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JRC Marine Modelling Framework in support of the Marine Strategy Framework Directive: Inventory of models, basin configurations and datasets. Update 2018

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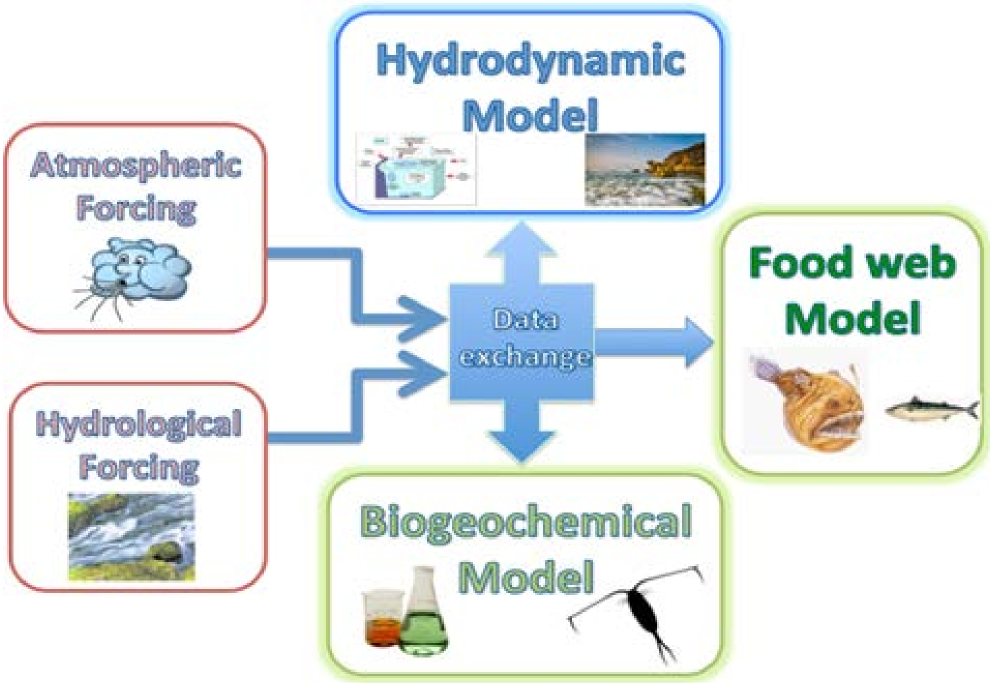

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Contents

Abstract

The Marine Strategy Framework Directive (MSFD) is expecting that all EU Member States take the necessary measures to maintain or progressively achieve Good Environmental Status (GES) in the marine environment by the year 2020. In recent years, the JRC has delivered to the Commission scientific and technical support to the implementation of the Marine Strategy Framework Directive (MSFD). The Administrative Arrangement (AA) N110661/ENV.C.2/2016/733192 between DG Environment and DG JRC requires the development of models aiming at helping the evaluation and with the implementation of policies conductive of achieving GES in the different European basins.

Within this AA, Deliverable 3.1 states that a report detailing the models held by JRC along with its physical location, technical installations and programme files should be produced by 31/12/2018. The present document fulfils this obligation by updating report #JRC100843 from 2016 with the latest developments in terms of model implementation at JRC. Concretely this report updates the previous one with a new biogeochemical model for the Black Sea, a new version of the biogeochemical model for the Mediterranean Sea, a set of new high trophic models for the Mediterranean Sea and hydrodynamic model implementations for the Baltic and Atlantic North-West European Shelf. Available model runs already stored at JRC HPC are also described.

1 Introduction

As stated in the DoW of AA N110661/ENV.C.2/2016/733192, this report contains '*the latest version of the modelling framework, in the form of models held by the JRC*'. This includes a thorough description of selected implementations to principally enable experienced marine ecosystem modellers and qualified third parties to operate the implemented model version. The document includes an inventory and description of all necessary technical installations, data and programme files and their location, any other information needed for successful operation, along with the identification of the responsible person for their management within the JRC.

2 Inventory of model codes

2.1 Hydrodynamic model

Within the marine modelling group of the JRC D02, we use the General Estuarine Ocean Model (GETM) to simulate the 3-D hydrodynamics in the Atlantic North-West European Shelf (including the North Sea), the Baltic Sea, the Black Sea and the Mediterranean Sea. A detailed description of the GETM equations can be found in Burchard and Bolding (2002), Stips et al. (2004) and in http://www.getm.eu. The hydrodynamic model GETM includes the General Ocean Turbulence Model (GOTM, http://www.gotm. net).

At JRC, the marine modelling group members use the cluster hpc-gw.jrc.it to run the coupled biogeochemical-hydrodynamic experiments for the different ocean basins, as described in the following sections for this report. More details on this high-performance computing environment are in http://hpc-gw1.jrc.it/HPC_description.html. In brief, it is composed by 2 frond-end, hpc-gw1.jrc.it and hpc-gw2.jrc.it, with Operating System Centos 7.1, IBM Model X3550 M4 and CPUs 2 x Intel Xeon Processor E5-2620v2. The cluster currently includes 42 nodes with 32 processors each, Intel Xeon Processor E5-4620.
Specifically for the GETM/GOTM compilation, we use GCC/GFORTRAN compiler and the libraries of mpi and netcdf, for parallelization and file-reading respectively

2.2 Biogeochemical model(s)

The biogeochemical models used are the following, in alphabetical order:

- The Black Sea Specific Ecosystem Model (BSSM) is used in the Black Sea. This model is based on Oguz et al. (2002) but has been further developed and validated at the JRC. Especially the constrains included in the original model implementation have been removed so the model is able to run ‘freely’ and react more properly to changes on the hydrological conditions.

- The Ecological Regional Ocean Model (ERGOM) in the Baltic Sea, which is based on Neumann (2000).

- The European Regional Seas Ecosystem Model-ERSEM (Baretta, 1995 and Butenschön, et al., 2015) is planned to be used for the Atlantic North-West European Shelf runs.

- Finally, the Mediterranean Sea Ecological Regional Ocean Model (MedERGOM) has been developed and validated at JRC (Macias et al., 2014; 2018). They are based on the ERGOM model but include higher complexity and specific features tailored for the Mediterranean Sea. A newly developed implementation of MedERGOM includes a variable internal nutrient ratio considering the plasticity of plankton cells to incorporate phosphate. This version of the code is named MedERGOM-LoF, which stands for the Line of Frugality concept (Galbraith and Martiny, 2015).

To couple the model GETM with any of the biogeochemical models mentioned above we use the Framework for Aquatic Biogeochemical Models (FABM, Bruggeman and Bolding, 2014), which is a general framework that allows the operational communication and exchange of data between the hydrodynamic and the biogeochemical models.

2.3 High trophic level model

Ecopath with Ecosim (EwE) software is a food web modelling approach used to explore changes in ecosystem structure and functioning, the impact of fishing and climate change on the species (autotrophic and/or heterotrophic) of the system and related policies exploration. Details about the available programing environments, recent developments and limitations of the EwE approach can be found extensively described in the literature (Christensen and Walters 2004; Steenbeek et al. 2016).

At JRC D02, we have been implementing an EwE model for the Mediterranean Sea basin which consisted of 103 functional groups, ranging from phytoplankton and invertebrates to top predator species, and divided in four sub-models representing the four MSFD areas: 1) Western Mediterranean Sea (W); 2) Adriatic Sea (A); 3) Ionian and Central Mediterranean Sea (I); and 4) Aegean Sea and Levantine Sea (E) to account for sub-regional differences in environmental and biological characteristics of the ecosystem. Currently, a newly developed implementation of the basin has been built to separate the commercial species from the non commercial ones (#205 functional groups) and to have the most updated input data (up to 2017).

Table 1: List of codes used at JRC ordered by type, code name, where the codes are available from, specific basins where they are applied at JRC, as well as person responsible of the models at JRC. The models are physically stored and run at the JRC in the cluster hpc-gw.jrc.it.

Model Type	**Code name**	**Available from**	**Specific basin**	**JRC Responsible**
hydrodynamic	GETM GOTM (turbulence module)	git://git.code.sf.net/p/getm/ and http://www.getm.eu http://www.gotm.net	All basins in this Report	A. Stips E. Garcia-Gorriz D. Macias Moy S. Miladinova-Marinova
coupling framework hydrodynamic-biogeochemical	FABM	git://git.code.sf.net/p/fabm/ and http://www.fabm.net	All basins in this Report	A. Stips E. Garcia-Gorriz D. Macias Moy S. Miladinova-Marinova
biogeochemical	BSSM	hpc-gw.jrc.it cluster	Black Sea	S. Miladinova-Marinova D. Macias Moy
biogeochemical	ERGOM	git://git.code.sf.net/p/fabm/ and ies-hpc.jrc.it cluster	Baltic Sea	A. Stips D. Macias Moy
biogeochemical (carbonate module)	ERSEM	http://www.pml.ac.uk/Research/Projects/European-Regional-Seas-Ecosystem-Model-(ERSEM)	North Sea	A. Stips
biogeochemical	MedERGOM	hpc-gw.jrc.it cluster	Mediterranean Sea	D. Macias Moy
biogeochemical	MedERGOM-LoF	hpc-gw.jrc.it cluster	Mediterranean Sea	D. Macias Moy
HTL	EwE	hpc-gw.jrc.it cluster	Mediterranean Sea	C. Piroddi

3 Inventory of model data requirements

The location at JRC of the datasets mentioned in this report is included in Table 2. These datasets, the configurations and the runs for all the basins in this report are physically stored at the JRC hpc-gw.jrc.it cluster. That cluster contains the storage volumes ACQUA, ARCHIVE, MSFD and SCRATCH-AS mentioned throughout the Tables.

3.1 Hydrodynamic/biogeochemical models

To build the basin configurations and/or to force the model runs, we need a number of datasets that numerically describe the bathymetry of the basin, the atmospheric variables forcing the sea, the rivers discharges, the nutrient loads and the initial/boundary conditions of sea temperature and salinity.

3.1.1 Bathymetric/boundary/initial data

The bathymetric grid necessary for each basin configuration is built from the Earth topography ETOPO1 database (https://www.ngdc.noaa.gov/mgg/global/).

For the Mediterranean Sea, the sea temperature and salinity 3D fields required at the start of the model integration are from the Mediterranean Data Archaeology and Rescue database (MEDAR/MEDATLAS, http://www.ifremer.fr/medar/), which uses in-situ historical hydrographic observations. The nitrate, phosphate and oxygen 3D fields necessary at the start of the coupled hydrodynamic-biogeochemical runs are climatologies produced by the World Ocean Atlas 2005 (WOA05, https://www.nodc.noaa.gov/OC5/WOA05/pr_woa05.html). The World Ocean Atlas 2013 version 2 (WOA13, https://www.nodc.noaa.gov/OC5/woa13/) also provides sea temperature, salinity, nitrate, phosphate and oxygen climatologies to build the initial and boundary conditions for the coupled model.

The Black Sea model bathymetry grid is produced from ETOPO1 global bathymetric grid with horizontal resolution of 1 min. The maximum depth of the model domain is 2200 m with a 70 levels general vertical grid, which is compressed towards the surface. The model is initialized by means of temperature and salinity 3D fields coming from the MEDAR/MEDATLAS II project (http://www.ifremer.fr/medar/). The nitrate, phosphate and oxygen initial fields are produced on the base of model data available (MAST / ULg Production Unit by means of the GHER 3D circulation model online coupled with the BAMHBI biogeochemical model, http://marine.copernicus.eu).

For the Baltic Sea, the model domain covers the entire Baltic Sea area with an open boundary in the northern Kattegat. Initial distributions of water temperature and salinity fields for the hindcast simulation were constructed using the Data Assimilation System coupled with the Baltic Environmental Database at Stockholm University (http://nest.su.se/das). For sea level elevations at the open boundary in the northern Kattegat, 1-hourly averaged measurements in Smøgen (Sweden) were used. Salinity and temperature at the open boundary were adopted from Janssen et al. (1999) climatological mean fields. The digital topography is taken from Seifert et al. (2001). Initial distribution of biogeochemical model variables were given uniform distributions over the model domain based on reported typical values (Lessin et al. 2014). The daily ice concentration values over the Baltic Sea were provided by the Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/).

For the Atlantic North-West European Shelf, the domain covers the North Sea and surrounding areas and parts of the depth North Atlantic Ocean (Skagerrak and Kattegat in the east, Norwegian Sea in the North, English Channel and Celtic Sea in the South, Irish Sea) to ensure a sufficient distance to the open boundaries. Sea level data and surface currents at the open boundaries were generated every 30 minutes with the tide model provided by Oregon State University (http://volkov.oce.orst.edu/tides/AO.html) and enhanced by the daily deviation from the long-term mean using HYCOM (www.hycom.org). Salinity and water temperature at the open boundaries were also taken from HYCOM (Cummings & Smedstad 2013; Helber et al. 2013). Bathymetry of the model domain was adjusted from NOOS (North West European Shelf Operational Oceanographic System, http://www.noos.cc/; Stips et al. 2015), combined with a spatially variable bottom roughness. Model validation was conducted using gauge data taken from EMODNET (http://www.emodnet-physics.eu/Portal) and salinity and water temperature data compiled by Bersch et al. (2016) (http://icdc.cen.uni-hamburg.de/1/daten/ocean/knsc-hydrographic.html)

3.1.2 Atmospheric data

For the hindcast runs, we use three sources of atmospheric forcing. First the European Centre for Medium Range Weather Forecast (ECMWF) atmospheric variables available from http://www.ecmwf.int. Secondly, the atmospheric forcing produced through the EuroCORDEX initiative (http://www.euro-cordex.net/) by the COSMO Climate Limited-area Modelling (CCLM) atmospheric regional climate model. In our hindcast runs we use three datasets of modelled atmospheric variables produced by the CCLM when it is forced by the ECMWF ERA-interim reanalysis (ERAin) and by two different global climate models, which are the Max Plank Institute MPI-ESM-LR (http://cmip-pcmdi.llnl.gov/cmpi5) and the Earth System Model of the EC- Earth Consortium (http://ecearth.knmi.nl/). For simplicity in this report, we will call these three datasets CORDEXerain, CORDEXmpi and CORDEXece. Finally, we also use in the atmospheric forcing from the National Centers for Environmental Prediction (NCEP, http://www.esrl.noaa.gov).

The three sources of atmospheric forcing present different horizontal resolution and time coverage. The model time-frame of our runs is prescribed by the availability we have of the atmospheric datasets, which covers from 1958 to present for ECMWF, from 1979 to 2010 for NCEP, and from 1989 to 2005 for CORDEXerain, CORDEXmpi and CORDEXece.

Additionally, for the scenario runs in Section 4, CORDEXmpi and CORDEXece are also available, each one for the two emission scenarios rcp4.5 and rcp8.5 throughout the 21st century. They cover from the present to year 2100 (Table 2).

3.1.3 River data

The river discharges are derived from the Global River Data Center database (http://www.bafg.de/GRDC/) while freshwater nutrient loads are computed from Ludwig et al. (2010) to have the most realistic nutrient dataset available. Some hindcast runs include nutrient scenarios. The type of nutrient forcing used is indicated throughout the basin runs in the following sections and Tables. The total river runoff and nutrient loads to the Baltic Sea were obtained from the hydrological model HYPE (Lindström et al., 2010). Freshwater runoff to the North-West European Shelf was extracted from LISFLOOD model established at JRC (Burek et al. 2013).

The nutrient loads of atmospheric deposition are from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP). In this report, only the Baltic Sea and the Atlantic North-West European Shelf runs include atmospheric deposition as additional forcing. For the other basin, including atmospheric deposition in the runs is foreseen in the near future.

3.2 High trophic level models

To build the basin configurations and run the model, we need a number of input data per each functional group:

- Biomass (B)
- Production over biomass (P/B)
- Consumption over biomass (Q/B)
- Diets
- Catches/Discards/By-Catch

3.2.1 Biomass, P/B, Q/B input data

Marine mammals

Marine mammals abundance was extracted from scientific literature and available, as few data points or time series data, between 1990s and 2010s. To calculate the biomasses for each species we calculated the mean weight using the general empirical equation:

$$W= a*(L)^{b} \qquad (1)$$

where a and b are constants, W is the weight in kg and L is the standard body length in cm. For all the cetaceans, length was extracted from the Italian Stranding Data Bank (http://mammiferimarini.unipv.it/) while for monk seal length information was taken from Murphy et al., (2012). The P/B for all the species was assumed to be equal to M (natural mortality), and it was calculated through a life history table model (Barlow & Boveng 1991) that estimates survivorship and mortality according to the longevity of a given species.

Consumption per unit of biomass was found by using an empirical equation applied by Perez et al. (1993) to describe energy requirement (Eq.4):

$$E = a \cdot W^{0.75} \qquad (2)$$

where E is the energy requirement per day (kcal · day-1), W the mean body weight (kg) and a is a coefficient varying with the group of mammals (a=320 for otariids, 200 for phocids, 192 for mysticetes, 317 for odontocetes, and 320 for sea otters). The coefficient of 0.75, as often used in general for mammals, was subsequently changed to 0.714 following Hunter (2005) who estimated a more precise coefficient for marine mammals. The energy requirement of these mammals was divided by the average prey caloric content.

Seabirds

As for marine mammals, abundance was extracted from scientific literature and available, as few data points or time series data, between 1990s and 2010s. To estimate the biomass we considered only breeding populations estimates and not wintering one.

To calculate the biomass, we multiplied the abundance by the mean weight of each species available from the literature. P/B for all the species was assumed to be equal to M (natural mortality), and it was calculated as the inverse logarithm of survivorship (considering both adult and immature) which was extracted from the literature.

Consumption was calculated multiplying the yearly food intake (breeding and no breeding season) by abundance estimates following the same methodology of Karpouzi et al 2007.

Loggerhead and green turtles

The biomass was calculated using the number of nests found in the Eastern Mediterranean Sea, in particular, in Greece and Turkey, which are the main nesting sites (Casale & Margaritoulis 2010). To calculate the abundance we assumed a 1:1 male to female ratio (Turtle Expert Working Group 1998). Biomass was calculated multiplying the # of individuals by the mean weight, obtained using the general equation (1) where L instead of length is the carapace (CCL in cm) and extracted from the literature (Casale et al. 2009a, Casale et al. 2009b, Casale et al. 2011) and weight in kg.

P/B was assumed to be equal to M (natural mortality), and it was calculated as the inverse logarithm of survivorship (considering both adult and juvenile) which was extracted from the literature.

For the consumption, we followed the same methodology from Bjorndal (1980, 2003).

Pelagic sharks and large pelagic_non commercials

The estimates of abundance for some pelagic sharks (Carcharodon carcharias, Carcharodon taurus and Carcharhinus plumbeus) and non commercials large pelagic were obtained from visual surveys. In particular, we obtained the abundance of Mobula mobular from Notarbartolo et al (2015) that accounted for a correction function to include also animals not visible at the surface. Since we didn't find this correction for any other pelagic sharks or non commercials large pelagics, we decided to apply the same correction to the rest. For Mola mola and Galeorhinus galeus we used MEDITS data. Regarding the rest of the shark group, since no abundance data was obtained/found, we decided to apply the ratio between Galeorhinus galeus CPUE and each of the remaining CPUE species (Prionace glauca, Alopias vulpinus, Isurus oxyrinchus) as observed by Megalofonou et al., 2005 to obtain an estimate of their abundance.

To calculate the biomass, we extracted weight information from the literature. PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org).

Bluefin and swordfish

The estimates for these two large pelagic_fish were obtained from ICCAT stock assessments runs (www. iccat.org). PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org)

Other commercial large pelagics

Of this group, we were able to find only three biomasses: Coryphaena hippurus (from literature stock assessment), Lichia amia and Seriola dumerili available through MEDITS data. PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org).

Mackerels, Horse mackerels, Other medium pelagics

The estimates for these medium pelagics groups were obtained combining data from MEDITS and acoustic surveys. In particular we had few data points coming from the acoustic surveys (ECOMED) (mainly for 2006) that we were able to compare with the sampling of MEDITS. Then we estimated the difference and applied it to the values of MEDITS. PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org)

E. sardines, E. anchovies, other small pelagics

The estimates for these small pelagics groups were obtained from acoustic surveys (ECOMED, MEDIAS, PELMED) and from literature. PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org)

Benthopelagic, Bathypelagic, Demersal fish species, Elasmobranchs, Invertebrates

Medits trawl survey database was used. PB and QB were calculated using empirical equations and species traits available through DCF data call and Fishbase (www.fishbase.org)

Jellyfish and salps

Very scarce information exists for jellyfish in the Mediterranean. The majority of scientific papers found gave us ind/m3 or ind/m2, which didn't allow us to estimate the density (g/m2) due the variability of the weighting and the lack of knowledge of the life stage of the species collected, as also observed by Lilley et al (2011). We decided to use the estimate coming from Lucas et al (2014), who created a global database of jellyfish/salps biomass from scientific literature and unpublished information and found a biomass of 0.11 gWW/m2 for the whole Mediterranean Sea. As for P/B we used the approach from Palomares and Pauly (2009) that estimated PB from natural mortality (M) divided by growth coefficient (K).

QB was obtained from the literature.

Corals and gorgonians

For corals and gorgonians we extracted the biomasses, PB and QB from scientific literature.

Zooplankton

Biomasses were taken from the outputs of MedERGOM while PB and QB came from the literature.

Seagrasses and seaweeds

For all these groups, seagrasses and seaweeds, we extracted the biomasses from scientific literature. PB and QB came from the literature.

Phytoplankton

Phytoplankton biomass was taken from MedERGOM. PB was calculated dividing the primary production from MedERGOM by the biomass.

3.2.2 Diet

Diets for all the functional groups were taken from a database constructed at Institute of Marine Science (ICM, Barcelona) under the SAFENET project (MARE/2014/41). The use of the database is restricted and can be accessed only under prior authorization and request.

3.2.3 Catches, discards, effort

Total Catches were taken from FishStat (http://www.fao.org/fishery/statistics/software/fishstatj/en) FAO, which gave us for all the countries (EU and non EU) of the Mediterranean Sea the global catch production by species in tonnes. We used DCF data call to separate total catches by fishing gears. Discards and by-catch were taken from the literature (e.g., Tsagarakis et al., 2014) and from the DCF data call.

DCF databases were requested to each MS representative under the conditions that they will be used only for the scope of this project. For this reason, their access is restricted.

Effort was extracted per country using data coming from DCF, FAO and literature. As for catches, the use of DCF datasets are restricted.

Table 2: Datasets necessary to build the basin configurations and/or to force the model runs.

Data type	Name of dataset	Stored at hpc-gw.jrc.it	JRC Responsible
Atmospheric hindcast	ECMWF CORDEXerain CORDEXmpi	/COMMONDATA/ECMWF/ /COMMONDATA/CORDEX/historical/erain/ /COMMONDATA/CORDEX/historical/mpiesm/	A. Stips

	CORDEXece NCEP	/COMMONDATA/CORDEX/historical/ecearth/ /COMMONDATA/NCEP/	
Atmospheric scenarios	CORDEXmpi_rcp45 CORDEXmpi_rcp85 CORDEXece_rcp45 CORDEXece_rcp85	/COMMONDATA/CORDEX/rcp45/ /COMMONDATA/CORDEX/rcp85/ /COMMONDATA/CORDEX/rcp45/ /COMMONDATA/CORDEX/rcp85/	A. Stips
River discharges	GRDC	/COMMONDATA/RIVERS/	A. Stips
Nutrients from atmospheric deposition	DEPOSITION	/COMMONDATA/DEPOSITION/	A. Stips
Bathymetry	ETOPO1	/COMMONDATA/TOPO/	A. Stips
Sea temperature and salinity climatologies	MEDAR/MEDATLAS	/COMMONDATA/CLIMATOLOGY/MEDAR/	A. Stips
Sea nitrate, phosphate and oxygen climatologies	WOA05	/COMMONDATA/CLIMATOLOGY/WOA05nc/	A. Stips
Sea temperature, salinity, nitrate, phosphate and oxygen climatologies	WOA13	/COMMONDATA/CLIMATOLOGY/WOA13nc/	A. Stips
Demersal species biomass	MEDITS trawl survey	Restricted data	C. Piroddi
Pelagic fish biomass	MEDIAS acoustic survey	Restricted data	C. Piroddi
No commercial species biomass	Literature	/MSFD/maciadi/HTL_data_directory	C. Piroddi
Large pelagic fish biomass	ICCAT stock assessments	/MSFD/maciadi/HTL_data_directory	C. Piroddi
Mediterranean species diet	Literature	Restricted data	C. Piroddi
Mediterranean species traits	Fishbase/Sealifebase/Literature	/MSFD/maciadi/HTL_data_directory	C. Piroddi
Mediterranean catches	Fishstat-FAO	/MSFD/maciadi/HTL_data_directory	C. Piroddi
Mediterranean catches/discards	DCF	Restricted data	C. Piroddi
Mediterranean fishing effort	DCF	Restricted data	C. Piroddi
Mediterranean fishing effort	FAO	/MSFD/maciadi/HTL_data_directory	C. Piroddi

4 Hindcast run results per basin

In each basin, several runs are included in the corresponding Tables. Each run corresponds to a specific modelling experiment which is relevant to the work in that basin. Different experiments in the same basin may differ, for example, in model time-frame, horizontal and/or vertical resolution, the atmospheric forcing, nutrient loads, initial/boundary sea conditions, scenarios of rivers, scenarios of nutrients, atmospheric scenarios, climatologic conditions, bathymetric smoothing, tidal formulation, albedo approximation, advection schema, turbulence formulation, etc. For some basins, a number of different modelling experiments have been necessary in the validation phase to obtain the optimal configurations which runs will be producing the most accurate results when compared with available observations. In general, the hydrodynamic runs are calibrated/validated first without biogeochemical coupling to obtain a configuration that provides the most realistic physical environment that will control and condition the biogeochemical variables in the sea. The coupled systems hydrodynamic-biogeochemical are run afterwards and the biogeochemical variables validated with available observations.

Outputs from the hydrodynamic/biogeochemical models are used to 'drive' the HTL model runs for the different time-periods as described below.

For specific details in each basin, the following subsections include the relevant scientific publications produced by the JRC marine modelling group that have used and/or have benefited from the results of the runs listed in the corresponding Tables.

4.1 Black Sea

A description of the model runs and associated hydrodynamic and biogeochemical results can be found in Miladinova-Marinova et al. (2016 a, b and 2017). The determination of key model parameters has been completed. Two hindcast setup scenarios of the coupled hydrodynamic and biogeochemical model are stored in the JRC, namely, in the storage hpc-gw2.jrc.it/ACQUA/miladsv/BD_Blacksea_BSEM_ini. The setups contain files used for the necessary technical installations, initial and boundary data. All configuration files that are required for the model run are also provided (Garcia-Gorriz et al., 2016). The first scenario is stored in hpcw2.jrc.it /ACQUA/miladsv/BD_Blacksea_BSEM_ini/getm-setups/b2_hind_bsem_47p/ and covered the period from 1960 to 2017 and the second can be find in hpcw2.jrc.it /ACQUA/miladsv/BD_Blacksea_BSEM_ini/getm-setups/b2_hind_bsem_47p_1995/ and cover the period from 1997 to 2017.

Table 3: Hindcast runs for the Black Sea. List of model configurations and run results including location of run results in the ies-hpc.jrc.it cluster, specific atmospheric and nutrient forcings, and person responsible at JRC.

Basin	**Run type (code)**	**Specific forcing: atmospheric nutrients**	**Run results at hpc-gw.jrc.it**	**JRC Responsible**
Black Sea	Hydrodynamic (GETM-GOTM) 1960-2015 1980-2015	ECMWF	 /ARCHIVE/miladsv/HYDRO1 /ARCHIVE/miladsv/HYDRO2	S. Miladinova-Marinova
Black Sea	Hydrodynamic (GETM-GOTM)	CORDEXerain		S. Miladinova-Marinova

	1990-2005 1990-2001		/ARCHIVE/miladsv/b3_svetla_50_cordex/b200_70_15e_29_9_atten85_ddu2_1989_04 /ARCHIVE/miladsv/b3_svetla_50_cordex/b200_70_15e_33_05_atten8_ddu4_1989_04	
Black Sea	Coupled Hydrodynamic (GETM-GOTM) – biogeochemical (BSEM) 1981-2003	ECMWF No nutrients from rivers	/MSFD/miladsv/bsem_70_15e_31_05_atten95_ddu2_1980_04_PER_noni	S. Miladinova-Marinova
Black Sea	Coupled Hydrodynamic (GETM-GOTM) – biogeochemical (BSEM) 1960-1970 2001-2015 1991-2016 1997-2011 2011-2015	ECMWF Realistic nutrients from rivers	/MSFD/miladsv/bsem_95_alpha_8_35_eps008_GRDC_1958 /MSFD/miladsv/bsem_95_alpha_8_35_eps008_GRDC_2000 /MSFD/miladsv/bsem_al_10_as_10_redf_06_1998_01 /ACQUA/miladsv/CORDEX_MEDAR_GRDC_atten /SCRATCH/miladsv/CORDEX_MEDAR_GRDC_atten	S. Miladinova-Marinova

4.2 Mediterranean Sea

4.2.1 MedERGOM

A description of the model runs and associated hydrodynamic and biogeochemical results can be found in Macias et al., 2014a, 2014b, 2015, 2016a, 2016b, 2018a, 2018b and 2018c. All these studies have been performed with basically the same hydrodynamic model (GETM/GOTM) but the biogeochemical model has two different version as described above. One (MedERGOM) is an adaptation of the ERGOM model developed for the Baltic Sea by Neumman (2000) and the latest one (MedERGOM-LoF) is the 'Line of Frugality' version of the former. This LoF approach allows phytoplankton plasticity in the use of phosphate versus nitrate uptake and it is a necessary modification to correctly represent the nutrient conditions of the Mediterranean Sea (see Macias et al., 2018c)

Table 4: Hindcast runs for the Mediterranean Sea. List of model configurations and run results including location of run results in the ies-hpc.jrc.it cluster, specific atmospheric and nutrient forcings, and person responsible at JRC.

Basin	**Run type (code)**	**Specific forcing: atmospheric nutrients**	**Biogeochemical code**	**Run results at hpc-gw.jrc.it**	**JRC Responsible**
Mediterranean Sea	hydrodynamic	ECMWF	None	/ACQUA/garciel/m5sd27seg_RR95p_iow_AnemedNOadr2pre /ACQUA/garciel/m5sd27seg_RR95p_newiow_An2preNOadr /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnemedNOadr2pre /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnemedNOadr2pre_biasoldriv /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnemedNOadr2pre_blue2682r /ACQUA/garciel/m5sd18seg_RR95p_Kgetm_AnKemedNOadr2pre /ACQUA/garciel/m5sd18seg_RR106p_Kgetm_NOAnemedNOadr2pre	E. Garcia-Gorriz

Mediterranean Sea	hydrodynamic	NCEP	None	/ACQUA/garciel/m5sd27seg_RR95p_newiow_AnNCEPcfsr /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnNCEPcfsr_biasoldriv_blue2tot /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnNCEPcfsr_blue2 /ACQUA/garciel/m5sd27seg_RR95p_newiow_AnNCEPcfsr_blue2tot	E. Garcia-Gorriz
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	Climatological meteo No nutrients from rivers	MedERGOM	/ACQUA/maciadi/medsea_5x5_fabm_1958_self_clima_atmospheric_forcing_noNuts_rivers	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	Climatological meteo Realistic nutrients	MedERGOM	/ACQUA/maciadi/medsea_5x5_fabm_1958_self_clima_atmospheric_forcing_FullRivers	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	ECMWF Realistic nutrients	MedERGOM	/ACQUA/maciadi/medsea_5x5_fabm_new_1958_Exp4	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXerain Realistic nutrients	MedERGOM	/MFSD/maciadi/medsea_5x5_fabm_CORDEX_cordex_ERAIN_FABM_true	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXmpi Realistic nutrients	MedERGOM	/MFSD/maciadi/medsea_5x5_fabm_CORDEX_MPI_historic_1989_2005_shallowGib	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXece Realistic nutrients	MedERGOM	/MFSD/maciadi/medsea_5x5_fabm_CORDEX_EC_EARTH_historic_1989_2005_deepGib	D. Macias Moy
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	ECMWF Realistic nutrients	MedERGOM-LoF	/SCRATCH-AS/garciel/m5_RR_chiara_PP	D. Macias Moy E. Garcia-Gorriz

4.2.2 Ecopath with Ecosim

A detailed description of the model runs and associated results can be found in Piroddi et al., 2015, 2017). The model was fitted to time series of data and it run temporal hind-cast (1950-2011) analyses to assess the response of the Mediterranean marine ecosystem to changes in primary productivity (output of MedERGOM) and fishing effort. As mentioned above, a new version of the model has been built to separate commercial and non commercial species and to have the latest input data updated (up to 2017). This model will be fitted to time series data and will be spatially explicit (release date December, 2018).

Table 5: Hindcast runs for the Mediterranean Sea HTL model. List of model configurations and run results including person responsible at JRC.

Basin	Run type (code)	Specific forcing:	Higher trophic level code	Run results at hpc-gw.jrc.it	JRC Responsible
Mediterranean Sea	Higher trophic level	MedERGOM/fishing effort	EwE	/MSFD/maciadi/HTL_data_directory	C. Piroddi

4.3 Baltic Sea

A description of the model runs and associated hydrodynamic and biogeochemical results can be found in Lessin et al. (2014).

The ERGOM model version applied in this study contains 10 state variables: 2 phytoplankton groups (diatoms, flagellates), nitrate, ammonium, phosphate, detritus, dissolved oxygen, sediment detritus, iron-bound phosphorus in water and in the sediments.

The model domain covers the entire Baltic Sea area with an open boundary in the northern Kattegat.

The horizontal resolution of the model grid is 2 nautical miles, and there are 25 layers in the vertical direction.

A simple approach is used for the modelling of ice conditions. The model is missing the dynamical ice model, so a minimal thermodynamic ice approximation is implemented in the model. When sea surface temperature is equal to freezing temperature, the model grid cell is assumed to be covered with ice. The sea ice observation data are from Swedish Meteorological and Hydrological Institute and covers the whole Baltic Sea.

Table 6: Hindcast runs for the Baltic Sea. List of model configurations and run results including location of run results in the hpc-gw.jrc.it cluster, specific atmospheric and nutrient forcings, and person responsible at JRC.

Basin	Run type (code)	Specific forcing: Atmospheric Nutrients	Run results at ies-hpc.jrc.it	JRC Responsible
Baltic Sea	Hydrodynamic (GETM)	ECMWF	/ARCHIVE/stipsad/baltic_2x2_oxy_mean/	A. Stips
Baltic Sea	Hydrodynamic (GETM)	ECMWF	/ARCHIVE/baltic_esto15_2012/	A. Stips
Baltic Sea	Coupled Hydrodynamic (GETM) – biogeochemical (ERGOM)	ECMWF Realistic nutrients	/ARCHIVE/stipsad/baltic_esto/	A. Stips

4.4 Atlantic North-West European Shelf

A description of the model runs and associated hydrodynamic and biogeochemical results can be found in Stips et al. (2016). An extension was started mid of 2018

Table 7: Hindcast runs for the Atlantic North-West European Shelf. List of model configurations and run results including location of run results in the hpc-gw.jrc.it cluster, specific atmospheric and nutrient forcings, and person responsible at JRC.

Basin	**Run type (code)**	**Specific forcing: atmospheric nutrients**	**Run results at hpc-gw.jrc.it**	**JRC Responsible**
Atlantic North-West European Shelf	Hydrodynamic (GETM) ERSEM-Carbonate system	ECMWF 20 different scenario simulations	/TEST/stipsad/NorthSea/	A. Stips
Atlantic North-West European Shelf	Hydrodynamic (GETM) 2001-2012	ECMWF No nutrients	t.b.a.	R. Friedland

5 Forecast (scenario) run results per basin

For these runs, we use the atmospheric forcing CORDEXmpi and CORDEXece produced through the EuroCORDEX initiative, mentioned in Section 3. Both datasets include two emission scenarios from the present to year 2100.

The first scenario is the worst-case or business-as-usual scenario rcp8.5, where emissions continue to grow throughout the 21st century. The second is the intermediate scenario rcp4.5 in which emissions peak around 2040 and decrease afterwards. For simplicity in this report, the corresponding atmospheric datasets are called CORDEXmpi_rcp4.5, CORDEXmpi_rcp8.5, CORDEXece_rcp4.5 and CORDEXece_rcp8.5.

5.1 Black Sea

The forecast scenario for the Black Sea is still in preparation, since the simulations with the CORDEXerain atmospheric forcing show a strong warm bias in winter and a cold bias in summer in comparison with the simulations done with the original ECMWF. Additionally an enormous increase of the surface salinity has been calculated using the CORDEXerain atmospheric forcing, indicating a probable bias in wind speed and precipitation. The bias correction of the CORDEXerain for the Black Sea is ongoing.

5.2 Mediterranean Sea

5.2.1 MedERGOM

The basin where most scenarios have been run is the Mediterranean Sea as it has been, traditionally, our 'test basin'. A complete description of the corresponding model runs and associated hydrodynamic and biogeochemical results can be found in Macias et al. (2015a), Macias et al. (2015b), Macias et al. (2016a) and Macias et al. (2018b).

Table 8: Scenario runs for the Mediterranean Sea. List of model configurations and run results including location of run results in the hpc-gw.jrc.it cluster, specific atmospheric and nutrient forcings, and person responsible at JRC.

Basin	Run type (code)	Specific forcing: atmospheric nutrients	Biogeochemical code	Run results at ies-hpc.jrc.it	JRC Responsible
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	CORDEXece_rcp4.5 Constant nutrients in rivers	MedERGOM	/MFSD/maciadi/medsea_5x5_fabm_CORDEX_2013_EC_rcp45_bias_corrected_riv_cte	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXece_rcp8.5 Constant nutrients in rivers	MedERGOM	/MSFD/maciadi/medsea_5x5_fabm_CORDEX_2013_EC_rcp85_bias_corrected_riv_cte	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXmpi_rcp4.5 Constant nutrients in rivers	MedERGOM	/MSFD/maciadi/medsea_5x5_fabm_CORDEX_2013_MPI_rcp45_bias_corrected_riv_cte	D. Macias Moy
Mediterranean Sea	Coupled hydrodynamic – biogeochemical	CORDEXmpi_rcp8.5 Constant nutrients in rivers	MedERGOM	/MSFD/maciadi/medsea_5x5_fabm_CORDEX_2013_MPI_rcp85_bias_corrected_riv_cte	D. Macias Moy
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	CORDEXmpi Climatologic nutrients	MedERGOM-LoF	/SCRATCH-AS/garciel/m5_RR_chiara_CORDEXmpi45	D. Macias Moy E. Garcia-Gorriz

Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	CORDEXmpi Climatologic nutrients	MedERGOM-LoF	/SCRATCH-AS/garciel/m5_RR_chiara_PP_2050	D. Macias Moy E. Garcia-Gorriz
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	CORDEXmpi Climatologic nutrients	MedERGOM-LoF	/SCRATCH-AS/garciel/m5_RR_chiara_CORDEXmpi852006	D. Macias Moy E. Garcia-Gorriz
Mediterranean Sea	Coupled Hydrodynamic – biogeochemical	CORDEXmpi Climatologic nutrients	MedERGOM-LoF	/SCRATCH-AS/garciel/m5_RR_chiara_CORDEXmpi852018	D. Macias Moy E. Garcia-Gorriz

5.2.2 Ecopath with Ecosysm

No forecast scenarios have been yet implemented.

5.3 Baltic Sea

No forecast scenarios have been yet implemented.

5.4 Atlantic North-West European Shelf

After the biogeochemical model of the Atlantic North-West European Shelf is established and validated, it is intended to use for forecast simulations, utilizing the outcome of other compartments and scenarios within the BLUE2 project, focussing on changes of nutrient loads and the distribution of selected contaminants.

6 Conclusions

Within the Administrative Arrangement N110661/ENV.C.2/2016/733192 between DG Environment and DG JRC D02, the JRC has developed the Marine Modelling Framework (MMF) to support Member States in the implementation of the MSFD. This MMF allows the assessment of MSFD descriptors and provides independent and evidence-based scientific and technical support throughout the whole policy cycle of the MSFD. In this context, the models in the MMF, hydrodynamic, biogeochemical and food web, can provide the numerical tools to determine baseline conditions from the past, to estimate the future impact of pressures on the marine environment, and complement spatially and temporally the scarcity in sampling of some marine-related datasets relevant for the assessment of the MSFD descriptors.

This report constitutes Deliverable 3.1 of the Administrative Arrangement and it includes an inventory of models, basin configurations, atmospheric and nutrient forcing datasets and scenarios, and run results within MMF. This inventory is structured in hindcast runs and scenario runs. Within both hindcast and scenario runs, the results are grouped by basin. The basins included are the Atlantic North-West European Shelf, the Baltic Sea, the Black Sea and the Mediterranean Sea.

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List of abbreviations and definitions

ACCMIP: Atmospheric Chemistry and Climate Model Intercomparison Project

BSSM: Black Sea Specific Ecosystem Model

CCLM: COSMO Climate Limited-area Modelling atmospheric regional climate model

CORDEXece: atmospheric dataset produced by CCLM with the Earth System Model of the EC- Earth Consortium

CORDEXece_rcp4.5: atmospheric dataset produced by CCLM with the Earth System Model of the EC- Earth Consortium for the intermediate emission scenario

CORDEXece_rcp8.5: atmospheric dataset produced by CCLM with the Earth System Model of the EC- Earth Consortium for the worst-case or business as usual emission scenario

CORDEXerain: atmospheric dataset produced by CCLM with ERA-interim reanalysis of the European Centre for Medium Range Weather Forecast

CORDEXmpi: atmospheric dataset produced by CCLM with the Max Plank Institute MPI-ESM-LR model

CORDEXmpi_rcp4.5: atmospheric dataset produced by CCLM with the Max Plank Institute MPI-ESM-LR model for the intermediate emission scenario

CORDEXmpi_rcp8.5: atmospheric dataset produced by CCLM with the Max Plank Institute MPI-ESM-LR model for the worst-case or business as usual emission scenario

DG ENV: Directorate General Environment

DG JRC: Directorate General Joint Research Centre

ECMWF: European Center for Medium Range Weather Forecast

ERAin: ECMWF ERA-interim reanalysis

ERGOM: Ecological Regional Ocean Model

ERSEM: European Regional Seas Ecosystem Model

ETOPO1: Earth topography database

FABM: Framework for Aquatic Biogeochemical Models

GRDC: Global River Data Center database

GES: Good Environmental Status

GETM: General Estuarine Ocean Model

GOTM: General Ocean Turbulence Model

JRC: Joint Research Centre

MEDAR/MEDATLAS: Mediterranean Data Archaeology and Rescue database

MEDEM: Mediterranean Sea biogeochemical Model

MedERGOM: Mediterranean Sea Ecological Regional Ocean Model

MS: Member State

MSFD: Marine Strategy Framework Directive

NCEP: National Centers for Environmental Prediction

WOA05: World Ocean Atlas 2005 database

WOA13: World Ocean Atlas 2013 database version 2

List of tables

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