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1st year of PhD

Can hybrid machine-learning and mechanistic models improve our ability to forecast jellyfish blooms?

Jellyfish blooms are increasing and pose growing risks to coastal ecosystems, human health and maritime activities. Improving our ability to forecast bloom timing and intensity is therefore crucial for preparedness and decision-making.



Predicting Jellyfish Blooms in the North Sea

PhD student Rutendo Musimwa

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Jellyfish: Ecology of an Expanding Drifter

Key Traits & Characteristics

- Gelatinous cnidarians; nematocysts
- Polyp ↔ medusa life cycle (bloom potential)
- Summer peak (North Sea)
- Favor stratified, nutrient-rich waters
- Major zooplankton grazers
- Compete with forage fish
- Prey for higher predators
- Blooms increasing; carbon export via jelly-falls



When Drifters Disrupt: The Global Rise of Jellyfish Incidents



Current Gaps and Consequences

Jellyfish blooms: from drivers to solutions

Drivers

- Heatwaves & salinity extremes
- Nutrient-rich, stratified waters
- Non-linear ecosystem shifts

Impacts

- Zooplankton depletion
- Fisheries losses
- Infrastructure fouling
- Biodiversity decline

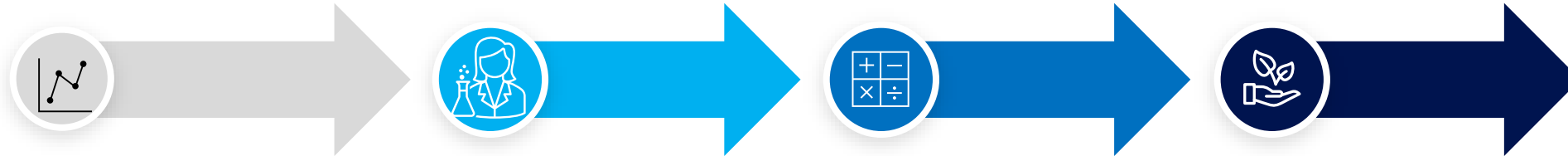
Solution

- Real-time, data-integrated models
- Capture tipping points & extremes
- Early-warning system for blooms



Key Objectives

Develop an early-warning system for jellyfish blooms driven by climate extremes in the North Sea.



Historical Trend Analysis

Analyze historical jellyfish and zooplankton trends using detailed time-series analysis techniques

01

Mesocosm Experiments

Conduct controlled experiments to measure species responses to stressors like heatwaves and acidification

02

Hybrid Predictive Models

Develop hybrid models blending machine learning and mechanistic approaches for better predictions

03

Stakeholder Tools Design

Create interactive dashboards and tools to help fisheries and policy makers utilize model outputs

04

Study species

Species #1

Blue jellyfish



Cyanea lamarckii

As they mature, blue jellyfish transform from pale juveniles into vivid purple-blue adults, making them one of the most visually striking species in northern waters.

Species #2

Mauve stinger



Pelagia noctiluca

The mauve stinger glows in the dark when disturbed, it flashes bioluminescent light, turning waves and ship wakes into glowing purple spark trails.

Species #3

Moon jellyfish



Aurelia aurita

This jellyfish have literally been to space. Their polyps and early life stages were launched aboard a 1991 NASA space shuttle mission to study how they develop in zero gravity.

Species #4

Compass jellyfish



Chrysaora hysoscella

The compass jellyfish gets its name from the 16 dark brown V-shaped markings on its bell, which look just like the points of a traditional maritime compass.

Species #5

Barrel jellyfish



Rhizostoma pulmo

Juvenile fish often hide inside the barrel jellyfish's frilly oral arms for protection, a real-life "moving jellyfish shelter" drifting through the sea.

Methodological Framework of the PhD

❑ Pillar 1: Computational & Hybrid Modelling

- ML + mechanistic biophysical coupling
- Capture non-linear dynamics & tipping points

❑ Pillar 2: Experimental Marine Ecology

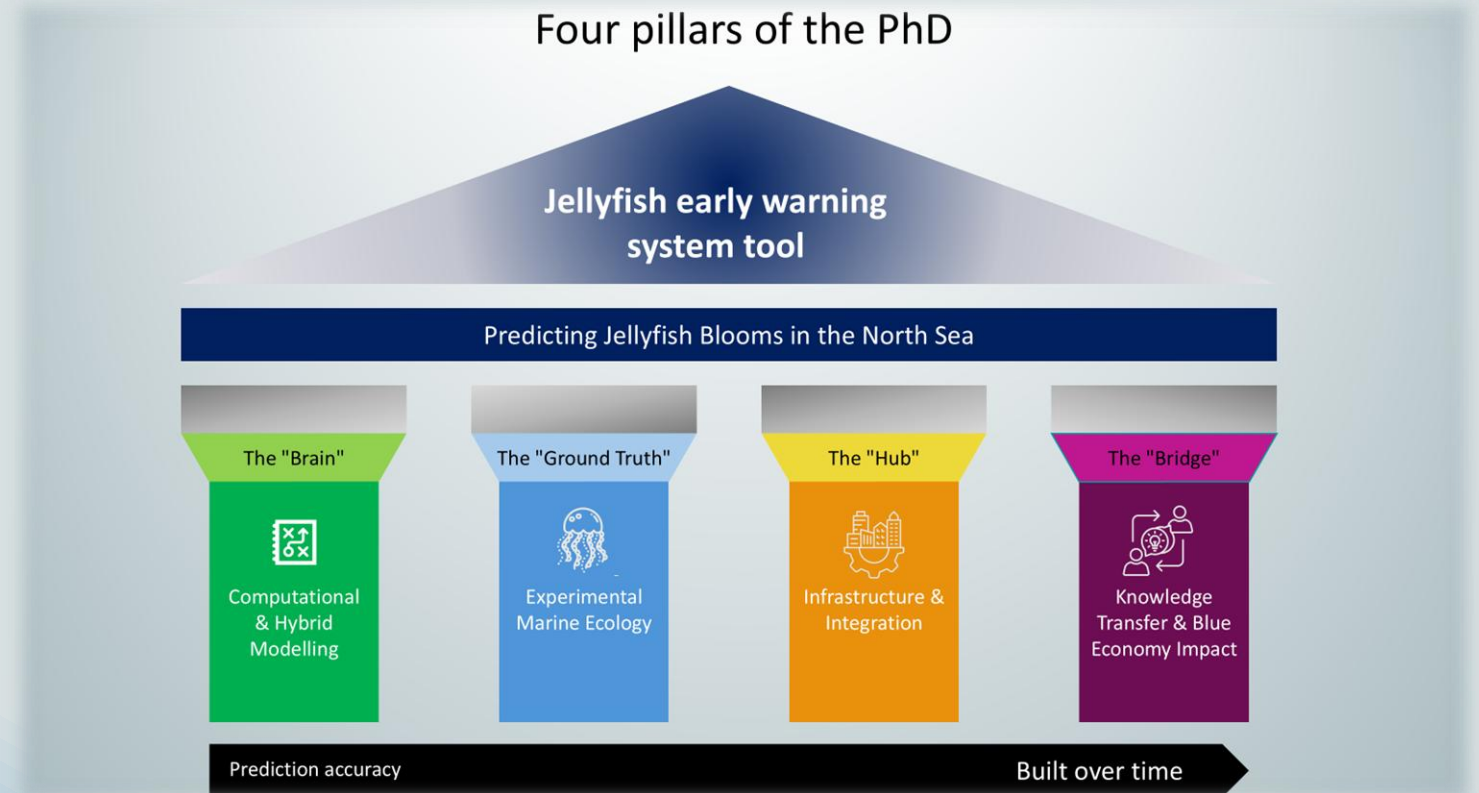
- Seasonal in situ biodiversity sampling
- Controlled simulations of extremes
- Trophic interaction monitoring

❑ Pillar 3: Infrastructure & Integration

- Ostend Science Park platform
- Advanced materials & monitoring tools
- Interactive dashboards for end-users

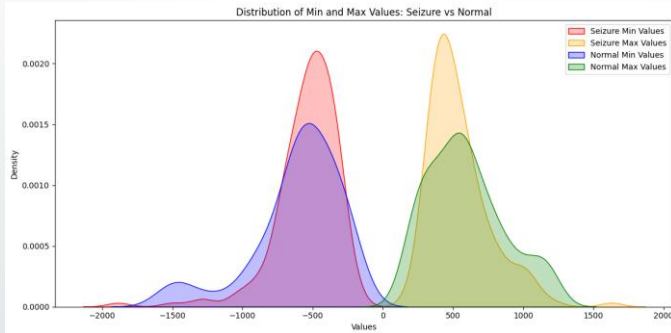
❑ Pillar 4: Knowledge Transfer & Blue Economy Impact

- Stakeholder-driven Early Warning System
- Industry integration
- Scalable framework

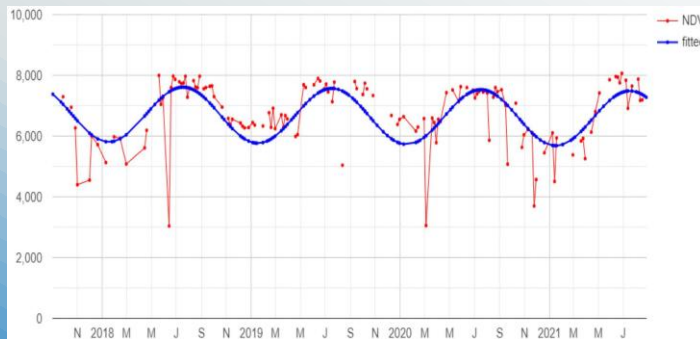


Mathematics behind it all

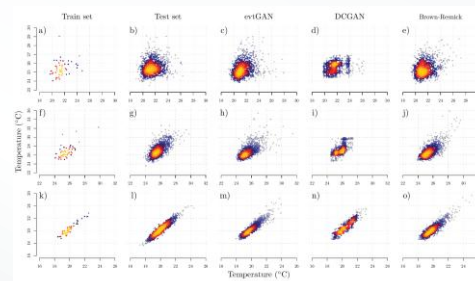
Data driven approach



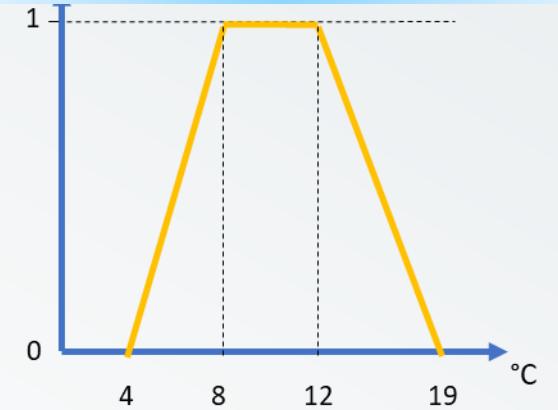
Extreme Value Theory (EVT)



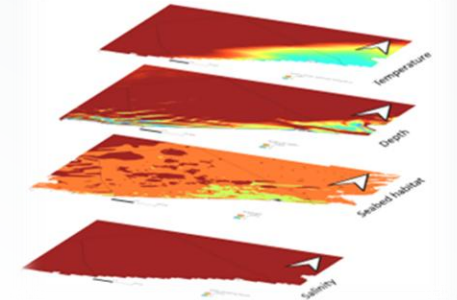
Hybrid approach



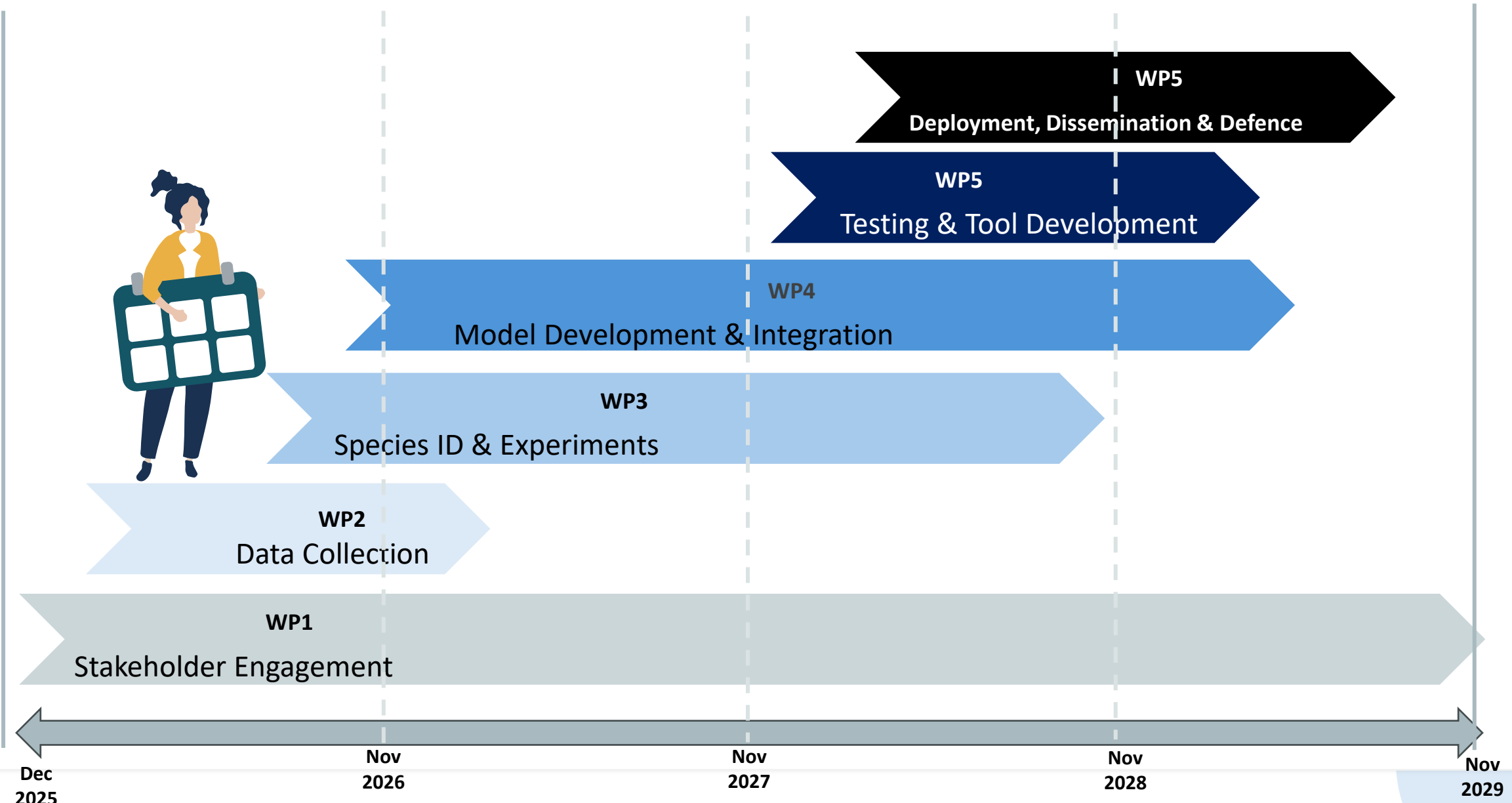
Mechanistic approach



Based on species specific response curves



Timeline



End goal



1. Deployment of a fully operational EWS
2. Fusion of real-time data + ML + mechanistic models
3. Forecasts with risk levels, uncertainty scoring, scenario simulations
4. A dashboard designed for managers & stakeholders
5. Protection of ecosystems, fisheries, and communities through proactive action

Background

Justification

Objectives

Research
Questions

Materials
and
Methods

Timeline

Future plans

Questions?

