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ERA Acute – A Multi-Compartment Quantitative Risk Assessment Methodology for Oil Spills

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2017 – 432 Abstract

Awareness of environmental risk and the demand for oil spill response planning associated with offshore marine operations has increased during the last decades. Environmental Risk Assessments (ERAs) are a crucial part of planning and execution of oil and gas (O&G) activities offshore. A sound ERA can support the O&G industry in environmental risk management (ERM) of operations. Authorities and operating companies have requested an updated methodology based on more recent research from oil spill events such as the Deep Water Horizon incident, with the possibility to perform more detailed analyses in e.g. sensitive areas.

ERA Acute was developed to meet these requirements for oil spills. It is a transparent method of quantitative analysis for environmental screenings, full ERAs and Net Environmental Benefit Analyses (NEBAs) of oil spill response options in four compartments: sea surface, shoreline, water column and sea floor. The methodology is grid-cell based and results can therefore be shown in a geographical information system (GIS) for any region globally. The user can identify areas of high risk - for use in decision support and spill response planning - independently of the region. Three levels of detail are defined, depending on availability of data on Valued Ecosystem Components (VEC), suitable for screening purposes or more detailed studies.

Calculations are carried out in two main steps: First, ERA Acute uses input from an oil spill fate and transport model of choice to calculate exposure and impact to VECs in each grid cell and for each simulation. Calculations follow a common methodology framework, applying different mechanisms of exposure and impact, as well as recovery for each compartment. Impacts are summarized, and in the second step, potential lag- and/or restitution time and risks are calculated for each VEC at a monthly resolution. The resulting final resource impact factor (RIF) is an index that combines the extent of impact and recovery time. A statistical approach is used, based on numerous oil spill simulations covering each season in order to capture variations in spill drift and fate, species abundance and vulnerability.

This poster describes the methodology in brief, including some of the many application possibilities. The ERA Acute methodology is currently being documented through sensitivity studies, validations against field data from selected spill incidents and comparison to relevant, currently used ERA methods. The methodology will be disseminated in several steps including publications and a guideline for best industry practice.

Introduction - What is ERA Acute?

ERA Acute is a methodology for environmental risk assessment of acute oil spills, which uses continuous risk functions. The model can be used at several levels of detail with respect to data on sensitive natural resources. Screening-level analyses can be carried out with few data, whereas more details on the presence of resources and knowledge of recovery parameters allow for more detailed results to be obtained in the assessment.

Impacts and risks are modeled in four environmental compartments: sea surface (SS), water column (WC), shoreline (SH) and sea floor (SF). A common impact calculation framework provides the basic methodology, whilst maintaining the scientific integrity of each of the four compartments. Impact and restitution modelling is based on the different mechanisms of exposure and harmful action of oil to the impacted species in each environmental compartment. Grid-cell based results are useful for preparing maps displaying impact in specific areas, suitable for oil spill preparedness planning and risk management of sensitive areas.

Current project status

The risk assessment calculation steps for ERA Acute have been developed and documented, as well as programmed as a core calculator (CC), which is used for testing and validation. Following sensitivity testing, validation, familiarization by comparison to existing models and calibration and adjustments, the methodology will be openly documented in an industry guideline.

Acknowledgements

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Model outline – Initial impact calculation

- Degree of impact is calculated for a population or habitat (the "resource" or VEC), assigned to a primary compartment of exposure to oil.
- For species exposed at the sea surface, inputs from oil spill modelling are coverage and oil film thickness, which together with behavioral and physiological parameters determine the probability for a given individual to encounter a lethal amount of oil (Bjørgesæter & Krajczyk, 2015).
- In the water column, the input is THC-concentration to an SSD-curve (Nilsen *et al.*, 2006) or a quantitative structure-activity relationship (QSAR) approach (Brönner *et al.*, 2015) which determines toxicity to eggs and larvae and thereby loss of recruitment to the spawning stock.
- For sensitive shoreline habitats, sensitivity is related to Environmental Sensitivity Index (ESI) ranking, the thickness of oiling is calculated to give the length of oiled shore above the threshold (Brude *et al.,* 2015).
- At the sea floor, oil in the sediment is used to calculate the THC-concentrations in the interstitial water through equilibrium partitioning (EqP). Biota-to-sediment accumulation factor (BSAF) calculations determine THC-concentrations in *intra-biota* gut-water. *Infauna* and *epifauna* have a complex array of different exposure routes and impact algorithms (Stephansen *et al.,* 2015).

Basic impact calculation (expected loss) is calculated in each oil drift simulation and each grid cell: **Imp =** $\boldsymbol{p_{exp} \times p_{let} \times N}$ *(generalized formula)* (Spikkerud *et al.,* 2006) where:
(p_{exp})is probability of being exposed to oil given presence of resource in a grid cell, (p_{let}) is the probability of lethal effect given exposure and (N) is population fraction in a given grid cell.

- Three levels of detail can be used to calculate the initial **Imp**, depending on the resolution of the N-value representing the probability of presence or population fraction in the VEC data.
- Monthly resolution of VEC data gives variation of environmental risk in different months.

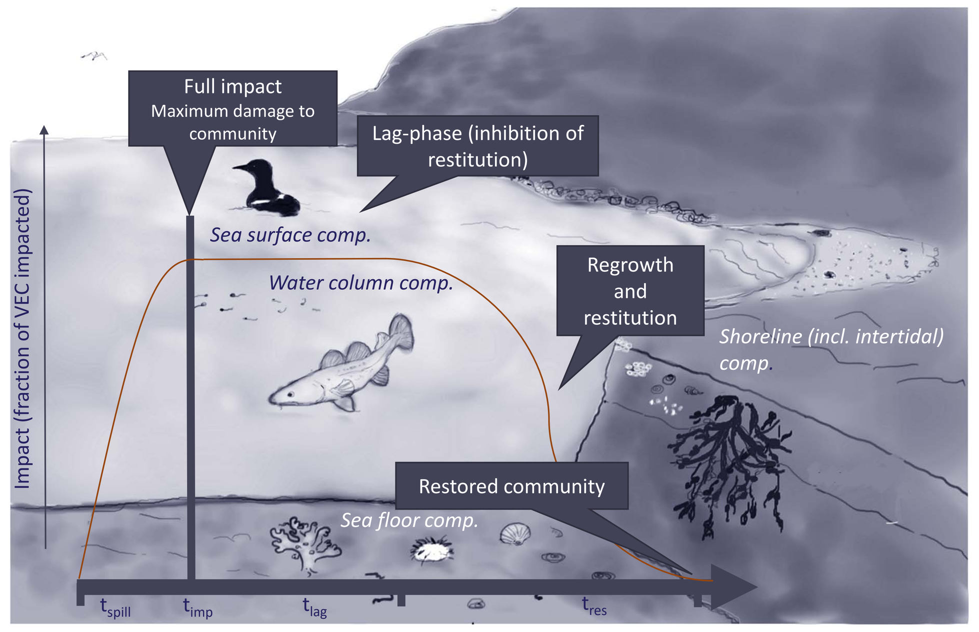

Figure 1. Illustration of the impact and time-factors of ERA Acute. The total summarized resource impact extent and duration of the damage is represented by the area under the curve (integral), which is simplified in figure 2.

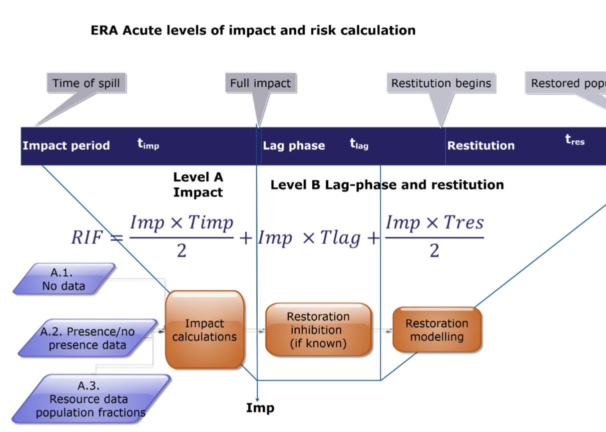

Figure 2. Simplified impact function of ERA Acute. Three levels of detail for VEC data are used. The calculated extent of the total impact to the VEC summarized over all cells and averaged over all simulations are entered into restitution modelling which give lag- and/or restitution times. The three areas comprise the RIF calculation formula to provide a combination of extent and duration.

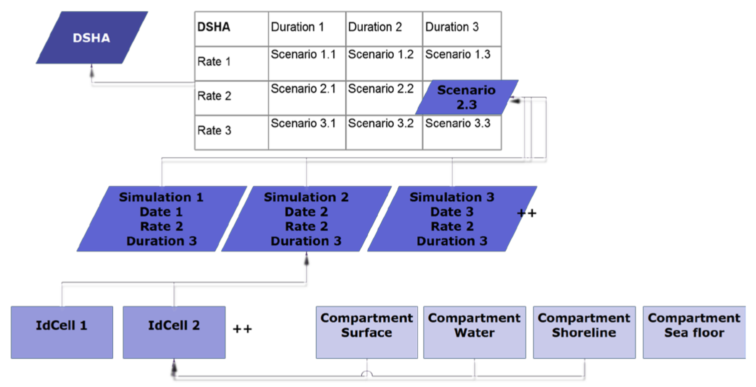

Figure 3. A model case, a Defined situation of hazard and accident (DSHA) can be comprised of several spill scenarios characterized by a spill rate and duration, and with a probability. Each scenario is modelled with several simulations of the oil spill trajectory model representing different outcomes. For each simulation and VEC, impact is calculated in for each cell for each month separately, and then summarized and averaged for the DSHA.

Model outline – From spill simulations impacts to spill case risk

- *Defined Situation of Hazard and Accident (DSHA)* consists of one or several *oil spill scenarios*, each defined by a spill rate and duration, and with a probability of occurrence given a spill incidence. The spill incidence has a probability based on frequencies of the given spill type.
- Each *scenario* is modelled in numerous *simulations*.
- Impacts are calculated at each of these levels. A series of summarizations and statistical presentations are carried out in steps, based on the initial impact calculation in a cell from one simulation, for each VEC (species, habitat or community) in a given month. Monthly resolution is maintained throughout the calculation steps to provide information on variability of risks through the year.
- Statistics and summarizations are carried out for grid cells, simulations, scenarios and DSHA. This gives an *expected average impact* in each grid cell for a spill of a given rate and duration. In the next several calculation steps, scenario probabilities and incidence frequencies are entered, and all scenarios are included to provide measures of total risk for the DSHA case. All steps can be visualized in maps if the results are cell-based and as graphs when summarized over all cells. (See figure 3).
- Each compartment is treated separately (see full list of references). Full descriptions of the following summarization steps are given in Spikkerud *et al.* (2010) and Stephansen *et al.* (2015).

Impact time, lag-phase and restitution modelling

- Total impact is entered into restitution modelling in ERA Acute level B to calculate Impact time (T_{imp}): the time from the spill until full impact (Figures 1 & 2).
- Lag-time (T_{lag}): the time before an impacted population can re-grow to pre-spill status, e.g. due to residual contamination. Restitution time (T_{res}): time it takes to restore the population once it starts re-growing.
- Sea surface compartment: T_{res} for e.g. seabirds and marine mammals is calculated based on the total impact to the population which is entered into a growth model.
- Fish resources: the time until the fish spawning stock is restored is calculated based on reduced recruitment to fish stocks due to loss of eggs and larvae.
- Sea floor compartment: Lag-time for corals and sponges is given as user-input, and in soft substrate sediments it is based on the THC-concentration in the substrate in each cell.
- In the shoreline compartment, the lag- and restitution times are given as a user-input table, (wave energy of the shoreline, ESI type, oil density and degree of oiling of the shoreline).
- Impact-, lag-and restitution times (in years) are combined with the total extent of impact to a VEC (Figure 2), to produce the Resource Impact Factor (RIF), a simplified geometrical area calculation representing the combination of extent and duration.of impact. The unit is "impact-years".

Value for decision-making and environmental risk management

- Many steps of impact and risk calculations allows for a variety of applications for answering questions related to environmental risk management (ERM).
- Steps with grid cell-based results can be shown in a map, and the total number of cells or total average impacted area can be given for a species, etc.
- Example: Figure 4 shows maps of the expected average impact to Atlantic puffins following a assumed crude oil spill of 5000 Sm3/day for 15 days (left) and 2 days (right), from the simulations that started in or lasted into June, when the number of puffins present (*N*) is high.
- Summing up the expected impacts to a VEC over all grid cells in a scenario gives the total average impact in a month to a VEC from a spill scenario of a given rate and duration. This step is useful, e.g. for comparing potential impacts to different species in compartments or between different spill scenarios (Figure 5 left and right).
- Some frequently carried out ERM analyses have been standardized within the ERA Acute project and will be available as ERM applications that are openly documented as industry guidelines as well as modules of the software tool that will be developed. These common applications are ERAs for Authority applications, a comparison module (e.g. for Net Environmental Benefit Analysis (NEBA)) and a risk matrix approach for risk acceptance decision-making.
- Grid-cell based results of impacts and risk contributions to the total risk have special value in decision making for planning activities with a potential impact in sensitive areas, as the impacted areas can be viewed with other contingency-related data, e.g. with areas that are too shallow for chemical dispersion, areas that are inaccessible to Oil Recovery (OR) vessels of a certain size, priority- and protected areas etc.
- Differences in risks at different calculation steps can be compared for two or more DSHAs, for different spill scenarios or the same scenario with and without an array of different oil spill response measures in a NEBA.
- The openly documented methodology is aimed at experts. It will require some degree of user-input and data sets, due to its high level of possible detail. All "default" values can be adapted by the user, allowing for a high level of flexibility with respect to e.g. regional differences in the biological parameters entered, but also requiring that the input data be openly documented, especially when ERAs are compared.

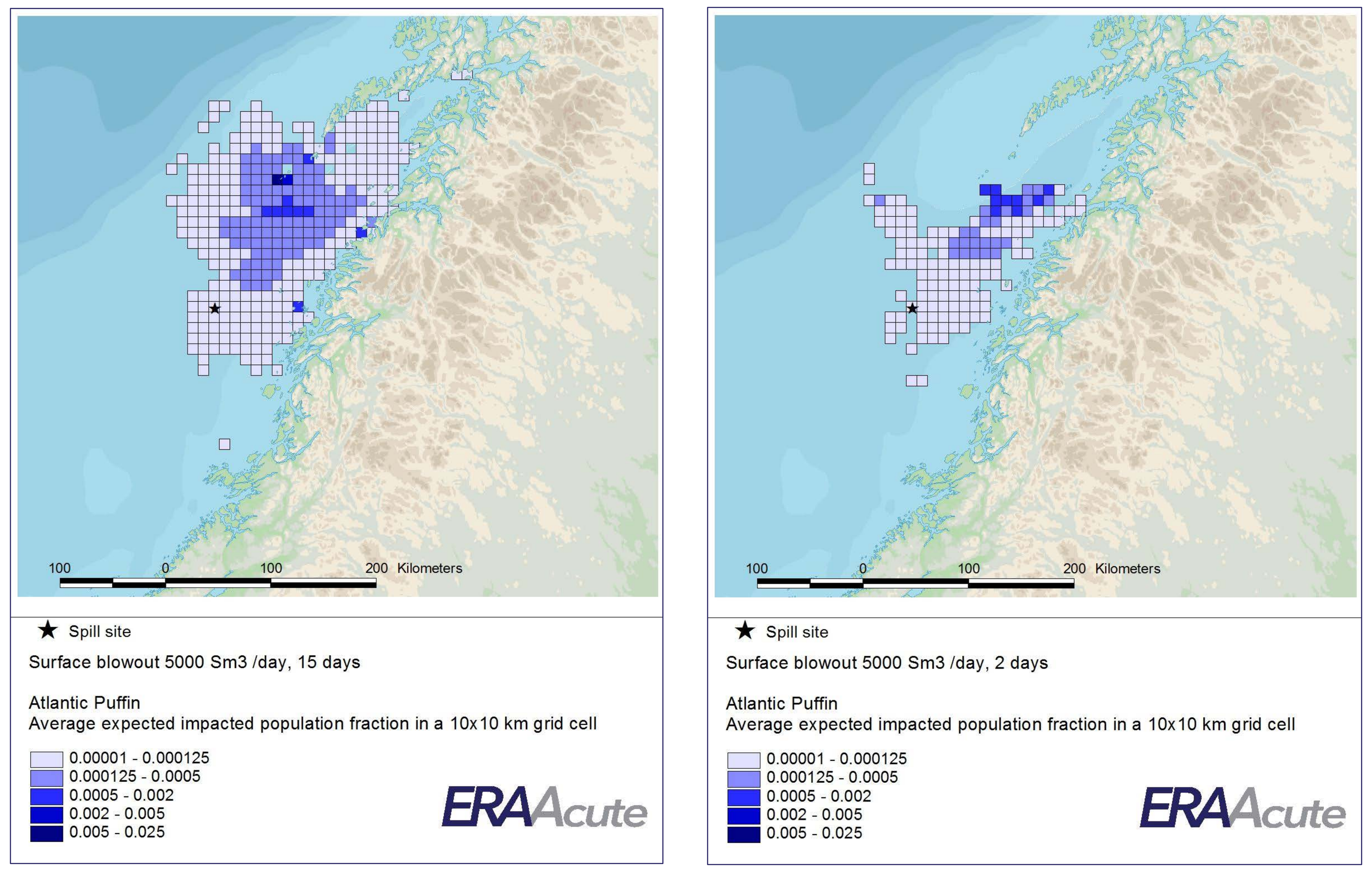

Figure 4. Expected average impacts as impacted fraction of the population in 10x10 km grid cells to Atlantic puffins following a hypothetical spill scenario of 5000 Sm^3/day for 15 days (left) and the same spill stopped after 2 days (right). Impacts are shown as the average of all simulations that started in or lasted until June.

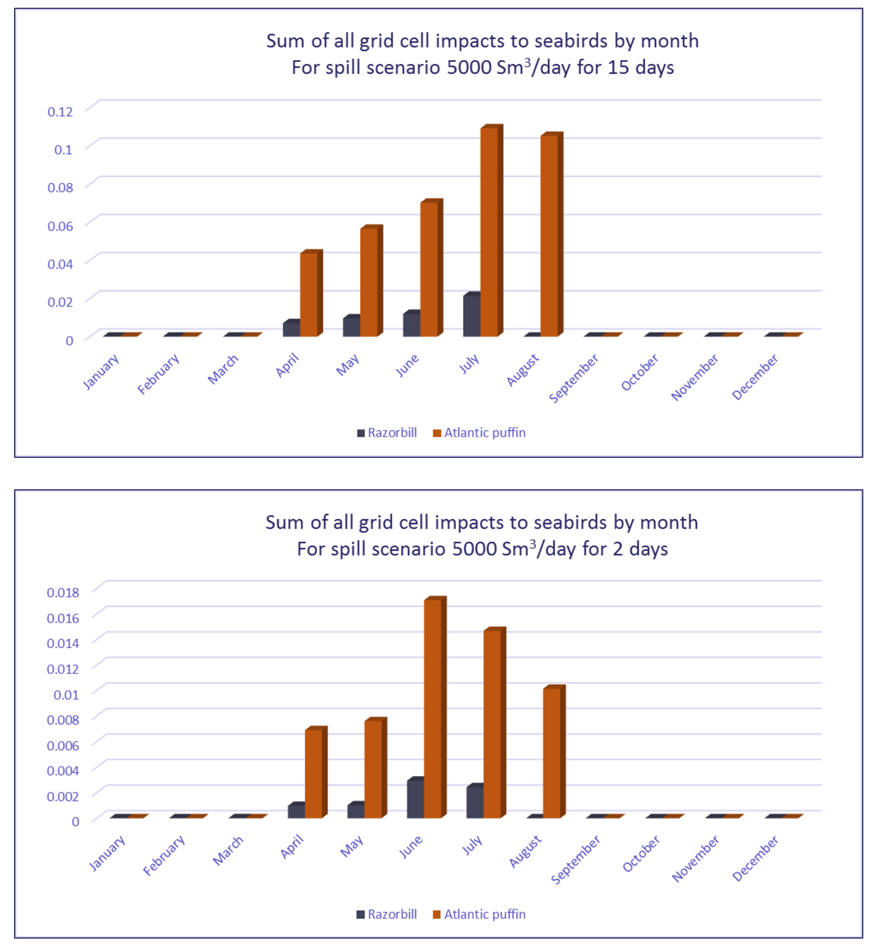

Figure 5. Sum of expected average impacts in 10x10 km grid cells to two species of sea birds and following a hypothetical spill scenario of 5000 Sm^3/day for 15 days (above) and 2 days (below). Impacts are shown as average of simulations that started in or lasted until each month separately. The difference in duration is reflected in the different impacts for the months.

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