SOMOS secretariat
PO Box 68
1970 AB IJmuiden
Netherlands

t: +31 (0)317 487 036
m: Luc.vanhoof@wur.nl
w: www.wur.nl/SOMOS.

Report on economic, ecological and societal impacts of the integration of multi-sector activities:

Description of hazards, assessment and visualization
D3.3

Authors: S.W.K. van den Burg, C. Röckmann
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Contents

1. Introduction

As has been highlighted in literature as well as in previous SOMOS deliverables, integrating multi-sector activities at sea may increase their economic performance through synergies. Multi-use has the potential to promote "a more efficient use of infrastructure and logistical resources" between different economic sectors, that can result in an "efficient and environmentally sustainable management of maritime industries" (Kite-Powell 2017; Röckmann et al. 2017; Masters et al. 2018). Parallel to these opportunities, there are also potential disadvantages, in particular when moving from coast to further offshore: higher personal and asset safety risks, higher costs, less working days, rougher conditions (wind, wave, current loads) (Klijnstra et al. 2017)[1].

1.1 Objectives

The objective of this SOMOS report D3.3 is to identify and visualize the possible cause-effect chains including mitigating and recovery measures. The hazards are studied from a SOMOS WP3 perspective, i.e., the analysis focuses on cumulative effects, ecosystem interactions, and other changes in the surroundings.

In the SOMOS project, the following framework (see Figure 1) has been developed to assess hazards associated with multi-use.[2] A second objective of this deliverable is to reflect on various methods/tools available to use in the various phases of the SOMOS Framework.

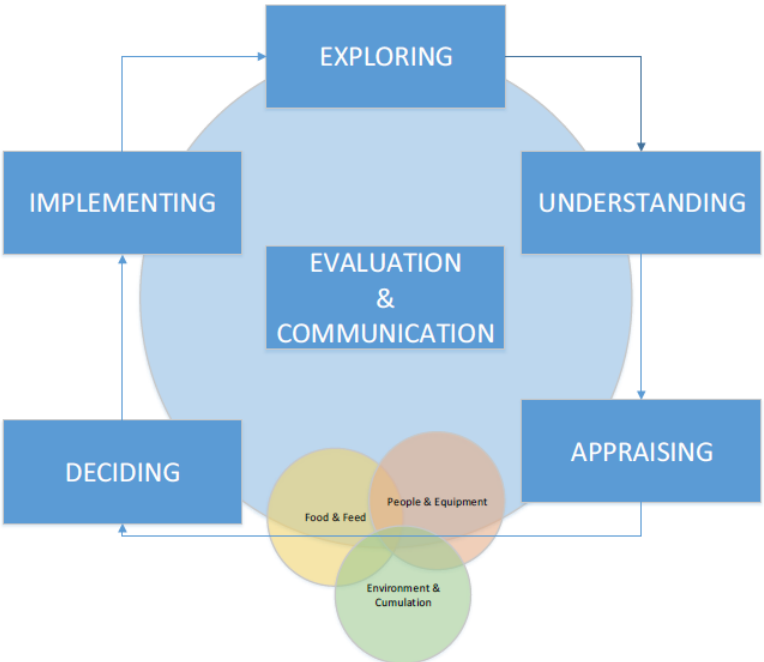

Figure 1: Framework for safety assessment of multi-use at sea

1.2 Reading guide

This deliverable is structured as follows. In chapter 2 the methology is described, including a description of tools for visualisation. Chapter 3 presents the results of identification and visualisation of cause-effect chains using Visio. In chapter 4, two alternative methods for visualisation are experimented with. In chapter 5 the

[1] See also SOMOS D2.1 and D2.2
[2] See for more details SOMOS D4.3

results of the identification and visualisation are discussed, comparing the different methods and giving an outlook on how these methods can be using the assessing cumulative effects and interactions.

2. Methodology

Here, we build on the SOMOS work conducted in task 3.1 "Identify safety aspect of Interactions and Cumulative Effects" as well as the results up to date from SOMOS work packages 1 and 2. In D3.1, overviews of potential hazards resulting from interactions and cumulative effects were presented, based on literature review and stakeholder consultation. These overviews are combined in Table 1 below.

Visualization of cause-effect relations and hazard-impact relations is a major challenge when dealing with the complexities of multi-use. Here, we chose the programme Visio as a way to clearly visualize the cause-effect/impact chain including mitigating and recovery measures.

The analysis of the cause-effect/impact chain requires one to look at the 'top event' and 'hazards'. The 'top event' is the undesired impact (or 'event') at the end of the cause-effect/impact chain. Such a 'top event' can be caused by various hazards; these have the potential to cause harm, including ill health and injury, damage to property, products or the environment, production losses or increased liabilities. We further identified and visualized measures that could mitigate the consequences of a 'hazard scenario' or even lead to recovery.

The method allows us to tell a story about the environmental, economic and social interactions around a single top event presented in one, easy to understand picture. Step by step the following layers of the cause-effect chains are visualized:

- top event
- hazards
- Consequences
- Preventive measures – to prevent that a hazard becomes reality/ happens
- Mitigating measures – to mitigate the consequences/impacts if a hazard has happened
- Recovery measures – to recover from the undesired consequences of a hazard.

Two alternative visualisation methods are used in Chapter 3. First, Bow Tie Analysis itself is used. Bow Tie Analysis is a valuable tool for participatory risk assessment and is a familiar method in risk assessments (Khazed et al, 2013; Mulcahy et al, 2017). Mental Modeller is used in participatory scenario analysis. It is concluded that these two programmes are considered promising tools to together with stakeholders implement the next steps of risk and scenario assessment.

2.1 Bowtie

A 'bowtie' is a diagram that visualizes the risk you are dealing with in just one, easy to understand picture. The diagram is shaped like a bow-tie, creating a clear differentiation between proactive and reactive risk management. The power of a Bowtie diagram lies in the fact that it provides an overview of multiple plausible scenarios, in one single picture. In short, it provides a simple, visual explanation of a risk that would be much more difficult to explain otherwise. [3]

A hazard is defined as something which has the potential to cause damage. The moment 'control is lost over the hazard', it causes a 'top event' , with consequences. Barriers appear on both sides of the bowtie; they interrupt the scenario so that the threats do not result in a loss of control (the top event) or do no escalate into an actual impact (consequences). The barrier decays mode include anything that will make a barrier fail (i.e. a door can be a barrier to fire spreading; a 'door left open' is a barrier decay mode).

[3] https://www.cgerisk.com/knowledgebase/The_bowtie_method

2.2 Mental modelling

Mental Modeler is a decision-support software package that allows the user to build Cognitive Maps (Kosko, 1986; Gray et al., 2013). By capturing, communicating and representing knowledge, it is intended to help the users (individuals and/or groups) understand the impacts associated with (environmental) change and develop mitigation strategies to reduce unwanted outcomes.

Through a multi-step process based on Fuzzy-logic Cognitive Mapping (FCM), mental modeller allows groups of stakeholders to come together and easily develop semi-quantitative models of environmental issues which (1) define the important components relevant to a community, (2) define the strength of relationships between these components, and (3) run "what if" scenarios on these models to determine how the system might react under a range of possible conditions. It thus allows stakeholders to pool and represent collective knowledge and test ideas about their assumptions in "real time" workshop sessions.

The Mental modelling approached is developed to allow for integration of knowledge across disciplines. It does so by standardizing the manner in which different pieces of information from different stakeholders are incorporated into the analysis. The mental modelling approach also allows for specifying the strength of relationships and for the characterization of the degree of certainty with respect to the relationship and its strength.

2.3 Demarcation

Coming from the SOMOS WP3 perspective, the analysis focuses on cumulative effects, ecosystem interactions, and other changes in the surroundings. The uncertainties as well as the many facets to multi-use render the investigation very complex. There is therefore a need to focus on a limited number of issues in such an early stage of analysis, which covers steps 2 'understanding' and 3 'appraising' of the "SOMOS framework" (SOMOS D4.3 and Figure 1). In order to contrast the very obvious risks that arise from direct and acute hazards, such as an oil spill, in this deliverable we zoom in on some "slowly occurring" hazards, highlighted in bold in table 1.

Table 1: overview of potential hazards of the combination of offshore wind and seaweed farming, from the perspective of interactions and cumulative effects. Highlighted in bold are the 'slowly occurring' hazards that this report focuses on.

Cause	Hazard	Effect	Opportunities
• hydrodynamic changes due to piles/ foundations • Excessive sedimentation of seaweed	Negative ecosystem changes (potentially long-term)	• less primary production • benthic community deteriorates	
additional artificial hard substrate • **from turbines** • **(from seaweed farm/ ropes?)**	**Negative impact on biodiversity/ foodweb**	• **potential habitat to invasive exotic species, translocations & bioinvasions** • **artificial structures as stepping stones**	• **higher biodiversity due to sheltering effect and thanks to the additional hard substrate**
• **noise from turbines** • **coating of foundations** • **turbine foundations and seaweed**	**Negative impact on marine animals, in particular birds, marine mammals, bats**	• **Noise disturbs animals** • **Toxic substances of coating could harm animals**	• **sheltering effect of growing seaweed might attract**

lines/netting are obstacles		• **Mammals/ birds get entangled/ stuck in seaweed/ seaweed lines/ netting**	**additional animals (more fish)**
• **Operation &Maintenance of offshore wind and seaweed farm**	**Increased ship/vessel traffic**	• **Increased chance of emergencies/ accidents → see operational safety (WP2)** • **Oil spill after accidents/ collisions**	• **Possibility to share vessels** • **'known entrants' limit accessibility to unknown entrants**
• **Coating/ anti-fouling/ cathodic protection of foundations, ships** • **lubrication oil in turbines/ rotors** • **oil/ gas of vessels** • **ship accident/ collision**	**Increased pollution**	• **(permanent) leaking of toxic substances during operation → food/feed safety (WP1)** • **sudden leakage of toxic substances due to accidents (WP1, 2)**	
Inconsistent regulation in EU member states.	Lack of financing	Paralysis, no multi-use	
Inconsistent regulation in EU member states.	Lack of regulation permitting multi-use	Paralysis, no multi-use	
Passing of recreational boats, in particular at night; getting entangled by the longlines	Theft Vandalism (e.g. instead of calling the police, they cut the lines)	Loss of harvest (seaweed); Loss of equipment	Presence of windfarm could have mitigating effects because of increased controls/ patrolling
Terrorists	Bio-terrorism	Poisoned seaweed	Presence of windfarm could have mitigating effects because of increased controls/ patrolling
Reduced sunlight availability	Negative ecosystem changes (potentially long-term)	• less primary production • benthic community deteriorates	

Due to the fact that the offshore multi-use combinations investigated in SOMOS D3.1 are still only theoretical and do not exist yet in reality, it is important to acknowledge the considerable degree of uncertainty related to this investigation of potential hazards, interactions, cumulative effects and cause-effect relationships.

3. Visualization

3.1 Cause-Effect Chains

Slowly occurring changes in the environment, and specifically to biodiversity can be triggered by different events. Based on literature and stakeholder workshops, we identified the following four hazards as the most relevant to study further:

- Birds/bats collide with the rotor blades of the windmills.
- The seaweed farm might attract more birds or mammals than normally, due to the presence of a seaweed farm.
- Chemicals leach from the wind and/or seaweed farm infrastructure.
- The artificial hard substrate of the wind turbine foundations and/or of the seaweed farm is a stepping stone for invasive or exotic species growth.

In the next step we visualize cause-effect chains, the relations between hazards and their potential environmental, social/economic and technical impact (see Figure 2):

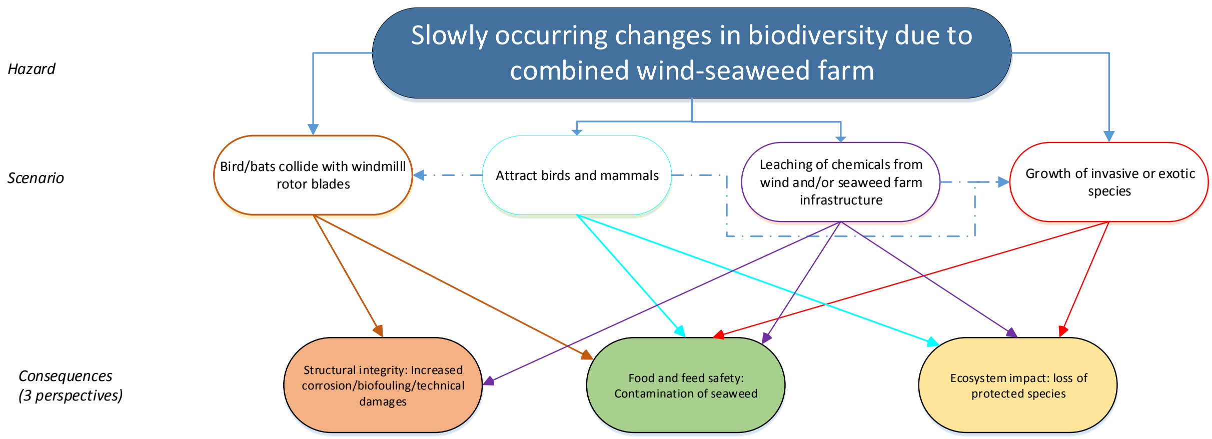

Figure 2: visualisation of impact of four key hazards

During operation of the wind turbines, bird/bat mortality caused by collision with the moving turbine blades is of concern. The collision can lead to food safety and operational safety concerns:

- The wounded or dead bird/bat bodies might fall in the seaweeds cultivated with potential consequences for food and feed safety. The dead bodies in the water can cause pollution around the seaweed farm, leading to toxic contamination of the seaweed.
- Substances from the decaying dead organisms in the water could render the surrounding water more corrosive, leading to increased corrosion, biofouling, or other technical damages.

The vicinity of a seaweed farm might attract more birds and mammals, due to higher presence of fish, increasing in turn bird mortality. Higher density/ abundance of mammals or birds near the multi-use farm poses extra risks to these species:

- higher bird mortality due to collision with the windmill rotor blades. This in turn might lead to seaweed contamination (see above).
- Higher mammal density around the multi-use area can result in higher mortality as well, due to entangling in structures of the seaweed farm, leading to loss of a protected species, thus ecosystem impact. Also, species avoidance responses may result in displacement from key habitats, this might

involve more/longer swimming, thus more activity and as a consequence increase the species' energetic costs (Bailey et al., 2014).

Leaching of chemicals from the offshore structures can cause all three, technical, food safety and environmental safety issues:

- The chemicals themselves can lead to increased corrosion/ biofouling and thus impair structural integrity (see Figure 3)
- The chemicals can cause a contamination of the seaweed.
- The chemicals can cause pollution of the environment and thus impact the ecosystem.

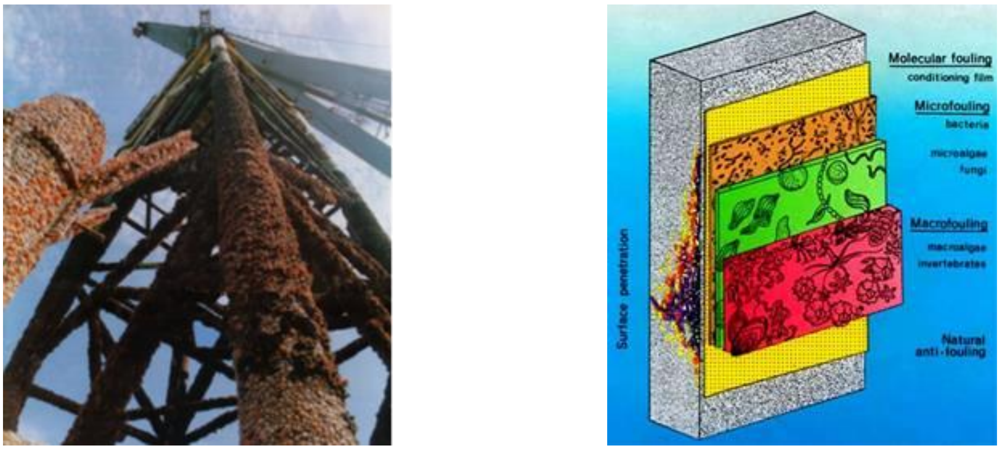

Figure 3. Examples of damages to structural integrity: biofouling on an offshore jacket foundation (left); schematic representation of different stages in marine biofouling process (right) (Davies & Williamson, 1995)

An increase in invasive or exotic species on the artificial hard substrate, through biofouling, of the wind turbine foundations and/or of the seaweed farm can lead to:

- Food and feed contamination, if the species produce toxic substances
- Impact on the natural ecosystem by out-competition of indigenous species

3.2 Preventive, mitigation or recovery measures

In the next step we add measures to the diagram, in square boxes, visualizing possibilities how to potentially prevent risks, mitigate them or recover from incidents (see Figure 4). This is elaborated for bird mortality due to collision with rotor blades and leakage of chemicals.

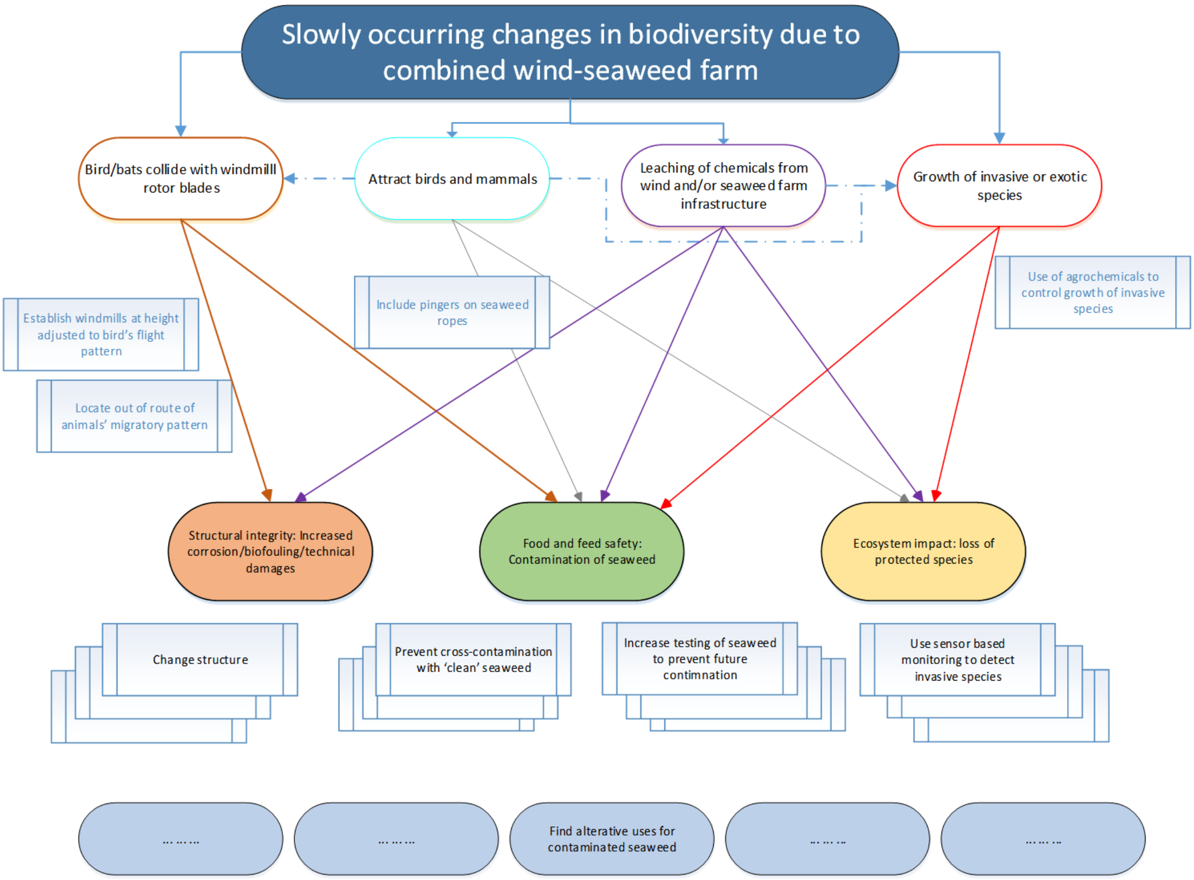

Figure 4: *visualisation of impact of four key hazards and preventive, mitigation of recovery measures*

3.2.1 Hazard: Bird mortality due to collision with rotor blades

While there are few, if any studies on birds in seaweed farms, birds are well known to use kelp forests around the world, particularly cormorants, eider ducks and egrets (Wood et al. 2017). It is conceivable that many seabirds may benefit from the aggregated prey within the macro-algae farm. Conversely, changes to seabed habitat need to be considered in terms of prey availability, particularly in areas where seabird species depend on benthic fish such as sandeels for food (Furness & Tasker 2000; Rindorf et al. 2000). Finally, the surface floats and navigational markers offer some limited resting points and allow birds to extend foraging ranges (Ronconi et al. 2015). The Scottish Seaweed Policy Statement Consultation Document also mentioned these effects and states that "for example, seabirds are known to use gaps in the seaweed forests to hunt for small fish and crabs." (Wood et al. (2017).

- A preventive measure specifically targeted at mammals would be to include pingers on seaweed ropes.
- A mitigating measure would be to change/ repair the technical structure that has been impaired.

Potential preventive measures would be to establish windmills at height adjusted to bird's flight pattern, or to locate a multi-use farm out of the route of the animals' migratory pattern.

3.2.2 Hazard: Leakage of chemicals/ lubricants

The hazard of a chemical spill or lubricant leakage was identified by Kaldellis et al. (2016) as one of the potential negative impacts of offshore wind on the ecosystem: "noise, toxic effects from lubricant spills and electromagnetic fields from cables during the construction and operation of an offshore wind project may affect negatively the marine species".

Lubricant spills can cause ecological damage. In their study, Hammar et al. (2014) tried to assess the risk of lubricant spill and the effect on cod: "finally, it was found undecided whether recruits can become exposed to toxic levels of lubricants from turbine breakdowns. Although major turbine breakdowns may occur, such events seem very rare. In addition, most lubricant components have low water solubility, and cod eggs and larvae generally drift a few metres below surface reducing exposure to substances adhered to the surface". For seaweed, this could be different since they grow closer to the water surface. The potential consequence is that the spilled lubricant ends up in the seaweeds, thereby rendering it useless for food and feed markets.

- A mitigating measure here could be rapid dilution of the chemical in the marine environment, or solution of the lubricants. If the lubricants are not soluble, they will remain on the water surface.
- Cross-contamination with "clean" seaweed has to be prevented. Also, testing of seaweed needs to be expanded, in order to detect contamination.

4. Bow ties and Mental Modelling as alternative methods for visualisation

4.1 Bow Tie: Negative impact on marine fauna: Bird mortality

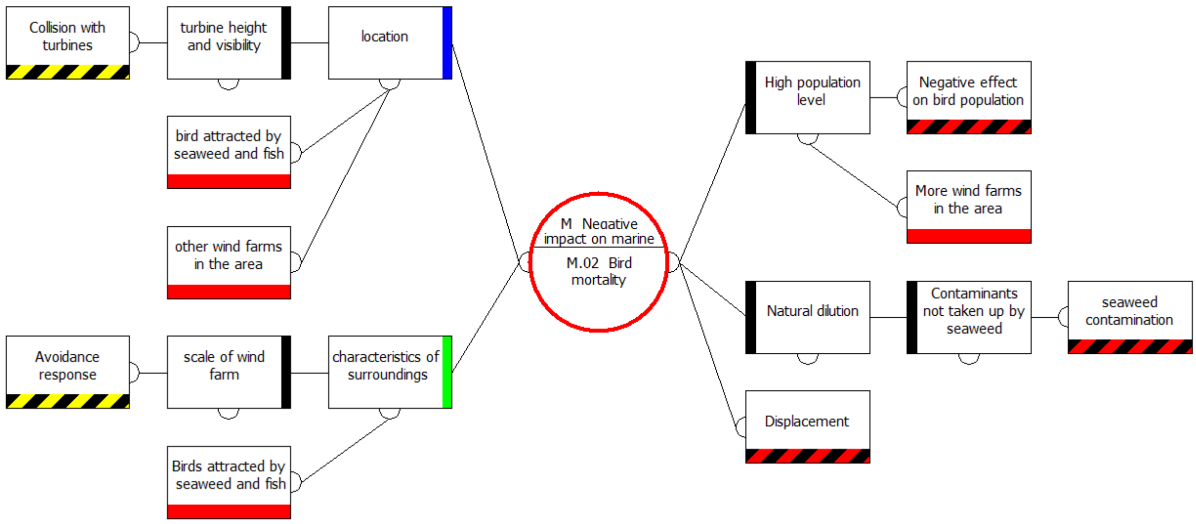

Figure 5: Bow tie visualization for "bird mortality"

Top event

The top event is defined here as bird mortality.

Threat: Collision with turbines

Birds might collide with the turbines. This risk can be assessed with theoretical risk collision models based on technical turbine specifications, bird-related parameters and bird densities (Brabant et al., 2015).

Barriers

- This effect could be mitigated if the turbine height is adjusted, such that the height is higher or lower than the bird's flying altitude – and if it is visible/audible
- This effect could be mitigated if the birds do not visit the area
  - This barrier is decayed if there are other wind farms in the area – or along the migratory route – and birds cannot take a different route
  - This barrier is decayed if the seaweed farm – and attracted fish – make it a more favourable area for birds

Threat: Avoidance behaviour

This is about birds that use different migratory routes or foraging areas because of the siting of a wind farm. This might imply they have to fly longer (more energy use) or forage in areas with less feed. This in turn can lead to higher mortality. This, indirect mortality and decreases in productivity as an ecological consequence of displacement from foraging habitats has been neglected until recently, due to the lack of evidence for impact pathways (Busch & Garthe, 2016).

Barriers

- The significance of this effect is dependent on the scale of the wind-farm.

- The significance of these effects is not only dependent on the characteristics on the wind farm – but also on the characteristics of the surroundings.
- Seaweed aquaculture might mitigate this effect as birds are less inclined to avoid the area.

Consequence: Population level effect

A consequence could be that higher bird mortality (direct or through avoidance behaviour) reduces total population of the birds concerned. When it comes to impact assessment on birds, the focus is on impact on bird *populations* (see e.g. Furness et al 2013; Snyder et al 2009). This has consequences for assessing the threat. First, the size of the population is an important parameter. Secondly, one needs to know the effect of multiple wind farms in the area on bird populations. A cumulative assessment is needed, looking at the total of wind turbines present.

Recovery measure

Whether or not this effect is significant is dependent on

- Total bird population
- Effect of other wind farms in the area or along migratory routes

Consequence: contaminated seaweed

This might happen when a dead bird falls onto the seaweed aquaculture site and decays in the area. This might have a negative effect of the seaweeds. So far, the literature seems to provide no answer to the question whether or not this is a serious concern.

Recovery measure

In literature, little information can be found on the potential food safety risk of dead birds. Also, no information was found on mitigating/recovery measures. As argued by Kaldellis et al (2016), in offshore sites, detecting and counting dead bird bodies is almost impossible, thus scientific surveys related to collision mortality offshore, appear quite limited.

Since we are talking about offshore farming, we can assume that the currents, waves and tidal forces should contribute to the dilution of contaminants.

Consequence: displacement

In addition to the highlighted need for further research into realistic displacement and mortality rates, the different impacts of displacement on breeding adults and non-breeding (adult or immature) birds during the colony-attendance season, and season-specific variations in the ecological consequences of displacement also need to be addressed to improve the reliability of displacement assessments (Busch & Garthe 2016).

4.2 Bow Tie: Negative changes to the benthic environment

The hazard discussed here is defined as "negative changes to the benthic environment". Increased sedimentation is reported by various authors (Buschmann et al. 1996; Zhang et al. 2009). This is a well-known hazard of aquaculture in general. The sedimentation of fall-off seaweeds could lead to organic enrichment. This effect is potentially stronger in a combined seaweed & wind system. Wind turbine foundations cause disturbances in the water layers. This effect itself is also a hazard as the mixing of water layers can reduce primary production (Broström 2008). Other argue that primary growth might be stimulated around farms (Lagerveld et al., 2014).

A recent news item reported on the sediment plumes in offshore wind farms in the North Sea, visible through NASA's Operational Land Imager[4] See figure 6 below.

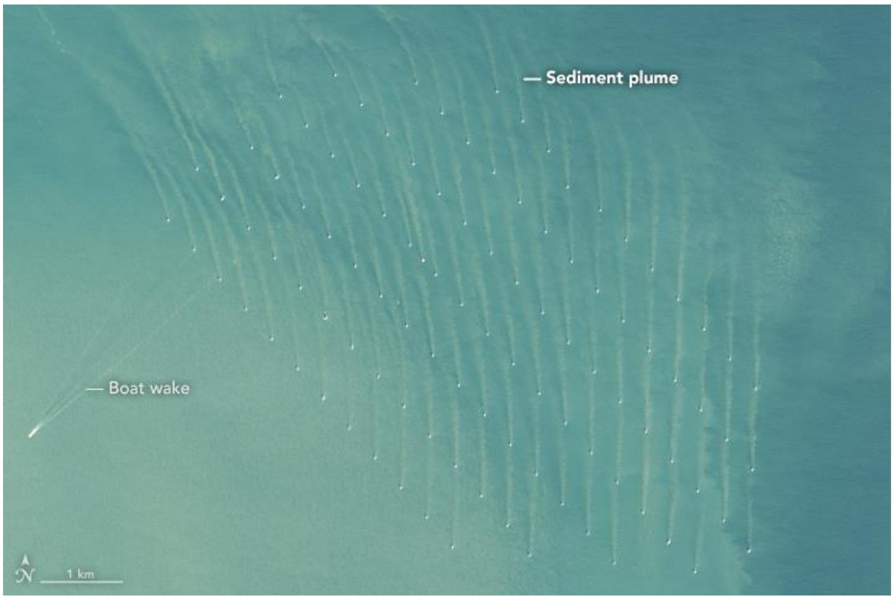

Figure 6: sediment plumes due to offshore wind farms (NASA)

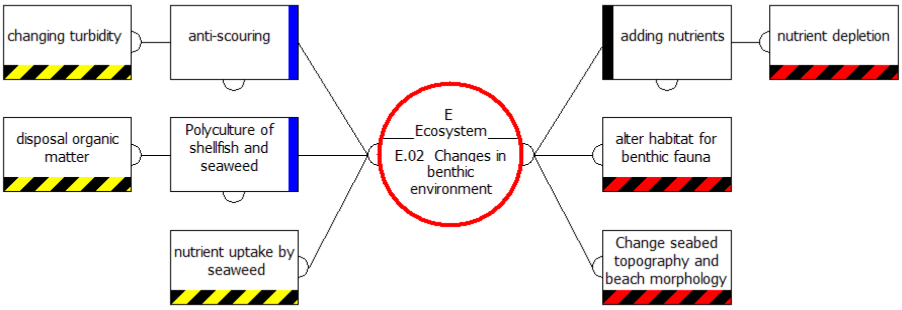

Figure 7: Bow tie visualisation for "changes in benthic environment"

Top event

The top event is defined as a change to the benthic environment with negative impact on benthic epifauna (living on the sea floor) and infauna (living in the sediment on the sea floor).

4 https://www.offshorewind.biz/2016/11/08/offshore-wind-turbines-make-sediment-plumes-in-north-sea/ (19032018)

Threat: changing turbidity

Miller et al. (2013) describe benthic responses to seabed disturbance. Scouring alters habitats near marine renewable energy devices (such as offshore wind turbines) by removing fine sediments, at larger scales cumulative scouring may create megaripples and wake trails (Miller et al., 2013). Wave dissipation effects from the structures themselves may also alter seabed dynamics (evidence of such effects is limited to a number of modelling studies at particular locations). In each case the extent of the disturbed area will depend on the sediment type, device type, water depth, anchoring depth of device foundations into the seabed, and surrounding flow regimes (Miller et al., 2013).

Barriers

Scouring is also a risk for offshore wind constructors and there are a number of anti-scouring measures, like dumped stone riprap, stone or concrete pitching, soil-cement bagging or grouted fabric mattress, and positioning of a horizontal collar/deflector (Matutano et al., 2013).

Threat: Disposal of organic matter

Buschmann et al. (1996) argue the increased sedimentation found in some subtidal cultivation systems associated with Gracilaria cultivation is a documented environmental effect. The effects of variations in the sediment on faunal composition and abundance are unknown and require further study. Zhang et al. (2009) describe this threat as well. The fall-off of the seaweed has accumulated on the seabed which may not only affect the benthic ecosystem, but may also deteriorate the environmental conditions.

Barrier: Polyculture

Zhang et al (2009) state that polyculture of shellfish and seaweed can reduce the risk of oxygen depletion to to disposal of organic matter. The photosynthesis activity of aquaculture seaweed produces oxygen, which may help to meet the demand of the benthic life avoiding localized oxygen depletion or sulphide accumulation.

Threat: Nutrient uptake by seaweed

Aldridge et al (2012) conclude that the effect of the seaweed farming activity on nutrient concentrations are not expected to be insignificant but more likely marginally significant. Given a sufficient high level of farming activity (combination of intensity and size of the farms, the effects might become 'certainly significant').

Consequence: nutrient depletion

In their assessment Aldridge et al (2012) conclude that the effects of nutrient removal would be "the reverse of the symptoms of eutrophication i.e. a lower nutrient concentration in the water, decreased productivity and energy fluxes through the pelagic system, decreased flux of organic material to the seabed, and a subtlealteration to community structure".

Recovery measure: Adding nutrients

One option to tackle nutrient depletion by seaweed farming could be to add nutrients to the seaweed farm, i.e. to fertilize the sea around the seaweed farm. This option is little discussed as of yet and it provokes ethical questions that need to be discussed, similar to the ocean iron fertilization experiment (Güssow et al, 2015)

Consequences: alter habitat for benthic fauna

Miller et al. (2013) describe how seabed disturbances fundamentally alter habitat provisioning for benthic epifauna and infauna and the geographical extent of these disturbances will determine whether substantial changes to individuals, populations, or species will occur. For a given species, long-term intensification of suspended sediments related to marine renewable energy installations may affect mobility, modify feeding and sediment clearance behaviour, increase pseudofeces and disrupt daily feeding cycles and escape behaviour.

Consequence: change seabed topography and beach morphology

Suspended sediment regimes influence the distribution limits of some benthic suspension feeders while changes to seabed topography and beach morphology may alter habitat provisioning tens or hundreds of kilometres away from a development (Miller et al., 2013).

4.3 Mental Modeller: Slow changes to biodiversity

In figure 8, the cause-effect chains, from hazards to consequences, is visualized using the Mental modeller software. On the left, we start with the top event: seaweed farm and windfarm changes biodiversity. Moving right, next are the four identified hazards, in grey boxes. From this hazard example, blue arrows are drawn towards the consequences marked in orange.

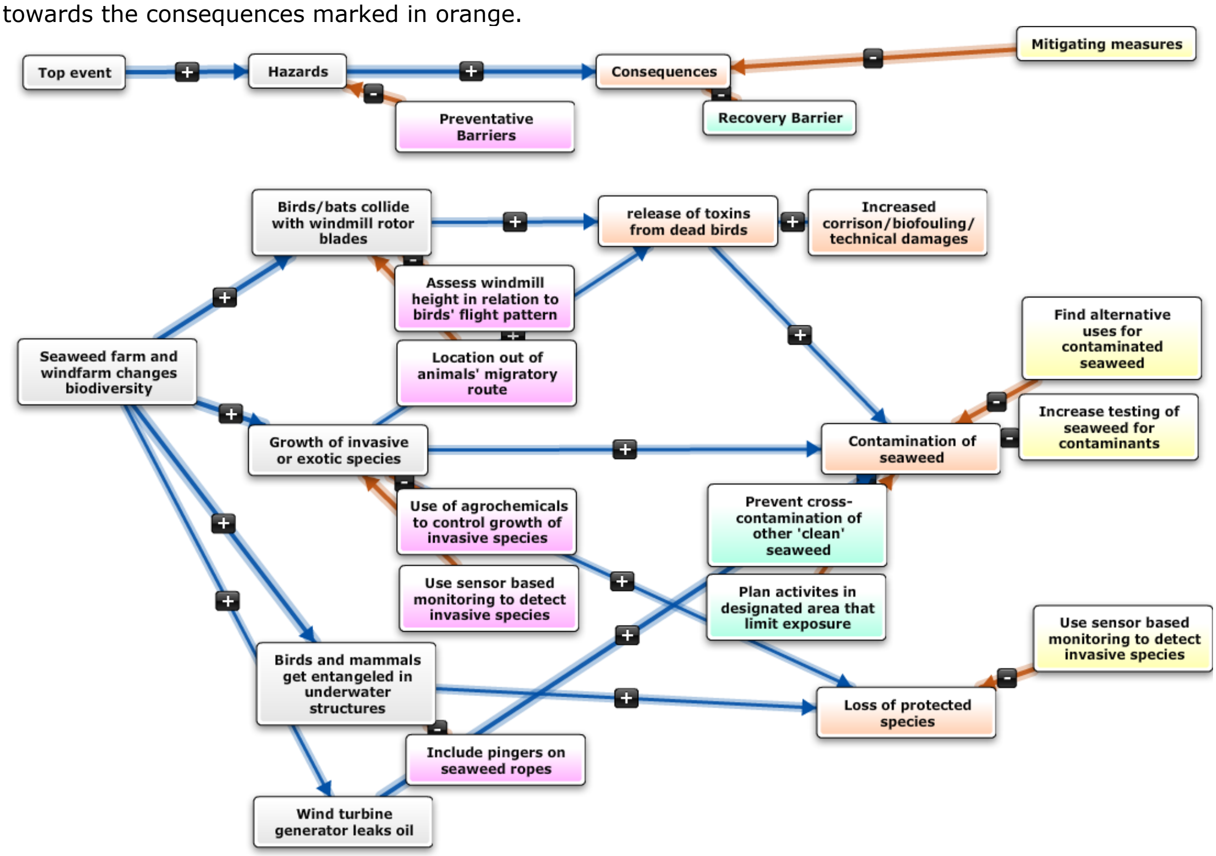

Figure 8: Mental modeler visualisation for slow changes to biodiversity due to the presence of a combined wind-seaweed farm

Note: Blue arrows indicate a positive relationship, i.e. a hazard resulting in a consequence, whereas orange arrows indicate negative relationships, such as preventative, recovery or mitigating measures that would counteract the event of a hazard or consequence. In addition to the cause-effect chain, the figure also visualizes three different barriers/ measures: preventative – in purple, recovery – in green, and mitigating – in yellow. The preventative measures are expected to prevent the hazards from happening. The recovery measures set in, to recover from the consequence, and the mitigating measure is a last remedy to adapt to a consequence in a way that mitigates its negative effects.

5. Discussion - reflections on risk assessment

In this section we reflect on the prospects for risk assessment of cumulative effects and ecosystem interactions. Three main points are addressed: the tools for visualisation, the need for context-specific data and an outlook on implementation of the methods in a real-life participatory process as foreseen in the "deciding" and "implementing" phase of the SOMOS framework.

5.1 Comparison of methods

The three methods studied in this report are compared in Table 2 below.

Table 2: Positive and negative aspects of the three methods for visualisation

Method for visualisation	**Positive**	**Negative**
Visio	Simple Flexible	No quantification possible, e.g. of the strengths/ certainty et cetera of interactions between the nodes/components Due to its flexibility having an agreed upon structure beforehand helps to avoid too complex models and loss of focus and overview
Bow tie	Familiar method in risk assessment Can be used in quantification	Rigid structure and terminology Interactions between hazards hard to visualise (only by combing several bowties which impairs visualisation
Mental modelling	Flexible Can be used for quantification Familiar method in participatory assessment Interaction between various hazards easy to model	Due to its flexibility having an agreed upon structure beforehand helps to avoid too complex models and loss of focus and overview

5.2 Context-specificity of risk assessments

The methods discussed above only provide relevant information if the characteristics of local environments and ecosystems are taken into account. The eventual assessment of risks is context-dependent; whether these effects will occur in real multi-use settings depends on local circumstances. In each case the extent of the disturbed area will depend on the sediment type, device type, water depth, anchoring depth of device foundations into the seabed, and surrounding flow regimes (Miller et al., 2013)

Further insight into the cause-effect relationships and the possible mitigating/amplifying ecosystem characteristics is needed and will be subject to research in the coming period. For example, Zhang et al (2009) conclude that disposal or organic matter is not an issue for their case-study area (Sunguo Bay) because (1) Low intensity of culture activities, (2) better hydrodynamic conditions, i.e. a higher turbidity than in other waters and (3) Polyculture of shellfish and seaweed.

Aldridge et al. (2012) point to another important complicating fact in assessing impacts on ecosystems. Human-induced changes occur in the long term against a background of considerable natural variability. Among the key lessons formulated by Bailey et al. (2014) are two important aspects for the risk assessment. Gathering baseline data to assess significance of impacts requires choices about the area over which biological effects may occur. Secondly, assessing significance of the effect at the level of population definition of population and an assessment of populations in and outside the wind farm. For this reason, population level is included as a recovery measure – albeit out of control – one needs to take into account when assessing risks.

Furthermore, the assessment of the barrier effect (migrating birds often change their flight path due to an obstacle), which also comprises a major concern for offshore installations, is fairly difficult and the use of remote techniques, to accurately plot and compare migration trajectories pre- and post-construction of the wind farms are required (Desholm et al., 2006).

5.3 Outlook on implementation of the methods

The SOMOS framework identifies two phases in which visualization of cumulative effects and ecosystem interactions is useful: understanding and appraising. In these phases, qualitative assessment is sufficient, and therefore methods such as Visio and Bow Ties can be useful in gaining better understanding of the cumulative interactions in cause-effect chains.

Once these interactions have been appraised, decisions need to be taken; this also requires trade-offs to be discussed. The SOMOS framework foresees in stakeholder consultation throughout the steps of the framework. In particular in such an innovative case as offshore multi-use, where little or no context-specific data is available, knowledge, insights and opinions/visions of stakeholders are crucial to describe potential risk situations and come to a decision. The mental modelling approach offers the possibility to include weights given by stakeholders to the different variables that are taken into account in a risk assessment. It is a transparent way to visualize trade-offs and come to a joint decision. It has been used successfully in Integrated Ecosystem Assessments in North America (DePiper et al. 2017).

As is argued by Masden et al (2010), properly addressing the cumulative impact of wind energy development of bird populations would benefit from conducting Cumulative Impact Assessment on a strategic spatial planning level.

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7. Justification

This deliverable has been peer reviewed by Luc van Hoof (project coordinator).