Deliverable 6.6: Report on environmental impacts of O&M

Lead partner:	France Energies Marines
Contributing partners:	France Energies Marines - Fraunhofer
Authors:	Karine Charbonier, Sébastien Ybert, Philippe Monbet.

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Abstract

This report presents DTOcean Deliverable 6.6. It consists of a comprehensive description of the environmental impacts related to Operations & Maintenance (O&M). All marine operations related to inspection, maintenance and repair lead to environmental impacts due to vessel traffic, noise emissions, handling of mooring lines, anchors and cables etc.

This report identifies and describes the environmental impacts of O&M. There are multiple expected potential environmental impacts. However, issues related to footprint, collision risks, underwater noise, increase of turbidity and chemical pollution are considered as the most relevant. A description of all these environmental impacts are given.

This report also describes the different environmental functions specifically designed for DTOcean in order to quantify the potential impacts using the Environmental Impact Assessment Module (EIAM). This module is based on several scoring principles to generate numerical values that will be converted to environmental scores (EIS - Environmental Impact Score).

Finally, environmental impacts are discussed regarding the different maintenance strategies. An example and some recommendations are provided.

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1 INTRODUCTION

Operations and maintenance (O&M) activities are essential operations for the development of Marine Renewable Energies (MRE) as they organize the flow of resources required to perform the various activities during the development, inspection and maintenance stages of future arrays. Such O&M activities drive inevitable environmental issues. The presence of vessels and equipment during a given period, causes some pressures on the marine environment. These pressures can be physical, chemical or biological. The large variety of vessel types used for O&M create impacts of different levels within the area of the farm of ocean energy devices. For instance, during the inspection and maintenance activities, a turbidity disturbance or a rise of underwater noise can occur and disturb species and special habitats living in the area. The period chosen for the activities of inspection and preventative maintenance have to be selected with respect to species seasonality in order to limit the disturbances.

Within the framework of DTOcean, different pressures are considered in order to ultimately determine an environmental impact score associated with each major O&M phase. Five main environmental impacts have been identified as significant:

- the footprint,
- the collision risk,
- the potential rise of turbidity,
- the underwater noise,
- the risk of chemical pollution.

To help the quantification of the environmental impacts during the operation and maintenance phases, the DTOcean vessels and tools databases have been used (see Work Package 5 “Lifecycle Logistics” deliverables).

2 ENVIRONMENTAL IMPACTS AND O&M

2.1 O&M ACTIVITY TYPES

O&M comprises of two distinct streams of activities. Indeed, "operations" refers to activities contributing to the high level management of the asset and "maintenance" is the up-keep and repair of the physical plant and systems. Maintenance can be divided into preventative maintenance and corrective maintenance. Preventative maintenance includes proactive repair to, or replacement of, known wear components based on routine inspections or information from condition monitoring systems. It also includes routine surveys and inspections. Corrective maintenance includes the reactive repair or replacement of failed or damaged components. It may also be performed batch-wise when serial defects or other problems that affect a large number of MRE devices need to be corrected [1]. Table 1 presents a non-exhaustive description of generic maintenance activities for wave and tidal devices, and the related required mobilised vessels and tools.

Table 1: List of O&M repair action in the case of preventive or corrective maintenance

DESCRIPTION OF THE TYPE OF MAINTENANCE	MOBILISED VESSELS AND TOOLS
Inspection or maintenance of topside element (either floating or surface-piercing bottom fixed).	Multicat / Crew transfer vessel / Helicopter / but no equipment
Underwater inspection or maintenance onsite at water depth < 30 meters	Multicat + diver team / crew transfer vessels (CTV) +diver team / diver support vessels + diver team
Underwater inspection or maintenance onsite by means ROVs	Multicat + inspection ROV / crew transfer vessels (CTV) + inspection ROV / multicat + workclass ROV / crew transfer vessels (CTV) + workclass ROV
Onsite maintenance of the mooring system	Multicat / crew transfer vessels (CTV) / helicopter / but no equipment
Onsite maintenance of static power cables (export and inter-array cables)	Cable repair Vessels (CRV) + workclass ROV / Cable repair Vessels (CRV) + burial ROV / CRV + workclass ROV + excavating tools

DESCRIPTION OF THE TYPE OF MAINTENANCE	MOBILISED VESSELS AND TOOLS
Retrieval of devices or array sub-component from site to shore for repair at port	AHTS + inspection ROV or divers (depending on water depth)/ tugboat + inspection ROV or divers / multicat + inspection ROV or divers / jack-up vessels + inspection ROV or divers / jack-up barge + tugboat + inspection ROV or divers / crane vessel + inspection ROV or divers / crane barge + tugboat + inspection ROV or divers.
Retrieval of devices or array sub-component from site to shore for repair at port with on-deck transportation	Multicat + ROV System workclass/ Multica + offshore diving team / Tugboat + ROV system workclas/ Tugboat + offshore diving team / Anchor Handling Vessel + ROV system workclass/ Anchor Handling Vessel + offshore diving team
Retrieval of mooring line or umbilical	Jack-up + ROV system inspection / jack-up vessel + offshore diving team / jack-up barge + tugboat + ROV system inspection / jack-up barge + tugboat + offshore diving team / crane barge + tugboat + offshore diving team / crane vessel + inspection ROV or divers / crane vessel + offshore diving team

2.2 O&M RELATED ENVIRONMENTAL IMPACTS

Different maintenance and operation activities can lead to environmental impacts. Vessels and tools can also generate a set of environmental effects. Within DTOcean and with regards to O&M, five significant environmental impacts are considered:

- Footprint,
- Collision risks,
- Underwater noise,
- Increase of turbidity,
- Chemical pollution.

The following sections describe each of these five environmental issues (Table 2).

Table 2: List of O&M repair action and environmental functions associated

DESCRIPTION OF THE TYPE OF MAINTENANCE	ENVIRONMENTAL FUNCTIONS ASSOCIATED
Inspection or maintenance of topside element (either floating or surface-piercing bottom fixed).	Collision risk
	Chemical pollution
	Noise
Underwater inspection or maintenance onsite at water depth < 30 meters	Collision risk
	Chemical pollution
	Noise
Underwater inspection or maintenance onsite by means ROVs	Collision risk
	Chemical pollution
	Noise
Onsite maintenance on the mooring system	Collision risk
	Chemical pollution
	Noise
Onsite maintenance on static power cables (export and inter-array cables)	Collision risk
	Chemical pollution
	Noise
	Footprint
	Turbidity
Retrieval of devices or array sub-component from site to shore for repair at port	Collision risk
	Chemical pollution
	Noise
	Footprint
	Turbidity
Retrieval of devices or array sub-component from site to shore for repair at port with on-deck transportation	Collision risk
	Chemical pollution
	Noise
	Footprint
	Turbidity

DESCRIPTION OF THE TYPE OF MAINTENANCE	ENVIRONMENTAL FUNCTIONS ASSOCIATED
Retrieval of mooring line or umbilical	Collision risk
	Chemical pollution
	Noise
	Footprint
	Turbidity

2.2.1 FOOTPRINT

Replacement of large or heavy items requires a crane barge service to ensure sufficient stability during lifting operations. These have typically been jack-up vessels but floating dynamically positioned, or anchor spread supported vessels, can also be used. Seabed can be degraded due to the anchoring systems themselves (and possibly the dragging of the anchoring lines). In this case, the main risk is the destruction of local habitats and associated communities. The environmental impact is directly related to the area of seabed contact under the footprint of the anchoring systems.

The main direct biological effect is the habitat removal affecting infauna (organisms living within the sediment) for mobile sediment (usually sands), epifauna (organisms attached to coarse sediments and rock) for coarser sediments like gravels, pebbles and cobbles. Infaunal communities consist of species that mainly burrow below the surface sediment. Energy exposure and sediment granulometry are the main factors that determine the nature of the infaunal communities. Thus, muddy sands will host bivalves, urchins or polychaete worms, as gravels and coarse sands will tend to host larger species such as molluscs, anemones and other polychaete worms. Epifauna can be composed of polychaete worms, barnacles, colonial ascidians, anemones; ophiuroids, sponges, bryozoans or hydroids within subtidal coarse (gravels) and mixed sediments (gravels, sands and muds). The loss of these communities indirectly affects the surrounding ecosystem with a particular effect on the mobile and errant species like crustaceans, molluscs, echinoderms and pisceans as they prey upon infauna and epifauna. As most infaunal and epifaunal species live in the top layer of the sediment (0.5m) and on the surface of the sediment respectively, any process such as abrasion, subsurface penetration and disturbance, that will affect this sediment layer will have an effect on these communities. Recovery time after alteration may vary from months to years. Hill et al.[2] estimated that biotopes can recover within a period ranging from 6 to 24 months for high energy environments with medium fine sediment. Biotopes associated with coarser sediment are expected to recover over longer times ranging from 8 years to more than 15 years [3]. Dernie et al. [4] also studied recovery rates of benthic communities following physical disturbance. These authors showed that clean sand communities had the most rapid recovery rate following disturbance, whereas communities from muddy sand habitats had the slowest physical and biological recovery rates.

2.2.2 COLLISION RISK

Categorized under 'collision risk' is consideration of the interactions between marine wildlife (mammals and birds) and vessels that may result in physical injuries. Indeed, O&M activities imply an unusual number of vessels within the project development area. As such, this may increase the risk of collision between vessels and marine wildlife. Chemical pollution resulting from vessels interactions themselves is treated in a separate environmental impact function.

Although not very well documented, the risk of collision between ships and marine mammals exists. Ship strikes are a known cause of mortality for both whales and dolphins worldwide and strikes are far from infrequent however the majority go unnoticed [5]. The main drivers identified to influence the number and severity of ship strikes are:

- Vessel type. Even though all vessel sizes and vessel classes are involved in collision with marine mammals, most fatal casualties are due to large vessels (more than 80 m length),
- Underwater noise as high levels of ambient noise can result in difficulty in detection of approaching vessels,
- Weather conditions and time of navigation can directly affect the ability of crew to detect or avoid marine mammals
- Mammal's specific behavior during specific feeding, preying or resting time
- Mammal's conditions as juvenile and sick individuals appear to be more vulnerable

Several factors affecting some aspects of bird species' behavior including ship and helicopter traffic have been recognized as important for offshore wind. Furness et al. [6] showed that marine bird species vary in their reactions to the ship (and helicopter) traffic that occurs during maintenance operations. Even if no significant operational experience is yet available, the same type of disturbance is also expected for wave and tidal developments during the installation and maintenance phases.

In particular, in the context of the installation phase, sea birds can be vulnerable to the presence of ships, especially due to vessel noise or enhanced light conditions during night operations [6]. Indeed, birds are attracted to lights and bird strikes commonly occur during darkness and heavy fog. High intensity lights used as navigation aids can attract birds in the fall season, often resulting in birds colliding with ship structures [7].

2.2.3 UNDERWATER NOISE

O&M activities can generate underwater noise through vessel traffic, but also due to other marine operations for example, repairs of foundations, device structures, cables or even underwater surveys (ROVs, divers). The quantification of underwater noise due to wave and tidal devices is still poorly known and documented.

Environmental effects related to noise are expected on marine life through a variety of ways. Marine mammals can adapt to a wide variety of natural sound and have adaptive mechanisms to many anthropogenic sounds. The frequencies that can be heard from marine mammals range from less than 100 Hz up to 180 kHz, making predictions of potential effects challenging. However, when anthropogenic sounds are excessive in level, frequency or even duration, they might exceed the mammals adaptive capacity and then cause the following main effects (see details in [8]):

- Physical injuries: with permanent threshold shifts or loss of hearing sensitivity resulting from either a brief exposure to very intense sounds or a longer duration to moderately intense sounds, or intermittently but repeatedly, to sounds sufficient to cause temporary threshold shifts [9].

- Physiological Reactions: with sound exposure that causes non-auditory physiological effects such as stress and tissue injury.
- Masking: when sounds are more difficult to hear because of added noise affecting a mammal's behavior in detection and interpretation. Masking may affect (1) reproduction if a female cannot hear potential mates vocalizing at a distance, (2) mother-offspring bonding and recognition if the pair cannot communicate effectively, (3) foraging if animals cannot detect prey or animals that hunt cooperatively cannot communicate, and (4) survival if an animal cannot detect predators or other threats.
- Behavioral responses: following the detection of sounds, mammals can change in habitat use to avoid areas of higher sound levels, modify patterns such as diving and surfacing or vocalizing for example.

As with mammals, fish are characterized by a wide range of hearing structures, resulting in different capacity and sensitivity to noise. They use biological noise to gain information about their surrounding environment in order to locate their prey and predators or even communicate. Noise may generate physical injury, hearing loss and behavioral changes. In their review paper on several European fish, Gill and Bartlett [10] indicated that fish that receive high intensity sound pressures (i.e. close proximity to the MRE construction) may be negatively impacted to some degree, whereas those at distances of 100s to 1000s of meters may exhibit behavior responses. However, the impact is unknown and will be dependent on the received sound. During operation there may be more subtle behavioral effects that should be considered over the life time of the MRE development. Slabbekoorn et al. [11] also stated that very loud sounds of relatively short exposure, can harm nearby fish.

For birds, noise is considered as an indirect effect as it may cause a reduction in fish abundance and therefore reduce food resources. For both mammals and fish, displacement is also another potential effect generated by noise where devices are deployed, but this effect is hardly quantifiable.

Overall noise produced during O&M is expected to be restricted at certain time of the year however, if arrays are significant in size and depending on the O&M strategy, underwater noise generated by O&M could last longer.

2.2.4 TURBIDITY

Turbidity gives an indication of the concentration of suspended particles in water as it represents the cloudiness or haziness of a fluid caused by large numbers of individual particles. MRE developments can modify the turbidity of ecosystems, especially during the installation and O&M phases, while activities necessitate interacting with the sediment. Marine operations such as dredging generally generate high turbidity waters through local resuspension of sediment particles in the water column. Jack up vessels or barges can also locally increase the concentration of suspended particulate matter (SPM) due to the disturbance caused by their legs/studs.

The modification of the turbidity related to the electrical components mostly occurs during the installation phase. However, it can happen during inspection for O&M purposes. Overall, turbidity issues are related to the nature of the sediment and local hydrodynamics. Impacts usually remain limited to the space around the O&M activity area. The difficulty to quantify this kind of impact is related to the high variability of turbidity in coastal waters. Typical concentration values range from a few mg/l to hundreds mg/l during storm events, or near estuarine areas.

High turbidity in the water column can modify light penetration and therefore affect phytoplancton and submerged seaweed and plants by temporarily reducing productivity and growth rates, which would in turn also impact the organisms dependent upon them for food and shelter. Reduced photosynthesis can also result in a lower daytime release of oxygen into the water. Overall, unnaturally high turbidity levels can lead to a reduction in the production and diversity of species. However, very high levels of turbidity for a short period of time may not be a significant issue.

2.2.5 CHEMICAL POLLUTION

Marine operations enhance the number of vessels and marine infrastructures that usually contain oil, lubricants and other chemical substances in the same area. For MRE developments, most wave and tidal energy converters also contains oil and lubricants. Therefore, there are potentially enhanced risks of leakages and collisions between the different entities due to vessel traffic during installation, operation & maintenance and decommissioning phases.

The main impacts related to chemical pollution will be the degradation of water quality altering the ecosystem in the vicinity of the accident. Hydrocarbon pollution in marine ecosystems is a well-known and growing global problem [12]. Associated harmful effects are killing organisms, stress on benthic communities [13] and major food chain disturbances [14]. Polmear et al. [13] have also recently shown evidence of toxicity of lubricants on phytoplanctonic community.

Anti-fouling coatings also represent a potential source of chemical pollution. Such coatings are likely to be applied to many sub-systems of ocean energy device arrays. These products contain a wide range of chemicals which have very different chemical properties and therefore differing environmental fates, behavior and effects. Despite being a natural element, copper has been used as an antifoulant for centuries as at a high concentration it is lethal for most marine species. Biocides such as Irgarol 1051 and Diuron have also been widely used over the last decades. There are also new, or candidate, biocides such as triphenylborane pyridine, Econea, capsaicin and medetomidine for which there is very little information in the public domain. The use of antifouling coatings can then introduce high levels of contaminants into the environment, raising some concerns about toxic effects on marine communities. Marine organisms can directly accumulate antifouling contaminants and transfer them to higher trophic levels. If the uptake of the contaminant exceeds the organism's ability for excretion and detoxification, this can reduce normal metabolic functions [15], [16].

The toxicity is directly related to the properties of the contaminant, especially to its bioavailability. Toxicity will increase if a contaminant is more bioavailable. This bioavailability is also driven by the environmental chemical conditions (e.g., temperature and pH) as well as the contaminant affinity for particles (sediment binding). Sediments tend to usually act as a contaminant sink when settled down. However, the re-mobilisation of sediments by natural (storms) or anthropogenic events, such as various marine operations, can be a major source of pollution through the release of contaminants in the water column.

2.3 RECOMMENDATIONS FOR O&M

A set of recommendations has been defined in order to help the user to reduce the impacts on the environment. These recommendations are given below per significant impacts.

Footprint:

- Reduce the number of vessels in the area.
- Have a good knowledge of the sensitive species (such as benthos and other sensitive ecosystem) in the project area.

Collision risk:

- Vessel speed limitation with special care in the sensitive areas. The speed limitation should be applied before reaching the site.
- Limit night or poor weather vessel traffic.
- Limit the vessel light which can attract some species (especially birds).
- Reduce the number of vessels in the area.
- Have a high level of knowledge of the sensitive species (mostly marine mammals) at the ocean energy site.
- Avoid circulating in the migrator corridor.
- Avoid presence at the site during the reproduction period.

Underwater noise

- Carefully choose the period of maintenance in order to reduce the impact on marine mammals.
- Choose the least noisy method of maintenance (type of vessels, tools etc.).
- Use a scaring sound system for marine mammals during any very noisy activities.
- Have good knowledge of the sensitive species in the ocean energy deployment area.
- Reduce the transit speed of vessels on-site.
- Reduce the number of vessels on-site.

Turbidity

- Avoid any embedment activity.
- Prefer gravity based foundations/anchors over other foundation/anchor types.

- Have a good knowledge of the sensitive species in the project area.

Chemical pollution

- Prohibit discharge of wastewater, ballast water and any garbage.
- Limit the number of vessels in the area.
- Limit the utilization of antifouling paints.

3 ENVIRONMENTAL IMPACT ASSESSMENT MODULE (EIAM)

3.1 PRINCIPLE

The whole Environmental Impact Assessment Module (EIAM) is based on several scoring principles detailed in the deliverable 7.2 ' Specification and architecture of a global software tool for ocean energy arrays, with performance models and characteristic curves." Briefly, the use of the environmental functions allows for the EIAM to generate numerical values that will be converted to environmental scores (EIS - Environmental Impact Score). The conversion from the function scores to the environmental scores is made through calibration matrices. Each function is associated with one calibration matrix (or several, depending of the complexity of the function) in order to qualify the initial pressure score that is defined as a numerical value based on the anthropogenic effect generated by the devices or other related items. Calibration matrices are based on literature data, or empirical data, when no sensible data are available.

The scoring allocation system developed within the framework of DTOcean is generic for each environmental function and based on three consecutive main steps as shown in Figure 1:

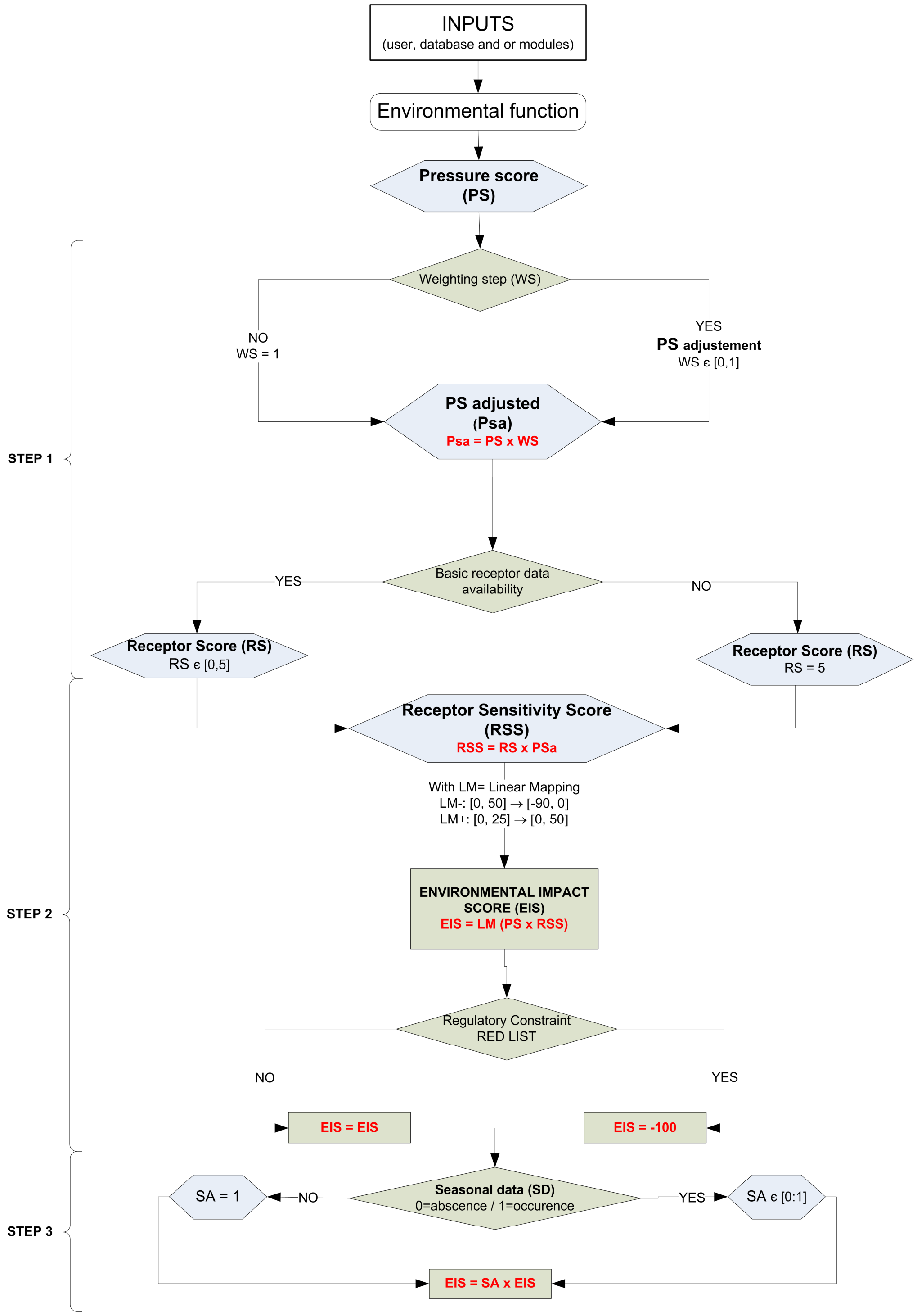

Figure 1: Provisional decisional flowchart for the DTOcean Environmental Impact Assessment Module (EIAM)

Details regarding all the equations and steps are given in the Deliverable D7.2. However, the main principle of the steps is summarized below:

- STEP 1: qualification and quantification of the 'pressure' generated by the stressors
- STEP 2: basic qualification of the occurrence (or absence) of receptors potentially affected by the stressors. If receptors chosen in the basic receptor data availability are also in the list of species protected by regulation, the Receptor sensitivity score does not use the standard qualification of the score, but takes the maximum score of 100.
- STEP 3: qualification refinement of receptors e. g. definition of slot of occurrence during the year where receptors are sensitive (i.e. nesting seasons for birds, breeding seasons for mammals, etc.).

3.2 EIAM FUNCTIONS ASSOCIATED WITH THE MAINTENANCE PHASE

Within this section, all parameters that are involved in the environmental processes are presented. Stressors create the pressure while the receptors are the sensitive animal and vegetal species that are impacted by the stressors. The environmental function uses inputs to produce results. As shown in Figure 1, a weighting factor also occurs in the first step of the evaluation process to better qualify the pressure. If there is no data on this Weighting Score, this stressor is assigned the maximum result as a precaution.

The impacts presented in the O&M activities are associated with the choice of maintenance presented in Table 2. The most relevant impacts regarding O&M activities are footprint, collision risks, underwater noise, increase of turbidity and chemical pollution. The pressures that are generated are mainly associated to vessels and equipment, devices and/or electrical components (outside the devices).

3.2.1 FOOTPRINT

Stressors

Stressors are the physical anthropogenic element that generates the 'footprint' pressure. With respect to O&M operations, the footprint is induced by vessels and equipment which can generate significant interaction with the sediment and lead to habitat degradation during marine maintenance. The footprint is here considered as the total surface area occupied by anchors (incl. mooring lines), ROV tracks etc.

Receptors

Receptors are all the biological (fauna and flora) species which can be impacted by the stressor. Regarding the footprint, the major species that can be impacted are the benthic species (living on the hard and/or soft substrate and particular habitats) and some other species, such as fish classified in the ecosystem group (hard and soft substrate).

Purpose

The footprint function aims at evaluating the pressure on the seabed occupied by equipment and anchors of vessels on the benthos and other species living in the sea bed ecosystem.

Inputs

To quantify the pressure and the impact, some inputs are required, provided either by the DTOcean database or by the user. These inputs are:

- Substrata surface area covered by equipment and anchoring systems (size of the tools or anchors) [m²] obtained through a formula based on the vessel's size (tbc)
- Total surface area of the lease area [m²]

Function's formula

The 'footprint' impact is calculated though the function defined in equation (2.1):

$$Footprint = \frac{Total\ substrata\ surface\ area\ covered\ by\ equipments}{Total\ surface\ lease\ area} \quad (2.1.)$$

Note: The total substrata surface area covered by equipment is the sum of footprints from anchors (incl. mooring lines lying on the seabed, cable burial, concrete mattress, subsea excavating, etc.)

Rule

If the result is 0 then the impact is null or minor. Increasing value corresponds to an increasing impact.

Weighting step

There is no data regarding constraints so the weighting score is calibrated for the worst pressure case using the precaution principal (i.e. the score is 1).

Calibration

Step 1

To qualify scores and calibrations for footprint, an empirical approach has been carried out. This approach is based on 4 ranges of footprint areas vs. lease area (see Table 3).

Table 3: Footprint Pressure Scores

FUNCTION RESULT	PRESSURE SCORE - PSa
<0,1	0
[0,1-0,3]	2
[0,3-0,5]	3
>0,5	5

Step 2

The ecosystem in hard substrata is potentially more vulnerable because species, in terms of number and variability, are richer than in a soft substratum. These species also are less mobile. The types of benthic species are more diversified in hard substrate. For this reason, a score of 3 has been assigned for species living in hard substrata, while a score of 1 has been assigned for species in soft substrata. The Receptor Scores (RS) are based on the nature of the ecosystem (See Table 4).

Table 4: Footprint Receptor Scores

SEABED GROUPS	SEABED TYPES	RS
Ecosystem living in hard substrate (cemented to hard rock soil types)	Rocky mediolittoral habitats, Rocky infralittoral habitats, Rocky circalittoral habitats (coastal and deep)	3
Ecosystem living in soft substrate (cohesion less soil group)	littoral sediment, Infralittoral sediment, Circalittoral sediment (coastal and deep)	1
Particular habitats	Zostera noltii beds, Zostera noltii beds, Maerl beds	4
Benthos	crabs, prawns, starfishes	3

After selecting the appropriate Receptor Score (RS), EIS step 2 can be obtained using the equation (2.2):

$$EIS\ step2 = linear\ mapping\,(PSa \times RS) \qquad (2.2.)$$

<u>Note: individual components of the formula</u>
PSa: Pressure Score Adjusted
RS: Receptor Score
EIS step 2: Environmental Impact computed in this step

In the case where the receptor is 'regulatory protected', the DTOcean database should be able to identify it during Step 2 and then assign the maximum negative EIS score (-100).

Step 3

The final step (STEP 3) takes into account the seasonal distribution of the receptors. If data are available (provided either by the user or the database), the EIS from Step 2 will be evaluated to a new value called *EIS final* using a new matrix containing the information of the receptor's monthly absence or occurrence. If there is data the seasonal score (SA) is allocated with a score of one, and if there is no data the seasonal score is allocated of a score of zero.

$$EIS - Environmental\ impact\ score = SA \times EIS\ step2 \qquad (2.3.)$$

<u>Note: individual components of the formula</u>
SA: Seasonal Score
EIS step 2: Environmental Impact Score computed in step 2

3.2.2 COLLISION RISK

<u>Stressors</u>

Stressors are the physical anthropogenic elements which cause collision risk. In the case of O&M activities, only collision is considered, disregarding entanglement. Vessels used for maintenance can generate a risk during the transport for marine mammals and birds.

Receptors

Receptors include all the sensitive species that can by impacted by the stressor. Regarding the collision risks, the major species that can be impacted are mainly marine mammals. Birds can also be affected by interactions with vessels.

Purpose

The goal of this function is to evaluate the collision risk, between fauna (marine mammals and birds) and vessels.

Inputs

To quantify the pressure and the impact, some parameters or inputs are required. They are provided by the DTOcean database, the other modules or the user. These inputs are:

- Total number of vessels used during the maintenance phase
- Total of the surface area of the lease area [m²]

Function's formula

The 'collision risk' function is calculated as a ratio of number of vessels and equipment during the maintenance phase and the total lease volume area (2.4):

$$Collision\ risk = \frac{number\ of\ vessels}{total\ surface\ lease\ area} \qquad (2.4.)$$

Rule

0 ≤ Collision risk ≤ 1

0 means that the impact is minor and increasing value corresponds to higher impact.

Weighting step

There is no data on the constraints so the weighting score is calibrated for the worst pressure case. It is the precaution principle; the score is one.

Calibration

Step 1

Due to the lack of quantitative data about the risk of collision between megafauna and vessels, an empirical and 'best guess' approach has been implemented. Based on the result of the function's formula, four ranges have been defined as presented in Table 5.

Table 5: Collision Risk Pressure Scores

FUNCTION RESULT	PRESSURE SCORE - PSa
[0-0.01]	1
[0.01-0.1]	2
[0.1-0.2]	3
>0.2	5

Step 2

The next step (STEP 2) is to consider if some species exist in the surrounding area and their degree of sensitivity though a coefficient (Receptor score (RS)) that will lead to the EIS Step 2. Receptor Scores (RS) were obtained from literature and other European regulations.

According to the GUYDRO project [17], marine mammals in Europe have a specific protected status. Cetaceans and pinnipeds are protected by numerous international regulations and texts, such as the Washington convention (CITES) [18], Berne convention [19], Convention on migratory species (CMS) [20], OSPAR etc. They are also directly protected by international agreements such as ASCOBANS [21], ACCOBAMS [22] or the International Whaling Commission [23].

At the European level, the Habitats Directive (Natura 2000) [24] also mentions many species of marine mammals in Annexes IV (species protection) and II (protection of species and their habitats). Finally, the Marine Strategy Framework Directive (MSFD) [25] also shows a close interest in marine mammals and the human activities that threaten them.

An example of RS for marine mammals and birds values is presented in the table below (

Table 6).

Table 6: Examples of Collision Risk for Birds and Mammals Receptor Scores

BIRDS DIVING DEPTH	EXAMPLE OF SPECIES FOR USER	SCORE
Shallow diving	Up to 5m - Fulmar	4
Medium diving	5 to30 m - Shag/Cormorant/Gannet	3
Deep diving	> 30 m - Common Guillemot/Puffin/Razorbill	2

NUMBER OF REGULATIONS CONCERNED	GROUPS	SCORE
[1-3]	Seal	3
[4-5]	Large odontocete, Mysticete or Dolphinids	4
> 6	Odontoncete	5

After selecting the appropriate Receptor Score (RS), EIS-Step 2 can be obtained using the formula (2.5):

$$EIS\ step2 = linear\ mapping\ (PSa \times RS) \qquad (2.5.)$$

<u>Note: individual components of the formula</u>
PSa: Pressure Score Adjusted
RS: Receptor Score
EIS step 2: Environmental Impact computed in this step

During this STEP, the DTOcean database is able to identify a case where the receptor is 'regulatory protected', resulting in the assignment of the maximum negative EIS score (-100).

Step 3

The final step (STEP 3) takes into account the seasonal distribution of the receptors. If data are available (provided either by the user or the database), EIS Step 2 will be evaluated to a new value called *EIS final* using a new matrix containing the information of the receptor's monthly absence or occurrence. If there is data available, the seasonal score (SA) is allocated with a score of one, and if there is no data the seasonal score is allocated of a score of zero.

As shown in Figure 1, the final Environmental Impact Score is ultimately calculated as follows (2.6):

$$EIS\ final - Environmentalimpactscore = SA \times EIS\ step\ 2 \qquad (2.6.)$$

Note: individual components of the formula
SA: Seasonal Score
EIS step 2: Environmental Impact Score computed in step 2

3.2.3 UNDERWATER NOISE

Stressors

Stressors are the physical anthropogenic elements that generate the environmental pressure, in this case, the noise generated during the maintenance phase. The speed and power of vessels and equipment influence the level of the noise.

Receptors

Receptors are all the species (fauna and flora) that can be impacted by the stressors. Underwater noise only impacts the fauna species, as the noise produced by vessels and equipment is a physical pressure that can affect marine mammals and fish.

Purpose

The purpose of this function is to evaluate the impact of underwater noise produced by the vessels and equipment during the maintenance phase.

Inputs

To quantify the pressure and the impact, inputs are required and provided by the either the DTOcean database, the different modules or the user. These inputs are:

- Initial underwater noise (=background noise) (DTOcean database)
- Noise produced by the vessels and equipment (mainly assessed from the speed of vessels and their sizes) [unit: dB re 1µPa (1m)] (user, or database by default)

Function's formula

The 'underwater noise' function (2.7) consists of a comparison (i.e. difference) between the initial underwater noise and the underwater noise level produced by the vessels and equipment (specified above).

$$\textit{Underwater noise} = \textit{comparison between Initial underwater noise (background noise) and underwater noise produced by vessels and equipment} \quad (2.7.)$$

Rule

The noise induced by the vessels is compared to the initial underwater noise to identify if there is an increase of noise (or not). If there is such increase, the risk is major.

Weighting step

There is no data on the constraints so the weighting score is calibrated for the worst pressure case as a precaution (i.e. the score is 1).

Calibration

Step 1

The underwater noise varies mostly depending on the type of vessels (speed, tonnage etc.), the power of equipment, as well as the vibration of equipment. In the DTOcean tool, a formula to deduce the underwater noise induced by a vessel adapted from Ross [26] is employed. The noise of vessels used in the DTOcean tool is presented in the Table 77.

According to Ross [26]
Inputs :
l = vessel size (m)
v = % speed (knots)

For frequencies higher than 500 Hz

$$\mathrm{ls0} = 173.2 - 18 \times \log_{10} f$$

For frequencies lower than 500 Hz

$$Is0 = -10 \times \log_{10}\left(10^{(-1.06\times\log_{10} f - 14.34)} + 10^{(3.32\times\log_{10} f - 21.25)}\right)$$

Power spectral density of radiated noise RPL

$$\mathrm{RPL} = \mathrm{ls0} + 60 \times \log_{10}\left({}^{v}/_{12}\right) + 20 \times \log_{10}\left({}^{l}/_{300}\right)$$

Table 7: Example of vessels noise calculated from Ross's formula (1976) for the DTOcean tool

VESSELS TYPE	NOISE BROADBAND LEVEL [0-500HZ] [dB re 1uPAa	PS-PRESSURE SCORE
crane barge	214,2	5
crane barge	207,4	5
crane vessel	229,4	5
crane barge	203,6	5
crane vessel	239,5	5
crane vessel	216,0	5
crane vessel	216,0	5
tug	211,3	5
tug	202,6	5

This formula takes into account the underwater noise of vessels but not that of the equipment or tools. It is difficult to calibrate the score of the vessel noise because the choice of vessels can change, the transit speed can also change, which is why underwater noise calibration is based on available data for different existing types of devices. Four ranges of underwater level of noise are presented (Table 8):

Table 8: Underwater noise Pressure Scores

UNDERWATER NOISE FUNCTION SCORE (FS)		PRESSURE SCORE (PSa)
no concordance of data (Noise stressor < initial underwater noise)		0
concordance of data **(Noise stressor ≥ initial underwater noise)**	[< 100 dB re 1µPa]	1
	[100 dB re 1µPa-150 dB re 1µPa]	2
	[150 dB re 1µPa-200 dB re 1µPa]	3
	> 200 dB re 1µPa	5

Step 2

To discriminate in terms of sensibility, Step 2 involves three expected types of effects:

- behavioral modification of species,
- TTS - temporary threshold shift,
- PTS - permanent threshold shift.

Behavior effect is considered as a moderate effect unlike TTS and PTS that are considered as major effects because of the potential physiological issues they can generate. Therefore, receptor scores are based on the following assignment:

- Behavioral modification: score 3
- TTS: score 5
- PTS: score 5

Values in each level (Behavioral, TTS and PTS) are also species specific. Some examples are given in Table 9.

Table 9: Example of underwater noise Receptor Scores assigned to different marine species

SENSITIVITY THRESHOLD	SPECIES	EFFECT	RS
< 143 dB re 1µPa	Large Odontoncete, odontoncetes, Delphinids, Mysticetes	behavioural	3
[143-224] dB re 1µPa		TTS	5
> 224 dB re 1µPa		PTS	5
< 160dB re 1µPa	Seals	behavioural	3
[160-200] dB re 1µPa		TTS	5
> 200 dB re 1µPa		PTS	5

After selecting the appropriate Receptor Score (RS), EIS-Step 2 can be obtained using the formula (2.8):

$$EIS\ step2 = linear\ mapping\ (PSa \times RS) \qquad (2.8.)$$

<u>Note: individual components of the formula</u>
PSa: Pressure Score Adjusted
RS: Receptor Score
EIS step 2: Environmental Impact computed in this step

The DTOcean database is able to identify whether a receptor is 'regulatory protected' during this STEP and then assign the maximum negative EIS score (-100).

Step 3

The final step (STEP 3) takes into account the seasonal distribution of the receptors. If data are available (provided either by the user or the database), EIS STEP 2 will be evaluated to a new value called *EIS final* using a new matrix containing the information for the receptor's monthly absence or occurrence. If data is available, the seasonal score (SA) is allocated with a score of one, and if there is no data the seasonal score is allocated of a score of zero.

As shown in Figure 1, the final Environmental Impact Score is ultimately calculated as follow (2.9):

$$EIS - Environmentalimpactscore = SA \times EIS\ step2 \qquad (2.9.)$$

<u>Note: individual components of the formula</u>
SA: Seasonal Score
EIS step 2: Environmental Impact Score computed in step 2

3.2.4 TURBIDITY

<u>Stressors</u>

Stressors are the physical anthropogenic elements that generate the environmental pressure, i.e. the turbidity created during the maintenance activities.

<u>Receptors</u>

Receptors are all the species (fauna and flora) that can by impacted by the stressors. The turbidity pollutants created during the maintenance phase is a physical pressure that can affect benthos and the ecosystem living on cohesion-less soils, cohesive soils or cemented and rocky soils, but also include fishes, marine mammals and sea birds.

<u>Purpose</u>

The purpose of this function is to evaluate the impact of a rise in turbidity during the maintenance phase in the area.

Inputs

To quantify the pressure and the impact, inputs are required and provided by the DTOcean database, the different modules or the user. These inputs are:

- Initial turbidity
- Turbidity measured during the maintenance activity.

Function's formula

The 'turbidity' function consists of a comparison (i.e. difference) between the data of the initial turbidity measured and the turbidity measured during the maintenance activities (2.10).

$$\mathit{Risk\ of\ turbidity} = \mathit{comparison\ between\ initial\ turbidity\ and\ turbidity\ during\ the\ maintenance\ phase} \tag{2.10.}$$

Rule

The rule of this function is to estimate an increase of turbidity between the initial data and data during the maintenance phase. If there is an increase, the risk becomes major.

Weighting step

There is no data on the constraints so the weighting score is calibrated for the worst pressure case using the precautionary principle (i.e. the score is 1).

Calibration

Step 1

The difficulty to quantify this environmental impact is related to the high variability of turbidity in coastal waters (see [27] [28]). Typical concentration range from a few mg L^{-1} to hundreds of mg L^{-1} during a storm event or close to estuarine areas. To quantify the turbidity risk we utilize a binary method which consists of comparing the initial turbidity and turbidity during maintenance activities (Table 10).

Table 10: Pressure Score for the risk of turbidity

RESULT OF THE FUNCTION	PRESSURE SCORE - PSa
no concordance of data (turbidity stressor < the initial turbidity)	0
concordance of data (turbidity stressor ≥ the initial turbidity)	5

Step 2

The ecosystem in hard substrata is potentially more vulnerable when presented with an increase of turbidity because the number and the variability of species are richer than in a soft substrata. That is the reason why a score of 3 has been assigned for species living in hard substrata and a score of 1 has been assigned for species in soft substrata. Marine mammals and birds can also be impacted by the increase of the turbidity but the lack of data and the low potential risk has led to a score of 1 (Table 11).

Table 11: Receptor Scores assigned to different marine species for the turbidity

BENTHIC ECOSYSTEM AND HABITATS		RECEPTOR SCORE - RS
Ecosystem living in hard substrate (Cemented to hard rock soil types)		3
Ecosystem living in soft substrate (Cohesion less soil group)		1
Particular habitats (other)		4
Benthos		3
DEEP SEA BIRDS	**EXAMPLE OF SPECIES FOR USER**	**RECEPTOR SCORE - RS**
0-5m	Fulmar	1
5-30m	Shag/Cormorant/Gannet	2
>30m	Common Guillemot/Puffin/Razorbill	3

FISHES AND MARINE MAMMALS	RECEPTOR SCORE - RS
Elasmobranch	3
Bony fish	3
Marine mammals	3

After selecting the appropriate Receptor Score (RS), EIS-Step 2 can be obtained using the formula (2.11):

$$EIS\ step2 = linear\ mapping\,(PSa \times RS) \tag{2.11.}$$

Note: individual components of the formula
PSa: Pressure Score Adjusted
RS: Receptor Score
EIS step 2: Environmental Impact computed in this step

The DTOcean database is able to identify a case where the receptor is 'regulatory protected' during this STEP and assign the maximum negative EIS score (-100).

Step 3

The final step (STEP 3) takes into account the seasonal distribution of the receptors. If data are available (provided either by the user or the database), EIS step 2 will be evaluated to a new value called *EIS final* using a new matrix containing the information of the receptor's monthly absence or occurrence. If there is data available, the seasonal score (SA) is allocated with a score of one and if there is no data available the seasonal score is allocated of a score of zero.

As shown in Figure 1, the final Environmental Impact Score is ultimately calculated as follows (2.12):

$$EIS\ final - Environmental\ impact\ score = SA\ \times EIS\ step\ 2 \tag{2.12.}$$

Note: individual components of the formula
SA: Seasonal Score
EIS step 2: Environmental Impact Score computed in step 2

3.2.5 CHEMICAL POLLUTION

Stressors

Stressors are the physical anthropogenic elements that generate the environmental pressure, i.e. the risk of pollution created during the maintenance phase. The stressor appears in the transport and handling of chemical pollutants during the maintenance phase.

Receptors

Receptors are all the species (fauna and flora) that can by impacted by the stressors. The chemical pollutants transported by vessels and equipment is a chemical pressure that can affect benthos and the ecosystem living on cohesion-less soils, cohesive soils or cemented and rocky soils.

Purpose

The purpose of this function is to evaluate the impact of chemical pollution during the maintenance phase dues to the presence of vessels in the area.

Inputs

To quantify the pressure and the impact, inputs are required and provided by the DTOcean database, the different modules or the user. These inputs are:

- List of potentially toxic chemical components (fuel, antifouling etc.) transported by vessels and equipment
- List of potentially toxic chemicals handled during maintenance actions
- List of potentially toxic chemical components (fuel, antifouling etc.) present initially in the area

Function's formula

The 'chemical pollution risk' function consists of a comparison (i.e. difference) between the initial presence of components in the area and a list of chemical components transported by vessels (2.13.)

$$\begin{gathered} Chemical\ pollution\ risk = \\ comparison\ between\ chemical\ components\ that\ are\ used \\ in\ the\ farm\ site\ and\ the\ initial\ list\ of\ chemical\ pollutants\ in\ the\ area \end{gathered} \tag{2.13.}$$

Note: List of potentially toxic chemical pollutants is hosted in the database. The user will need to tick the elements in the list in the GUI when using the tool.

Rule

The presence of chemical contents induced by the transport vessels is compared to the initial contents in the area to identify if there is an increase of chemicals in the area. If yes, the risk becomes major.

Weighting step

There is no data available regarding the constraints so the weighting score is calibrated for the worst pressure case using the precautionary principle (i.e. the score is 1).

Calibration

Step 1

Biocides are sometimes used in the offshore environment, most of which have a high level of toxicity. To allocate a score for chemical pollutants, an overview of the literature of the toxic effect of biocides and oil on different organisms is compared. This score is the Pressure Score (PS) (Table 12).

A score of 5 is allocated for the most toxic biocides which affect over 6 species on the list provided, a score of 4 for the biocides which impact more than 2 species on the list and for the bunker oil, and a score of 3 for the biocides which impact just a species and garbage & crude oil.

Table 12: Pressure Score for the risk of chemical pollution

RESULT OF THE FUNCTION		PSa
concordance of data (chemical pollution stressor ≥ initial pollutants in the area)	Irgarol 1051	5
	ZnPT	4
	CuPT	4
	Pyrizine sulfonic acid	4
	Seanine 211	4
	Chlorothalonil	4
	TBT	4
	copper oxide	4
	TPBT	3
	medetomidine	3
	lubricants	4
	Garbage of vessel	3
no concordance of data (chemical pollution stressor < initial pollutants in the area)		0

Step 2

During the second step, the sensitivity of species to the chemical pollution is analyzed. This results in the Receptor Sensitivity Score (Table 13). Six different groups have been considered and an arbitrary RS was attributed to each of these groups:

- Ecosystems living on cemented and rocky soils (the diversity of species is higher than in the soft substrata (cohesive less soils) therefore, the risk is considered higher for these species).
- Ecosystem living in cohesive-less soils (the diversity of species is less than a rocky substrate, but the risk is present because the pollutant particles can be accumulated in the sediment).
- Benthos species
- Fish, marine mammals and birds can be impacted by the presence of oil or garbage in the sea. Toxic particles can be lethal for these species.
- Marine mammals
- Birds

Table 13: Receptor Scores assigned to different marine species for the chemical risk

BENTHIC ECOSYSTEM AND HABITATS		**RECEPTOR SCORE - RS**
Ecosystem living in hard substrate (Cemented to hard rock soil types)		3
Ecosystem living in soft substrate (Cohesion-less soil group)		1
Particular habitats (other)		4
Benthos		3
DEEP SEA BIRDS	**EXAMPLE OF SPECIES FOR USER**	**RECEPTOR SCORE - RS**
0-5m	Fulmar	3
5-30m	Shag/Cormorant/Gannet	3
>30m	Common Guillemot/Puffin/Razorbill	3
FISHES AND MARINE MAMMALS		**RECEPTOR SCORE - RS**
Elasmobranch		3
Bony fish		3
Marine mammals		3

After selecting the appropriate Receptor Score (RS), EIS-Step 2 can be obtained using the formula (2.14):

$$EIS\ step2 = linear\ mapping\,(PSa \times RS) \qquad (2.14.)$$

Note: individual components of the formula
PSa: Pressure Score Adjusted
RS: Receptor Score
EIS step 2: Environmental Impact computed in this step

Step 3

The final step (STEP 3) takes into account the seasonal distribution of the receptors. If data are available (provided either by the user or the database), EIS step 2 will be evaluated to a new value called *EIS final* using a new matrix containing the information of the receptor's monthly absence or occurrence. If data is available, the seasonal score (SA) is allocated with a score of one and if there is no data the seasonal score is allocated of a score of zero.

As shown in Figure 1, the final Environmental Impact Score is ultimately calculated as follow (2.15):

$$EIS - Environmentalimpactscore = SA \times EIS\ step2 \qquad (2.15.)$$

Note: individual components of the formula
SA: Seasonal Score
EIS step 2: Environmental Impact Score computed in step 2

3.3 EXAMPLES

3.3.1 COLLISION RISK – WEST LEWIS PROJECT

Environmental methodology on the collision risk

AIM: evaluation of the collision risk between marine mammals and vessels during maintenance

STRESSORS: vessels and equipment used
RECEPTORS: marine mammals and birds

INPUTS: Total number of vessels used during the maintenance Total of the surface lease area
FORMULA: number of vessels/total surface lease area (~2,8km2)

WEIGHTING STEP: n/a So WS= 1 and PSa= PS x WS

Application: case logistic function 2 (LpM2) underwater inspection onsite at water depth < 30 m

STEP1: Function Score (FS) vs Pressure Score (PS)
West Lewis Project: **2 vessels** during the maintenance

INPUTS:

Total number of vessels used during the maintenance = 2 (multicat + dive boat)

Total surface lease area ~2.8 Km^2

FORMULA:

$$Collision\ risk = \frac{number\ of\ vessels}{total\ surface\ lease\ area}$$

RESULT = 2/2800 = **0.0007**

Table 14: Table of pressure score in the case of the collision risk in O&M

FUNCTION RESULT	PRESSURE SCORE -PSa
[0-0.01]	**1**
[0.01-0.1]	2
[0.1-0,2]	3
>0,2	5

The function result (0.0007) corresponds to the Pressure Score 1.
There is no Weighting Step in this example so PSa (Pressure Score Adjusted) is not calculated here.

STEP2: data available on RECEPTOR

RECEPTORS: Marine Mammals and birds are present in the area.

Receptor Score (RS) can be calculated from (PS). Receptors highlighted are receptors present in the area.

Table 15: Table of Receptor Scores birds and marine mammals

BIRDS DIVING DEPTH	EXAMPLE OF SPECIES FOR USER	SCORE
shallow diving	Up to 5m - Fulmar	4
medium diving	5 to30 m - Shag/Cormorant/Gannet	3
deep diving	> 30 m - Common Guillemot/Puffin/Razorbill	2

NUMBER OF REGULATIONS CONCERNED	MARINE MAMMALS GROUPS	SCORE
[1-3]	Seal	3
[4-5]	Large odontocete, Mysticete or Dolphinids	4
> 6	Odontoncete	5

The maximum score (RS = 4) is kept.

When the user provided the type of receptors in the area, neither has been detected as a species on the red list (maximum of protected regulation).

EIS score Step 2: receptor sensibility

$$EIS\ step2 = linear\ mapping\,(PSa \times RS)$$

EIS= -25

<u>STEP3: data available for seasonal distribution: birds and marine mammals</u>

The *EIS final* score can be calculated from the seasonality score SA.

<u>EIS FINAL SCORE</u>

$$EIS - Environmentalimpactscore = SA \times EIS\ step2$$

Case: marine mammals are missing during spring and summer, or the maintenance is planned in July (for example): **Environmental Impact Score (EIS) = 0**

Conclusion of this example: there are no impacts on marine mammals during spring and summer because marine mammals are in migration but some attention should be taken into account with regard to the presence of birds in the area.

3.4 RECEPTORS SEASONALITY

Birds, marine mammals, fishes and benthos are a concern due to the migratory processes from one location to another. They migrate to adapt themselves to temperature variations in between seasons, and also to satisfy their food requirements when conditions become harsher [29]. The purpose of migration is often related to reproduction or wintering. Regarding MRE arrays, migratory species can be affected, or not, depending of the array locations.

3.4.1 SEA BIRDS

Migratory sea birds carry out displacements on the north-east/south-west axis twice per year for the European Area. The first migration usually occurs during spring (February to May), when birds move to better reproduction sites. The second migration usually occurs from summer to autumn (up to November), when species reach their wintering location.

This period of wintering spreads from the end of autumn to the beginning of the spring. This period varies between species, however this biological cycle has important implications with an increased number of birds in the sea compared with the reproduction period. On the other hand, during the reproduction cycle, sea areas are less visited as a majority of species have relocated inland for nesting, and displacements are restricted to food necessity. This could have some important consequences for choosing when marine operations should be carried out in order to better protect bird species. In this context, Table 16 presents the different periods of critical biological cycles for birds and a recommendation for the best period to carry out marine operations such as maintenance activities (Table 16: Biological status of birds).

Table 16: Biological status of birds

Biological cycles	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Reproduction												
Wintering												
Migratory												
O&M activities												

Legend

Propice period

Maximal period

Best period of maintenance

The best period for the O&M activities to take place (calendar and preventive maintenance) in an attempt to minimize the impact of birds appears to be preferentially in June when only reproduction could be affected. August to November could be an appropriate period that only disturbs birds during their migration. During these two periods, no cumulative effect is expected. At this stage, note that this table is only informative and would require more detail to accurately consider the species and their associated behavior diversity. Various array locations may result in impacts on a variety of species.

3.4.2 MARINE MAMMALS

Marine Mammals are also characterized by a wide range of species, so displacements and migration are diverse. Migratory behaviors are different between mysticetes and odontoncetes. Mysticetes migrate seasonally whereas odontoncetes have no major seasonal behavior changes. These latter live closer to the coast during summer and more offshore during winter. It is difficult to report in detail about the seasonal repartition of different mammal species in Europe. However, the reproduction of marine mammals occurs during spring and summer, and some of migratory behaviors happen in winter and summer (sea Table 17: Biological status of marine mammals).

Table 17: Biological status of marine mammals

	Spring	Summer	Autumn	Winter
Reproduction				
Migratory				
Best period of O&M				

Legend

Maximal period

Best period of maintenance

<u>*Benthos*</u>

Benthos presents a wide range of specie variability. The biological activity is usually maximal during summer when the temperature, food and other conditions are favorable. During winter conditions, the biological activity is reduced. Some species such as decapod crustaceans may travel several kilometers for reproduction purposes. However, there is no migration process for benthos that is similar to the one for birds or mammals. In that context, it is difficult to give the best period of marine operations like O&M in order to minimize the impact on benthic species.

4 CONCLUSION

All marine operations related to inspection, maintenance and repair lead to environmental impacts due to vessel traffic, noise emissions, handling of mooring lines, anchors and cables etc. The pressures generated from O&M activities can be physical, chemical and biological. Within the framework of DTOcean, five pressure cases have been considered as significant during O&M: (1) footprint from vessels or other anchoring systems related to marine operations, (2) collision risks (with mammals) due to increased traffic, (3) rise of turbidity due to the interaction with bed sediments, (4) underwater noise generated by vessels and other tools for repairing devices and (5) risk of chemical pollution due to potential collision between vessels.

This document describes the kind of pressures that can be generated and the related receptors that can be impacted. It also provides details about the five dedicated functions designed for the Environmental Impact Assessment Module (EIAM). The latter is designed to take into account environmental issues within the DTOcean tool. Overall, the EIAM implements three main steps that allow the user to achieve an environmental impact score depending on the details of environmental data provided (by the user and/or available in the DTOcean database). In particular, the third step intends to give the opportunity to specify the temporal seasonal distribution of receptors which has major implications within the tool. As shown in this report, various species, such as sea birds or mammals, exhibit some seasonal migratory or other behavioral features. Therefore, the period chosen for O&M activities could be selected with respect to seasonality of species in order to limit the disturbances and impacts. Some general recommendations regarding these issues are provided within the document. Summer and autumn appear to be the most favorable seasons for carrying out O&M and less disturbing to birds and mammals, respectively. However, due to a high diversity of both birds and mammals, these evaluations still need to be refined regarding the location of the arrays and their related O&M effort. Specific monitoring should be carried out in any case to better define the surrounding fauna and its intrinsic characteristics in terms of sensitivity due to migratory constraints or biological cycles.

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6 ACRONYMS

MRE	Marine Renewable Energy
EIAM	Environmental Impact Assessment Module
EIS	Environmental Impact Score
PS	Pressure Score
PSa	Pressure Score Adjusted
WS	Weighting Score
WP	Work Package
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on Migratory Species
ASCOBANS	Agreement of the Conservation of Small Cetaceans in the Baltic North East Atlantic Irish and North Seas
ACCOBAMS	Agreement of the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Sea
MSFD	Marine Strategy Framework Directive