Annual PICES
Ocean Science Conference

Nainamo, Canada
October 2026

MERCATOR OCEAN INTERNATIONAL

The European Ocean Digital Twin: Innovative Approaches for Climate-Ready Fisheries and Spatial Planning

Patrick Lehodey
Mercator Ocean international, Toulouse, France
Pacific Community, Noumea, New Caledonia

Mercator Ocean International

A public interest organization for the Digital Ocean



3 core missions

1. Describe the marine environment
2. Develop uses and capabilities
3. Support governance stakeholders

Multinational governance
Delegated entity of the European Union
120 staff, Toulouse, Madrid, Barcelona
International partners network

Implementing EU & UN programmes

Transforming to

An intergovernmental organization for Digital Ocean Systems



GOVERNANCE

- governed by European States,
- entrusted by EC and UN,
- collaborating worldwide

EUROPEAN MEMBER STATES

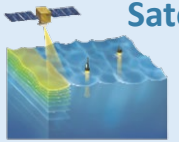
31 invited Founding Member States

INTERNATIONAL PARTNERSHIPS

Bilateral agreements with key organizations

Digital Ocean Systems, integrating satellite and in situ ocean observation

1 Observe



Satellite observations

Broad, frequent coverage of the ocean surface

In-situ observations

Measurements of the water column and independent reference information

2 Describe & Predict



Numerical Models & AI

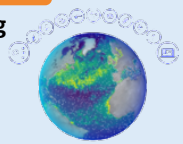
300 Ocean Products

A coherent view of the physical, sea-ice and biogeochemical ocean

3 Deliver

Ocean decision making





Marine applications

European Digital Twin Ocean

Ocean-intelligence products for users and decision-makers

EDITO
European Digital Twin Ocean

https://www.edito.eu



- get a space to work
- Select your variables / observations
- Create your tools
- Diffuse (or not) your results

The European Digital Twin Ocean: The machinery

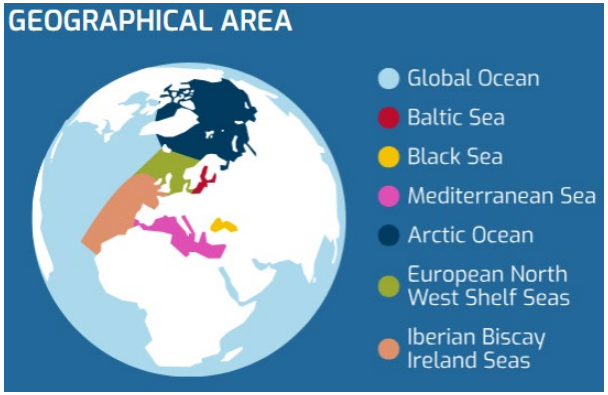






NECCTON

NEW COPERNICUS CAPABILITY FOR TROPHIC OCEAN NETWORKS



Observations (satellite / in situ)

Models (global / regional)

Data assimilation
Parameter optimisation
AI

- Reanalyses & hindcasts
  starting 1993 (altimetry); next => 1940 (ERA5)
- Near Real Time + 10-day forecast
- In progress:
  Seasonal ensemble forecast (7 month)
  Climate projections (corrected)
  Global multi scenarios & models
  Regional (downscaling high resolution)

The European Digital Twin Ocean: Brief overview of products (1/3)

Ocean physics

Explore MyOcean Pro

https://marine.copernicus.eu/access-data/

300+ products with hundreds of subsets. Zoom on regions. Near-real-time, hindcasts, observations, forecasts, from models, satellite and in situ observations, reanalysis.

Make point-and-click queries in selected regions and get detailed information at depth

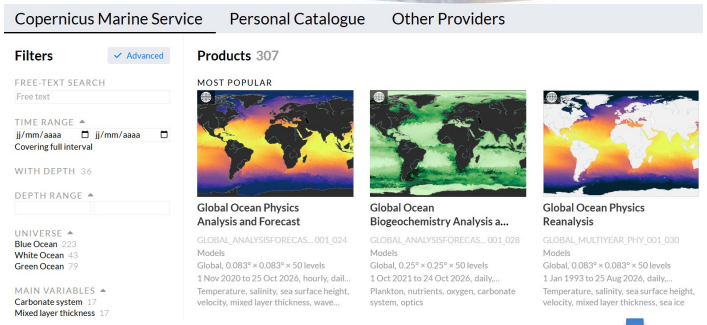
Polar stereographic view of Arctic and Antarctic regions

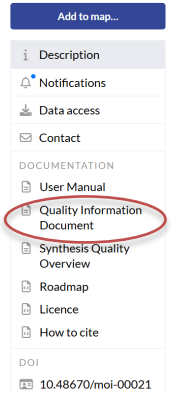
Download, share link, and/or embed videos and images of your selection.

Export data in a CSV file in both 1 dimentional and 2 dimentional queries

Access high-resolution graphs

> Read the help center article on MyOcean Pro

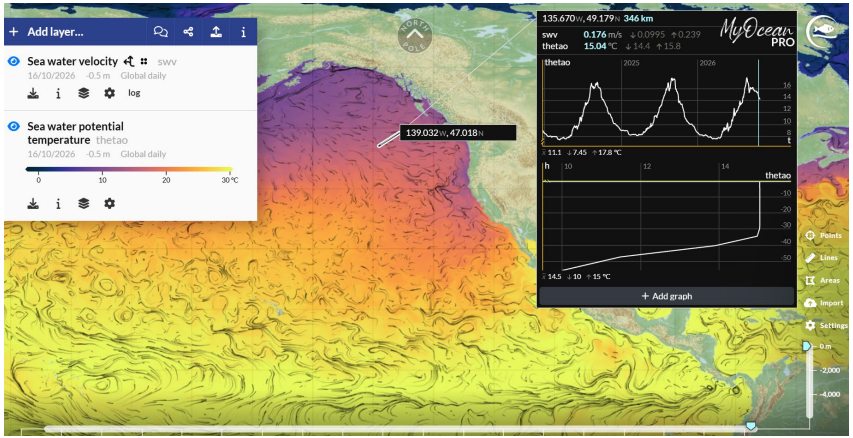


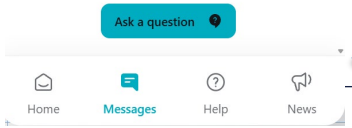




Global Ocean Physics Reanalysis
eddy resolving (1/12° x day/ month)

- sea_surface_height_above_geoid
- sea_water_potential_temperature
- sea_water_salinity
- sea_water_x_velocity
- sea_water_y_velocity
- sea_ice_area_fraction
- sea_ice_thickness
- sea_ice_x_velocity
- sea_ice_y_velocity





HELPDESK!

Lellouche et al (2021) https://doi.org/10.3389/feart.2021.698876

The European Digital Twin Ocean: Brief overview of products (2/3)

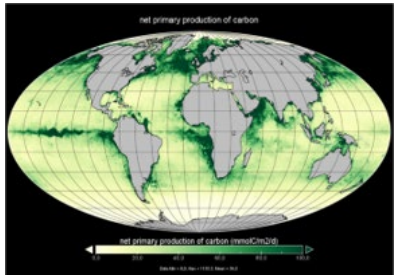
https://maps.biogeochemical-argo.com/bgcargo/

Ocean biogeochemistry

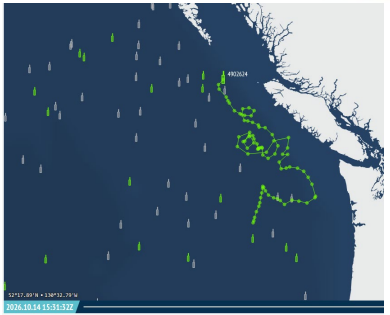
Copernicus Marine Service QUALITY INFORMATION DOCUMENT

Global Production Center
GLOBAL_ANALYSISFORECAST_BGC_001_028

Sat. Chl.



Data assimilation



biogeochemical Argo

Optimisation: in progress

ARGO BGC floats

Global Ocean BGCH
(1/4° x day/ month)

- Nutrients (NO3, PO4, Si)
- Chlorophyll
- Primary production
- Dissolved oxygen
- Surf. p.CO2
- DIC
- Kd
- pH
- Zooplankton

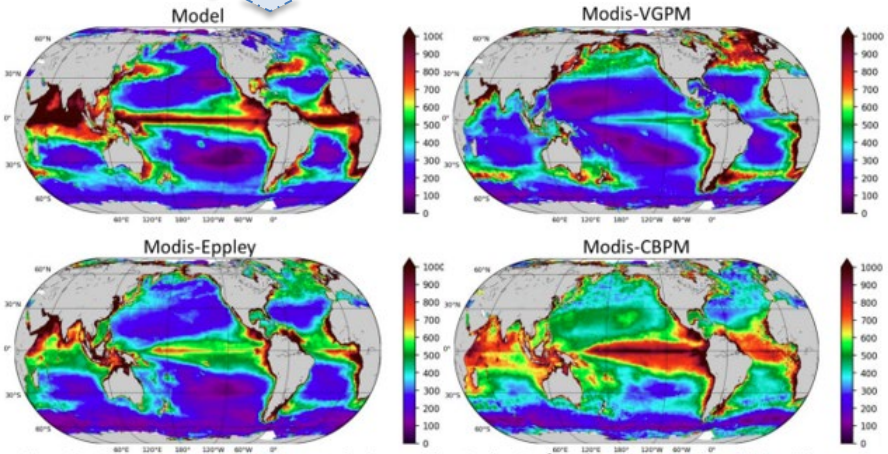


Figure 29: Annual mean of vertically integrated primary production (mgC m^{-2} day^{-1}) for year 2017; (top-left) model; (top-right) Modis satellite product based on VGPM algorithm (Behrenfeld and Falkowski, 1997); (bottom-left). Eppley algorithm; (bottom-right) CBPM algorithm

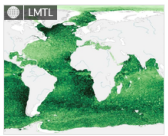
Key input to obtain realistic PP products:
The fundamental 1st level of ocean trophic web

Global hindcast (1993-2025)
Near realtime + 10d forecast
Coming:
- Seasonal forecast (IA product)
- Climate projections (corrected)

The European Digital Twin Ocean: Brief overview of products (3/3)

Ocean biology

Global ocean low and mid trophic levels biomass content hindcast



Add to map...

- Description
- Notifications
- Data access
- Contact

DOCUMENTATION

- User Manual
- Quality Information

Overview

The Low and Mid-Trophic Levels (LMTL) reanalysis for global ocean is produced at CLS on behalf of Global Ocean Marine Forecasting Center. It provides 2D fields of biomass content of zooplankton and six functional groups of micronekton. It uses the LMTL component of SEAPODYM dynamical population model (http://www.seapodym.eu). No data assimilation has been done. This product also contains forcing data: net primary production, euphotic depth, depth of each pelagic layers zooplankton and micronekton inhabit, average temperature and currents over pelagic layers.

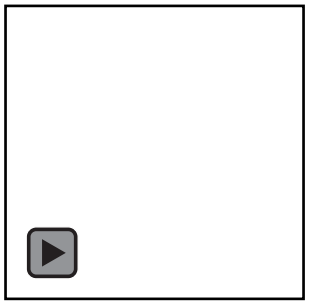
Forcings sources:

- Ocean currents and temperature (CMEMS multiyear product)
- Net Primary Production computed from chlorophyll a, Sea Surface Temperature and Photosynthetically Active Radiation observations (chlorophyll from CMEMS multiyear product, SST from NOAA NCEI AVHRR-only Reynolds, PAR from INTERIM) and relaxed by model outputs at high latitudes (CMEMS biogeochemistry multiyear product)

Vertical coverage:

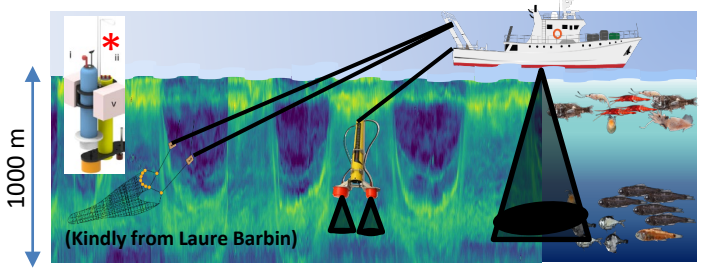
- Epipelagic layer
- Upper mesopelagic layer
- Lower mesopelagic layer (max. 1000m)

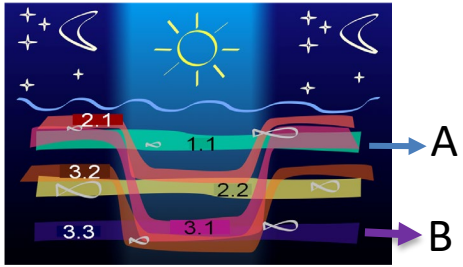


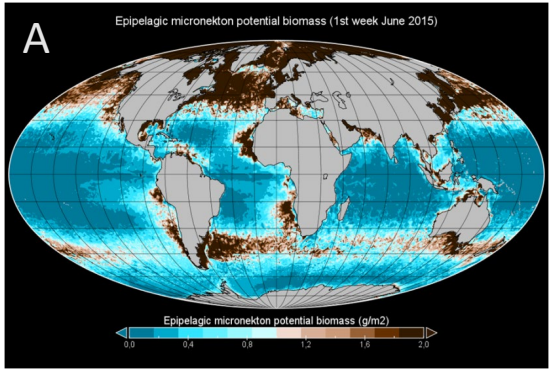


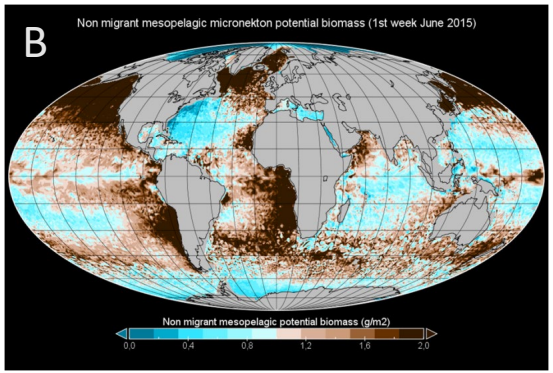
- Zooplankton
- Micronekton (epipelagic and mesopelagic groups)

6 functional groups in 3 vertical layers: epi-, upper meso- and lower meso-pelagic (Lehodey et al. 2010; 2015; Conchon 2016; Albernhe et al. 2024; CMEMS QUID document)



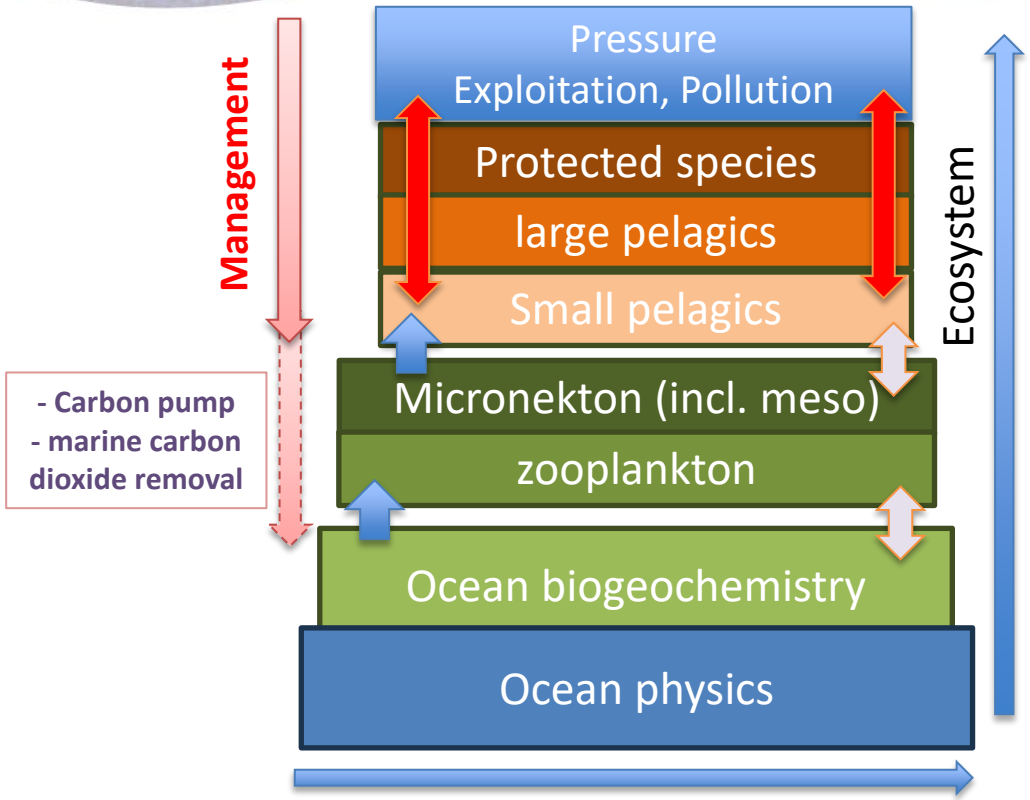






* Downie *et al.* (2026). Sonophore enables autonomous observation of micronekton communities in the ocean twilight zone. *Sci Rep* **16**, https://doi.org/10.1038/s41598-026-41581-5

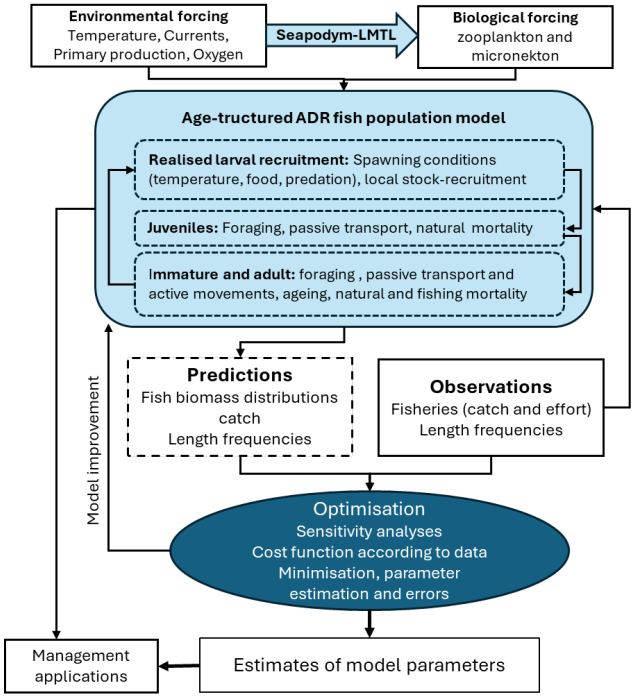
The European Digital Twin Ocean: Applications from physics to fish



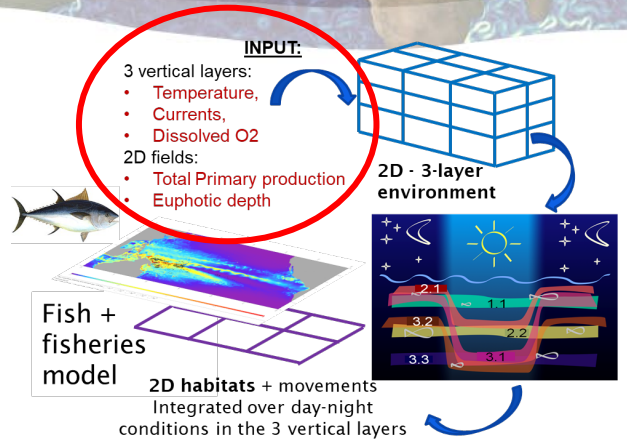
- Fishing, plastics, CO_2, Deep sea mining,…
- Protected species (e.g., turtles)
- Exploited large pelagics (e.g., tunas)
- Exploited small pelagics (e.g., anchovy)
- Micronekton (trait-based functional groups)
- Zooplankton (trait-based functional groups)
- Primary production (by PFTs) / dissolved oxygen, pH
- Ocean circulation modeling

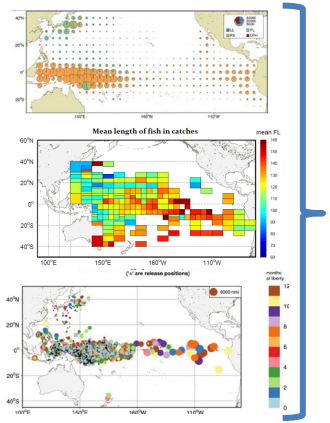
The European Digital Twin Ocean: Applications from physics to fish

Large pelagic fishes (tuna)



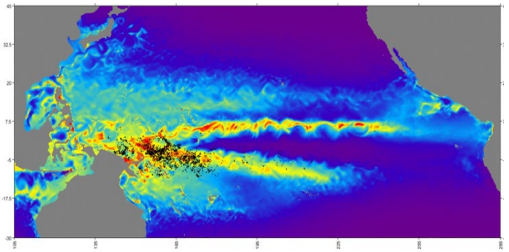
SEAPODYM
Spatial Ecosystem And Population Dynamics Model



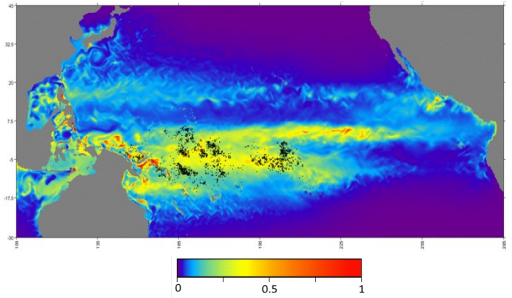


SEAPODYM estimates tuna biomass and catch distributions (by age) from *catch / effort / size / tagging* data and **environmentally driven** tuna habitats

Mid-Dec 2007 (La Niña)



Mid-Dec 2015 (El Niño)



Simulated **skipjack** biomass density (t/km2) and observed catch (black circles) during ENSO phases

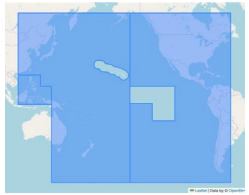
https://github.com/PacificCommunity/seapodym-codebase Lehodey et al (2008), Senina et al (2021)...

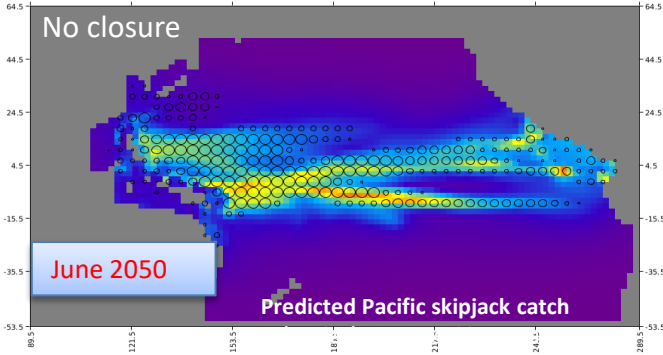
The European Digital Twin Ocean: transfer to EDITO

Large pelagic fishes (tuna)

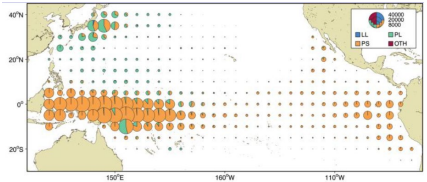
We are implementing a fishing tool on the EDITO plateform to test fishing scenarios under climate change and spatial management options, based on the following assumptions:

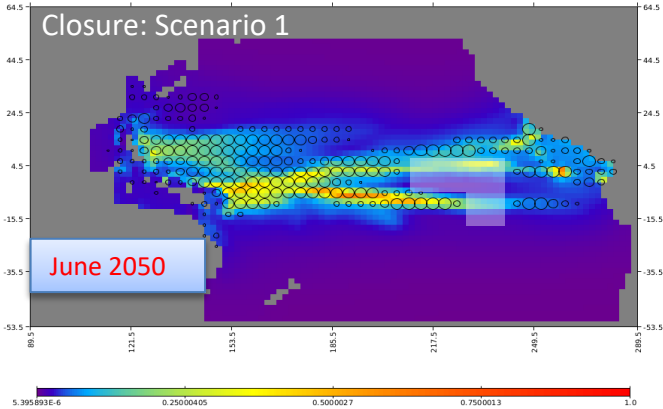
- relative distribution of unexploited and exploited biomasses are strongly correlated, accounting for a minimum threshold value of tuna density beyond which fishing is economically viable.
- An annual target catch for a type of fishery (e.g., surface or deep) can be redistributed in time and space according to the pre-calculated unexploited biomass.



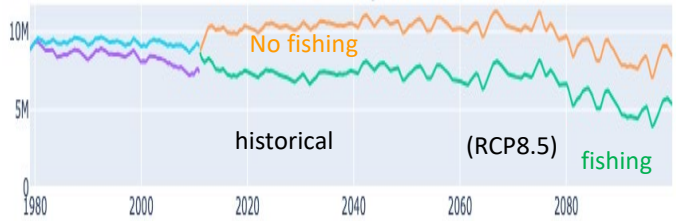


(Observed historical)

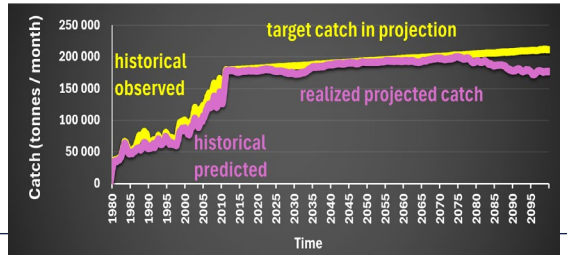




BIOMASS



CATCH



The European Digital Twin Ocean: Applications from physics to fish

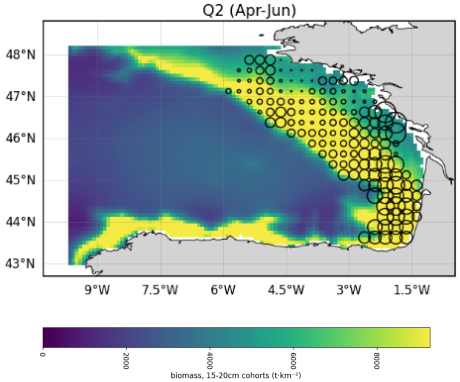
Small pelagic fish (Biscay anchovy)

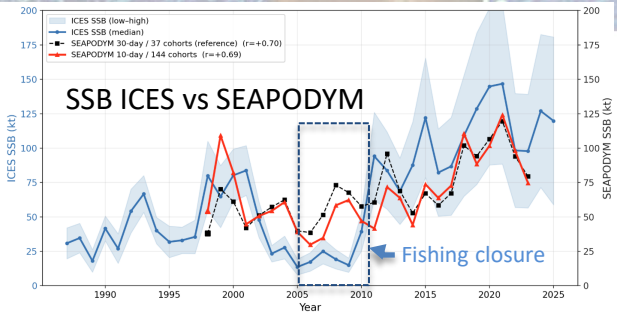
- **Full SEAPODYM** application describing **anchovy** population (from larvae to adults) and **fisheries** (1/12 deg; 30d; 10d)
- **INPUT**: **Temperature, Currents (U,V), Zooplankton** (SEAPODYM)
- **Quantitative estimate** using all available data (1998-2024) for parameter estimation: Catch; Fish sizes, Eggs density; Acoustic biomass estimates

- ➢ Consistent framework of population dynamics driven by environmental variables.
- ➢ Explain the collapse and recovery of population
- ➢ Ongoing implementation of operational NRT model in EDITO:

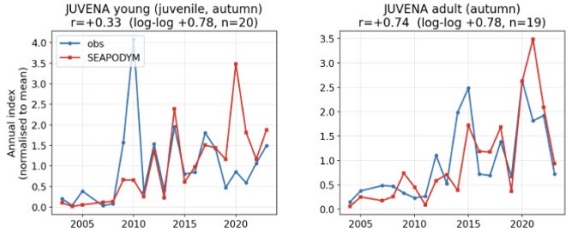
Forcing: T, UV, NPP => SEAPODYM-LMTL (Zoo) => SEAPODYM-FISH (anchovy)

Predicted biomass (15-20 cm) vs obs acoustic biomass

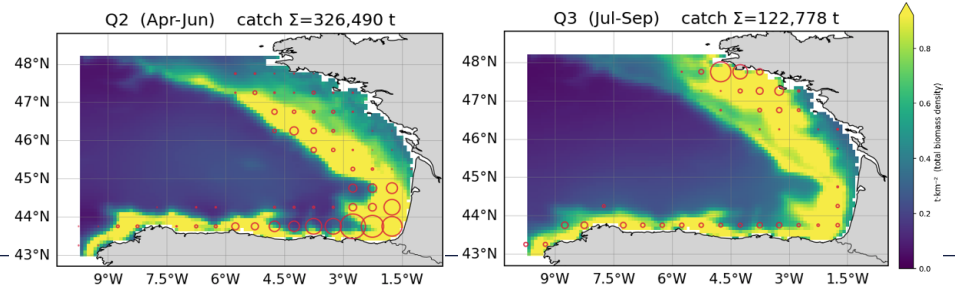




Interannual fit to juvenile and adult acoustic biomass estimates from spring and autumn annual surveys



Anchovy adult biomass and observed catch by quarter

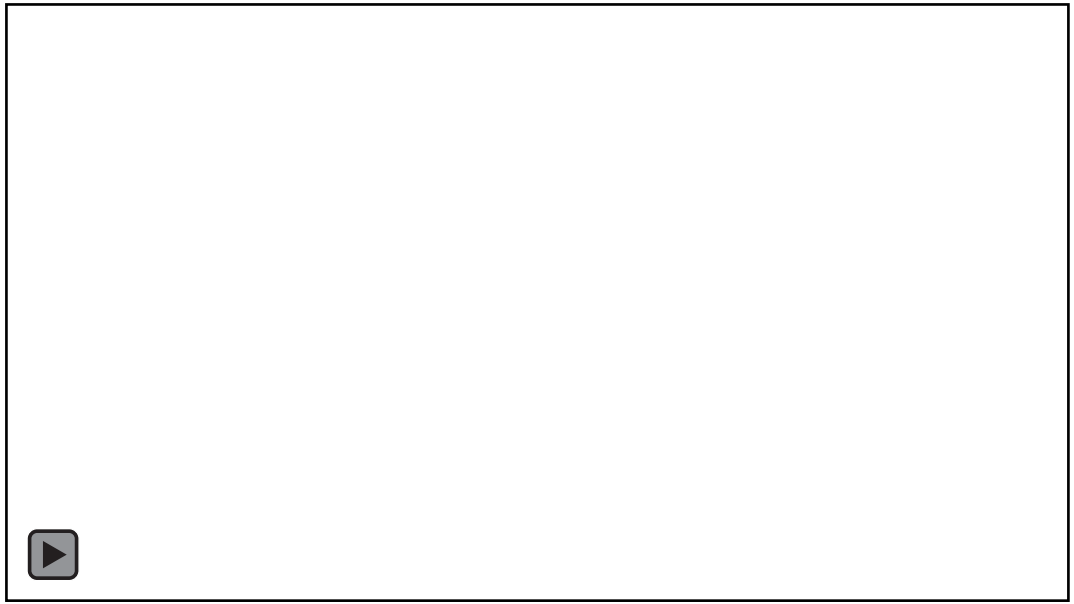


(Misi et al. 2026; Lehodey et al., *in prep.*)

The European Digital Twin Ocean: transfer to EDITO

Small pelagic fish (Biscay anchovy) Working on EDITO plateform:

1) Preprocessing of CMEMS variables temperature, Currents, Primary production;
2) Run the zooplankton model using regional CMEMS products;
3) Validate the zooplankton outputs



4) Import the seapodym parameter and binary files to excute.
5) Check / recalibrate if needed
6) Run hindcast + near realtime

Perspectives:

- Seasonal forecast
- Climate change (downscaling)
- Fishing tool for scenarios

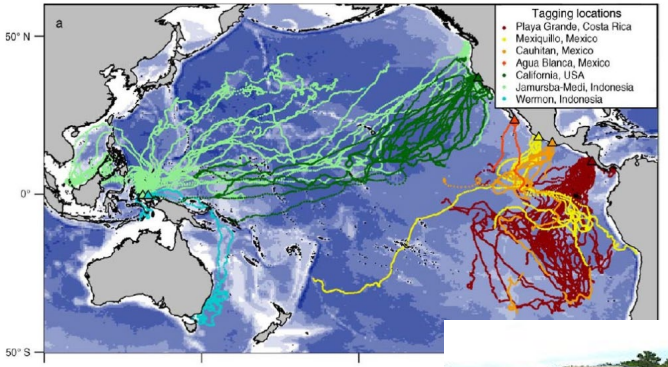
Applications:

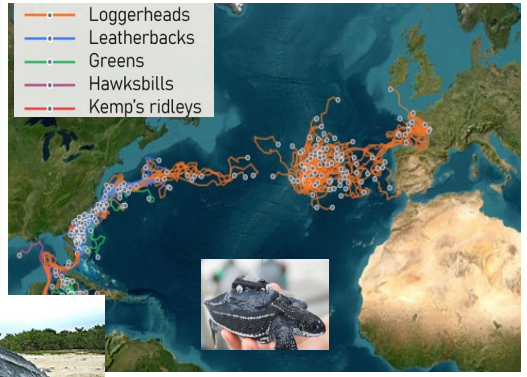
- Prevent population and fisheries collapse
- Interaction with dolphins /bycatch
- Northward expansion /change in size

The European Digital Twin Ocean: Applications from physics to fish

Marine turtles

Global populations of all species of sea turtles vulnerable, endangered or critically endangered.
Leatherbacks Eastern and Western Pacific sub-populations decreased by over 95 % during the past three decades.

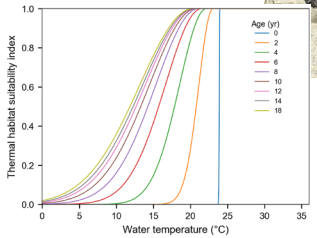


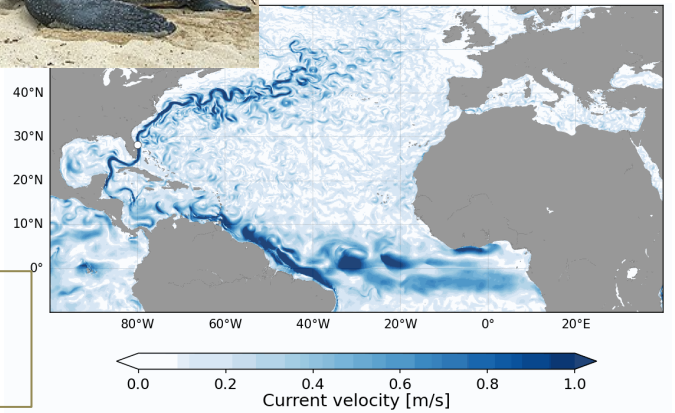




Lagrangian modelling (STAMM) and satellite tracking data are used to explore the dynamics of these endangered species to propose new tool to improve species conservation regarding the mortality at sea by fisheries.

Movement is controlled by the definition of a thermal habitat suitability index and a feeding habitat suitability index based on the local prey density (P) and the rate of food consumption $F(a)$





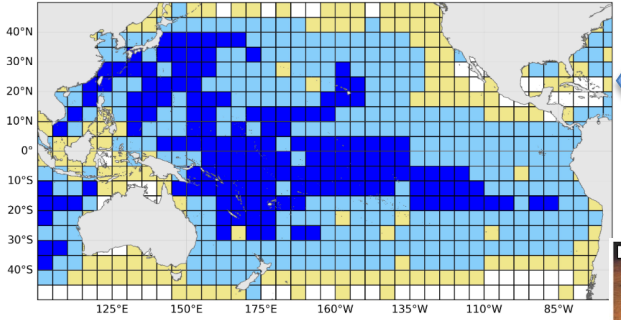
⇒ Calibration using individual tracks
⇒ Forcing: **Temperature, currents, NPP/ zoo/ micronekton (testing gelatinous group)**

Gaspar & Lalire (2017); Lalire & Gaspar 2019); Gaspar, Candela & Shillinger (2022); Candela et al (2026)

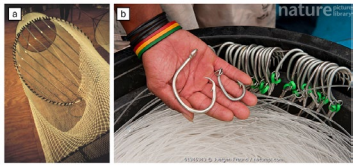
The European Digital Twin Ocean: transfer to EDITO

Marine turtles Transfer to EDITO :

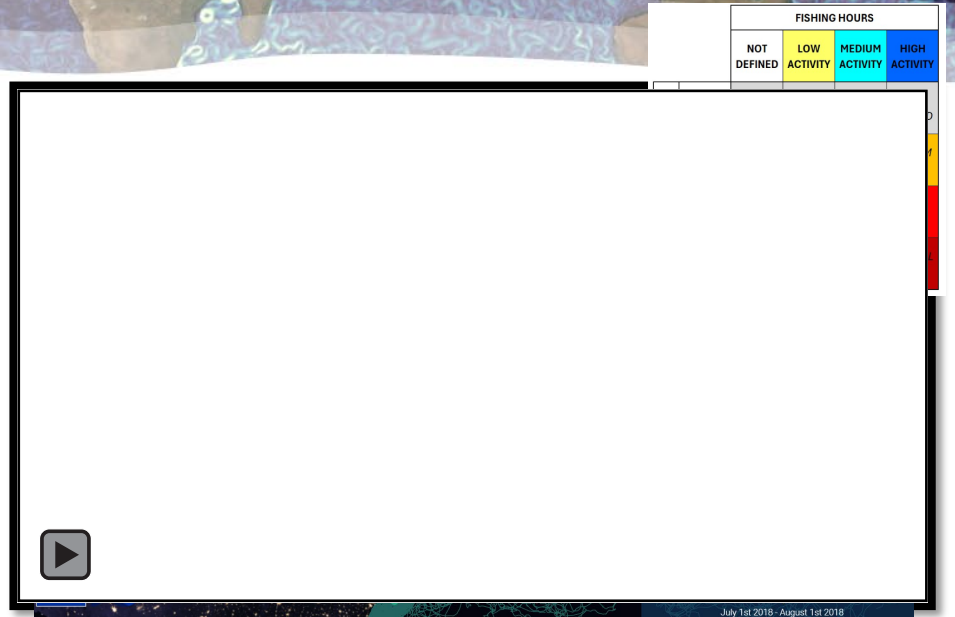
- Simulations generated to produce monthly maps of presence probability
- Crossing with available information to support efforts of protections

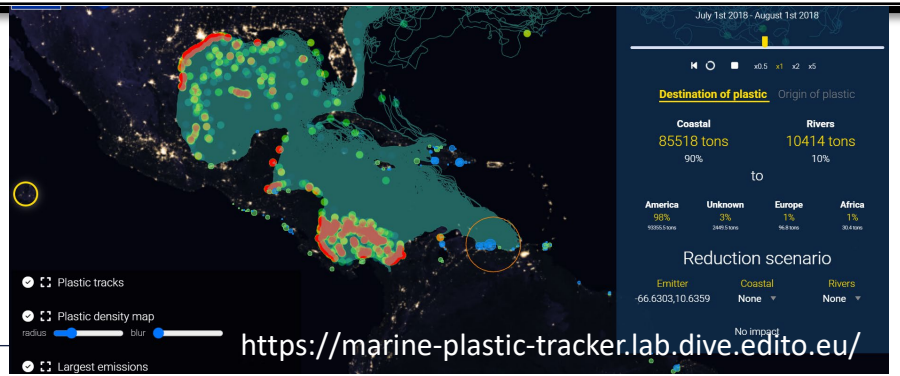


AIS derived longline fishing effort (Candela, 2026)



- Crossing with other EDITO applications, eg plastic back tracking from spawning beaches





https://marine-plastic-tracker.lab.dive.edito.eu/

Conclusion and perspectives

The Ocean digital twin is being developed to help marine scientists and stakeholders design their tools, without the burdens associated with:

- accessing and using essential ocean variables, which are subject to regular maintenances, evaluations and updates;
- accessing storage, computing, and dissemination resources.

It fosters collaboration and the sharing of tools for modeling and scenario generation.

Come, ask, develop, send feedback … It ‘s just the begining!

Thank you

