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Overview of safety aspects of interaction and cumulative effects

D3.1

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Contents

1 Summary

This report is a deliverable of the SOMOS project that deals with safe production of marine plants and use of ocean space. In this report D3.1, we present and describe a set of hazards that could arise due to the combined production of offshore wind energy and seaweed. Whereas WP1 focusses on food safety and WP2 on human safety, Work Package 3 specifically focusses on interactions with the marine environment and the cumulative effects of two activities on the wider environment within which these activities take place. Those results are presented below. The results are based on a literature study and consultations with experts in interviews and during a stakeholder workshop.

The main hazards identified based on a literature review are the following four:

- Ecosystem change due to excessive sedimentation and decreased primary production with long-term impacts. Both the wind farm and seaweed farm might impact on the ecosystem dynamics. Together, these effect might negatively affect the ecosystem.
- Effect on biodiversity, including invasive species, translocations & bioinvasions; the two activities potentially impact on biodiversity by introducing new species (on purpose or not) or by creating a habitat in which new species come to thrive.
- Impact on animals, including birds, marine mammals, bats. Both actitivies potentially attract new or more animals to the areas. The combination of activities can strengthen this effect.
- Increased ship/vessel traffic; with two activities taking place close to each other, more ship/vessel traffic is expected. This increases the chance that things go wrong, with potential detrimental effects on the environment
- Pollution. The activities might release polluting substancesin to the environment.

Additionally stakeholders pointed to the following hazards:

- Lack of financing of combined activities;
- Lacking or inconsistent regulation;
- Theft and vandalism.

Note that there is considerable uncertainty as to wether or not these effects will occur because no offshore windpark has as yet been combined with a seaweed farm. Therefore, the information available and used is now mostly context-independent, i.e. local conditions such as wave patterns, currents and state of the ecosystem, have not been taken into account. Whether these effects will/could occur in real multi-use settings depends on local circumstances. Further insight into the cause-effect relationships and the possible mitigating/amplifying ecosystem characteristics is needed and will be subject to SOMOS research in the coming period.

2 Introduction

SOMOS, short for “safe production of marine plants and use of ocean space”, focusses on the risks and cumulative impacts on human and ecosystem safety due to multi-use activities at sea.

When looking at the available methods and tools to conduct safety assessments and control safety in the domains of food/feed and the domain of location fixed offshore activities, a meaningful safety assessment and controlling safety of multiple simultaneous activities at a shared location at sea should be possible. However, insight into the specifities of multi-use is lacking. SOMOS will devise the necessary tools for this, test the tools in two concrete demonstrators and build capacity among policymakers, certifiers and operators to use the tools to increase safety at sea.

Work Package 3 of the SOMOS project seeks to identify the possible hazards and opportunities arising in the marine environment from the combination of (novel) maritime activities in a single location. Such a multi-use combination can lead to competition between alternative uses and cumulative (pollution) effects of all activities combined. The combination of (competing) activities creates obstacles as well as opportunities, and trade-offs need to be considered.

3 Tasks

The objective of this deliverable is to identify hazards of the combined production of offshore wind energy and aquaculture, specifically seaweed farming, with a focus on marine interactions and cumulative effects. Results presented in this deliverable feed into the development of a framework for safety assessment for safe production of marine food and feed and safe us of ocean space (WP4). Further detailing will take place in the coming period, to be presented in deliverable 3.3.

4 Methodology

To identify environmental hazards related to marine interactions and cumulative effects, a two step methodology was used: (1) a review of scientific literature and (2) consultation with stakeholders.

4.1 Literature review

As part of WP3, a database of environmental and social hazards of seaweed aquaculture was compiled, based on scientific literature review and consultation of key stakeholders. The database contains +100 entries, including references to the scientific publications in which these hazards were reported.

This database was the basis for a first assessment of the most relevant hazards for the SOMOS focus on offshore wind and seaweed farming. Criteria for identification were:

- Hazards are only relevant if they are environmental and/or social in nature, excluding food safety operations and health and safety aspects (these are dealt with in WP1 and WP2 respectively)
- Hazards are more relevant if they are aggravated by the combined production of wind and seaweed, either in likelihood of occurrence or impact
- Hazards are more relevant if they have a potential impact of the long-term sustainability of seaweed and/or wind production, either because of ecosystem changes or increased societal resistance.

For the initially identified hazards, we also assessed wether or not these issue were identified in the draft MSC/ASC Seaweed Standard.[1]

4.2 Stakeholder workshop

The results of the first assessment were presented to - and discussed with - stakeholders at the SOMOS stakeholder workshop (June 19-20, 2017 in IJmuiden, The Netherlands). Over 20 experts interested in safety aspects of multi-use offshore, including experts from scientific institutes, the offshore wind energy sector, other industries, NGOs and policymakers, discussed how to integrate the assessment of multi-use hazards into a framework for safety assessment.

[1] See https://improvements.msc.org/database/seaweed-standard for more information on the seaweed standard.

5 Results

5.1 Relevant hazards from the literature review

5.1.1 Ecosystem change due to excessive sedimentation and decreased primary production with long-term impacts

Increased sedimentation due to seaweed aquaculture is reported by various authors (Eng et al., 1989; 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 and impacts on existing benthic organisms when it changes their living environment, e.g. from sandy to high on organic matter. This effect is potentially stronger in a combined seaweed & wind system where wind turbine foundations cause disturbances in the water layers. More seaweed might break loose and sink to the seafloor.

This disturbances of water layers in itself is also a hazard as the mixing of water layers can reduce primary production (Brostrom, 2008).

These issues are covered in the draft MSC/ASC standard on seaweed, under Principle 2 “Environmental impacts”, which includes, among others, the topics habitats, ecosystem structure and functioning.

5.1.2 Effect on biodiversity, including invasive species, translocations and bioinvasions

Seaweed aquaculture can cause effects on biodiversity, including the possibility of introducing invasive species, translocations and bioinvasions. Bindu & Levine (2011) describe the hazard of introduction of non-endemic cultivars and bioinvasions (Bindu & Levine, 2011). Beveridge et al. (1997) elaborate on potential species translocations.

As regards offshore wind, there is a danger that the hard substrate of the foundations and turbines come to serve as stepping stones, enabling further distribution of invasive species. Petersen & Malm (2006) describe the ‘reef-effect’ of hard substrate that has an impact on habitat and species composition. In combination with seaweed aquaculture, the wind turbines can act as ‘stepping stones’ multiplying the risk of introduction and further distribution of exotic species.

This issue is covered in the draft MSC/ASC standard on seaweed, under Principle 1, topic “genetic impact on wild stock”. It is also covered under Principle 2 “Environmental impacts”, topic “translocations”.

5.1.3 Impact on animals, including birds, marine mammals, bats

Offshore wind farms and other marine constructions impact upon flora and fauna through various mechanism. Addition of hard substrate creates a new area for settlement of species while the (partial) closure of areas for other activities – like fishing - can lead to ‘sheltered areas’. Petersen and Malm (2006) describe changes in marine mammal abundance around wind parks due to the added hard substrate and increased food availability. Since seaweed farms are also considered to stimulate local biodiversity, the combination of wind and seaweed farm can have an even larger effect.

However, this is potentially also a negative effect. For example, large mammals can get stuck in seaweed (Stelzenmüller et al., 2016), or bird and bat mortality can increase due to collisions with turbines/blades (Röckmann et al., 2015; Lagerveld et al., 2014). If the seaweed farms attracts avian predators, the combination of wind with seaweed farming might even lead to increased bird/bat mortality (Lagerveld et al. 2014; MERMAID D6.3). For marine mammals, an offshore aquaculture farm can pose a possible barrier effect due to the ‘closed’ construction (Lagerveld et al., 2014).
This issue is not covered in the draft MSC/ASC standard on seaweed.

5.1.4 Increased ship/vessel traffic

The combination of offshore wind energy generation and seaweed aquaculture will increase ship traffic in the areas concerned – compared to single-use. Various authors have investigated the synergy between the two sectors (Lagerveld et al., 2015; Röckmann et al. 2017; MARIBE D6.1 for the combination of wind energy and mussel aquaculture); but fully shared Operations & Maintenance – where the two sectors will allways share ships - will not be possible. Hence, more ships will be necessary, coming in and out to serve the production areas. This comes with an increased chance of accidents, accidental oil spills (Brouwers, personal communication) and pollution and emergency responses with effect on the ecosystem (MARIBE D9.1).

A positive effect of multi-use, mentioned by the wind sector, can be that unknown entrants (e.g. recreational ships) are discouraged and hindered to access the wind park (van den Burg et al., 2016).

The issue of increased ship traffic is not covered in the draft MSC/ASC standard on seaweed.

5.1.5 Pollution

The infrastructures for offshore wind energy generation have to be protected against corrosion and biofouling. The substances used for this might pollute the seaweed produced and vice versa, the presence of seaweed aqaculture might increase corrosion and biofouling (see e.g. Lagerveld et al., 2014; Klijnstra et al., 2017). A vicious circle might develop, as this could then increase need to use anti-fouling, with negative effects on the quality or growth of seaweed.

The potential impact of both processes is large, also affecting the integrity of structures and food safety of produced seaweed. Yet, the severity of the effects and wether or not they are mitigated in highly dynamic environments (with strong waves and currents) remains uncertain and these topics require further investigation.

5.1.6 Summary overview of key hazards

The table below lists the hazards, including their causes and effects, as well as opportunities identified by the SOMOS team in relation to environmental safety of seaweed farming at an offshore wind farm.

Table 1. Hazards of the combination of offshore wind and seaweed farming, from the perspective of interactions and cumulative effects

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	Negative impact on marine animals,	• Noise disturbs animals • Toxic substances of artificial coating could harm animals	• sheltering effect of growing seaweed might

Cause	Hazard	Effect	Opportunities
• turbine foundations and seaweed lines/netting are obstacles	in particular birds, marine mammals, bats	• Mammals/ birds get entangled/ stuck in seaweed/ seaweed lines/ netting	attract additional animals (more fish)
• O&M 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)	

5.2 Results from the stakeholder workshop

In the stakeholder workshop, two presented hazards were discussed in more detail. In addition to the five major hazards presented (table above), workshop participants identified three additional hazards (listed in table 2 below).

5.2.1 New hazard: Lack of financing

The issue of financing was among the first issues mentioned by stakeholders, but there was little further discussion on this problem. A number of publications point to the difficulties in financing individual offshore wind and offshore (seaweed) aquaculture activities. More concerning, it is also argued that the combination of activities increases difficulties of getting financed by banks, govermmental investments funds and private equity investors alike. For investors in offshore wind, concerns about subsidies, long-term operational reliability and operational risk – where the wind turbines do not generate electricity and thus no income - are amplified by the introduction of another (unknown) business sector (MARIBE D9.1; van den Burg et al., 2017). The lack of regulations and standards adds to this problem as there is no uniform method to assess and mitigate risks.

Michler-Cieluch (2009) frames this financing risk as an "unsolvable problem of liability", caused by not assigning clear rights and responsibilities to the actors involved in multi-use projects, and in particular in the combined production of offshore wind energy and aquaculture.

5.2.2 New hazard: Lacking or inconsistent regulation

According to the workshop participants, an appropriate, clear and consistent regulatory framework is crucial for the development of multi-use. Until now, the legal situation regarding multi-use of offshore wind parks differs in the various EU member states bordering the North Sea. For example:

- In the UK, passing a wind farm is allowed, and multi-use is already happening.
- In Denmark, in theory, passing and multi-use are allowed, but all safety regulations have been drastically increased, so nobody can enter a wind farm. Additionally, coast guard vessels are controlling that nobody enters.
- In Germany, according to workshop participants, has very clear and strong procedures, how to enter a wind farm: when, where exactly (between which turbines). Windfarms have their own private 24/7 “guard vessels”, controlling each corner of the wind farm for tresspassers.
- In the Netherlands, the law for passing still has not been published. It is expected to be published soon, though. Also a new law for multi-use, specifically for all newly planned wind farms is expected to be passed shortly. Windfarms have CCTV to control tresspassing.

As a consequence, it can be unclear to wind farm operators and potential aquaculturists what is acceptable and what is not – as are the arguments underlying these decisions. Also, changes in regulation are a hazard, e.g. when multi-use would first be accepted and then prohibited later on.

5.2.3 New hazard: Theft & vandalism

In the workshop, theft and vandalism were raised as important hazards to safe seaweed production. It was stated that – even offshore – equipment is stolen (e.g. marine mammal click-detectors). Additionally, there can be on purpose theft of seaweeds and vandalism. Vandalism can take a more serious form, leading to bio-terrorism, on purpose contamination of the production

If seaweed aquaculture takes place within wind farms, it can be argued that the risk of theft and vandalism both can increase as wel as decrease. An increase could result if people enter a wind farm at night to steal something and – due to poor sight – get entangled in longlines for seaweed aquaculture. On the other hand, windfarms could have mitigating effects – benefitting the seaweed producer - because there is more surveillance present.

5.2.4 Detailing: Ecosystem change due to reduced sunlight availability

If a seaweed farm is located above or near an area of natural hard substrate, where seaweed is growing naturally, the natural seaweed below is potentially outcompeted by the farmed seaweed due to the absorption of the sunlight by the farmed seaweed near the surface. Also, competition for nutrients might occur. This relates to the carrying capacity of the ecosystem: How much nutrient extraction can the system handle/tolerate? These issues require further analysis into competitition between species.

5.2.5 Detailing: Invasive species

The presence of a seaweed farm (both offshore and nearshore) can amplify the risk of exotic species invasion. The multi-use setting poses a potential cumulative effect, because both activities introduce more additional artificial hard substrate to the environment, and the presence of seaweed itself can be a stepping stone/ substrate for exotic species.

When assessing the risk of invasive species, a number of questions still remain unanswered: Is it permitted to farm exotic, i.e., non-indigenous seaweed species? Does more traffic of ships without antifouling increase the risk of introduction of invasive species? To assess the hazards of invasive species, more clarity on these issues is needed.

5.2.6 Additional issues raised

Three additional issues were raised during the discussion.

Seaweed can be used as **scour protection** (real and/or artificial seaweed/seagrass), i.e., ropes, seeded by *Laminaria*, put on the seafloor to protect the scour of the wind turbine foundations. Seaweed does grow there, reducing water flow, catching sand, and thus protecting the foundation, similar to mangrove systems. Also, artificial seaweed or seagrass mats can prevent scouring. More information on this will be sought.

The (potential) marine protected area effect of a windfarm needs to be evaluated in the presence of a seaweed farm. In particular, the claim that wind farms can be **nursery areas** for fish needs scientific validation. An important ecological question is whether such nurseries are additional nursery areas or whether fish have abandoned their original nursery areas, which might result into other ecosystem changes.

In the discussion with stakeholders, it was also argued that SOMOS should focus on **future developments** and **opportunities** of multi-use combinations. Workshop participants emphasized that in the future turbines will be bigger (→ 10 MW) and smarter, incorporating principles of eco-design. Bigger turbines need more free space between the individual turbines to avoid wind shadows; hence, more space will become available for multi-use options. Bigger turbines/ more electricity per turbine also means that bigger transformers are needed. Until 2030, 700MW transformers are expected, which need more cooling water. Until now, it is not known whether the bigger transformers might have effects on the directly surrounding seawater (warming), on marine ecosystem components and on the productivity of seaweed aquaculture. The high voltage stations contain a lot of oil. There must be "leakage basins" in case the transformers leak. We should investigate whether this is still a real hazard, or whether the industry has already solved this issue.

5.2.7 Overview of additional risks discussed during the stakeholder workshop

Table 2 summarizes the additional issues raised by the stakeholders, which were further discussed during the workshop.

Table 2: additional hazards identified in the stakeholder workshop

Cause	**Hazard**	**Effect**	**Opportunity**
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

Cause	Hazard	Effect	Opportunity
Reduced sunlight availability	Negative ecosystem changes (potentially long-term)	• less primary production • benthic community deteriorates	
Invasive species	Negative impact on biodiversity/ foodweb	• potential habitat to invasive exotic species, translocations & bioinvasions artificial structures as stepping stones	

6 Concluding remarks

6.1 Status of these findings

The results presented in this deliverable are based on a literature study and consultation with stakeholders. It is important to acknowledge the considerable degree of uncertainty. There is uncertainy about certain cause-effect relationships. An important reason is that the information provided is mostly context-dependent; whether these effects will occur in real multi-use settings depends on local circumstances.For example, the risk of ecosystem change due to increased sedimentation is described by Zhang et al (2009), but they also conclude that this is not an issue for their empirical case (Sunguo Bay, China) where local conditions prevent this effect from occurring.

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.

6.2 Next steps

The results presented in this deliverable are a first overview of safety aspects of interaction and cumulative effects of the combination of offshore wind and seaweed farming. The overview is input to the development of a framework for safety assessment (WP4), since it gives a first list of hazards to focus on.

For a full assessment more insights in the cause-effect relationships and possible mitigating/amplifying ecosystem characteristics are needed. This further analysis will be conducted in the coming period. Results will be reported in deliverable 3.3.

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8 Justification

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