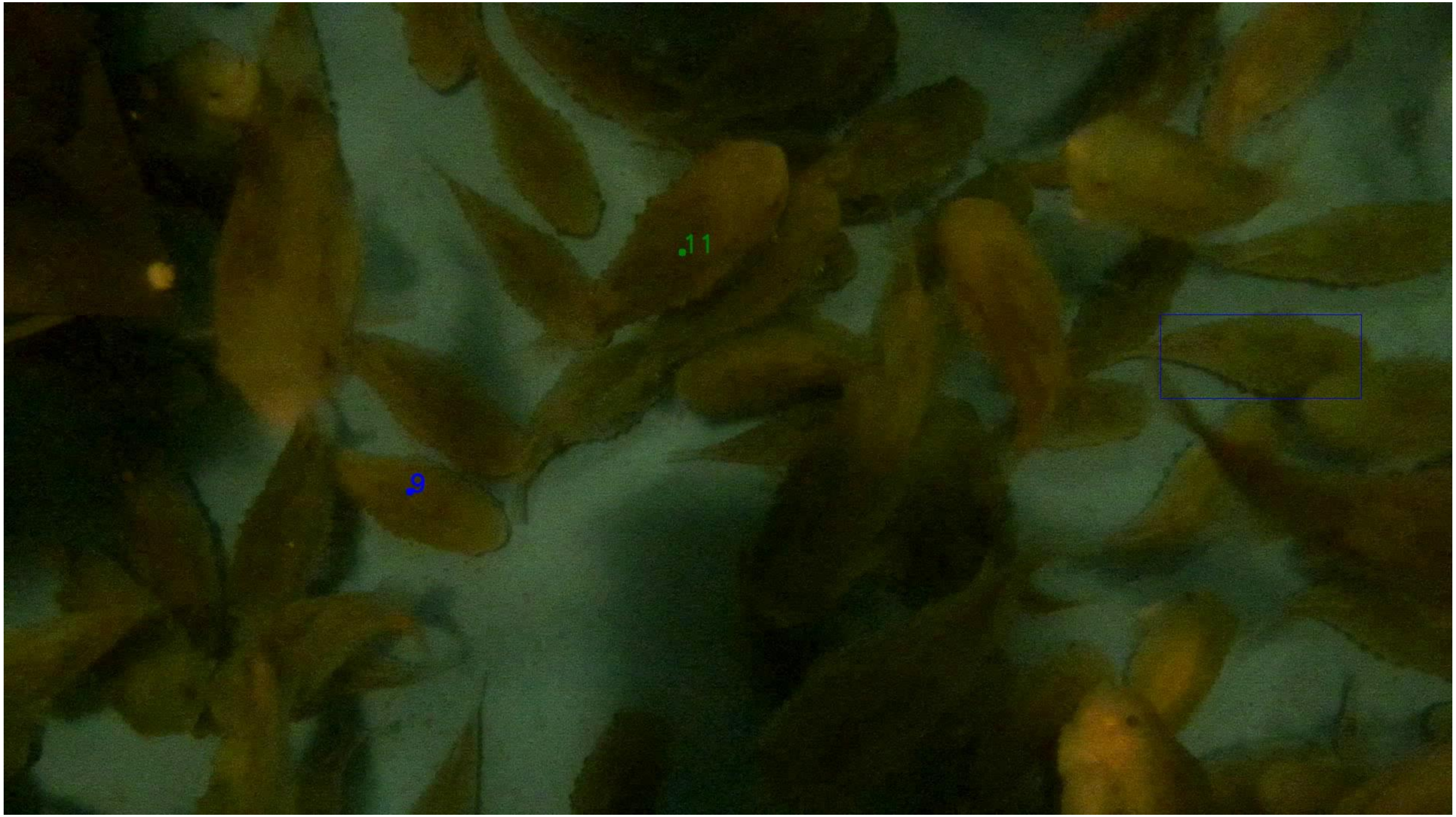
Clinging vs Swimming



Clinging vs Swimming



Clinging vs Swimming



Summary

- Machine Vision is here (technology is available)
- Next steps (focusing more on behaviour analysis)

Advantages

- Always available
- Non-invasive
- Predictive

For more information: info@faptic.xyz

SeaLens Technology to Monitor 3D Aquaculture In Wales

Christian Berger & Dani Abulhawa
PEBL-Plant Ecology Beyond Land

Application of Sensors in Precision Aquaculture

25 May 2021

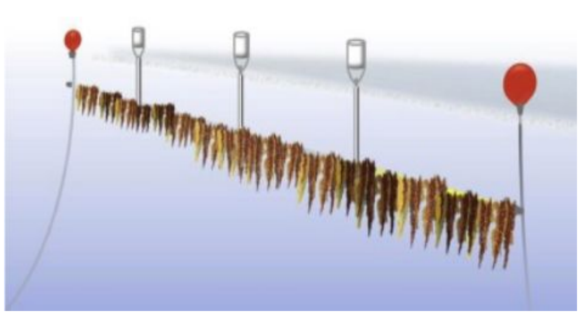
Why monitor your sea-farm?

✓ Improve consistency

✓ Reduce manual labour

Low-trophic sea-farms

Seaweed / Seagrass



Bi-valves / Crustaceans

Examples:

- New aquaculture location assessment
- Harvest schedule planning
- Early warning & troubleshooting (disease, rigging failure, pollution)
- Validating sustainability objectives (biodiversity, carbon, nitrogen)

Key requirement: Low-cost, Easy-to-use, Live data

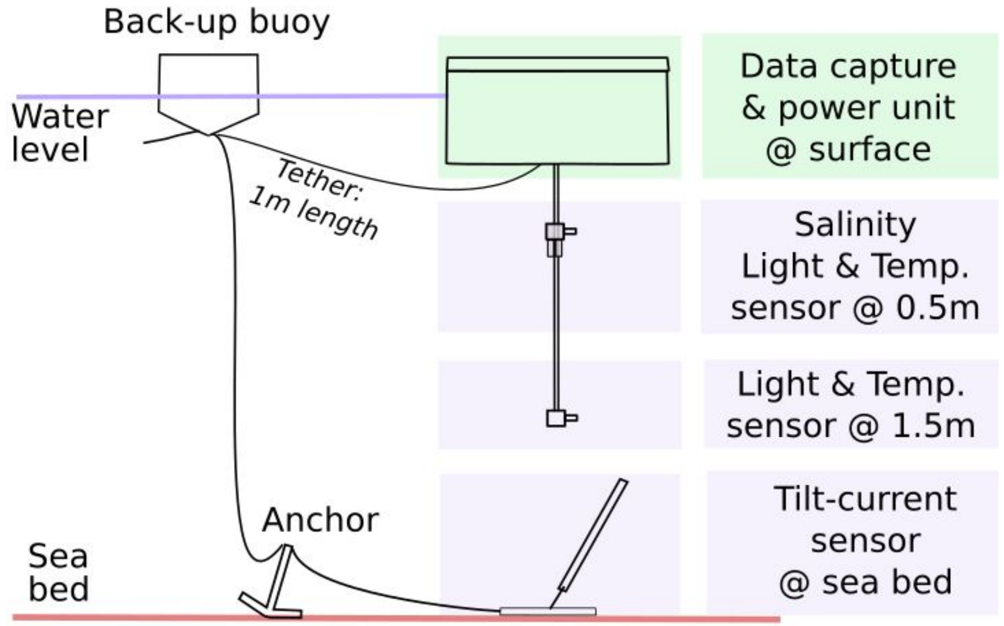
SeaLens: Low-cost sea-farm monitoring tool

Water quality
pH / Salinity

Physical environment
Light / Flow / Temp.

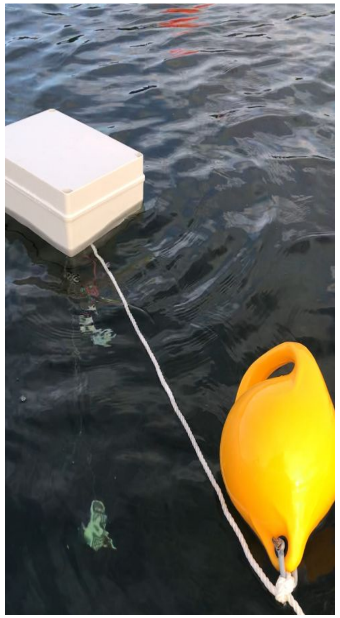
Imaging
Photo / Video

System overview



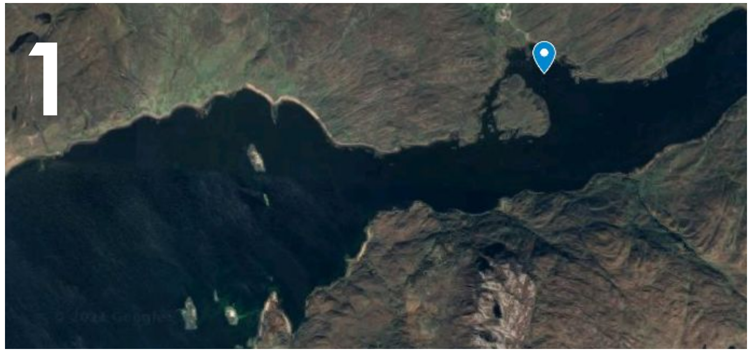
Deployment

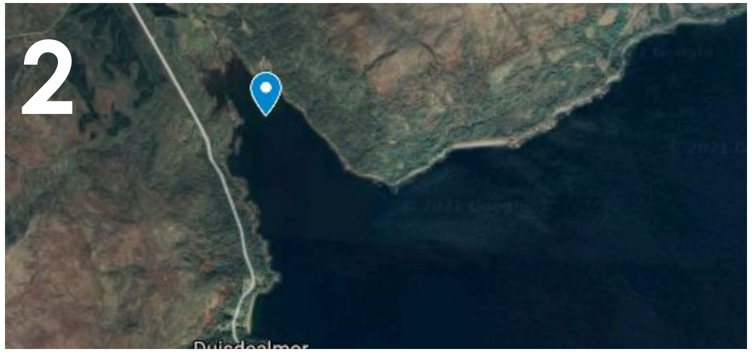
Surface unit



Current sensor

Case Study: Proposed seaweed & Shellfish farm Skye



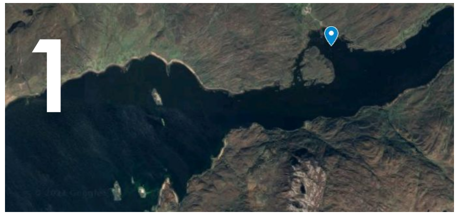


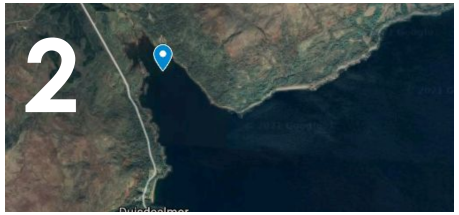
Site 1:
- Sheltered cove
- Near stream

Site 2:
- Semi exposed bay
- Near hotel

Site 3:
- Wide loch
- Deep

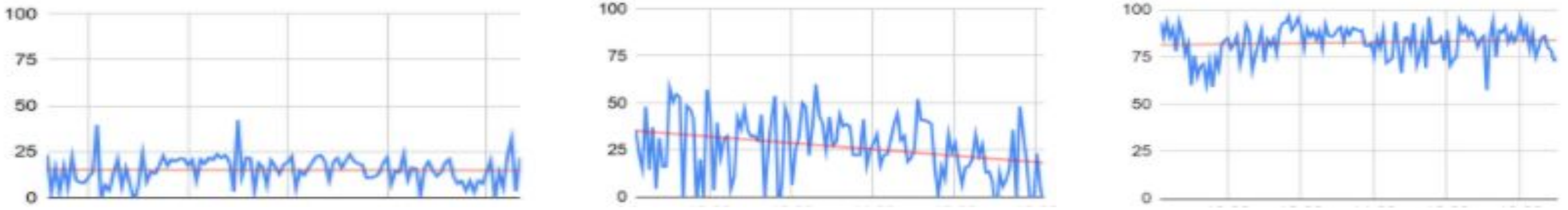
Case Study: Seaweed & Shellfish farm Skye



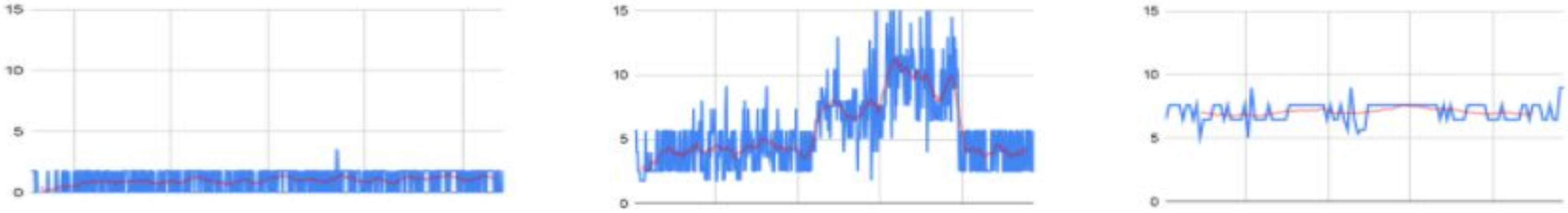


Salinity vs Time

Light attenuation vs Time



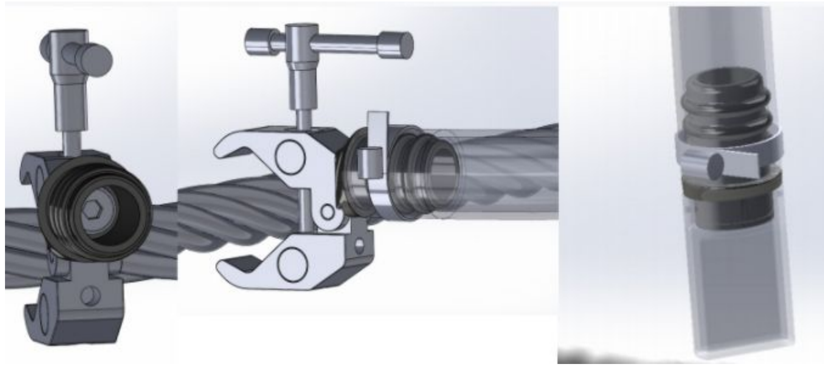
Current vs Time



Next steps:

IUK Project SeaLens:
April 21 - March 22

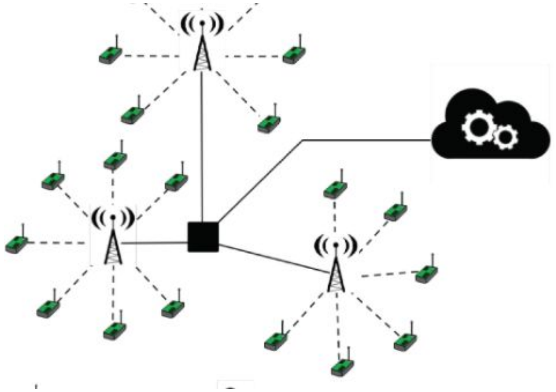
Adapt tools for sea-farms



Test long-term imaging

Implement comms back to land

LoRaWAN



Thank you

We hope you enjoyed the webinar

Updates on

- @csar_ace
- @irlwales
- #aquasensors