

WELCOME

Application of Sensors in Precision Aquaculture

25 May 2021 | 10:00 - 12:20



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

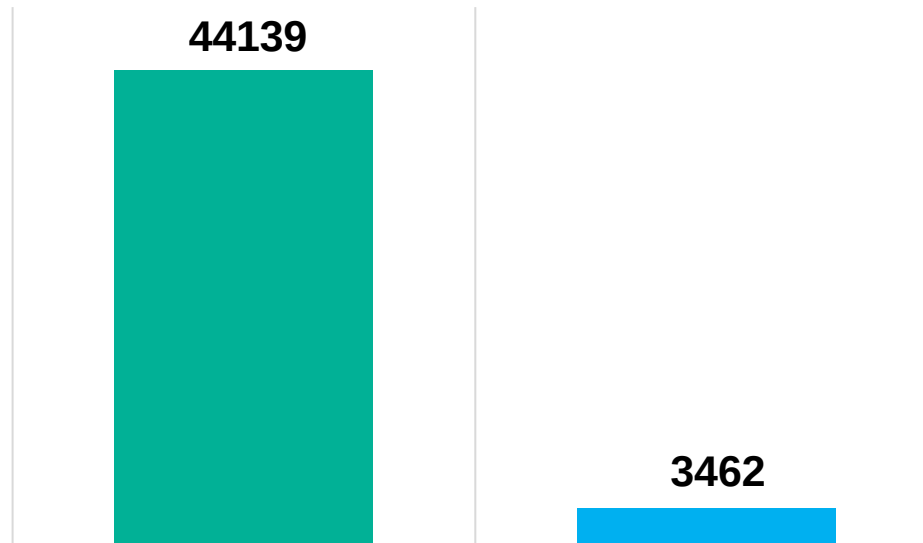
Amphibians ...

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



AGRICULTURE

AQUACULTURE

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



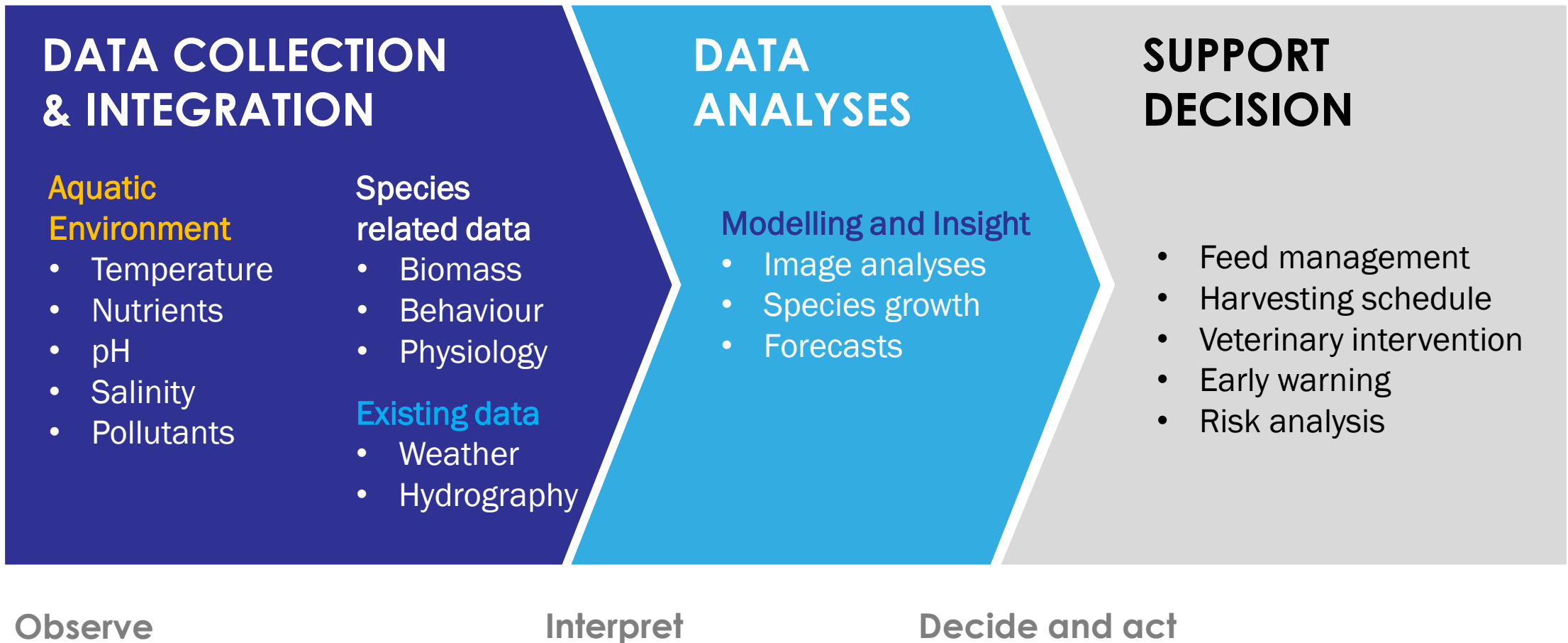
Pressure from consumers
and regulators



New real-time sensor
technologies

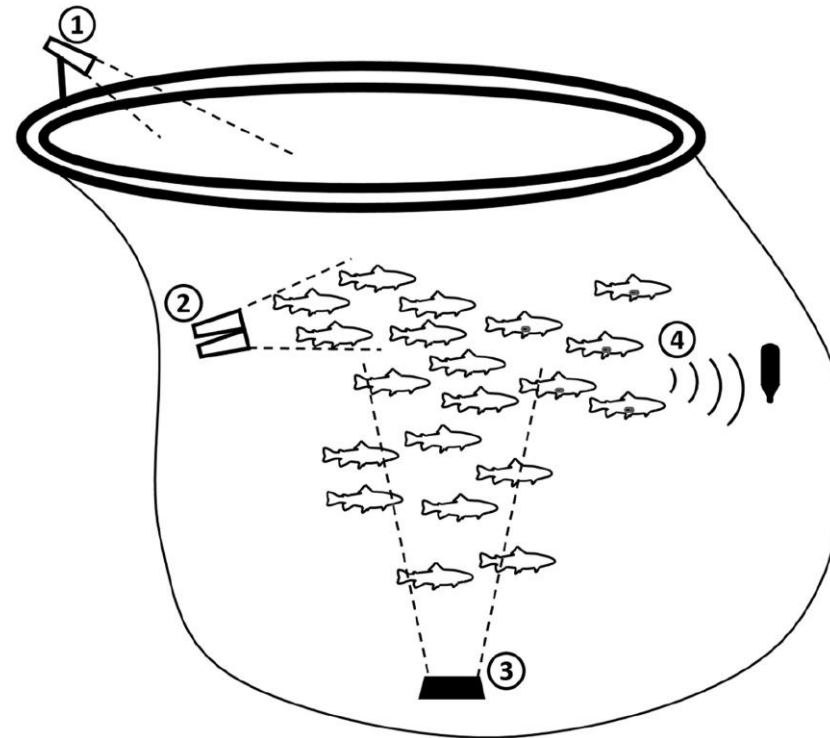


Precision aquaculture: the framework



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**

Føre 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
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Access2Sea aims

to improve the
availability of the
Atlantic shore for
aquaculture SMEs

How?

By Enabling

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



14-2020

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

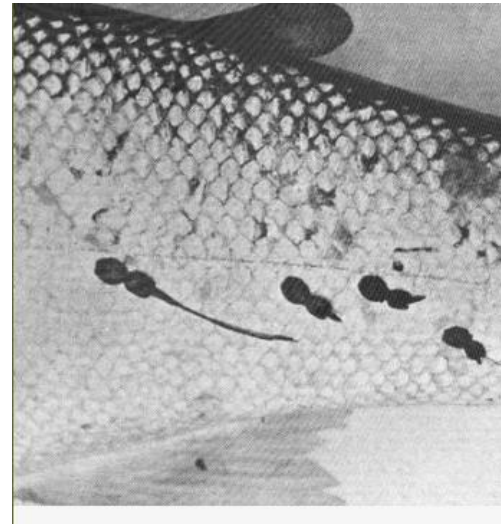
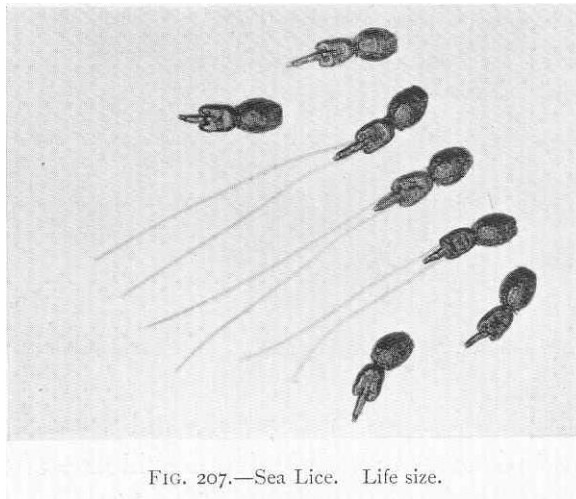
FRANCE

- Investir en Finistère
- Technopole Quimper - Cornuaille

Access2Sea Products



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.**

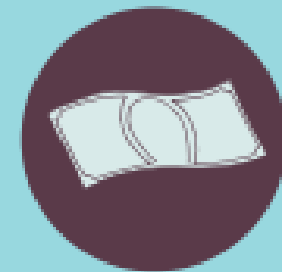
Lumpfish welfare

driving fish aquaculture social acceptability



Consumers in **Europe and Canada** have shown a high willingness to pay for better fish welfare. We estimate the cost of poor fish welfare at

**\$4.6
billion**



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 Watcher



Lumpfish Welfare E-learning

Online course on Lumpfish welfare



BMI Calculator

Calculates Lumpfish Body Mass Index (BMI)



Rapid Welfare Assessment Tool

Calculates the Lumpfish Operational Welfare Score Index (LOWSI)



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



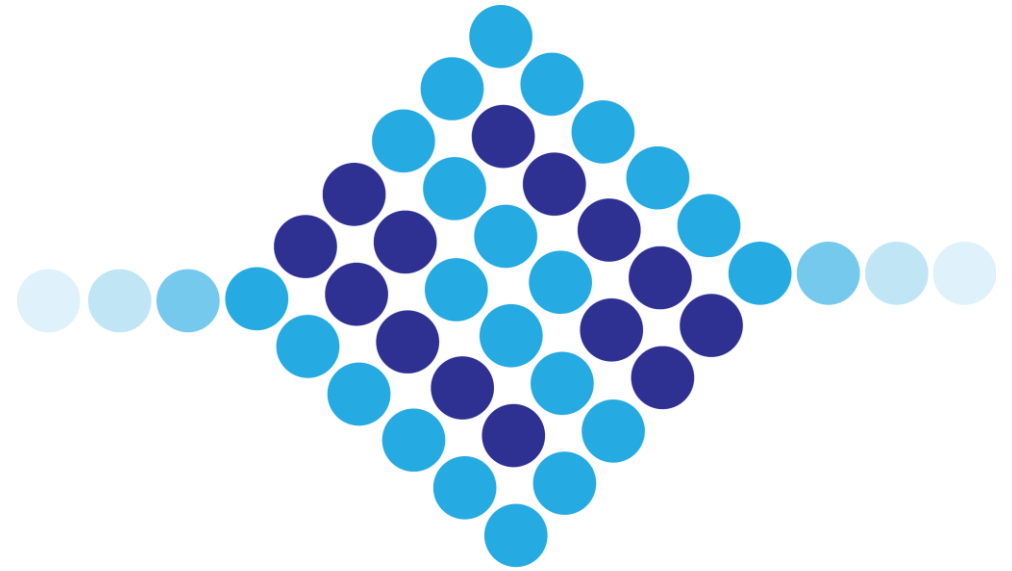
STREAM: Sensor Technologies for Remote Environmental Aquatic Monitoring

Prof. Carlos Garcia de Leaniz

Centre for Sustainable Aquatic Research (CSAR), Swansea University

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STREAM

STREAM

Purpose:

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

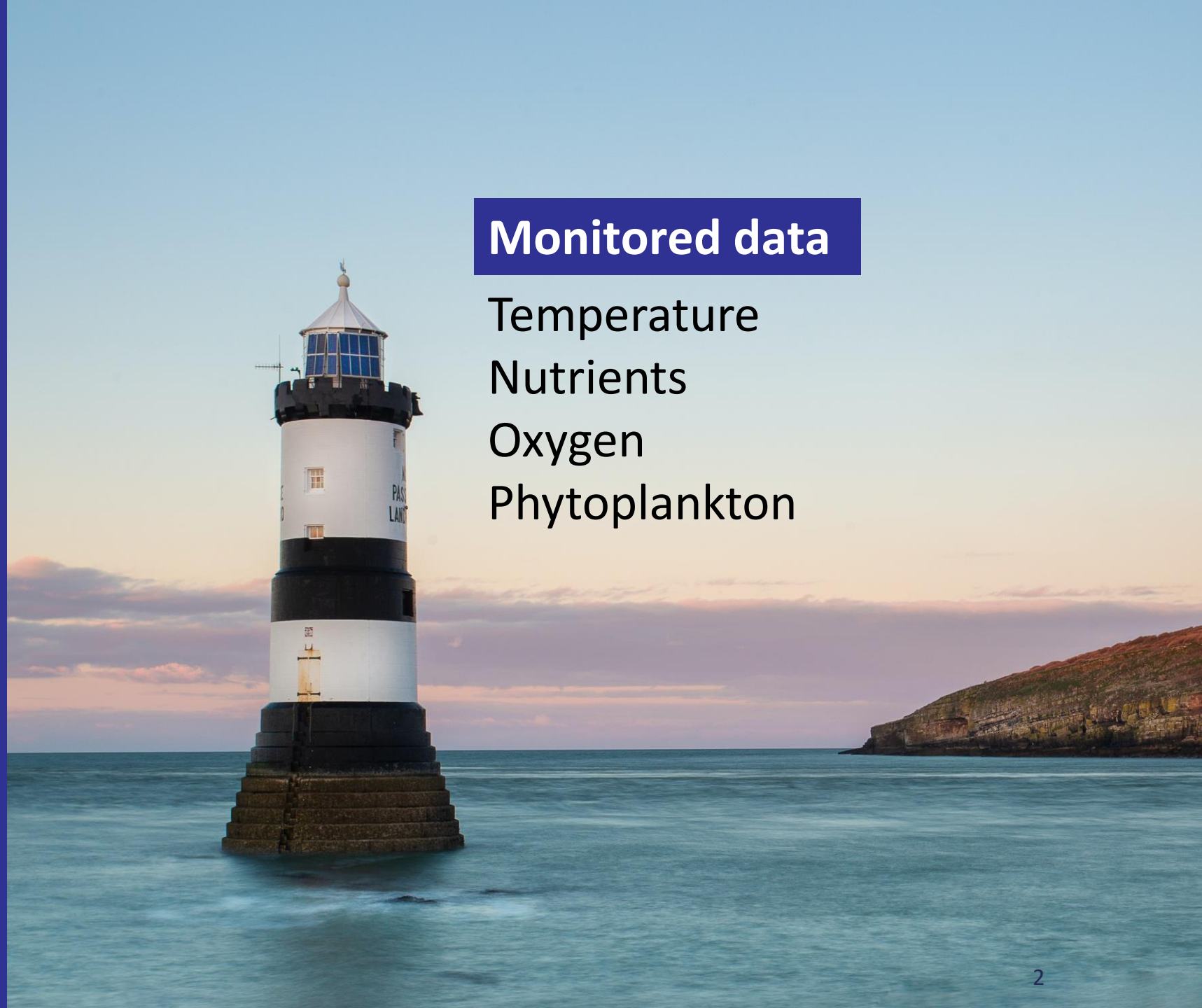
Monitored data

Temperature

Nutrients

Oxygen

Phytoplankton



The Team

Waterford Institute of Technology



Waterford Institute of Technology (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](#)



Principal Investigator and Project Lead | WIT | 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](#)

Dr Peter McLoughlin

Benyuan Yu

Stephen Norton

Hugh O'Sullivan

Jerry Horgan

John Ronan

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](#)



Head of Collegel PI | 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](#)

Dr Ambrose Fury

Dr Naghmeh Kamali

Paul Shanahan

Mike Grieve

Brid Cripps

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 | Swansea University | WCPC

Professor Gethin is a mechanical engineer and the Co-founder and Co-director of the Welsh Centre for Printing and Coating. Professor Gethin's research interests include powder forming with emphasis on tableting; 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.

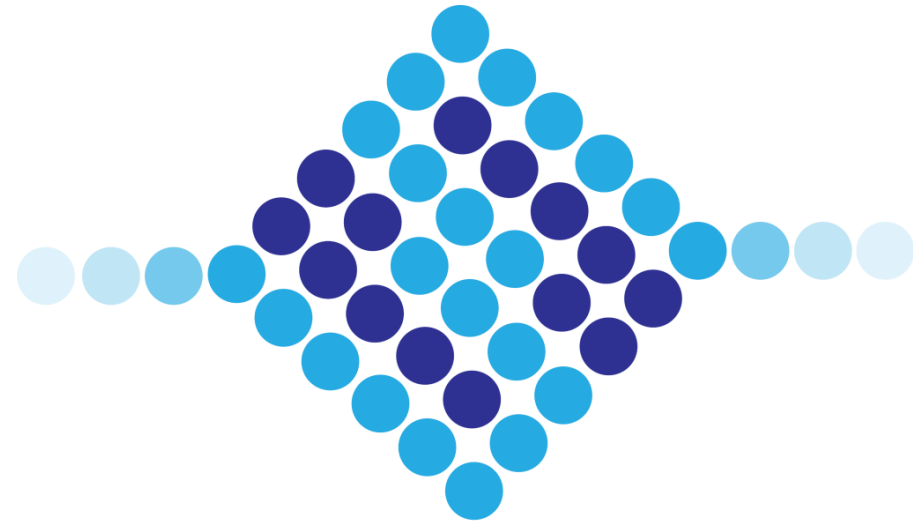


Portal

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



Thank you



STREAM



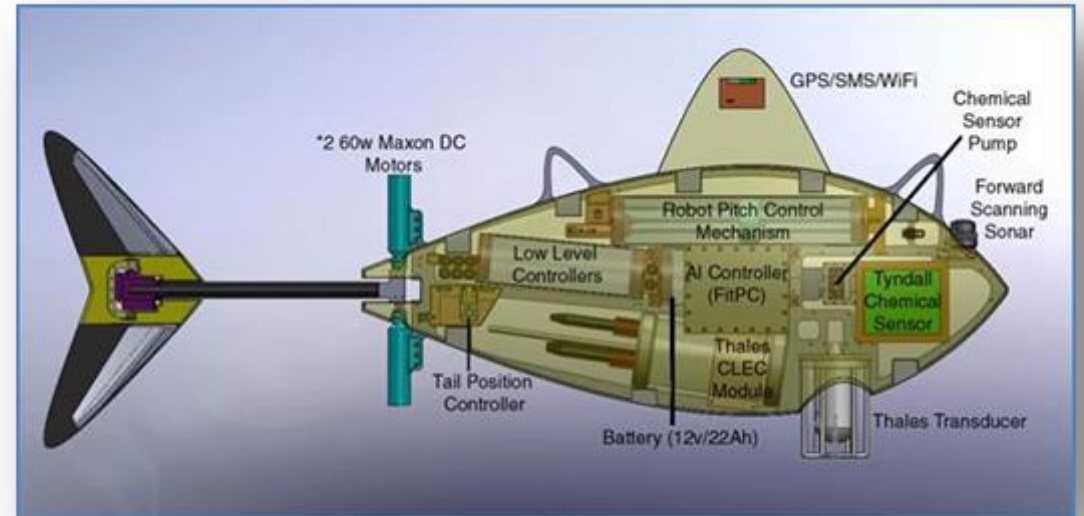
Application of sensors for fish health and welfare in aquaculture

Dr Sofia Teixeira

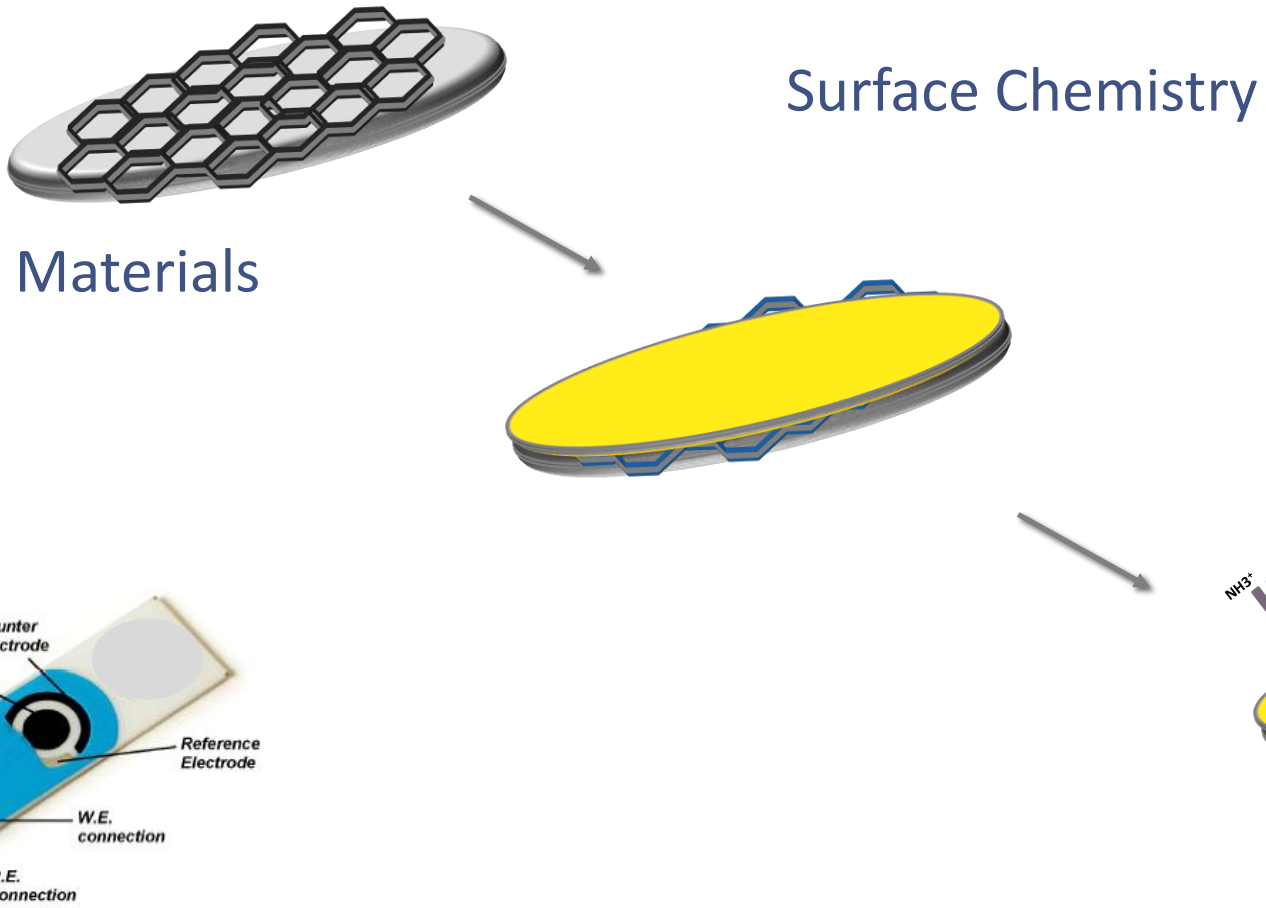
Tyndall National Institute, Ireland

**Application of Sensors in
Precision Aquaculture**

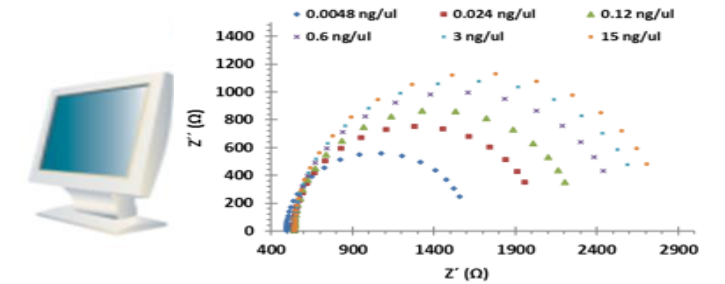
25 May 2021



Flexible, label free

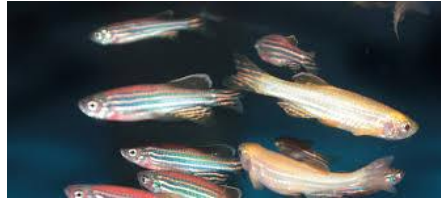


Electrochemical output

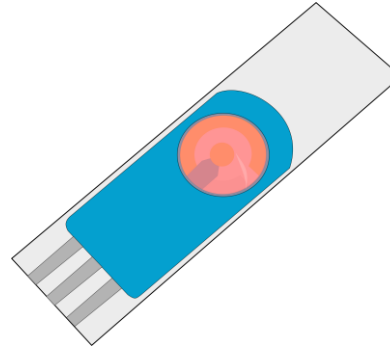


Bio-receptor

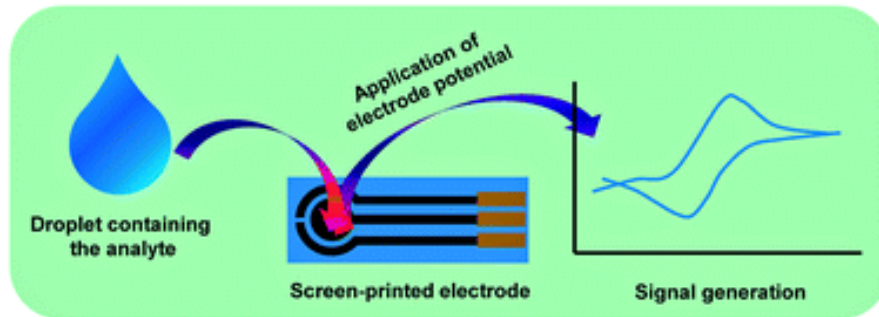
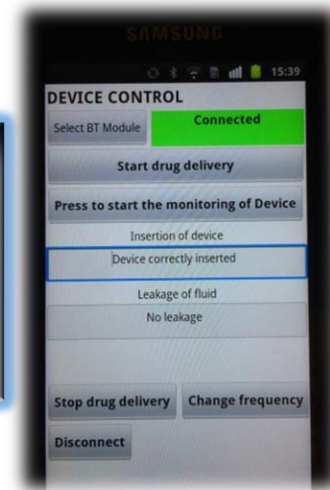
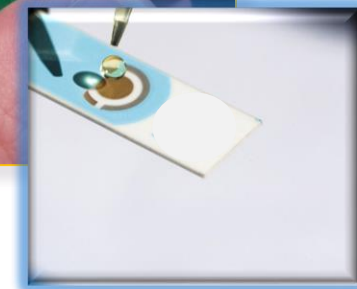
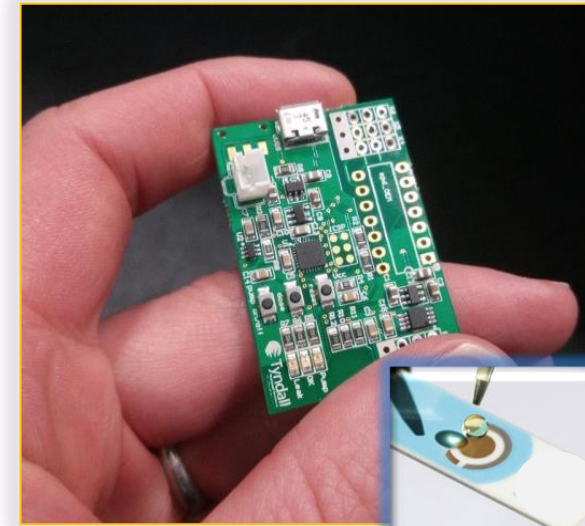
Quantification of Biomarkers



1. Identification of specific biomarkers



2. Biosensor development for objective biomarker selection



Biomarkers for...

SCREENING

Highly specific, minimize false positive and negative

Easily detected without invasive procedures

Cost effective

DIAGNOSIS

Sensitivity, specificity, and accuracy

Be prognostic of outcome and treatment

Biomarkers for...



Blood



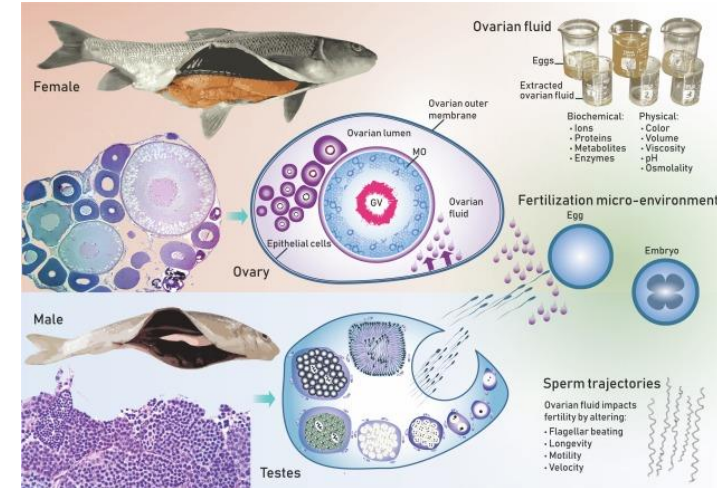
Urine



Other body fluids



Tissue samples



Cortisol

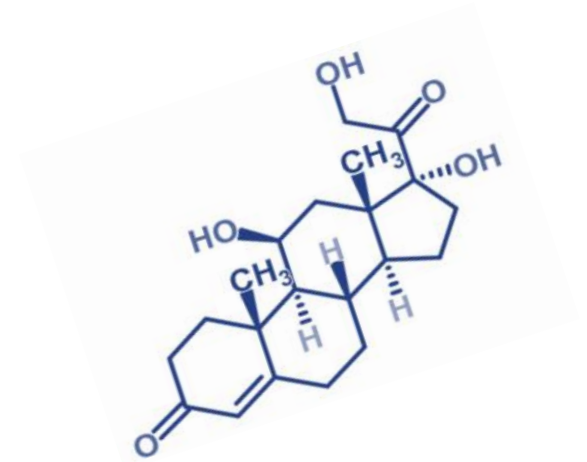
Exposure to causes of stress

Production and secretion of cortisol
from adrenal glands

cortisol levels

$10^{-7} - 10^{-6}$ M (high)

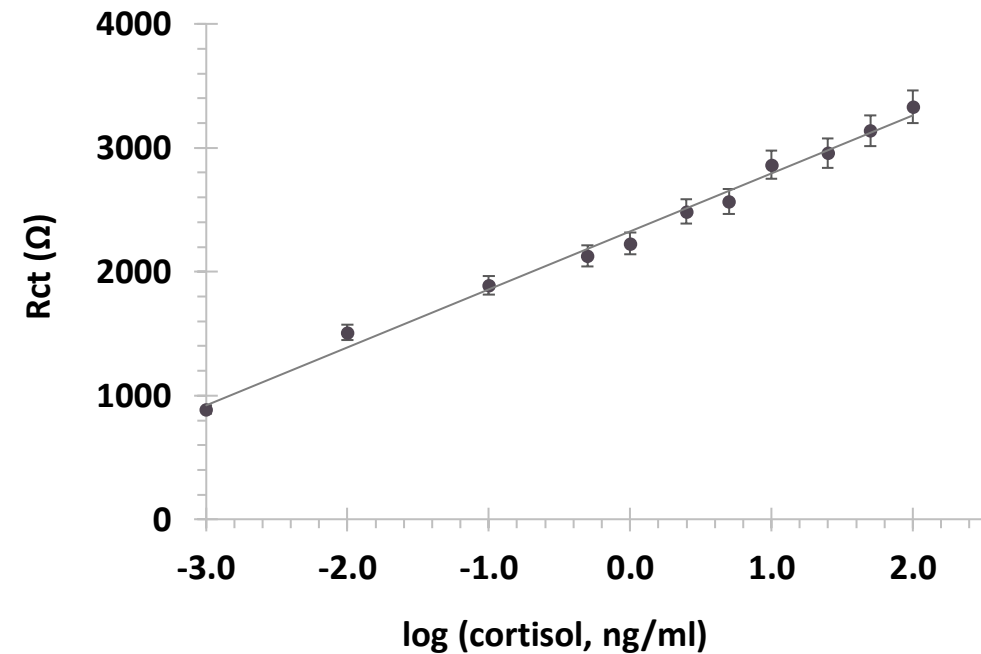
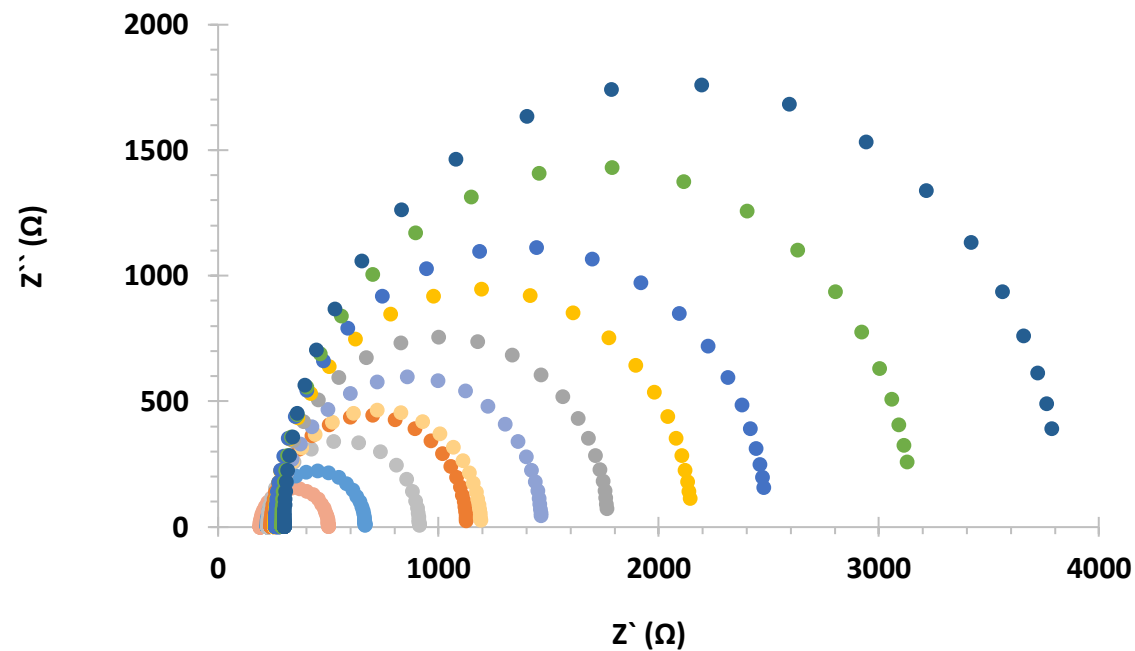
$10^{-9} - 10^{-8}$ M (low)



Altered cortisol levels

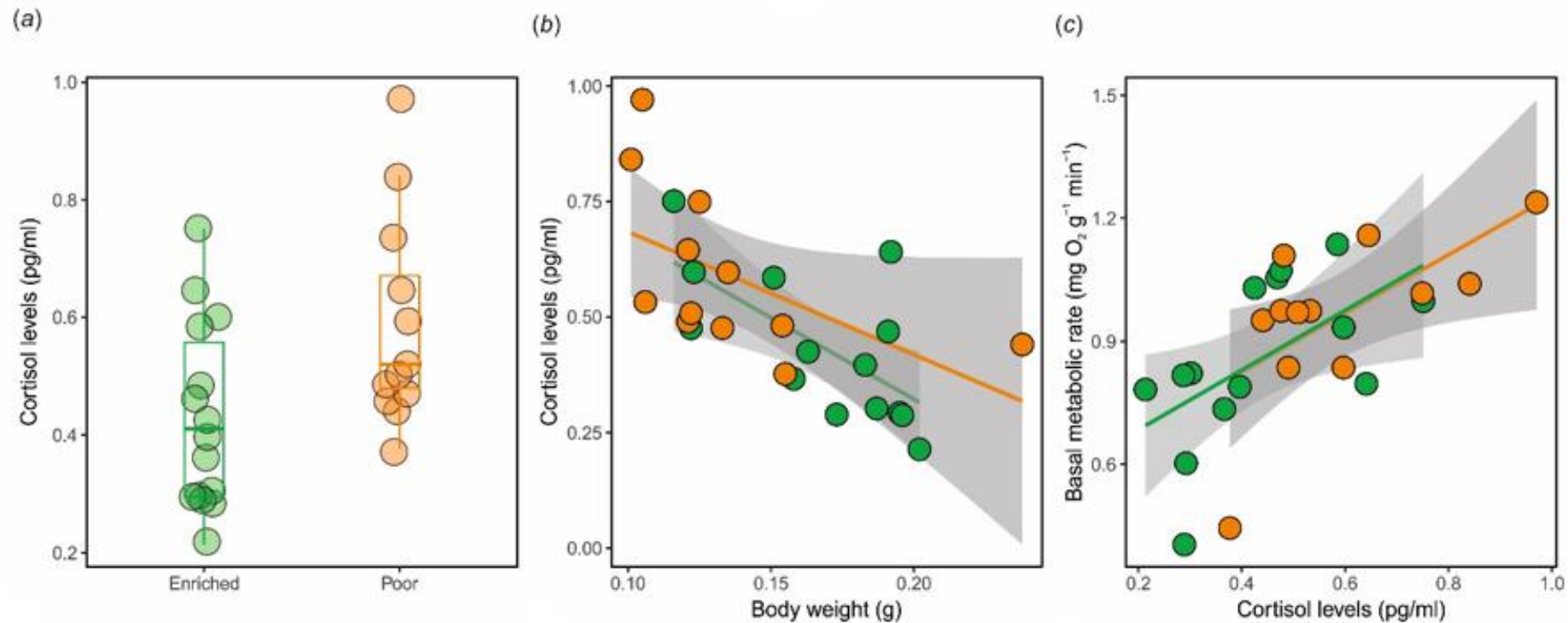
linked to a range of stress-related disorders.

Analytical Response - Detection



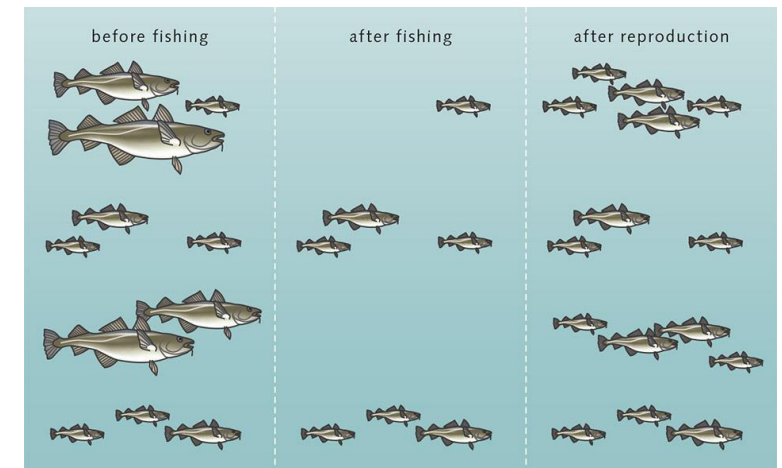
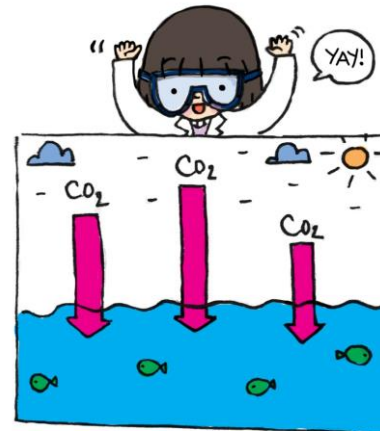
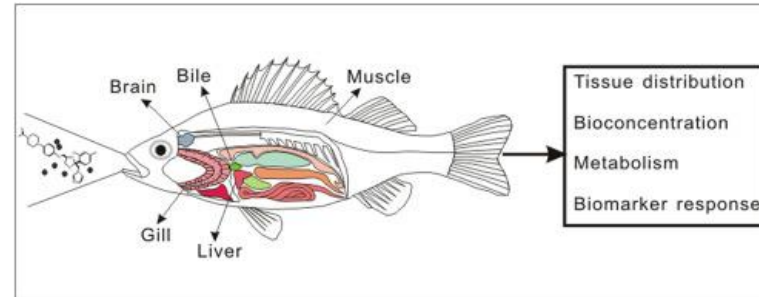
LOD = 0.005 pg/ml = 5fg/ml

Analytical Response - Physiological and behavioural relationships

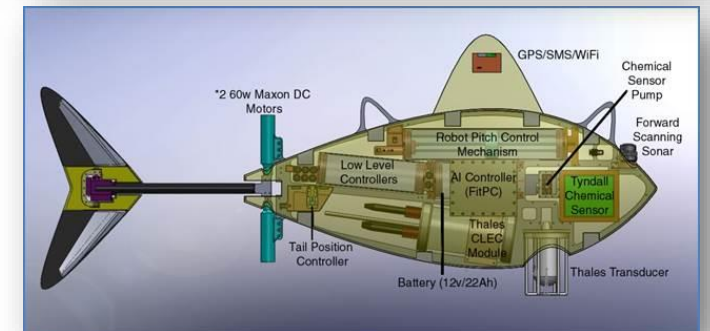
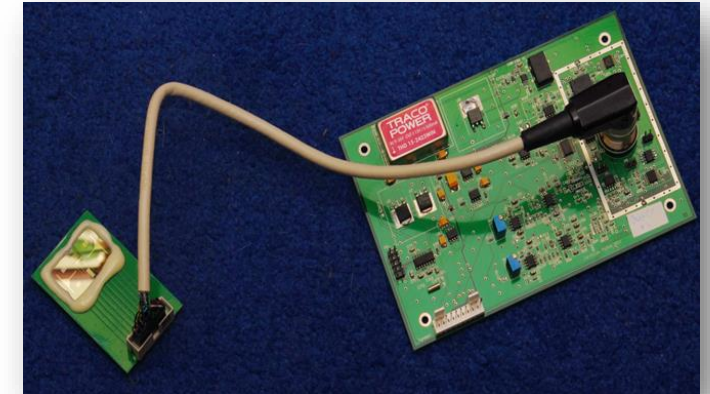
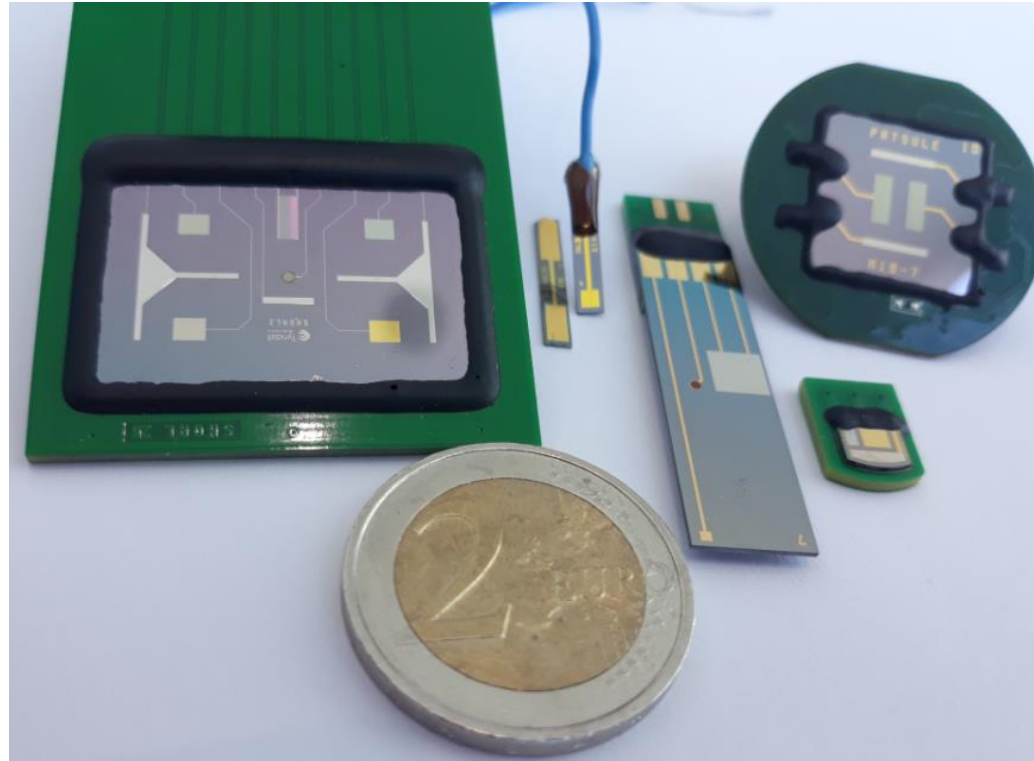


Applications on Welfare in Aquaculture

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



Smart Sensors for Wellness and Health in aquaculture



www.roboshal.com
FP7-ICT-231646

Acknowledgments



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LinkedIn: <https://www.linkedin.com/in/sofia-teixeira-690564b/>

UCC website: <http://research.ucc.ie/profiles/E024/sofia.rodriquesteixeira@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. Chlorophyll (0-200µg/l)
8. Turbidity (0-3000NTU)
9. Ionic salts (Nitrates etc)
10.

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



EXO2 Sonde – courtesy Xylem Analytics

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

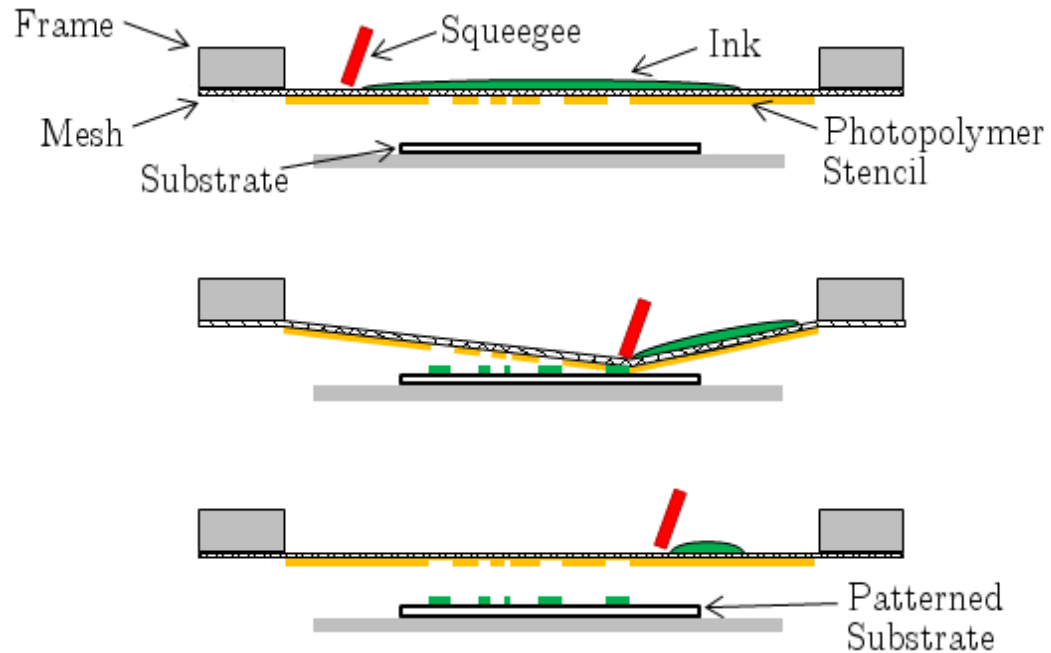
- Measurement accuracy – calibration against laboratory and commercial devices
- Survival in a harsh environment
- Working duration

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

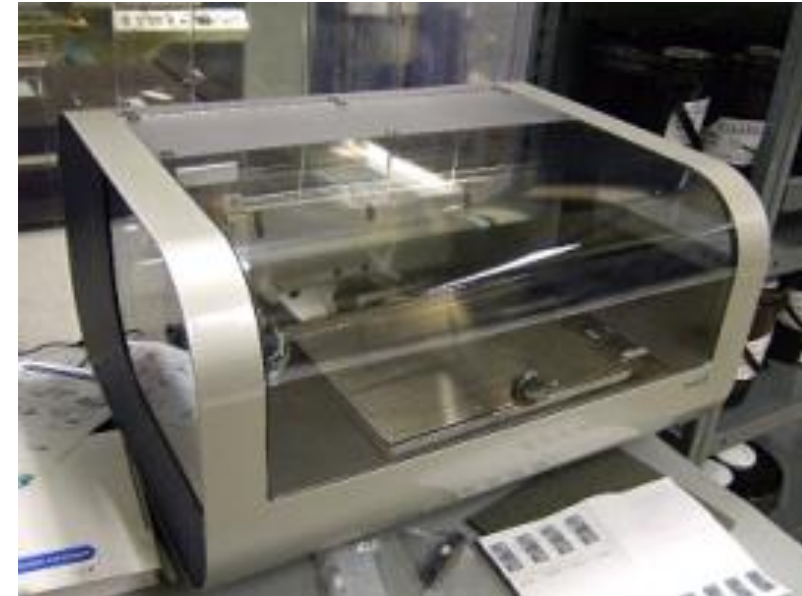
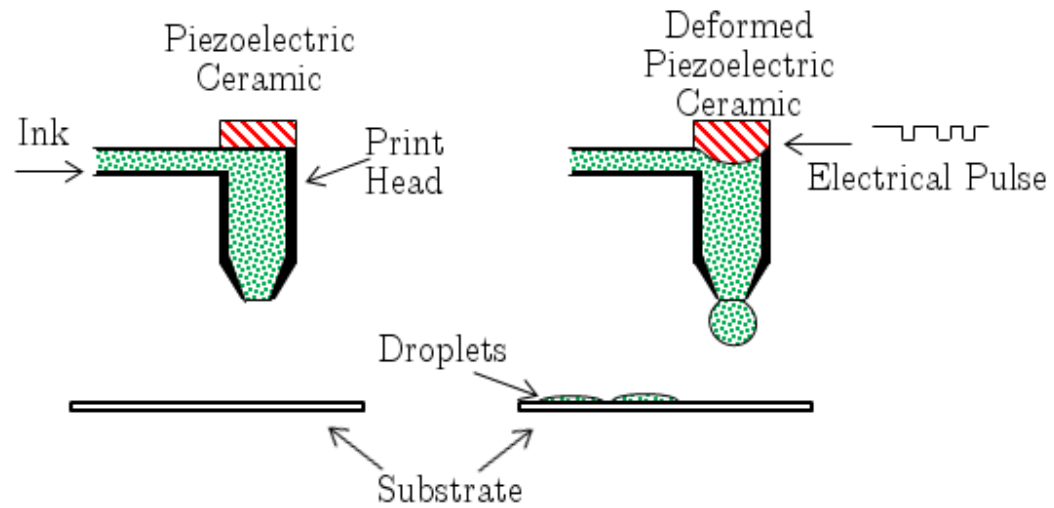
Remaining parameters may be measured by optical methods (being developed by Waterford)

Potential Printing Methods - Screen

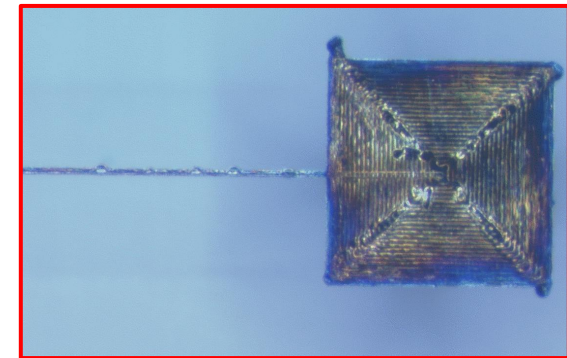
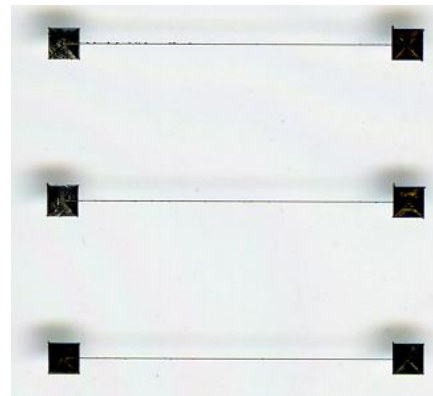
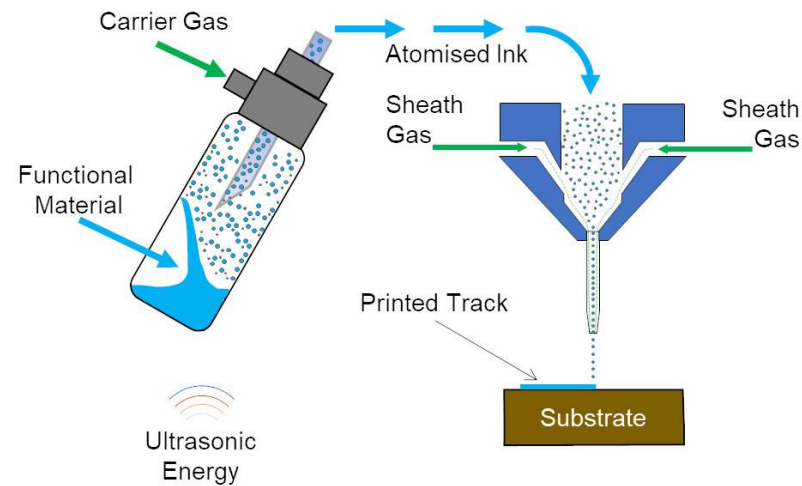


Screen is the principal process for sensor printing

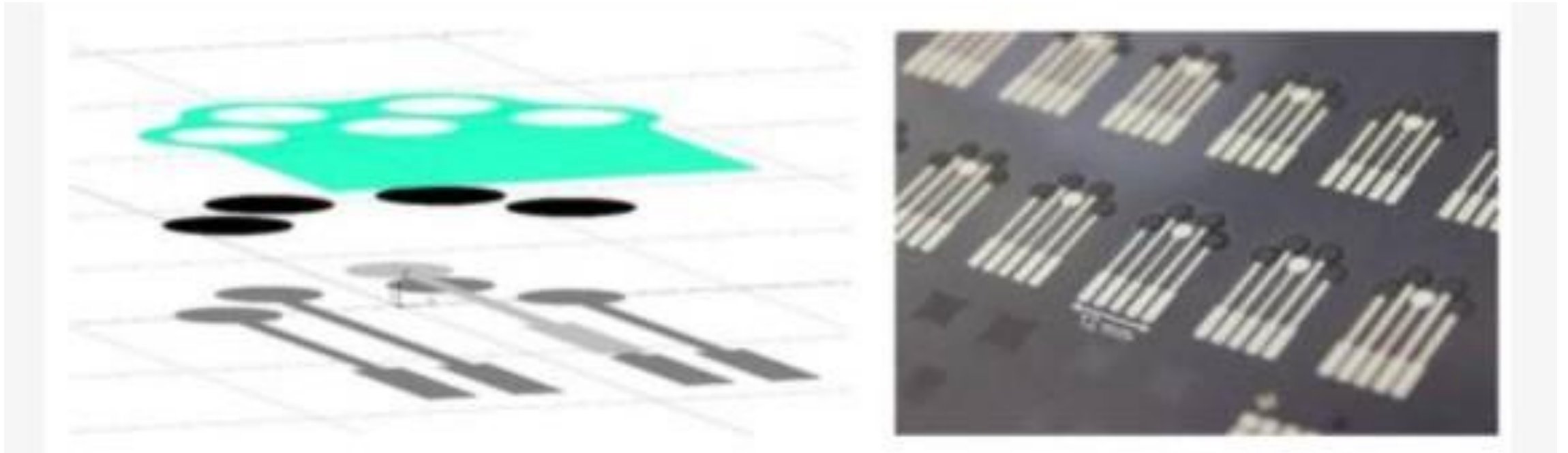
Potential Printing Methods - Inkjet



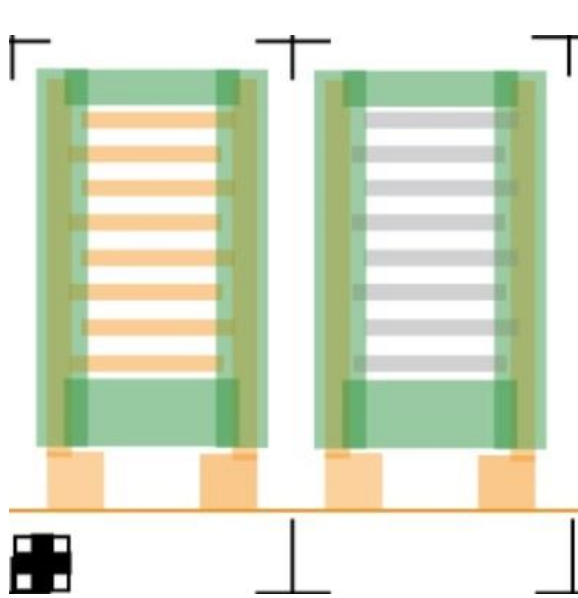
Potential Printing Methods – Aerosol Jet



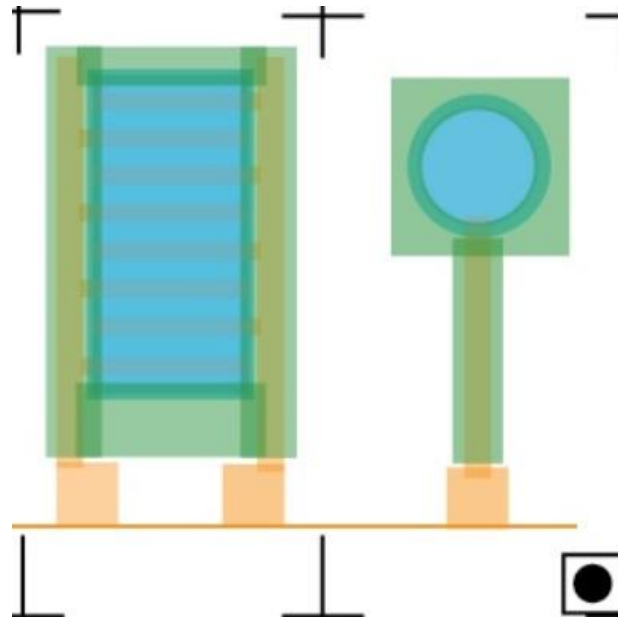
Fabricating a Sensor – multiple layers



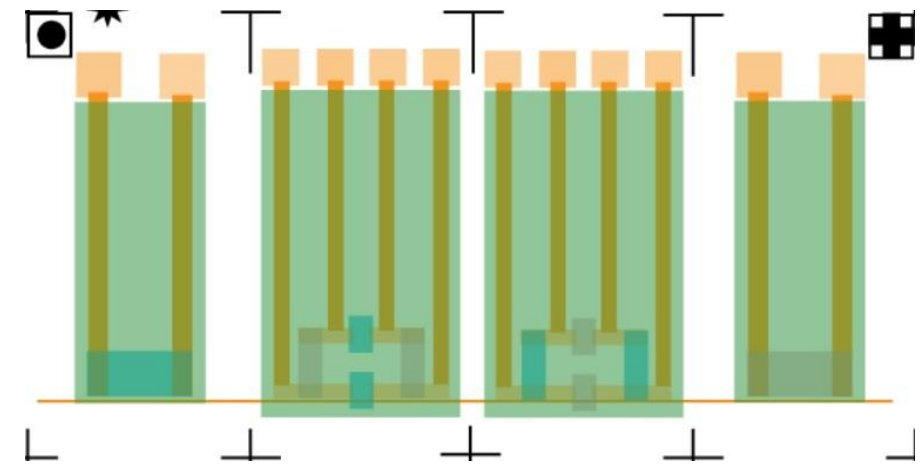
STREAM Sensors – Initial Study



Conductivity



pH

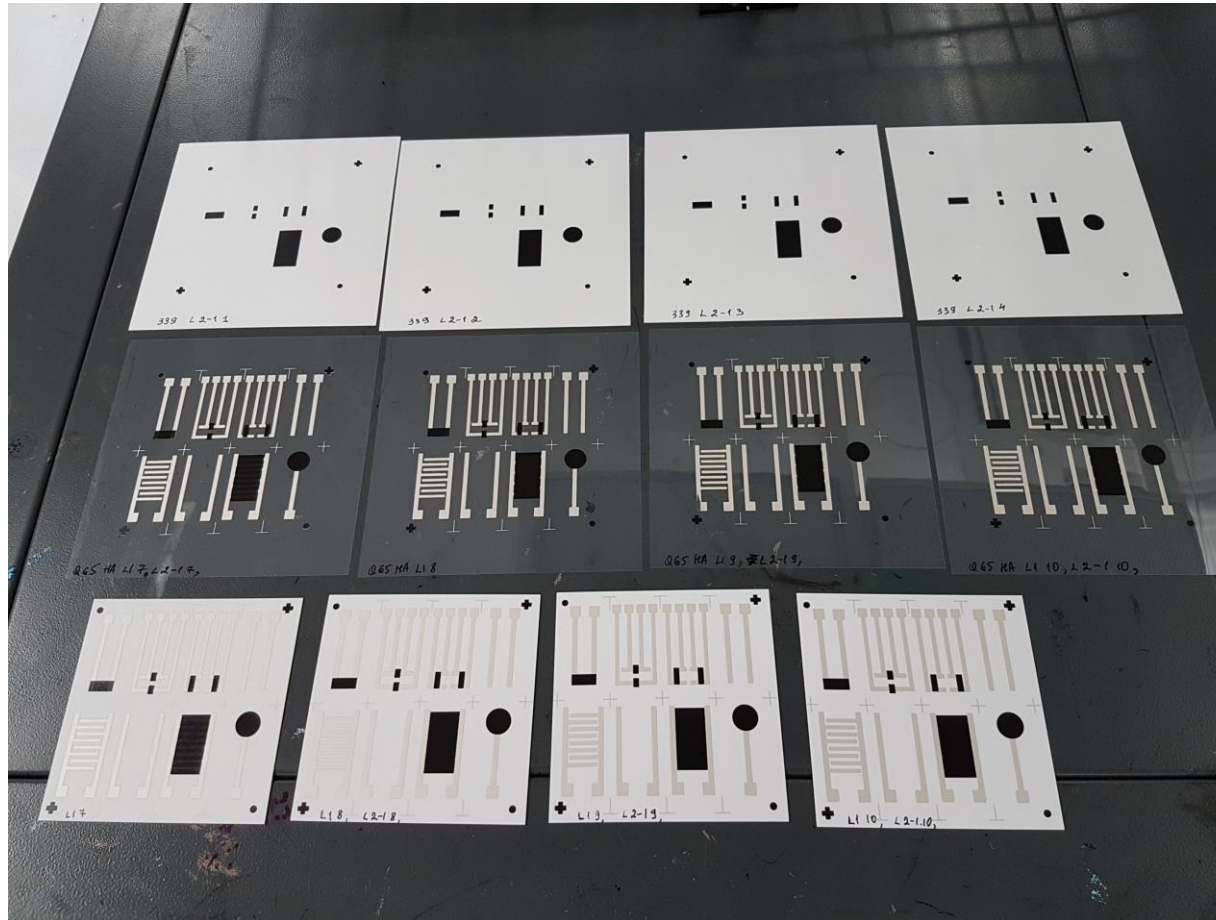


Temperature

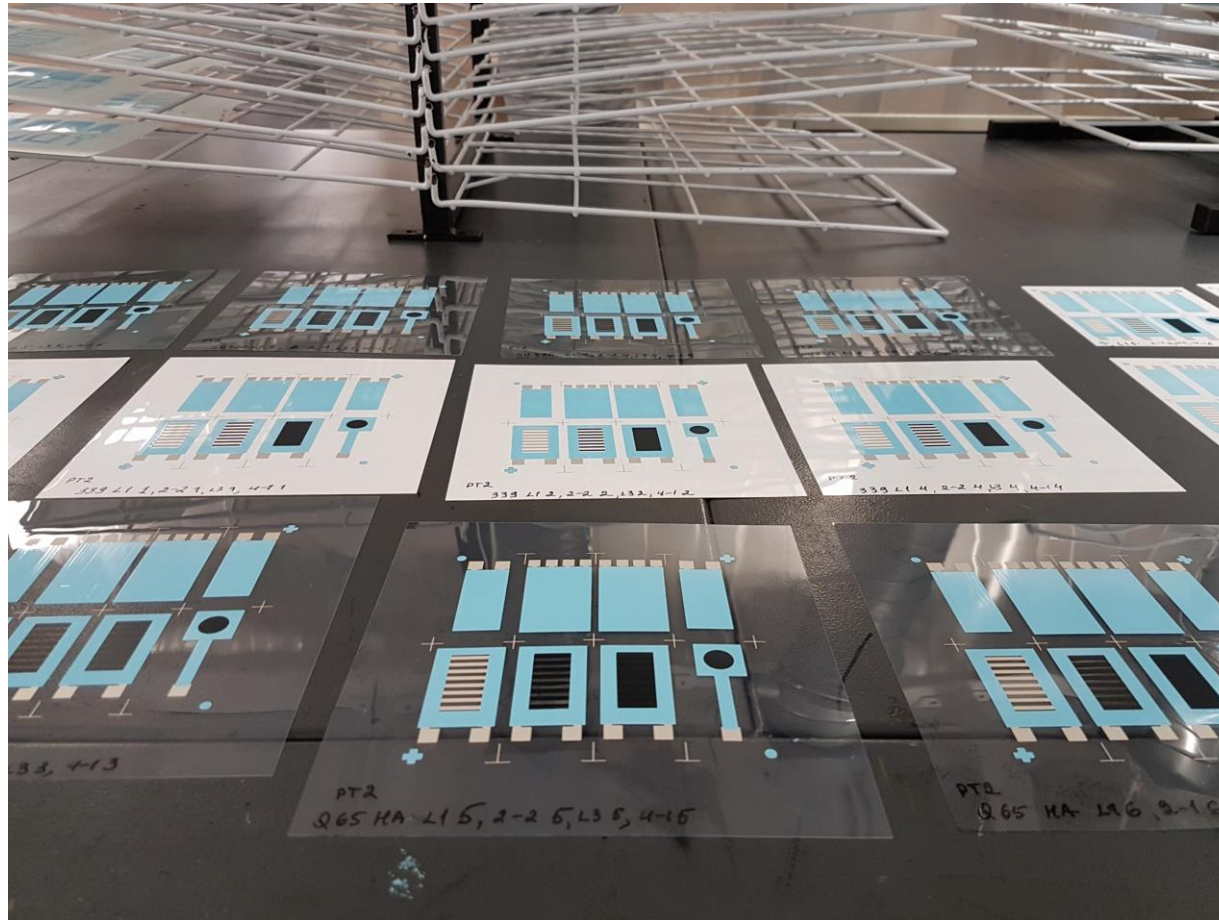
Silver Conducting Track Layer



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

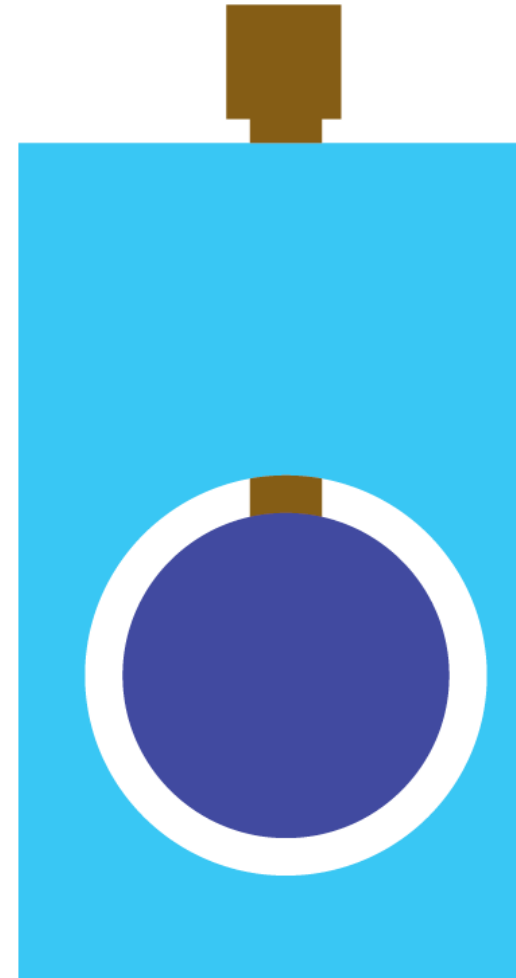
Conductor: 1 layer

Transducer: 1-2 layers

Insulator: 1-2 layers

Applied manually using a pipette

ISM: 1-2 layers

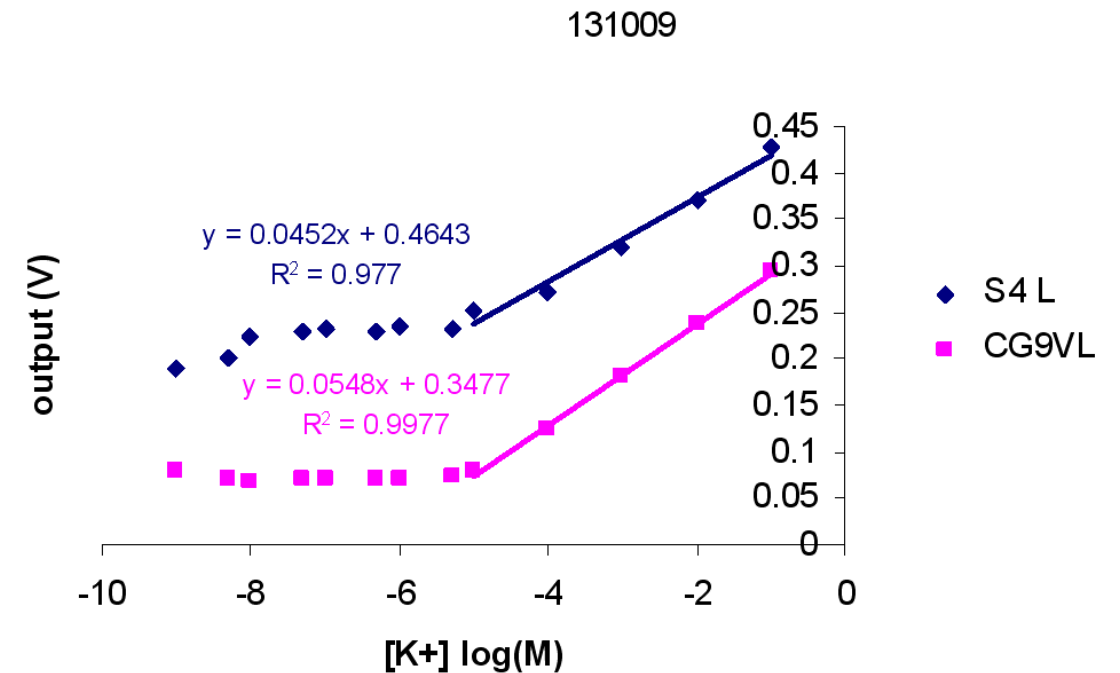


Example Printed Potassium Sensor

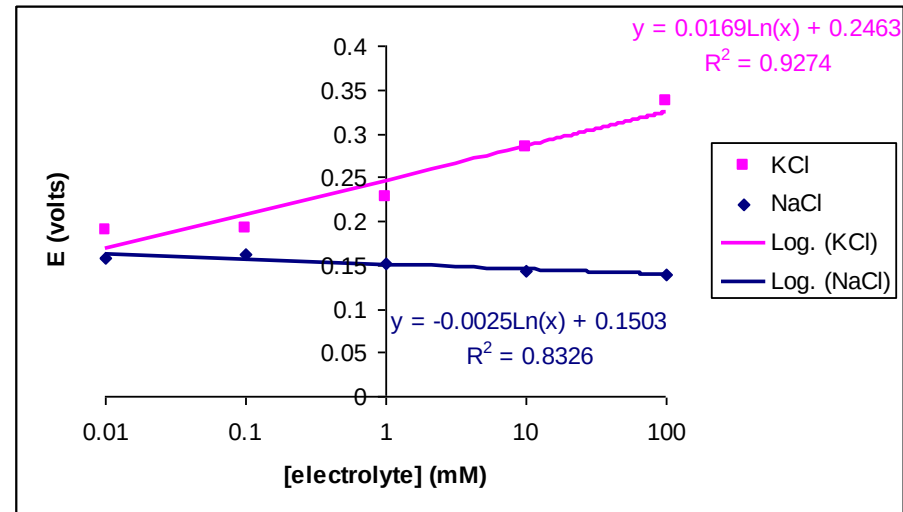
Sensitivity to K⁺: 55 and 45 (mV dec-1)

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



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

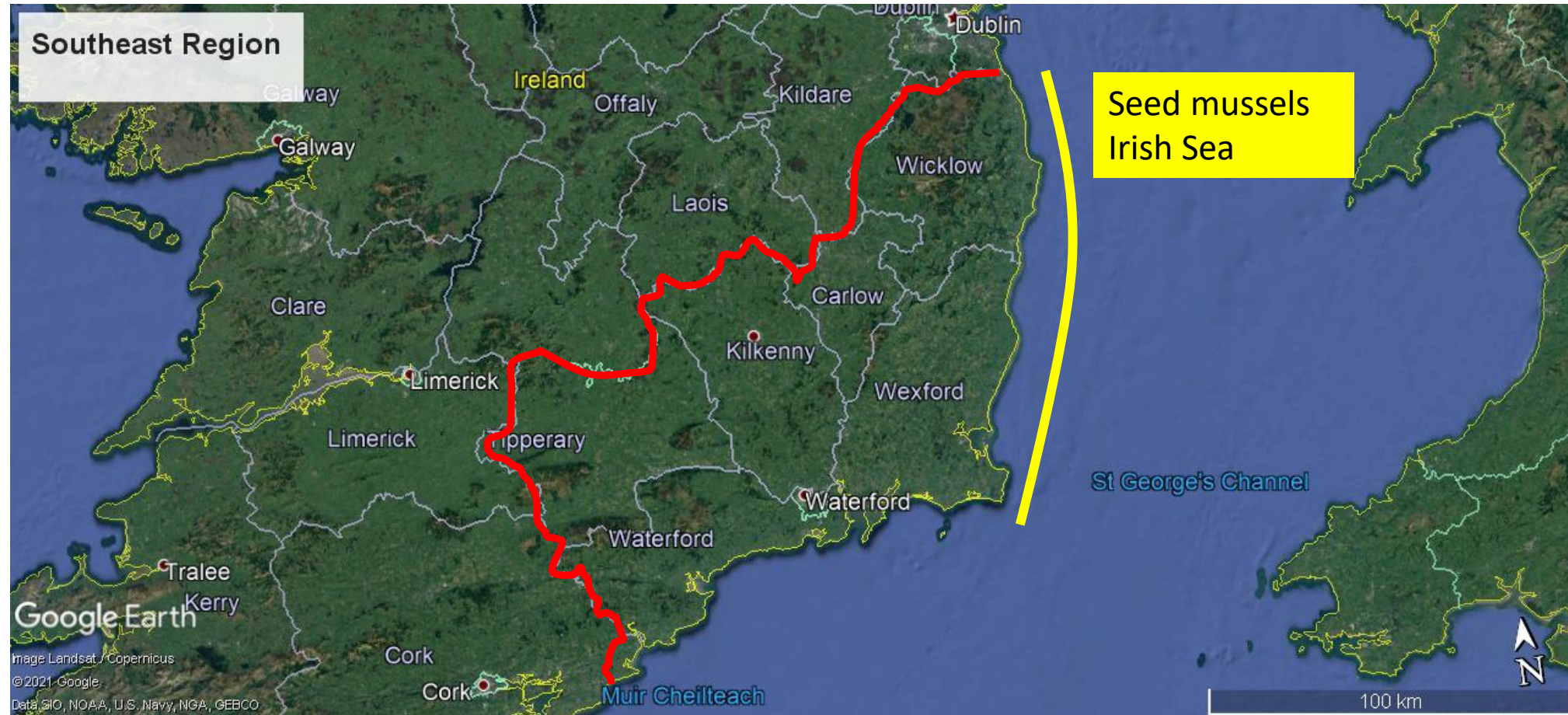
Performance of Monitoring Equipment

SE_Shellfish Industry Pressures and Concerns

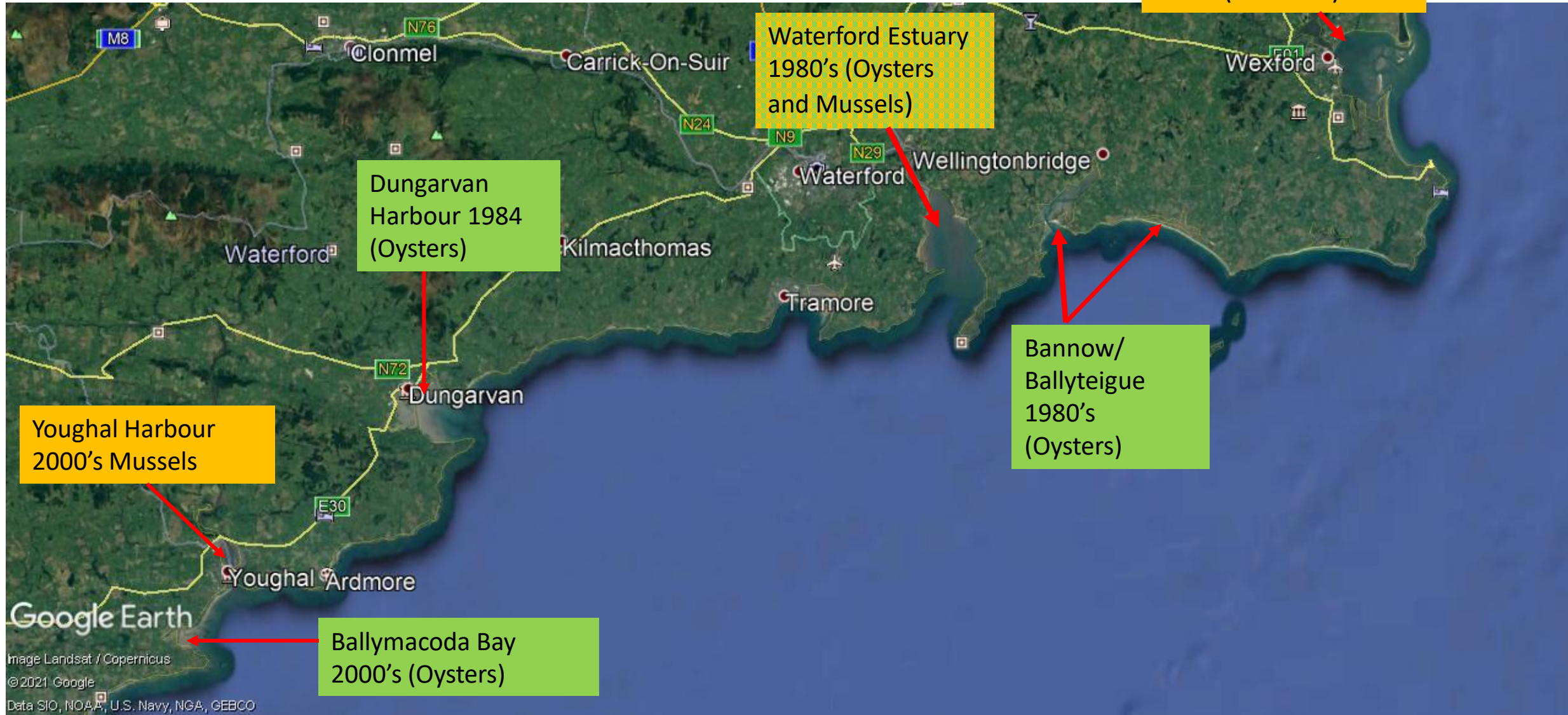
What the Industry (and I) would like in terms of Water Quality Sensors

Take Home Messages

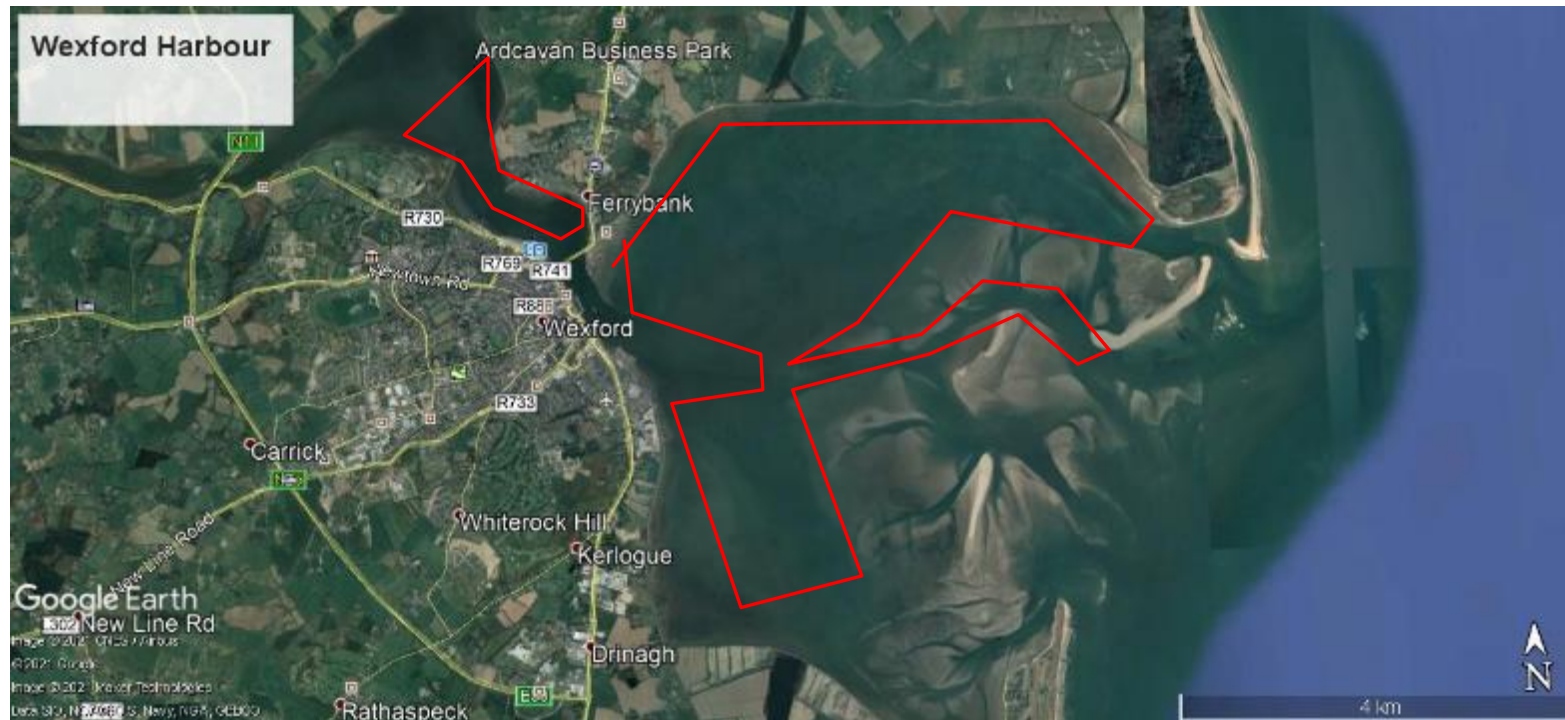
Full Southeast Region



Southeast Shellfish Aquaculture



Wexford Harbour Mussels



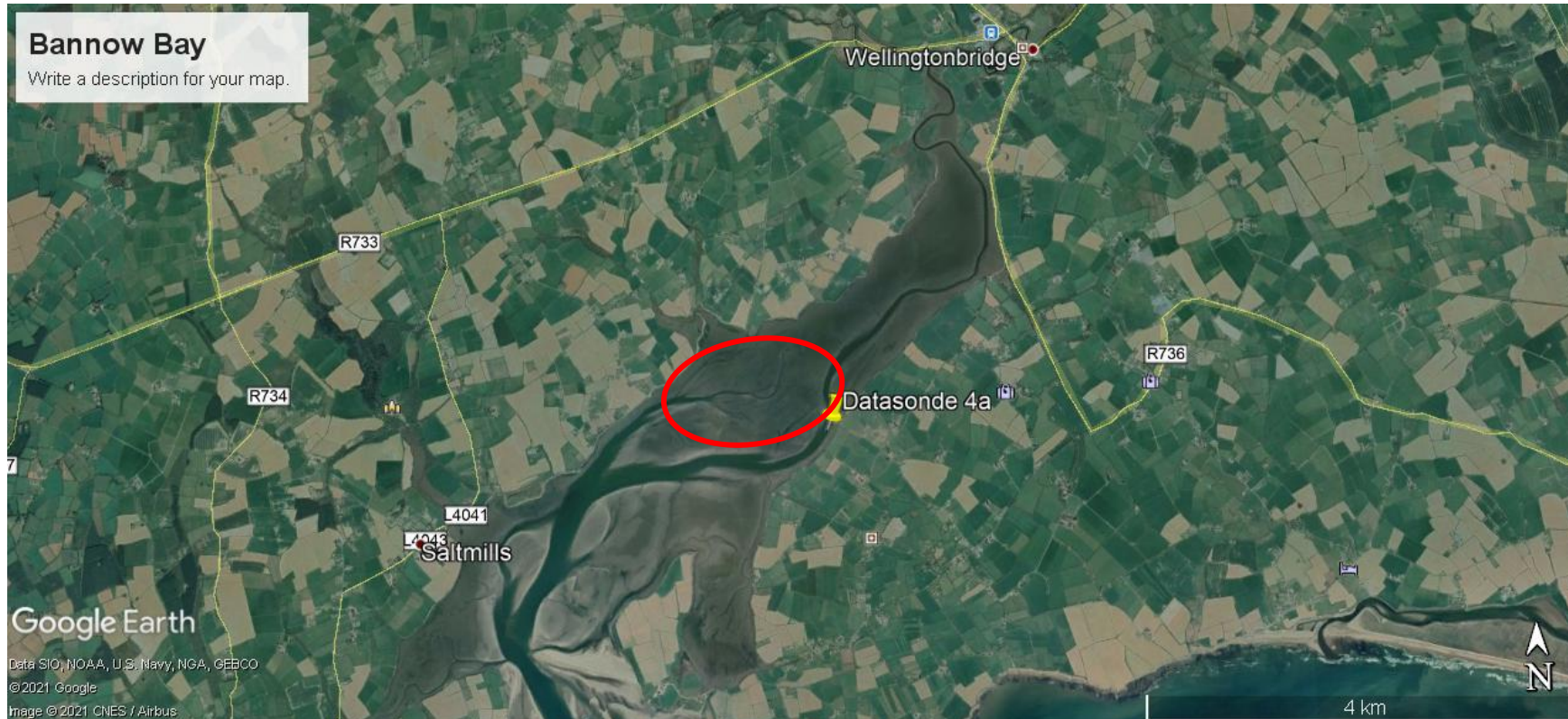
Subtidal Mussel Farming

Shallow/highly dynamic channels
and sandbanks

Major town on shore

Major agricultural hinterland
around the River Slaney

Bannow Bay (Oysters)



Soft substratum

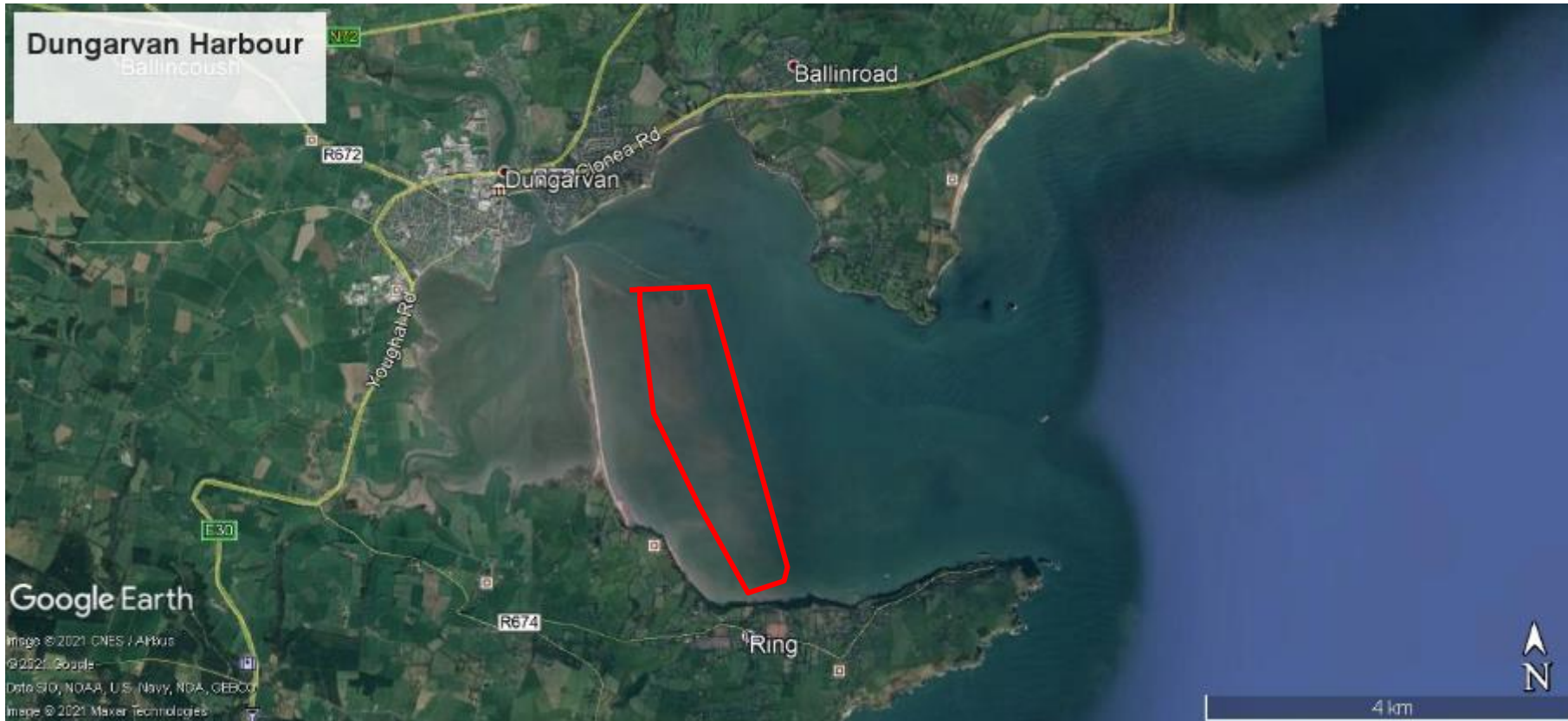
High productivity

Meaty oysters/world class

Flat bottomed Boat and
Tractor access

Large agricultural
catchment and several
rural villages nearshore.

Dungarvan Harbour (Oysters)



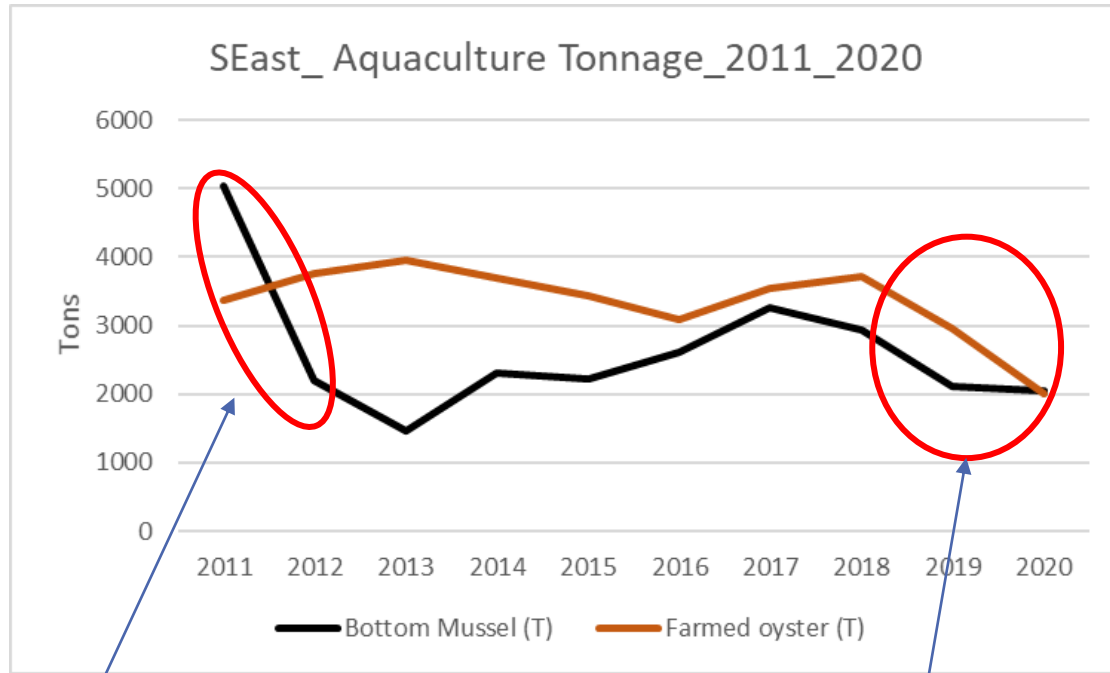
Intertidal Oysters/tractor only

Largest oyster producing bay

Small town

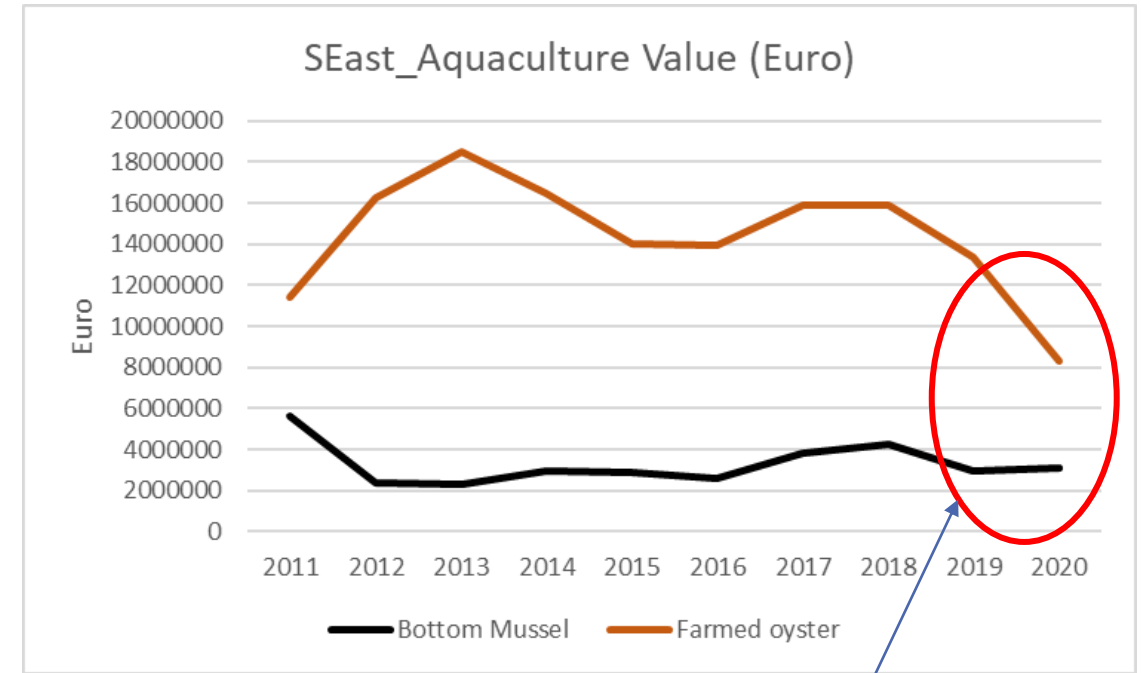
Ideal substratum for oyster farming

Southeast Tonnage and Value (Mussels and Oysters)



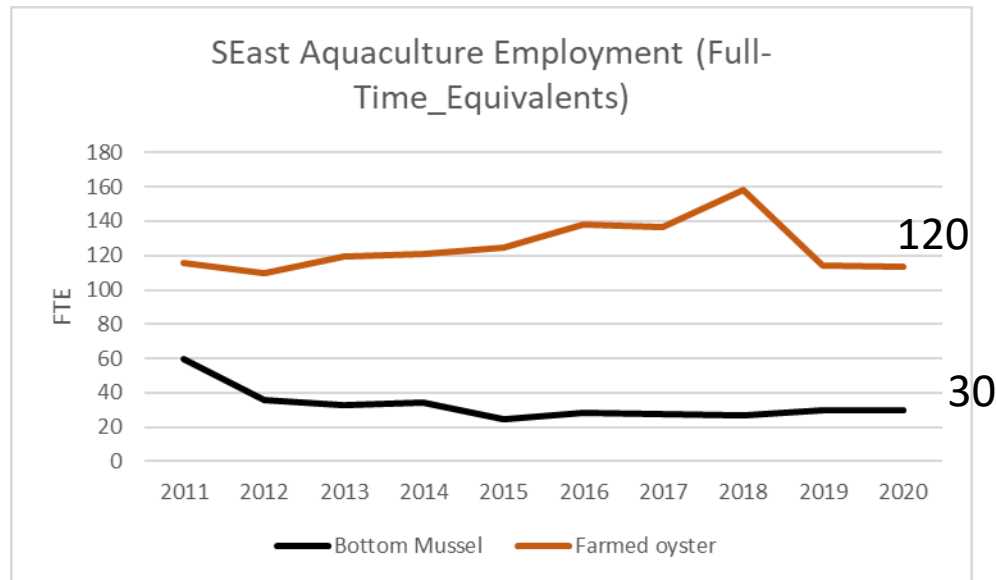
Drop in mussel seed supply from East Coast

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

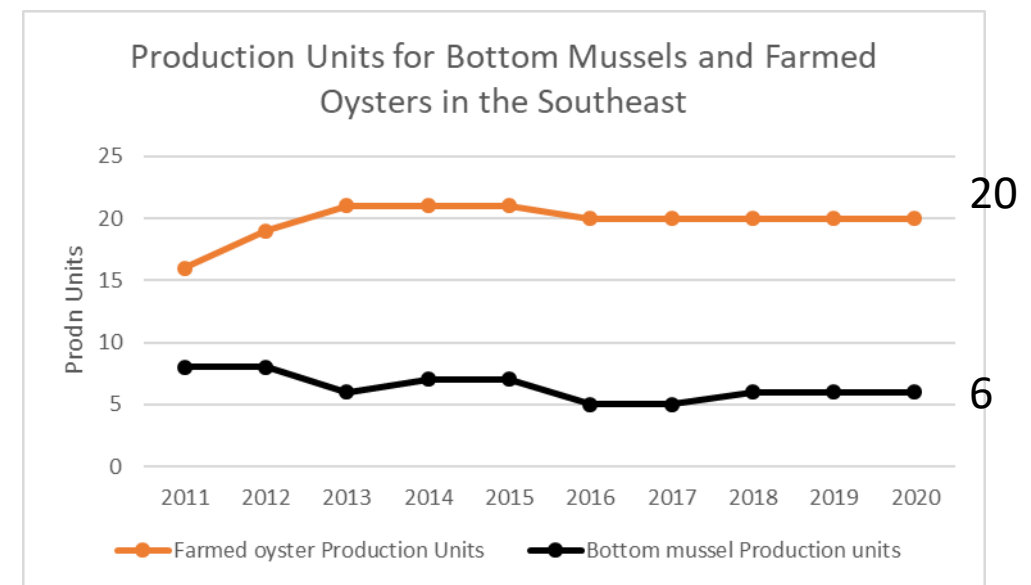
Employment_Full Time Equivalents and Production Units in the Southeast



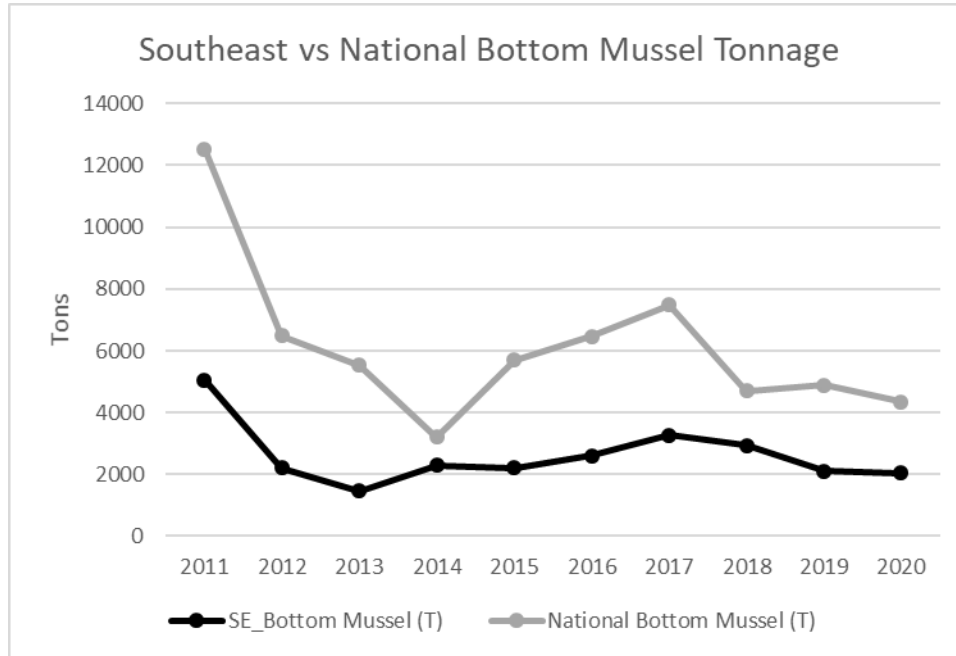
Jobs and production units relatively stable

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

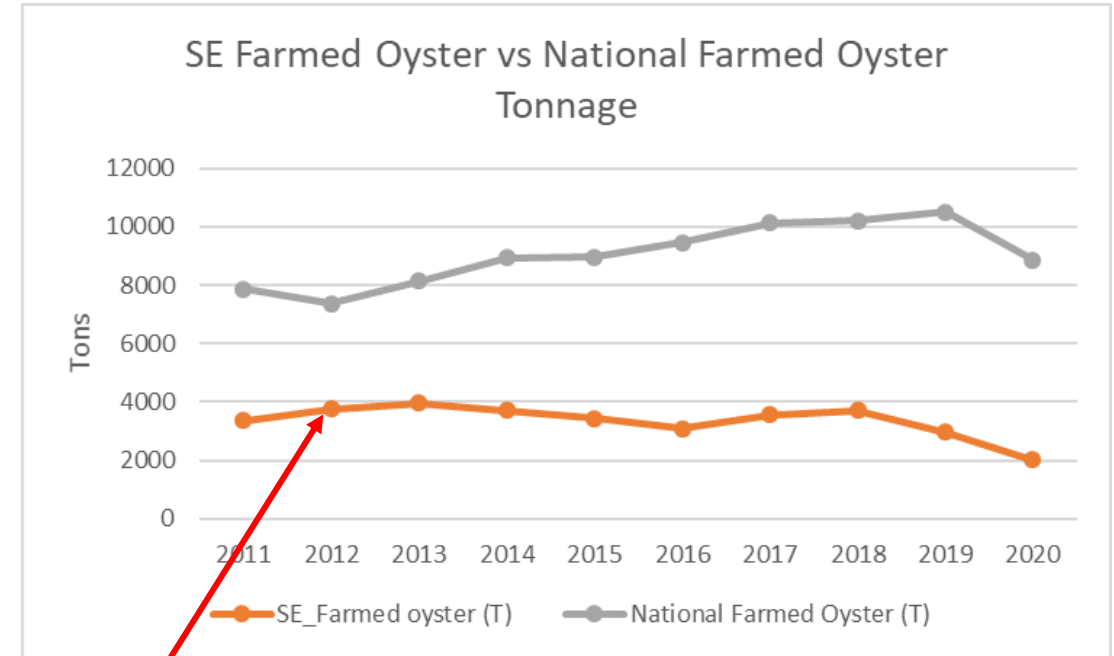
Oyster industry jobs spread across the region.



Southeast Very Important Nationally for Bottom Mussels and Oysters

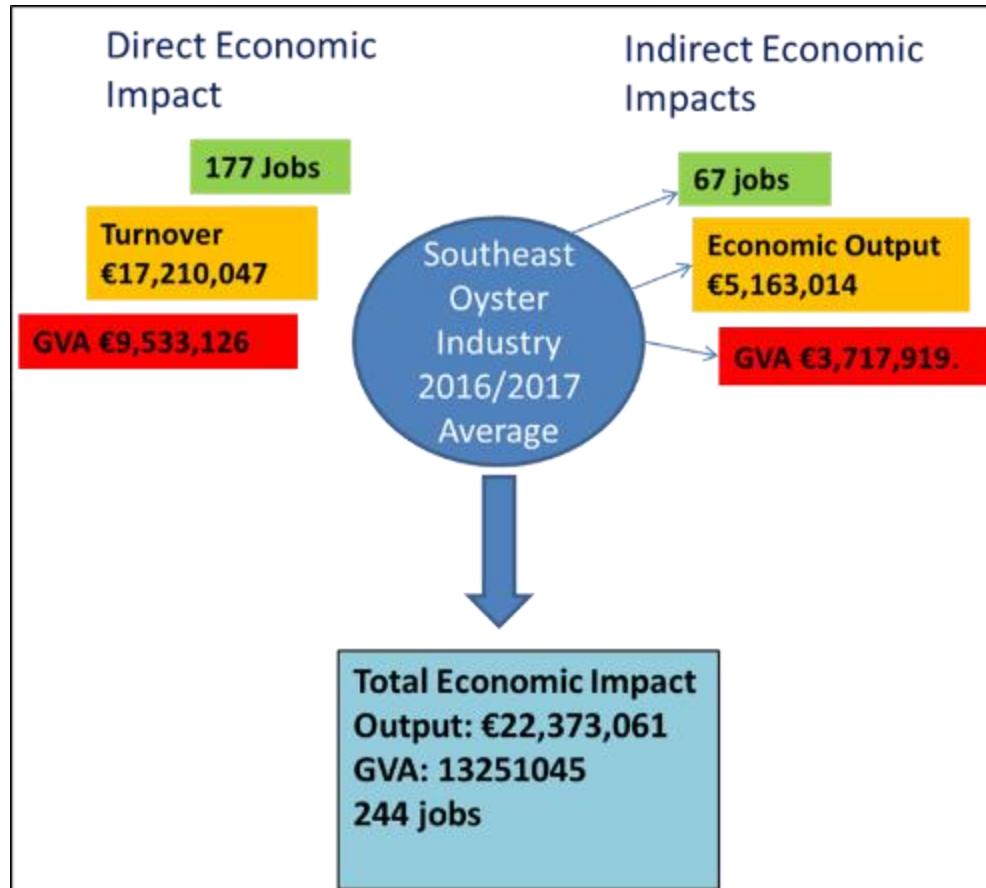


Wexford Harbour is a stalwart in the national bottom mussel industry (40% plus)

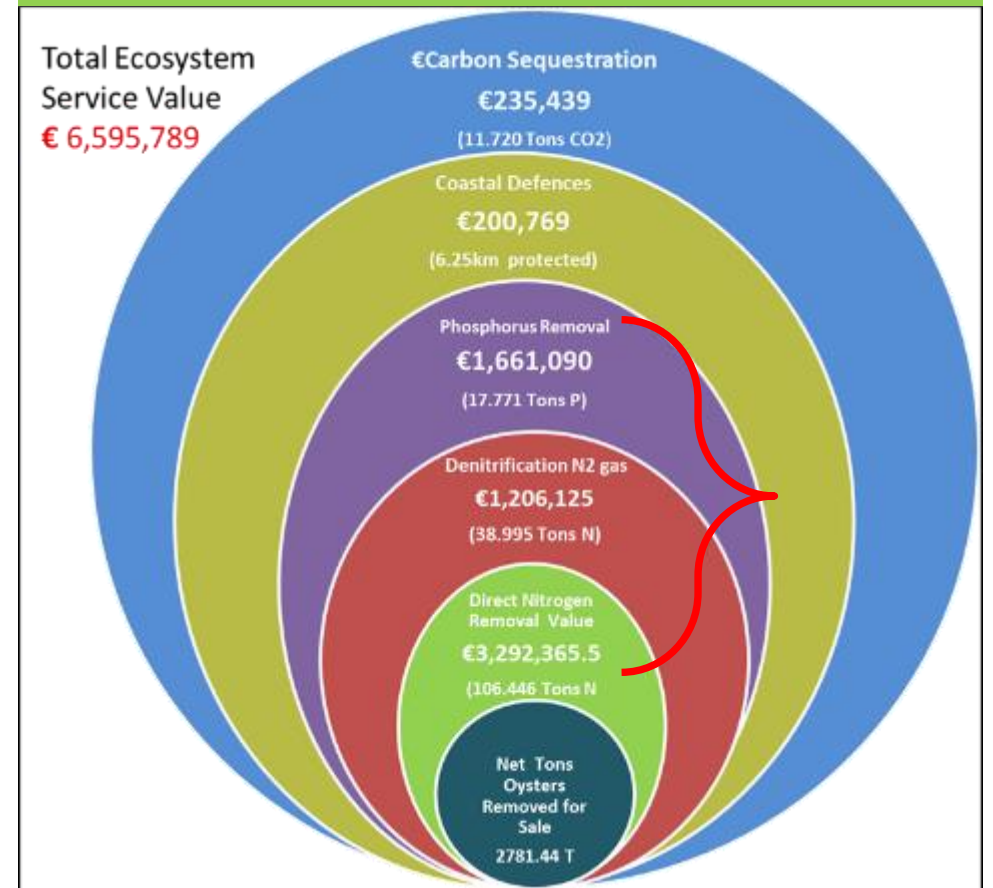


More than 50% at one point. Currently impacted by mortality and pandemic issues. Oyster production growing in other regions.

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
Logging Life Science

PRODUCTS - SUPPORT



Star Oddi CT and
CTD's



Hydrolab
Datasonde
5X's



Aanderra RCM9's
& Mooring
Bases/Frames



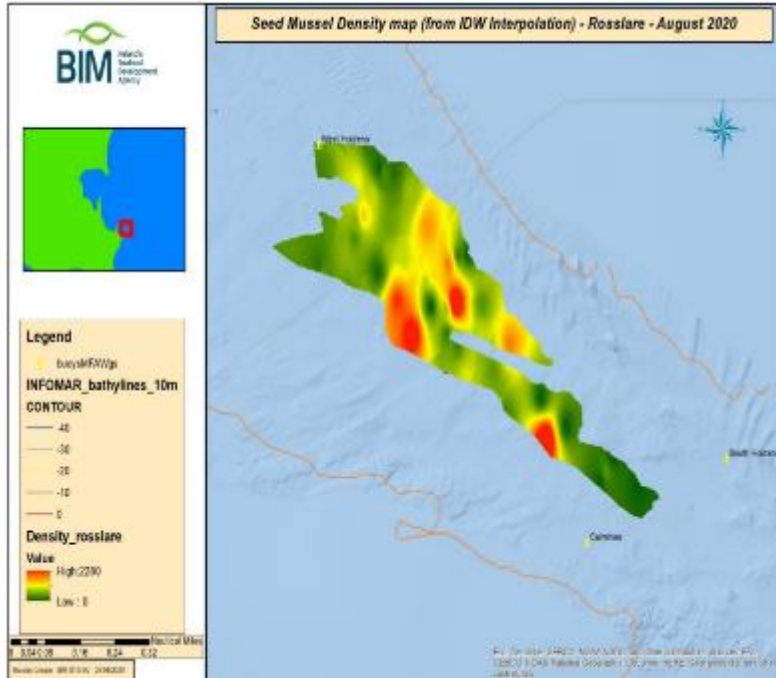
Quad and trailer

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.....

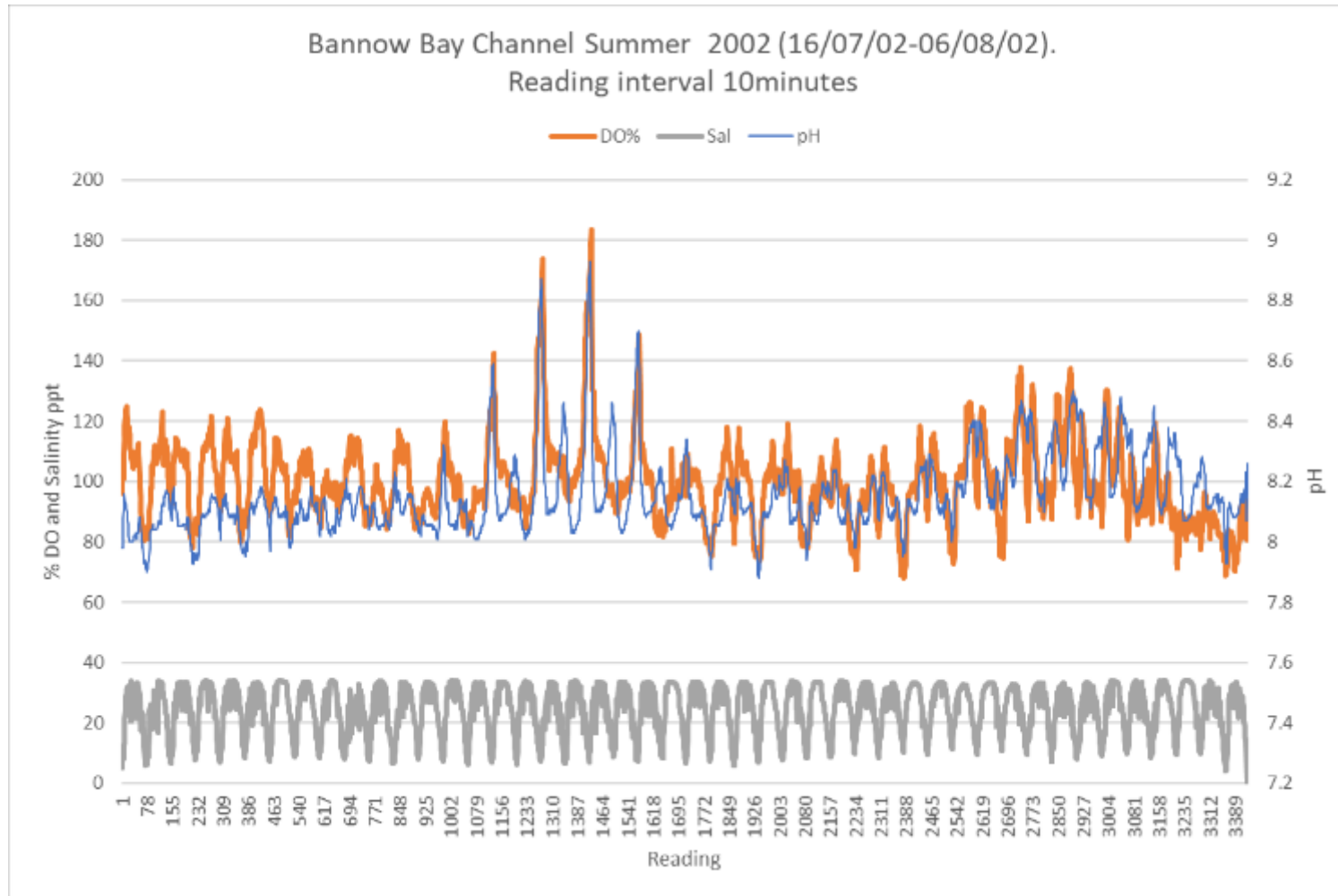
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First Sensor Deployment Bannow Bay 2002



Main Findings in Bannow Bay Summer 2002



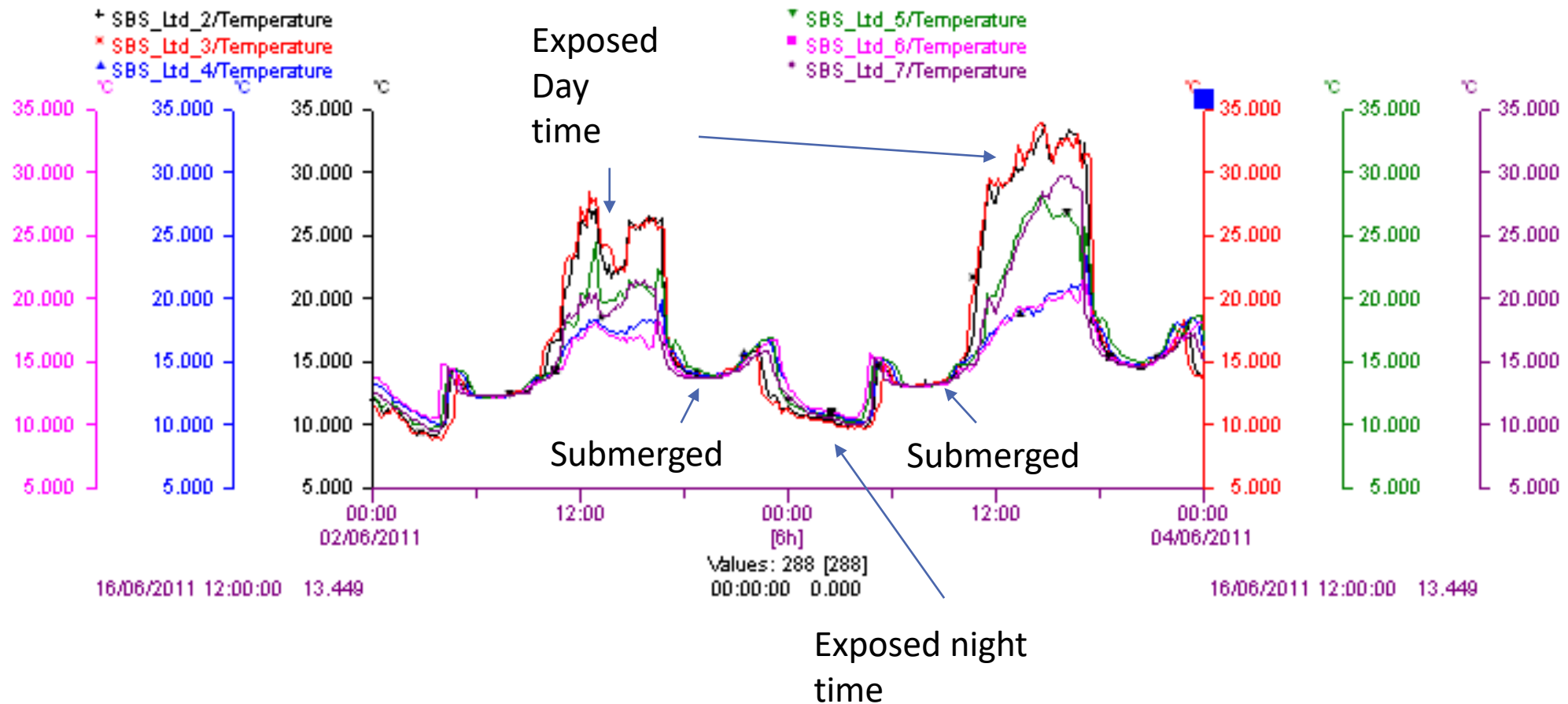
O₂ and pH swings

Freshwater influence
particularly on neaps

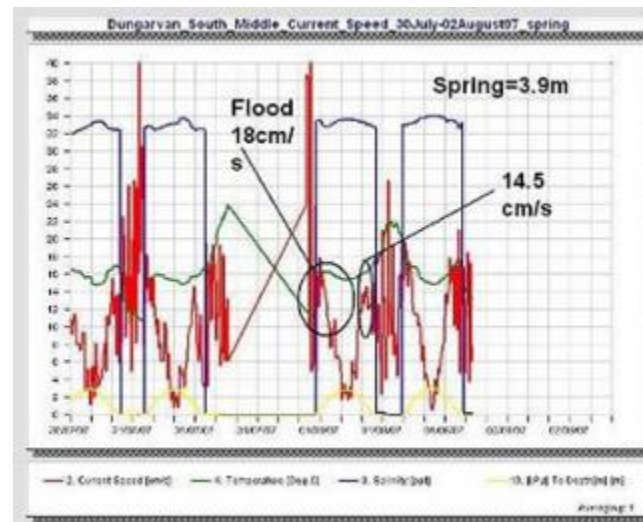
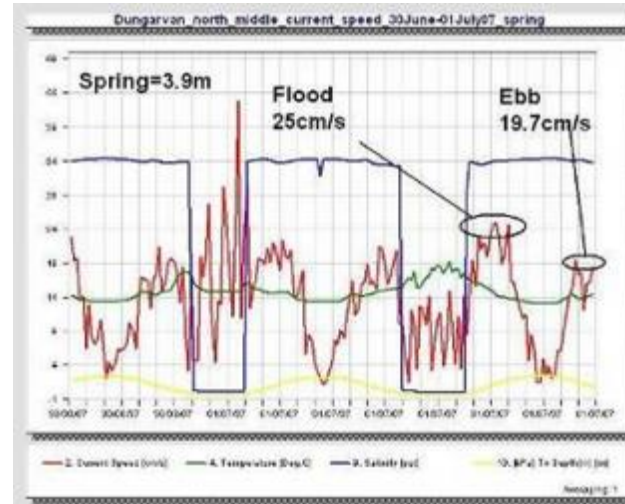
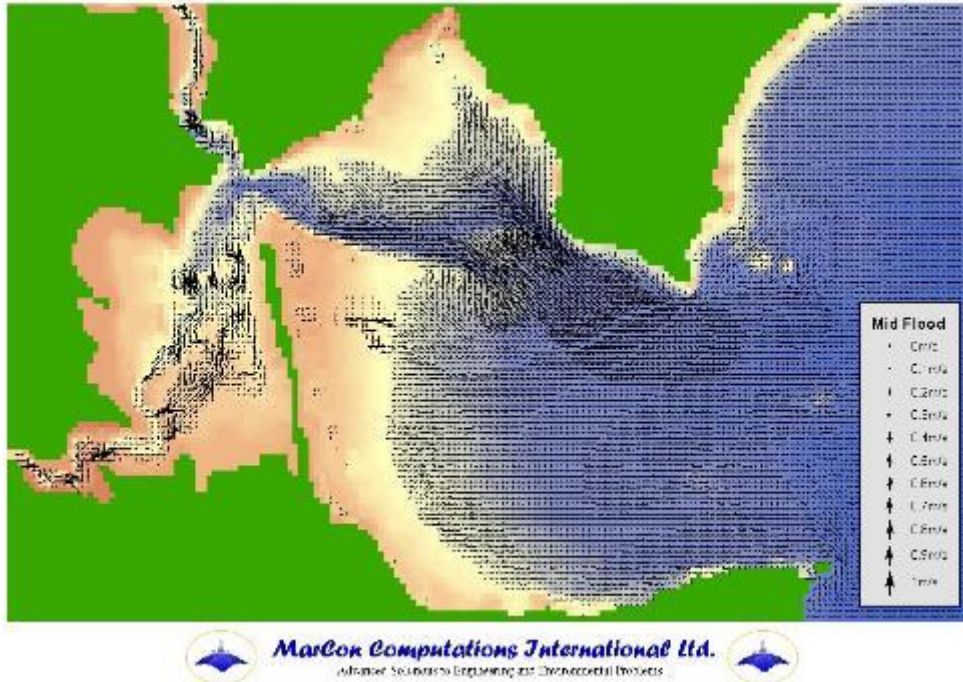
Applied for trial sites away
from channel

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)

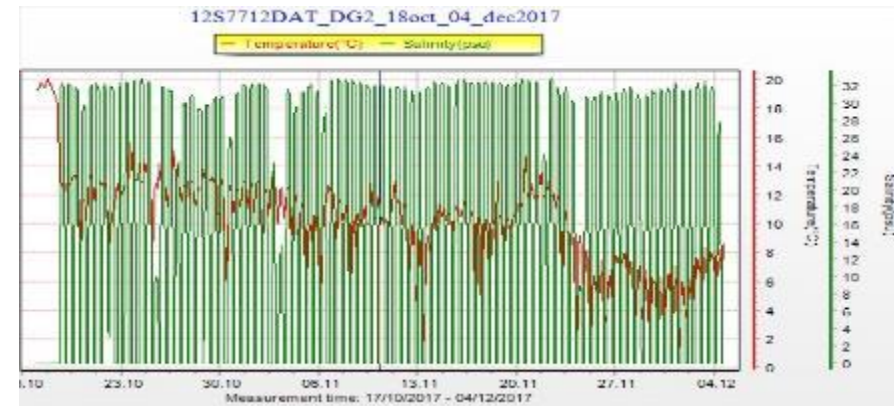
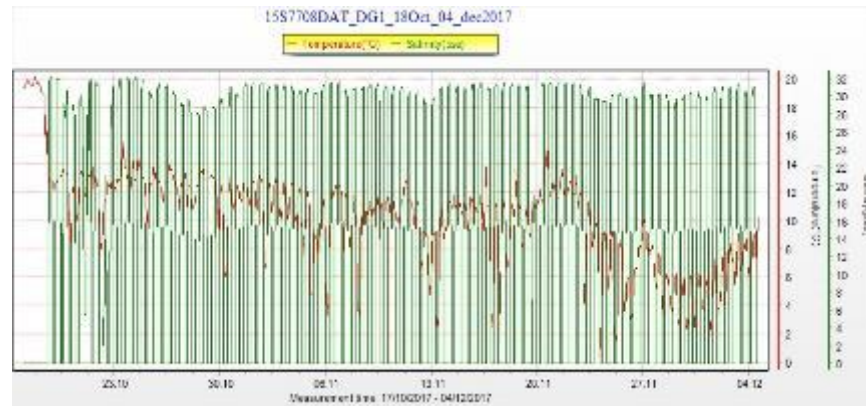
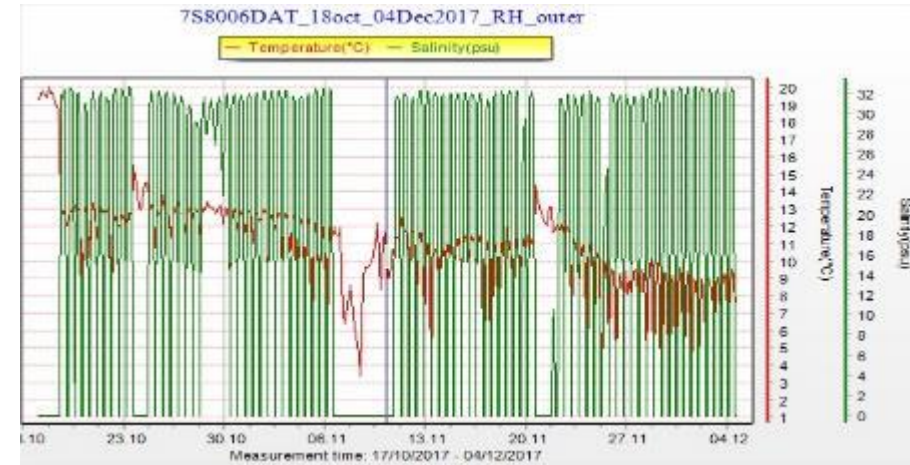
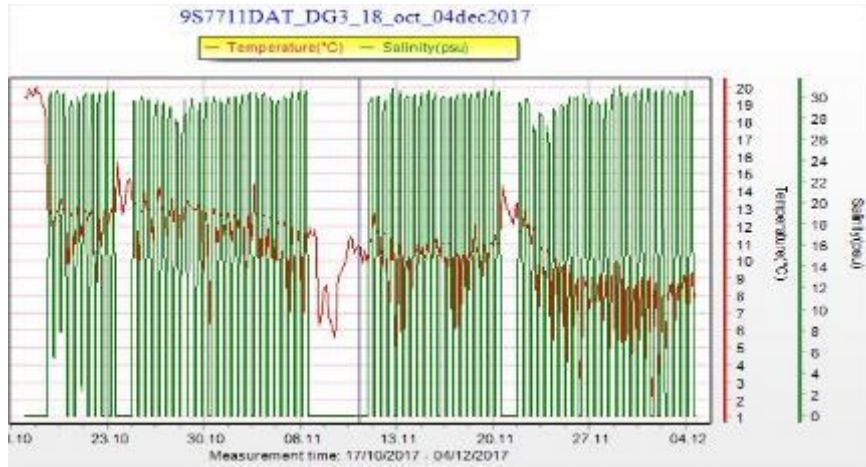


Pulse of chlor a
incoming tide-
benthic diatoms
from sandflats

Seed oysters did
better in the
slower currents in
southern sector

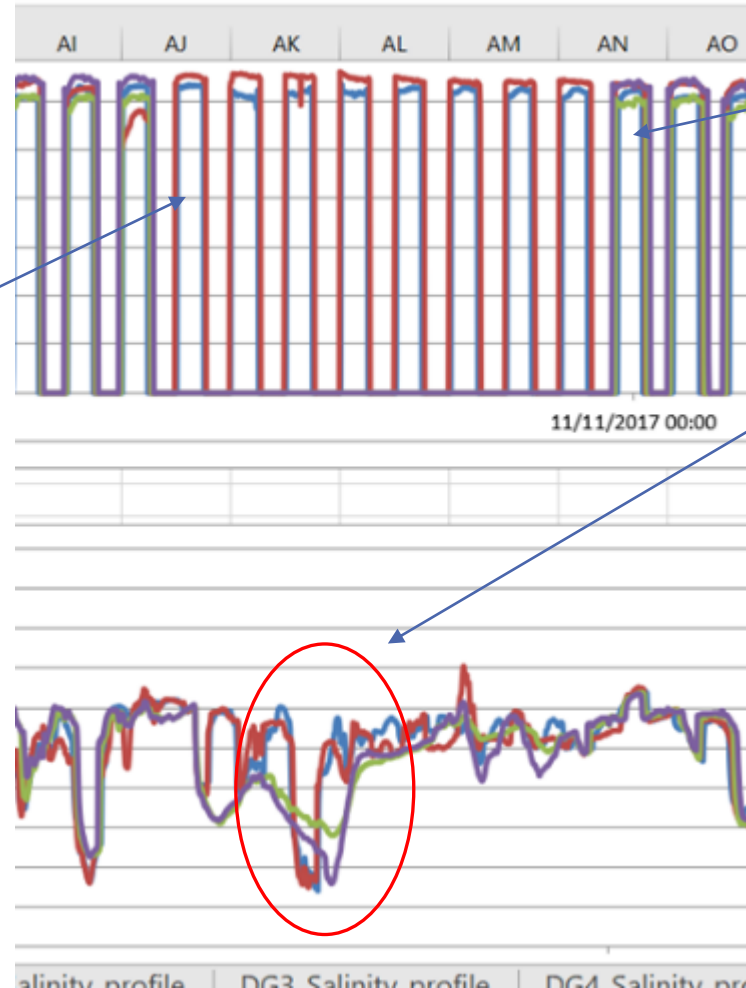
Northern sector
better for
growout to
market size

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

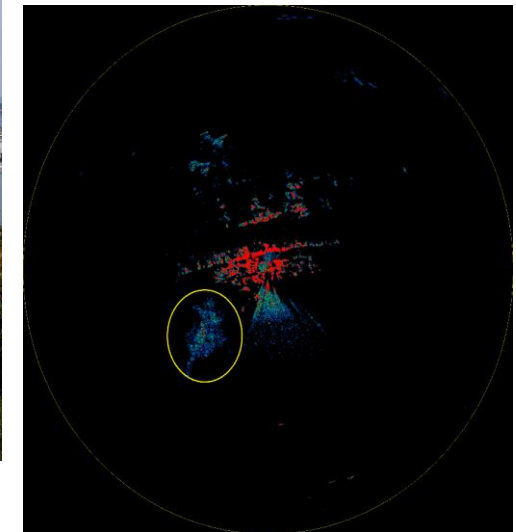


Halo-6 Radar

Battery Powered

Wind and Solar Generation

Detecting rainfall at 35km



Radar Deployment Sites

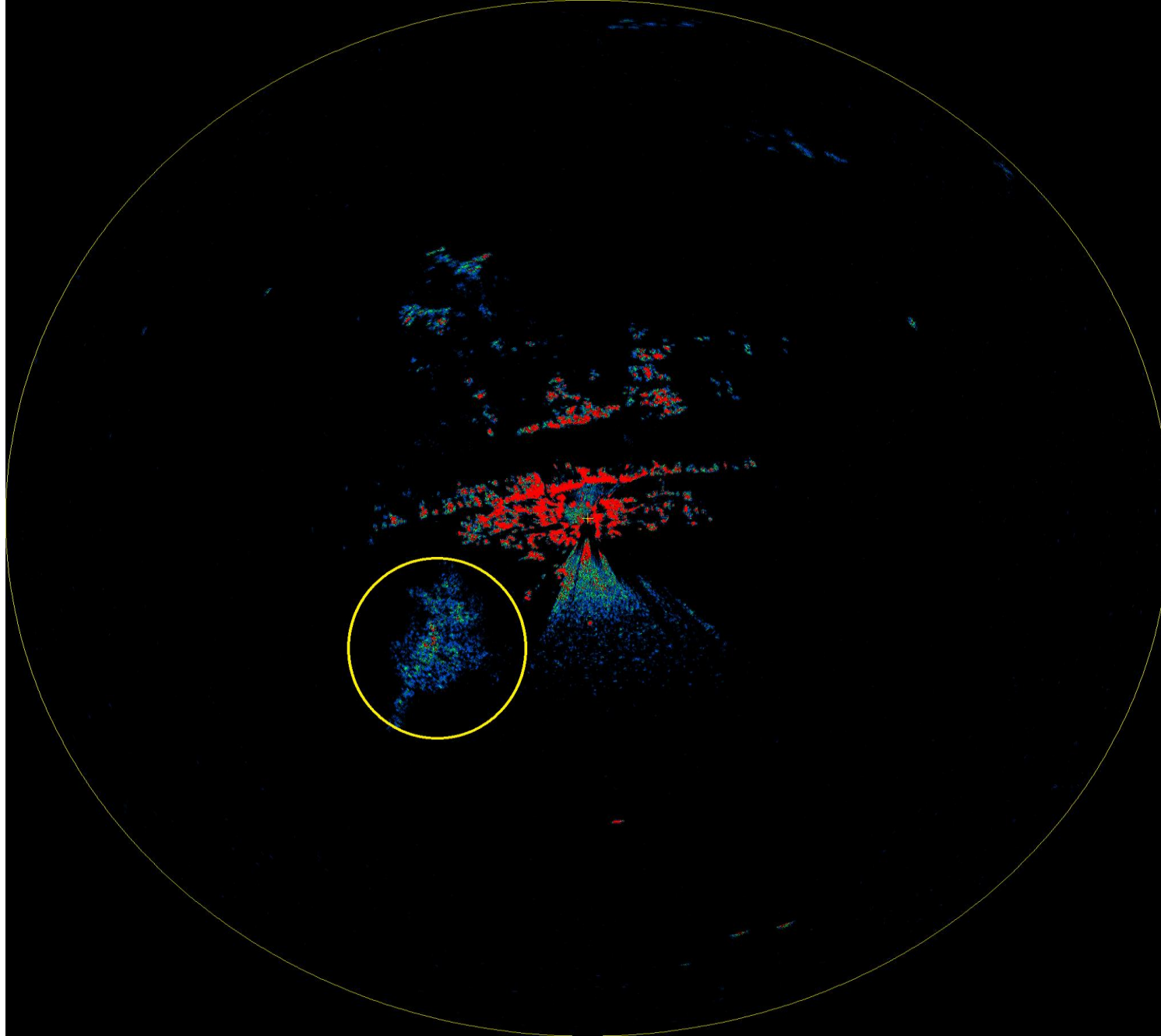
FT Davis Test Site (Cork Harbour)

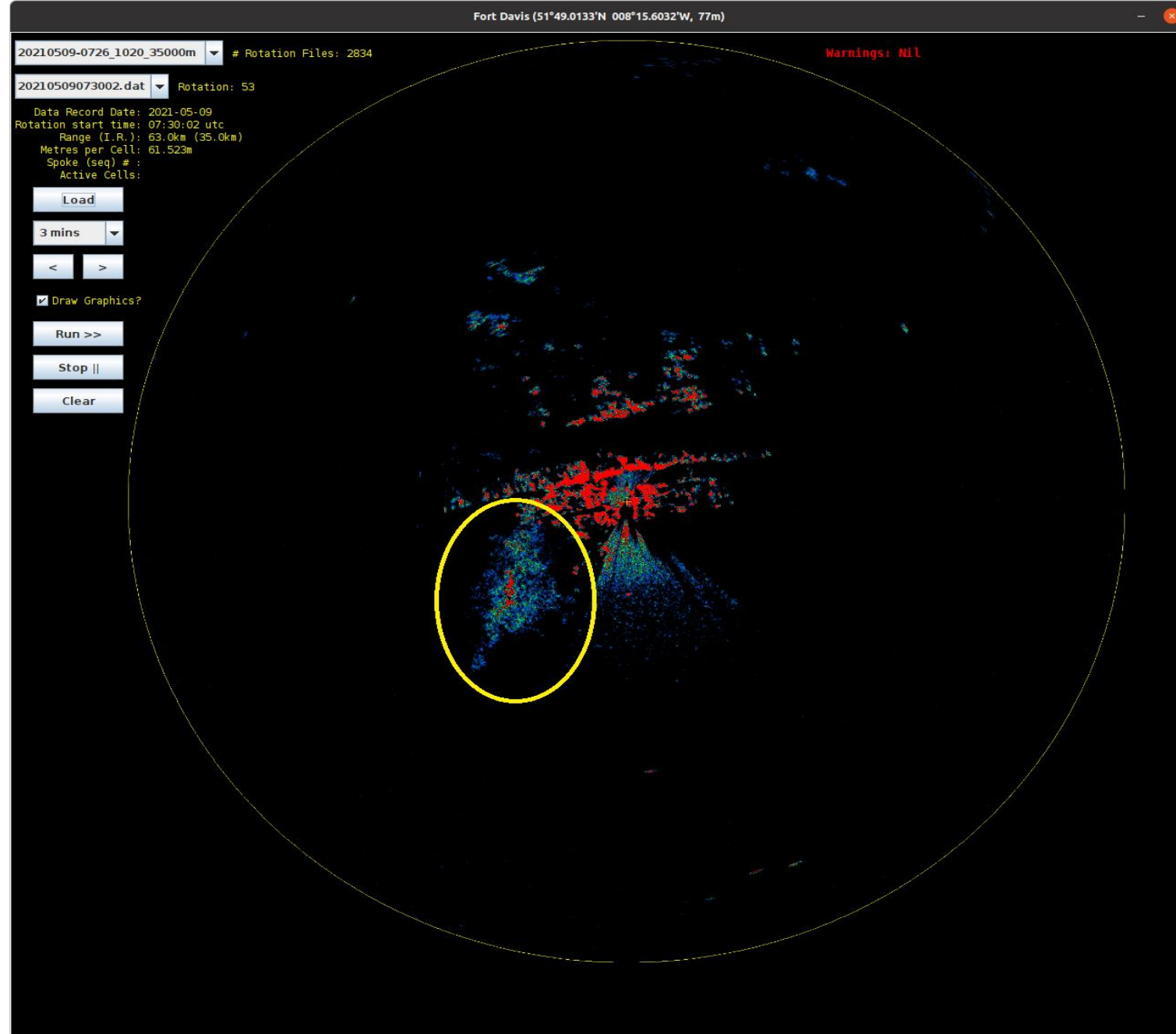
Kilmore Quay (2021)

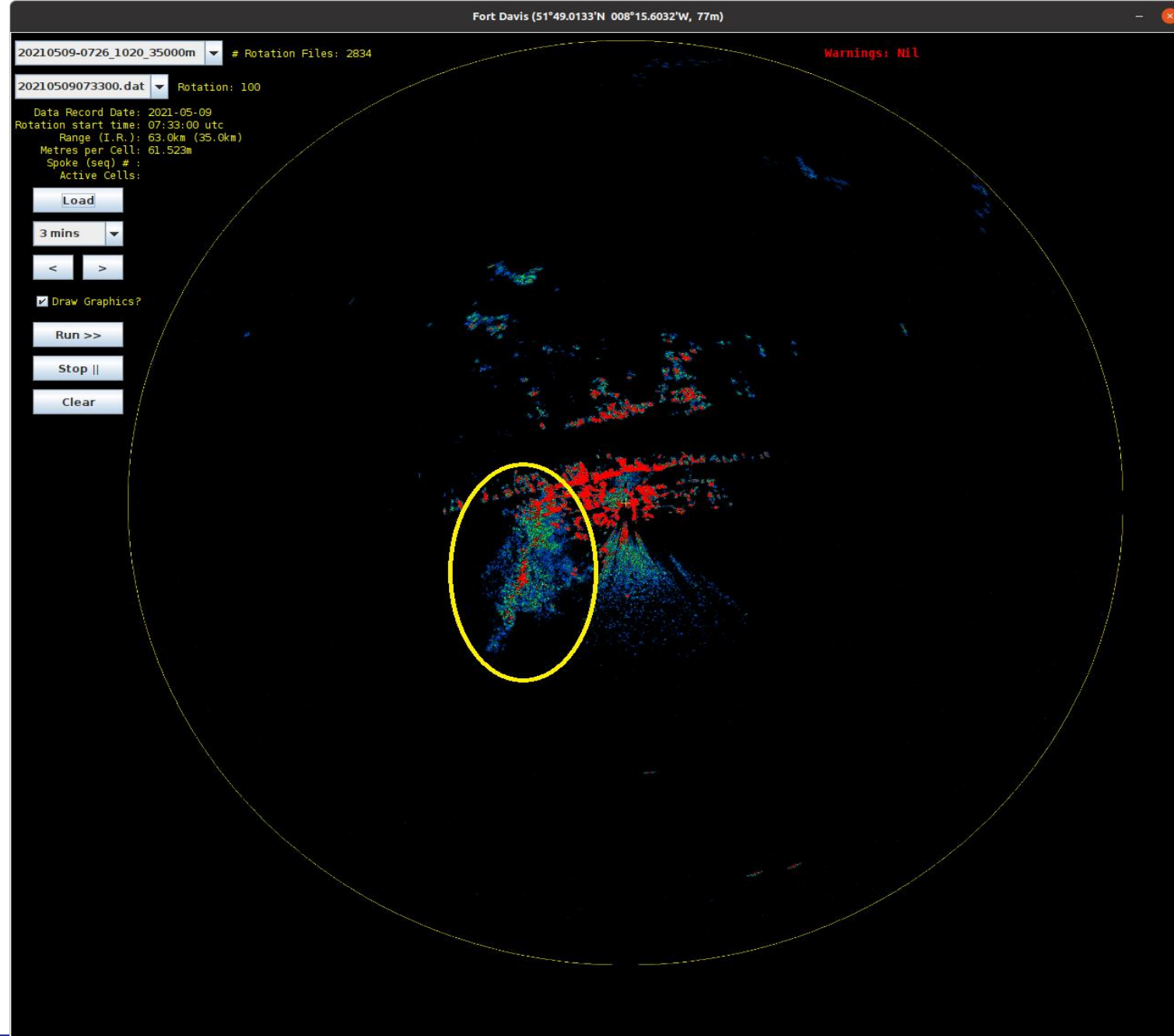
Swansea (2022)

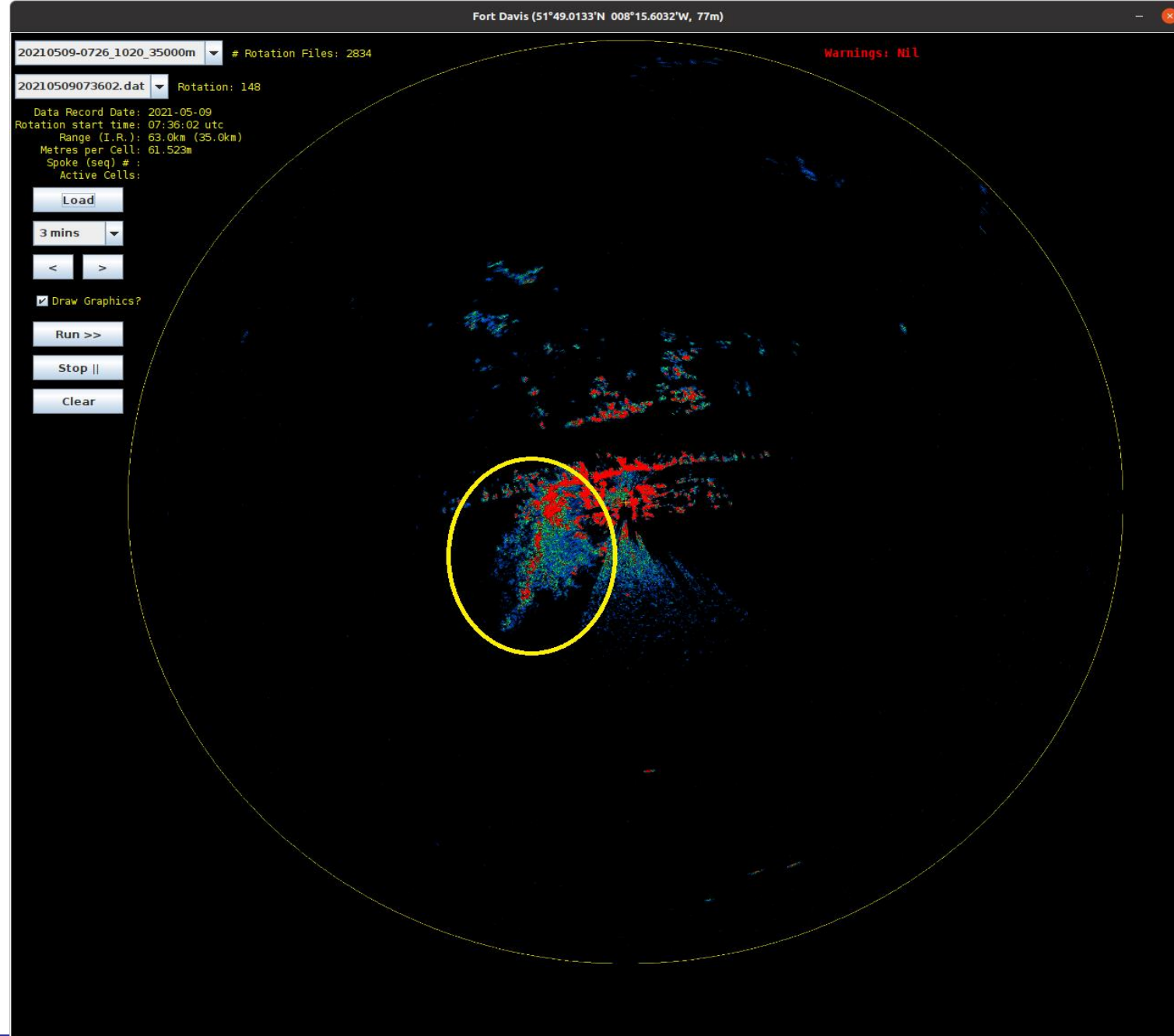
Other Deployments

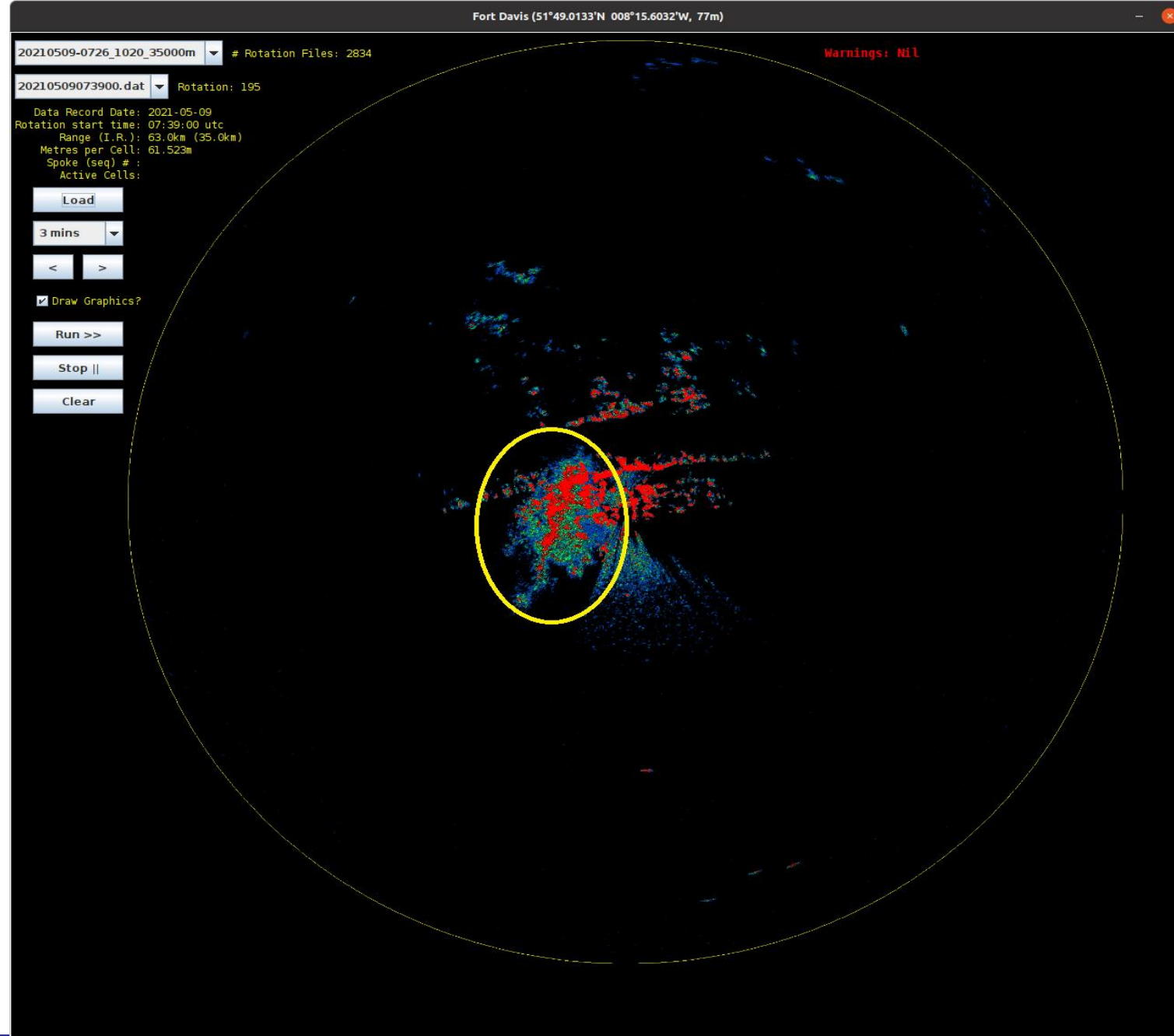


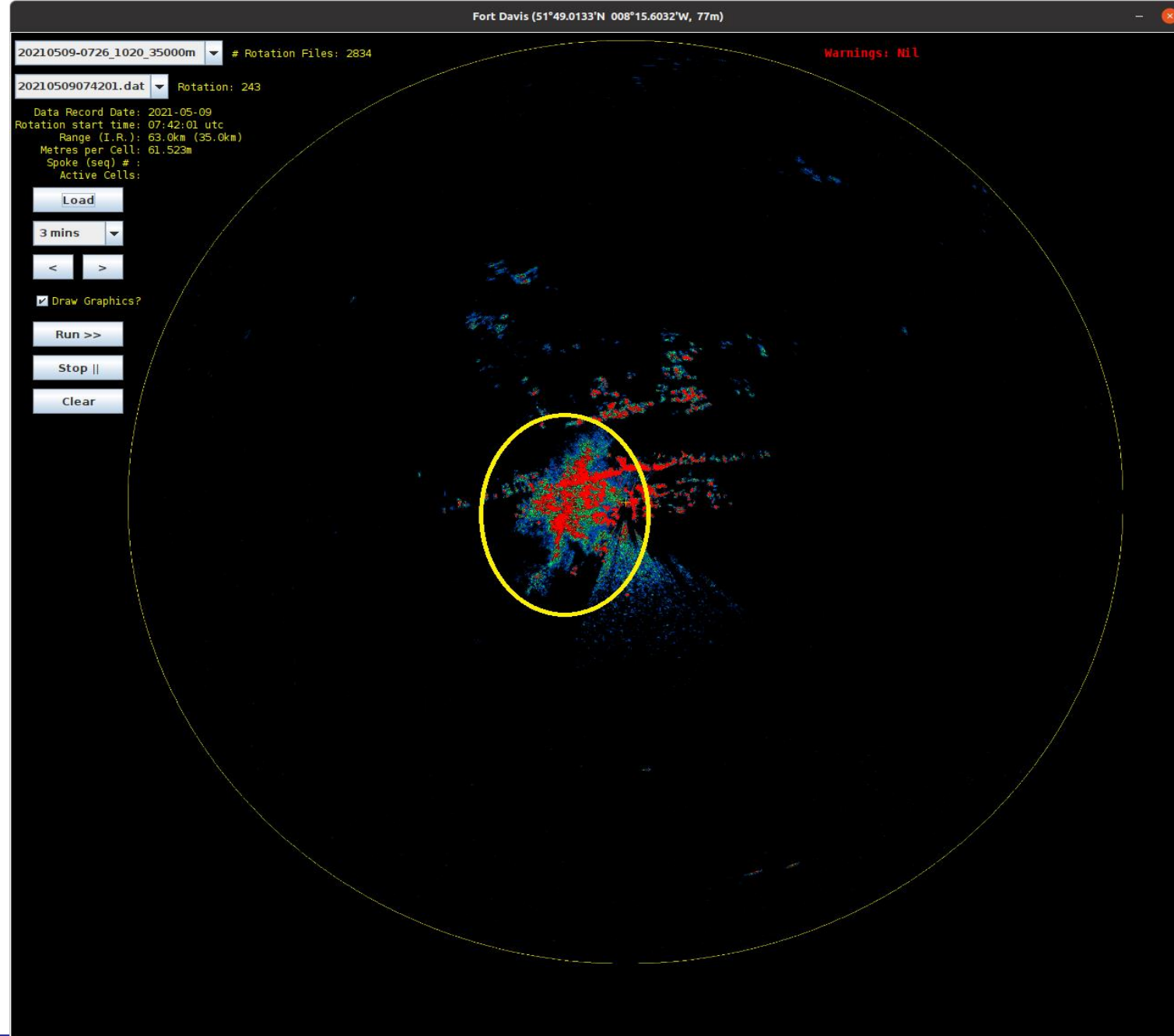












Thank You

Contact Paul Shanahan paul.Shanahan@cit.ie



Aquaculture at the Centre for Sustainable Aquatic Research using sensors

Paul Howes

Dr Pete Jones

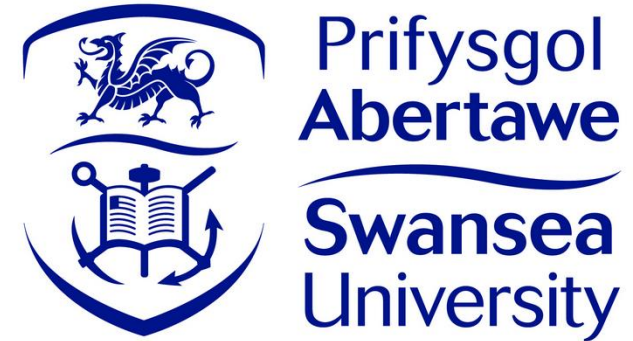
Dr Josh Jones

Swansea University

Centre for Sustainable Aquatic Research

**Application of Sensors in
Precision Aquaculture**

25 May 2021



Who are we?

Created with sustainability as a core principle in order to:

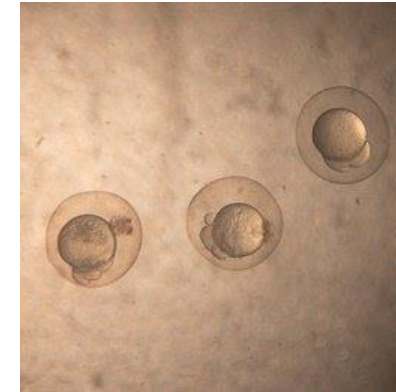
- Deliver unique training and research in aquatic science to enhance the student experience
- Deliver impactful and far-reaching research
- Provide meaningful support to industry, particularly in the areas of sustainable aquaculture, algal biotechnology and sector development



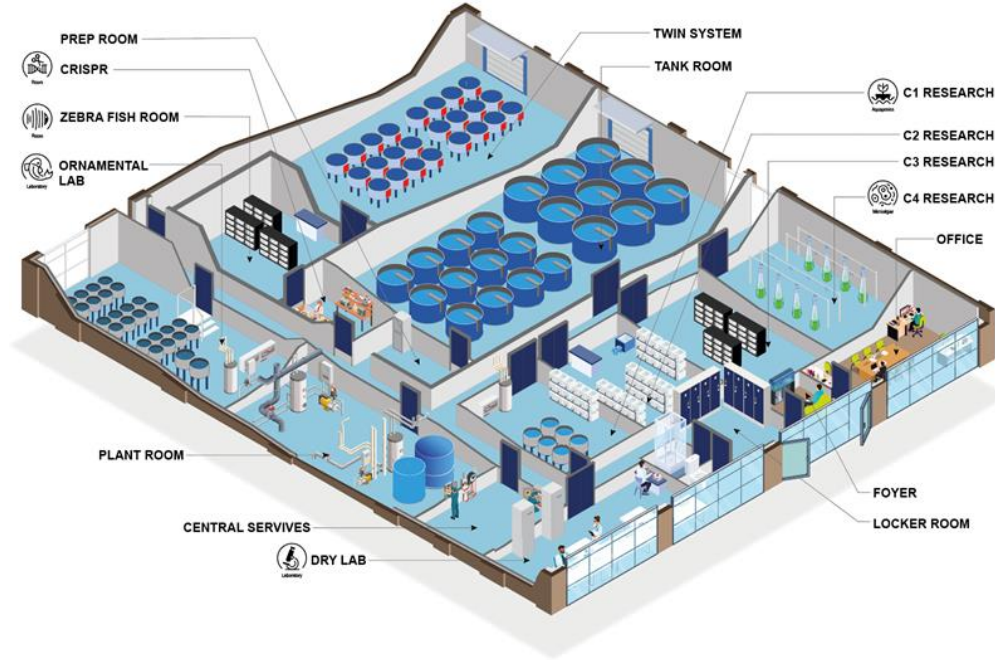
What do we do?

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***



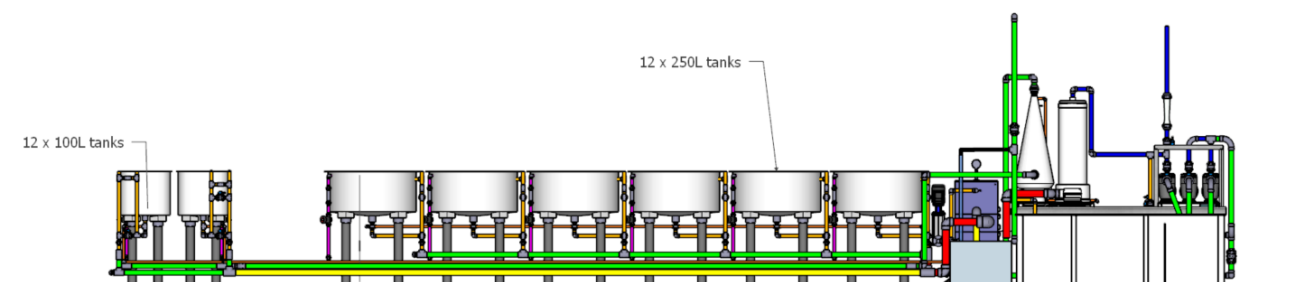
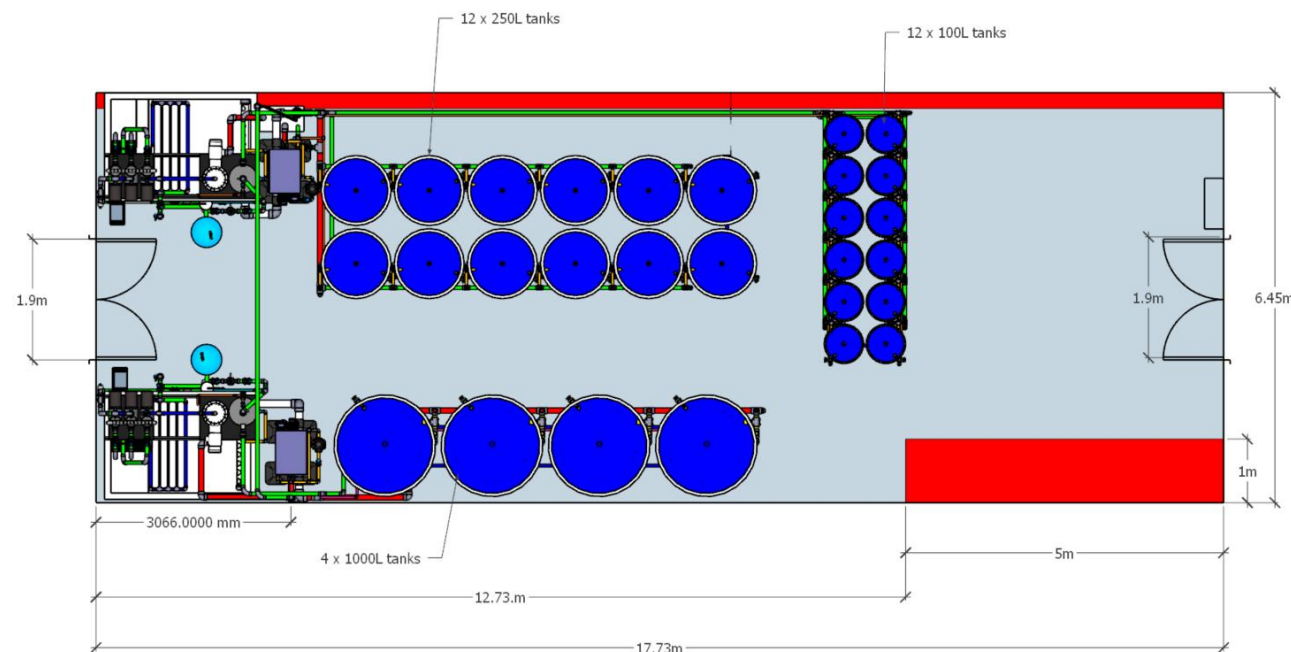
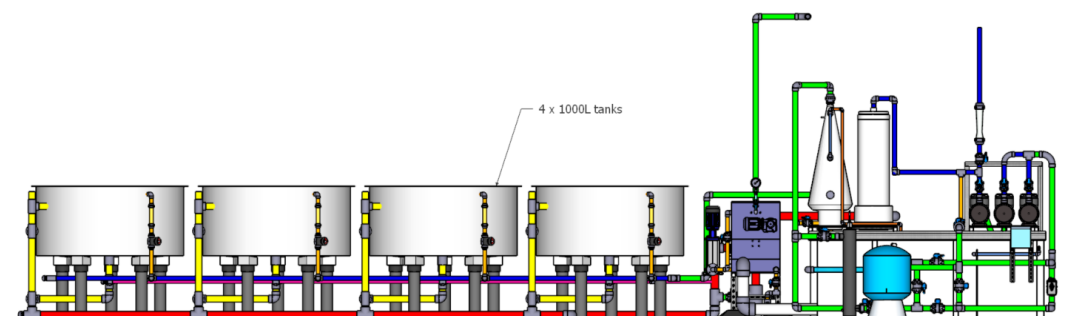
Facilities at CSAR



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



Multi-Trophic Aquaculture at CSAR

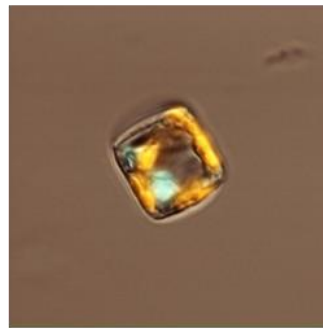
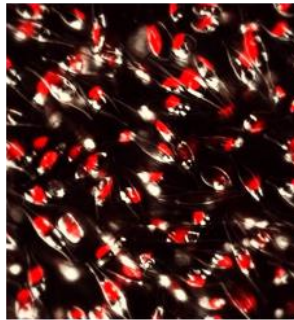


PBR from ALG-AD and EnhanceMicroAlgae INTERREG projects

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

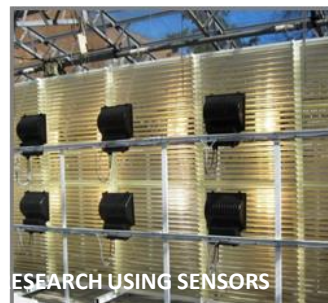
Paul Howes, Dr Peter Jones and
Dr Josh Jones



AQUACULTURE AT THE



FOR SUSTAINABLE AQU



RESEARCH USING SENSORS

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:

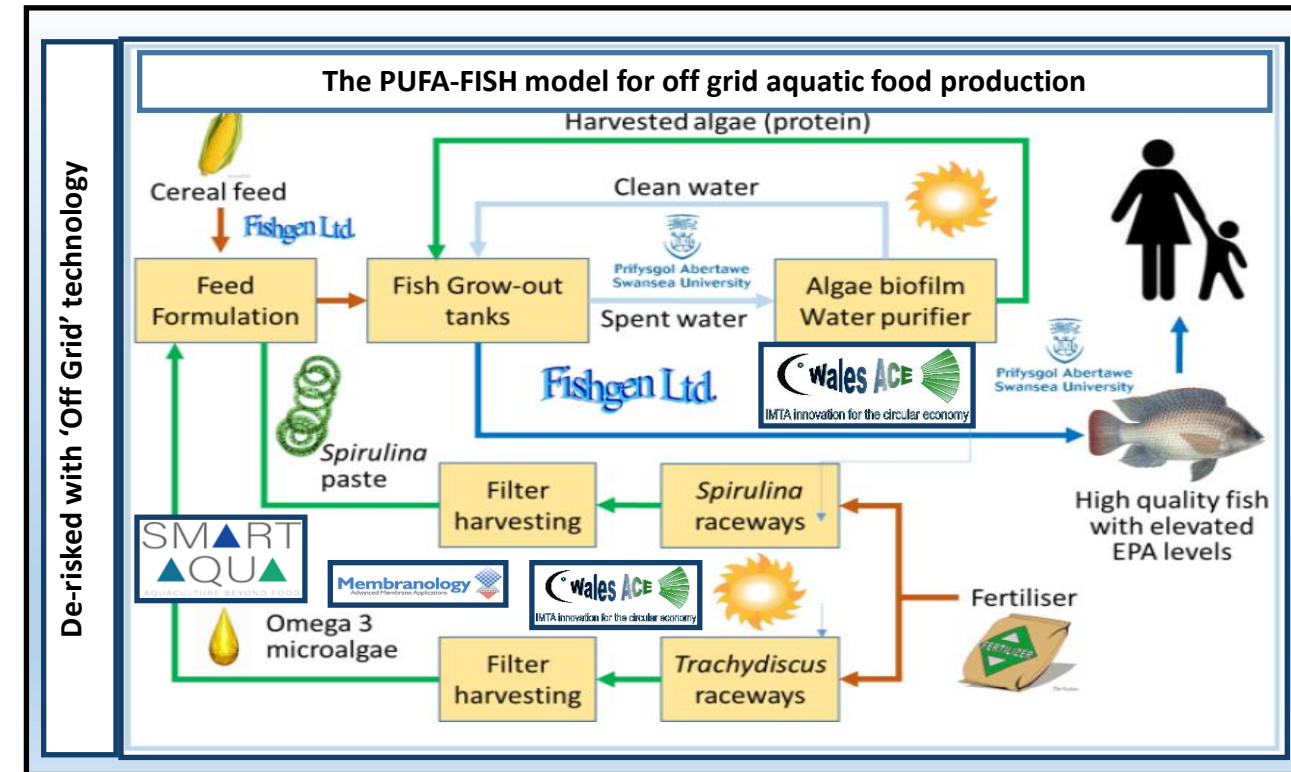
- Air temp, Water temp
- Salinity
- pH
- Oxygen levels
- CO2 levels
- Ozone
- Flow rates
- Tank depth

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?



Incorporating sensors in the circular economy



Incorporating sensors in the Biophilic sector



Picton Yard Biophilic 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

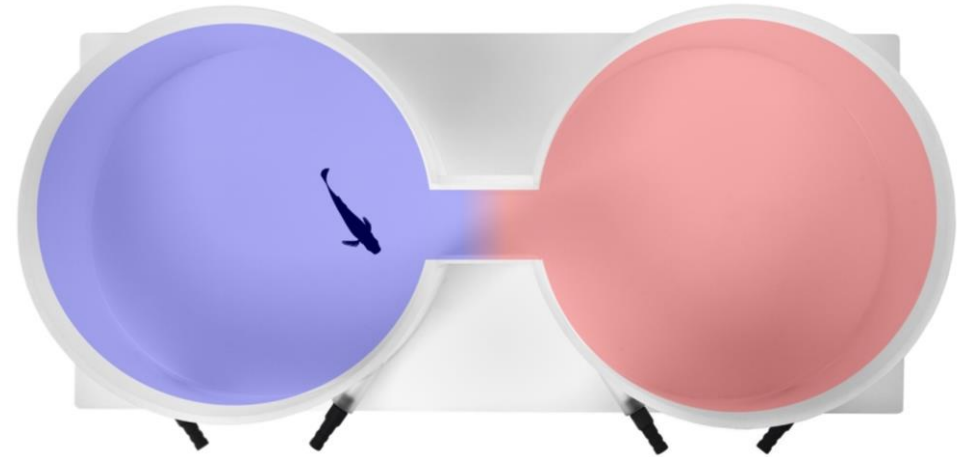
Shuttle box experiments

Allow choice experiments for fish and crustaceans

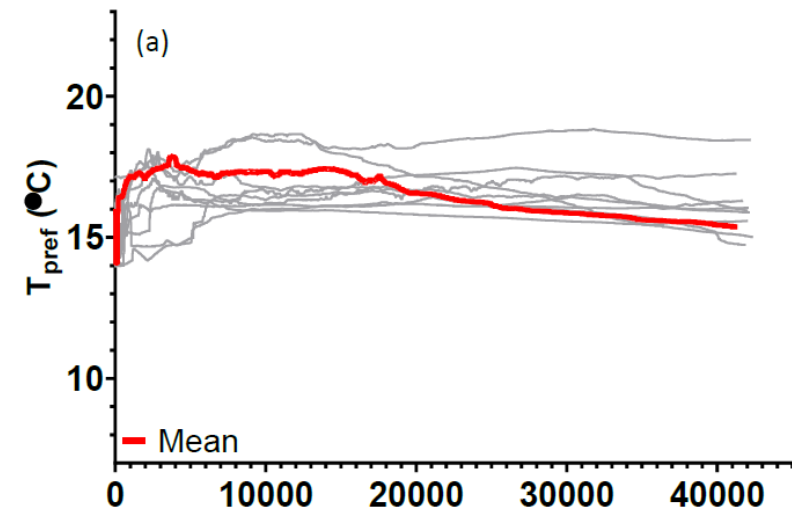
Can manipulate water quality parameters on each side independently

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

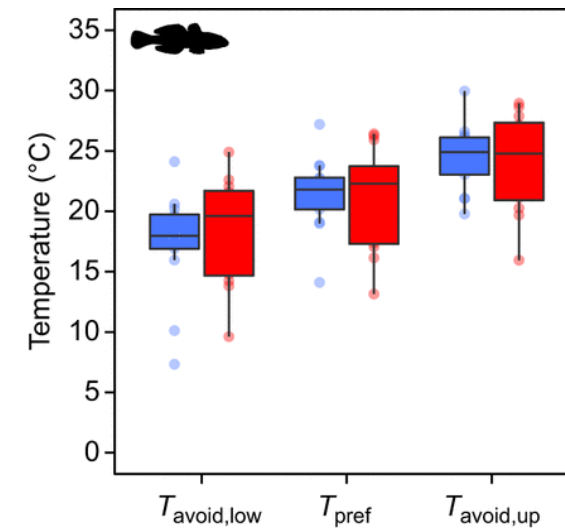
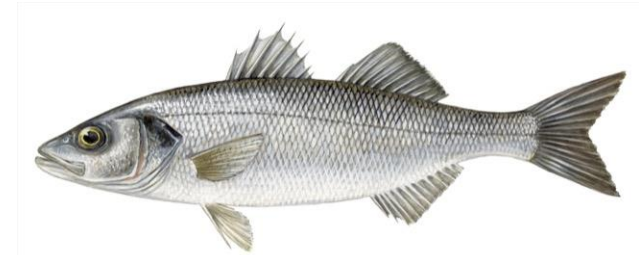
Sea bass (*Dicentrarchus labrax*)

Temperature, DO, pH, pCO₂, 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)

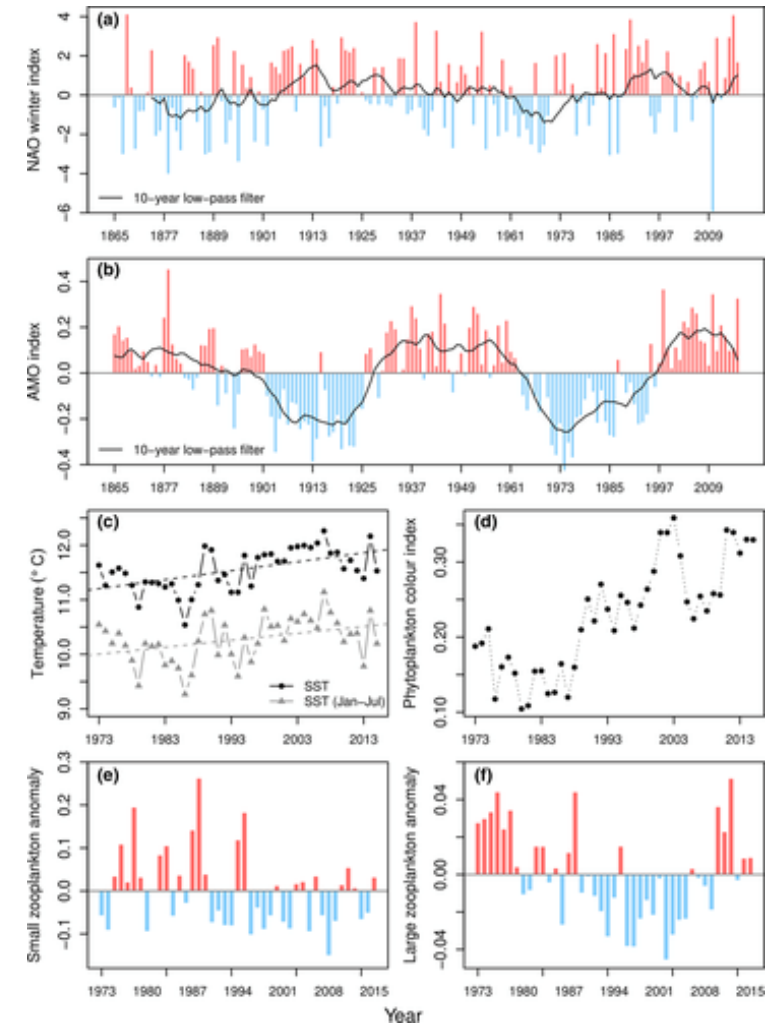
Mapping opportunities and challenges for aquaculture and fisheries

Historic suitability mapping

Dynamic Energy Budget theory
(koijman, 2010)

Model historic aquaculture and
fisheries suitability using:

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



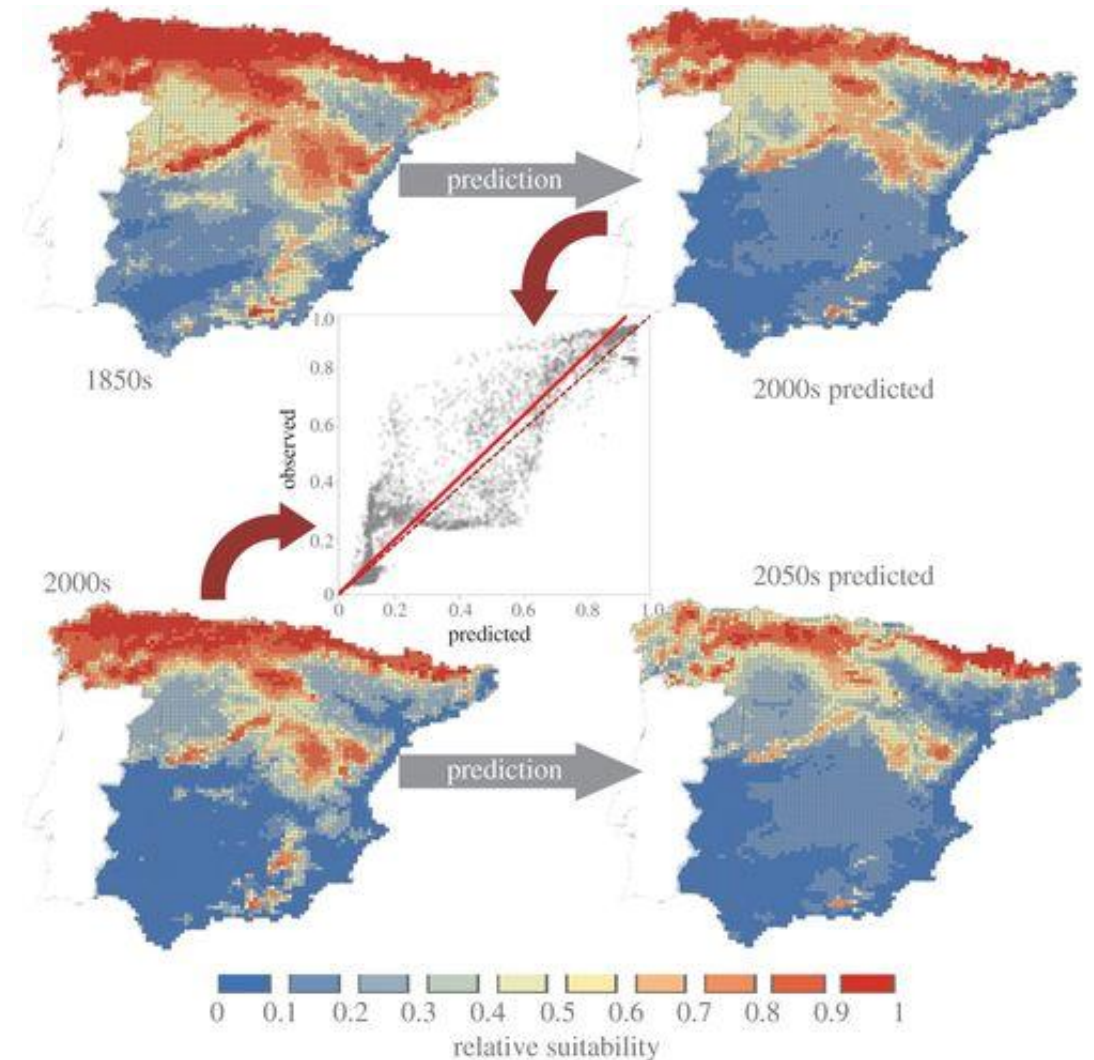
100 years of plankton and environmental trends of the Irish Sea
(Bentley et al., 2020)

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

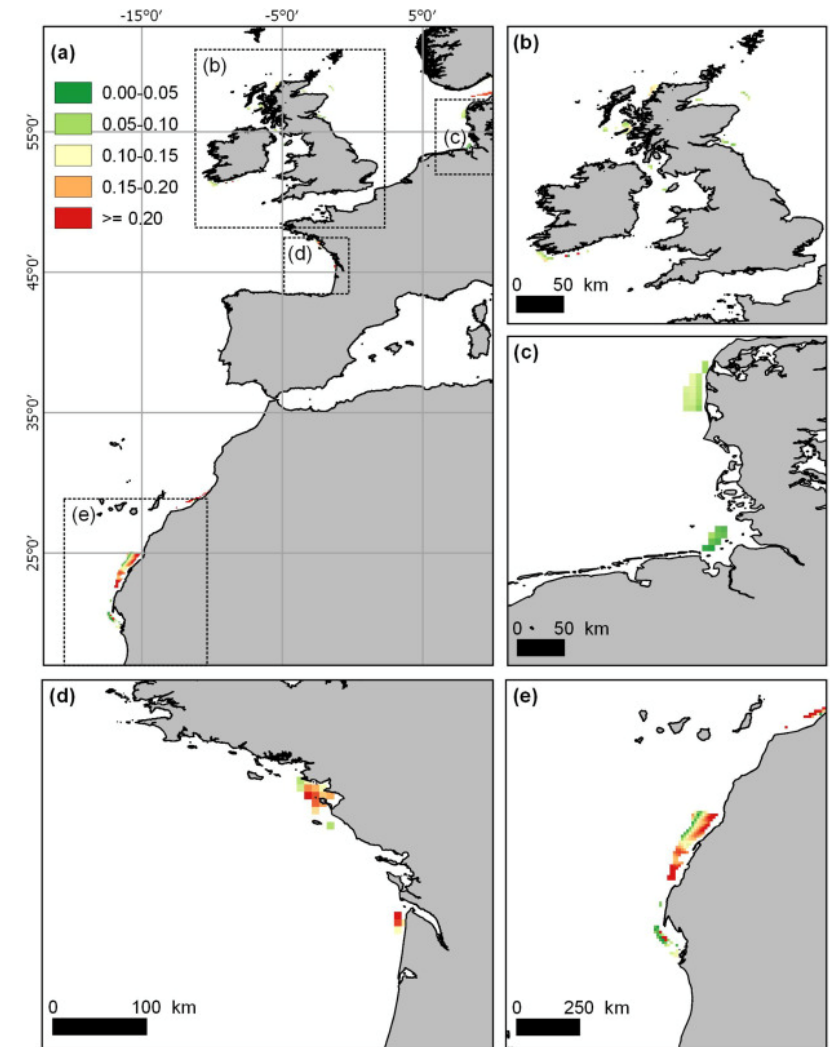


Distribution of suitable brown trout habitat
(Clavero et al., 2017)

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)

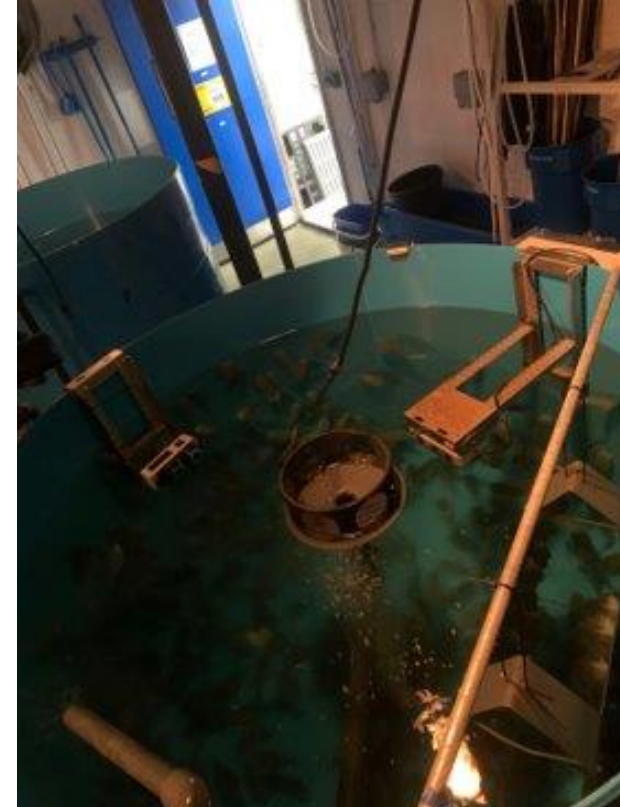
Reverse engineering: a machine vision solution for aquaculture

Gyopár Elekes

Data Scientist FAPTIC.xyz

**Application of Sensors in
Precision Aquaculture**

25 May 2021



REVERSE ENGINEERING: A MACHINE VISION SOLUTION FOR AQUACULTURE

Introduction

- 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:

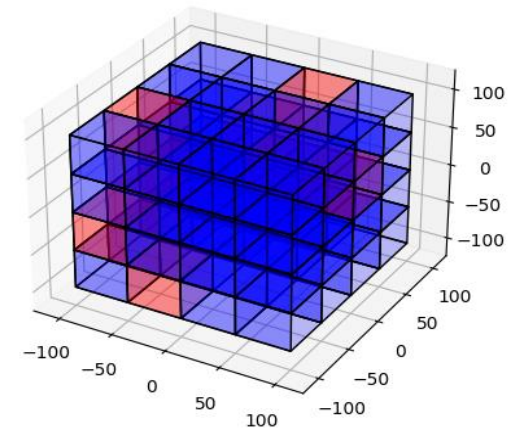
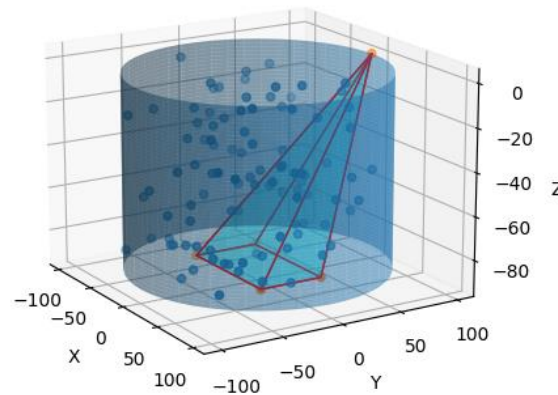
- visual representation

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

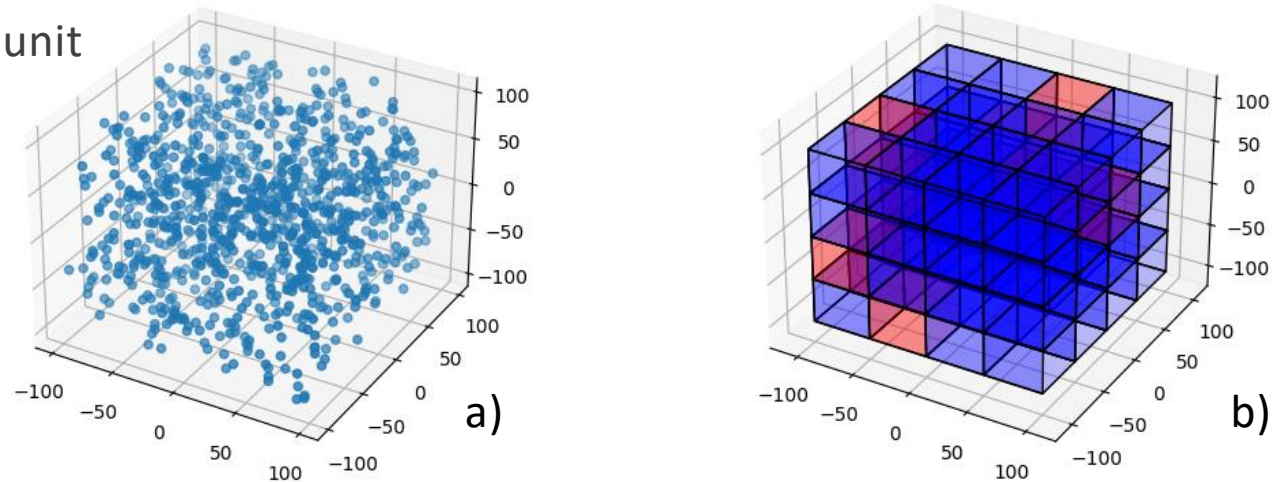


Fig. 1

a) Uniformly randomized position of 1000 fish in 200x200x200 m³ 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



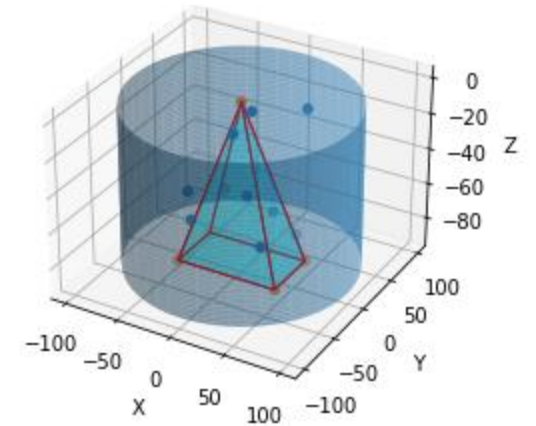
- AI - Deep Learning algorithms
- Fish position in the image 2D (pixel coordinates)

DEFINE POSITION IN 3D

Stereoscopic images are used in the recordings.

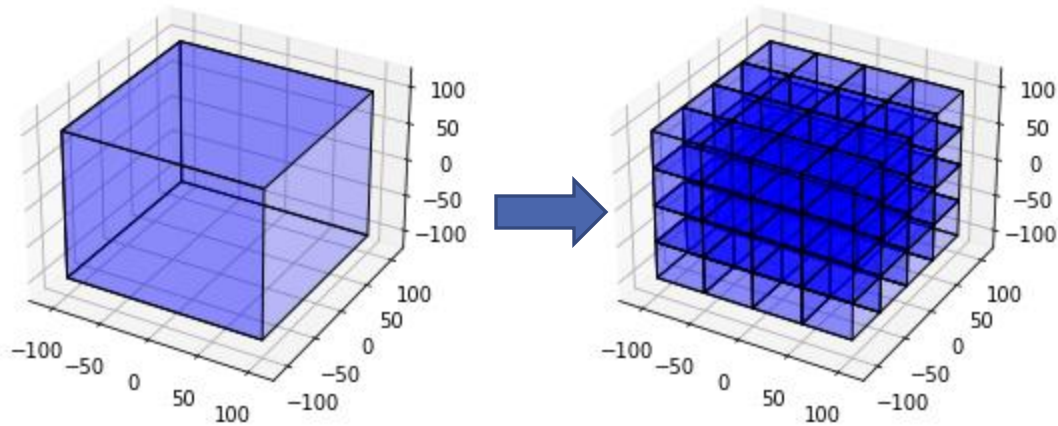
We can calculate the (x, y, z) coordinates of the detected fish.

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

$u_x, u_y, u_z = 50, 50, 50$

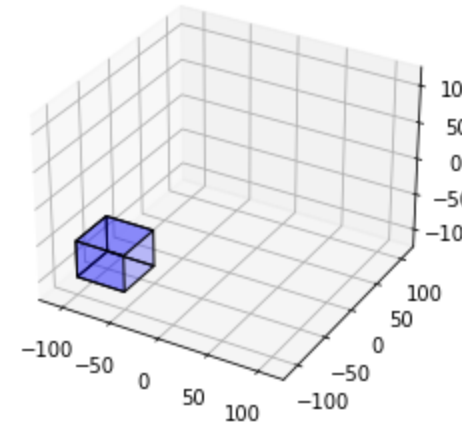
$units_x = \text{int}((x_{max} - x_{min}) / u_x)$

$units_y = \text{int}((y_{max} - y_{min}) / u_y)$

$units_z = \text{int}((z_{max} - z_{min}) / u_z)$

FISH IN UNIT VOLUMES

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



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

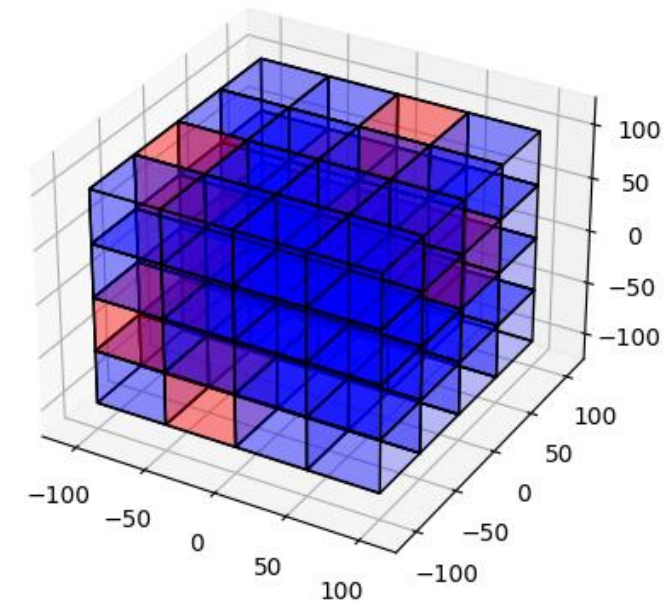
- The positions of the fish are known.
- Counting the number of fish, when its position is inside the unit volume (e.g. [25, 20, 36, 14, 22, ...])

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

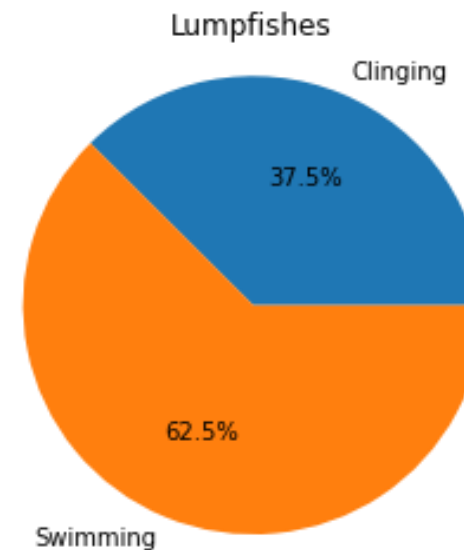
VISUALIZE THE RESULTS



2.Clinging and swimming behavior

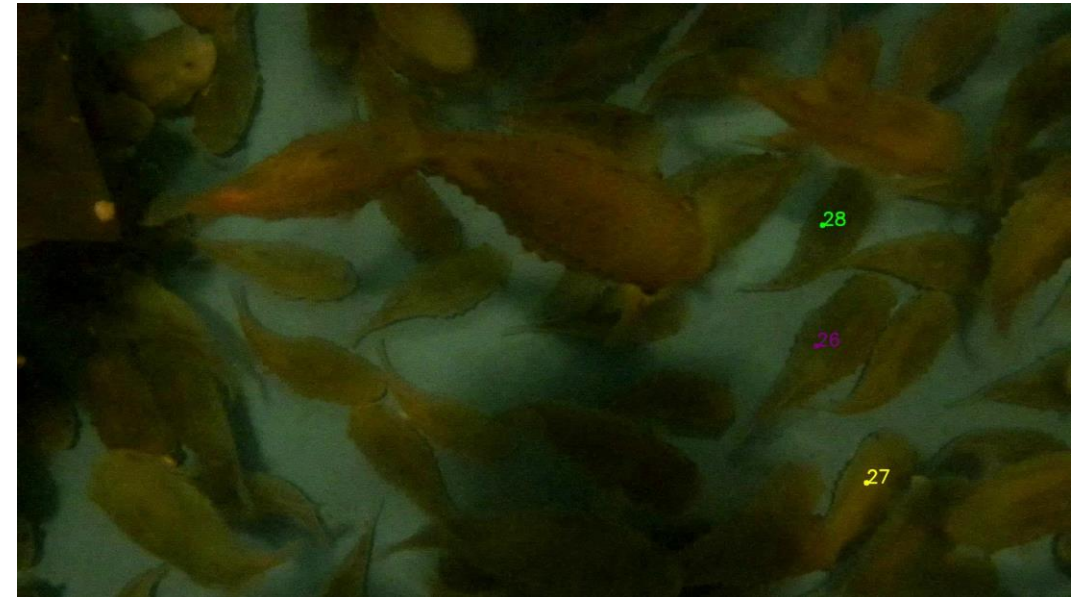
What we want to see

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

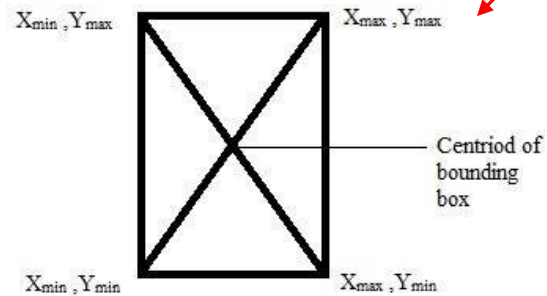


The process in reverse:

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

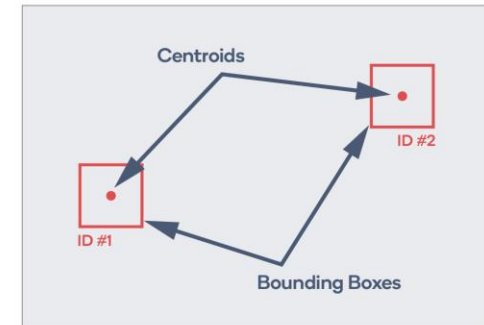


Fish detection

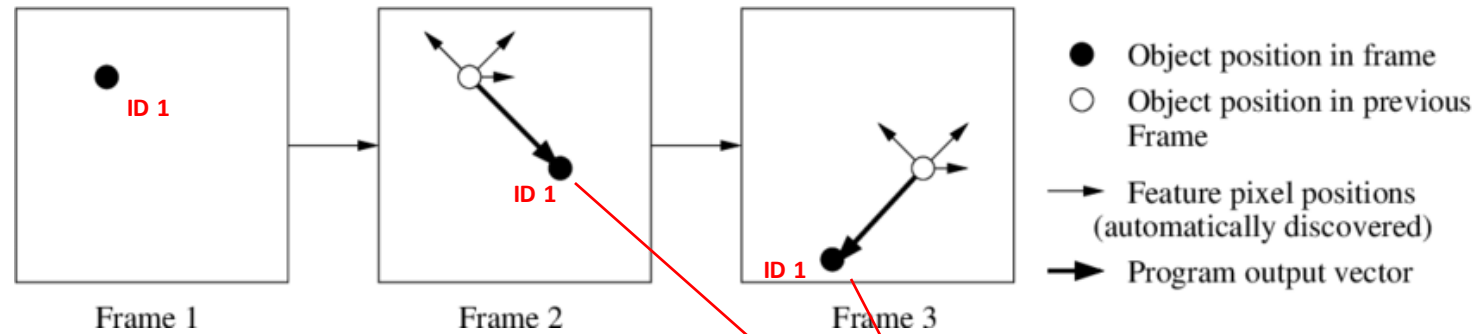


As input for tracking, we used the output of Deep Learning algorithm (detections of lumpfish)

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



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

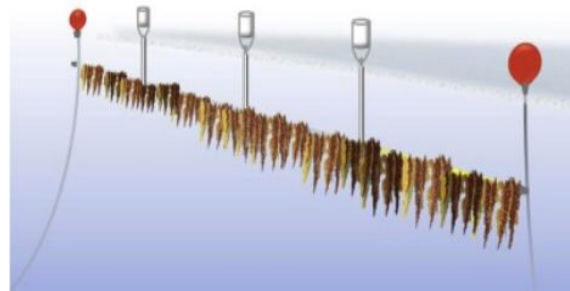


Why monitor your sea-farm?

- ✓ 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.

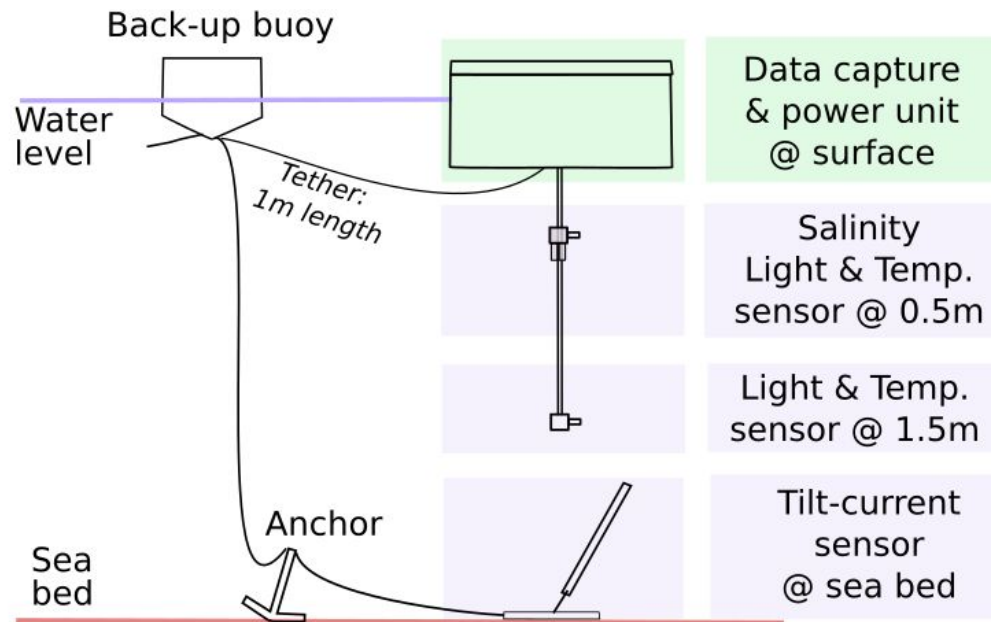


Imaging

Photo / Video



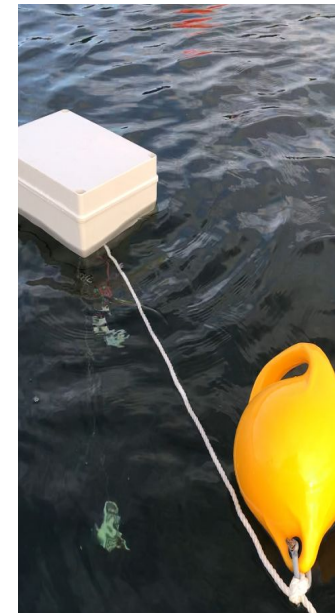
System overview



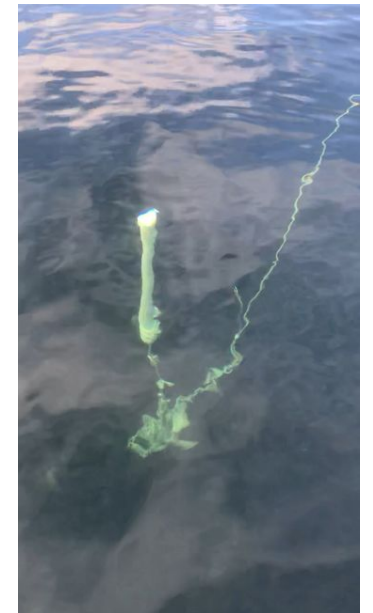
Deployment



Surface unit



Current sensor

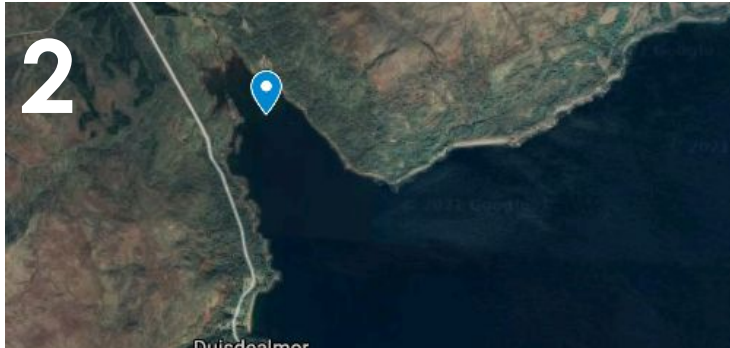


Case Study: Proposed seaweed & Shellfish farm Skye



Site 1:

- Sheltered cove
- Near stream



Site 2:

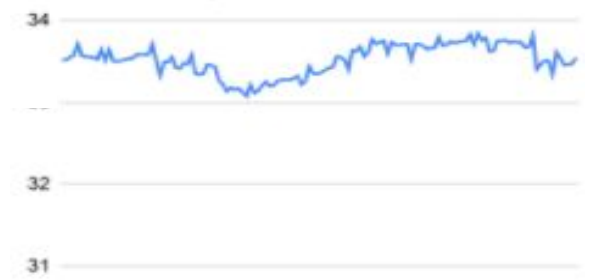
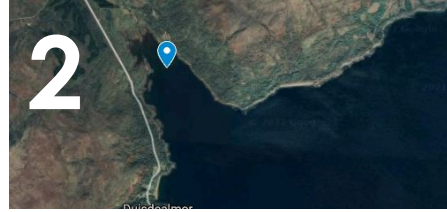
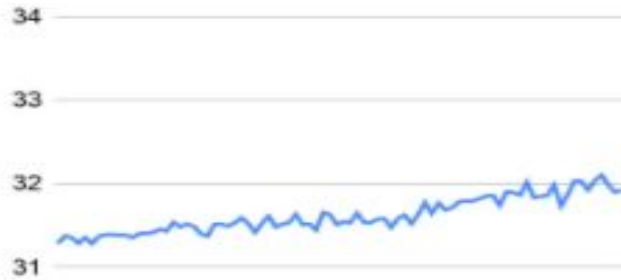
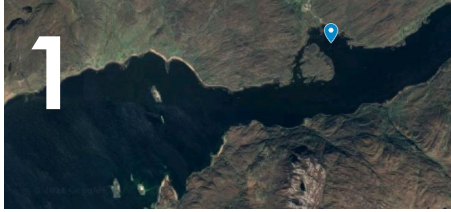
- Semi exposed bay
- Near hotel



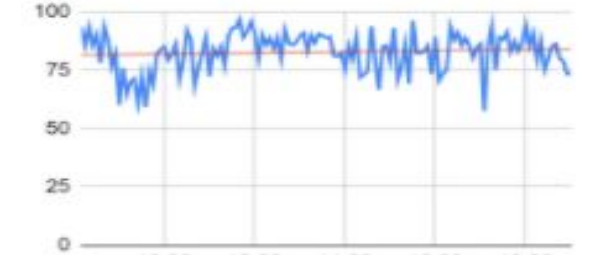
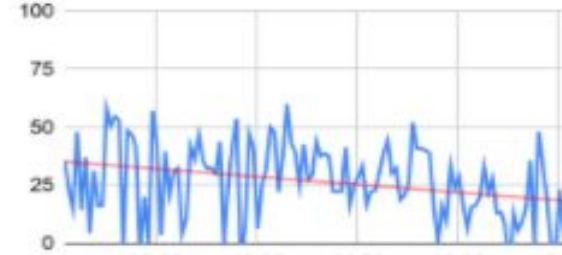
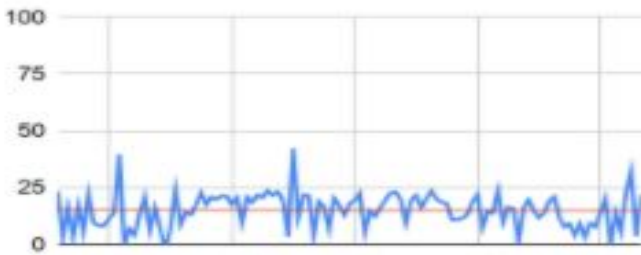
Site 3:

- Wide loch
- Deep

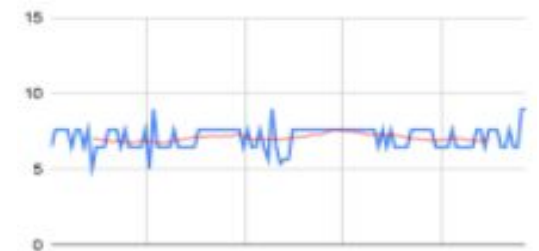
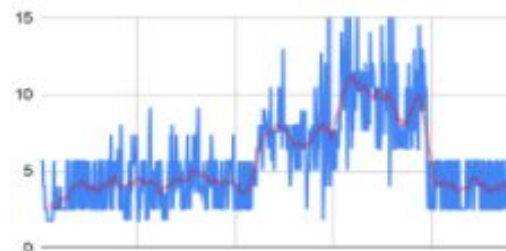
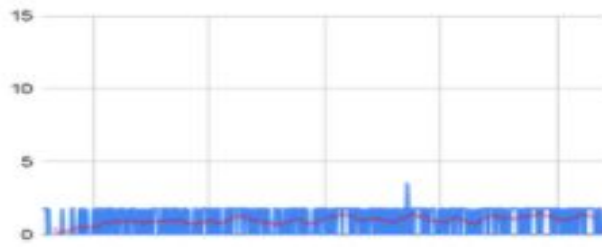
Case Study: Seaweed & Shellfish farm Skye



Light attenuation vs Time



Current vs Time



Next steps:

IUK Project SeaLens:
April 21 - March 22



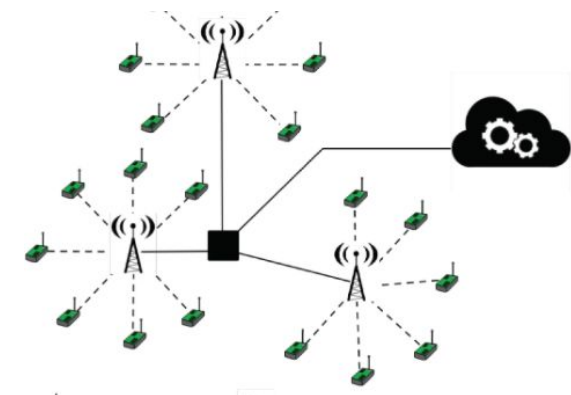
Adapt tools for sea-farms



Test long-term imaging



Implement comms back to land



Thank you

We hope you
enjoyed the webinar

Updates on

- @csar_ace
- @irlwales
- #aquasensors

