MSP CHALLENGE 2050 – ECOPATH LINK
DESIGN DOCUMENT

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VERSION HISTORY

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0.2	Magali Gonçalves	14-11-2016	Pressure layer definition
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Brief

In this document we describe a technical solution which will enable to connect Maritime Spatial Planning Challenge 2050 (MSP Challenge 2050) with a well-known and validated environmental model simulator – Ecopath with Ecosim (EwE).

This will allow a more robust and realistic simulation of the impacts on ecology within the game setting to allow meaningful reactions to the plans defined by the player. The reached solution is to develop MSP Challenge – EwE Link (MEL) application which is able to gather, convert, manage the lifecycle and assess the good function of the systems by serving as a bridge between both sides.

In this document the design and control of the MEL is discussed in detail, including, defining data input and output values, types, data conversion algorithms, the programmable interface, risks, and mitigation actions.

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Introduction

The Maritime Spatial Planning Challenge 2050 (MSP Challenge 2050) is a serious game that simulates the process, complexity and value of international coordination and cooperation in the management of marine areas and infrastructures (Mayer, Zhou, Abspoel, & Keijser, 2014)

It aims to simulate the maritime spatial planning process including stakeholder discussions, as well as to provide a picture of the long-term effects of maritime plans and how they can impact other activities and the environment (Mayer et al., 2014).

The most recent version of MSP Challenge 2050 (http://www.mspchallenge.info) is using a static ecologic model which is simple and unpolished. A dynamic model will allow more realistic interaction and increase the added value of the game (Steenbeek, 2015).

Problem definition

The ecology model used in the previous version of the MSP Challenge 2050 considers the North Sea as a single ecosystem and does not take into account the spatial distribution of the different species. As a consequence, the impact of the human activities on different species and their spatial distribution are not taken into consideration. For instance, the impacts of a construction site affects a marine area which implies that species can adjust by moving away from that area, but this is not included in the simple ecological model embedded in the present version of the MSP Challenge 2050 (Steenbeek, 2015).

In order to get a more realistic perspective, on the impact of human activities on ecology (and vice versa) it is imperative that the game can link with a proper and dynamic spatial ecological model. This will enhance the learning of the players about integrated, eco-system based maritime spatial planning and the overall game-experience.

In addition, the MSP Challenge 2050 seeks to further engage the players in discussions about impacts - positive or negative - in the planning phase. This dimension is still very limited in the present version of the model. For example, fishing is not included as an external pressure, but is represented as a fixed mortality term in the food web calculations. This implies that participants cannot play with the relation between fishing restrictions in certain areas and the effect it has on populations (Steenbeek, 2015).

Project Definition

In October 2016, Rijkswaterstaat-WVL, in the person of Mr. Xander Keijser and Kees Vlak, have asked NHTV to do a requirement study and make a conceptual design for a linkage between the MSP Challenge 2050 and Ecopath with Ecosim (EwE).

Such a linkage is relevant because the ministry of Infrastructure and the Environment (I&M), Rijkswaterstaat (RWS) and NHTV Breda have committed to the further development and use of the existing MSP Challenge 2050 simulation game in the Interreg NorthSEE project. RWS and I&M, have a strong wish to integrate Ecopath with Ecosim into the new game platform. This requires unforeseen and additional research and design activities by NHTV, among others in its collaboration with the Ecopath organization and technical team.

Activities

In order to be able to design a solution to link MSP Challenge 2050 to EwE the following activities have been conducted:

- Analysis of MSP Challenge 2050 game and documentation.

- Analysis of EwE platform and associated documentation.

- Identification of common points and divergences between MSP Challenge 2050 and EwE.

- Initial design session with Ecopath International Initiative Research Organization (EII) to discuss communalities and divergences between systems.

- Design session of the input and output information needed from EwE to MSP Challenge 2050 and vice-versa.

- Design session of application to link between MSP Challenge 2050 and EwE

- Design session to define the application programming interface API.

Content

This report serves as a design document which comprises the analyses on how to link the MSP Challenge 2050 and Ecopath with Ecosim. It contains essential information descriptions, with regards to explaining at high level the new architecture of MSP Challenge 2050 which is currently in development, followed by a section on EwE and its internal organization.

The design is the most important section because it details the possibilities for linking EwE and MSP Challenge 2050. First, the data analysis (both input and output) is described. It defines the input pressure layers that are delivered to EwE, and the categories of output ecology estimates which are calculated by EwE and delivered to MSP Challenge 2050. It includes a conceptual parametric conversion model between the MSP Challenge 2050 layer model and EwE grid data. Subsequently, the technical feasibility of the linkage is presented, and it defines essential high level system designs, including detailed information with regard to the MSP Challenge 2050 – EwE interfaces and sequence diagrams.

The final section of the document contains the plan for the implementation of the MSP Challenge 2050 – EwE link and analyses the risks which could be identified at this stage of the project and mitigation actions.

MSP Challenge 2050 Overview

Introduction

The objective of this project is to define and assess in detail the incongruent elements, and define the requirements and design a suitable plan to integrate both software systems. This requires technical team members from MSP Challenge 2050 and EwE to work from both sides towards a shared conceptual design and prepare its implementation.

Components

The new MSP Challenge 2050 architecture is much more server centric, since multiple scenarios and regions will have to be considered.
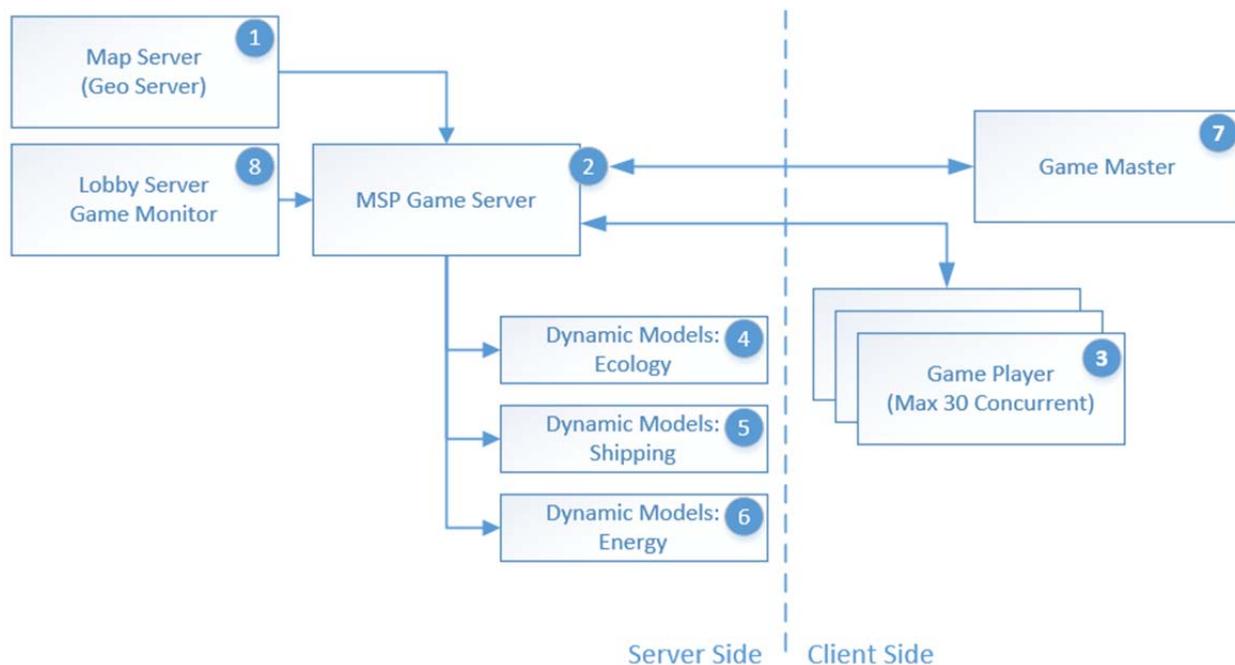
Figure 1: MSP Challenge 2050 High Level Architecture and component breakdown.

Figure 1 reflects the component breakdown of the most complete MSP Challenge 2050 software setup. In this setup the system is prepared client players to remotely connect to the game server, and perform an online multiplayer game session.

A single client application acts as Game Player (3) or Game Master (7). It's necessary to first connect to a Lobby Server (8), to authenticate the players and only then connect to a single instance of MSP Game Server.

There are two unique and persistent (always on) instances, the Lobby Server (8) and Map Server (1). The lobby server will allow new users to register,

log in, see active games, and when they desire, start new games as game master.

The Map Server (1) is the central repository for all scenarios, maps and data layers. The Map Server is available to provide a copy of the central data to the MSP Game Server (2), i.e., when a new game start, a new instance of MSP Game Server (2) is launched and retrieves a copy of the Map Server of all required data layers for a specific region/mode.

This allows all new games to have always up-to-date information, decentralizes game processes, and supports data management, while allowing players to modify, change, and morph existing data without altering the original data layers.

To support the MSP Game Server, a set of satellite applications named Dynamic models (4, 5 and 6), can collaborate to flexibly enrich the game environment by adding specific aspects to the game, such as Ecology, Shipping and Energy. In the future, if needed others dynamic models can also be considered to tackle other issues such as aquaculture, water pollution or climate change. The main reasons to keep Dynamic Models as independent units are:

- Focus on a single aspect of the game, reducing the complexity of the game, and the capacity to be reused in the long run.

- The added versatility, which allow specific scenarios running with specific models, or the ability to expand the game without major alterations to the MSP Game Server.

- Ability to horizontally scale the computation requirements in multiple machines if required, i.e., if models become computationally expensive, they can be served by a separate, dedicated computer.

- Improve quality assurance, by having smaller contained applications which are easier to test, and to recover from errors.

Challenges

The main challenges of the separation of the Dynamic Models to external component are:

- Extra complexity of defining a communication protocol between MSP Game Server (2) and the Dynamic Models (4, 5, and 6). This can be minimized by trying to maximize the functionality of the external protocol of the MSP Challenge 2050.

- Deployment and monitoring the state of multiple applications. MSP Challenge 2050 needs to have a watchdog mechanism that guarantee good fit satellite applications.

By weighting the pros and cons, it was decided to go for this decentralized approach since the extra effort in the development process is worth the future benefits.

Ecopath with Ecosim Overview

Introduction

Ecopath with Ecosim (EwE) is a free software that enables the representation of ecological systems as a food web in terms of biomass, and predation links between functional groups. Ecosystem dynamics can be simulated over time to explore impacts of fishing and environmental disturbances as well as for exploring optimal fishing policies (Christensen & Walters, 2004). Ecosystem dynamics can then be reproduced over a spatial temporal map grid (Ecospace) to allow different planning scenarios exploration such as marine protected areas (Christensen & Walters, 2004).

Components

Ecopath with Ecosim is a combination of 3 components: Ecopath, Ecosim and Ecospace (http://ecopath.org), which use a pyramid scheme and rely on the bottom of the pyramid to calculate estimate ecology biomass (see Figure 2).
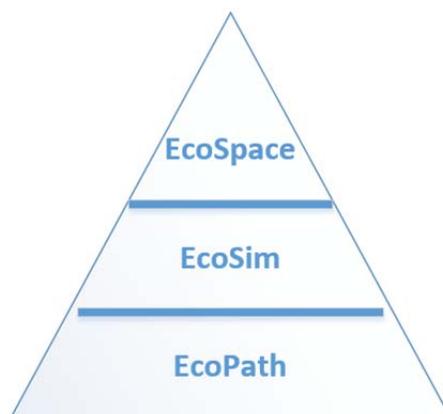
Figure 2: Pyramid model of EcoPath with EcoSim

Ecopath

The foundation of EwE is the Ecopath model, which creates a static mass-balanced model of different species from different functional groups that represent different parts of the ecosystem and map their interactions (Heymans et al., 2016). The functional groups may consist of a single species, or species groups representing ecological assemblages (Heymans et al., 2016).

The Ecopath model serves the purpose of finding the appropriate and representative balance between production and consumption and simulate specific ecology models like food webs (Steenbeek, 2015).

Ecosim

Ecosim module is an extension of Ecopath and enables to run an Ecopath model over time predicting its evolution, assess which species are going to thrive and which ones will decay. Ecosim is frequently used to test planning hypothesis, for example, what would happen if fishing of species A or B are increased, or will species C recover if we decrease or stop fishing (Christensen & Walters, 2004).

Ecospace

Using Ecospace it's possible to represent functional groups not only over time (Ecosim) but also their distribution over an area. This way ecological modelers can test different hypothesis like increase or decrease fishing efforts or placing marine protected areas and try to understand what would be the optimal area testing locations (Christensen & Walters, 2004).

Regions and models

To take full advantage of EwE software it's necessary that for each different region a specific model is developed, specifically designed to capture the ecosystem dynamics in the region. Each region has its own characteristics and local species which require to be characterized. EwE model cannot be a one size fit all solution and experts in the field are needed to develop the EwE model that will be used for a specific region of the MSP Challenge 2050.

Extended improvements

Using EwE as an external application in MSP Challenge 2050 will provide the game with more realistic results, giving that we will be able to use the full web food model rather than a simplification from it.

Besides a more accurate model, there are two main improvements achieved by separating the food web model from MSP Challenge 2050, which are:

Able to use a spatially explicit model

Previously MSP Challenge 2050 had a food web model incorporated, but such model was not linked to a spatially distribution, by linking MSP Challenge 2050 to EwE this issue will be fixed and the spatial planning activities will be translated into impacts over time and space (Steenbeek, 2015).

For instance, in the previous MSP Challenge 2050 version, the protected areas would affect the whole ecosystem's biomass, rather than affecting only the species whose habitat was being preserved (considering trophic relations). With this change, spatial planning will have spatial impacts that can be represented in the game.

Control over the Fishing Efforts

In the food web model the fisheries are a fixed parameter so the fishing efforts planned (increase/decrease) during the game were not being interpreted over time (Steenbeek, 2015). Any fishery plans to reduce or increase fleet efforts were not actually influencing the game results. This will also be fixed by creating a link between the MSP Challenge 2050 and EwE.

The link will allow players regulate the fishing efforts of specific fishing fleets, which will allow the ecology models to react to those changes and see impacts on the ecology information.

Linking MSP Challenge 2050 with EwE

EwE is a dynamic model that can be used to assess the ecosystem's evolution to certain pressures originated mainly by human activities (Christensen & Walters, 2004). As the MSP game aims to explore scenarios of spatial planning of multiple activities this is the appropriate tool to integrate in the game for this purpose. Nevertheless, there are design and technical issues that need to be analyzed in order for both systems to be compatible.

Integration concerns

Both systems are versatile by their design and implementation, and most of the integration is rather straight forward, but, there are specific issues that need to be handled by the designed solution. In this section we present the major issues.

Concern 1: Iteration over time

MSP Challenge 2050 is a game that emulates a different and variant time scales. An in-game year can be represented as merely seconds in real-life, i.e., it uses a variant time scale and notion that time can be paused or resumed during a game session.

The minimum pulse of time in MSP Challenge 2050 is a month which is compatible with EwE, but at this point, EwE processes the simulation with a continuous effort, without the possibility of external control over the time pulses. The solution needs to be exclusively from EwE to provide a mean to execute on demand.

Concern 2: Data

One of the first critical steps in this document is to take a close look to the input and output data from EwE. In addition, the data sources for both systems are fundamentally different. To be able to manage large sets of very detail and accurate data, with the ability to zoom in and out, MSP Challenge 2050 uses vector based data. EwE, more specifically, Ecospace uses a gross raster representation of the space, which for the scientific work is more than enough to represent the distribution of biomass, and it also facilitates calculations by reflecting the influence of adjacent cells.

There are algorithms that are able to convert from raster to vector and vice-versa, so an intermediate conversion needs to be handled.

Concern 3: Interface

For both systems to be able to communicate they will both need to agree upon a common protocol which standardizes the communication through a common network interface, units, coordinate system, and data types.

Although both systems are able to communicate with external parties, this is a very specific interaction with large amounts of data. This document needs to address it early on to avoid major gaps and pitfalls.

Design solution

Based on the integration concerns and to minimize the impact for both systems (MSP Challenge 2050 and EwE) and to address concern 2 and 3, it was decided to implement an intermediary application which will be responsible to manage and convert the required data and keep the modifications to both MSP Challenge 2050 and EwE to a minimum, to this application that we named MSP EwE Link (MEL).

Figure 3 reflects how MEL (2) is situated and enables the indirect communication between MSP game server (1) and Ecopath with Ecosim (3). Below the applications lifecycle and communication Application Programming Interface (API) between the three systems are discussed. The MSP clients will never interface neither with MEL or EwE directly.
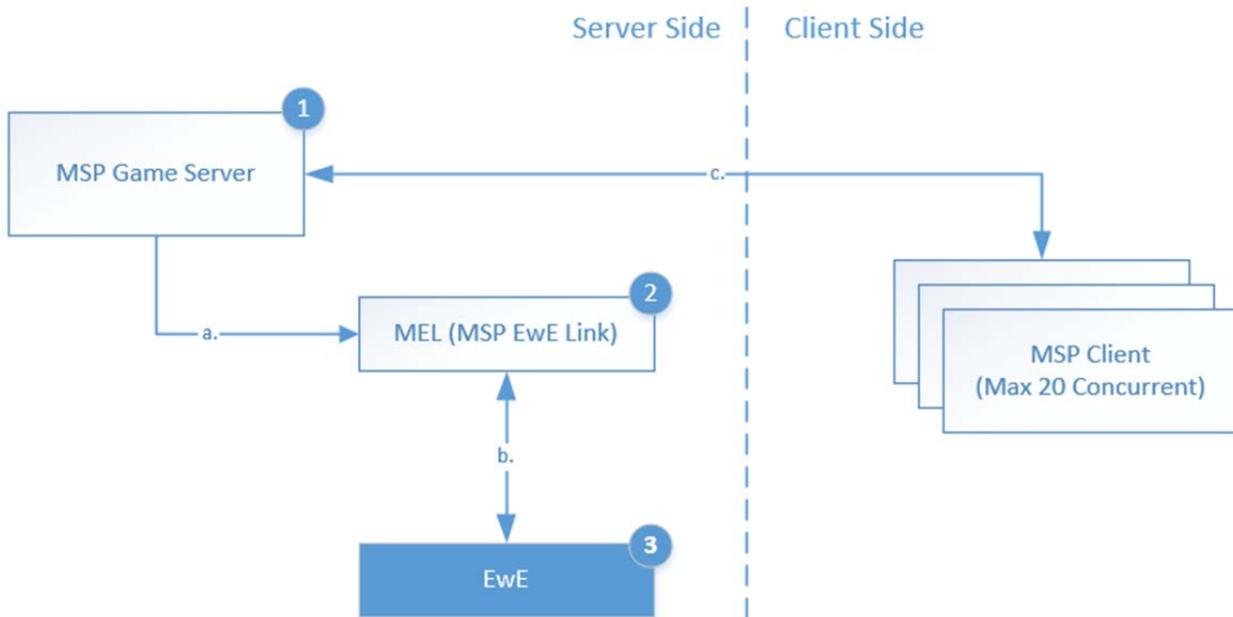

Figure 3: MSP Challenge 2050 and Ecopath with Ecosim Link

Data definition

As described in the previous section, the interface between MSP Challenge 2050 and EwE through MEL requires detailed specification mainly regarding input data to EwE and the types of output data EwE creates to be exported to MSP and their clients. In this section a detailed overview of EwE data input and output is provided.

EwE input data

EwE will be MSP Challenge 2050 source of information for ecological characterization and environmental modeling. Not only will EwE provide a snapshot picture of the ecosystem at game start, but, it will keep estimating the biomass of different species in the ecological model based in player input.

When a Game Master sets a gameplay session and a specific region and mode are defined, it's the responsibility of MEL to communicate these choices to EwE which will load the indicated model, for example the North Sea region and expert mode.

For every region/mode there is a per-agreed set of pressure layers and ecology layers that are relevant to game play. For instance, commercial species of fishes (cod, monkfish, whiting, etc.), iconic mammal species and ecologically important species of birds or other organisms.

MEL will be responsible for gathering and configuring the MSP game server with all the activities layers, (e.g. energy production, marine protected areas, aquaculture, etc.), administration layers (e.g. countries' exclusive economic zones, territorial waters, etc.), and calculated pressures on the ecosystem, see Figure 4.
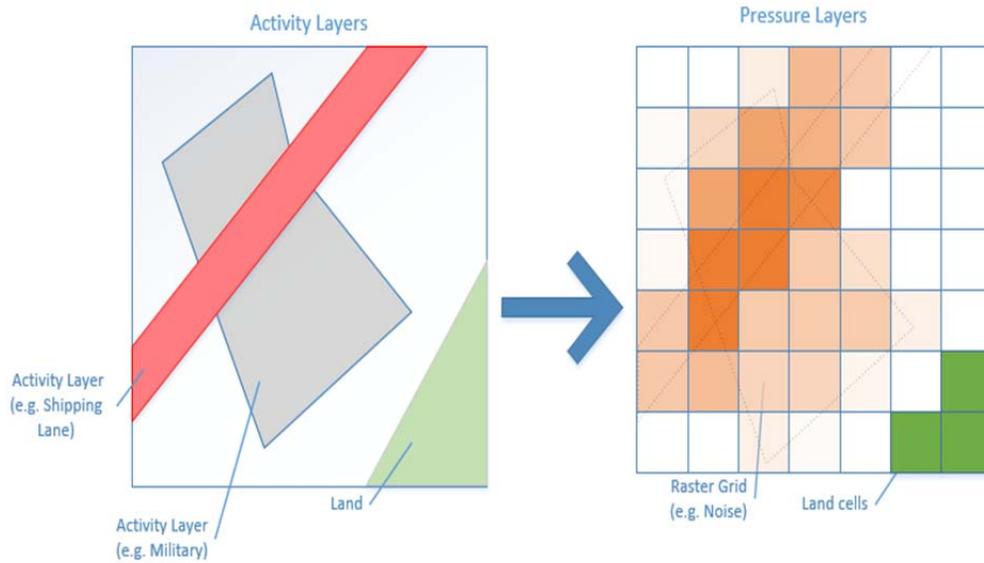
Figure 4: Example on how to convert Activity into Pressure information

With EII consultation seven pressures were defined, which will drive the ecological model. All of the pressure layers are fed by MSP Challenge 2050 and are spatial explicit except the pressure resulting from fishing efforts. Fishing efforts is considered an activity and is defined per fleet. This activity is translated into a pressure which we called fishing intensity, this is the parameter the ecological model will employ to calculate caught biomasses and by-catches.

In table 1 we present the different pressure information.

Table 1: Pressure layers to drive the ecological model.

Title	Description
Artificial Substrate	Manmade alterations of the sea floor, infrastructures, which provide shelter and habitat to specific species. It takes into account sea bed destruction and replacement by a hard substrate. Sometimes, in case of vertical structures some species like mussels can benefit from these structures and grow on the artificial substrate.
Noise	Alteration to environmental noise, which impacts specific ecological functional groups in a positive or negative way. It takes into account not only noise but also the vibration that can be created by operating heavy machinery. Most species will tend to relocate away from noisy activities.
Bottom Disturbance	Water disturbance near the sea floor, including pollution from emissions and sediment disturbance that can lead to solids in suspension in the water column.
Surface Disturbance	Water disturbance near the surface, considers pollution, detritus or other multiple sources of disruption like marine litter.
Protected Sites	Marine Protected Areas or areas which by the nature of the activities offer some sort of protection, or reduction of fishing. It reflects areas where no fishing is allowed, weather due to a protected area (Natura 2000 or Marine Protected Areas) or due to infrastructures installed such as wind parks.
Fishing Intensity	A scalar for EwE model fishing effort that can be used to reduce or intensify fishing pressure for a given fleet.

As described earlier, MEL will calculate a set of vector based pressure data already in a raster grid format, which will be sent directly to EwE. Those pressure grids represent the weighted sum of all activity layers.

In table 2 we show the list of activities which are part of the game and have direct or indirect impact on the ecology layers. It also refers to which system (MSP or EwE) is the owner of the information upon the start of the game.

Layer	EwE	MSP	Description
Military		✓	Zones of military use (Ammunition, Fly Zone, Practice)
Aquaculture		✓	Location of aquaculture installations, like, algae, fish, shellfish or shrimp.
Dredging		✓	Areas where dredging takes place, medium quantities per year (ton/year).
Energy Infrastructures		✓	Location of cables and sockets dedicated to the energy network
Fossil Fuel Extraction Platforms		✓	Location of fossil fuel extraction platforms.
Pipelines		✓	Location of pipelines.
Green energy		✓	Location of tidal, wave or wind farm turbines.
Fishery	✓		Fishery's intensity per fleet: e.g. trawlers, seiners.
Land Reclamation		✓	Marine/coastal areas transformed into land.
Beach Recreation Area		✓	Location of beach recreational areas.
Marinas		✓	Location of marinas.
Water Sport Area		✓	Location of water sport area.
Recreation		✓	Location of recreational areas.
Construction		✓	Location of construction sites.
Anchorages		✓	Location of anchorages areas.
Harbors		✓	Harbors locations.
Port Extensions		✓	Location of port extensions.
Shipping routes		✓	Location of most common shipping routes.
Sediment Deposit Areas		✓	Location of areas where sediments are deposited.
Telecom cables		✓	Telecom cables location.
Marine Conservation		✓	Location of Marine Protected Areas and Natura 2000 Areas.

For completion we also include the list of administration layers which are considered for the MSP Challenge 2050 and indirectly define or limit player's activities (see Table 3). In the table below, it also indicates if MSP and EwE possesses that information on start.

Table 3: Layers of administration considered for the MSP Game.

Layer	EwE	MSP	Description
Countries		✓	Country borders, also maps what is water / land.
Seas		✓	North Sea (and adjacent seas) ecosystem area delimitation.
EEZ		✓	Exclusive Economic Zone.
Territorial Waters		✓	12 nautical miles delimitation.
Contiguous zone		✓	24 nautical miles delimitation.
Cultural Heritage		✓	Wrecks' location.
World Heritage Sites		✓	Location of World Heritage Sites from UNESCO.
Fossil Fuel Availability		✓	Location of fossil fuel availability.
Oil and Gas Licensed Areas		✓	Location of oil and gas licensed areas.
Sand and Gravel Availability		✓	Areas where sand and gravel are available for extraction and medium quantities per year.
Marine Conservation		✓	Location of Marine Protected Areas and Natura 2000 Areas.
Bathymetry	✓	✓	Bottom sea elevation.
Current Direction	✓		Represent main current direction.
Current Speed	✓	✓	Medium current speed taking into account the winter and summer periods.
Wave high		✓	Medium wave high taking into account the winter and summer periods.
Temperature	✓		Medium temperature taking into account the winter and summer periods.
Wind Direction	✓		Predominant wind Direction.
Wind Speed	✓	✓	Average wind speed taking into account the winter and summer periods.
Eutrophication Status		✓	Water quality indicator related with the nutrients quantity in the water. When too many nutrients (mainly nitrates) are present, primary production will be intense and can latter originate algal blooms and lack of oxygen in the water. Waters can be classified as oligotrophic (low in nutrients), moderately eutrophic, eutrophic or hypereutrophic (very rich in nutrients).
Salinity	✓		Medium salinity taking into account the winter and summer periods.

As the game evolves and players create and implement plans, activities can be introduced, increased, or decreased in intensity. This will be translated by converting the activities into pressures. Each cell of a pressure grid is calculated based on the weighted sum of the dependent activities layers, i.e., a coefficient is applied to every possible activity in the game regarding possible pressures, this coefficient will be applied to each cell occupied by the activity in question.

Table 4 (next page) illustrates the initial proposition for that coefficient, based on expert judgement, again, this is just a draft proposal since this requires balancing to assure a good fit between activities and ecological modeling.

Table 4: Map between Activities and pressures including its coefficient of influence

Activities	Pressures				
	Artificial substrate	Noise	Bottom Disturbance	Surface Disturbance	Protected Sites
Anchorages	0,1	0,1	0	0,1	0
Construction	0,6	0,6	0,6	0	0
Dredging	0	0,3	1	0	0
Electricity cables	0	0	0	0	0
Fossil fuel extraction platforms	0,3	0,2	0	0	0
Harbors	1	1	1	1	1
Marinas	0,8	0,8	0,8	0,8	1
Pipelines (construction phase)	0	0	0,1	0	0
Pipelines	0,1	0	0	0	0
Protected area	0	0	0	0	1
Recreation	0	0	0	0,2	0
Sediment deposit Areas	0	0	1	0	1
Shipping	0	0,3	0	0,2	0
Tidal Farm Turbine (construction phase)	0	0,5	0,5	0	0
Tidal Farm Turbine (existing)	0	0	0	0	1
Wave Farm Turbine (construction phase)	0	0,5	0,5	0	0
Wave Farm Turbine (existing)	0	0	0	0	1
Wind farm (construction phase)	0,5	0,8	0,6	0	1
Wind farm (existing)	0,5	0,1	0	0	1
Military Areas	0	0	0.1	0.1	1

Undetermined pressure grid information

Based on the revision of the activity layers together with EII experts, there are two main activities for which EwE cannot account for impacts, given the current structure of the model, namely aquaculture and land reclamation.

Regarding aquaculture, EwE can be adjusted to account for this, but the setup is complex. Besides adding species biomass to the food chain, additional parasites, nutrients, and pollution will affect local species. Land reclamation can be managed by EwE by converting water cells to land. However, turning land to water requires provision of a range of environmental variables that the MSP game cannot account for.

If this data is required, the solution for both cases is to supply separate pressure grids to EwE so the model can account for those variants.

EwE output data

The output results of the pressure layers in EwE will be a simulation over time, where for each iteration, the alterations to the pressure grids will be passed as input to EwE. In response, a set of ecological estimates in the form of grids will be outputted by EwE. This section describes in more detail what those outputs are, and how this information is captured and visualized by the MSP game.

Categories of output

The EwE model will be defined to provide specific information based on the Region/Mode (level of difficulty of the game) of the MSP game, which means that it will be possible to output different information depending on the specific game. It's expected that for harder/realistic modes, much more data and less aggregation is provided, while easier modes would have less data layers with more merged information about larger functional groups.

In addition, the ecological model that will be used by EwE needs to be developed/adapted for the game purpose specifically, so at this point it's not possible to define which layers will be outputted by EwE. For the purpose of this document we provide the output categories which are considered at the moment.

Table 5: Considered Ecology Output Categories.

Title	Description
Species Biomass	Present quantity of each species considered important for the game purpose. A species can be considered of interest due to their commercial value, ecological importance or iconic/preservation status.
Functional Group Biomass	Present quantity of each functional group considered relevant, such as commercial fish species, sea birds, marine mammals, top predators, primary producers.
Biodiversity Indicator	Value between 0 and 1 that represents species' richness per cell. Biodiversity is also often used as an indicator of ecosystem's health.
Fishing Efforts	Amount of fishing efforts per fleet. EwE will provide MSP Challenge 2050 with this information upon game start and for every iteration. For concept purposes a fleet in EwE is a type of gear (trawler, seiner, etc.) with a target species and associated by-catch.

As an indicator we included a set of species that we are considering for the North Sea (see Table 6, next page). A definitive list of important species to include will be defined as soon as the final ecology model is defined by experts. This will fall under the responsibility of EII.

Table 6: List of considered species for the North Sea.

Name	Aim
Birds species	
Black Guillemot	Ecology relevance
Black-legged kittiwakes	Ecology relevance
Common Scoter	Ecology relevance
Fulmar	Ecology relevance
Gannet	Ecology relevance
Great black-backed gull	Ecology relevance
Great Skua	Ecology relevance
Herring gull	Ecology relevance
Red Knot	Ecology relevance
Fish species	
Atlantic Cod	Commercial relevance
Common sole	Commercial relevance
Atlantic herring	Commercial relevance
Mackerel	Commercial relevance
Whiting	Commercial relevance
European hake	Commercial relevance
Sandeels	Commercial relevance
Mammals	
Bottlenose dolphin	Iconic Species
Grey Seal	Iconic Species
Harbour Porpoise	Iconic Species
Harbour Seal	Iconic Species
Minke whale	Iconic Species
White-beaked dolphin	Iconic Species
Others	
Crustaceans	Food Web dependency
Plankton	Food Web dependency
Shellfish	Commercial relevance

Units

Real figures will be avoided since estimations will be a predictive value and the most important in the game is to explore scenarios and understand relations and trends, which can be explored by offering comparison values with the initial situation. In short, for most of the variables there can't be an estimation of maximum values, everything will be indicated in terms of comparison with the base scenario (time zero in game) and thus indicated in terms of reduced or increased.

The model will provide the information in a logarithmic scale represented by colors (heat map); note most players don't have an ecology background, they would get overwhelmed with actual figures of quantities and will not have and understanding if 10 tons of biomass is a low or high figure. For real ecologists, the scales will still make sense and can clear represent the state and evolution of the ecological state of the region.

Technical implementation

There are a few technical details which have to be taken into account when defining the implementation of MEL. Specifically, both systems - MSP Challenge 2050 and EwE have independent datasets, which use different base formats. While MSP Challenge 2050 uses vector data to represent the different layers required for the game, EwE uses intricate representations of the relationships of the food web and a 2 dimensional raster (grid) based spatial representation (see Figure 5).

In addition, MSP Challenge 2050 is designed to be able to run several different regions that can be selected by a Game Master. It is also the Game Master's responsibility to select the Mode: for each mode a set of challenges, objectives, levels of difficulty and game focus (energy, shipping, etc.) is selected. This means that not only EII will be required to define models which will require to match the regions defined for the MSP Challenge 2050 and play modes, but, also that this configuration needs to load on demand and both systems use a matching configuration for that scene/mode.
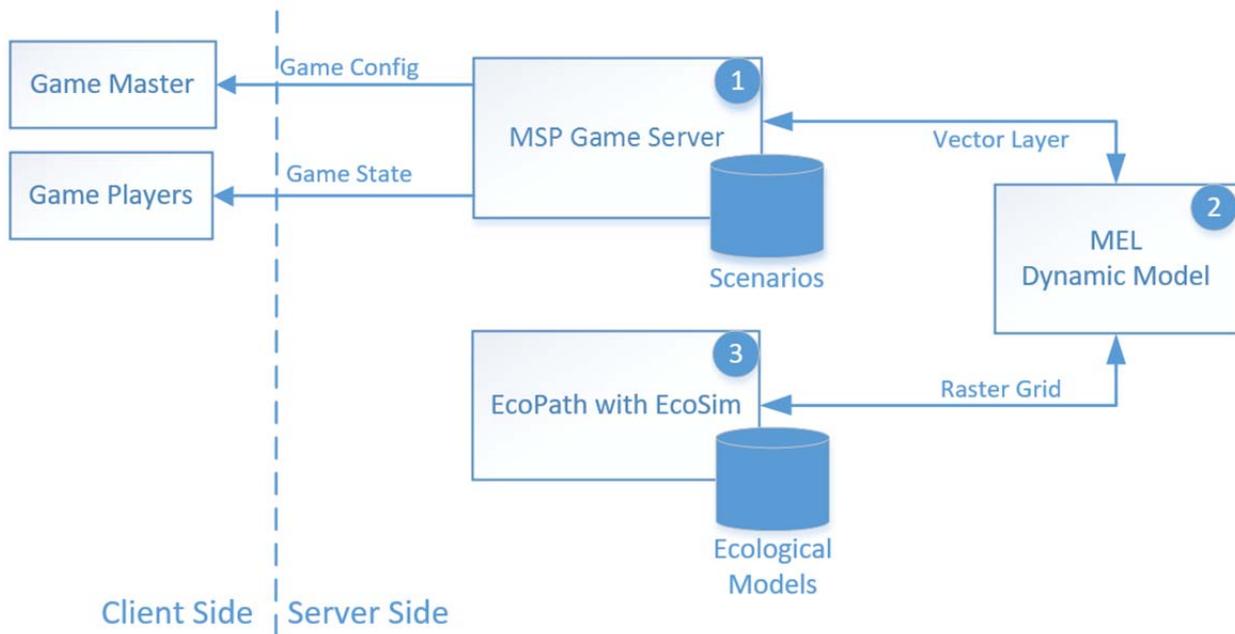

Figure 5: Technical components involved and data sources and flow.

In this section we will discuss: system lifecycle describing the different stages of execution (launching, running, terminating and recovery), describe in detail the interfaces for this stages, and finally detail how the conversion of the different models of input and output data will be handled by MEL.

Lifecycle of the applications

Launch

The MSP Game Server (Figure 5, component 1) will be the first application being executed, and it will always be running while the game is active independently of the state (stop, play and pause). MSP Game Server is a RESTful (Richardson & Ruby, 2008) application, and its main task is to respond to external requests.

After a game master has defined which region and mode will be played, the MSP Game Server will first launch MEL which will collect all the required information from MSP Game Server. Only after this MEL will launch EwE and request to load a specific configuration.

Figure 6 shows the sequence diagram, describing in detail the major steps and which messages and data are sent and received.
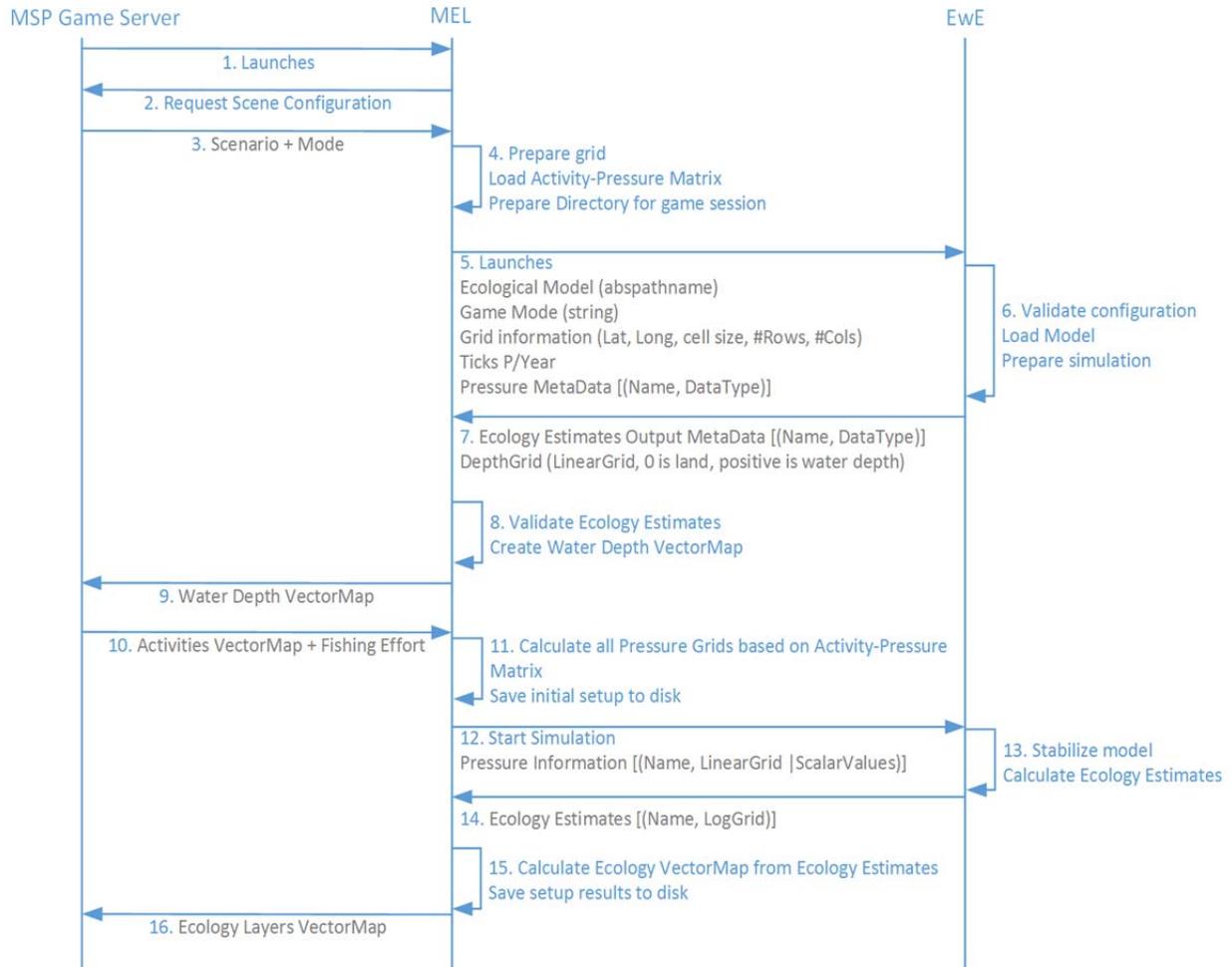
Figure 6: Startup sequence diagram between MSP Challenge 2050, MEL and EwE

Step 5 defines the startup information and configuration for the predefined model which needs to be loaded by MEL and EwE, which is represented in Table 7.

Table 7: Required start configuration for MEL and EwE.

	Data Type	**Source**	**Example**
Game Region	String	MSP Game Server	North Sea
Game Mode	String	MSP Game Server	Easy
Grid Location	2xfloat	Local database	56.511, 3.515
Grid Size	2xinteger	Local database	75, 125
Cell Size	Integer	Local database	0.2
Tick p/ Year	Integer	Local database	12
Pressure Layers	name, dataType	Local database	Noise, linearGrid
Outcome Layers	name, dataType	Local database	Noise, logGrid

Execution

MEL will work as a bridge between MSP Challenge 2050 and EwE. It will be the responsibility of MEL to periodically verify the state of MSP Server (play, pause or stop) and collect all updated information to recalculate the pressure layer data.

This should add minimum impact to the MSP Game Server, which will use the same interface that is defined for the clients. To avoid stressing the MSP Game Server, it will request only the layers which have been updated.

In the figure below, it's possible to see the communication flow, between the three parties, MSP Challenge 2050, MEL and EwE. The end product of this loop, is an update to all ecology related layers.
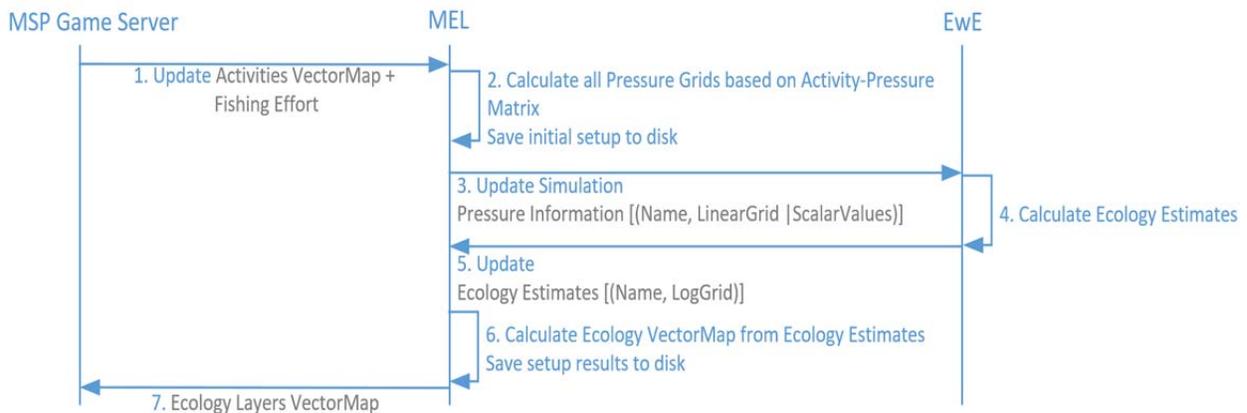

Figure 7: Running sequence diagram between MSP Challenge 2050, MEL and EwE.

Since the MSP Challenge 2050 software works with vector based data this data will be converted into the agreed normalized grid with linear information regarding pressure layers, and send it to the EwE. The defined pressure layers were listed in the input data section (see page 21), and conversion model is defined below (see page 38).

EwE will receive this information (see Figure 7, step 3), combine this new data to the existing dynamic ecological model and recalculate ecology layers. As soon as the ecology outcome is calculated it's the responsibility of EwE to provide this information to MEL.

MEL will then convert estimate ecology layers received from EwE to a vector based information which will be send to MSP Game Server for updating the ecology layers. This information will be then propagated to all MSP clients, and visible to all players.

Termination

When the game session is terminated it's the responsibility of the MSP Game Server to inform MEL to perform a clean shutdown. MEL will first cascade

this information to EwE which will proceed with the shutdown procedure, depicted in Figure 8.

Both MEL and EwE will store locally the latest information with regards of pressure layer information and the ecology layers, so this information can be used in the future if desired, although this is not critical, neither it will require specific API.

Figure 8: Termination sequence diagram between MSP, MEL and EwE.

Application Programming Interface

MSP-MEL Interface

MEL application is launched by the MSP Game Server, the command line execute command will pass the URI of the MSP Game Server (otherwise it will assume http://localhost/).

The rest of the communication between MSP Game Server and MEL will be performed through RESTful web services. REST-compliant web services allow requesting systems to access and manipulate textual representations of web resources using a uniform and predefined set of stateless operations.

By making use of a stateless protocol and standard operations REST systems aim for fast performance, reliability, and the ability to grow, by reusing components that can be managed and updated without affecting the system as a whole, even while it's running.

There are three main restful interface commands that MEL can perform to the MSP Game Server:

- Game state: /api/game/state
- Layer meta-information: /api/game/layers
- Layer geospatial data: /api/geometry

Game state

Request to obtain the game speed and game status (start, pause, stop).

Layer meta-information

Request to obtain the list of available layers in the game, and it returns the list of unique identifier, name, category, last update timestamp, and a set of useful metadata associated with all active game session layers.

Layer geospatial Data

The MSP Game Server protocol will be based on GeoJSON format to transfer layer information between MSP Game Server and MEL. GeoJSON uses a geographic coordinate reference system, World Geodetic System 1984, and units of decimal degrees.

MEL-EwE Interface

Since the EwE developed in .NET, and was conceived to be versatile, it will be possible to integrate EwE directly in MEL through a Python external library. Although not tested with the MSP code base, earlier case studies have integrated the EwE source code into other Python programs. The major benefits to this approach is the ability to reduce the overhead of network based communication, better traceability of development problems, and ability to contain the application into a single executable.

If such approach is not possible for any unforeseen situation by this analysis, then it's possible to use network based communication, with very minimal alterations to the design, since the method definition for the interface can be maintained.

Error recovery

Recovery mode is MEL's responsibility since it's not possible to save intermediate steps in EwE. MEL will save all pressure layers that were computed. If a problem occurs within EwE, it's the responsibility of MEL to restart it.

Similarly, MSP Server is responsible to check and maintain the state of MEL, and to shut it down and restart the service if necessary. The intermediate steps saved by MEL will support MEL and EwE to resume the computation of states, although some delay might be noticeable.

Converting between Vector and Raster

Since conversion between vector and raster is performed frequently, it might become somewhat heavy for calculation, therefore in this section we discuss the conversion process.

To reduce computation requirements, the conversion will only be required for layers and specifically for polygons that have been updated, requiring a larger memory footprint, to maintain copies of previous layer information.

This memory footprint estimated to be a maximum of 400Mb, which is not a concern in current computers.

Figure 9 illustrates the conversion process from vector to raster. The vector information (left) is represented by a sequence of points which defined the limits of a polygon. The right illustration depicts a grid representation, where each cell in the grid holds a single value that defines the intensity (represented by the color) and indicates for example how much that cell is occupied by an element.
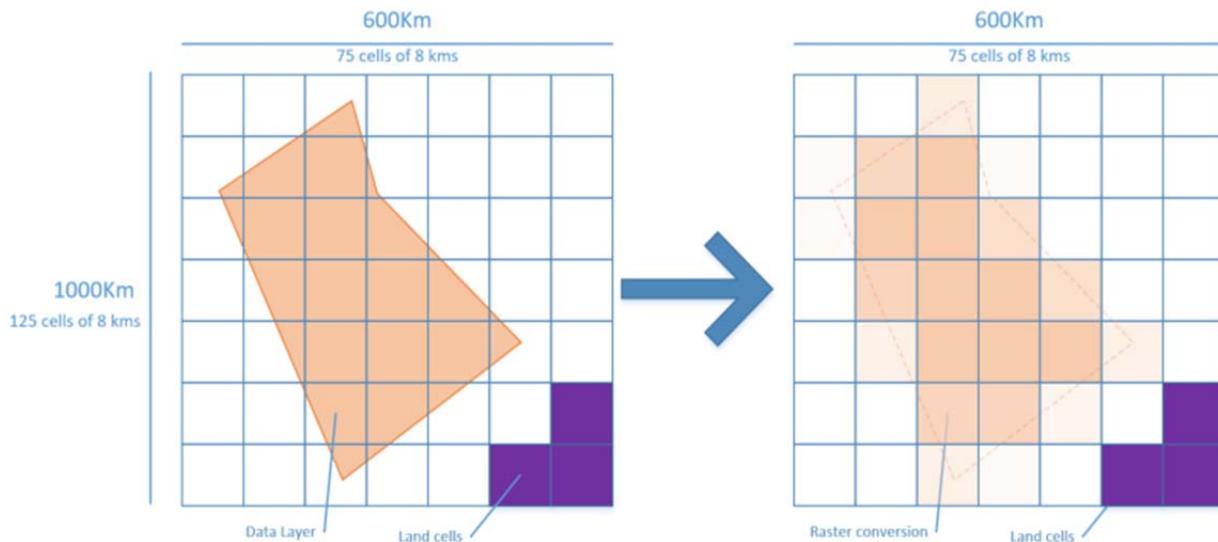

Figure 9: Demonstration of the conversion process between vector and raster data.

The conversion between vector and raster will be performed by calculating the occupied area for each cell of the grid, and translating the ratio of occupied area versus the total area of the cell. This ratio defines the intensity, and can be calculated through two methods:

Intersection: For each cell a mathematical intersection can be calculate with all polygons and determine the area. This process is computationally heavy, depending on the number of cells and polygons; by splitting the polygon and the cells into triangles, it might be possible to speed the process using modern graphics cards (GPUs).

Sampling: This technique requires that one or more point samples probe the contents of each cell, and based on the number of samples that are contained within polygons determine the cell intensity. The samples can be determined either randomly or systematically, and if enough probes are present, they provide a reasonable accuracy, in addition, this method tends to be less expensive in terms of computation and it's easily to tune the trade of between accuracy vs. speed.

There was no need for a selection of an approach at this point, since both approaches have advantages and disadvantages. Performance tested during the implementation, can assure a more reliable estimation of the capabilities of both approaches.

Future steps

In this section we discuss in detail the implementation plan, and focus on what are the steps to solve some issues which were not completely resolved in this document.

Planning

In the next phase we believe that the link between MSP Challenge 2050 and EwE will require minimal alterations for both entities, but, there is still the need to perform a set of relevant activities, see Table 8.

Table 8: List of follow up large scope implementation activities.

Activity	Duration	Internal dependencies	External dependencies
Defining the last version of layers	1 week		Stakeholders of the different regions.
Gathering Layer data	3-4 weeks		Stakeholders of the different regions.
Library for raster-vector data conversion	1 week		Sample data from EwE and sample activity layers.
EwE Stub	1 week	API definition (this document)	
MEL Implementation	2 weeks	EwE Stub	
Quality Assurance & Fine-tuning	1 week	MEL Implementation & Gathering Layer data	

Based on the list of activities we draft a timeline plan depict in Figure 10, which mainly depicts a 6 week development (5 weeks + 1 week for troubleshooting), if all external dependencies are meet. It is our aim to start implementing this plan early next year.
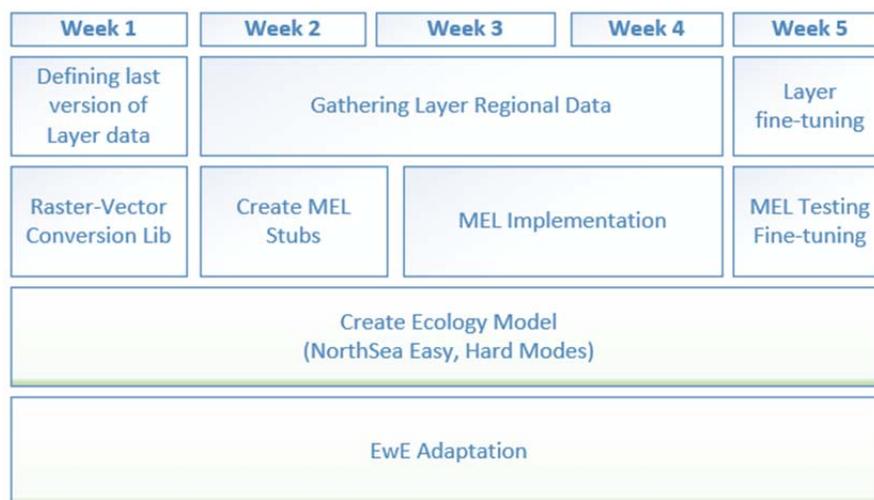
Figure 10: Timeline for the implementation of MSP Challenge 2050 and EwE Link and all surrounding activities.

Risks and unresolved issues

We summarize the list of associated risks, in Table 9. The table includes not only a detailed description of the risk, but, also the mitigation actions that are currently defined for those risks.

Table 9: List of risks for the MSP Challenge 2050 – EwE Link

Id	Risk	Mitigation
1	This plan is directly dependent on EII support to be able to accommodate the requested alterations, namely the support of the temporal dependency required by MSP Challenge 2050.	There are no mitigation actions for this risk at the moment, EII has been available to provide support, and actively involved in the design phase.
2	Missing information on specific layers for critical information required to calculate pressure grid data.	If data is not available, then one of two possible mitigation can be used: 1) calculate pressure layers without them, 2) manually design the data through approximation or informed presumption.
3	Conversion vector-raster being too slow considering the amount of data that needs to be converted.	The design contemplates that only delta information is being processed, and tests are being performed. Alternatively, less accurate strategy (sampling) can be used.
4	EwE is not possible to be included in MEL using a Dynamic Library strategy.	This was not tested yet, therefore a risk. The mitigation is to have EwE as a separate application, and the communication be done by socket based communication.

Conclusion

Already described on an analysis conducted by Steenbeek (2015) a set of modifications of the simulation in the game, could provide a more accurate feedback of impacts on ecology, which increases realism and enhances the gameplay. Considering that the MSP Challenge 2050 software is currently being redesigned and re-implemented, it will be of great advantage to increase the representation of the ecology model at this stage.

In this document the analysis of the technical possibility and feasibility of integrating EwE with MSP Challenge 2050 is described. With the designed solution it will be possible to have a realistic estimate of the impacts resulting from pressures caused by human activities (existing and/or planned). When implemented, MEL will provide MSP players with a clear overview of the interactions between the different plans and the ecosystem.

With this work, we not only reach the conclusion that it is possible to link EwE and MSP Challenge 2050, but also specified the technical design of the solution (MEL), and defined a clear path for the implementation, specifically we covered:

- Integration concerns,

- Defined input information for EwE based on in-game human activities,

- Defined output categories respectively to ecology estimation,

- Implementation data types and interface and configuration,

- Data conversion algorithms from raster to vector and vice-versa,

- Defined the application life-cycles and programmable interfaces,

- Described division of work and responsibilities,

- Analyzed the risks, and associated mitigations actions.

In short, the defined technical solution will require to create an application to bridge both MSP Challenge 2050 and EwE. This application (MEL) will be responsible to periodically retrieve MSP Human Activities and convert them into pressure grids, i.e., a set of modeling data which will drive the ecology model implemented by EwE. The EwE model will respond with a set of ecology estimates to MEL. It's MEL's responsibility to convert those ecology estimates and deliver them to MSP Server which will share them with the players.

The work presented here is the keystone for implementing the link between MSP Challenge 2050 and EwE and together provide a more rich and realistic scenario for the MSP 2050 Challenge, which can bring a direct contribution

to the scientific community, and educational classes across the globe to train future Maritime Spatial Planners by using an validated environmental model.

Acronyms and Glossary of Terms

The following table provides definitions for terms relevant to this document.

Table 10 – Acronyms and Glossary of Terms

Term	Definition
API	Application Programming Interface
EII	Ecopath International Initiative
EwE	EcoPath with EcoSim
External library	Set of functions and methods which are allowed to be integrated into multiple applications.
Game Master	Person responsible for the game setting, can make some changes during the game.
Impact	Impacts are the expected effects from pressures. For instance a new shipping route (activity) will originate noise and surface disturbance (pressure), those pressures will have an impact on ecology, making species migrate or increase mortality.
Mb	Mega Bytes, 2^{20} = 1024x1024 Bytes
MEL	MSP Challenge 2050 - EwE Link
MSP Challenge 2050	Maritime Spatial Planning Challenge 2050
Pressure Layer	Spatial grid in which a type of pressure resulting from the sum of human activities is represented in each cell.
Python	Scripting programming language
Region (in the game)	Game area focus, for example the North Sea.
RESTful web services	RESTful web services are one way of providing interoperability between computer systems on the Internet. REST-compliant web services allow requesting systems to access and manipulate textual representations of web resources using a uniform and predefined set of stateless operations.
RWS	Rijkswaterstaat
WVL	Verkeer en Leefomgeving

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