SOMOS secretariat
PO Box 68
1970 AB IJmuiden
Netherlands

t: +31 (0)317 487 036

D5.2 and D4.2: The Dutch Case Study: Multi-use at the North Sea

D4.2 A worked example of the application of the generic framework at the North Sea

Authors: Goossen, M, Banach, J., Burg, S van den, Hoof, L van., Rockmann, C., Vredeveld, L.,

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SOMOS
Safe production Of Marine plants and use of Ocean Space

Contents

1 Introduction

1.1 Multi-use at sea

The world population is expected to reach about 10 billion people by 2050, meaning there is an increasing urgency to develop sustainable solutions for food production, drinking water and energy. This means for example that in the coming decades, food and energy production needs to increase by 50% to be able to meet our population needs.

As our seas and oceans cover 71% of Earth, we should use this area and its resources efficiently to tackle this challenge. Activities at sea can help free up scare land, while initiative that make use of salt water can reduce the pressure on our already limited fresh water resources.

Offshore aquaculture may provide an answer to this challenge. However, a large number of activities are already taking place at sea. Especially in the near shore area the competition for available resources and space is already imminent. Under these circumstances multi-use at sea, combining activities within the same space is imperative, but complicated. Assessing the safety of multi-use activities is indispensable to be able to address the complexity of production at sea and sustainable solutions for food production.

In the SOMOS project, through the interaction of several work packages we have investigated the potential for multi-use at sea and the safety concerns that may arise when multiple activities and stakeholders come together. In this report, we aim to illustrate the potential for multi-use at sea given the Dutch North Sea as a case study, highlighting with our framework for safety assessment how to incorporate perspectives from food and feed, people and property, as well as marine interactions and cumulative effects.

The North Sea is unquestionably crowded, meaning competition for space is evident and the need to find multi-use solutions dire (Fig. 1). Given the rapid development of offshore wind energy in the North Sea and resultant spatial claims, there is a growing interest in combining offshore wind parks with other activities like the production of seaweed for food and feed. Liability and risks often mentioned as show-stoppers to multi-use. As of today, there are no real-life examples of seaweed cultivation inside a wind farm. Nonetheless, the importance of combining offshore wind and food and feed sectors may provide societal and economic advantages for the growing world population. In order to analyse the safety aspects related to the multi-use of offshore wind and seaweed cultivation at the Dutch North Sea (Fig. 2), we constructed a hypothetical case study. We utilized the location and characteristics of the Egmond aan Zee offshore wind farm (OWEZ), a Dutch offshore windmill park, along with the characteristics of the Stichting Noordzeeboerderij (the North Sea Farm Foundation) seaweed-testing site.

Based on a series of workshops with relevant stakeholders and a literature review of safety frameworks and risk and hazard concepts, an approach to safety assessment of multi-use at sea was developed. This approach consists of a framework with steps leading up to recommended practices for safe multi-use. The framework was applied to the case study at the North Sea. In each step, actions are defined, tools that can be of help are presented, and stakeholder participation steps are described. Moreover, we sought to integrate food and feed safety aspects, operational safety aspects of people, and equipment and environmental impacts.

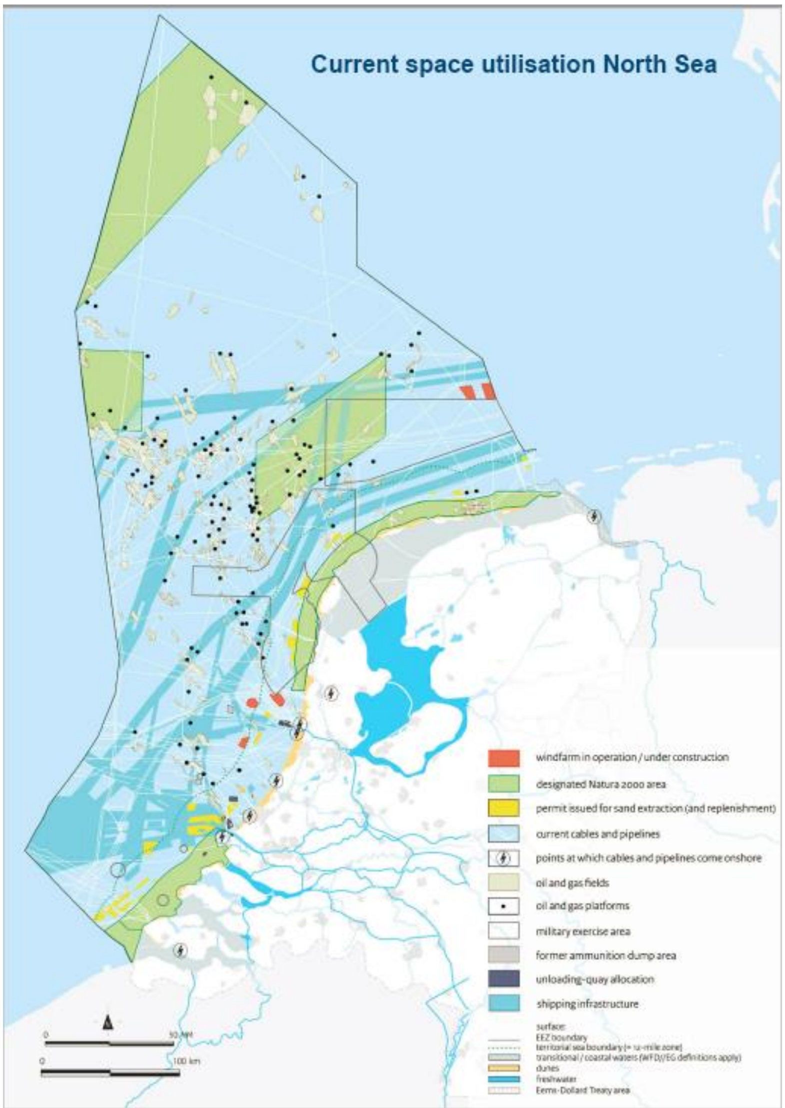

Figure 1. Current space utilisation North Sea (Integraal Beheerplan Noordzee 2015)

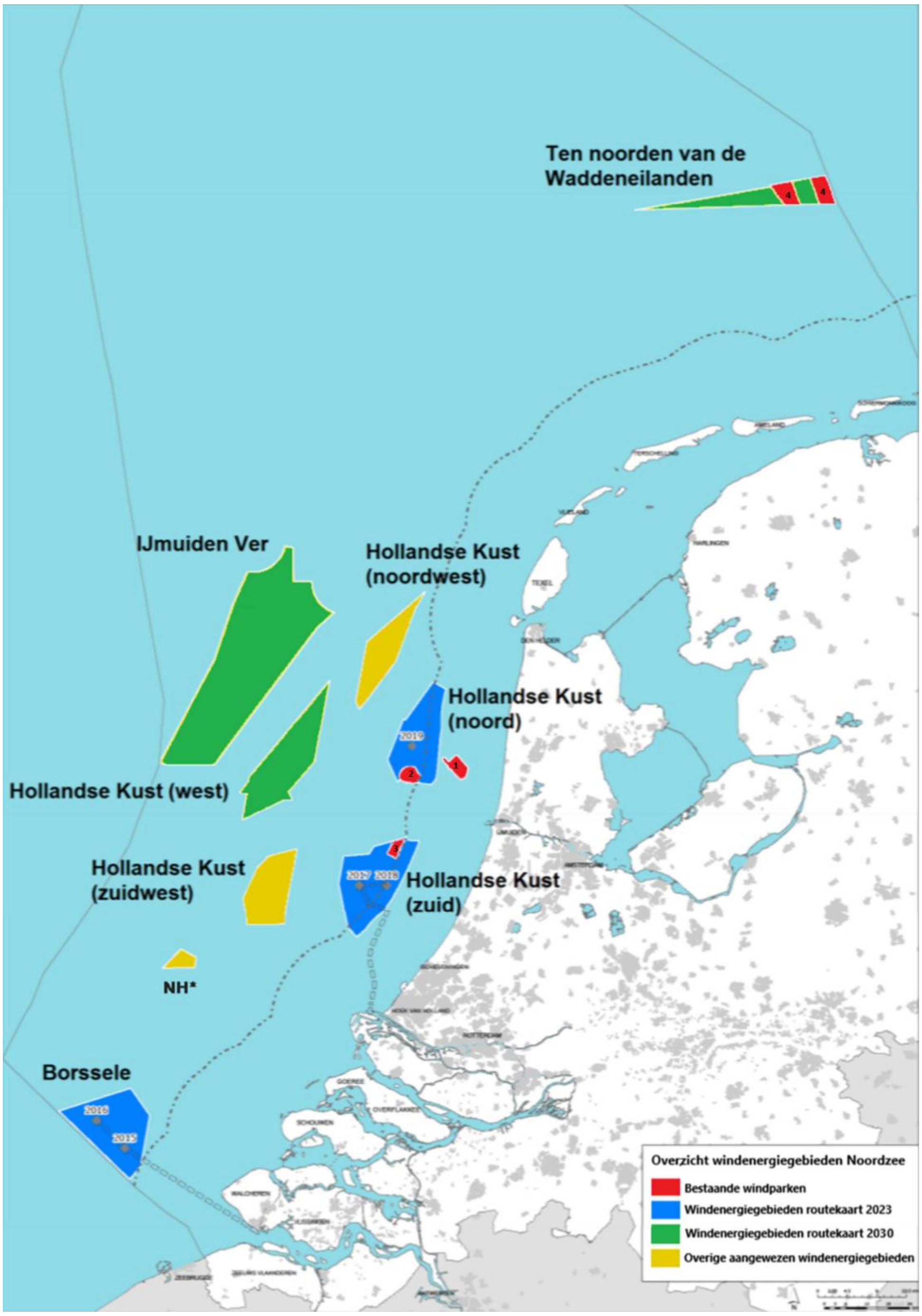

*Figure 2. Map of the existing wind parks in the Dutch North Sea (red): (1) Egmond aan Zee, (2) Prinses Amalia, (3) Luchterduinen, and (4) Gemini. Wind energy areas: road map 2023 (blue), road map 2030 (green), and other designated wind energy areas (yellow). * NH: Wind energy area north of the North Hinder shipping intersection. Adapted from Ministerie van Economische Zaken en Klimaat (2018).*

1.2 Short description of the framework

The framework (fig. 3) we developed consists of six phases (Van Hoof et al, 2018, deliverable D4.3) with safety aspects looked at from three perspectives: food and feed, people and equipment, and environment and cumulative aspects. Each phase defines actions, describes the information actors need, and identifies tools that can be of help.

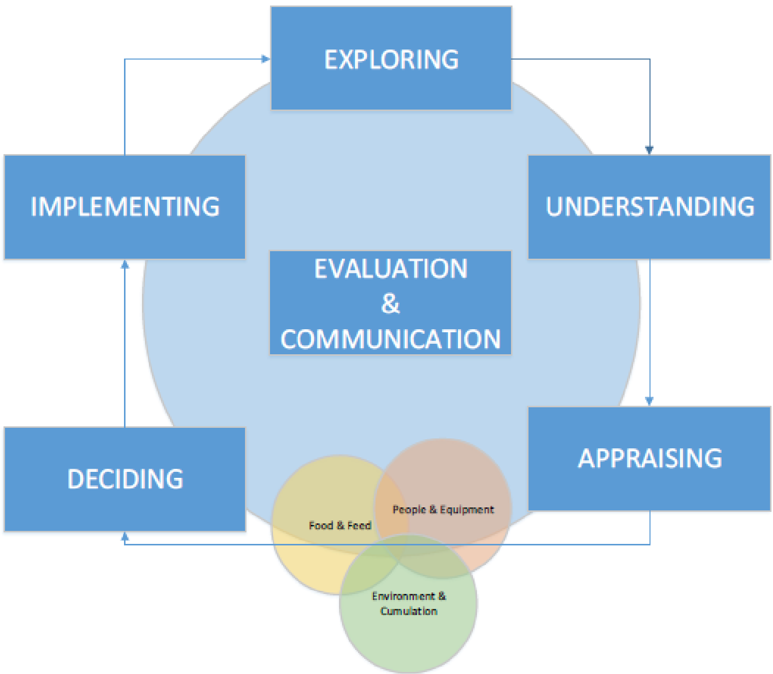

Figure 3. Framework for safety assessment of multi-use at sea

The *Exploring* phases identifies the multi-use system and the relevant actors and stakeholders. Among others, it contains a description of the exact activities and the location of these activities including its physical characteristics, and the policy, societal, economic/market, sectoral and governance context in which the individual and multi-use activities are taking place.

The *Understanding* phase identifies the opportunities and threats (hazards) surrounding the multi-use system. It will, given possible scenarios, likelihoods and consequences, and given the current level of knowledge and understanding, implement and identify risk control options. This will include an analysis of the interplay of the different activities in the system and the uncertainties and ambiguities surrounding the system. Based on the identified hazards and consequences mitigating measures can be defined.

In the phase of *Appraising,* the different management options based on the hazards, risks, consequences under different scenarios and events, given the current level of knowledge and understanding will be valued. This entails among others providing data and information that will allow support to the decision making process. It also encompasses an assessment of the perceived costs and benefits of the different events and possible mitigating measures.

The phase of *Deciding* focusses on deciding on recommendations regarding safe operations in a specific multi-use setting. This is the phase during which information from the prior steps is combined with the acceptance criteria developed and the "values" as defined by the relevant actors to arrive at a set of recommended practices. This against a backdrop of the different scenario's and strategies as identified by the stakeholders during the understanding and appraisal phases.

During the phase of *Implementation* the multi-use activities and the mitigating measures are being implemented by the relevant actors. This among others will also include relevant actions by the pertinent authorities in terms of monitoring and control and by application of relevant public standards and protocols.

Central in the safety assessment for multi-use are *Evaluation and Communication*. During and after each step informing relevant actors and stakeholders is of importance. Also after each step, it is important to evaluate findings and progress and decide to either take a step further in the process or, perhaps, take a step back. As multi-use at sea in its current form is a relatively new phenomenon, background knowledge is not widely available. With time and growing experience, knowledge and understanding may well increase. This then may call for a renewed safety assessment, against the backdrop of new information.

1.3 Goal and objective

The purpose of our case study is to gain insight into the extent to which the integrated framework can be applied to a specific location. We aim to illustrate the potential for multi-use at sea given the Dutch North Sea as a case study, highlighting with our framework for safety assessment how to incorporate perspectives from food and feed, people and property, as well as marine interactions and cumulative effects. This multi-dimensional safety framework will enable authorities and certifying organisations to bring safety implications of multiple activities under a common denominator. The ultimate goal of the framework is to help ensure safe operations when combining two or more activities at the same time at the same location at sea.

To gain insight, we evaluate which information is needed for an integrated approach of the three perspectives and examine if this information is available. We test our framework in a preliminary fashion to consider if a safety assessment of multi-use at sea is possible, meaning given a theoretical approach, we try to fill in the first two phases of the framework with the available information.

1.4 Limitations

This report focuses on the first two steps (exploring and understanding), because a real multi-use location of seaweed cultivation at a windmill park is not yet existing at the Dutch North Sea. This also means that we don't have empirical findings from this location. In this report we give an overview of more common information related to, but sometimes not directly focused on the case-study. Information that is already partly described in other deliverables, but to test our framework we put it in this report all together.

We do not deal with the appraise phase because at the moment there is no worldwide, nor national or corporate standard for management options, specifically for the combination of Seaweed Aquaculture and Wind Farms. Although there is no standard, tools and methods based on literature and interviews are available and described in deliverable 2.3. A Multi-Criteria Analysis (MCA) is recommended as a method for managers for multi-use. MCA is a form of appraisal that, in addition to monetary impacts, measures variable such as material costs, time savings and project sustainability as well as the social and environmental impacts that may be quantified but not so easily valued. Given the fact that standards are not (yet) clear, this seams the most practical way to evaluate risks. Stakeholders must provide norms and values to be included in the appraisal of scenarios, likelihoods and consequences and in the development of acceptance criteria for mitigating measures and how this can be done. In this case-study we are not going that far, because our case-study is virtual and stakeholders are not dealing with multi-use yet. Therefore we can’t test this phase in our framework.

Also information about how actors and stakeholders decided and implemented multi-use are not yet available and therefore cannot be evaluated.

1.5 Method

In order to grasp the safety concerns given multi-use, three perspectives were used when evaluating the framework with the case study.

Food & Feed: Looks at identifying relevant feed/food safety hazards with marine production, as well as potential control options for the identified hazards. It also identifies public and private standards for food and feed safety that are relevant for marine production in multi-use settings, and evaluates the applicability of these standards.

People & Equipment: Looks at identifying hazards to people and the equipment they operate. It looks at hazards and actions that can be taken to reduce risks and impacts.

Environment & Cumulative: Looks at identifying the possible risks and opportunities arising in the marine environment from the combination of (novel) maritime activities, competition between alternative uses and the cumulative pollution aspects of all activities combined. It looks at balancing ecological, economic and societal goals.

We obtained information through a series of interviews, discussions, literature reviews, and workshops. To make this virtual case-study more liveable, we organised a boat trip with experts to the location of the seaweed farm in the North Sea. With the Augmented Reality technique of TU-Delft we have placed (virtual) wind turbines at the location of the seaweed farm while we were sailing (fig. 4).

Figure 4. Snapshot of the combination seaweed and windfarm with Augmented Reality

2 Explore

This first phase describes all the activities at sea in and around the chosen location, equipment, jurisdiction, ecosystem and stakeholders involved. We describe the multi-use system throughout the three perspectives from food and feed, people and property, as well as marine interactions and cumulative effects.

2.1 Location and characteristics of the multi-use site

Offshore wind farms and seaweed farms seek access to locations, which share the same physical characteristics (shallow areas, specific depth ranges, proximity to coast, etc.). These locations are part of an ecosystem with their own specific characteristics.

2.1.1 Characteristics of the wind farm park

Windpark Egmond aan Zee (OWEZ) is the first Dutch offshore wind farm in the North Sea. It is located between 10 and 18 km off the coast of Egmond aan Zee, the Netherlands (Fig. 2, 6). The size of the farm is a projected 27 km^2. The OWEZ has 36 wind turbines (Vestas V90-3.0 MV Offshore), each with a capacity of 3 MW. Altogether, this can supply around 100,000 households with sustainable energy (https://en.wikipedia.org/wiki/OWEZ). The turbines have a total height of 115 m, a hub height of 70 m, and a rotor diameter of 90 m founded on a grounded monopole (see example Fig. 5) with a 4.6 m diameter (4Coffshore 2018). The export cables with a length of 20.4 km connect the offshore transformer to the onshore component (https://www.4coffshore.com/windfarms/egmond-aan-zee-netherlands-nl02.html).

Wind farms at sea are usually built close to the coast to keep the cost price low. To avoid wind turbines influencing each other's production, on average they are placed about six rotor diameters apart. At rotor diameter of 90 meters, that is about 600 meters in total length. The wind turbines have a monopile foundation. This is the most common type of foundation for an offshore turbine. It is simply a vertical pole that is driven deep into the earth beneath the turbine (Fig. 5).

Several times a year, large maintenance boats of 6000 tonnes sail from the port of IJmuiden to the location for maintaining the turbines. They share the sea with cruise ships, fishing vessels, cargo vessels and recreational ships, but also (virtually) with the boats for the seaweed coming in and out to serve the production areas. This makes the environment in and around the location a very crowded area (Fig. 6).

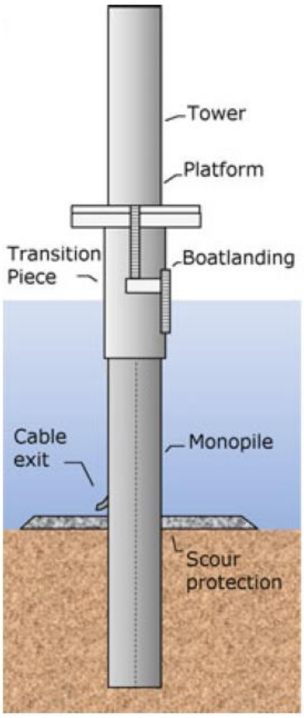

Figure 5. Example of a monopile turbine foundation. Adapted from Klijnstra, Zhang et al. (2017) (CC BY 4.O).

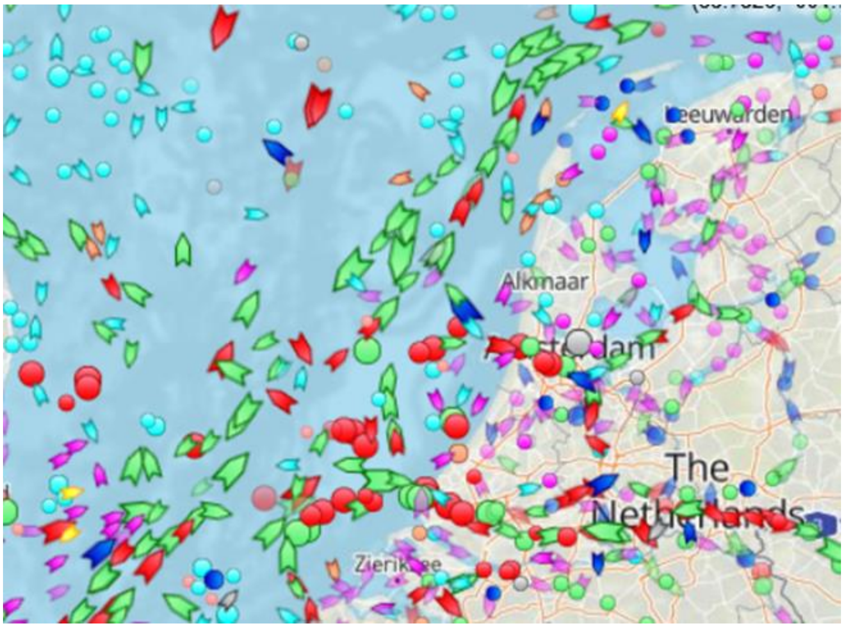

Figure 6. A timeslot of the traffic in the North Sea. The colours are different type of boats from cargo (green) to tourist vessels (blue)

2.1.2 Characteristics of the seaweed farm

Although the North Sea Farm Foundation's seaweed-testing site is located about 15 km off the coast of Scheveningen, the Netherlands (Fig. 7), we moved the location virtually between the turbines of the OWEZ. The size of the seaweed location will become 64 ha with a water depth of ±20m.

Figure 7. Location of the Egmond aan Zee offshore wind farm, OWEZ, (black star) and Noordzee Boerderij's seaweed testing site (red star). The arrow shows the movement from the seaweed site to the wind farm site.

Based on the dimensions provided by the North Sea Farm Foundation, for an offshore farm area, the following information was provided:

- Length of each singular module: 800 m (production module including mooring system)
- Parallel distance between modules: 250 m, leading to 5 singular modules

Figure 8 provides an overview of the case study combination of seaweed aquaculture, given the North Sea Farm Foundation's characteristics, along with the characteristics of the OWEZ wind farm characteristics. The seaweed farm has its own (semi-permanent) mooring system and is not attached to the wind turbines.

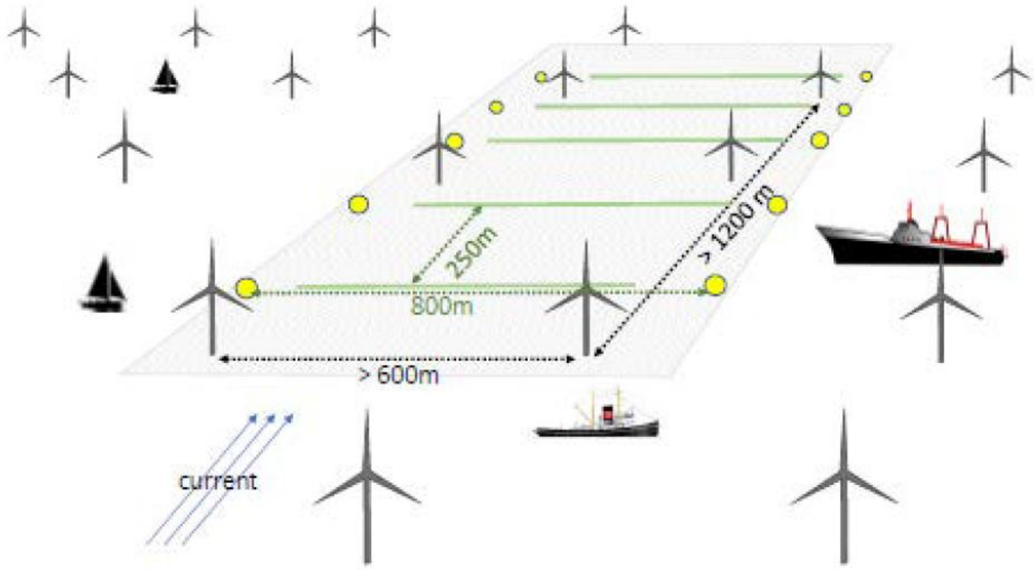

Figure 8. Dutch North Sea case study with the multi-use combination of wind energy production and seaweed cultivation (Buck, Nevejan et al. 2017).

The seaweed production system consists of substrate lines in a vertical plane positioned between an upper and lower support line. Vertically the lines are positioned through an array of buoys, while horizontally the lines are tensioned through anchor lines at each side of the substrate system. A schematic of the seaweed long line cultivation dimensions as used at the North Sea Farm Foundation's Scheveningen seaweed-testing site is provided in Figure 9.

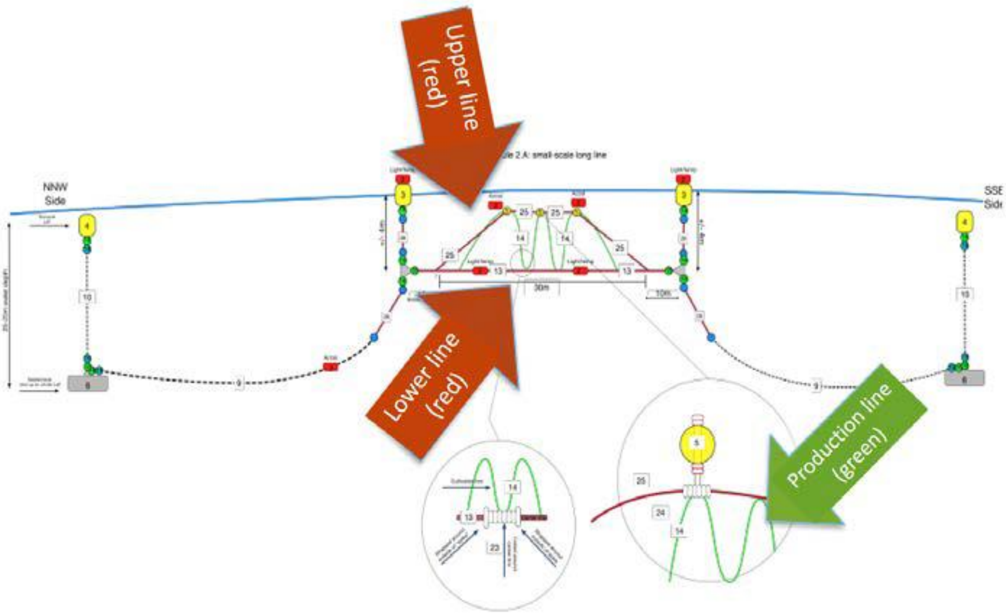

Figure 9. Schematic of the North Sea Farm Foundation seaweed test farm long line dimensions.

The North Sea Farm Foundation grows *Saccharina latissima*, meaning this case study focuses on this brown seaweed, formerly referred to as *Laminaria saccharina* and more commonly known as sugar kelp, sea belt, or Devil's apron (Fig. 10). This seaweed grows from autumn to spring (Noordzee Boerderij 2018). Currently operating on experimental scale, expected production levels are set at 25 ha, producing 20 ton DM per hectare per year. In the North Sea coastal waters nutrients are available in excess. This especially relates to the formation of spring blooms of micro-algae that profit from high winter nutrient concentrations. Therefore, seaweeds produced during winter could benefit from these high nutrient concentrations and mitigate the problems caused by these (van den Burg et al., 2016). Two times a year the seaweed can be harvested using harvesting boats, which share the location with the other users.

Figure 10. A depiction of the brown seaweed Saccharina latissima.

Algae are simple nonflowering chlorophyll containing aquatic plants. Macroalgae or seaweed refers to several species of macroscopic multicellular marine algae. Seaweed can be broadly classified into three main groups based on pigmentation: brown algae (Phaeophyceae), red algae (Rhodophyceae), and green algae (Chlorophyceae). Brown seaweeds are typically larger than green and red seaweeds and can range in length from 30-60 cm to 20 m (McHugh 2003). In the North Sea, indigenous seaweeds include *Laminaria digitata* (brown), *Ulva lactuca* (green), *Palmaria palmata* (red), and *Saccharine latissima* (brown) (Reith, Deurwaarder et al. 2005, Van den Burg, Stuiver et al. 2013).

Over 30 million tons (live weight) of farmed seaweed were reported in 2016, with nearly all cultivation occurring in Asia: China (47.9%), Indonesia (38.7%), the Philippines (4.7%), the Republic of Korea (4.5%), Japan (1.3%), and Malaysia (0.7%) (FAO 2018). In comparison to Asia, European seaweed production is still in its infancy (Buck, Nevejan et al. 2017). In the last two decades, however, cultivation of brown algae, especially of *Saccharina latissima*, in Western countries occurs in the North Atlantic Ocean. Considering offshore cultivation of seaweed, brown algae is an appropriate candidate due to its low need for maintenance and harvest (Kim et al. 2017). Given the biological, economic, and regulatory requirements, *Saccharina latissima* has been seen as a favourable seaweed for offshore cultivation in the German North Sea given adaption to offshore strong currents as young cultured sporophytes (Buck and Buchholz 2005, Buck, Krause et al. 2017).

Saccharina latissima is a short-lived perennial, with sporophytes typically having a lifespan in the wild of 2 to 4 years. It tends to grow fastest from late winter to spring, with growth rates declining in early summer possibility due to nitrate limitation (White and Marshall 2007). Optimal water temperatures for growth are <18 °C (Van den Burg, Stuiver et al. 2013), with reported optimal growth conditions in the Oosterschelde at water temperatures between 5-10 °C with salinity at about 32% (Groenendijk, Bikker et al. 2016). Cultivated *Saccharina latissima* has shown variation in biomass production (Groenendijk, Bikker et al. 2016, Sharma, Neves et al. 2018) with both biomass production and chemical composition reported to depend on the depth of cultivation and harvest time (Sharma, Neves et al. 2018).

2.1.3 Characteristics of the eco-system

The environment of the location is also used by fish and birds. Any structure placed in the sea will become colonised by marine organisms (Firth et al., 2014). Because of the windfarm there could be an abundance of marine mammals due to the added hard substrate and increased food availability. Although we don't know the exactly route, during the autumn migration, the sky above the multi-use location could be used by many migrating birds like the godwit, spoonbill and little swan flying to Africa or South-Europe (Volkskrant, 2018). The bottom of the Dutch North Sea consists mainly of soft sediments but because of a potential fall-off seaweeds the sedimentation could lead to organic enrichment. Especially because wind turbine foundations cause disturbances in the water layers and more seaweed could break loose and sink to the seafloor.

2.2 Legislation and governance

2.2.1 Legislation

Until now, the legal situation regarding multi-use of offshore wind parks differs in the various EU member states bordering the North Sea. In the Netherlands, the proposal to allow transit and multi-use of wind farms under conditions has recently been approved by the Ministry of Infrastructure and the Environment. She has decided that wind farms will be passable under certain conditions for water sports activities and other users. In order to limit the risks of this new policy and to maintain the conditions, a number of measures are taken:

- Passage of the safety zone around wind farms is only permitted for vessels with a length of 24 meters or less;
- Passage of the safety zone around wind farms is only allowed during the day;
- Passage of the safety zone around wind farms is only permitted for vessels that have an AIS (automatic identification system) on board that is also in operation during the passage of the safety zone;
- Passage of the safety zone around wind farms is only permitted for ships that have a VHF radio on board and also listen to them and communicate with them during the transit of the safety zone;

- Practicing diving is prohibited within the safety zone;
- Within the safety zone, activities that pose a danger or hindrance to the operation of the park are prohibited. In addition, every activity by third parties at a distance of less than 50 meters from the wind turbine is considered dangerous and / or annoying.

In the European Union, the General Food Law (Regulation (EC) 178/2002 and its amendments) lays down general principles, requirements, and procedures about food and feed at EU and national levels. These principles also apply to the production of seaweed for food or feed purposes in a multi-use perspective. Moreover, additional legislation related to macroalgae are embedded in overarching subjects surrounding food and feed safety such as hygiene, novelty, labeling, additives, production, control, hazardous substances, etc.

EU legislation on contaminants in foodstuffs (Regulation (EC) 1881/2006, including amendments thereof) includes some legislation specifying maximum limits in macroalgae. For lead, cadmium, and mercury, maximum levels in food supplements are 3.0, 3.0, and 0.1 mg/kg wet weight, respectively. Furthermore, for each of these maximum levels, the amount of dry matter needs to be adjusted accordingly: "The maximum level is given for the liquid product containing 40% dry matter, corresponding to a maximum level of 50 µg/kg in the dry matter. The level needs to be adjusted proportionally according to the dry matter content of the products." Moreover, the maximum limit for cadmium in food supplements is based on: "food supplements consisting exclusively or mainly of dried seaweed, products derived from seaweed, or of dried bivalve molluscs." Although maximum levels of lead and cadmium are included for vegetables, respectively 0.10 and 0.050 mg/kg wet weight, these levels specifically exclude that of seaweed. For mercury, no indication for macroalgae is provided. Finally, maximum levels of inorganic arsenic in seaweed in the form of food or food supplements are not provided.

EU legislation also sets maximum permitted levels for undesirable substances in feed ingredients and complete feedingstuffs (Directive 2002/32/EC and its amendments). Within this directive, the maximum content is relative to a feed with a moisture content of 12%. Total arsenic in feed for seaweed meal and feed materials derived from seaweed is 40 mg/kg, while for fish, other aquatic animals and products derived thereof it is 25 mg/kg, and for feed materials, it is 2 mg/kg. However, for seaweed meal and feed materials, as well as aquatic animals and products thereof, it is required to demonstrate that inorganic arsenic is lower than 2 mg/kg (ppm), with particular emphasis for *Hizikia fusiforme* seaweed. Furthermore, the maximum permitted levels for cadmium, lead, and total mercury in feed materials of vegetable origin is 1 mg/kg, 10 mg/kg, and 0.1 mg/ respectively (relative to a feed with a moisture content of 12%). Other limits in feed for fluorine, nitrate, melamine, dioxins, dioxins and dioxin-like PCBs, and non-dioxin like PCBs are outlined in Table 1.

Table 1. Overview of limits for food supplements and feed related to seaweed.

Hazard	Form	Limit	EU Legislation
Cadmium	Food supplements	3.0 mg/kg wet weight	Regulation (EC) No 1881/2006
	Feed	1 mg/kg (relative to a feed with mositure content of 12 %)	Directive 2002/32/EC
Lead	Food supplements	3.0 mg/kg wet weight	Regulation (EC) No 1881/2006
	Feed	10 mg/kg (relative to a feed with mositure content of 12 %)	Directive 2002/32/EC
Mercury	Food supplements	0.1 mg/kg wet weight	Regulation (EC) No 1881/2006
Total mercury	Feed	0.1 mg/kg wet weight (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Total arsenic	Feed	40 mg/kg* (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Fluorine	Feed	150 mg/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Nitrite	Feed	15 mg/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Melamine	Feed	2.5 mg/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Dioxins	Feed	0.75 ng WHO-PCDD/ F-TEQ/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Dioxins and dioxin-like PCBs	Feed	1.25 ng WHO-PCDD/ F-PCB-TEQ/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC
Non-dioxin like PCBs	Feed	10 µg/kg (relative to a feed with a moisture content of 12%)	Directive 2002/32/EC

* According to Directive 2002/32/EC: "Upon request of the competent authorities, the responsible operator must perform an analysis to demonstrate that the content of inorganic arsenic is lower than 2 ppm. This analysis is of particular importance for the seaweed species *Hizikia fusiforme*."

European legislation to protect the environment is mainly regulated through Natura2000 legislation but this legislation does not apply for this location.

International Standards provide specifications for products, services and systems, to ensure quality, safety and efficiency. ISO International Standards are developed by the International Organization for Standardization (ISO), an independent, non-governmental organization. The following ISO standards might be relevant for the offshore production of feed, food and energy:

- ISO 14001:2015 Environmental management systems — Requirements with guidance for use
  http://www.iso.org/iso/catalogue_detail?csnumber=60857
- ISO 22000 - Food safety management
  http://www.iso.org/iso/home/standards/management-standards/iso22000.htm
- ISO 31000:2009 — Risk management — Principles and guidelines, provides a set of principles, a framework and a process for managing risk.
- http://www.iso.org/iso/home/standards/iso31000.htm ISO 45001 - Occupational health and safety
  http://www.iso.org/iso/home/standards/management-standards/iso45001.htm)

Various standards exist for the identification and assessment of occupational health and safety risks. In addition to the ISO 45001 standards mentioned above, the following can be relevant for offshore production of feed, food and energy:

- OHSAS 18001: Occupational Health and Safety
  https://www.ohsas-18001-occupational-health-and-safety.com/
- ILO-OSH 2001: Guidelines on occupational safety and health management systems
  http://www.ilo.org/safework/info/standards-and-instruments/WCMS_107727/lang--en/index.htm

The environmental impact assessment Directive (2011/92/EU) and its amendment Directive 2014/52/EU outline the procedure for environmental impact as a procedure to ensure that the environmental implications of decisions are taken into account before the decisions are made. Environmental assessment can be undertaken for individual projects, such as the construction of a dam, motorway, airport or factory, on the basis of Directive 2011/92/EU (known as 'Environmental Impact Assessment' – EIA Directive) or for public plans or programmes on the basis of Directive 2001/42/EC (known as 'Strategic Environmental Assessment' – SEA Directive). The common principle of both Directives is to ensure that plans, programmes and projects likely to have significant effects on the environment are made subject to an environmental assessment, prior to their approval or authorisation.
http://ec.europa.eu/smart-regulation/guidelines/ug_chap3_en.htm

2.2.2 Stakeholders

Stakeholders are individuals, groups, or organisations that are (or will be) affected, involved or interested (positively or negatively) by marine spatial planning management actions in various ways. A multi-use stakeholder analysis can be used as a tool to capture the degree of influence and level of interest of each stakeholder. Making an 'Importance versus Influence Matrix' (Fig. 11) helps to map out stakeholders and their relation to the seaweed-windfarm combination. It generates insights on the importance and influence of each stakeholder.

- Importance: The priority given to satisfying the needs and interests of each stakeholder.
- Influence: The power a stakeholder has to facilitate or impede the achievement of an activity's objective. The extent to which the stakeholder is able to persuade or coerce others into making decisions, and following a certain course on action.

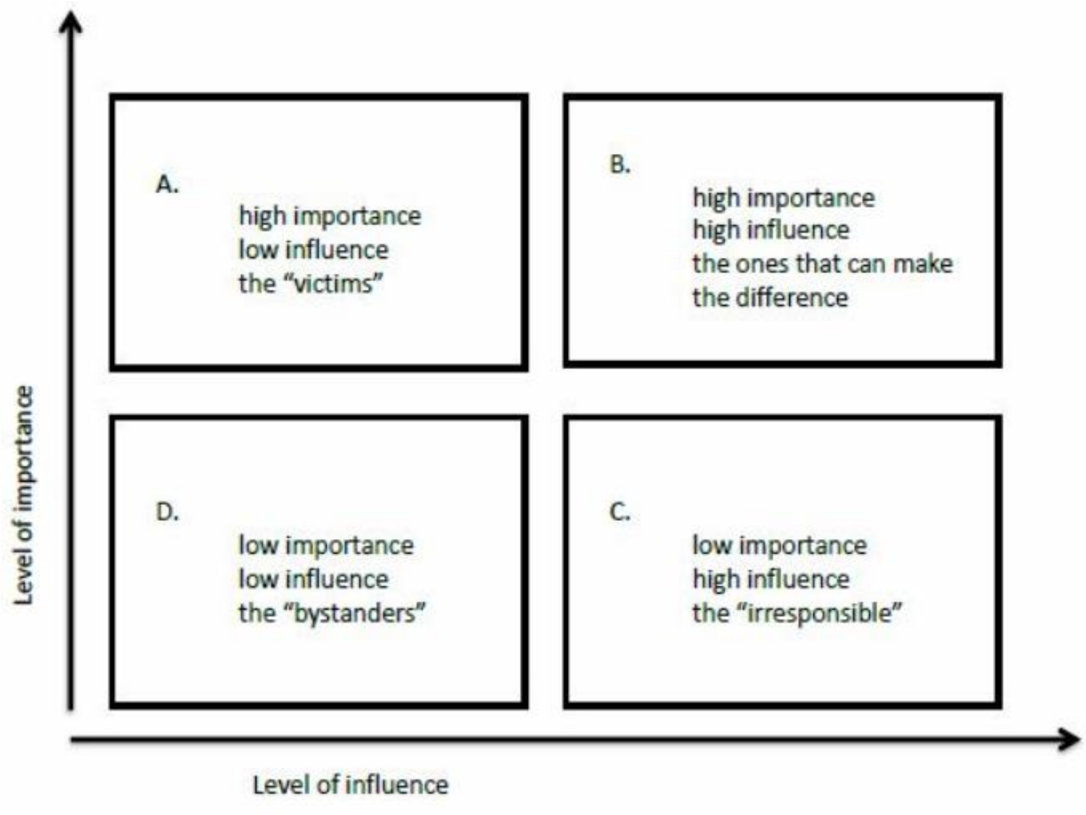

Figure 11. Importance/influence Matrix (Source: APMAS Knowledge Network)

Considering this case study, a series of workshops and interviews were held with relevant practitioners and operators, policy makers, risk assessors and NGOs. Stakeholders provided data, information and evidence on crucial steps in the multi-use system. This information was utilised to assess the requirements of a safety assessment framework for multi-use and to test findings on aspects of food and feed safety, safety of people and equipment, and environmental and cumulative impact. Because of the three perspectives, the amount of stakeholders is large and they can be placed in the following matrix according to their level of influence and/or importance (Fig. 12).

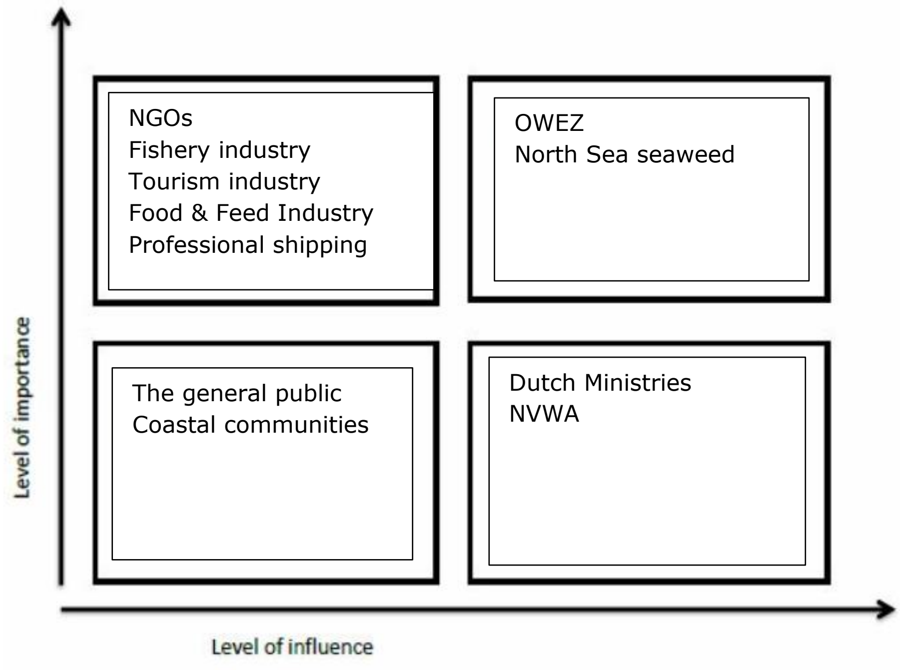

Figure 12. Importance/influence Matrix of the case study

The wind farm park OWEZ and the North Sea seaweed farm are key players in this location. They can make the difference because they have a great interest and/or financial means to develop the location. They have a high influence and they are very interested (virtually) to operate together in this location.

The Dutch ministries have a high influence because they make the laws and regulate the use. In the end, they give the permission. They operate on a national scale, so their involvement in this specific location is lower; other locations are also useful. Although they have made the obligation to diminish the CO_2 emission through renewal energy. The NVWA (Nederlandse Voedsel- en Warenautoriteit) has the possibility to reject seaweed for the market and their influence is very high, but their involvement with this specific location is lower.

The specific location was/is also used by other users (fishery, tourism, professional shipping) and they have an interest to use this location also, but their influence is a little bit lower although they can "lobby" for access like the water sport lobby did. NGOs for flora and fauna stand up for nature protection and their importance is also high, but a lower influence.

The general public has a demand for renewal energy and to buy seaweed and also coastal communities have a relation with this multi-use (jobs, experience) but their importance and influence is relatively limited. Depending on the industry, however, the influence of the public on which products are sold may influence other stakeholders. For example, if the public demands more seaweed related food products, then retail organisations can adapt their strategy to complement this.

One of the results of the workshops and interviews was that the cultures of stakeholders are varying. Given single use, stakeholders have a few persons to communicate and negotiate with, yet given a multi-use perspective, the systemic nature of multi-use creates more complexity in the stakeholder analyses. Meaning there are more people trying to get the 'same slice of the pie.' During multi-use, stakeholders need to be able to communicate with many other stakeholders they normally do not encounter. This difference in culture makes it a challenge to find a "common language".

2.3 Seaweed uses and markets

Seaweed can be cultivated for several markets, among which food and feed are gaining more attention in the Western world. Seaweed can be consumed fresh, but dried seaweed products and snacks (e.g., baked goods) are making their way to the European market. Seaweed is an ingredient for future product development for both the food and beverage industry, yet marketability for Western consumers, who do not yet regularly consume seaweed in their diet, is key (Askew 2018). Seaweed can also be used in food as a salt replacer, flavour enhancer, or a texturizer. Many red and brown seaweeds produce three hydrocolloids: agar, alginate, and carrageen, which can be used as gelation and thickening agents in food products (e.g., ice cream) as well as binders in feed for abalone (McHugh 2003). However, hydrocolloids can also be used in pharmaceuticals or in biotechnological applications.

Animal feed is another sector with which seaweed is used. Dried seaweed can be milled into a fine powder and used as seaweed meal as has been done in Norway (*Ascophyllum nodosum*), France (*Laminaria digitata*), Iceland (*Ascophyllum* spp. and *Laminaria* spp.), and the United Kingdom (*Ascophyllum* spp.). Also in fish farming, finely ground seaweed meal (from brown seaweeds), as well as fresh seaweed, have been used (McHugh 2003). More recently, the application of seaweed as cattle feed can help lower methane emissions as demonstrated during in vitro experiments simulating ruminant digestion with fermented seaweed (Kinley, de Nys et al. 2016) including that of S. latissima (Maia, Fonseca et al. 2016).

In additional to seaweed use for food, feed, or even pharmaceutical purposes, seaweed has several other applications such as for fertilizers, biofuels, cosmetics including lotions and creams, in integrated aquaculture, and for wastewater treatment (McHugh 2003). For example, the seaweed *S. latissima* is reported to be used as a source of biogas production (Kumar, Sahoo et al. 2015) and in commercial cosmetics (FAO 2018).

More recently, seaweed is being marketed in bio-based products, for example as a bioplastic in packaging and bio-based textile for the fashion industry. Seaweed uses as a bioplastic include that for biodegradable water bottles, bags, containers, etc. For instance, the start-up company Skipping Rocks Lab (London, UK) has created an edible water bottle "Ooho!" from seaweed. Moreover, another start-up company called Evoware (Indonesia) makes cups, containers, and other biodegradable alternatives to plastics from seaweed to help solve the environmental concerns around plastic use and as a solution for Indonesian farmers' unused seaweed. Regarding seaweed being used as a bio-based textile, the company AlgiKnit uses seaweeds, like kelp, as a source of alginate to create their "bioyarn" to be used for footwear and apparel. Given the societal challenge and trends towards global sustainability, seaweed appears to be an excellent option for use in both food, feed, and non-food purposes.

The market value is estimated as $6 billion in 2014 existing of 80% food and 20% non-food market. 95% of seaweed is produced in Asia in large and professional farms, nearshore and with intensive labour. In Europe 300.000 ton-w/year is produced, mostly (90-99%) wild harvest in Norway, France, Iceland, Ireland and Spain (Brouwer, 2018).

The ambition for The Netherlands is to produce 1mln ton-d seaweed in 2030 in an area of 500km2 in which 25% is combined with wind farms (Brouwer, 2018).

2.4 Conclusion

The virtual case-study shows that this first phase (explore) of the framework is applicable. The situation at the location can be describe from the perspectives of food and feed and people and property. But, because of the virtual status, it was rather difficult to describe the situation from the marine interactions and cumulative effects. Although we could indicate the information needed for a description of the marine interactions and cumulative effects. An overview of the importance and influence of the stakeholders involved is also possible. Information about the market, the legal and governance factors is also available.

3 Understand

This phase of Understanding aims at identifying the opportunities and threats (hazards) surrounding the multi-use system. It will, given possible scenarios, likelihoods and consequences, identify risk control options. Based on the identified hazards and consequences mitigating measures can be defined.

3.1 Hazards and knowledge gaps

Given the limited information regarding the subsequent effects of multi-use at sea considering the offshore wind park and seaweed farm combination, the available information on potential hazards given single use, *i.e.* hazards that can occur during seaweed cultivation, are invested. But participants in the workshops found it rather difficult to define hazards, causes and consequences without common rules. E.g. for certain activities with vessels safety zones are installed. What if these zones were not there? This may be an issue, because for new activities and/or new operators, safety zones may be unknown or lacking.

3.1.1 People and property

In terms of safety of people and property there are additional potential hazards to be identified when embarking on a combined use of sea space. A longlist of hazards was identified by the SOMOS team and discussed at a workshop with international experts and during interviews with authorities and experts on wind park maintenance and sea weed farming (see also deliverable 2.1 Report describing relevant hazards for the combination of Seaweed Aquaculture and Wind Farms). Subsequently, the longlist was reduced to a shortlist of relevant hazards (Table 2) based on the input of the experts and other interested parties. Hazards which are not consequence of combining activities are not considered.

Table 2: Hazards related to the combined activities of wind park operation and seaweed farming

No.	Hazard / undesired event
1	Seaweed substrate system out of position
2	Contaminants in the water[1]
3	Seaweed vessel collides with wind turbine
4	Ship-ship collision
5	Ship hits diver
6	Windfarm vessel hits substrate system
7	Seaweed vessel hits electric power lines

For this case-study we further focused on the hazard of a vessel colliding with a wind turbine. The vessel makes a maneuvering error and consequently collides with a wind turbine pylon. This may cause a dent in the pylon structure which jeopardizes the buckling strength of the pylon forcing it to shut down and launch a repair action. The collision can also lead to deformation and even rupture of the ship's hull, causing pollution of the marine environment by oil and chemical spills, or serious injuries or fatalities to crew present on-site.

[1] E.g. failure of the hydraulic system of the wind turbine leading to hydraulic oil in the water contaminating the seaweed which then cannot be sold on the market (= loss of property).

To understand the impact on the wind turbine of this hazard information is needed. The most critical factors affecting the magnitude of damage caused by collisions between a ship and an offshore wind structure are as follows (Moulas et al, 2017):

- Technical specifications of the ship such as its tonnage, average speed, stiffness, etc.
- Structural properties of the wind turbine and its foundation such as strength, toughness, elastic properties, ductility, brittleness, etc.
- Head on bow and sideway collision of ships with wind turbine foundations.

3.1.2 Food and Feed

By trying to assess both single and multi-use of seaweed cultivation, we provide a holistic overview of potential hazards. The main hazards with respect to the seaweed consumption include:

1. heavy metals (arsenic, cadmium, lead, and mercury);
2. iodine;
3. pesticide residues;
4. toxic metabolites;
5. microbiological pathogens; and
6. the presence of micro- or nanoparticles in plastics.

Furthermore, other relevant hazards may include halogenated components – e.g., dioxins, dioxin-like PCBs, non-dioxin like PCBs, nitrate, anti-nutritional factors – e.g., lectin, as well as processing contaminants – e.g., benzo(a)pyrene, polycyclic aromatic hydrocarbons, of which the latter is particularly relevant during seaweed processing.

Besides literature studies, personal interviews were conducted with stakeholders involved with different stages of seaweed cultivation. The nine interviewees included seaweed producers (1), seaweed producer/processors (1), traders (1), business innovators (1), retailers (1), certification bodies (1), and national governmental authorities (3). The identified current and potential concerns related to food and feed safety relevant for seaweed and seaweed aquaculture focused on single-use application, with the exception noted by governmental authorities of the increased probability given an oil spill at a multi-use setting of an offshore windmill park and seaweed farm. Contaminants, including heavy metals like (inorganic) arsenic and mercury as well as iodine were noted by all interviewees. Additional concerns noted by governmental authorities included microorganisms on seaweed or from storage thereof (e.g., *Salmonella* spp.) as well as toxic metabolites (e.g., marine biotoxins or phytotoxins). Also, the interviewed seaweed trader identified a concern with traceability of products, which is also a relevant issue given a multi-use setting. Some interviewees also expressed that the location of seaweed cultivation and handling of seaweed should be such that contamination is avoided, meaning the location for a multi-use setting when food or feed are to be cultivated should be situated in a clean environment so that biological, chemical, or physical contaminations or influence of environmental pollutants (e.g. oil spill) is avoided.

Moreover, to try to better identify potential hazards, experts were consulted during a stakeholder workshop to discuss hazards related to seaweed farming at an offshore wind farm. The experts identified possible knowledge gaps that should be considered when critically evaluating food and feed safety hazards given a multi-use perspective (Table 3). These knowledge gaps warrant future research, to be able to quantify the impact that an event has on the occurrence of a hazard.

Table 3. Potential knowledge gaps and opportunities for future research given the multi-use at sea perspective

Knowledge gap	Explanation
Physical hazards	Relevant if materials from substrates and equipment releases into the surrounding environment. Dead animals can also have an effect on the ecosystem, especially if they are present during cultivation.
Effect of processing	Useful to understand the hazards that may appear at later stages in the supply chain.
Contaminant transfer rate to crops	The rate that certain hazards transfer (e.g., in the water) to the seaweed and is taken up by the seaweed can influence the final exposure and thus any potential concerns for human health.
Effect of antifouling or protective coatings	May influence genetic mutations or be of a concern for certain species.
Seaweed type, adaption, and farming practices	The needs for sustainable farming and rotating crops may be of a different need or concern depending on the seaweed species cultivated. The cultivation or harvesting practices including the frequency thereof and machinery used are relevant. In addition, chemical weapon munition dumping may have occurred. On or nearby the multi-use site and could alter the list of relevant hazards.

3.1.3 Marine interactions and cumulative effects

A hazard can have an effect on the interactions with the marine environment and the cumulative effects of two activities on the wider environment within which these activities take place. A hazard can have quick changes to the environment but also slowly occurring effects. The results are based on a literature study and consultations with experts in interviews and during a stakeholder workshop (see also deliverable D3.1).

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

- 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 substances into the environment.

The slowly occurring changes due to combined wind-seaweed farm could be:
- Increased corrosion/biofouling/technical damage
- Contamination of seaweed
- Loss of protected species

Note that there is considerable uncertainty as to whether or not these effects will occur because no offshore wind park has as yet been combined with a seaweed farm.

3.2 A hazard in a multi-use approach for the case study

A hazard to property can lead to a problem with food or environment. An event of an oil spill caused by a collision may have as a consequence that the substrate is chemically polluted, the seaweed crop is contaminated and lost for consumption. For this virtual case-study we choose this event in our framework (fig. 13). The first question is: will this collision damage the wind turbine pylon and will there be full damage? The extent of damage can be predicted from ships mass, impact velocity/ location, and impact velocities. The explicit finite element method can be used for this. The next question is: how large is the oil spill? This can be estimated with outflow calculation methods. But also: will the seaweed absorb the oil and is it still edible or can it be only used as raw material. The consequence is that the seaweed has to be tested in a laboratory to find out if it still meets the safety requirements of food and feed.

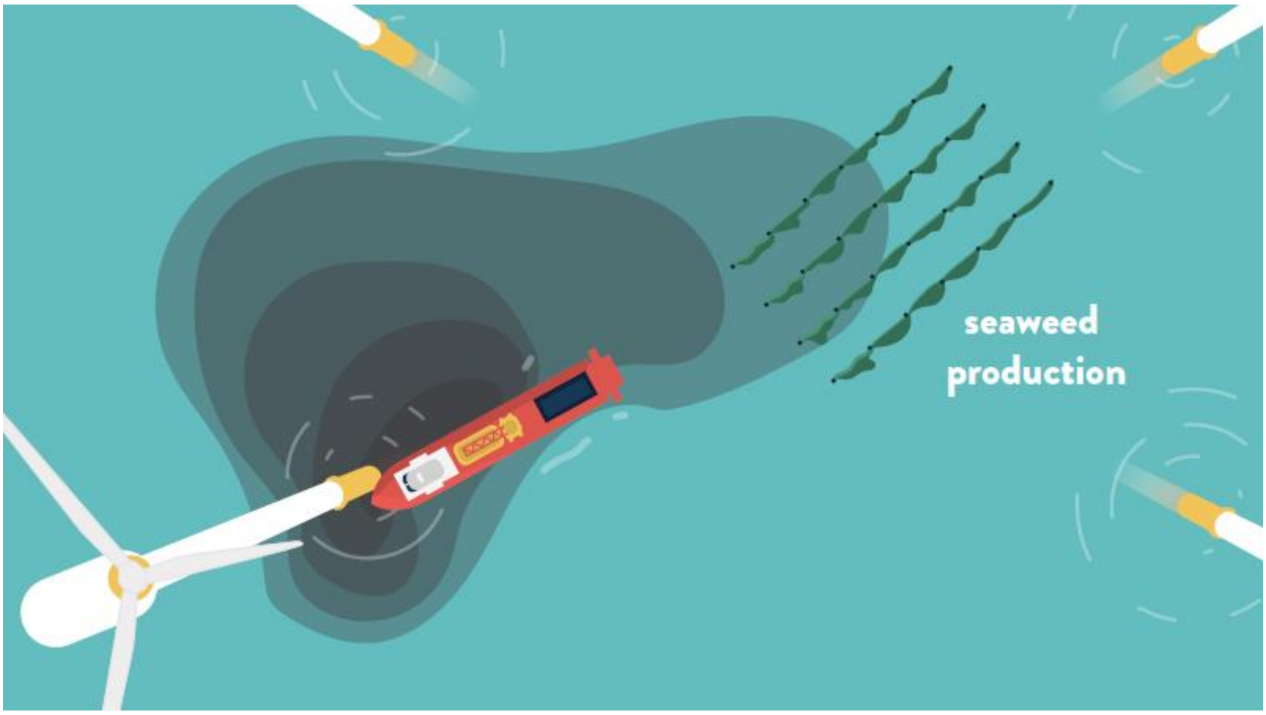

Figure 13. a vessel collides with a wind turbine leaking oil over the seaweed

The specific factors to assess the impact on food and feed are the extent of the oil spill, the type of oil, the oil uptake, the length and intensity of exposure but also the type of seaweed grown and time of harvesting. To assess the impact of the ecosystem you need specific factors on the soil- and marine life and birds. This means that information is needed for these specific factors. This type of information in multi-use is crucial.

In general, oil spills can affect animals and seaweed in two ways: from the oil itself and from the response or cleanup operations. Understanding both types of impacts can help spill responders minimize overall impacts to ecological communities and help them to recover much more quickly.

Spilled oil can harm living things because its chemical constituents are poisonous. This can affect organisms both from internal exposure to oil through ingestion or inhalation and from external exposure through skin and eye irritation. Oil can also smother some small species of fish or invertebrates and coat feathers and fur, reducing birds' and mammals' ability to maintain their body temperatures (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants-marine-environments.html).

Oil usually spreads out rapidly across the water surface to form a thin layer that we call an oil slick. As the oil continues spreading, the layer becomes thinner and thinner, finally becoming a very thin layer called a sheen. Depending on the circumstances, oil spills can be very harmful to marine birds and mammals and also can harm fish and shellfish. Oil destroys the insulating ability of fur-bearing mammals and the water-repelling abilities of a bird's feathers, thus exposing these creatures to the harsh elements. Many birds and animals also ingest (swallow) oil when they try to clean themselves, which can poison them. Depending on just where and when a spill happens, from a few up to hundreds or thousands of birds and mammals can be killed or injured (https://response.restoration.noaa.gov/training-and-education/education-students-and-teachers/how-do-spills-happen.html).

The type of oil spilled matters because different types of oil behave differently in the environment, and animals and birds are affected differently by different types of oil (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants-marine-environments.html). However, it's not so easy to say which kind is worst. First, we should distinguish between "light" and "heavy" oils. Fuel oils, such as gasoline and diesel fuel, are very "light" oils. Light oils are very volatile (they evaporate relatively quickly), so they usually don't remain for long in the aquatic or marine environment (typically no longer than a few days). If they spread out on the water, as they do when they are accidentally spilled, they will evaporate relatively quickly.

However, while they are present, light oils present two significant hazards. First, some can ignite or explode. Second, many light oils, such as gasoline and diesel, are also considered to be toxic. They can kill animals or seaweed that they touch, and they also are dangerous to humans who breathe their fumes or get them on their skin.

In contrast, very "heavy" oils (like bunker oils, which are used to fuel ships) look black and may be sticky for a time until they weather sufficiently, but even then they can persist in the environment for months or even years if not removed. While these oils can be very persistent, they are generally significantly less acutely toxic than lighter oils. Instead, the short-term threat from heavy oils comes from their ability to smother organisms whereas over the long-term, some chronic health effects like tumors may result in some organisms.

Also, if heavy oils get onto the feathers of birds, the birds may die of hypothermia (they lose the ability to keep themselves warm). After days or weeks, some heavy oils will harden, becoming very similar to an asphalt road surface. In this hardened state, heavy oils will probably not harm animals or seaweed that come in contact with them.

In between light and heavy oils are many different kinds of medium oils, which will last for some amount of time in the environment and will have different degrees of toxicity. Ultimately, the effects of any oil depend on where it is spilled, where it goes, and what animals and seaweed, or people, it affects.

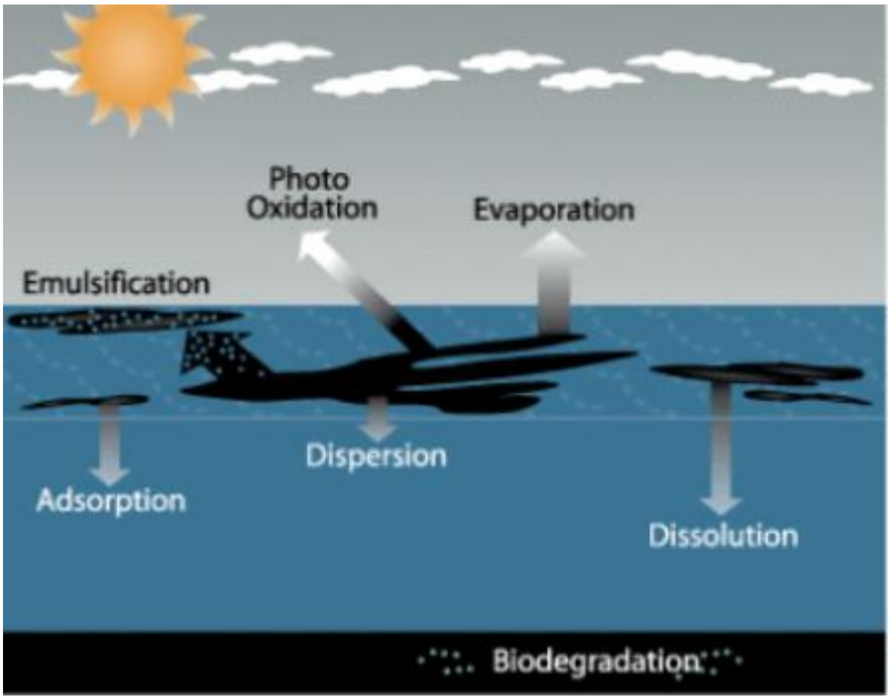

Figure 14. weathering processes affecting oil spills (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/oil-types.html)

The period in which the oil is in the water is another important factor and what kind of weathering process could occur. There are many weathering processes (fig. 14) affecting oil spills (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/oil-types.html):

- Adsorption (sedimentation): The process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure.
- Biodegradation: The degradation of substances resulting from their use as food energy sources by certain micro-organisms including bacteria, fungi, and yeasts.
- Dispersion: The distribution of spilled oil into the upper layers of the water column by natural wave action or application of chemical dispersants.
- Dissolution: The act or process of dissolving one substance in another.
- Emulsification: The process whereby one liquid is dispersed into another liquid in the form of small droplets.
- Evaporation: The process whereby any substance is converted from a liquid state to become part of the surrounding atmosphere in the form of a vapor.
- Photo Oxidation: Sunlight-promoted chemical reaction of oxygen in the air and oil.

The various types of oil differ in how they weather (chemically or physically change when exposed to the elements). Most crude oil blends will emulsify quickly when spilled, creating a stable mousse that presents a more persistent cleanup and removal challenge. Even in high winds, usually over 70% of a Fuel Oil No. 6 spill will persist as floating or beached oil for a week or longer. On the other hand, over 90% of the diesel in a small spill in the marine environment is either evaporated or naturally dispersed into the water column in time frames of a couple of hours to a couple of days.

Once oil has spilled, any of various local, state, and federal government agencies as well as volunteer organizations may respond to the incident, depending on who's needed. People may use any of the following kinds of tools to clean up spilled oil (https://response.restoration.noaa.gov/training-and-education/education-students-and-teachers/how-do-spills-happen.html):

- booms, which are floating barriers to oil (for example, a big boom may be placed around the location of the leaking oil, to collect the oil).
- skimmers, which are boats that skim (scoop) spilled oil from the water surface.
- sorbents, which are big sponges used to absorb oil.
- chemical dispersants and biological agents, which break down the oil into its chemical constituents.
- in situ burning, which is a method of burning freshly spilled oil, usually while it's floating on the water.
- washing oil off with either high-pressure or low-pressure hoses.
- vacuum trucks, which can vacuum spilled oil off of the water surface.

Which methods and tools to choose depends on the circumstances of each event: the weather, the type and amount of oil spilled, how far away from shore the oil has spilled, what kinds of birds and animal habitats are in the area, and other factors like the presence of seaweed in the location. Because of the presence of seaweed, tools like chemical dispersants and biological agents, which break down the oil into its chemical constituents and in situ burning, are not applicable because it will destroy also the seaweed or make the seaweed worthless for consumption.

3.2.1 Likelihood of occurrence

The likelihood of occurrence of collision accidents in an offshore wind farm depends on a number of factors such as: the type of ship vessels involved (commercial or in-field), shipping traffic, navigation routes, layout design of the wind farm, and the meteorological conditions in the area (Christensen et al., 2001).

A probabilities-effects matrix can be used to get insight in the impact on people, assets and environment (fig 15). Because our case-study is a virtual case-study, we do not have information on the type of oil or other specific factors which are related to this hazard and we don’t know exactly how dangerous oil in water is for our crop. So we need to assume the worst, hence the high effect rating.

						Low	Probabilities		High
						A	B	C	D
Effects	Rating	People	Assets	Environment	Reputation	Has occurred in industry	Has occurred in operating company	Occurs several times a year in operating company	Occurs several times a year at location
	0	No injury	No damage	No effect	No impact				
	1	Slight injury	Slight damage	Slight effect	Slight impact				
	2	Minor injury	Minor damage	Minor effect	Limited impact				
	3	Major injury	Local damage	Local effect	Considerable impact				
	4	Single fatality	Major damage	Major effect	Major national impact				
	5	Multiple fatalities	Extensive damage	Massive effect	Major international impact				

Figure 15. risk matrix

The collision likelihood varies also depending on the type of collision, which can be either powered collision (when the ship strikes the wind turbine under propulsion) or drifting collision (when the vessel loses its control and drifts towards the wind turbine under the effect of waves, wind and current). The probability of collision depends for example on the diameter of the turbine and the ship beam but also on the amount of ship traffic near the location of the seaweed production and wind farm (Moulas et al, 2017).

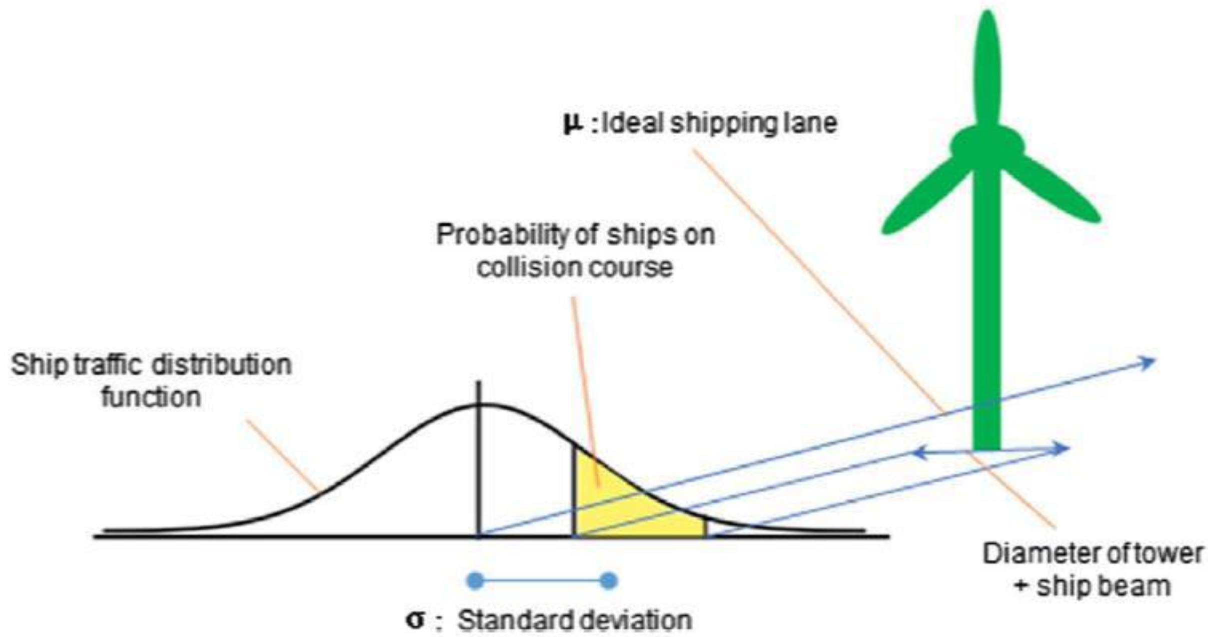

Figure 16. probability of collision

The traffic distribution on the shipping lanes is assumed to usually follow a Gaussian distribution with mean μ and standard deviation σ, as shown in Fig. 16 (SSAP Sweden AB, 2008). In a case study in Norway on Vesterhav Nord offshore wind farm the frequency of ship-wind turbine collisions in the area was estimated. The analysis showed a return period of 72 years for powered collisions (due to human errors) and a return period of 863 years for drifting collisions (due to technical errors), thus an estimated annual frequency of 1.5×10^{-2} for both types of collision was obtained. For our case study the incident databanks could not be used, since no sea weed farms in wind parks exist. Therefore no incident statistics are available yet for our virtual location.

Other tools which can be used to measure the likelihood of occurrence and their effects are the Severity Index and the Frequency Index.

Table 3: Severity Index

Severity Index				
SI	SEVERITY	EFFECTS ON HUMAN SAFETY	EFFECTS ON SHIP	S (Equivalent fatalities)
1	Minor	Single or minor injuries	Local equipment damage	0.01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
3	Severe	Single fatality or multiple severe injuries	Severe damage	1
4	Catastrophic	Multiple fatalities	Total loss	10

Table 4: Frequency Index

Frequency Index			
FI	FREQUENCY	DEFINITION	F (per ship year)
7	Frequent	Likely to occur once per month on one ship	10
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during the ship's life	0.1
3	Remote	Likely to occur once per year in a fleet of 1000 ships, i.e. likely to occur in the total life of several similar ships	10^{-3}
1	Extremely remote	Likely to occur once in the lifetime (20 years) of a world fleet of 5000 ships.	10^{-5}

3.2.2 Risk analysis

There are many risk analysis available (see deliverable 2.3). For the step of risk analysis the method of fault trees and event trees has been chosen. One of the reasons why fault trees and event trees were chosen is they are by far and large the most well-known and most widely applied type of logical trees in both qualitative and quantitative risk analysis. Fault trees and event trees are in many ways similar and the choice of using one or the other or a combination of both in reality depends more on the traditions and preferences within a given industry than the specific characteristics of the logical tree.

A significant difference between the two types of trees is though that whereas the fault trees take basis in deductive (looking backwards) logic the event trees are inductive (looking forward). This is why a combination of fault trees and event trees is used where the fault tree part of the analysis is concerned about the representation of the sequences of failures, which may lead to events with consequences and the event tree part of the analysis which is concerned with the representation of the subsequent evolution of the consequence inducing events.

3.2.3 Scenarios and mitigating measures

Scenarios can be used to give an overview of the impacts. When the large ship runs a risk of going adrift and damaging a wind turbine pillar we might considering to set up a scenario to prohibit the 6000 tons vessel from entering the wind farm and allow only small service vessels of 30 tons on a regular basis which are more harmless in a case of collision, apart from the slight coating damage.

Another scenario could be that a limited degree of oil in the water is not at all dangerous for the seaweed crop, but this still needs to be tested.

An Event Tree Analysis as a fault tree is used to define several scenarios which can occur with this event. Each scenario has different consequences from severe damage to ship, wind turbine and seaweed to no consequences. In our case-study because of the collision there is a damage to the wind turbine and a whole in the ship. Whether or not the ship is sinking, it spills oil with the consequences of damage to ship, wind turbine and seaweed crop (fig. 17).

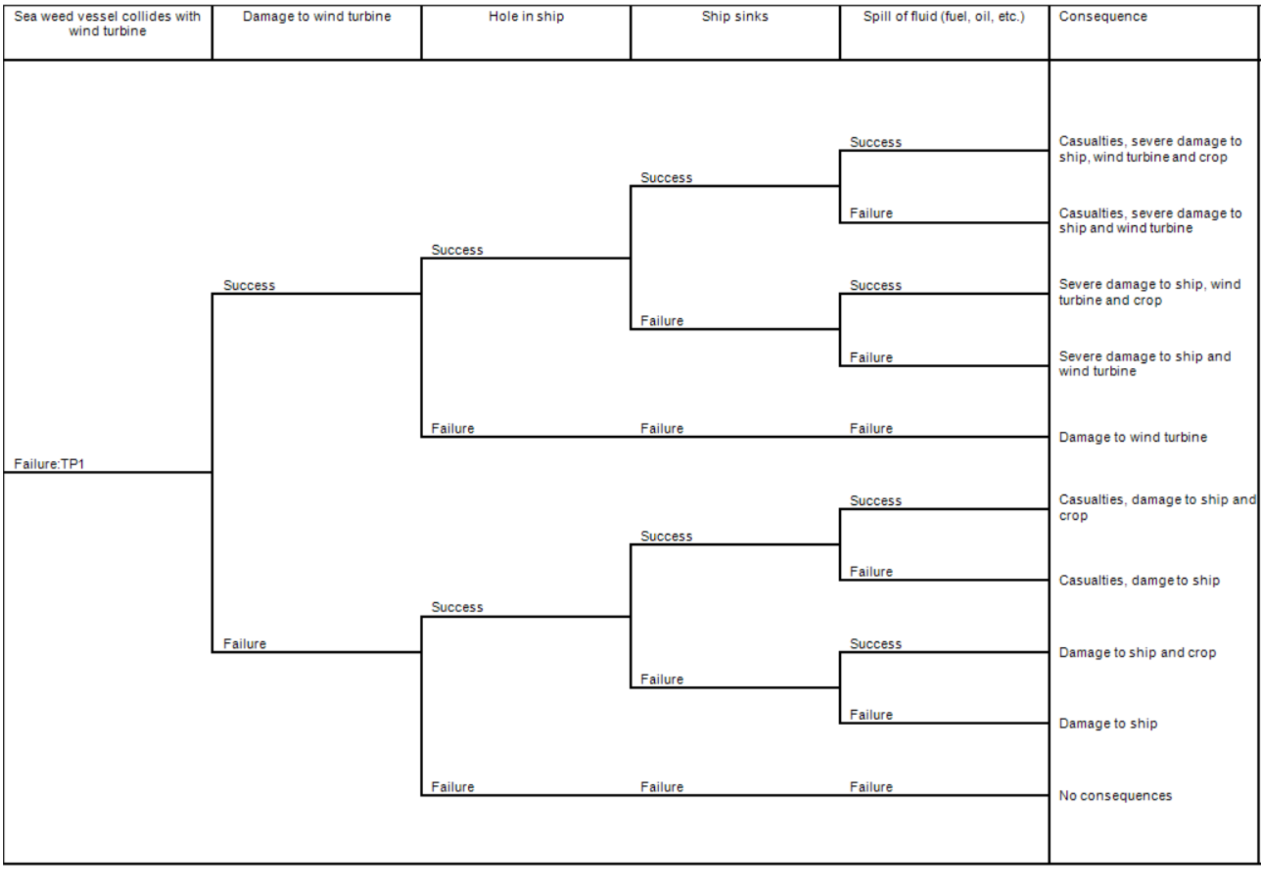

Figure 17. Event Tree Analysis (ETA)

Mitigating measure

In our case study we show that the leakage of oil due to a collision of a maintenance boat has consequences for the seaweed. The measures that can be taken to reduce the chance of a collision and with that the production of the seaweed, have consequences for the consideration of a safe multi-use. For each new measure the framework must be re-followed. There are several mitigating measures to make in this scenario of collision with leaking oil like restrictions to enter the location because of the weather, using smaller vessels with the chance of minor impact in a case of collision or change the type of oil the vessel is using. If there is no oil uptake, the risk is low (green part in figure 18). There are more risks if we move upward in the risk matrix because of the different scenarios. No oil uptake means that the effect decreases, but the probability of the event does not decrease. Weather restriction mainly means that the chance of a collision decreases because maneuvering becomes easier. Smaller boats reduce the chance of a collision event, small boats maneuver easier, but also reduce the effect because they can cause less damage.

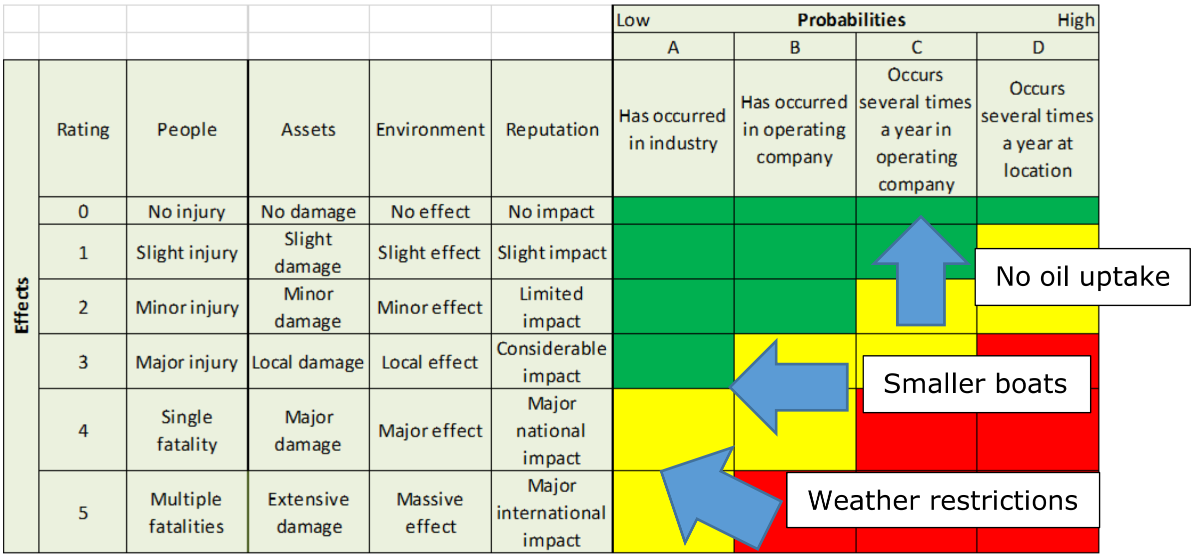

Figure 18. Movement upwards in risk matrix

An example of a mitigation measure is to use a type of oil that breaks down quicker which can have a limited effect on the seaweed that is produced. The chance of contamination is then much smaller. But the question is whether the new type of oil can be used in the maintenance boat. Perhaps the machine where the oil is used must be adjusted or a new machine has to be installed. Such a measure therefore results in costs for the maintenance company, and the maintenance company has thus become a new stakeholder that was not yet involved. The next question is who will pay for such an intervention and how high are the costs? And is that something to insure and who pays that insurance. Then it appears that the insurance company is also a new stakeholder.

Subsequently, the question can be asked whether the costs of the intervention outweigh the chance that such an accident will happen. And are there any agreements to be made with the stakeholders involved if it turns out that the costs are too high compared to the chance of such an event and what is the legal status of such agreements?

All in all, focusing on safety, there are different if-then situations that can have far-reaching consequences for the stakeholders involved. It is therefore important that the safety-issue is discussed with the stakeholders in advance and that principle agreements can be made about the possible consequences.

3.3 Conclusions

The Understanding phase of our framework was complex. Many stakeholders are involved and there are many hazards. With each event you need information that you do not need or need directly in a single use situation. The case-study shows that, given the tools and methods available, a safety assessment can be done in any multi-use of ocean space.

For the SOMOS project a case study was chosen to find a recommended practice. For this specific purpose and for the specific case of seaweed in combination a with wind farm fault and event trees as methods were chosen. When another combination of activities is chosen the tool and methods will have to be re-evaluated to decide on the best combination. Furthermore when a full-scale risk assessment is done, greater detail is needed.

4 Conclusions and recommendations

4.1 Conclusions

As of today, there are no real-life examples of seaweed cultivation inside a wind farm and we were unable to fully follow the framework. We have therefore limited ourselves, by means of a virtual case study in the North Sea to the first two phases. Therefore the framework is "work in progress". But we gain some insights into the extent to which the framework can be applied to a specific location. In general, the framework structure is applicable to all cases where different operators try to co-locate activities.

The virtual case-study shows that this first phase (explore) of the framework is applicable. The situation at the location can be described from the perspectives of food and feed and people and property. But, because of the virtual status, it was rather difficult to describe the situation from the marine interactions and cumulative effects. Although we could indicate the information needed for a description of the marine interactions and cumulative effects. An overview of the importance and influence of the stakeholders involved is also possible. Information about the market, the legal and governance factors is also available.

Assessing the safety situation with multi-use at sea is complex. The Understanding phase of our framework wascomplicated . Many stakeholders are involved and there are many hazards. With each event you need information that you do not need or need directly in a single use situation. For this case-study of seaweed in combination with a wind farm, fault and event trees as methods were chosen. When another combination of activities is chosen the tool and methods will have to be re-evaluated to decide on the best combination. Furthermore when a full-scale risk assessment is done, greater detail is needed.

Focussing on safety, there are different if-then situations that can have far-reaching consequences for the stakeholders involved. It is therefore important that the safety-issue is discussed with the stakeholders in advance and that principle agreements can be made about the possible consequences.

Cooperation between the stakeholders is essential to the potential of multi-use in the oceans. A common goal of the stakeholders is needed, complementary expertise, a desire to work together and the opportunity to spend time to learn to speak each other's language and to delve into each other's knowledge.

In every phase stakeholders must stay informed. Safety concerns and actions that were taken must be reviewed. It forms the input for stakeholders to communicate and decide how to proceed onto the next phase. Safety in multi-use at sea is complex and every option you choose has to be continually evaluated. A cyclical assessment of our framework can be used for that.

Combing the three perspectives in our SOMOS framework, in a multi-use safety assessment:

- the framework helps actors to assess hazards and evaluate control measures to ensure safe multi-use at sea.
- you need information about specific factors which you don't need in a single use
- bringing together different stakeholders, with different cultures and perspectives, and ensuring their involvement is needed and an important task.
- methods (like multi criteria analysis) and tools are available to appraise multi-use

- multi-use is possible, but safety given a multi-use perspective should be continually evaluated.

4.2 Recommendations

Because the framework is "work in progress", we hope that many will use it and provide us with their feedback so we can improve our work.

This case-study was virtual. To actually test and validate our framework, we need a real case-study. A real case-study could be an EU project called ENTROPI which looks into multi-use in the Canary Islands (http://www.plocan.eu/index.php/en).

Another recommendation is to make a practical handbook where safety in multi-use is discussed for various if-then situations for the most common hazards. Our case study shows that it is possible, but very complex. It could help all kind of stakeholders in their search towards safe multi-use at sea.

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6 Justification

This deliverable has been peer reviewed by Luc van Hoof, Project Coordinator