All Atlantic Ocean Sustainable Profitable and Resilient Aquaculture

ASTRAL POOL OF TECHNOLOGIES
DIGITAL TWINS TO SUPPORT IMTA WITHIN THE ATLANTIC AREA

Marcelo Pias, FURG (Federal University of Rio Grande), Brazil

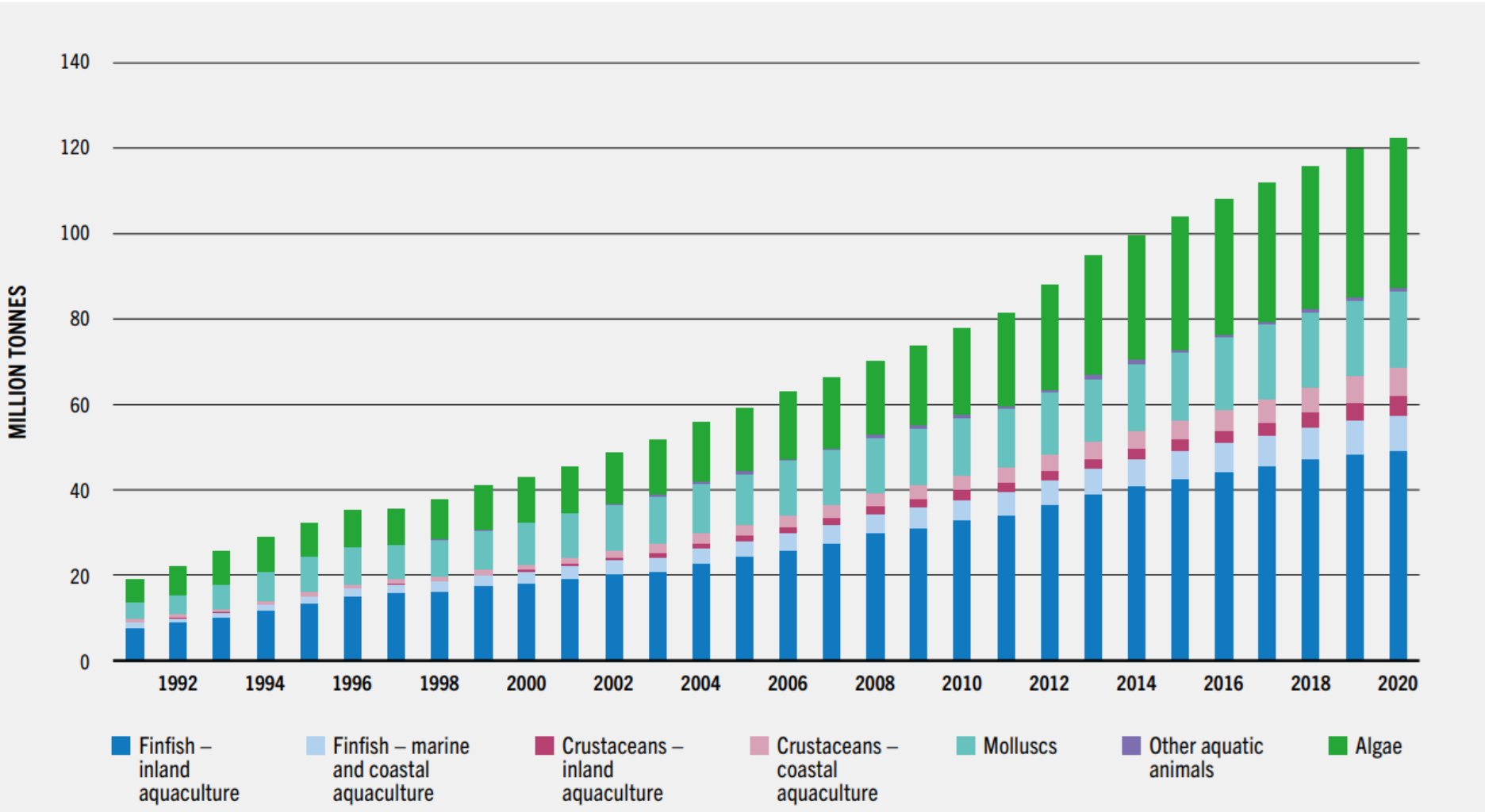
Co-authors: Gilles Orazi, Maxime Paris, Paulo Drews, Charlotte Dupont, Marié Smith, Kati Michalek, Lisl Lain, Javier Martinez, Iheb Khelifi, Shaw Bamber, Bård Henriksen, Ahmed Abid, Arthur Tré-Hardy, Aitor Garcia, Xavier Rodriguez, Bruna Guterres, Elisa Ravagnan

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863034.

Outline

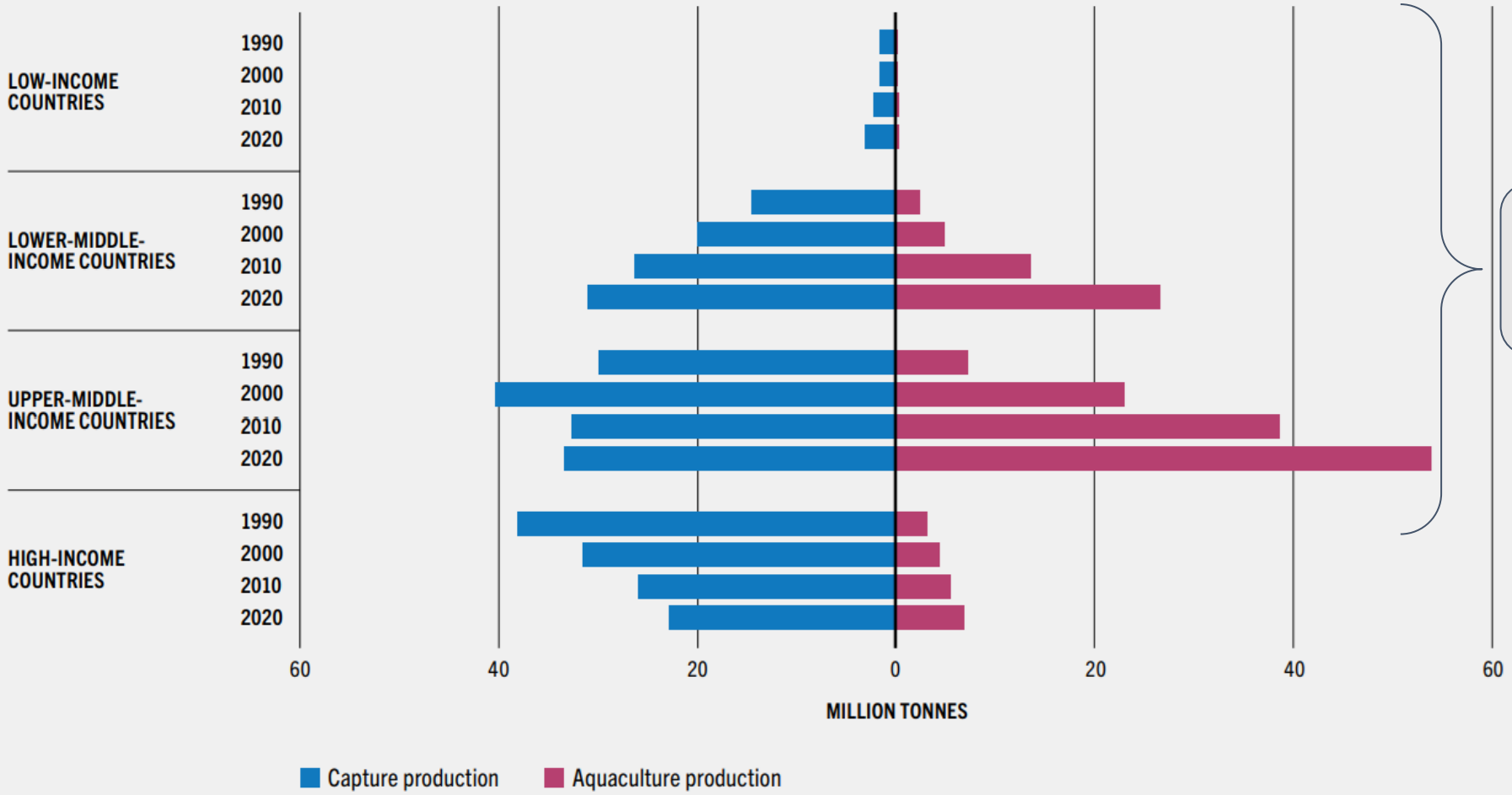
- Integrated Multi-Trophic Aquaculture (IMTA)
- ASTRAL Pool of Technology Innovations
- Take-away message

FIGURE 13 WORLD AQUACULTURE PRODUCTION, 1991–2020



Source: FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO.

FIGURE 17 FISHERIES AND AQUACULTURE GROWTH COMPARISON BY COUNTRY GROUP BY INCOME LEVEL (EXCLUDING ALGAE), 1990–2020



Macro-level opportunity
Low-cost technology

Source: FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO.

The Need

Interviews with end-users (from December 2021 to September 2022)
10 countries, 38 interviews done (14 IMTA, 6 co-culture, 18 monoculture)

"Monitoring is very important for us. We control the salinity and temperature of the water, to ensure good production processes" – **Brazilian producer** 

"We would like to use monitoring devices for monitoring water quality but they are very expensive especially for small producers" – **Portuguese producer** 

"We are using open water pen culture system with automatic feeders, water quality is key. It is monitored by taking manual samples routinely" – **Irish producer** 

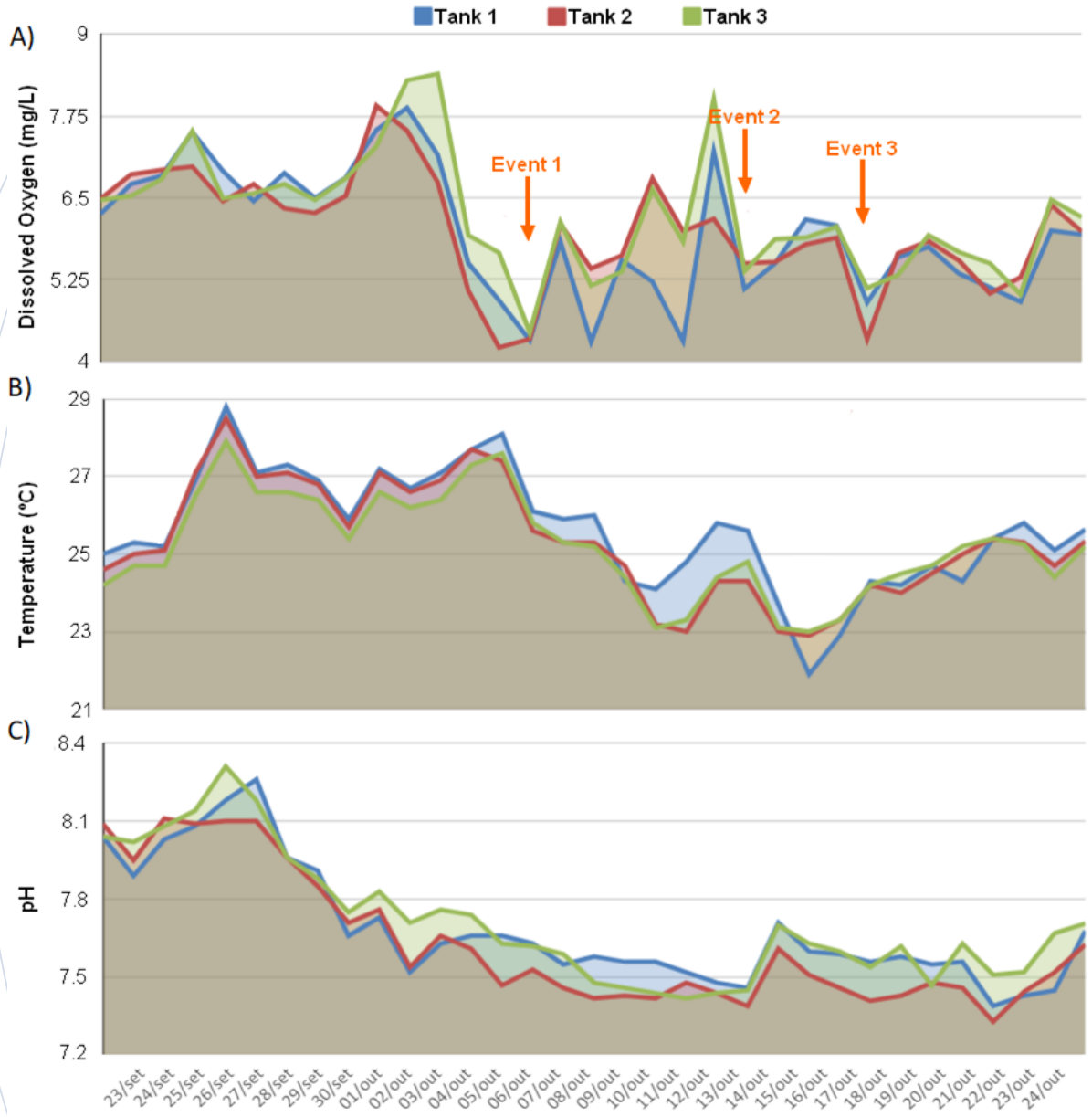
"We do daily monitoring for pH and determine CO2 based on the pH and alkalinity. This is difficult and expensive to measure with a probe" – **South African producer** 

Integrated Multi-Trophic Aquaculture (IMTA)

- ASTRAL supports and promotes sustainable aquaculture production in the Atlantic area
- Integrated multi-trophic aquaculture (IMTA)
- Exposed to many threats
  - Climate change
  - Harmful Algae Blooms (HAB)
  - Microplastics
  - Critical physicochemical parameters
- Complete technological suite to best address end-user needs
  - ASTRAL pool of innovative components

https://www.astral-project.eu

One of the many problems in IMTA



- **Event 1**
  - Event 1: Power outage of aeration; water temperature above average. Backup power generator should be started soon. Otherwise hydrogen peroxide to be used (30 min)
- **Event 2**
  - Power outage situation; lower water temperature (slow animal metabolism). Backup power generator started in a few minutes causing a less sharp oxygen drop.
- **Event 3**
  - Use of hydrogen peroxide to control the dissolved oxygen level.

30-minute for mitigation

Integrated Multi-Trophic Aquaculture (IMTA)

Is it possible to design and deploy a digital twin to enable closed-loop feedback and operational autonomy in aquaculture farms?

- **Planetary Digital Twins** explore closed-loop feedback and control as key features to build a global-scale virtual replica of farming physical facilities

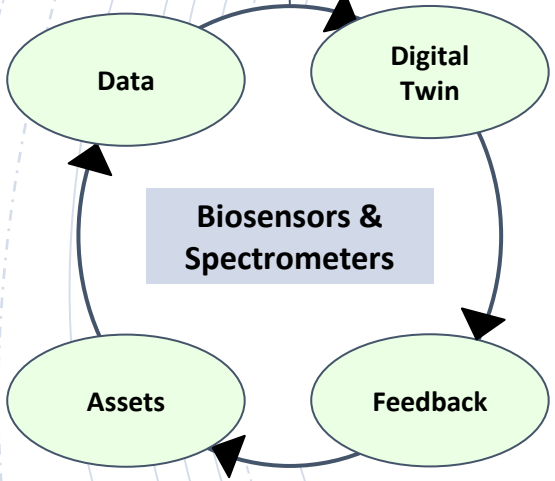
ASTRAL Pool of Technology Innovations

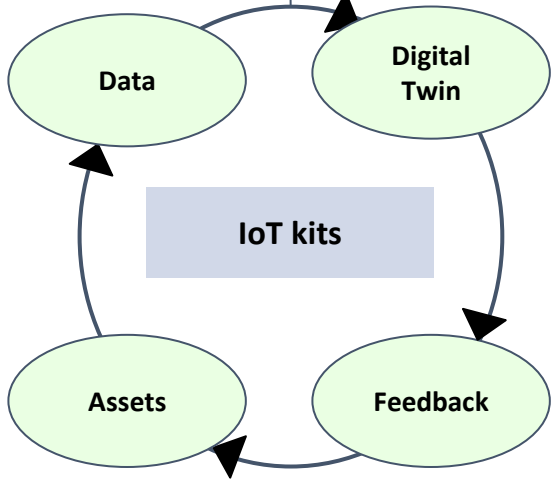
ASTRAL AIDAP
Artificial Intelligence Data Analytics Platform

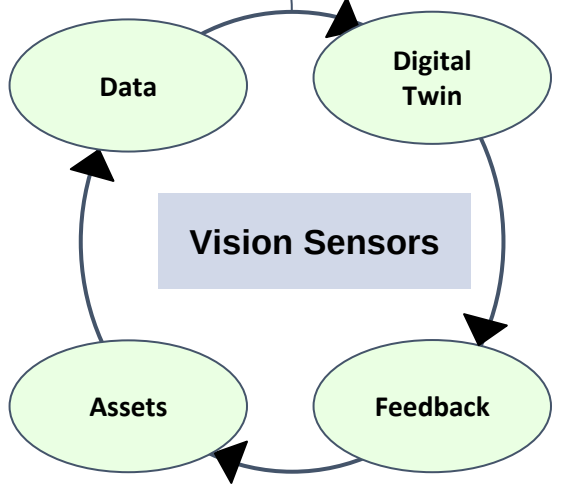
+ Environmental proxy
+ Animal welfare
+ Microplastic

+ Physico-chemical variables
+ Essential water quality variables

+ Biomass estimation
+ HAB monitoring







The Royal Society, Digital technology and the planet: Harnessing computing to achieve net zero Issued: December 2020 DES7035 ISBN: 978-1-78252-501-1

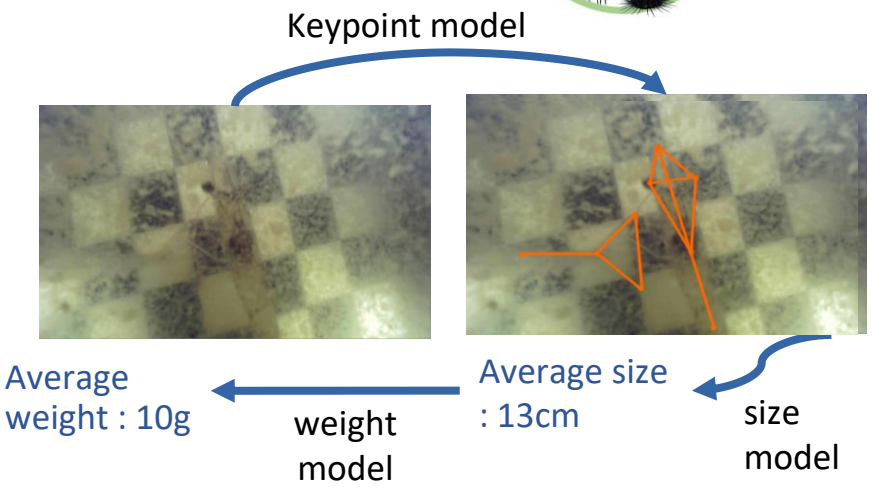
Low-cost IoT kits (Internet of Things)

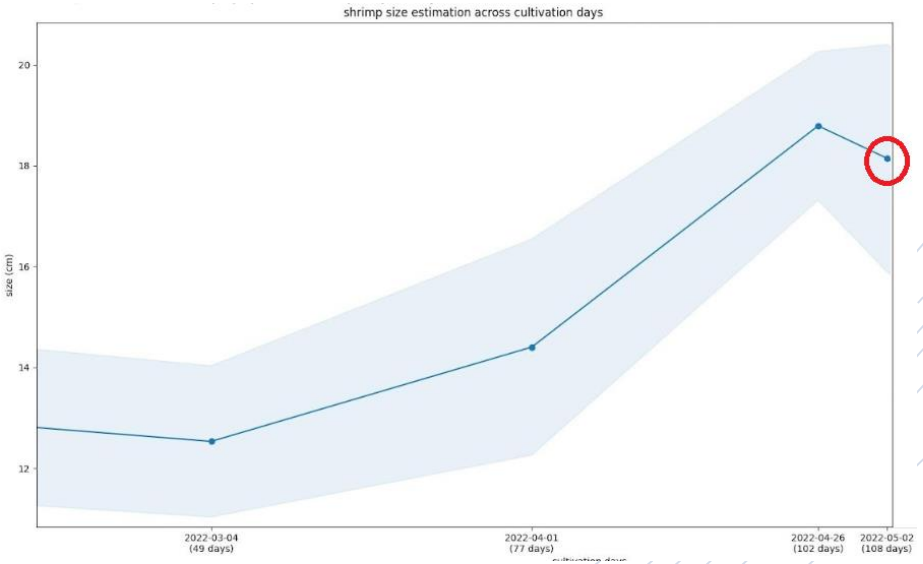
- Adaptable device
  - Various IMTA requirements and constraints
- No need for technology migration
  - Off-the-shelf sensors and probes for aquaculture monitoring
- Technology under deployment in industrially relevant environments
- Versatile solution
  - Compromise between cost, aquaculture needs, constraints and expectations

Vision sensors

Biomass estimation

- Biomass estimation
  - Daily feeding optimization, control stocking densities and determining ideal time for harvesting
- Biometric approaches are recommended practice
  - Labour intensive, time consuming…
- AI vision-based solutions for non-invasive automatic biomass estimation
  - Off-the-shelf camera systems coupled with advanced deep neural networks
  - Continuous end-user feedback and prototype deployment
- Shrimp biomass estimation (Brazilian IMTA lab)
  - Key-point detection model calibrated
  - 15% average relative error using initial models

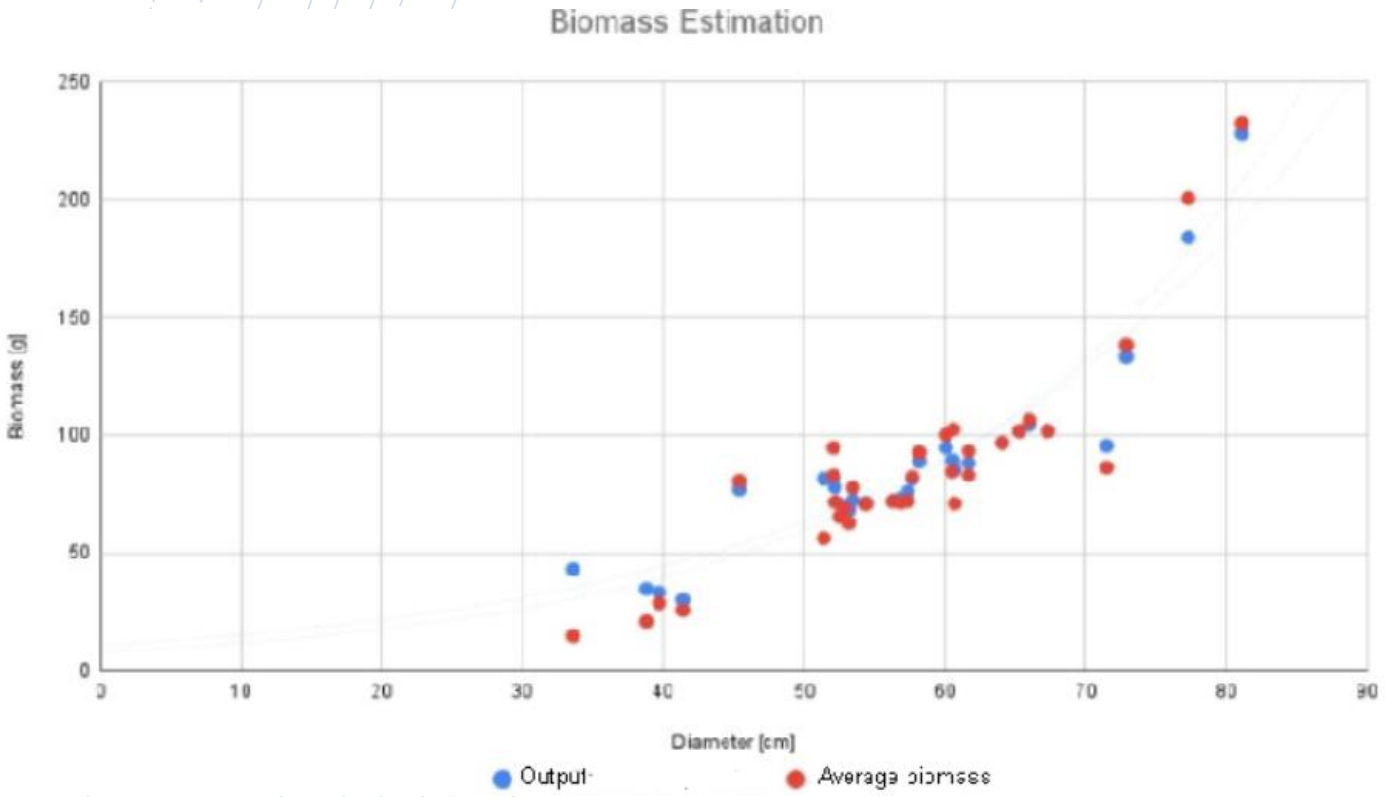


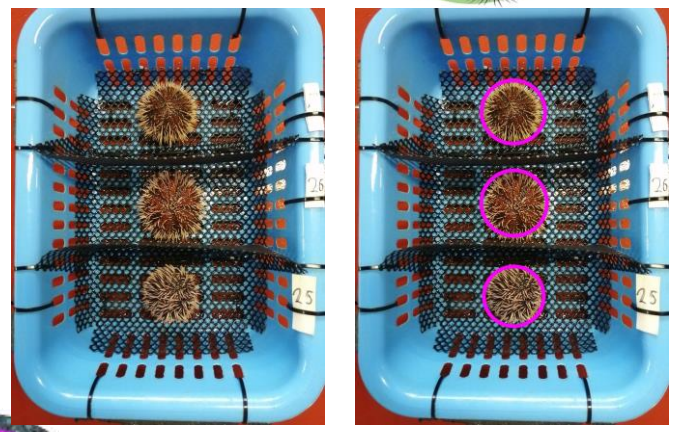


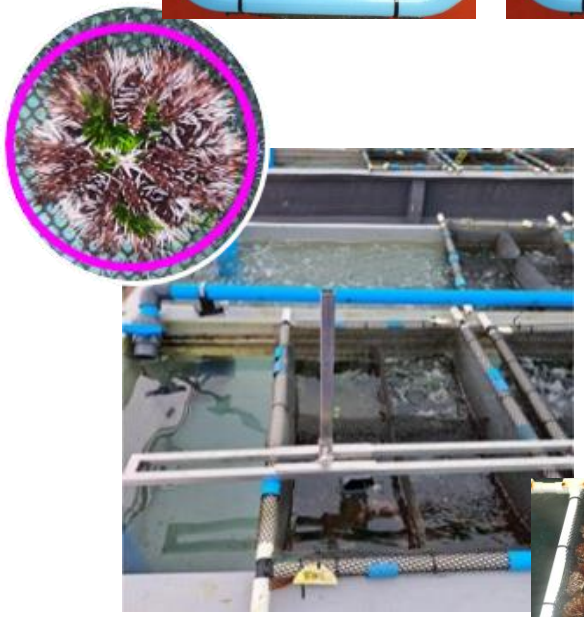
Vision sensors

Biomass estimation

- Urchin biomass estimation
  - South African IMTA lab
  - Mean relative error of 14.53%

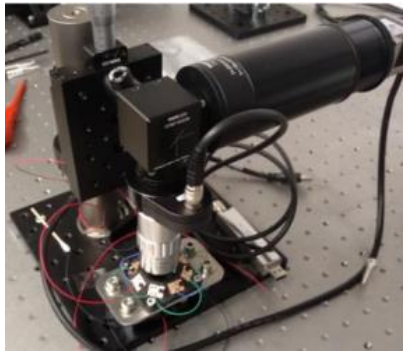






HAB/microplastic monitoring device

- Tailored state-of-the-art deep learning models for regional specie recognition
- Off-the-shelf cameras integrated with edge-based GPU platform (benchtop device)



- Phytoplankton monitoring (>10 micron)
  - Data integration pipeline[1]
  - Deep collaborative models (F-Score 0.91)

Genus	Aquaculture farm
Alexandrium	
Anabaena	
Azadinium	
Centric	
Chaetoceros	
Cilliates	
Dinophysis	
Euglena	
Fragilaria	
Gonyaulax	

Genus	Aquaculture farm
Karenia	
Katodinium	
Leptocylindrus	
Lingulodinium	
Mesodinium	
Nematodinium	
Nodularia	
Paralia	
Pennate	
Prorocentrum	

Genus	Aquaculture farm
Protoceratium	
Pseudo-nitzschia	
Rhizosolenia	
Scrippsiella	
Skeletonema	
Tetraselmis	
Thalassiosira	
Tripos	

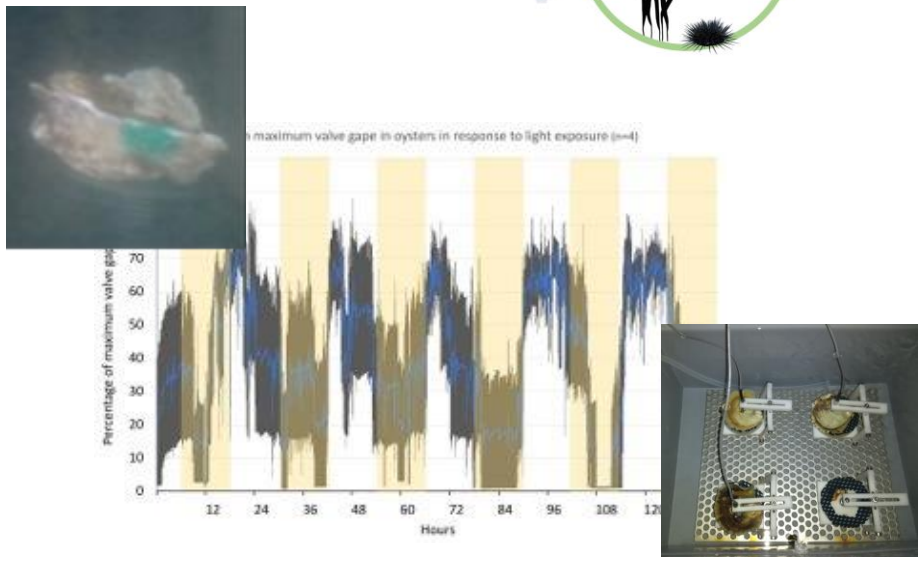
*Argentina ( ), Brazil ( ), Ireland ( ), South Africa ( ) and UK ( )

[1]GUTERRES, Bruna et al. A data integration pipeline towards reliable monitoring of phytoplankton and early detection of harmful algal blooms. In: **NeurIPS 2021 Workshop Tackling Climate Change with Machine Learning**. NeurIPS, 2022.

Biosensors and MEMS-based Spectrometer

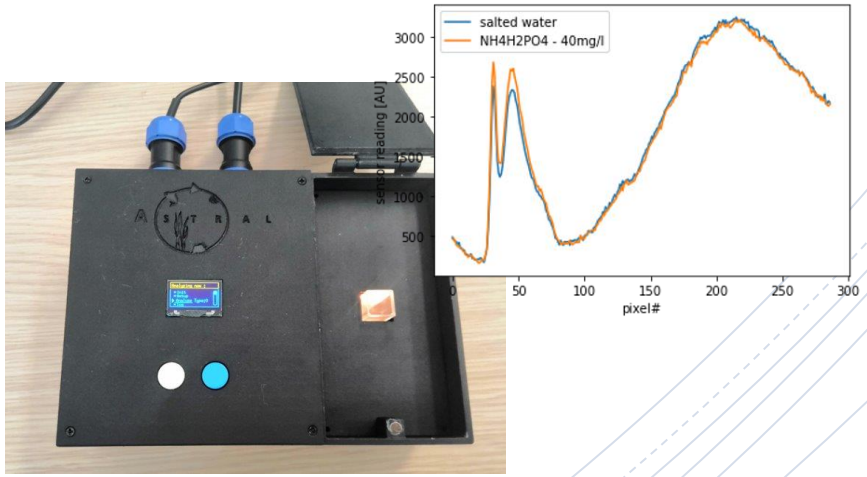
Biosensor

- Vision-based and MEMS-based valvometry techniques
  - Easy deploy and animal welfare
- Proxy information for water quality monitoring



MEMS-based spectrometer and fluorometer

- MEMS spectrometer coupled with AI models
- Quantification of key aquaculture nutrients
- Goal: Broad spectrum physico-chemical parameters (e.g. ammonium, nitrate and dissolved oxygen)



Take-away Message

- ASTRAL technology offer cost-effective and flexible solutions
  - Planetary Digital Twins
  - Industry 5.0: co-robots, human and technology collaboration, environmental awareness
- Cost-effective Internet of Things (IoT) sensors
- AI tailored vision and MEMS-based sensor:
  - Early HAB detection
  - Microplastic
  - Water quality: biosensors, nutrients monitoring, physicochemical parameters
- AIDAP platform for predictive modelling of physico-chemical parameters and biological water-quality indicators

Thank you!

Marcelo Pias

mpias@furg.br

astral@norceresearch.no

astral-project.eu

@ASTRAL_H2020

ASTRALH2020

astral-h2020project

ASTRAL_H2020

Welcome to visit **ASTRAL booth** for further information on ASTRAL and the Pool of Technological Innovations

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863034.