Report for Collaborative Oceanography and Monitoring for Protected Areas and Species (IVA5015)

Deliverable T5.4.1

Full release of data layers and habitat maps via freely accessible web interface

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Report by: Scottish Association for Marine Science, Marine Science Scotland and Marine Institute

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1. Introduction

In the field of habitat modelling, when it comes to the identification of suitability areas for species in the ocean environment, one common approach is to combine the information provided by data layers describing different environmental parameters (e.g. sediment type, bottom slope, water temperature, etc.) that are relevant to that species. See, for instance, Bailey and Thompson (2009), who used generalized linear models to investigate habitat preferences of different marine mammals in relation to several environmental variables.

One of the main objectives of the modelling work package in the COMPASS project was the delivery of environmental variables as habitat data layers, including physical environmental factors from hydrodynamic modelling for the period 2016-2020. This report describes the format and contents of the data layers produced under the framework of the COMPASS project. Section 2 provides a general overview of the format, structure and contents of the data layers, after data have been interpolated from the native model grids onto a regular, non-rotated grid. Detailed information about the specific physical variables included in the layers is provided in Section 3. Section 4 describes how to access the COMPASS habitat data layers online.

2. Overview

The COMPASS habitat data layers consist of 2016-2020 monthly statistics (average, minima and maxima) of different physical parameters relevant to the distribution of marine species that can be directly obtained from the hydrodynamic models used under the COMPASS project. Detailed information about the selected parameters is provided in Section 3.

A hydrodynamic model is a computational system that, after being provided with information describing the ocean seafloor, atmospheric forcing, boundary conditions and the initial state of the region of interest, can simulate the dynamics of the ocean circulation, sea surface elevation and distribution of salinity, temperature and density. Two hydrodynamic models have been used under the COMPASS project:

(a) The ROMS-based North-East Atlantic model (NEA-ROMS) developed by the Marine Institute Ireland (Dabrowski et al., 2014; Dabrowski et al., 2016).
(b) The FVCOM-based West Scotland Coastal Ocean Modelling System (WeStCOMS) developed by the Scottish Association for Marine Sciences (Aleynik et al., 2016).

The latter model (WeStCOMS) is nested within the former (NEA-ROMS) and receives boundary information from it. This model system has been described in previous COMPASS deliverables D.T5.4.1.1 and D.T5.4.2.2.

Separate sets of habitat data layers have been produced for each of these hydrodynamic models. In general, the advantage of the NEA-ROMS model relies on its wider coverage, but the WeStCOMS model should be preferred when focus is on the waters neighbouring the complex Scottish coastline, with innumerable islands and lochs that are not well resolved by the large-scale NEA-ROMS model.

The grids used by these two models are greatly different in terms of structure and resolution. For the sake of consistency, data from these models have been linearly interpolated from their native grids to a common, regular, 0.01°-resolution, non-rotated grid covering from 53°N 11°W to 59°N 2.8°W (Fig. 1). It is important to notice that this interpolation step involves a loss of resolution in some areas, in particular, in the waters near the complex coastline of Scotland which are properly resolved by the native grid of the WeStCOMS model with its fine triangular mesh. Users concerned with this loss of resolution are encouraged to download the data from the native product, which is freely accessible through the THREDDS server at the Scottish Association for Marine Sciences (https://thredds.sams.ac.uk/thredds/catalog/SCOATS.html).

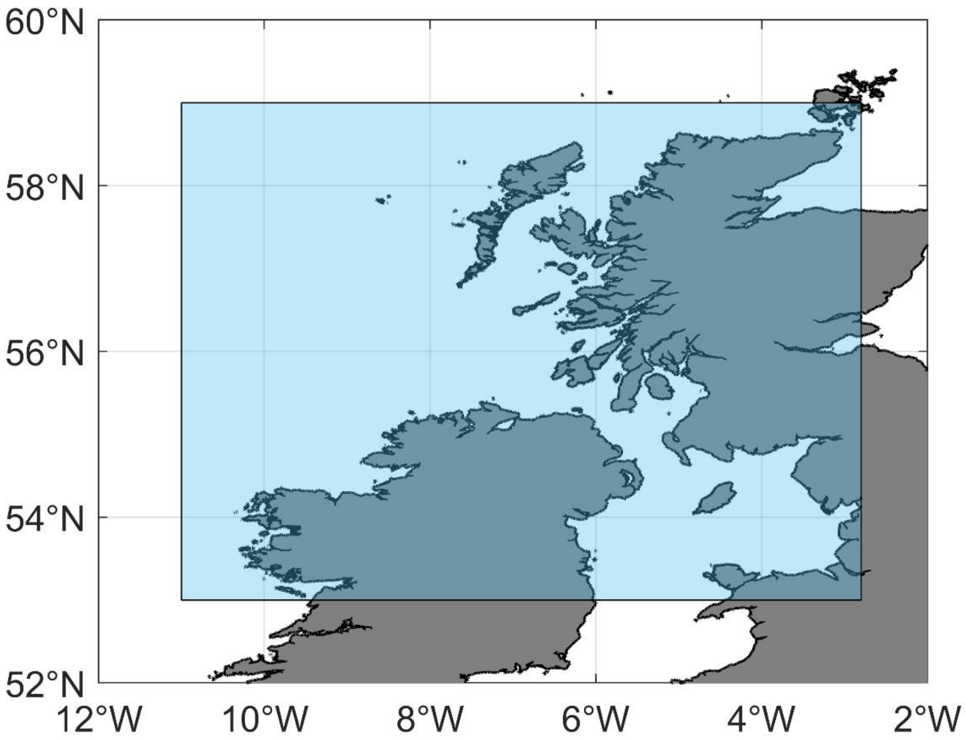

Figure 1. Domain covered by the 0.01° COMPASS regular grid on which habitat data layers are provided.

3. Ocean variables

3.1. Potential temperature

The potential temperature (°C) is the temperature that a water parcel would attain if adiabatically moved to a reference pressure level, usually the surface. The NEA-ROMS model directly provides potential temperature as an output, but the FVCOM-based WeStCOMS model provides *in situ* temperature instead. Therefore, the TEOS-10 Thermodynamic Equations of Seawater (IOC et al., 2010a) have been used to convert WeStCOMS *in situ* temperature to potential temperature. Potential temperature is provided as monthly averages, minima and maxima at the surface, 10-meters depth, 30-meters depth and bottom.

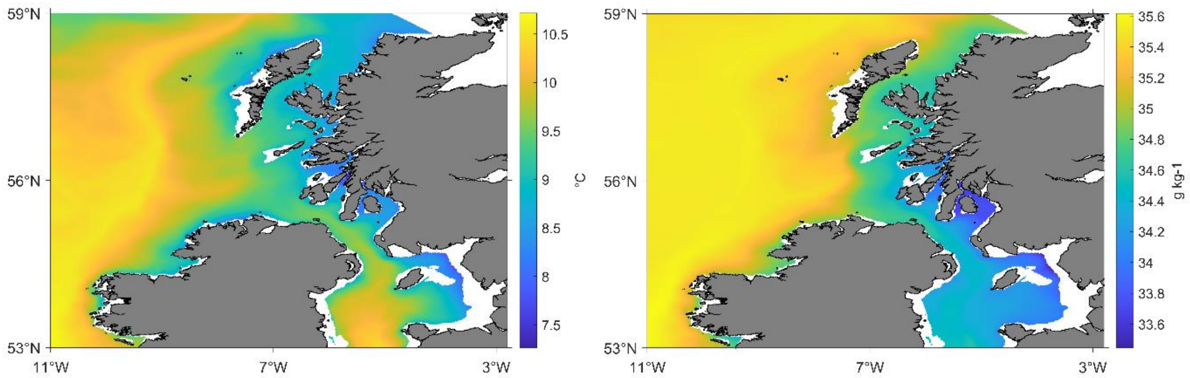

Figure 2. Test: January 2016-2017 mean temperature (left) and salinity (right) at 30 meters depth

3.2. Absolute Salinity

The Absolute Salinity (g kg^{-1}) is the mass fraction of total dissolved solids per kilogram of seawater and has been calculated from practical salinity using the TEOS-10 Thermodynamic Equations of Seawater. Again, it is provided as monthly averages, minima and maxima at the surface, 10-meters depth, 30-meters depth and bottom.

3.3. Mixed Layer Depth

The mixed layer depth (m) is provided as the depth at which a potential density difference of 0.03 kg m^{-3} with respect to a near-surface reference value is observed, with the near-surface reference value set at 10 meters depth (de Boyer Montégut et al., 2004).

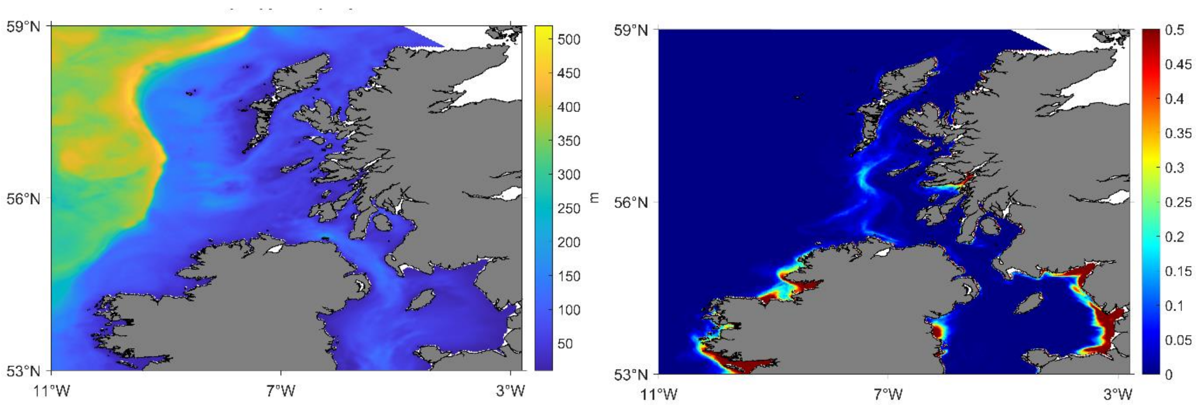

Figure 3. Test: January 2016-2017 mixed layer depth (left) and frontal probability index (right).

3.4. Frontal Probability Index

Ocean fronts can be characterized by sharp gradients of different ocean properties, such as temperature, salinity or density. Existing methods for identifying ocean fronts have mostly focused on the use of satellite imagery, mainly sea surface temperature or ocean colour. For instance, Breaker et al. (2005) used a standard gradient operator to estimate the magnitude of the gradients in SST images, and pixels with gradients greater than 0.375 °C per pixel were classified as a front. Then, it is possible to define a frontal probability index for each pixel taking into account how often the threshold gradient of 0.375 °C is exceeded in that pixel.

Here, a similar procedure was followed to define a frontal probability index. However, fronts in the region of concern can be characterized not only by strong temperature gradients but also by sharp variations in surface salinity due to the presence of freshwater plumes resulting from the discharge of numerous rivers. In order to take into account the contributions of both temperature and salinity, the surface density has been used here to characterize ocean fronts in the region. First, density (kg m^{-3}) was calculated from temperature and salinity using the TEOS-10 Thermodynamic Equations of Seawater. Then, it was considered that ocean fronts existed where a threshold surface density gradient of 0.075 kg m^{-3} km^{-1} was exceeded. Finally, a frontal probability index in the range of 0 to 1 was determined based on how often the threshold gradient of 0.075 kg m^{-3} km^{-1} was exceeded at each grid cell.

3.5. Current speed

The current speed (m s^{-1}) has been determined from the east-west and north-south components of velocity. It is provided as monthly averages and maxima at the surface, 10-meters depth, 30-meters depth, bottom and vertically-integrated through the water column.

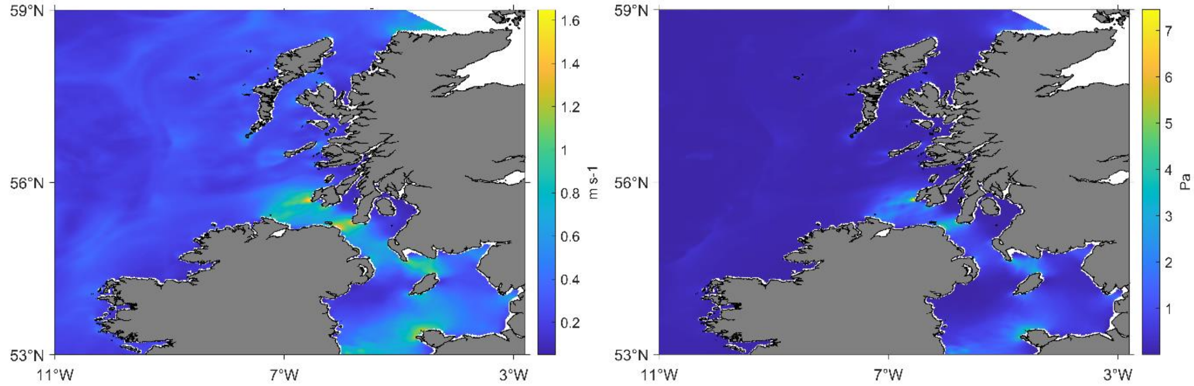

Figure 4. Test: January 2016-2017 mean surface current speed (left) and mean bottom stress (right).

3.6. Bottom stress

Finally, the average and maximum bottom stress (Pa) is also provided. Bottom stress τ has been determined using the von Kármán-Prandtl logarithmic law of the wall $\tau = \rho_s u_*^2$ where ρ_s is the seawater density and u_* is the friction velocity (Ganju and Sherwood, 2010). A roughness length z_0 = 1 cm has been used.

4. Data access

Habitat layers are in NetCDF format and will be freely accessible through both ERDDAP (erddap.marine.ie/erddap/index.html) and THREDDS (thredds.marine.ie/thredds/catalog.html and thredds.sams.ac.uk/thredds/catalog/SCOATS.html).

5. References

Aleynik, D., Dale, A. C., Porter, M., Davidson, K., 2016. A high resolution hydrodynamic model system suitable for novel harmful algal bloom modelling in areas of complex coastline and topography. Harmful algae, 53, 102-117. https://dx.doi.org/10.1016/j.hal.2015.11.012

Bailey, H., Thompson, P. M., 2009. Using marine mammal habitat modelling to identify priority conservation zones within a marine protected area. Mar. Ecol. Prog. Ser., 378, 279-287. https://dx.doi.org/10.3354/meps07887

de Boyer Montégut, C., Madec, G., Fischer, A. S., Lazar, A., Iudicone, D., 2004. Mixed layer depth over the global ocean: an examination of profile data and a profile-based climatology. J. Geophys. Res., 109, C12003. https://dx.doi.org/10.1029/2004JC002378

Breaker, L. C., Mavor, T. P., Broenkow, W. W., 2005. Mapping and monitoring large-scale ocean fronts off the California Coast using imagery from the GOES-10 geostationary satellite, Publ. T-056, 25 pp., California Sea Grant College Program, University of California, San Diego, La Jolla. http://repositories.cdlib.org/csgc/rcr/Coastal05_02

Dabrowski, T., Lyons, K., Berry, A., Cusack, C., Nolan, G. D., 2014. An operational biogeochemical model of the North-East Atlantic: Model description and skill assessment. J. Marine Syst., 129, 350-367. https://doi.org/10.1016/j.jmarsys.2013.08.001

Dabrowski, T., Lyons, K., Cusack, C., Casal, G., Berry, A., Nolan, G. D., 2016. Ocean modelling for aquaculture and fisheries in Irish waters. Ocean Sci., 12, 101-116. https://doi.org/10.5194/os-12-101-2016

Ganju, N. K., Sherwood, C. R., 2010. Effect of roughness formulation on the performance of a coupled wave, hydrodynamic, and sediment transport model. Ocean Model., 33, 299-313. https://dx.doi.org/10.1016/j.ocemod.2010.03.003

IOC, SCOR and IAPSO, 2010: The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, UNESCO (English), 196 pp.

Appendix – Acronyms used

COMPASS – Collaborative Oceanography and Monitoring for Protected Areas and Species

FVCOM - Finite Volume Community Ocean Model

MPA – Marine Protected Areas

NEA-ROMS – The implementation of ROMS in the northeast Atlantic (as used by COMPASS)

NetCDF – Network Common Data Form

ROMS – Regional Ocean Modelling System

SST – Sea Surface Temperature

TEOS-10 – Thermodynamic Equation of Seawater 2010

THREDDS - Thematic Real-Time Environmental Distributed Data Services

WeStCOMS - The implementation of FVCOM in western Scotland (as used by COMPASS)