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Deliverable 8.3 Report on setup of analysis framework and compilation of initial input data for each region

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

Deliverable 8.3 Report on setup of analysis framework and compilation of initial input data for each region, is a contribution to

Task 8.2: Comparative analysis of North Atlantic marine food web structure and function. This Task will focus first, on performing comparative food web analyses, based on the principles of Ecopath, for a set of North Atlantic regions. Then, the Task will conduct scenario analyses of the effects of changing fishing and environmental conditions in each region.

The aim of the food web analyses will be to distil out of historic data via retrospective analyses , metrics to describe food web structure and function such as are required for the EU-MSFD indicators of good ecological status. The approach will be to harvest the new information on diet and abundance coming from the other WP's in EURO-BASIN, and merge this with existing data sets. These data will form the basis for applying the linear Ecopath equations to estimate the steady state annual flux of biomass in feeding networks representative of each of the study regions. The analysis will allow assessment of the role of key species in each region, ratios of production by integrated functional groups, and a variety of network metrics. For example, ratios of benthic/pelagic production and benthic invertebrate/demersal fish production which have been found to be diagnostic of ecosystem status in a variety of regions.

Analyses based on the linear Ecopath equations provide steady state estimates of biomass fluxes. However they do not allow scenario testing to determine, for example, the ecosystem consequences of changes in fishing patterns or environmental conditions. For this, a dynamic simulation system is required. Ecosim – the dynamic version of Ecopath – is one of a number of options for dynamic simulation and forward projection. However, Ecosim does not represent environmental effects on primary production or nutrient recycling, so is of limited use for investigating bottom-up effects on the food web. For EURO-BASIN, we will develop an alternative simulation system incorporating more explicit representation of low-trophic level and nutrient processes drawing on output from models developed in WP5 and WP6. Finally, scenario analyses with Ecosim will be used to investigate interacting effects of climate change and fishing on food web structure and functioning, including the examination of indicators representing good ecological status within the MSFD.

Responsible: USTRATH; Participants: ALL
Start month 1, end month 48

Specification of end-to-end ecosystem model regions and boundary driving data requirements for EURO-BASIN Task 8.2

Mike Heath, University of Strathclyde, June 2012.

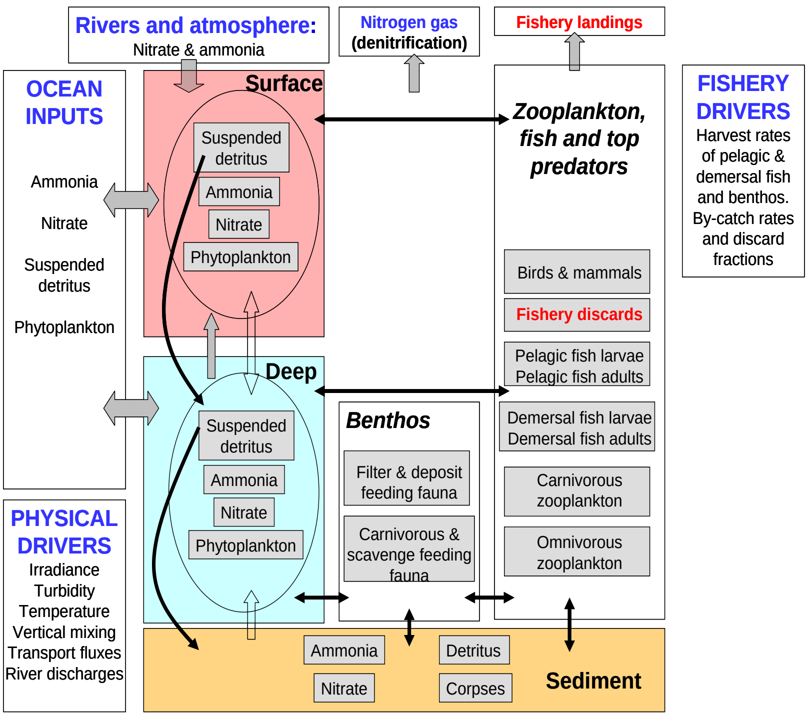
Potential policy impact:

The objective in task 8.2 is to implement the end-to-end ecosystem model in a variety of regions of the northeast Atlantic, and test the hypothesis that, at the given level of species aggregation into functional groups, the system dynamics can be explained in terms of external physical, chemical and fisheries forcing, with a common parameter set despite differences in the species composition of the functional groups in each region. If this proves to be the case, then the model represents a powerful tool for assessing the high level management strategies required to achieve different societal goals for the ecosystem in a range of regional settings.

Summary of the model framework:

The end-to-end ecosystem model developed in Task 8.2 for simulating whole ecosystem dynamics (Deliverable 8.4; Heath 2012), is a spatially aggregated functional group model of taxa, detritus and dissolved nutrient, based on a set of linked ordinary differential equations (Fig.1). So far, the stationary solution of the model has been fitted to observed measures of the state of the North Sea ecosystem averaged over the period 1970-1999, with 1970-1999 climatological oceanographic driving data, in order to estimate the maximum likelihood set of parameters for the model. Using these parameters, the model has then been used to explore the sensitivity of ecosystem state and fisheries yields, to joint variations in pelagic and demersal fishing rates.

***Figure 1**. Schematic of the state variables in the ecosystem model, their connectivity, and relationship to oceanographic and fishery drivers*



Data Requirements:
The external driving data required for the North Sea model are listed in Tables 1-5, and build on the initial data needs analyzed in Deliverable 8.1 (Report specifying regions, taxa representation, data needs & sources for linear food-web analysis). In the analysis reported by Heath (2012), these data were provided to the model as climatological annual cycles.

***Table 1**. Physical configuration parameters of the North Sea model.*

Parameter and units	Value	Source
Surface layer thickness (m) (mean depth of layer bounded by the sea surface, and the seabed or 30m, whichever shallower)	28	Derived from ETOPO5 5 min gridded elevation dataset (National Geophysical Data Centre, www.ngdc.noaa.gov/mgg/global/global.htm)
Deep layer thickness (m) (mean thickness of layer bounded by 30 and the seabed, where seabed deeper than 30m)	42	Derived from ETOPO5 5 min gridded elevation dataset (National Geophysical Data Centre, www.ngdc.noaa.gov/mgg/global/global.htm)
Bottom boundary layer thickness (m) (for feeding by suspension feeding benthos)	20	Estimated
Sediment layer thickness (m)	0.1	Law and Owens 1990
Sediment porosity ($m^3.m^{-3}$)	0.45	Ruardij & Raaphorst 1995; Heath et al. 2002
Sediment-water diffusion coefficient ($m^2.s^{-1}$)	10^{-8}	Ruardij & Raaphorst 1995; van Raaphorst et al.,1990
Length scale for sediment-water diffusion (m)	0.01	Ruardij & Raaphorst 1995; van Raaphorst et al.,1990

***Table 2**. Time-dependent oceanographic driving data required by the North Sea model and their derivation.*

Driving data	Derivation	Data source
Vertical diffusion coefficient per unit	Climatological monthly average values for sub-regions of the North Sea combined with area weighting,	Lenhart et al. (1995) and Pohlmann

length ($V(t)$, $m^2.s^{-1}$)	to produce a monthly resolution time series for the whole North Sea.	(1996).
Length scale for vertical diffusivity ($T_{Vsd}(t)$, m)	Linear variation between a value of (1.0)x(seabed depth) at mean winter values of vertical diffusivity ($\log_e V(t) = -1.8$) and (0.4)x(seabed depth) at summer values in the northern stratified parts of the North Sea ($\log_e V(t) = -3.5$).	Lenhart et al. (1995)
Temperature ($TZ(t)$, °C)	Individual hydrographic casts between 1970 and 2000 averaged over ICES sub-areas and depth layers, by month and year. For each month, the median and quantiles of the annual values were then calculated. Sub-area medians and quantiles for each layer were then combined to derive North Sea wide values by volumetric weighted averaging	ICES Environmental Data Centre
Ocean boundary transport rates $I_s(t)$, $I_d(t)$ ($m^3.d^{-1}$)	Median and quantiles of monthly averaged volume inflow and outflow rates to the upper (0 - 30m) and lower (30m – seabed) layers through each of the four model boundaries, calculated over years in the period 1970-2000. The total volume inflow to the North Sea was the sum of the inflows through the boundary sections	Monthly averaged volumes of from the NORWECOM ocean circulation model (courtesy of Morten Skogen, IMR Norway; Skogen et al., 1997, Skogen and Soiland, 1998).
Freshwater inputs ($m^3.d^{-1}$)	1960-2005 monthly averaged freshwater discharge rates and were estimated for the three ICES sub-areas separately by summing the inputs over relevant segments of coastline, and summed to provide the discharge rate for the whole North Sea.	Heath (2007).

***Table 3**. Time-dependent nutrient input and concentration data required by the North Sea model and their derivation.*

Driving data	Derivation	Data source
Flow-weighted concentrations of nitrate and ammonia in freshwater inputs	1960-2005 monthly averaged nutrient discharge rates estimated for the three ICES sub-areas separately by summing the inputs over relevant segments of coastline, and summing to provide input rates for the whole North Sea. Flow weighted concentration was then the input rate divided by the freshwater discharge rate over the same period.	Heath (2007).
Atmospheric deposition of nitrate and ammonia	50 x 50 km^2 gridded data on annual atmospheric deposition rates of total oxidized and reduced nitrogen for the years 1980, 1985, 1990, 1995 and 2000 averaged over grid cells corresponding to the North Sea.	Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air pollutants in Europe (EMEP) Unified 50 x 50 km^2 grid model (revision 1.7; Simpson et al., 2003; Tarrasón 2003; www.emep.int/Model_data/yearly_data.html; accessed 11 Jan 2008)
Ocean boundary concentrations	Individual analyses of water samples collected in each 0-30m and >30m depth layers between 1970 and 2000 were averaged over spatial compartments aligned with the 4 open boundaries of the North Sea (Fig. 2). For each month, the median and quantiles of the annual values were calculated. Medians and quantiles for boundary were then combined to derive North Sea wide values by volumetric weighted averaging	Individual sample nitrate, ammonia, and chlorophyll data from the ICES Environmental Data Centre. Phytoplankton-nitrogen and detritus-nitrogen were estimated by scaling from chlorophyll. Carbon:chlorophyll ($g.g^{-1}$) was assumed to be 40, along with molar Redfield nitrogen:carbon (16:106; Redfield et al., 1963). Deep suspended detritus was

	based on the monthly averaged inflow volume.	assumed to be 10-times the nitrogen mass of phytoplankton. The surface boundary concentration of suspended detritus was assumed to be zero.

***Table 4**. Time-dependent irradiance and attenuation driving data required by the North Sea model and their derivation.*

Driving data	Derivation	Source
Sea surface irradiance (L(t), E m^{-2} d^{-1})	30d averages of a resolution sinusoidal function, varying over 360d between a seasonal maximum (on day 180) and minima (on days 0 and 360).	Seasonal maximum and minimum from 15min average irradiances measured continuously during 2007-2008 at Aberdeen, UK (latitude 57º 15'N) (Marine Scotland Science, unpublished data).
North Sea monthly averaged suspended particulate matter (SPM) (mg.m^{-3})	Monthly averaged SPM in the surface layer over the area of the North Sea derived from simulated data. These values then used to estimate the vertical attenuation of irradiance.	Simulated data set on SPM concentrations in the North Sea (1/5 latitude x 1/3 degree longitude spatial resolution, 5d temporal resolution for a 1980's climatological year) (Pohlmann and Puls, 1994).
Relationship between SPM and vertical attenuation of surface irradiance (Kvert(t) (log_e), m^{-1})	Parameterised from a pair of relationships linking a) vertical attenuation and turbidity (Formazine Turbidity Units, FTU), and b) turbidity and suspended particulate matter (SPM, mg m^{-3}) a) Kvert = 0.1775 +0.061(FTU); r^2 = 0.646, n = 140, p<0.01 b) ln(FTU) = -10.547 + 1.567(ln(SPM)); r^2 = 0.358, n = 162, p<0.01	a) Vertical profiles of irradiance and turbidity measured weekly during 2007-2008 at 57ºN 2ºW (Marine Scotland Science, unpublished data). Attenuation coefficients derived from the irradiance data, turbidity averaged over 0-10m depth. b) Simulated annual cycle of SPM in a region centered on the weekly sampling site (56.9ºN – 57.1ºN, 2.2ºW – 1.9ºW, 5d time intervals) extracted from Pohlmann and

	Puls (1994) and related to the time series of depth averaged (0-10m) turbidity,

***Table 5**. Fishery driving data required by the North Sea model*.

Driving data	Source
Harvest ratios (proportions of biomass removed per day by fishing) by demersal and pelagic fisheries, and by fisheries for the two classes of benthos	FAO landings and stock assement data
Discarding rates (proportion of catch discarded) for each fishery	Stock assessment and monitoring data
By-catch rate of benthos in demersal fisheries (proportion of demersal harvesting rate)	Fishery observer monitoring data
By-catch rate of demersal fish in benthos fisheries (proportion of benthos harvesting rate)	Stock assessment data

The first step in this investigation is to define a suite of regions, for which the necessary physical and chemical driving data can be extracted from existing hydrodynamic-nutrient-phytoplankton-zooplankton models. Using the bathymetric grid for the NEMO-ERSEM model being used in EURO-BASIN WP5 (Living Resources) and WP6 (Basin-scale modelling), a set of regions was defined as shown in Fig. 2. For each region, WP6 has been asked to provide the physical and chemical driving data defined in Tables 2 and 3, for available hindcast runs, and when available from forecast runs under different climate scenarios.

The modelling framework will be applied to each of the regions in the NE Atlantic shown in Fig.2.

Application of the model to the Norwegian Sea and the open North Atlantic is currently limited by the availability of suitable stock assessment data.

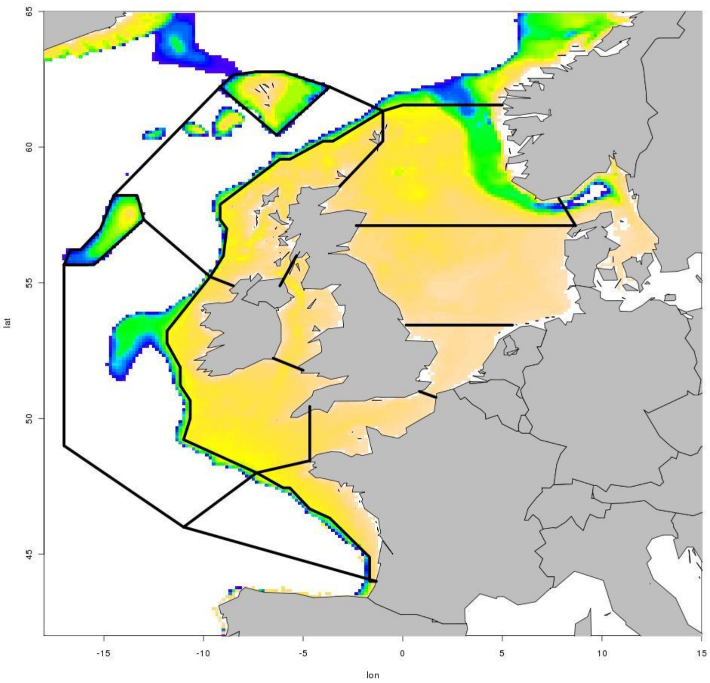


***Figure 2.** NEMO-ERSEM model domain from WP6, with seabed bathymetry to 500m shown as colour shading, and task 8.2 model boundaries overlaid as black lines.*

References

Heath, M.R., 2007. Spatially resolved monthly riverine fluxes of oxidised nitrogen (nitrate and nitrite) to the European shelf seas, 1960-2005. FRS Internal Report 02/07: 59p www.scotland.gov.uk/Uploads/Documents/0207.pdf accessed 10 May 2011.

Heath, M.R.,2012. Ecosystem limits to food web fluxes and fisheries yields in the North Sea simulated with an end-to-end food web model. Progress in Oceanography, published online http://dx.doi.org/10.1016/j.pocean.2012.03.004 published via Open Access: http://openaire.cern.ch/record/884

Heath, M.R., Edwards, A.C., Pätsch, J., Turrell, W.R., (2002). Modelling the behaviour of nutrients in the coastal waters of Scotland. Fisheries Research Services Report 10/02. 107pp. www.scotland.gov.uk/Uploads/Documents/ersem_report_final.pdf accessed 10 May 2011

Law, C.S., Owens, N.J.P., 1990. Denitrification and nitrous oxide in the North Sea. Netherlands Journal of Sea Research 25, 65–74

Lenhart, H.J., Radach, G., Backhaus, J.O., Pohlmann, T., 1995. Simulations o fthe North Sea circulation, its variability, and its implementation as hydrodynamical forcing in ERSEM. Netherlands Journal of Sea Research 33 (3/4), 271-299.

Pohlmann, T., 1996. Calculating the annual cycle of the vertical eddy viscosity in the North Sea with a three-dimensional baroclinic shelf sea circulation model. Continental Shelf Research 16, 147-161.

Pohlmann, T., Puls, W., 1994. Currents and transport in water. In: Sundermann, J. (Ed.), Circulation and contaminant fluxes in the North Sea. Springer Verlag, Berlin, pp. 345-402.

Redfield, A.C., Ketchum, B.H., Pritchard, F.A., 1963 The influence of organisms on the composition of seawater. In: The Sea, vol 2 [Hill, N., ed.]. Interscience, New York.

Ruardij, P., van Raaphorst, W., 1995. Benthic nutrient regeneration in the ERSEM ecosystem model of the North Sea. Netherlands Journal of Sea Research. 33(3-4), 453-483.

Simpson, D., Fagerli, H.J., Jonson, J.E., Tsyro, S., Wind, P., Tuovinen, J.-P., 2003. Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe. EMEP Status Report 1/2003 PART I Unified EMEP Model Description., Norwegian Meteorological Institute, Oslo, Norway. 104pp

Skogen, M.D., Moll, A., 2005 Importance of ocean circulation in ecological modelling: An example from the North Sea. Journal of Marine Systems 57, 289-300.

Skogen, M.D., Søiland, H., 1998. A User's guide to NORWECOM v2.0. The NORWegian ECOlogicalModel system. Technical report Fisken og Havet 18/98. Institute of Marine Research. Pb 1970, N-5024 Bergen. 42pp

Tarrasón, L., 2003. Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe. EMEP Status Report 1/2003 Part II, Unified EMEP Model Performance, Norwegian Meteorological Institute, Oslo, Norway. 170pp

van Raaphorst, W., Kloosterhuis, H.T., Cramer, A., Bakker, K.J.M., 1990. Nutrient early diagenesis in the sediments of the Dogger Bank area, North Sea: pore water results. Netherlands Journal of Sea Research 26, 25–52.