UNITED

DELIVERABLE 7.4

JOINT PRODUCTION, MONITORING, OPERATION AND MAINTENANCE PROTOCOL

Work Package 7

Implementation of multi-use concepts within pilots

December 31st, 2022

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Abstract	The UNITED project focuses on the combination of different uses within and of marine areas. It focuses on different aspects of multi-use. This is the core of the project. In five different study sites, the pilots, different uses are combined and tested. Each of the pilots is situated in a unique environment. Hence different and site specific obstacles and adversities have to be

	overcome. Within this deliverable focus is given to the site specific production, monitoring, operation, maintenance and also synergies effects that were experienced at the different pilot sites in Germany (pilot1), the Netherlands (pilot2), Belgium (pilot3), Denmark (pilot4) and Greece (pilot5).
Keywords	Multi-use, offshore, wind energy, solar energy, algae-farming, fish-farming, blue-mussel-farming, oyster-farming, oyster restoration, tourism, diving, monitoring, safety prerequisites
Change Log	Resubmission 1 – change in cover page and introduction tables

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2. ACRONYMES

ADCP	Acoustic Doppler Current Profiler
Chl-A	Chlorophyll A
CPOD	Cetacean Porpoise Detector
DGUV	Deutsche Gesetzliche Unfallversicherung (German Legal Accident Insurance)
EBS	Emergency Breathing System
EC	European Commission
FINO3	Forschungsplattform in Nord- und Ostsee Nr. 3 (Research platform in North and Baltic Sea No.3)
G41	Specific occupational-medical health examination
GoPro	Underwater action camera
HUET	Helicopter Underwater Escape Training
IPR	Intellectual Property Right
NO_3	Nitrate
NSF	North Sea Farmers (partner)
OTS	Offshore Test Site
Pilot1	German pilot – blue mussels, seaweed and offshore wind energy
Pilot2	Dutch pilot – offshore seaweed and floating solar energy
Pilot3	Belgian pilot – offshore wind, flat oyster aquaculture & restoration, & seaweed cultivation
Pilot4	Danish pilot – offshore wind and tourism
Pilot5	Greek pilot – aquaculture and tourism
PPE	Personal Protection Equipment
RIB	Rigid Inflatable Boats
ROV	Remotely Operated Vehicle
UNITED	Multi-Use offshore platforms demoNstrators for boostIng cost-effecTive and Eco-friendly pro-Duction in sustainable marine activities.
WP	Work Package

3. EXECUTIVE SUMMARY

Within the UNITED project the effects of the combination of different uses of marine areas and waters are investigated. The so called Multi-use concept is the core of the project. In five different study sites, the pilots, different uses are combined and tested.

Each pilot is situated in a unique location, while pilots 1 (German), 2 (Dutch) and 3 (Belgian) are more remote and combine cultivation of algae and mussels with wind and solar energy production pilots 4 (Danish) and 5 (Greek) focus on the combination and integration of tourism in the running of a fish aquaculture and wind production site. Hence different and site specific obstacles and adversities have to be overcome. We focus within the different pilots on the production, the monitoring, the operation and the maintenance of the pilots at the different sites. We also take a first look in the synergy effects that were experienced. It is shown that each pilot has adapted to the specific locations.

Production is divers. In the German, Dutch and Belgian pilot focus is given on the extensive prerequisites and trainings that were established and implemented, the techniques of anchoring the production system and also restoration. As well as the efforts and special adversities related with the need of divers for the implementation and production in far remote, high-energy environments. The Danish and Greek pilot focus in the production more on the tourist site and also the possibilities for recreational diving is mentioned. Also, the use of ROVs is shown to be beneficial. In Monitoring the remote and the aquaculture locations focus on a combination of real time monitoring of environmental and fish relevant (pilot5) parameters, logging data and collecting them during maintenance trips (pilot 1 and 2) and also sampling campaigns (pilot 3). The data collected in the pilots is also amended by using publicly available sources for weather, tides and general oceanographic data for the respective area (pilot 1, 2 and 3). The collected data is and will be uploaded into the HiSea platform (pilot1, 2, 3, 5) and also for modelling (pilot3), but will not be included in this deliverable. In pilot 5 also the use of video cameras for animal welfare (behaviour and density) are used. Within the Danish pilot focus is given to numbers of visitors and no environmental data is collected. See also D10.2, 10.3 and 4.4 for further uses of data. For Operation different schedules and protocols were established in the pilots. Times for different tasks are planned and adhered to establish a good workflow. Integration of different partners is of importance and reflected in the different planning schemes for operation (pilot 1, 2 3 and 5). Also, the focus and complexity differ due to the locations and the different products aimed for in the pilots. All pilots are dependent on the weather, especially the pilots involving tourist activities have also to adhere to more rigid restrictions to ensure safety for example when entering the windmill (pilot4). Maintenance is often already planned in during operation (pilot 1, 2, 3 and 5). Remote cameras (pilot1) are also used to indicate the need for maintenance trips. In case of "seasons" maintenance also is shifted to the "off season" when production (pilot5) or to tourist season (pilot 4 and 5) is over. Finally, the report taps also shortly into environmental economic and social Synergies, these have been experienced in all pilots (except for the Danish pilot4 in the area of environmental synergies, as this is not applicable for the pilot). However, the synergies will also be explored in deliverables D4.3 and D7.7.

4. INTRODUCTION

WP7 has entered the operational phase in December 2020. Despite being hit by Covid-related challenges only one month after starting the project (see Covid note and D7.2) all pilots managed to overcome these delays and are working at their offshore locations since 2021. So, all pilots have gained years of experience in production, monitoring, operating and maintenance of combined uses in the same marine area. The pilots are:

Pilot1: German pilot – blue mussels, seaweed and offshore wind energy research

Pilot2: Dutch pilot – offshore seaweed and floating solar energy

Pilot3: Belgian pilot – offshore wind, flat oyster aquaculture & restoration, & seaweed cultivation

Pilot4: Danish pilot – offshore wind and tourism

Pilot5: Greek pilot – aquaculture and tourism

Each pilot is situated in a unique location, while the German, Dutch and Belgian pilots are more remote and combine cultivation of algae and mussels with wind and solar energy production respectively The Danish and Greek pilot focus on the combination and integration of tourism in the running of a fish aquaculture and wind production site.

The deliverable D7.4 – "Joint production, monitoring, operation and maintenance protocol" reports on operating the multi-use system. It focuses on **environmental, economic** and **social factors** and also strives to determine the degree of **synergy** effects experienced during operation. The deliverable is built upon several subtasks.

Subtask 7.2.1 looks upon **installation at the pilots**. Containing not only information on the installation of different the multi-use elements, but also looking in relevant workboats and personnel with sufficient background and the knowledge necessary. Also it sheds light upon the different health and safety regulations and gives a method statement.

Subtask 7.2.2 focuses on **operating the multi-use system.** It includes **production, monitoring** and **maintenance** and provisions undertaken for unforeseen cases in all the pilots. Within the German (pilot1), Dutch (pilot2) and Belgian (pilot3) pilot functionality checking of the longlines is included , while in the Dutch (pilot4) and Greek (pilot5) pilot functionality checking of monitoring and safety equipment and the new landing platform (pilot 4) are in the focus. In addition operational aspects of the service platform fishing activities and boat service is looked upon and also test visits are checked in the pilot 4 and 5. Results will also be reported in the upcoming deliverable D8.5 "Implementation plan for the operation and maintenance".

Subtask 7.2.3 touches upon **data management**, **acquisition** and **monitoring**. This subtask taps upon data collection and new combination for parameter to be monitored. Furthermore a priority ranking of parameters specific for each pilot shall be established. However, within deliverable D10.2 a draft data management plan including which parameters shall be monitored was already agreed upon. Hence this will not be reported in this deliverable. Where possible the optimum position for monitoring location and frequency of sampling and tested will be reported and finalized in form of a guideline, also included in the final data management plan, deliverable D10.3. In addition to field measurements predictive numerical models will be established. These are however not reported in this deliverable but will be part of deliverable D4.4 "Environmental impact assessment models for the commercial rollout of multi-use platforms".

The deliverable is hence focusing on

- **Production**, chapter 5 (mainly comprising subtask 7.2.1)
- **Monitoring**, chapter 6, (mainly comprising subtask 7.2.3.)
- **Operation**, chapter 7 (mainly comprising subtask 7.2.2)
- **Maintenance**, chapter 8 (comprising of all subtasks, where applicable)
- **Synergies**, chapter 9 (summarising all experiences and expected effects)

5. PRODUCTION

5.1. German Pilot

Within the German pilot, mussel and algae cultivation is carried out at the very exposed offshore location FINO3 in the North Sea. Also, a nearshore site was utilised to test equipment material and handling of it, however the following report focuses only on the offshore location at FINO3.

The highly energetic offshore site of the German pilot required a highly professional implementation of each single part and step of the offshore equipment and work step to avoid and mitigate the risks associated with such a location. The essential components of the conducted operation are presented in the following chapter. These are in principle transferrable to most other offshore locations of future projects and undertakings and fulfils thereby one aim of UNITED.

For the production of the German pilot specialised workers, vessels and helicopters needed to be selected due to site-specific and task-specific requirements. Several meetings with owners and crew members were hold to discuss every single step of the production and to find the best available and affordable option.

The following selected contractors for the production needed to be booked way in advance as the market offer is extremely limited in Europe:

- Ship-crew
- Industrial offshore divers
- Vessels (Tug Boats and Shoalbuster [multi-purpose workboat]) for installation, maintenance, monitoring and material transport
- helicopter for crew and equipment transfer from shore to FINO3
- personnel from producers of system parts

Figure 1: German Pilot FINO3

Time Requirements for booking transportation:

Depending on the task and the needed service (vessel, helicopter or specialised workers) the preparation and final booking times differ. For example, a final booking of vessels for a certain task more than 48h ahead of the mission isn't applicable for offshore work due to the dependency of reliable weather forecasts. Close communication and collaboration between client and supplier are of great importance to be able to react on changing weather conditions and to combine as many tasks as possible during one field trip.

For installation:

- Contact and pre-reservation of vessels and divers one year in advance
- Reservation/Final booking on short notice, depending on weather forecast (1week/ 2-3days)
- Contact and final booking of helicopter on short notice (2weeks/ 2-3days depending on weather forecast)
- External consulting personnel (half a year in advance)

For maintenance:

- Contact and reservation of vessels half a year in advance
- Final booking on short notice, depending on weather forecast (1week/ 2-3days)
- Contact and final booking of helicopter on short notice (2weeks/ 2-3days depending on weather fore-cast)

For monitoring:

- Contact and reservation of vessels half a year in advance
- Final booking on short notice, depending on weather forecast (1week/ 2-3days)

Regulations and Requirements: It is necessary for all operations on or around the FINO3 platform to get permission for e.g. to enter the safety zone, anchoring, diving, fly via helicopter, work at the platform, stay overnight etc. from the director of the FINO3.

As also stated in D7.2:

Everyone travelling to the FINO3 platform requires the following safety certificates

- occupational health examination (G41)
- first aider offshore (according to DGUV)
- sea survival and HUET (Helicopter Underwater Escape Training, according to DGUV)

If climbing is required (for example inside the monopile to connect/plug the sea cable from the lander)

- working at heights (according to DGUV)

If electrical work has to be done (for example when connecting the sea cable from the lander/ when installing server/computer equipment at the supply container)

- electrically instructed person (according to DGUV)

The following personal protective equipment (PPE) is required on the FINO3 platform

- on the flight:
  - survival suits and life jackets with EBS (Emergency Breathing System)
- on the platform:
  - Safety helmet
  - Safety footwear
- Task specific PPE requirements shall be:
  - Safety glasses
  - Safety harness
  - Safety helmet

Everyone external who does not belong to the staff of the vessel/ship requires the following certificates:

- negative COVID19-test - no older than 48h

The following PPE is required on the vessel/ship:

- Mouth-Nose-Guard (FFP2 mask)
- safety footwear
- safety helmet
- work overall or work pants and jacket
- work gloves
- life jacket

Critical selection criteria for contractors like vessels, consultants were:

- References of successful accomplished missions
- Personal experience regarding reliability

- Availability on short notice (e.g. the extreme long planning process of federal ships excluded them for the tasks and circumstances of the German pilot)
- Flexibility
- Financial conditions: e.g. obligatory payments only with final booking

Recreational diving is not permitted at FINO3. Only industrial divers have been hired for the installation of the lander and the AquaBuoy equipment on the mussel-system. Divers will also be necessary for deinstallation.

For all other visitors, depending on the work and the location (on FINO3 or on a vessel in the surroundings of FINO3), health certificates can be mandatory.

- Workers require a health certificate "*occupational health examination (G41)*" when working at FINO3

During the operational phase of the German Pilot several trips via ship or helicopter could be combined to benefit offshore users, the operation of the FINO3 and the operation of the aquaculture systems, showing benefits of a joint production:

- 2x joint boat trip for refuelling of FINO3 and maintenance of side marking buoys
- 4x joint flight for installation of UNITED equipment on FINO3 (Server, AquaBuoy receiver, Webcam, Lander subsea-cable) and general FINO3 maintenance (corrosion protection campaign, maintenance of BSH measuring instruments etc.)
  More synergies could be achieved through the inter-pilot cooperation within UNITED:
- The close exchange of technical solutions in terms of design and availability of material during the lockdown led to a reduction of the unavoidable delay due to the pandemic and a reduction of costs.

The research for highly experienced additional experts assured the avoidance of a lot of possible mistakes. So producers of system parts, offshore engineers within the pilot lead and experts within UNITED were asked to collect every important information for the optimal installation procedure.

Shared logistics with all users of the offshore location led to a reduction of costs and a constant availability and independency despite national and international lockdowns.

This joint production results in reduced costs, time savings and reduced CO_2 emissions for traveling to and from the offshore site. Especially the joint boat trips have a huge impact on the CO_2 emissions and the costs since the distance between the operational harbour and FINO3 is about 120 sea miles.

5.2. Dutch Pilot

In the Dutch pilot two types of multi-use are combined: floating solar energy and seaweed cultivation. For both types of offshore uses, the pilot within the UNITED project is used as a stepping stone towards multi-use within a wind farm. The lessons learned on the pilot location, the North Sea Farmers Offshore Test Site, can be taken to the next step operation in a wind farm.

The Offshore Test Site (OTS) is managed by North Sea Farmers (NSF). North Sea Farmers has a permit for testing multi-use innovations in this 6km^2 test site at the North Sea, 12km off the coast of Scheveningen, The Hague. Users of the OTS don't have to apply for a permit anymore, they do need to show to licensing authority (via NSF) that they can install and operate the pilot in a safe way.

It's important to realise that pre-testing for the seaweed farm and re-design has happened but not as part of the UNITED project. It builds on design and test efforts already performed in preceding pilots such as under the H2020 IMPAQT project. The same is true for the solar farm. Conceptual design, basin testing, modelling and first offshore tests (and concurrent design improvements) have taken place from 2017 onwards under other (National and European) subsidy projects.

The solar farm from Oceans of Energy was installed in plot 2 of the OTS prior to the UNITED project. The production will therefore not be discussed in this deliverable. The following items will focus on the production of the seaweed farm from The Seaweed Company.

In general, before every offshore operation a work plan will be made and a Permit to Work needs to be requested by the "user" of the plot at the OTS. North Sea Farmers will check and approve the work permit application. This work permit includes having a list of all the people working offshore including the Next of Kin forms. With the approval all the important stakeholders (licensing authority Rijkswaterstaat, Coast Guard, KNRM, harbourmaster and 24/7 remote monitoring service of the OTS) are informed of the offshore operation.

Regarding specialised workers and staff requirements, North Sea Farmers had in general already some years of experience with offshore installations of seaweed cultivation systems. Their experience and contacts were used for the realisation of this operation.

- Installation anchors and backbone structure (for two systems):
  - The vessel and staff needed be able to operate in offshore conditions and they need to have the right paperwork. The vessel needs a winch and or crane with enough capacity to pull the anchors in the seaweed and to set the structure on the required pre-tension. There was good contact with two vessels that could do the job and were flexible to deploy when the weather conditions were sufficient.
- Installation of the seeded nets (4 nets for 2 systems):
  - Next to the standard requirement of being able to work in offshore conditions and having the right paperwork, for the installation of the seeded nets it is important to have a vessel with a crane that can handle the seeded nets carefully when placing them in the water and connect the nets to the main structure.
- Skippers need to have the necessary certificates. For workers or visitors there is no obligation to have offshore certificates. However, North Sea Farmers is promoting all the users to do at least a Sea Survival Training.

In terms of regulations to adhere to, the Dutch pilot is located at the Offshore Test Site. The North Sea Farmers have a permit for this location for "testing of innovations in the field of co-use of offshore windfarms". Therefore a permit application was not mandatory for the seaweed cultivation and floating solar parts of the pilot. Part of the permit for the Offshore Test Site is the check of a "working plan" of the pilot activities within the requirements of the overall permit. In addition, all the offshore activities need to be reported in advance to the relevant stakeholders (as mentioned above). When the pilot is finished, all the structures need to be removed: the test site needs to be left as found.

Concerning diving activities, in the Netherlands it is not allowed to dive within a wind farm. One of the advantages of the Offshore Test Site is that it is allowed to dive here for inspection purposes. These divers must be professional divers. At least two weeks before the diving activity takes place, a diving plan needs to be send to the licensing authority Rijkswaterstaat (via NSF). Rijkswaterstaat will check and approve the diving plan with SodM, a Dutch service that is focussing on human safety and environmental protection. For diving activities below 7m depth, you need to bring a decompression tank offshore (as, in case it needs to be used, going to land takes too long). In addition, like all the offshore work, before the actual operation a Permit to Work needs to be requested and approved.

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5.3. Belgian Pilot

In the Belgian Pilot, algae culture, oyster culture and oyster restoration efforts are combined with wind energy production. Different parameters and cultivation techniques were tested in the nearshore site, but this report focuses on the offshore location and tasks only. Oyster restoration does not constitute a production but plays a major role for nature restoration and possible future production of endemic European oysters. Algae production showed already some promising results on different substrates. Although these findings and results will be reported in D4.3, D8.3 and also in parts in D3.4 and in D7.7.

Several prerequisites had to be met by the staff to conduct oyster restoration and culture, and algae culture in the wind park. The vessel's crew and captain were trained for offshore work (as described in D6.1 and will be further described in D6.2 and D6.3). All other persons are classified as visitors and have to adhere to the following standards. To go offshore, visitors must have the correct safety licenses. This entails a basic safety training level 1. This training is implied by the Belgian government but also by the wind farm in which we operated (Belwind). Exemptions can be made one time per year for just one day for visitors who visit the wind farm, but this mostly is meant for governmental people visiting the wind farm to understand how it works. One that would have to visit the wind farm multiple times in the future for work (like e.g., installation of the backbones in the wind farm or sampling actions), would probably not be allowed the exemption license for a day. Next to the basic safety training level, a visitor also needs to be medically approved. Before being able to access the wind farm, an introduction also needs to be followed. Everything has to be documented. All these documents and certificates need to be uploaded to the online system of the wind farm no later than 48h before embarking.

Some tasks also involve diving. Diving in the wind farm in which the pilot is located is not allowed for aquaculture-related purposes, but is allowed for scientific diving activities in the framework of the oyster restoration project within the Belgian pilot. Only scientific divers (very experienced divers that also underwent an extra scientific diving training and dive regularly as determined within the statute to keep the scientific diving permits) are allowed to dive for the latter reasons.

Although in other pilots, touristic activities are included, no tourists are allowed in the Belgian offshore wind farm, hence this does not apply for the Belgian pilot within Belwind.

5.4. Danish Pilot

The Danish Pilot organises guided tours to Middelgrunden Wind Farm.

Boats used for the activities within this pilot need to be booked and are not owned by the pilot operators. Normally the pilot operator works with two boat operators. The pilot consists of a cooperation between commercial boat operators, which are booked for the date of trip, and the wind park operator. Different boat operators are selected depending on the number of visitors. Both boat operators have their own insurance.

Following the high demand of tours experienced in the spring and summer of 2022, a new guide has been trained. A guide manual was developed as part of UNITED, and it has been used. It shall be noted that guides work on a demand-basis, depending on the number of booked tours. This can be a bit challenging and requires flexibility, as some tours are booked with several months´ notice, whereas others with very short time e.g. two weeks in advance.

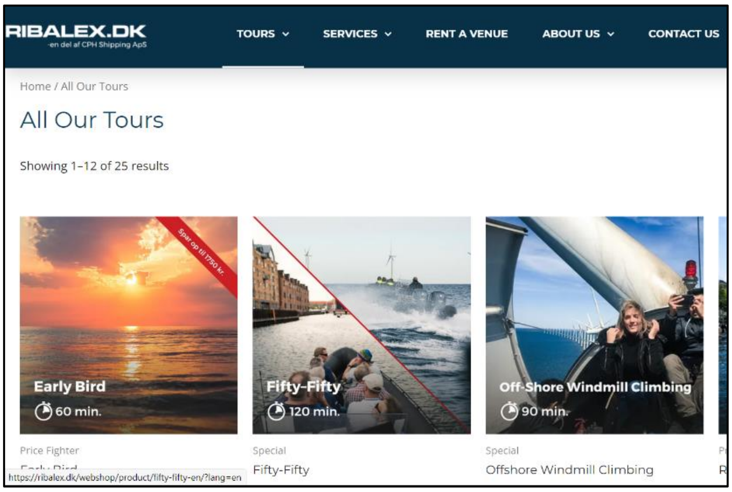

Figure 2: The web site from the boat operator offering tours to Middelgrunden Wind

A boat tour operator has expanded his activities to also now promote tours to Middelgrunden Wind Farm. These tours are advertised on their website and can be directly booked there.

To cope with the lack of visitors during Covid and to expand the guided tours to *onshore* visitors in the city of in Copenhagen, we have created a set of virtual tours that aim to show the citizens of Copenhagen and tourists what happens at sea – and for example how Middelgrunden Wind Farm was built. The virtual tours can be accessed via a QR code placed at several landmarks of Copenhagen, from which the wind farm can be seen. It shall be noted that Middelgrunden Wind Farm is visible from many places of the capital – it is a highly present renewable energy facility, voted as the 2nd landmark of Copenhagen.

5.5. Greek Pilot

The Greek pilot combines fish aquaculture and diving tourism. Hence in order for someone to investigate the aquaculture site underwater the respective visitor should be a certified diver. The trainings must have six theoretical sessions, six pool water sessions and four offshore diving sessions. Except for that the staff is also trained for the use of ROVs. People with no open water diver certification are not allowed to dive in the aquaculture site. Moreover, most professional divers are required by national or state legislation to be qualified as first aid providers to a specified standard as occupational health and safety are important aspects of professional diving. For the specific pilot, no extra training was required since the divers had already been trained for underwater investigation, which also includes the site of the aquaculture farm.

6. MONITORING

6.1. German Pilot

Monitoring data sources in the German Pilot can be divided into three different categories:

1. Real-time data from sensors

2. Real-time via observation and

3. Sampling/inspection on site.

Data is uploaded as soon as it is available to the UNITED Data platform in HiSea.

Figure 3: CPOD deployment at German Pilot

1. Real-time data from sensors:

- Water quality
  - Conductivity/salinity
  - temperature
  - dissolved oxygen
  - NO3
  - pH
- Growth monitoring (after decommissioning available on aquaculture systems)
  - Photos via subsea-cameras
  - Echograms via split beam echo sounder
- Hydrodynamic data (limited)
  - wave-height, -length, -period, -direction
  - current-speed, -direction, -profile
  - water depth
- Load/stress data (after decommissioning)
  - Tension-load of mussel-system mooring
- Activity/presence of harbour porpoises

2. Real-time observation

- Webcam monitoring of FINO3 platform and aquaculture area (several webcams to observe the platform itself and its surroundings 24/7)
- Mobile underwater camera: Inspection of mussel growth, biofouling

3. Sampling/inspection on site

- Visual inspection of aquaculture nets
- Visual inspection of side marking buoys
  - Data collection from CPODs
  - functionality checking of monitoring equipment (e.g. sensors and transmitters), safety equipment

The **data transfer infrastructure** of FINO3 is co-used in the German Pilot including power supply by the FINO3. The following figure shows the diagram of the data transfer in the German Pilot form the offshore site to the onshore office in Kiel.

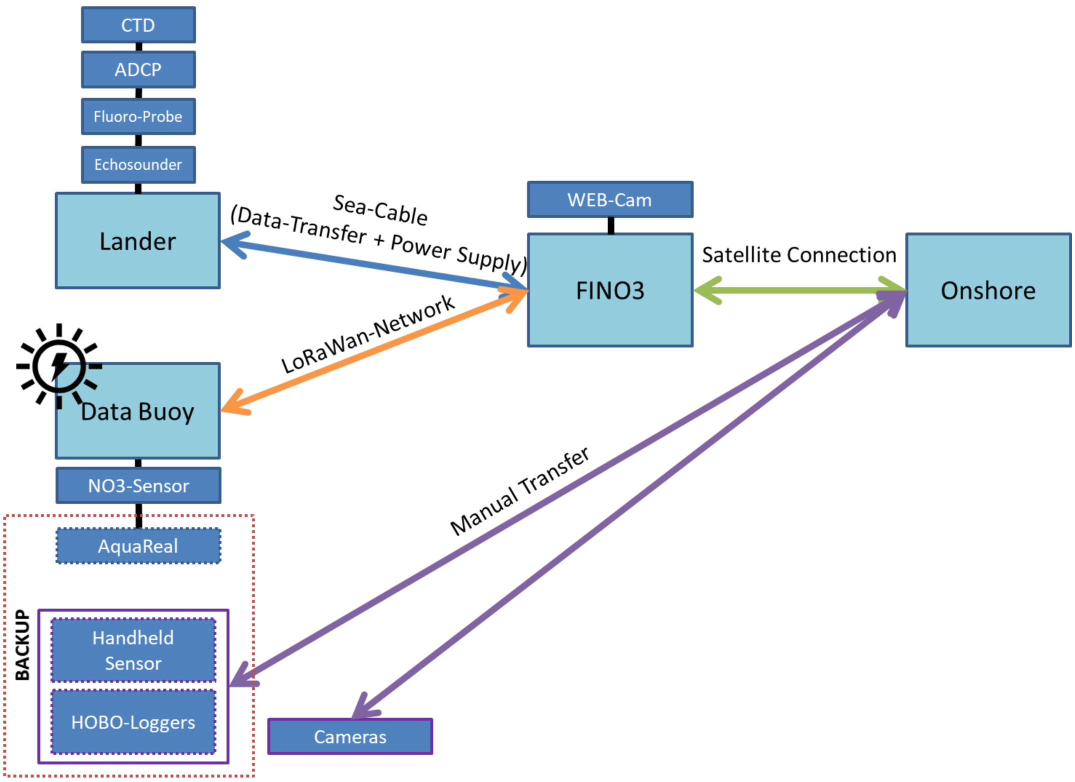

Figure 4: German Pilot - data transfer diagram

Existing knowledge about the operation and monitoring of an unmanned offshore platform, as well as contacts to possible suppliers (vessels, helicopter, equipment etc.) have been shared within the German Pilot and across the other pilots during WP7 meetings and smaller workgroup meetings between the German, Dutch and Belgian Pilot.

Important monitored parameters vary, depending on the application.

For any **offshore sea mission** wave height and wind are monitored to determine the optimal weather window for a safe operation. The decision when to schedule a sea mission is based on the consultation of all offshore users at this location and several data providers, which deliver the most important and reliable data as Windfinder[1].

For **mussel growth** water temperature, light and chlorophyll a are the most important parameters.

For **seaweed growth** water temperature and light conditions are the most relevant parameters.

For **technical questions** wind, wave height, load forces on mooring system are of highest interest.

For **licensing authorities'** requirements the CPODs data to monitor the presence of harbour porpoise is the most important.

Sampling frequency is also important.

Remote data sampling and system observation is planned to take place 24/7 and is checked at least once per day.

[1] (https://de.windfinder.com/#3/49.5042/9.5421), Windy (https://www.windy.com/de/-Webcams/D%C3%A4nemark/Region-S%C3%BCdd%C3%A4nemark/Blavand-Oksby/FINO3-Heliport-Offshore-Nordsee/webcams/1378260648?waves,55.219,4.931,8) and BSH (https://www.bsh.de/DE/THEMEN/Beobach-tungssysteme/Messnetz-MARNET/FINO/fino_node.html)

Ideally the maintenance and sampling of the aquaculture system takes place every 2-3 months. On a trip, as many tasks as possible are combined and carried out.

Table 1: German Pilot – testing frequency

No.	Testing / task	Frequency
1.1	Checking/investigating aquaculture area and systems via webcam (re-mote)	Once per day
1.2	Checking/investigating aquaculture area and systems via binoculars (on site)	Once every flight to FINO3 (~50 per year)
2	Checking/investigating the lander system and data-buoy (remote)	Once per day
3	Checking/maintaining site marking buoys (on site)	Every 2-3 months
4	Checking/maintaining mussel system including sampling (on site)	Every 2-3 months
5	Checking/maintaining seaweed system including sampling (on site)	Every 2-3 months
6	Checking/maintaining CPODs (on site)	Every 2-3 months

6.2. Dutch Pilot

General monitoring:

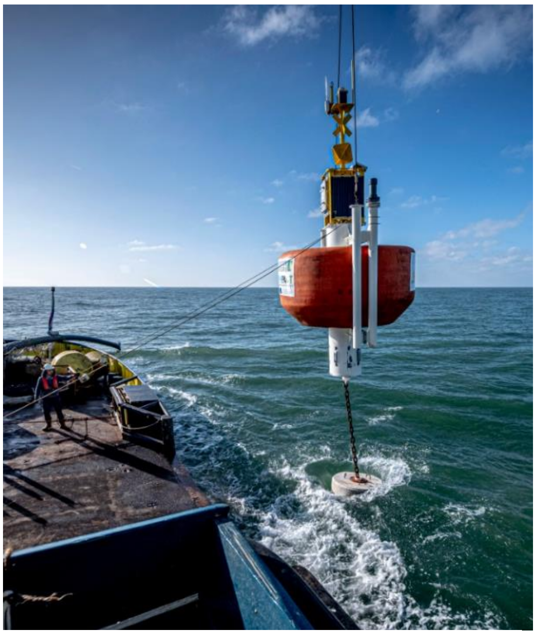

Figure 5: Installation big data buoy at the Offshore Test Site

- Big data buoy
    - Turbidity
    - Chlorophyll-A:
    - Conductivity
    - Temperature
    - Vertical flow profile (ADCP)
- Small data buoy (to be deployed)
    - Time-lapse camera
    - GPS
    - Measuring anchoring loads
    - Pressure sensor
    - Aquatroll with: turbidity, Chl-A, conductivity and temperature
- Svasek model specifically for the Offshore Test Site location with 5-day predictions of:
    - Water level
    - Flow velocity
    - Flow direction
    - Significant wave height
    - Wave period
    - Wave direction
- In addition, general available met ocean data & mod-els are used for the planning of offshore work (waves + current + wind) and the data from the pilots is used by other partners (like Deltares) as input and validation for their models.

Seaweed farm monitoring:

- Real-time
    - GPS
    - Time-lapse camera (Obscape) every 30 minutes (see picture below)
- Data logging
    - Load cells
- Field measurements
    - Diving for inspection and seaweed sampling (see picture below)

Floating solar farm monitoring

- Real-time
    - GPS
    - Time-lapse camera (Obscape): photos and video image
    - Wave buoy
- Data logging
    - Load cells
- Ecological samples during monitoring

Figure 6: Time-lapse camera footage at one of the two seaweed cultivation systems

Figure 7: Divin expedition at the seaweed farm 5-03-2022

An observed **synergy effect was** that all the data collected under "general" was used by both parties in the Dutch pilot. In addition, the experiences on the sensor equipment installed in the separate pilots was shared as well. This resulted in using the same type of time-lapse camera and sharing ideas on the use of load cells for measuring the anchor loads and GPS. In addition, when possible, monitoring trips to the two farms were combined.

The most important parameters for the installation phase and planning of offshore work were met ocean data and prediction models. For the operational phase, GPS and life camera footage are of most importance from a safety perspective. The other parameters mentioned above are of most importance when it comes to production and environmental impact assessments.

6.3. Belgian Pilot

No remote real-data collection was performed in the Belgian Pilot; however, data was collected and used from the following sources:

- Oceanographic variables were extracted from Copernicus marine satellite (Sentinel2/3), model (ERSEM, DCSM Deltares) products. Those products are freely available in hind cast, real-time. Modelled variables are also available in 3-month forecast. Used variables included; chlorophyll a, suspended solids, salinity, temperature, alkalinity, current speed, wave height, shear stress
- Weather forecast data was extracted from Windguru. Variables of importance are wind speed, wave height, weight period,
- Tidal information
- Sediment data was extracted from EMODNET

In addition, experimental variables were monitored through sampling missions.

Those variables included:

- oyster growth (shell length, shell weight, total weight, tissue weight),
- fouling (species composition, estimate of species cover, presence of non-indigenous species),
- seaweed (seaweed length, seaweed weight),
- oyster settlement (number of settled spat, survival, size)

Numerical modes were set up and field measurements were used to validate them. Two types of numerical models were constructed and were linked to satellite products, ERSEM data and DCSM data:

- 1.DEB models for the European flat oyster which enables prediction of growth, fitness, survival, reproduction and nutrient budgets of individuals
- 2. DEB population models for the European flat oyster which enables prediction of population dynamics

Models were applied to 10 year geospatial data for the North-Atlantic, Channel and North Sea. Oyster samples will result in information about growth, fitness, reproductive status, disease status and fouling of the organisms.

No physical and biochemical parameters were monitored.

6.4. Danish Pilot

The Danish Pilot is focusing on tourism and there is no monitoring activity of the sea or its surroundings associated to it.

We monitor the number of trips per year, including number of visitors per trip, etc., as included in the table below. It is clearly seen that in year 2022 we are above the number of trips before year 2020.

Table 2: Number of trips, guests and turnover from 2017 to 2022 in the Danish pilot

	2017	2018	2019	2020	2021	2022
Bussiness Trips	31	35	48	4	13	75
Guests	676	930	1117	130	246	1672
kEUR	38,9	44,3	55,6	4,4	19,5	98,2

6.5. Greek Pilot

Within the Greek pilot aquaculture production **parameters are monitored in real time**. These parameters are salinity, water quality, temperature, Dissolved Oxygen (DO), pH, electrical conductivity, total dissolved solids (TDS), turbidity, Chlorophyll-a, Nitrates (NO3) and ammonium (NH4). Furthermore the co-location activities connectivity is monitored, and the aquaculture infrastructure by using underwater sensors, fish sensors, water quality sensors and meteorological sensors. Also the sea transportations infrastructure is monitored (vessel movements and speed, meteorological sensors). By the use of underwater cameras the fish behaviour and performance is monitored. Monitoring infrastructure continues in diving activities by using individual diver position sensor, mechanism for unexpected surface event such as rapid weather change or other incident. For the aquaculture infrastructure that are placed in great depths (such as anchors) a ROV is used. A **Real-time data management** and decision support system is in place and the water quality data are being uploaded continuously in real time in the AQUAWINGS platform where the users of the pilot can have access to them. The **aquawings platform** was **co used** in the pilot for the planning of different activities that take place in the aquaculture farm e.g. diving and feeding. Fish behaviour was continuously monitored through cameras in order to check the fish stress when diving activities were taking place.

The **most important parameters** monitored concerning fish aquaculture are: Dissolved oxygen, water temperature, ammonia, and of course the number of tourist divers is also of great importance.

7. OPERATION

7.1. German Pilot

The **requirement for a safe offshore operation** is a wave height below 1m .As shown in Table 1 there is a general routine to check several systems and items in the German Pilot. Due to its exposed location and the accomplishing weather conditions the maintenance intervals have to be adjusted to the actual conditions by following the planned intervals as close as possible. Therefore, it is necessary to be flexible with the coordination and planning of trips and to use all possible weather windows.

The **routines for checking** the equipment, monitoring and maintenance trips are described in the following protocols (Table 3-Table 8). Each task shown in Table 1 has its own protocol with subtasks. After the work has been done the protocols can be filled with simple marks for done successfully or done with deviation. If a task is carried out with deviation, the comment column gives room for explanation. Also, the comment section gives instructions for what to do if damage/failure etc. is detected.

Table 3: General protocol for checking/investigation of aquaculture system status

1. Checking/Investigating the systems via webcam and binoculars from FINO3				
frequency / interval		once per day		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT
1.1	CHECK WEBCAM DATA via remote access from Kiel at least once per day to see if the systems are still in place and functional			#If drifting or damage is detected immediately plan maintenance trips
1.2	Check the systems with **binoculars** from the FINO3 tower to check if there is any damage or wear of parts			#at least on every flight to FINO3 from the FINO team ~50 flights/year #If drifting or damage is detected immediately plan maintenance trips

Table 4: General protocol for checking/maintaining site marking buoys

2. Checking /Maintaining the site marking buoys				
frequency / interval		every 2-3 months		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT
2.1	CHECK SPAR BUOY 1 -move and hold in position **N55° 11.94068 E7° 9.30972** -lift the spar buoy form the water to check on the shackles and mooring rope -replace the buoy at its original position			#replace/repair worn materials #check function of light via webcam

2.2	CHECK SPAR BUOY 2 -move and hold in position **N55° 11.89872 E7° 9.22283** -lift the spar buoy form the water to check on the shackles and mooring rope -replace the buoy at its original position			#replace/repair worn materials #check function of light via webcam
2.3	CHECK SPAR BUOY 3 -move and hold in position **N55° 11.76522 E7° 9.45675** -lift the spar buoy form the water to check on the shackles and mooring rope -replace the buoy at its original position			#replace/repair worn materials #check function of light via webcam
2.4	CHECK SPAR BUOY 4 -move and hold in position **N55° 11.80717 E7° 9.54362** -lift the spar buoy form the water to check on the shackles and mooring rope -replace the buoy at its original position			#replace/repair worn materials #check function of light via webcam

Table 5: General protocol for checking/maintaining the mussel system

3. Checking/Maintaining the mussel system				
frequency / interval		every 2-3 months		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT
3.1	CHECK MOORING CONNCETIONS -move to NW and SE end of mussel system, lift mussel system to water surface and check the mooring connections and load-cells			#replace/repair worn ma-terials
3.2	CHECK BUOY ATTACHMENT -lift each spar-buoy of mussel system out of the water to check chains and shackles			#replace/repair worn ma-terials #check condition of transmitter at top of 4m Buoy
3.3	CHECK NETS -lift a part of the netting out of the water to check the yield and to take samples			#replace worn materials #take pictures of spat/mussel growth
3.4	CHECK CAMERAS -lift the part of the netting out of the water where the cameras are attached -detach cameras to clean them and to re-place SD-Cards -reattach the cameras to the net			#check if cameras are still operating (wiper is run-ning) #clean housing and lenses when necessary #replace SD-Cards

3.5	CHECK SENSORS lift the part of the netting out of the water where the Sensors are attached; detach sensors to clean and calibrate them -reattach the sensors to the net			#check if sensors are still operating (wiper is running) clean housing and sensor when necessary #check conditions of cable from transmitter (top of 4m Buoy) to Sensors

Table 6: General protocol for checking/maintaining the seaweed system

4. Checking/Maintaining the seaweed system				
frequency / interval		every 2-3 months		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT
4.1	CHECK MOORING CONNCETIONS -move to NW and SE end of seaweed system, lift seaweed system to water surface and check the mooring connections			#replace/repair worn materials
4.2	CHECK BUOY ATTACHMENT -lift the SPREADERS out of the water to check the ropes and shackles check floatation status of SPARS			#replace/repair worn materials
4.3	CHECK NETTING -lift a part of the netting out of the water to check the yield and to take samples			#replace worn materials #take pictures of seaweed yield
4.4	CHECK CAMERAS -lift the part of the netting out of the water where the cameras are attached -detach cameras to clean them and to replace SD-Cards -reattach the cameras to the net			#check if cameras are still operating (wiper is running) #clean housing and lens when necessary #replace SD-Cards

Table 7: General protocol for checking/maintaining the CPODs

5. Checking/Maintaining CPODs				
frequency / interval		every 2-3 months		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT

5.1	CHECK CPOD-1 -move and hold in position **N55° 11.94068 E7° 9.30972** -lift the spar buoy form the water, detach the CPOD and maintain according to IBL-instruc-tion -reattach maintained or new prepared CPOD -replace spar buoy to original position			
5.2	CHECK CPOD-2 -move and hold in position **N55° 11.89872 E7° 9.22283** -lift the spar buoy form the water, detach the CPOD and maintain according to IBL-instruc-tion -reattach maintained or new prepared CPOD -replace spar buoy to original position			
5.3	CHECK CPOD-3 -move and hold in position **N55° 11.76522 E7° 9.45675** -lift the spar buoy form the water, detach the CPOD and maintain according to IBL-instruc-tion -reattach maintained or new prepared CPOD -replace spar buoy to original position			
5.4	CHECK CPOD-4 -move and hold in position **N55° 11.80717 E7° 9.54362** -lift the spar buoy form the water, detach the CPOD and maintain according to IBL-instruc-tion -reattach maintained or new prepared CPOD -replace spar buoy to original position			

Table 8: General protocol for checking/investigating the status of the Lander

6. Checking/Investigating the Lander system				
frequency / interval		once per day		
NO.	TASK DESCRIPTION	DONE SUC-CESS-FULLY	DONE WITH DEVIATION	COMMENT
6.1	CHECK SENSOR DATA via remote access from Kiel at least once per week to see if the systems are still in place and functional			#data will be uploaded to the FTP server once per day

Unforeseen cases that happened during operation:

- Detachment and loss of marking buoys
  - The detached marking buoys will be retrieved and installed at the original position.
- Drifting of marking buoys
  - , The German Pilot team decided to increase the anchoring weight to 3.000kg to ensure the buoys will not move during heavy winter storms.
  - Additionally, the mooring wires and shackles have been strengthened.

7.2. Dutch Pilot

The multi-use systems at the Dutch Pilot are, as the name says, pilots. Therefore the main goal is to learn from it, ideally in all possible ways, in practice on as much aspects as possible within the project. The operation around these multi-use systems will be different, more elaborate, then the commercial versions in wind farms.

The real time monitoring that is done for both activities within this pilot is checked on a daily basis, to make sure the systems are in place. In addition, there is regular monitoring and, if necessary, maintenance. For the sea-weed cultivation pilot, the monitoring of the seaweed was focused on the months February/March/April/May on a monthly basis. With this monitoring, the growth of the seaweed could be monitored (before February the sea-weed is still small). Next, the structure was checked after heavy storms in February and March 2021 & 2022, as these caused heavy loads on the installation. The latest also applies to the floating solar pilot. In addition, the solar doesn't have a biological growth. Therefore the monitoring is more consistent, starting with roughly once a month in the beginning towards once every week/two weeks at the moment. All the offshore monitoring trips are of course depending on a suitable weather window.

Most of the normal monitoring routine is done with a RIB (see picture below). In addition, larger vessels with a crane are used when (part) of the structure needs to be taken out of the water. Part of the monitoring is clean-ing the sensors (from fouling), checking the structure, both visually above sea level, but also underwater with a GoPro or ROV, and taking samples. Next monitoring trips with divers in the first 7m (otherwise a decompression tank is needed, which is a bigger and more expensive operation) have been executed.

Figure 8: Example of a monitoring trip with a RIB vessel to the Offshore Test Site

Also unforeseen cases happened: The main structures of the pilots have survived the big February & March storms. However, they did cause local damage to the systems. This was repaired successfully. No further unforeseen cases have occurred.

7.3. Belgian Pilot

The routine operations for the offshore site of the Belgian pilot are divided into the monitoring for aquaculture and the one for restoration.

- Sampling for aquaculture is foreseen:
  - For seaweed aquaculture: at installation (December 2022), the buoys of both the oyster and seaweed longlines are visually inspected. After that, we plan one sampling mission half February by sampling the seaweed leaves on the nets and that way measure intermediate growth. Then we will have the harvest end of April or beginning of May.
  - For oyster aquaculture: the buoys are visually inspected when the seaweed line is sampled. Upon harvest of the seaweed, we foresee a first cleaning mission of the lines. Then two more cleaning and sampling missions are foreseen. One in summer and one upon removing of the structures in October.
- Sampling for restoration is foreseen twice per year: one time in spring and one time in autumn.

There are two ways for checking the lines: one is by visual inspection of the surface buoys. This can be done by crew vessels passing by, by scientific vessels passing by and during any other sampling mission.

The other way for checking is by actually lifting the longline and that way also be able to visually check the structures attached to the longline. This is done via special method statements with a vessel that is approved to enter the wind farm.

The oyster cages for restoration are inspected by divers. Sampling is foreseen twice per year. Divers then retrieve one sub cage per oyster cage placed at the bottom of the monopile and film the other subpages. They also film the surrounding fauna and flora. Upon retrieval of the cages on land, the other organisms are also monitored.

As one of our oyster restoration structures was misplaced and landed upside down. We had to deal with unforeseen events: As is far from ideal for the oysters to reside upside down, it was decided to recover and reinstall the structure at the correct location. This had to be done using ROV as operational diving in the wind farm is not allowed for safety reasons. This mission resulted in a huge extra cost for the project, but could luckily be shared with another project that had to do operations in the area with the same vessel.

7.4. Danish Pilot

A routine has been developed internally to note all guided tour enquiries. Based on that, the suitable boat operator is contacted, and if available a pre-booking is made, which is inserted in the system. A guide is assigned and a contract is made with the client.

Guided tours are weather dependent. In case of bad weather, high wind speeds, or a combined wrong direction of currents and wind, we shall sometimes cancel the trip. Also the boat captain can cancel the trip. In those circumstances, the client would get all money refunded – or alternatively we look for another date.

The most unforeseen event experienced in the Pilot operation has been to be able to access the foundation with a RIB boat, but later could not access it again This was due to increased wind speed and current, and so the RIB could not wait still – and the visitors and tour guide could not board the RIB until 1 hour later.

Figure 9: Approaching the foundation at sea level with a RIB Boat (Zodiac) can be a challenge when the wind speed is more than 8 m/sec and the current is not as the wind direction

7.5. Greek Pilot

The **monitoring routine** *is* done on a daily basis. All the real time monitoring parameters are being checked through the online platform in order to check that all the systems are in place and if any adjutancy need to happen. Mainly during the summer months (From May to October) on weekly base touristic diving tours are taking place around the aquaculture farm. Every second day, the diver of the aquaculture farm is visiting all the cages in order to check and monitor the infrastructure and the fish.

The technological equipment (sensors and cameras) is being checked online on a daily basis and in case there is an alert or disconnection or malfunction a member of the technical team is visiting the aquaculture farm and checks the equipment.

The ROVs are being checked on a weekly basis by the diving company that provides them in order to be sure for the correct use of camera and energy.

Also some unforeseen events happened: Wired connection between cameras and sensors with router to provide power and internet did not seem as a proper solution (operational vessels often cut the wire and aquaculture operators also turn off the power at times). Solar panels for power supply have been added.

8. MAINTENANCE

8.1. German Pilot

For easy and low-cost inspections of underwater equipment and mussel growth, a simple remote-controlled camera (No ROV in the true sense) is used.

General workflows/protocols for maintenance trips were established as described in chapter 7. The protocols describe the tasks that need to be done during the maintenance trips themselves. For the coordination of the trips a close communication between the shipping company, FINO3 offshore engineering team and the FuE UNITED team was established. However, most of the trips had to be planned and arranged on short notice. Often, they had to be postponed due to the weather situation at FINO3. Therefore, it became clear, that a good preparation and easy protocols help to be flexible when coordinating the maintenance trips. Once it is fully functional, the Decision Support System (DSS D2.5) will be a great tool to assist in the planning of future trips.

The different structures at FINO 3 also require different maintenance:

- Maintenance of CPODs
    - recovering the CPODs, cleaning of housing and replacing of memory cards and batteries
- Maintenance of side marking buoys
    - Replacement of lost buoys (due to storm damage)
        - Transport from shore to operational harbour
    - Visual inspection of mooring (shackles, wires, concrete blocks) during CPOD maintenance
    - Visual inspection of buoys (buoyancy body, light, radar reflector) during CPOD maintenance
- Maintenance/inspection of mussel system
    - Visual inspection of buoys from ship
    - Diving inspection during lander installation
        - Inspection of (mussel spat) growth
        - Inspection of mooring chains and buoy attachment
    - Video inspection with a simple remote underwater camera from the ship during CPOD maintenance trip
        - Inspection of mussel growth
- Maintenance of seaweed system
    - Visual inspection of seeded seaweed net in the harbour (interim storage place before offshore deployment)
    - Cleaning of seaweed net after first algae trial in the harbour failed due to poor water quality
    - Re-seeding of seaweed net right before offshore deployment

Figure 10: maintenance of buoys at German Pilot

8.2. Dutch Pilot

Maintenance in the Dutch pilot is depending on the seasons. The seaweed cultivation pilot has two growing seasons. During a growing season, no other than the operational & monitoring work was executed: installation, monitoring, harvesting. After the harvest of the first season (May 2021), the main structure was kept in place offshore. Before the next growing season, a check and necessary maintenance of the whole offshore installation has taken place. The cultivation nets were brought to land, where they were cleaned and replaced by a different type of net / substrate for the next growing season.

The operation of the floating solar pilot is part of another project. In general, this installation is currently being extended step by step towards a 1 MW. This project will continue beyond UNITED to an even larger scale.

Oceans of Energy is constantly checking its system on (structural) safety, performance, environmental impact, etc. This also includes the regular maintenance to the system and repair of damage after for example storms.

8.3. Belgian Pilot

Maintenance for aquaculture is foreseen on the below time-points:

- For seaweed aquaculture: none. There is only the installation, intermediate sampling and harvesting. The buoys of the longlines are of course cleaned together with the ones from the oyster longline.
- For oyster aquaculture: the buoys are visually inspected when the seaweed line is sampled. Upon harvest of the seaweed, we foresee a first cleaning mission of the lines. Then two more cleaning and sampling missions are foreseen for the oyster line. One in summer and one upon removing of the structures in October.

8.4. Danish Pilot

Maintenance of the wind farm is done by the wind operator (Middelgrunden Wind Farm) and maintenance of the boats are done by the boat owners.

The virtual tours are seated at different museums / local attraction in Copenhagen. QR codes lead to a website which is maintained by the pilot leader's part of UNITED.

8.5. Greek Pilot

Maintenance of the different systems is done by:

- Diving expeditions for cleaning aquaculture area from waste
- Inspection with the use of (Remote Operating Vehicle) ROV of the aquaculture diver while repairing the infrastructure
- Inspection with the use of ROV of the aquaculture infrastructure that are placed in great depths (anchors)

Underwater inspection and photographs of the anchorage system have shown that all the targets are in good condition, showing that the expeditions are safe for the divers.

9. SYNERGIES

9.1. Environmental Synergy Effects

9.1.1. German Pilot

One positive effect is the reduction of CO_2-emissions by combining as much UNITED and general FINO3 maintenance trips onshore and offshore as possible compared to two single uses.

Potential synergies are:

- Aquaculture facilities provides fish nursery and feeding habitats
  - possible increase of fish abundance in this area
  - possible increase of predators like seals and harbour porpoises [2]
  - Mooring equipment like anchor stones serve as artificial reefs as they are rare hard structures.
- positive effect on the nutrient content in the water through algae and mussel cultivation as those are low trophic filter feeding and absorbing species
- Reduced amount of material use due to close exchange and cooperation between the UNITED pilots. So anchors weights, net etc. could partially be obtained in a used or refurbed conditions within the aquaculture network

9.1.2. Dutch Pilot

The synergies in the Dutch pilot:

- Using the same type of vessels for the offshore work and when possible, joining activities in one offshore trip.
- Using the same type of anchors for the offshore installations, sharing experiences on procurement, installation and calculations.
- Sharing knowledge on monitoring equipment and sharing the retrieved data.
- In potential (not yet executed in this pilot): using the floating solar panels for supply of energy for monitoring equipment of the seaweed farm.

Next to the synergies we encountered at the Offshore Test Site pilot, there are synergies for combining seaweed cultivation and floating solar with offshore wind. The potential on economic & social level will be discussed in WP3. To give some examples, the wind turbines project the seaweed and floating solar farm from infringement of vessels. The floating solar farm can be connected to the same electricity cable, and therefore increase the efficiency.

Cultivating seaweed within a wind farm can increase the biodiversity within the wind farm and therefore contribute to the required nature based solutions within a wind farm. Having more than one type of multi-use could ensure that no monocultures are created with negative effects, of course if deployed in a right way.

9.1.3. Belgian Pilot

Synergies encountered

- The crew vessels were also applied to monitor visually the buoys that are attached to the longlines as to see whether these are still present, whether all is fine with the installed aquaculture longlines offshore and whether we need to add/remove buoys. Hence shared fuel costs/ less fuel needed due to multiple purpose use.
- The same counts for the seaweed and oyster activities: the missions to install the lines and anchors were combined, and the sampling missions used for seaweed will also be taken advantage of to inspect

[2] During the maintenance trips, fish and seals were identified in the direct vicinity of the mussel system. This could be a first indication of this synergy effect.

the oyster longlines and/or to clean the structures containing the oysters that need to be cleaned (the latter during the seaweed harvesting).

- For the sampling of the restoration structures via a scientific diving team, in most occasions a scientific vessel (RV Simon Stevin or the Belgic) was applied and hence shared. Hence shared fuel costs/ less fuel needed due to multiple purpose use.
- Potential synergies:
  - With oysters and seaweed having complementary seasonal requirement, the boat use synergy would be ensured all year long – with oysters being harvested in the summer, and seaweed being harvested in the winter. Maintenance and checking of the infrastructure could happen all year long thanks to the wind park year ling maintenance requirement, hence boats and technicians' visits.
  - Oyster restorations, in the long future, could provide the spats to colonize lines for oysters' culture.

9.1.4. Danish Pilot

No environmental synergies were encountered

9.1.5. Greek Pilot

Through the scheduling system, to plan the multi-use activities between the aquaculture unit, the touristic expeditions (and all the linked activities and scenarios between the two). Planet Blue or KASTELORIZO can have access to the calendar and are able to check availability of the aquaculture and book a co-use activity. In this way, an activity/ inspection that happens by one party can prevent the situation of taking place this activity twice. This leads to synergies:

- Less stress because of the use of camera. Calculation of average weight instead of manual sampling that can cause physical damage.
- Early detection of disease à quick prevention of outbreak
- Attraction of other species à more ecological niches
- Optimal feeding time depending on the fish behaviour

9.2. Economic Synergy Effects

9.2.1. German Pilot

Due to the close collaboration with the FINO3 team some economic synergy effects in the German Pilot have been found.

- Combining flights to FINO3 helped to keep costs manageable despite rising energy costs. Combination of:
  - General FINO3 maintenance (Corrosion protection work, general server work and UNITED spare parts transport (server equipment, cables, cameras etc.))
  - UNITED lander installation (connection of power and server equipment as well as the sea cable)
- Combining material transport onshore whenever possible to decrease transport costs for FINO and UNITED (from/to operational harbour in Cuxhaven to/from FuE office in Kiel)

9.2.2. Dutch Pilot

The economic synergies will mainly be discussed and assessed in WP3.

- Floating solar: sharing the same offshore electricity cable, making the use of the cable more efficient
- Seaweed: combining (monitoring) trips with the offshore crew vessels of the wind farm

9.2.3. Belgian Pilot

Focusing on economic synergies, sharing vessel time was the biggest cost reduction we have experienced.

Potential synergies (for upscale scenarios):

- Development of 'luxury' sustainable products: seaweed from the windfarm or oysters from the wind-farm - products could be developed with a label designating multi-use.
- Potential for development of new sectors in Belgium: algae based bio-plastic, Belgian sushi, Belgian oysters, Belgian cosmetics (from algae), etc.
- More space for other economic sectors if activities are combined in offshore windfarms. In this case, having a sustainable form of aquaculture with restoration activities would allow for big areas to be dedicated for other uses such as recreation (aquaculture is often perceived as an issue for recreational activities when close to coast) and conservation (EU 2030 30% 10% targets will require more space under strict protection).

9.2.4. Danish Pilot

We have found that two of the main turbine producers worldwide, also Danish based, also organise boat trips to visit their turbines. This activity is normally addressed to the clients.

The turbines at Middelgrunden are now old – built in year 2000, they are rated at 2 MW power and belong to Bonus – now Siemens Gamesa.

We have settled a meeting with the two turbine manufacturers to understand the synergies that can arise from the current visiting programme we promote at Middelgrunden.

9.2.5. Greek Pilot

No effects could be observed.

9.3. Social Synergy Effects

9.3.1. German Pilot

The outreach of the German Pilot team has led to several social synergy effects which will benefit for future aquaculture multi use projects and the acceptance and interest in the general public.

- Online workshops (e.g., Safety & Logistics and Technology Transfer) gained both, interest in the project and its findings for the audience as well as new input for the German Pilot (and the UNITED project in general) from external experts in the audience and participants.
- The broad field of tasks in the German Pilot of the UNITED project has generated interest in school projects. A newly started collaboration between the German Pilot and a local Club of Rome school benefits both parties:
    - The students learn scientific practices on a live and up to date topic and the FuE team gains new insights into potential improvements for algae cultivation at the nearshore site (grow out substrates, seeding techniques, yield etc.).

Discussions with politicians, authorities and leading employer representatives have shown great potential in social synergy effects like:

- increase in jobs in the aquaculture sector
- restructuring of maritime spatial planning to drive multi-use to the next level

9.3.2. Dutch Pilot

The main social synergies were:

- Combining activities in a multi-use way requires less space of the North Sea, leaving more for other stakeholders.
- Combining activities may lead to better social acceptance and awareness
- Joining forces in shared outreach and communication on both the pilots

9.3.3. Belgian Pilot

Although the focus differed per event, the project was promoted at various (inter)national events and to a very broad audience: from governance via Blue Cluster and EC-events over broad audience via television broadcast to scientific public on scientific conferenced. This shared outreach definitely created synergies in communication.

Potential synergies in case of upscale scenario:

- If aquaculture happens in windfarm, more space will be available in the rest of Belgian part of the North Sea for other activities such as fishing (professional and recreational), recreational navigation, recreational sailing activities. Recreational activities are popular amongst the local population and aquaculture is often seen negatively. That is because aquaculture projects tend to aim for close-to-shore areas (it makes maintenance easier and is better protected from the elements), but these areas are also used by recreational activities so there is a conflict over space use. Local population and fishermen would be better off if aquaculture shares the windfarms space.
- Jobs creation – need for more technicians, engineers and marine technicians/biologists to maintain and monitor the project all year long.
- New local products to be valorised – good for tourism which is an important source of income and activities in the summer at the Belgian coast.
- Development of community identity around local and sustainable seafood production. New source of local and sustainable protein.
- Enhanced attractiveness of the coast in general – potential for communication and visibility about the Belgian coast and the North Sea, more jobs will attract an active population which will in turn stimulate the economy and the community.
- Satisfaction of living in a region where sustainability is really taken into account, where innovation happens (efforts are made to develop sustainable activities in windfarms), where sustainable production is (re)-developed.
- Satisfaction of living in a region where change is possible – with traditional activities often being in conflict with conservation, there is a need to evolve/transition to other practices. Seeing that happen will make people proud.

9.3.4. Danish Pilot

We have seen how companies are more and more appealed by the idea of combining day meetings with a tour to a turbine in the afternoon. This seems to be a success side event as we hear from our clients. We have settled a meeting with the two Danish organisations of tourism: *State of Green*. In charge of industrial relationships, and *VisitDenmark*. We are looking forward to hear how to expand the tourism activities at Middelgrunden.

9.3.5. Greek Pilot

Main social synergy effects were

- Tourists become more aware of the environmental protection of the area
- Tourists get acquainted with the fish farming activities in an effort to become educated about the damage done by overfishing, as well as dissolve the myth of the harm done by fishing farms
- Tourists enjoy diving in fauna rich area

10. CONCLUSION AND OUTLOOK

Within this deliverable several topics were covered. The findings are as diverse as the pilots themselves. Looking upon **Production**, within the offshore pilots in Germany, the Netherlands and Belgian the greatest reported product were the setup of the blue mussel, algae and oyster-restoration systems respectively. For Offshore work advance preparation is vital and weather conditions are crucial. Many legal and safety prerequisites had to be met and were reported upon by the offshore pilots. First results for algae production and oyster restoration were reported by the Belgian and Dutch pilot while the German pilot will get production results in 2023. For the Greek and Danish pilot production consists of providing guided tours or diving with tourists. However the Greek pilot has a running fish production. However this is not considered during the project as the production existed already before the UNTIED project. Both pilots reported on the prerequisites for visitors and on successful integration and start of tourist activities. **Monitoring** does also differ among the pilots. While the Danish pilot monitor's numbers of visitors and sets it in context to the different years, the Greek pilot does focus on monitoring fish aquaculture related parameters and also environmental parameters. Measurements are done in real-time and can be accessed remotely. These measurements are amended by the use of ROVs and the observations of divers. The German and Dutch pilots combine real-time monitoring, data collection by sensors that are retrieved later and sampling on site, collecting data by observations. The Belgian pilot does not conduct real-time measurements, but takes measurement trips and uses publicly available data for environmental monitoring. In addition the Belgian Pilot uses the data collected by the pilots to create numerical models, which will be reported upon in D4.4. All Datasets collected will also be uploaded into the HiSea platform. For the regular **Operation** the German Dutch and Belgian Pilots established different routines and protocols for checking equipment, monitoring and maintenance. These routines also varied with the distance to shore, and are getting more sophisticated the longer the trip is. While the Dutch pilot can for example use RIBs this is not possible for the Belgium and German pilot. The Danish pilot focuses on internal routines and coordinating the different boat operators and trips to the windmills, that mainly take place in summer. The same is true for the Greek pilot that is operating diving tours with its partner mainly in the summer months. In addition for normal operation the online real time monitoring is for the Greek pilot of great help. All Pilots looked also into the effects of unforeseen events and have established different plans to handle them, ranging from backup solar panels (Greek pilots) to compensate power loss, novel ladder and landing platform design at the Danish pilot for a safer and easier use of the entrance of the windmill for tourists, the use of ROVs in the Belgian pilot to retrieve bad positioned oyster restoration tables , addition of extra weight to marker buoys in the German pilot to prevent moving in heavy weather of the marker buoys or repairing and enforcing the offshore structure in the Dutch pilot after heavy winter storms. **Maintenance** is partly covered by operations but was also considered separately. The pilots report on the combination of maintenance and normal operation to save time and costs. Also the link and value to Deliverable D2.5, the Decision support system was pointed out in planning trips especially to the more remote offshore locations. Visual inspection is one of the major maintenance works performed by all pilots, sometimes aided by an underwater camera (German pilot), combining inspection with harvesting trips (Dutch and Belgian pilot) or also done by divers and ROVs (Greek pilot) Maintenance could also be a shared responsibility, as the Danish pilot reports. The boats are maintained by the boat operator, the windmill by the windfarm operator. Finally **Synergies** were looked upon within the report. Environmental and economic synergy effects were entwined. The German, Dutch and Belgian pilots report on time, money and CO2 saving effects of vessel usage for monitoring and work, that they encountered or expect to encounter in future. While the Greek pilot reports on environmental benefits of adjusted feeding and quick detection of diseases due to the synergy effect of remote monitoring and diving tours, the Danish pilot sees also an economic synergy potential in joining forces with neighbouring windfarm owners to organise trips. All pilots have encountered social synergy effects that are attributed to a better understanding of multi-use activities, generating a broader social acceptance based on the understanding of positive effects of multi-use systems. Also the public opinion was positively influenced by education of visitors especially in the Greek pilot, Information in this report spans from schedules over checklists to information on safety and regulations in the different countries. These information can serve as stepping stones for further offshore undertakings and represent a valuable source of knowledge for future projects. It can be used as a first step on the journey to an integrated, industrial use of until now untapped marine resources.