Development of an Environmental Impact Assessment Module (EIAM) in the DTOcean project

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Abstract- The "Optimal Design Tools for Ocean Energy Arrays" or DTOcean project, was a FP7 (Call ENERGY 2013) European Project, whose objectives were the acceleration of the industrial development of ocean energy power generation knowledge and providing a performant design tool, in the form of a software package, for deploying the first generation of wave and tidal energy converter arrays.

The software generated by the DTOcean project automates the design of a feasible array of ocean energy converters (OECs) for a relevant geographical location and technology type. The design process is modularized into the following stages: Hydrodynamics, Electrical Sub-Systems, Moorings and Foundations, Operations and Maintenance.

The software also evaluates each stage of the design, and the design as a whole, using three thematic assessments, which are: Economics, Reliability and Environmental.

The challenge and ultimate goal of the project was to optimize the designs created by the software, against a suitable metric, chosen as the levelized cost of energy (LCOE).

Keywords- Design Tools, DTOcean, Environmental Impact, Ocean Energy Arrays.

I. INTRODUCTION

In a consortium of 18 partners from 11 countries, France Energies Marines (FEM), the French institution dedicated to the development of Marine Renewable Energies (MRE), leaded the development of the Environmental Impact Assessment Module (EIAM) within the DTOcean framework.

The purpose of the EIAM is to assess the environmental impacts generated by the various technological choices in the optimization of the OEC array consisting of either wave or tidal devices. The results of the EIAM also support the decision-making process concerning the choices that minimize the global environmental impact of the OEC array.

One of the main challenges encountered for the development of the EIAM was the translation of the mostly qualitative knowledge available in environmental impact assessment published literature into a more quantitative approach.

In order to assess the potential environmental impacts of the tidal and wave arrays, a set of generic environmental issues (e.g. collision risk, noise, temperature, etc.) were selected and translated into specific environmental functions to be able to qualify and quantify the potential pressures generated by the array of devices on the marine environment.

The EIAM provides a rating (overall score and detailed by design module scores) for the various technological choices selected in the tools in the form of a color code that can easily be interpreted by the user.

At the end of the EIAM evaluation, recommendations based on the pressure and the receptor's scores are provided to the user in order to help improve the overall environmental score and mitigate the

negative environmental impacts of the proposed OEC array using more environmental friendly solutions.

The concrete application of this innovative global environmental impact assessment of the OEC arrays will be illustrated by a real case study.

II. GLOBAL CONCEPT OF THE MODULE

Environmental risk assessment is a process that estimates the likelihood and consequence of adverse (or positive) environmental impacts (United States Environmental Protection Agency, 2015). In that regard, conceptual model development is critical to assessing the environmental risk. The approach used here is based on the concept of environmental effects generated by 'stressors' and the related exposure of 'receptors' to these effects. A stressor is any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact. A receptor is any environmental feature, usually an ecological entity. Examples of stressors and receptors associated with tidal energy developments given in Table 1.

Stressors
Presence of devices: static effects
Presence of devices: dynamic effects
Chemical effects
Acoustic effects
Electromagnetic effects
Energy removal
Cumulative effects

Receptors
Physical environment: near field
Physical environment: far field
Habitat and invertebrates
Fish: migratory
Fish: resident
Marine mammals and seabirds
Ecosystem interactions

Table 1: Example of environmental stressors and receptors associated with tidal energy developments (United States Environmental Protection Agency, 2015)

Within this framework, it is therefore a matter to systematically identify and evaluate the relationships between all stressors and their impact on receptors. In order to achieve this, a set of environmental functions have been specifically designed, as well as a scoring system to build a framework of scenarios that are able to:

Qualitatively and quantitatively characterize the effects of the different stressors for tidal and wave array developments;

Quantitatively estimate exposure (and risk) to receptors;

Provide environmental impact assessment estimates (through the scoring system) to inform array design decisions.

Based on this conceptual approach, when assessing the environmental impacts the array development phases are collection into two groups as follows:

1. Installation, O&M and decommissioning phases
2. Exploitation phase

Indeed, the installation, O&M and decommissioning phases often generate significant but short-term impacts, whilst the impact of the exploitation phase is often lower in magnitude but occur over a longer time period.

III. ENVIRONMENTAL FUNCTIONS OVERVIEW

In order to assess the potential environmental impacts of tidal and wave arrays for these two phases, a set of generic environmental issues have been specifically selected and described. These are shown in Table 2.

Function's name		Brief description
Footprint		Evaluation of the footprint impact of the array components
Collision risk		Evaluation of collision risks between fauna (marine mammals, fish and birds) and devices
Collision risk vessel		Evaluation of collision risks between fauna (marine mammals, fish and birds) and vessels
Energy modification		Evaluation of impact of the energy modification due to the array
Noise (underwater)		Evaluation of the impact of underwater noise produced by the array (devices, moorings, electrical components, installation and maintenance operations)
Electric fields		Evaluation of the electric fields from the electrical components
Magnetic fields		Evaluation of the magnetic fields from the electrical components
Chemical pollution		Evaluation of potential chemical pollution due to devices or facilities in the array (eg oil leaks, antifouling leaks...)
Turbidity		Evaluation of the intensity of the modification of the turbidity in the water column due to the array
Temperature modification		Evaluation of the impact of the water temperature modifications around electrical components
Reef effect		Evaluation of the impact of the creation of new habitats from device's parts (mainly foundations)
Reserve effect		Evaluation of the reserve effect (safe area) due to array area where no fishing activity is allowed
Resting place		Evaluation of the impact of emerged parts of the devices as resting place for pinnipeds and birds.

Table 2: List of environmental impacts assessed by DTOcean

Each issue is specifically allocated to the different DTOcean modules (Hydrodynamics, Electrical Sub-Systems, Mooring and Foundations...), as each module generates different stressors depending on its purpose. Table 3 shows which issues are assessed for each of the DTOcean modules. As can be seen, the computational modules with the highest number of issues are the Hydrodynamics and the Electrical Sub-Systems modules.

Considering these issues for all the modules results in 13 specific environmental functions, with specific input values depending on the module. These functions quantify the pressure generated by the devices and their components.

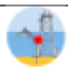
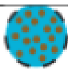
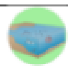
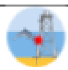
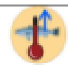
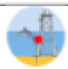
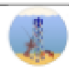
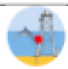
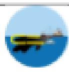
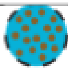
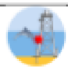
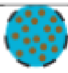
Module / Issue	Energy modification	Footprint	Collision risk	Collision risk vessel	Chemical pollution	Turbidity	Noise (underwater)	Electtric fields	Magnetic fields	Temperature modification	Reserve effect	Reef effect	Resting Place
Hydrodynamics													
Electrical Sub-Systems													
Moorings & Foundations													
Installation													
Operations & Maintenance													

Table 3: Environmental issues associated with each DTOcean modules

IV. SCORING SYSTEM PRINCIPLES

The use of environmental functions allows the EIA to generate numerical values (function's scores) that will be converted to an EIS ranging from +50 to -100 (scale shown in Figure 1).

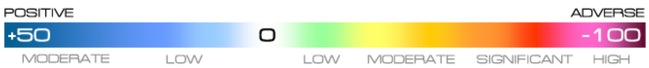


Figure 1 : Example EIS scale

The scoring allocation system developed within the EIA is generic for each environmental function and is shown in Figure 2. The main principle for the different steps is summarized below and is based on three main steps:

STEP 1: quantification of the 'pressure' generated by the stressors

The quantification of the pressure is obtained from the environmental functions selected and the produced Pressure Score (PS). The PS is then adjusted to a new numerical value called the Pressure Score adjusted (PSa) through a 'weighting protocol' by multiplying the PS with a coefficient ranging from 0 and 1. This happens if local environmental factors exist, which are independent from the receptors, and are not included in the function's formula. If no weighting is selected, a default value of 1 used.

At this stage the level of confidence is at its lowest value of 1.

STEP 2: basic qualification of the occurrence (or absence) of receptors

The second step is triggered if the user is able to indicate the existence of receptors onsite. Step 2 uses the score initially generated in step 1 and then adjusts it depending on the receptor's sensitivity by multiplying the PSa with the Receptor Sensitivity coefficient (RS), which ranges from 0 to 5, unless the user has no receptor data, in which case the RS is assumed to be at its maximum value 5. This process leads to the Receptor Sensitivity Score (RSS). The different receptors are gathered within main classes reflecting their sensitivity to pressure. The user will have to choose between these different main classes of receptors that will be characterized by having RS values ranging from 0 to 5 for low to high sensitivity, respectively. When several receptors are identified onsite, the most sensitive receptors will be considered for the EIS calculations. To ultimately obtain the EIS a linear mapping is applied and specific calibration tables are used to convert RSS to EIS. In the case where the user declares a receptor that is regulatory protected (list provided by the database), by default this will automatically lead to an EIS of -100.

If the user is able to provide details about the existence of receptors, the level of confidence increases to medium, corresponding to the value 2.

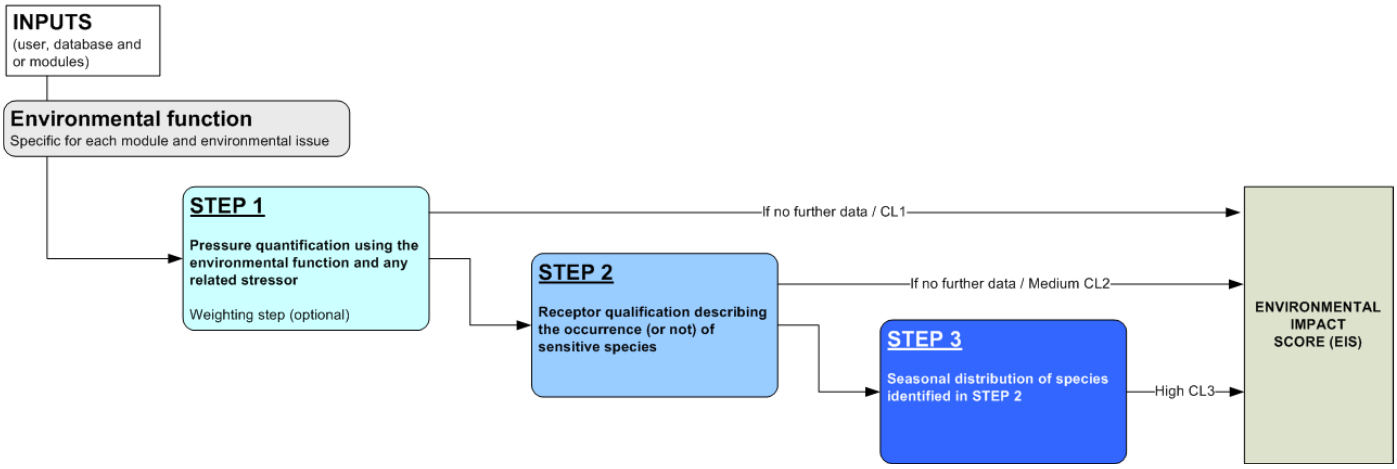


Figure 2: Scoring architecture for the Environmental Impact Assessment Module (EIAM)

STEP 3: qualification of the seasonal distribution of receptors

The last step is triggered if the user has monthly data for the existence of receptors onsite. The step then modulates the final EIS to take into account less sensitive receptors when the highest sensitive receptors are declared absent. Step 3 is similar to step 2 for each specific receptor declared onsite and the EIS is equal to 0 for any receptors absent in a particular month. For each month, the EIS is given by the most sensitive species present.

If the user has such monthly data, the level of confidence is at its highest value of 3.

As most marine mammals, birds and reptiles are protected by European regulations (Bonn convention, Berne convention, Birds directive, Ascobans, Accobam…), a “red list” has been established in the EIAM for those with the highest level of protection. The user has the possibility to indicate the occurrence of one (or more) of these protected species on top of the main receptor categories.

The list is presented in Table 4. The 26 species are baleen whales species classified by the annex I of the Bonn Convention. The bird species in the list are also classified by the annex I of the birds directive and the reptiles species by the annex IV of the Habitats directive.

Baleen whales	Sei whale
	Blue whale
	Fin whale
	North Atlantic right whale
	Humpback whale
Toothed whales	Long finned pilot whale
	Risso s dolphin
	Killer whale
	Striped dolphin
	Rough toothed dolphin
	Common bottlenose dolphin
	Sperm whale
	Harbour porpoise
Seals	Mediterranean monk seal
Birds	Lesser White-fronted Goose
	Red-breasted Goose
	Slender-billed Curlew
	Steller's eider
	Audouin's Gull
	White-tailed Eagle
Reptiles	Loggerhead sea turtle
	Green sea turtle
	Kemp's Ridley
Fish	Great White Shark
	Basking shark
	Sturgeon

Table 4: List of protected species

Reminder: If the user declares the presence of a receptor that is highly protected in the European regulations so included within the “red list” (list provided internally in the tool), by default this choice will automatically lead to an EIS of -100.

V. RESULTS

In order for the user to have both a global environmental assessment and detailed information when using the DTOcean software, two levels (L1 and L2) of results will be available within the software. The relationships between the levels will also be made available. At each level, adverse and positive impacts are always given separately. The different display levels are defined as follow:

Level 1: The first level of assessment provides a global (agglomerated) EIS given for each module. The result for each module is generated by the summation of EIS obtained by each function selected for that specific module and normalised on the scale ranging from +50 to -100. This level also contains the range of impacts associated with the EIS for each module. A graphical example of the level 1 results is given in Figure 3.

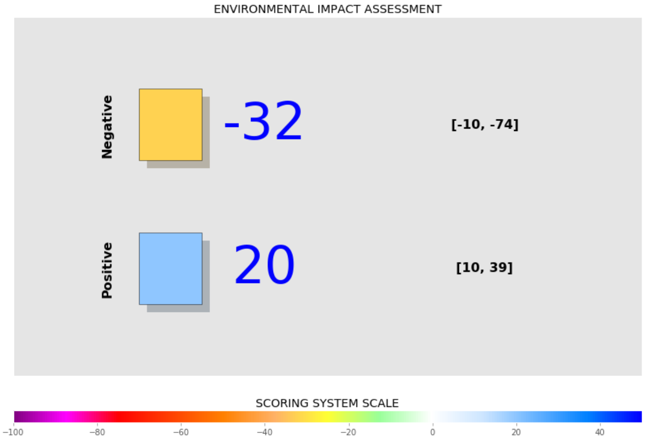


Figure 3: Illustration of the module environmental impact global score display

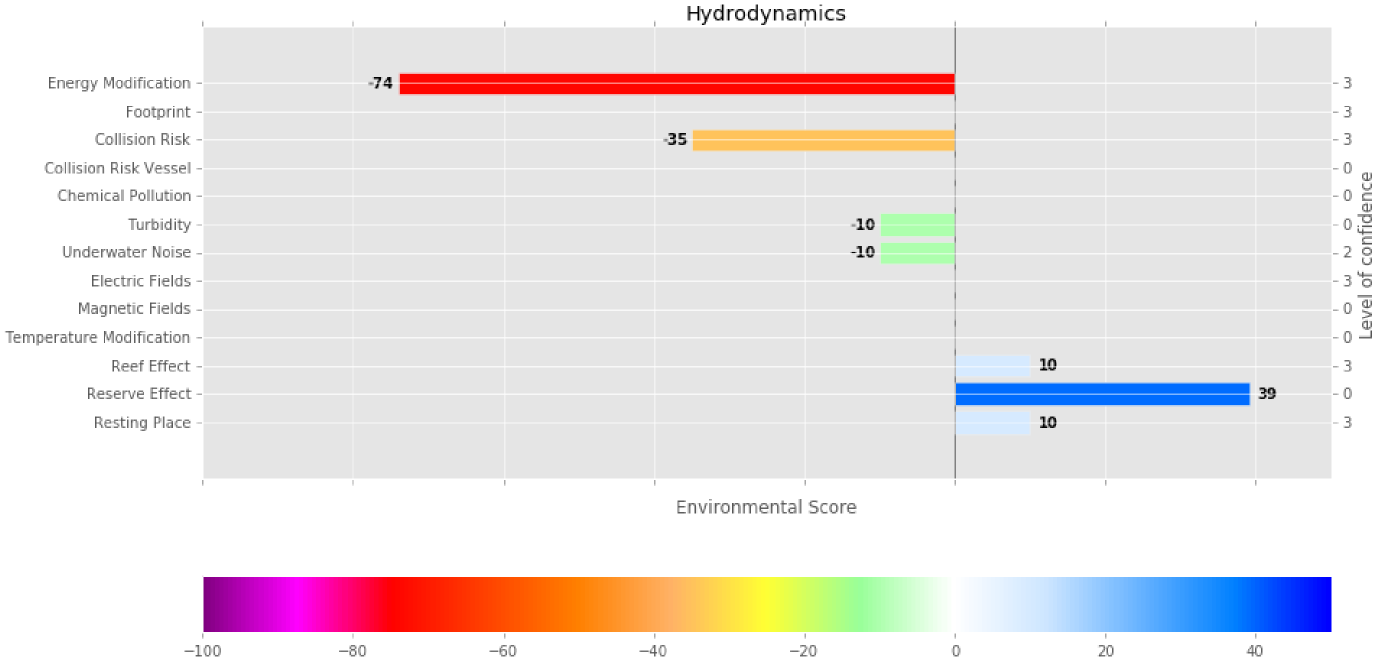


Figure 4: Illustration of the module environmental impact score display detailed by function

Level 2: The second level provides full details at the function level. This level also contains the level of confidence associated to the EIS for each function. A graphical illustration of this level is shown in Figure 4.

A set of recommendations is also implemented in the EIAM module. Its purpose is to help the user to better understand what lies behind the scores in term of qualitative issues related to the pressure scores. The recommendations are specific and a set of recommendation is available for each function of the modules. They are available through the Graphical User Interface (GUI) when EIS are displayed. Examples of recommendations are given in Figure 5.

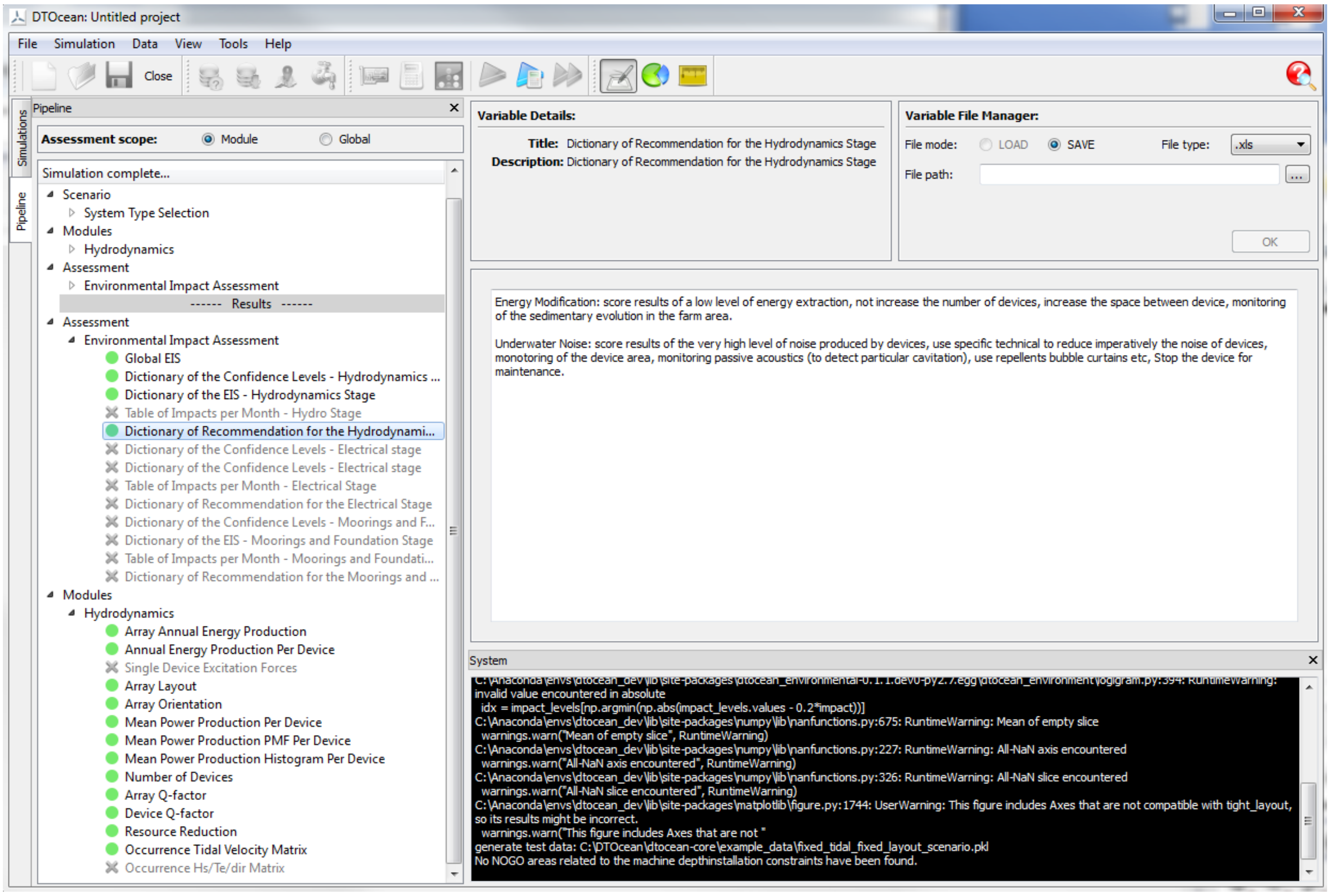


Figure 4: Illustration of the DTOcean Graphical User Interface (GUI) and one set of recommendations from the environmental impact module assessment.

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