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Sentinel-3 products for detecting EUtROphication and Harmful Algal Blooms in the French-English Channel (S-3 EUROHAB).

Summary of outputs and results.

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EXECUTIVE SUMMARY.

Overall Objective:

To improve the management of harmful algal blooms (HABs) and water quality (WQ) in the French-English Channel (FCE) by creating a system with increased coverage, faster reaction time and improved spatial and temporal harvesting of affected areas.

Three main outputs:

1. A Cross border monitoring network data portal,
2. A Web based alert system for HABs and WQ which will provide faster response times for the events,
3. Socio-economic assessment of the effect of HABs along the French and English coasts.

Program output (to fulfill INTERREG-VA indicator 3.2. Enhancing and protecting the coastal and transitional water ecosystems):

A. The project engaged with 70 stakeholders,
B. Organised 6 stakeholder workshops, received x questionnaires and did y individual interviews with stakeholders, and ran a Project Symposium.
C. Conducted 10 demos to stakeholders of the web alert system,
D. Produced 8 main reports,
E. Published 11 scientific papers,
F. Published 5 popular magazine articles,
G. Created 1 web site,
H. Produced two project brochures.

Main Results:

Work Package 1. Cross Border data portal.

Task 1.1. A cross-border data portal.

- The project created a cross-border data portal consisting of in situ data from monitoring stations, data from high frequency moorings, and Copernicus Sentinel-3 data, which can be accessed here: ftp://ftp.ifremer.fr/eurohab
- The in situ and mooring data were from the Environment Agency, IFREMER REPHY, University of Southampton Solent data buoy, Plymouth Marine Laboratory western Channel Observatory (www.westernchannelobservatory.org.uk) and include temperature, salinity, nutrients, chlorophyll-a (Chl-a), phytoplankton counts (including HAB species), dissolved oxygen, turbidity and wind speed.
- In addition, a unique bio-optical dataset was analysed from the western Channel Observatory samples for the development of satellite HAB algorithms.
- The Sentinel-3 data was processed by IFREMER and include Chl-a, turbidity and particulate inorganic carbon.

Task 1.2. Environmental drivers of HABs in the FCE.

- Wind speed and direction determine *Dinophysis* sp. abundance along the south coast of Cornwall.
- Low air temperature in June was associated with low toxicity in the shellfish flesh.
- Water temperature around 17 °C and above was associated with higher *Dinophysis* sp abundance at the east of the Seine's bay, the onset of toxic episodes (DSP above sanitary thresholds) and higher toxin concentration on shellfish.
- Higher abundance of *Pseudo-nitzschia* was observed during relative lower nutrient concentration, turbidity and high temperature. Biotic pressure on *Pseudo-nitzschia* seems related with toxic events (ASP above sanitary thresholds).

Task 1.3. Dispersion and transport of HABs in the FCE.

- Use of *Phaeocystis globosa* and *Pseudo-nitzchia* as eutrophication species indicators was tested.
- Significant shift in the 2000's between the two species occurred in response to changes in Dissolved Inorganic Nitrogen (DIN).
- Molecular dataset of Harmful algae water and sediment samples from the station L4 in the western Channel Observatory (www.westernchannelobservatory.org.uk) were analysed to assess the linkage between surface blooms and benthic occurrence.

- The molecular dataset showed differences in HABs detected using taxonomic data for some species and illustrated an uncoupling between pelagic and benthic occurrence at this site.

Task 1.4. GES baselines for the English Channel.

- Good Environmental Status baselines consist of a suite of parameters that do not exceed defined thresholds of 11 descriptors which include shifts in phytoplankton composition to nuisance and / or toxic blooms. During the project changes in these parameters were analysed in English Channel waters.
- The results showed there was an increase in phytoplankton abundance that was due to an increase in the proportion of small cells and dinoflagellates which correlated with an increase in DIN : DIP ratio.
- The data contributed to the new OSPAR QSR 2023 reports PH1, PH2 and PH3 which will be published in February 2023.
- In addition, a new method of using satellite derived primary production to define threshold indicator values of primary production P90 for OSPAR regions was developed.
- Case studies were included to show how the threshold indicator values can be utilised to detect anthropogenic disturbances in coastal and open ocean waters.
- This work contributes to is relevant to the OSPAR QSR indicator reports PH2 (plankton biomass and abundance) and FW2 (Pilot Assessment of primary productivity).

Task 1.5. Creation of Five HAB detection algorithms and Water Quality products for Sentinel-3.

- Specific algorithms for the detection of HAB risk from *Karenia Mikimotoi*, *Pseudo-nitzschia*, *Phaeocystis* and *Lepidodinium chlorophorum* were developed by PML using optical data available from Sentinel-3.
- Proxies for the detection of the HAB species *Dinophysis*, that causes Diarrhetic Shellfish poisoning was also trailed.

WP 2. Web alert system.

Task 2.1. Creation of a web-based alert system for HABs and poor water quality.

- The web based alert system includes simple and easy to visualise maps, at a resolution of 1km or 300 m, to indicate the presence of blooms of *Pseudonitzschia* spp., *Karenia mikimotoi*, and *Phaeocystis globosa*.
- Maps of Chlorophyll-a P90 and primary production P90 are also available as indicators of water quality.
- Satellite Chl-*a* times-series showed a decrease in Chl-*a* in the English Channel in May, June and July from 1998 to 2017.
- The trend is correlated with lower river discharges at the end of the period and a reduction in the riverine input of phosphorus.
- Examples of Vulnerability indices of the scallop fisheries to HABs in the fishing zones around the Bay of Seine are also included.
- Other environmental parameters such as temperature, salinity, ocean mixed layer depth, rainfall, wind speed and direction are also available from the web alert system.

Task 2.2. A report on Parameters to increase productivity and efficiency of operations.

- A number of the parameters that enhance and decrease the productivity of shell fish are available from satellite remote sensing data. These include temperature, salinity, light, Chlorophyll-a (Chl *a*) as a proxy for phytoplankton biomass, suspended particulate matter (SPM) and proxies for bathymetry and / or habitat type.
- Following stakeholder consultation through dedicated workshops in England and France, a number of these parameters have been made available through the S-3EUROHAB web alert system to help shellfisherman target seeding time of spats.

Task T2.4. Accuracy of the web-based system.

- The accuracy of the HAB risk indicators for *Karenia mikimotoi, Phaeocystis globosa* and *Pseudo-nitzschia spp.,* were tested for the English Channel S-3 OLCI images were used to train the HAB classifier.
- For *Karenia* and *Phaeocystis*, there was a good correlation between abundance and HAB risk whereas for *Pseudo-nitzschia* sp. were a large number of false positives.

- A Fuzzy logic method using environmental parameters to constrain the HAB risk indicator for *Karenia* sp. improved the accuracy of the HAB risk maps.

WP 3. Socio-economic assessment of HABs.

Task 3.1. Stakeholder inventory and interest matrix.

- A stakeholder inventory matrix was mapped.

Task 3.2. Report on perceptions of HABs and requirements for the web alert system.

- Stakeholders indicated that information about the HAB species (which species, at what density) and also about population movement (especially species that produce lipophilic toxins that dwell offshore) and movement of water bodies that might contain seed populations would be useful.
- They were interested in having plume modelling included in the forecast system.
- In addition, stakeholders asked for data on a number of abiotic factors such as air and water temperature, nutrient levels, water transparency, currents, wind, salinity and altimetry.

Task 3.3. Report on the socio-economic impacts of HABs.

- Based on selling price of Mussels and the quantity produced weekly during summertime in the case-study location, the weekly loss in sales for the producers in South Devon and Cornwall £26,350 and £100,000 (data based on 4 shellfish producers, 50% of the total number of producers in the area).
- This cost range does not include the cost of recalling the mussels if they have already been dispatched. Recalling 1 tonne of mussel can cost around £160.
- For the French scallop fishery in the eastern Channel, analysis of the commercial bans associated with HABs and associated potential economic impacts, showed that a dynamic decision-making process involving experts and the Administration could balance acceptable health risks and economic impacts.

- Vulnerability indices for the shellfish community were developed to help build anticipatory responses and adaptive actions after regional closures of shellfish beds.

WP C. COMMUNICATIONS.

Task C.1. Web site.

- https://www.s3eurohab.eu/

Task C.2. Stakeholder Workshops.

- Six dedicated workshops were conducted.
- 12 on-line demos of the web alert system were conducted.
- 16 one-to-one interviews were conducted in the UK.
- >70 stakeholders were engaged.
- >70 questionnaires on the web alert system were received.

Task C.3. Magazine articles published during the project:

- Fish Farming Magazine;
- Fishing News;
- The Marine Biologist;
- Ocean Challenge;
- Cultures Marines;
- Produits de la Mer.

Task C.3. Scientific Peer-Review publications from the project:

1) Tilstone, G. H., Land, P. E., Pardo, S., Kerimoglu, O., Van der Zande, D. 2023. Threshold indicators of primary production in the north-east Atlantic for assessing environmental disturbances using 21 years of satellite ocean colour. *Sci. Tot. Env.,* 854, 158757. https://doi.org/10.1016/j.scitotenv.2022.158757

2) Chenouf S, Merzereaud M, Raux P, Pérez Agúndez JA. Dataset for Estimated Closures of Scallop (Pecten maximus) Production Areas Due to Phycotoxin Contamination along the French Coasts of the Eastern English Channel. Data. 2022; 7(8):103. https://doi.org/10.3390/data7080103
3) Pérez Agúndez JA, Chenouf S, Raux P. Addressing the Governance of Harmful Algal Bloom Impacts: A Case Study of the Scallop Fishery in the Eastern French Coasts of the English Channel. Journal of Marine Science and Engineering. 2022; 10(7):948. https://doi.org/10.3390/jmse10070948
4) McCluskey, E.; Brewin, R.J.W.; Vanhellemont, Q.; Jones, O.; Cummings, D.; Tilstone, G.; Jackson, T.; Widdicombe, C.; Woodward, E.M.S.; Harris, C.; Bresnahan, P.J.; Cyronak, T.; Andersson, A.J. On the Seasonal Dynamics of Phytoplankton Chlorophyll-a Concentration in Nearshore and Offshore Waters of Plymouth, in the English Channel: Enlisting the Help of a Surfer. *Oceans* 2022, 3, 125-146. https://doi: 10.3390/oceans3020011
5) Karasiewicz, S., Lefebvre, A. 2022. Environmental Impact on Harmful Species *Pseudo-nitzschia* spp. and *Phaeocystis globosa* Phenology and Niche. *J. Mar. Sci. Eng.* **2022**, 10, 174. https://doi.org/10.3390/jmse10020174
6) Panton, A., Purdie, D. A. 2022. Dinophysis spp. abundance and toxicity events in South Cornwall, U.K.: Interannual variability and environmental drivers at three coastal sites. *Harmful Algae*, 112, 102169, https://doi.org/10.1016/j.hal.2021.102169.
7) Tilstone, G.H.; Pardo, S.; et al. Consistency between Satellite Ocean Colour Products under High Coloured Dissolved Organic Matter Absorption in the Baltic Sea. *Remote Sens.* **2022**, *14*, 89. https://doi.org/10.3390/rs14010089
8) Lefran, A., Hernández-Fariñas, T., Gohin, F., Claquin, P. 2021. Decadal trajectories of phytoplankton communities in contrasted estuarine systems in an epicontinental sea, *Estuarine, Coastal and Shelf Science*, 258,: 107409, https://doi.org/10.1016/j.ecss.2021.107409.
9) Lefebvre, A., Dezécache, C. 2020.Trajectories of Changes in Phytoplankton Biomass, *Phaeocystis globosa* and Diatom (incl. *Pseudo-nitzschia* sp.) Abundances Related to Nutrient Pressures in the Eastern English Channel, Southern North Sea*. J. Mar. Sci. Eng.,* 8, 401; https://doi:10.3390/jmse8060401
10) Gohin, F., et al. 2020. Satellite and In Situ Monitoring of Chl-a, Turbidity,and Total Suspended Matter in CoastalWaters: Experience of the Year 2017 along the French Coasts. *J. Mar. Sci. Eng.,* 8, 665; https://doi:10.3390/jmse8090665
11) Gohin, F., Van der Zande, D., Tilstone, G.H. et al. 2019.Twenty years of satellite and *in situ* observations of surface chlorophyll-*a* from the northern Bay of Biscay to the eastern English Channel. Is the water quality improving? *Remote Sensing of Environment*, 233, 111343. https://doi.org/10.1016/j.rse.2019.111343