Development and demonstration of an automated, modular and environmentally friendly multi-functional platform for open sea farm installations of the Blue Growth Industry

D4.3 – Environmental monitoring measures and data elaboration report

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BGF	Blue Growth Farm
EIA	Environmental Impact Assessment

ESSS	External Surveillance and Security System
GA	Grant Agreement
HD	High Definition
ISSS	Internal Surveillance and Security System
MOI	Multipurpose Offshore Installation
MMO	Marine Mammals Observers
ROV	Remotely Operated Vehicle
WEC	Wave Energy Converter
WP	Work Packages

APPLICABLE DOCUMENTS

[AD1] European Commission, Directorate-General for Research & Innovation, Grant Agreement Number 774426 The Blue Growth Farm (GA-2018-774426), 2018.

[AD2] Technical Annex I to the Grant Agreement Number 774426: "Description of Work", April 2018, Part A and Part B.

REFERENCE DOCUMENTS

[RD 1] BGF deliverable, 2019, "D4.1 Environmental impact assessment for the representative sites report", 31st October, Rev 0.0.

2 INTRODUCTION

2.1 Identification of the document and its structure

The present document has been identified as Deliverable D4.3 "Environmental monitoring measures and data elaboration report" of the Blue Growth Farm contract ([AD1], [AD2]). The document constitutes an output of the activities carried out in WP 4, which addresses the overall Environmental Impact Assessment issues of the Blue Growth Platform and, specifically, it has been developed within Task 4.2, "Environmental monitoring measures and data elaboration".

This document analyses strategies to allow a close monitoring of environmental impacts in a short and long term of the Blue Growth Platform planned operations, in order to identify the best management practice along the Platform's life-cycle.

The contents of the document are structured as follows:

- Chapter 1: Introduction;
- Chapter 2: Main Expected Environmental Impacts;
- Chapter 3: Monitoring Plan;
- Chapter 4: Risk Analysis;
- Chapter 5: Data Processing Model;
- Chapter 6: Conclusions.

Thus, the pillars of the document are identified as:

- the definition of the monitoring plan, based on the expected environmental impacts;
- the integration of the monitoring plan with a qualitative risk analysis, in order to highlight the most critical actions foreseen by the monitoring plan itself and based on a risk minimization criterion;
- the structuring of data processing models to exploit the output of the platform systems for the purpose of environmental monitoring.

3 MAIN EXPECTED ENVIRONMENTAL IMPACTS

This chapter builds on the main findings of the Environmental Impact Assessment (EIA) carried out within D4.1 “Environmental impact assessment for the representative sites report” [RD 1] for the selected project sites. Indeed, such findings can be considered as a starting point for the development of monitoring guidelines specific for the BGF platform.

However, for the purpose of this document, the impacts generated by the BGF are not considered as site-specific. Thus, the main impacts outlined in the EIA are extracted and generalized for the purpose of the monitoring plan, which is not site-specific.

In addition to the considerations set out in the deliverable D4.1, the impacts generated by the BGF platform can be assimilated, in a first approximation, to those of an aquaculture facility in an offshore environment, with the addition of those impacts produced by a wind turbine positioned at a height of 119 meters above sea level, but not embedded in the seabed. In this Chapter, a description of the impacts is provided as the detailed monitoring plan will be drawn up in the following Chapter 3 of this document.

The offshore environment defined for the installation of the BGF platform limits or, in some cases, completely reduces certain categories of impacts that are peculiar to a coastal environment.

The following Table 3.1, derived from a recent review work focused on Environmental issues related to fish farming in offshore waters [RD 1], offers a comparison between the possible categories of impacts generated by the placement of an aquaculture facility in a coastal or offshore environment. Impacts are listed by category as low (barely detectable), medium (enrichment/detectable) and severe (negative impact), and offshore predictions as lower, no change or higher impact compared to coastal/off-coast ([RD 1]).

Table 3.1. Environmental impacts and change in ecosystem services of aquaculture in coastal and off-coast locations and predictions for offshore locations

Impact	Observed change in ecosystem services coastal/off-coast	Categorization of impact	Offshore prediction	Source
Visual impact and ecological footprint				
Visual impacts	Conflicts with coastal users, loss of property value	Severe	Lower	Ersan (2005)
Use of fish as feed	Pressure on wild fish stocks to produce feed for mostly carnivore aquaculture species	Severe	No change	Naylor et al. (2009)
Seed collection	Pressure on wild fish stocks	Severe	No change	Naylor et al. (2009)
Benthic impact				
Benthic flora	Loss of seagrass habitat, impact on maerl	Severe	Lower	Holmer et al. (2003), Hall-Spencer et al. (2006)
Enrichment of sediments	Accumulation of organic matter	Medium	Lower	Hargrave et al. (2008)
Sediment microbial activity	Increased sulfide production leading to poor sediment conditions	Medium	Lower	Holmer & Kristensen (1992)
Benthic fauna	Increase in productivity and diversity under oligotrophic conditions; loss of productivity and diversity under eutrophic conditions	Medium	Lower/no change/ higher	Kutti et al. (2007, 2008), Holmer & Kristensen (1992)
Wild fish and fisheries				
Wild fish (genetics)	Escapees (incl. spawn) interact with wild fish, affecting gene pools, and compete for habitat	Severe (salmon)	Lower/no change	Jørstad et al. (2008), Toledo-Guerdes et al. (2009)
Wild fish (disease)	Spreading of disease between cultured and wild fish	Medium	Lower/no change	Vike et al. (2009)
Invasion of exotic species	Introduction of species into new habitats	Medium	Lower	Williams & Smith (2007)
Wild fish (attraction)	Wild fish are attracted to cages due to food availability	Medium	Lower/no change	Dempster et al. (2002)
Fisheries	Conflicts for space, increased landings	Medium	Lower/no change	Machias et al. (2005)
Other issues				
Use of antifoulants/chemicals	Accumulation of hazardous compounds	Medium	No change/higher	Samuelsen et al. (1992)
Carbon footprint	Energy consumption and CO_2 release	Low	Higher	Bunting & Pretty (2007)
Water quality (nutrients)	Higher primary productivity under oligotrophic conditions	Low	Lower	Pitta et al. (2009)

If, as highlighted in the red square, the offshore environment implies that the potential impacts generated by an aquaculture facility are reduced. On the other hand, operational costs for sampling in deep waters are considerably higher, and most information is available from sites selected for scientific or exploitation purposes, whereas monitoring of water column conditions and benthic habitats is largely absent. Lack of background information on environmental conditions may significantly hamper the expansion of offshore farming, particularly due to the high costs of pre-screening surveys of biological, chemical and physical oceanography at potential offshore sites. Lack of knowledge from benthic habitats is critical, as sediments are likely to become organically enriched by offshore farming [R1].

After these considerations, the impacts potentially generated by the BGF platform are described below, taking due account of those generated by the presence of the wind turbine installed on the platform, with particular attention to the birdlife component that will characterize the installation site of the BGF platform. In particular, the following topics are considered in the analysis:

- landscape;
- benthic communities;
- pelagic communities and predators;

- birds;
- use of chemicals / antifouling;
- carbon footprint;
- water quality.

The BGF platform is unique installation, and no extensive literature exists on impact of such structures, especially on the additional impacts given by the concomitant activities. Being located several km offshore, the most of impact is referred to marine environment, and terrestrial and human components can be considered as marginally affected. Thus, the most of the attention has been focus on effects on marine components.

The matrix below has been drawn based on the impacts most commonly reported in literature for offshore installations as wind farms, fish farms and Oil&Gas platforms.

Table 3.2. Matrix of expected impacts for a generic BGF Platform

Component	Resources	Aquaculture	Noise	Rotor blades	Entangling structures	Electromagnetic fields	Moorings
Sea water	Nutrients	O					
	Oxygen	O					
Marine communities	Phytoplankton	O					
	Benthos	O					O
	Cetaceans		O				
	Fish	O	O		O	O	
	Seals		O		O		
	Sea Turtles		O				
	Pelagic birds	O		O	O		
	Migratory birds			O			
	Bats			O			
Landscape	Visibility	O		O			

3.1 Impact on landscape

Visual impact is of primary concern in coastal farming (see [R1]), and is one of the main reasons for moving farms towards offshore waters.

3.2 Impact on benthic communities

Benthic impacts are of primary concern in aquaculture (see Table 3.1), in particular under eutrophic conditions where accumulation of organic matter in the sediments may result in anoxia and loss of secondary production and biodiversity [R2].

Even if studies conducted on off-coast farms show a limited benthic impact compared to coastal farms due to larger dispersion of particulate waste products, this kind of impact cannot be excluded. For instance, a dedicated study on an off-coast farm located at 230 m water depth revealed increased rates of sedimentation at distances up to 900 m away from the farm, suggesting that deep-water farms can induce enrichment of sediments over large areas [R3]. Interestingly, they found an increase in the benthic fauna biomass and diversity, suggesting a stimulation of the production in the benthic community.

Findings of enriched benthic communities have been confirmed by other observations carried out in different offshore farms, suggesting a possible positive enrichment of fauna density and increasing of fauna biomass, whereas the community structure is modified with greater incidence of pollution-tolerant species under the net cages.

Benthic impacts can thus be expected also in offshore farms, despite their location in deeper water and more exposed conditions.

3.3 Impact on pelagic communities and predators

Fish farms are artificial structures in the sea and act as fish aggregation devices [R4], and the loss of waste feed and nutrients increases the availability of food, attracting wild fish to the farms [R5]. Predatory fish, mammals and birds have also been observed in farm surroundings predating on both the cultured and attracted fish [R6].

Predators' population generally reflects the specie present in the area, but due to the lack of general knowledge on offshore fish (e.g. feeding habits, population dynamics), their interactions with farms are consequently difficult to predict. Aggregation of predators around fish farms can also act as ecological traps, misleading fish to inappropriate habitat selection or diverting migrating fish from migration routes, making them susceptible to capture and thereby increasing their mortality rates [R7].

A concern at offshore farms is the attraction of large predators, potentially able to cause damage to nets during their hunt for prey. Damage of nets is an economic as well as ecological risk due to the release of farmed fish to the wild. Moving farms offshore could attract larger and more abundant predators to the farms, including species such as sharks and killer whales. If offshore net cages are attacked, there is a risk of releasing millions of cultured fish due to the large size of the farms. Escapees, cultured fish unintentionally released into the wild, are a major and increasing concern in aquaculture [R8]. A proper net design has then to be guaranteed in order to preserve the capital.

3.4 Impacts on birds

Birds may be affected by different types of impacts due to the presence of the BGF platform: those generated by the aquaculture facility and those due to the wind turbine. Although seabirds do not belong strictly to this category, they are top predators of the marine trophic network and therefore may be affected by the same impacts as other marine predators. This section is dedicated to the description of the potential impacts due to the presence of the wind turbine on the BGF platform.

A Danish study [R9] describes the impacts of wind farms on birdlife. It points out that offshore wind farms represent the single most extensive industrial infrastructural development in the marine environment to date, and the erection of tall towers supporting rotating turbine blades presents three types of hazard to birds at sea (see Figure 3.1).

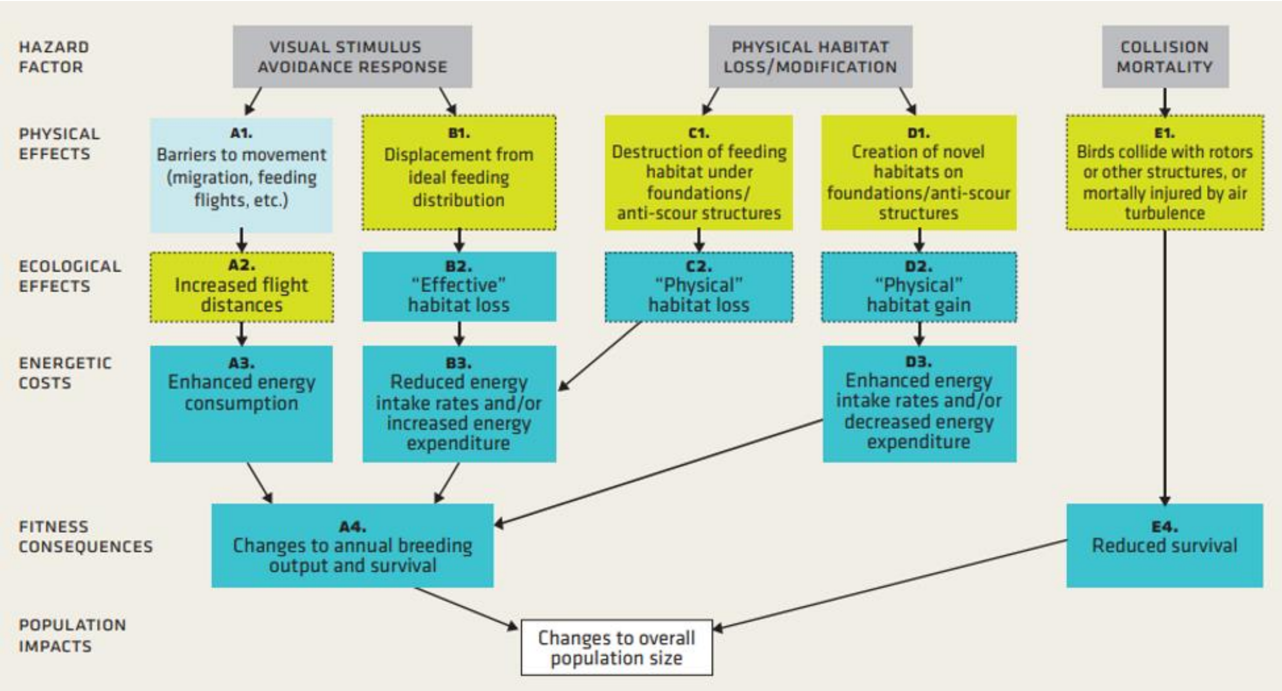

Figure 3.1: Major hazard factors to Birds

This flow chart describes the three major hazard factors (grey boxes) affecting birds by the construction of offshore wind farms. It shows their physical and ecological impacts, the energetic costs and fitness consequences of these effects, and their ultimate impacts on the population level (white box). The light green boxes indicate potentially measurable effects; the dark blue boxes indicate processes that need to be modelled [R9].

The three main potential impacts on birds are described below:

- *Flight displacement*

First, wind turbines present a barrier to movement of migrating or feeding birds. Many bird species avoid unfamiliar man-made objects, especially large moving structures, the erection of which may deflect prior migration routes or feeding movements, although some may be attracted to them. Displacement of migration routes will likely add little to energetic costs by slightly extending traditional routes to avoid the turbine.

- *Changes in distribution*

An impact can be determined by the modification of the habitat (loss or increase of resources) due to the presence of the new installation. These changes can potentially reflect on changes in specie distribution.

- *Risk of Collision*

If birds do not show avoidance behaviors, there is a potential risk of collisions with the turbine blades and body. It is often considered the most important hazard because of its demographic effect on populations, adding directly to the death rate. The impact of this elevated mortality depends on the population dynamics of the species concerned. Long-lived species with naturally low reproductive output (such as divers *Gavia* spp and common eider ducks *Somateria mollissima*) are slow to replace themselves and can suffer rapid declines in population size in response to relatively small increases in annual adult mortality rates. This issue makes such species much more vulnerable to collision mortality than, say small finches, that regularly experience high mortality (e.g. on migration), but exhibit higher reproductive potential to rapidly replace annual losses.

3.5 Use of chemicals and antifouling

Various chemicals, including antifouling, can be used in fish farms and accumulate in the benthic organisms and sediments below the net cages [R10], [R11]. The use of medicines for treatment of cultured fish, such as antibiotics, poses an environmental threat in the form of transmission to wild organisms and development of bacterial resistance in nature [R13]. Given that use of these remedial is expected to decrease in offshore farming due to a better water quality and the less growth of biofouling combined with increased dispersal, the environmental threat is most likely lower (see [R10]).

3.6 Carbon footprint

The carbon footprint is predicted to increase as fish farms move offshore due to increased energy use for transportation of material, feed and cultured fish (see Table 3.1). Optimizing energy use at offshore farms with renewable energy sources, as per BGF concept, compensates some of the increased energy use.

3.7 Water quality

Water quality is considered one of the less severe impacts produced by aquaculture installations [R12]. The water quality around coastal fish farms is affected by the release of dissolved and particulate inorganic and organic nutrients, but, due to rapid dispersal, only limited impacts have been documented. By moving the farms further offshore to exposed conditions, the dispersal of nutrients is expected to increase, minimizing the pressure on the environment.

4 CHAPTER 3: MONITORING PLAN

The proposed monitoring plan is based on the impacts identified in the D4.1 document [RD 1] and on what has been summarized in Chapter 2 of this present document. In particular, the monitoring plan is defined with reference to:

- the practical implementation of conditions and plans arising from the EIA;
- the state of the environment in the vicinity of a farm;
- the state of the environment more widely, which may be influenced by other farms or activities, in a cumulative way.

The monitoring plan is structured in order to describe the state of the components potentially subject to environmental impacts, both in the **short** and **long term** timeframes.

The aim of the proposed plan is to provide a clear direction on the implementation of environmental management best practices during the following phases of the project development:

- installation (anchoring and umbilical plugging of the BGF MOI platform towed by tugs from the construction site to the installation site);
- operational;
- decommissioning.

4.1 Literature analysis for aquaculture monitoring and RES monitoring procedures

This paragraph synthetizes the state-of-the-art applicable guidelines for the development of an environmental monitoring plan of an MOI like the one considered in the BGF project. Such references are then referred to for the setting the basis of the BGF proposed monitoring plan. Specific BGF needs that are not covered by the current guidelines, are highlighted and discussed for a potential future implementation in the applicable documents by relevant authorities.

4.1.1 Guide d’évaluation des impacts sur l’environnement des parcs éoliens en mer

This report [R14] is developed by the French Ministry of the Environment, Energy and Sea as guideline for the drafting of environmental impacts assessment studies for wind farms. The guide, which focuses on offshore wind farms (excluding connection to the grid of electricity transmission and distribution), is in line with previous guides published by the Ministry, and in particular the "Guide to the impact assessment on the l'environnement des parcs éoliens" published in 2010. It is also based on the "Study methodology of the environmental and socio-economic impacts of marine energies renewable" published in 2012. It takes into account the evolution of methods and knowledge as well as feedback on existing projects and parks.

4.1.2 OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development

Purpose of the guidance [R15] is to assist OSPAR contracting parties, developers, consultants, regulators or any other interested parties or individuals in the identification and consideration of some of the issues associated with determining the environmental effects of offshore wind farm developments. OSPAR guidance has been structured to consider the main stages of the life history of an offshore wind farm, starting from the choice of the location to the removal/decommissioning phase.

4.2 Definition of the monitoring plan

Based on the environmental stressors identified, information gathered from existing literature and experience in this field, the proposed monitoring plan for the BGF MOI described hereafter.

4.2.1 Monitoring points design

In order to be able to compare the data collected during the monitoring phases of the identified environmental components, the following scheme of positioning of the monitoring points has been adopted.

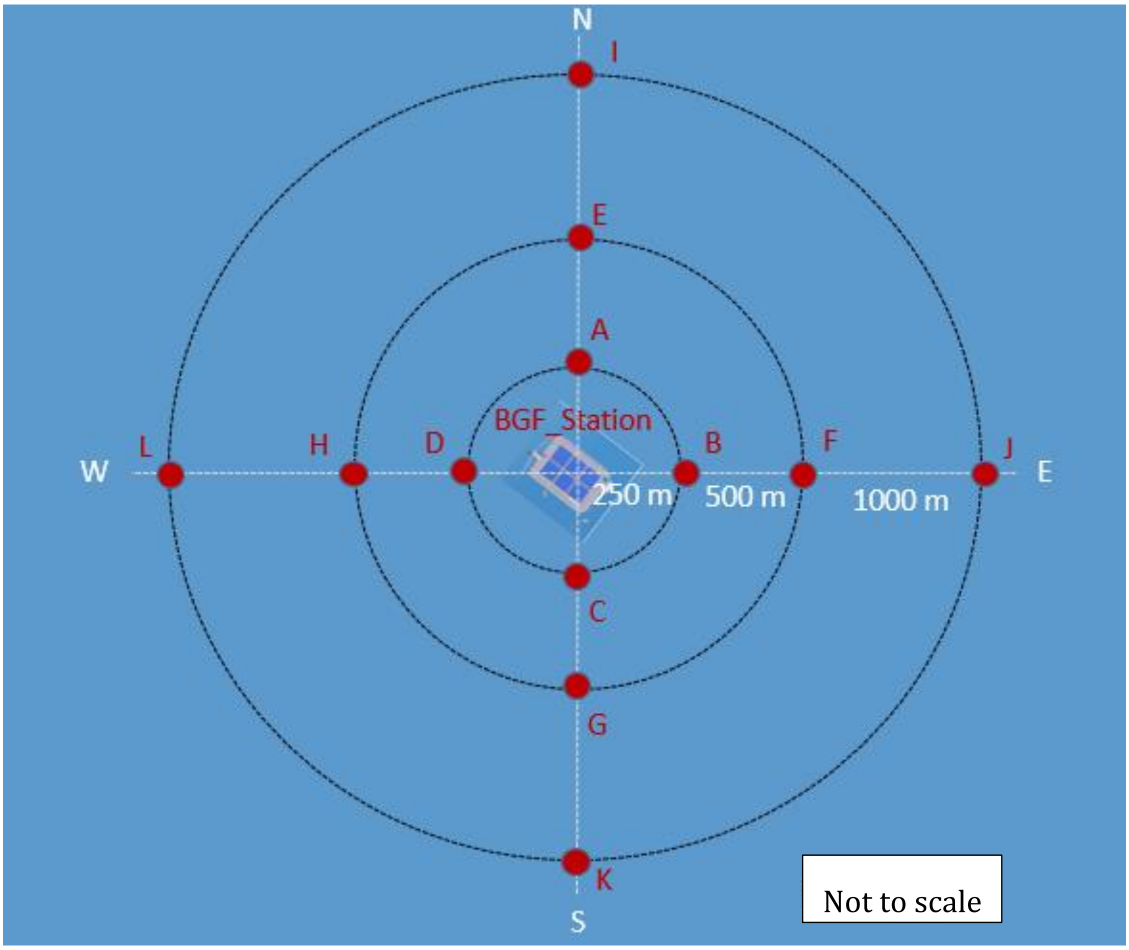

Figure 4.1: Monitoring points positioning

The proposed scheme provides for the positioning of 13 points, one ("BGF_Station") in correspondence of the offshore installation and the other 12 are equi-spatially positioned from the "BGF_Station" point along the North-South and East-West lines, in order to evaluate the trend of the values at increasing distances from the location of the offshore plant:

- A, B, C and D were located at a distance of about 250 meters from BGF platform;
- E, F, G and H were located at a distance of about 500 meters from BGF platform;
- I, J, K and L were located at a distance of about 1000 meters from BGF platform.

A further monitoring has to be carried out at an indicative distance from the BGF platform of 2.000 m. This point, chosen randomly, will have the function of control.

The monitoring scheme proposed is not dependent from the direction of the main current. As a general approach, the orientation shall be adjusted in time, after gaining a general understanding of the behavior of the entire BGF platform. Nevertheless, it can be decided to align the monitoring axes parallel and perpendicular to the main current direction, especially for those sites where a stable trend can be observed along the entire year.

4.2.2 Monitoring of abiotic parameters

At each point, the following sampling is planned to be measured. The analysis of the collected samples of sediments will allow to establish the concentration of substances deriving from the presence of the BGF platform through the comparison of the values sampled immediately before the beginning of the works and during the following phases of installation and, subsequently, during the operational phase of the platform. The sediment samples will be stored and returned to the BGF onboard laboratory for analysis or delivered to land shouldn't such facility be provided onboard.

4.2.2.1 Water quality

The monitoring of water quality will be carried out by comparing the results obtained during the pre-operational campaign with those that will be found during the BGF MOI installation phase and, subsequently, once the platform is fully operational. Water quality will be monitored by measuring the following parameters:

- temperature;
- salinity;
- density;
- currents.

Parameters measurement is carried out by using a CTD probe equipped with an Acoustic Doppler Current Profiler (ACDP). To monitor the BGF_Station point, data are collected by CTD probes and current meters already connected to the BGF platform.

To monitor the points of the sampling scheme far from the BGF_Station, use of a portable CTD probe equipped with an ADCP for seawater currents data collection is considered. Should the use of the probe be necessary also to collect data at BGF_Station point, launch and recovery of the instrumentation is carried out by means of one of the cranes positioned along the BGF platform deck (Figure 4.2).

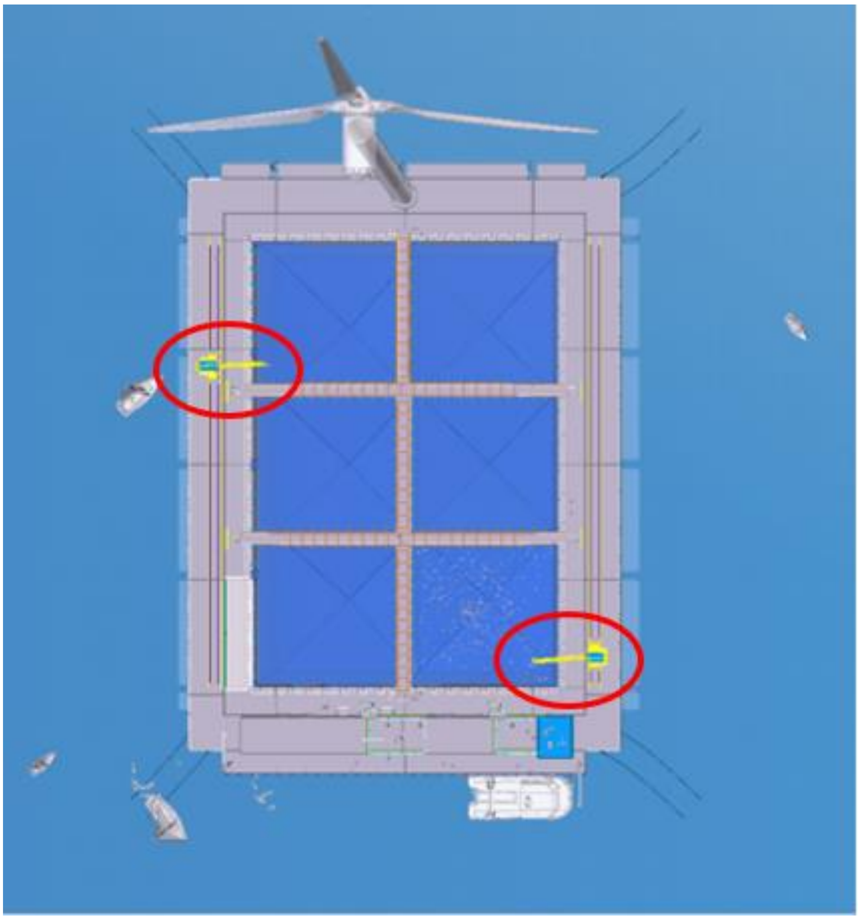

Figure 4.2: BGF cranes position

For the monitoring of the outer 13 points (12 of the monitoring scheme + 1 chosen randomly for control), it will be necessary to use a dedicated vessel possibly equipped with a winch to facilitate the descent and recovery of the sampling instruments.

In addition to the data collected with the probe, water samples will be collected at different depths. Analyses of the water samples will be useful to calibrate the instruments and to establish the nature of the dissolved particulate matter. The use of Niskin-type bottle is therefore foreseen. It will be lowered and recovered using the same crane positioned on the platform or on board the vessel used for sampling. The collected water samples will be properly stored and sent to the laboratory for analysis.

The frequency of sampling will vary according to the development phase of the project. This point is better described in the following sections.

4.2.2.2 Sediment quality

Sediment samples are collected for a variety of reasons including chemical, physical, toxicological and biological analysis. A Van Veen grab will be used to collect sediment samples. A representative sketch of the technology is provided in Figure 4.3.

Figure 4.3: Van Veen grab for soft bottom sampling

For each of the 14 previously identified stations a sample of sediments will be collected and sent to the laboratory for analysis.

According with the most used technical guidelines for marine sediment monitoring, the main parameters object of measurement and analysis are:

- Physical-chemical parameters:
  - granulometry, percentage of humidity, specific weight;
  - Hg, Cd, Pb, As, Cr total, Cu, Ni, Zn, Mn, Al and Fe;
  - Total hydrocarbons, PAHs, PCBs, organochlorinated pesticides;
  - Tributyltin (TBT), dibutyltin (DBT), mono-butyltin (MBT);

- Total organic matter, nitrogen and total phosphorus, total organic carbon (TOC).

- Microbiological parameters:
    - Total and faecal coliforms, faecal streptococci;
    - Additional parameters can be added according to the type of emissions from the work in question (e.g. Ba, Se, V, chloroorganic compounds, etc.).
- Ecotoxicological parameters:
    - Battery of biological tests including several different species, belonging to trophic levels and taxonomic groups phylogenetically different.

4.2.3 Monitoring of biotic communities

In order to assess the suitability of the BGF installation with respect to the biological features to be protected, the relevant basic information (e.g. spatial distribution and temporal variability) are to be made available for benthos (epifauna, infauna, macrophytobenthos), fish, mammals as well as resident, migratory, resting or feeding birds (including any combination of these parameters).

Monitoring of the biotic communities will therefore be carried out during all phases of the project, from the pre-installation campaign to the decommissioning phase. The monitoring periodicity will vary in relation to each phase.

The next paragraphs present the monitoring techniques for each category of species composing the biotic compartment.

4.2.3.1 Monitoring of benthic communities

4.2.3.1.1 Visual inspection

The monitoring of benthic communities will be carried out directly by the BGF platform by means of the Remote Operate Vehicle (ROV) already part of the BGF fittings. The ROV is equipped with one camera, navigation sensors, a scanning sensor for the seabed analysis around the anchors, hydraulic manipulators used for simple jobs, like net checking, etc. Remote control is carried out through copper or fibre optic cables (Figure 4.4).

Figure 4.4: Remotely operated vehicle (ROV)

To monitor the points from A to L, positioned at a distance between 250 and 1000 metres from the BGF _Station, the ROV will be operated by means of the dedicated monitoring vessel.

Benthos monitoring activities will be performed on all 14 points (13 on the monitoring scheme + 1 chosen randomly for control, Figure 4.1).

4.2.3.1.2 Monitoring of macro-zoobenthos

The characterization of the fauna on soft bottoms will be made through the sampling with the grab used for the monitoring of the sediments.

During the survey, the following data are collected and recorded:

- person responsible for the sampling program;
- project or contract identification code;
- date and time for each sample and/or sampling station;
- weather conditions;
- state of the sea;
- grab type and characteristics;
- geographical coordinate;
- water depth for each sampling station and each replicate sample (if performed);

- number of replicates per sampling station (if performed);
- rejected samples;
- bite depth or sediment volume for each sample;
- smell, color (referring to the "Munsell Soil Color Chart System"), visual sediment characteristics;
- pH and Eh measurement;
- debris;
- sieve mesh sizes used in the sorting process;
- main sorted faunal groups per sampling station.

Samples should be discarded if:

- the grab has not closed properly;
- the bite is obviously uneven;
- spillage occurs during transfer of samples;
- surface layer is disturbed;
- samples clearly deviate from others taken in the same site/area, for example, a change in sediment type between replicates in the same sampling station (should replicate be performed). Nevertheless, different samples should be kept to record faunal/sediment patchiness, and other samples should be taken to replace them.

4.2.3.2 Monitoring of pelagic megafauna (fish and turtles)

Design of technologies hosted on the BGF platform foresees the use of an underwater video camera for each cage. For example, in order to optimize the cabling already provided for the cage cameras, the potential presence of predators from the outside environment is detectable by means of manoeuvrable by remote control underwater cameras.

Figure 4.5 indicates the location of the underwater cameras. The visual cover reached is identified as well (purple circles).

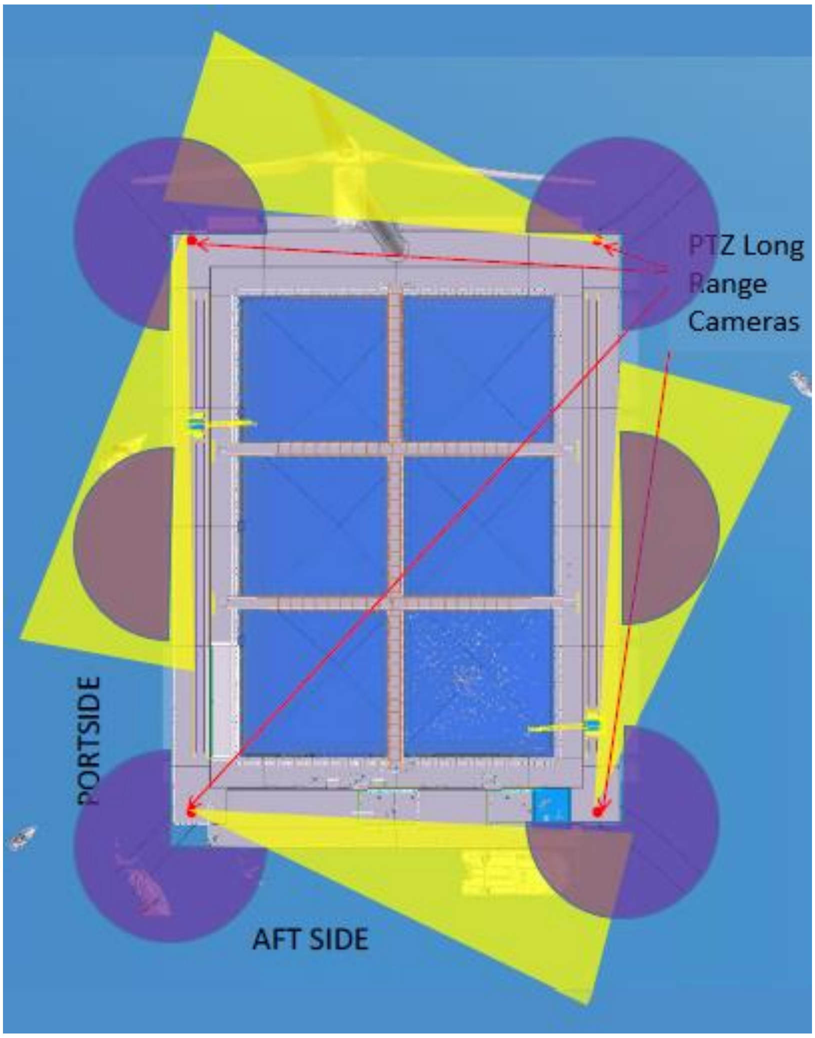

Figure 4.5: PTZ Long Range Cameras on BGF platform and location of underwater cameras to monitor presence of marine predators

The final position of the cameras should be chosen in such a way as to optimise the view of the external environment near each cage and should therefore be refined during the installation phase.

As a general reference, the underwater video cameras will be placed on dedicated supports that allow the cameras to reach depths that optimize the view to the outside of the cage. A PVC pole or an anticorrosive anodized aluminium pole, for example, could represent a valid alternative and offer the appropriate support to which the video cameras can be attached. These should be positioned at the external surface of the net and oriented outwards.

The following figure shows a hypothetical position of the underwater cameras and the immersed part of the supports that support them. The cameras, remotely adjustable by an operator, will allow you to monitor the areas immediately outside the cages.

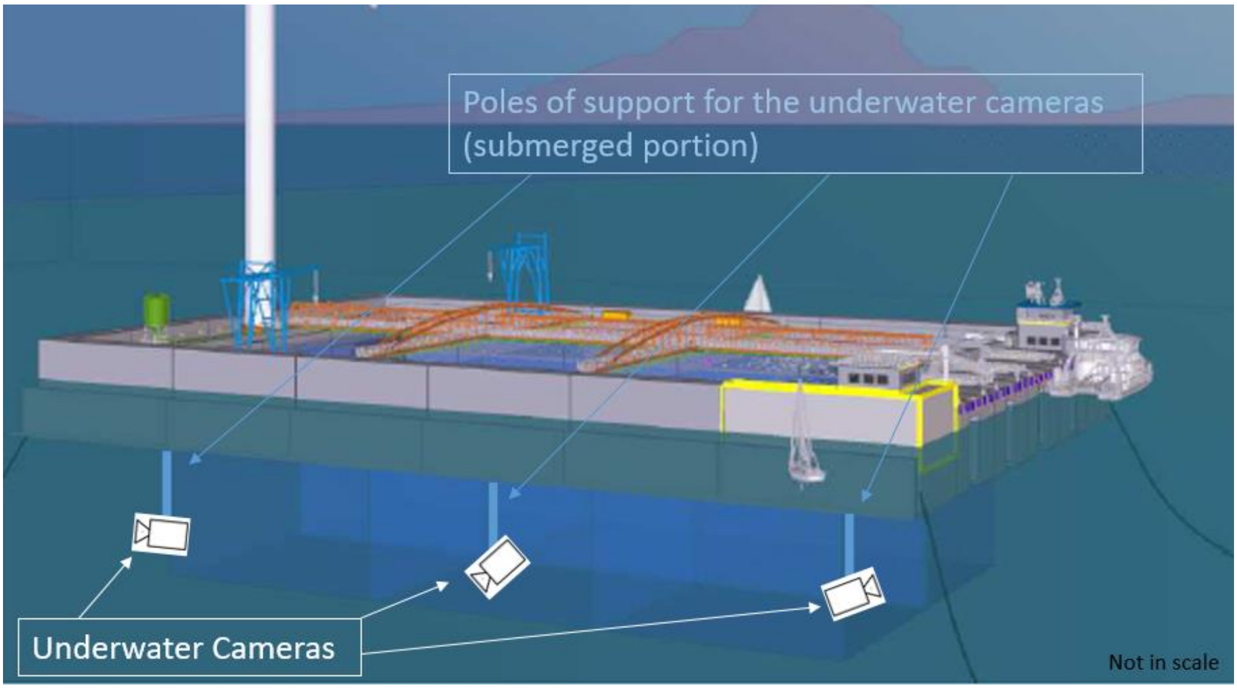

Figure 4.6: Theoretical positioning of underwater cameras near cages

In addition to the underwater video images, the project of the BGF platform provides for the installation of medium-long distance cameras, capable to provide an accurate surveillance of maritime traffic as well as the identification of potential intrusion by small boats approaching the platform. These medium-long distance cameras are located at the four platform corners, as shown in Figure 4.5**,** with the yellow triangles representing the approximately coverage.

Figure 4.7: PTZ Long Range Camera

Finally, when boat based surveys for monitoring of abiotic components will be carried out during the different life cycle BGF phases, at least 2 qualified and trained observers will be present on board to assess the marine fauna species in proximity of the platform (see Paragraph 3.2.1).

4.2.3.3 Marine mammals monitoring

The monitoring of marine mammals will be carried out by both visual and passive acoustic localization techniques, exploiting the possibility of establishing the presence of cetaceans in an area by detecting their acoustic signals, even in conditions where the mere visual observation would not be effective (night hours, rough sea conditions).

4.2.3.3.1 Marine mammals visual monitoring

During the boat-based surveys, at least 2 qualified and trained marine mammals observers (MMO) will be embarked. MMOs will be equipped with binoculars, photographic and video equipment and dedicated survey and sighting cards. For the entire duration of the monitoring activities, other 2 qualified and trained MMOs will be placed on board the BGF platform to monitor the presence of animals close to the same.

4.2.3.3.2 Marine mammals acoustic monitoring

The acoustic detection of marine mammals will be carried out through the positioning of stationary hydrophones with appropriate technical characteristics depending on the location of the BGF platform and the characteristics of the species commonly present in the area.

During the boat-based surveys, the operators will be equipped with a stationary hydrophone with transmission cable and digital recording system. The hydrophone will be lowered during the vessel's stationing period at the sampling point (see Figure 4.1) and recovered before the vessel starts moving to the next point. One of the operators will be equipped with headphones and will note on the card the presence of acoustic signals attributable to marine mammals. The data collected will then be analysed in the laboratory to verify the presence/absence of acoustic signals. Figure 4.8 shows an example of instrumentation to be used in cetacean boat-based monitoring surveys

Figure 4.8: Example of stationary hydrophone for boat-based surveys

An almost continuous passive acoustic monitoring will then be performed using a passive acoustic device able to record the sounds of the marine environment through regular recording cycles. The instrument will be placed on the bottom near the BGF platform and it will be recovered during each boat-based monitoring activity and replaced by a similar instrument.

Figure 4.9 illustrates an example of a passive acoustic monitoring device anchored to a weight on the bottom.

Figure 4.9: Example of Passive Acoustic Monitoring device

As general criteria, when passive acoustic detection systems are placed on relatively shallow sea bottoms, they are installed and retrieved manually by underwater technicians. On the other hand, for deep water monitoring, the instruments are left from the vessel directly into the water and recovered by means of an acoustic releaser. Ideally, the instrument will be positioned in the middle of the quadrilateral formed by the 4 anchorage systems of the platform, so as to have a constant reference on the position and facilitate the recovery operations by the various. A position equidistant from the chains of the platform anchors would also limit the risk of obtaining recordings of the acoustic environment excessively disturbed by the noise produced by the catenaries, which could even reach the point of saturating the signal picked up by the hydrophone.

The final positioning of the instrument will be chosen in order to optimize the deployment and recovery at each monitoring activity.

Such monitoring activity is also targeted at the characterization of potential noise emissions generated by the BGF platform, which at this stage of the project are currently not well known.

It is suggested to compare the acoustic monitoring results during operation with records acquired during pre-installation phase, characterizing the baseline. In case clear discrepancies in the noise sources from pre-installation to operation is observed in the location of the BGF platform, it is recommended to make use of data collected through measures with the hydrophone are also exploited for the characterization of noise emissions.

4.2.3.4 Birds monitoring and mitigation of risk collision

The monitoring of the birdlife will be carried out autonomously by means of detection sensors placed on the wind turbine. Figure 4.10 shows an example of a self-working system for Bird Monitoring and/or mortality mitigation at offshore wind turbine.

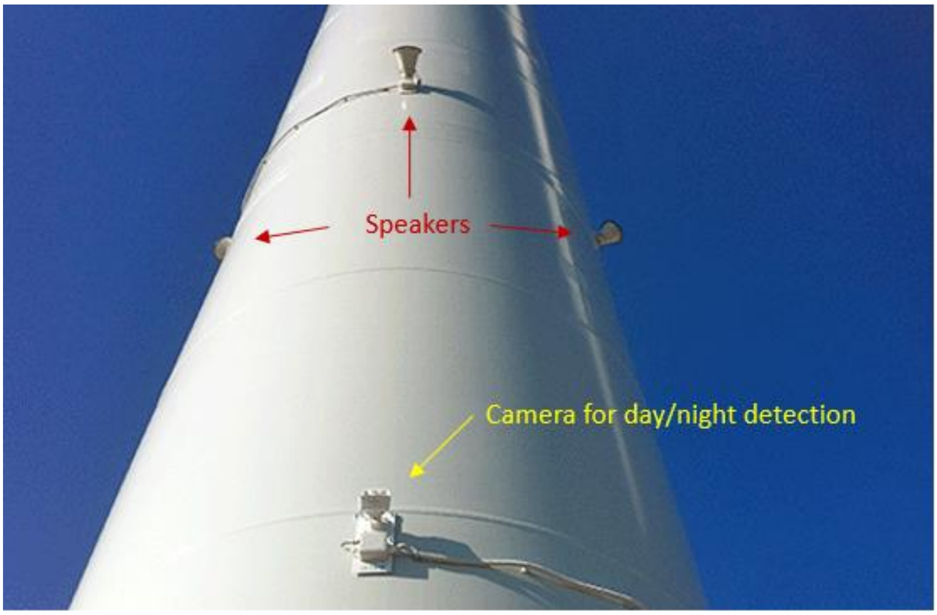

Figure 4.10: Example of Detection/Collision Control Module

The system automatically detects birds. On event, it can optionally support two independent actions to mitigate bird collision risk: the activation of warning sounds and/or alert for the wind turbine blades stop.

Daylight HD cameras survey 360º around the wind turbine. Optionally, at night 2-8 thermal cameras survey the monitored areas around the wind turbine. Birds are detected in real-time whilst videos and data are stored.

Online data analysis platform provides transparent access to review bird flights including videos with sound, environmental data and WTG operational parameters. Graphics and Automatic Service Reports for selected periods are also available. Figure 4.11 shows an example of a data analysis output.

ID	Date & Hour	Flight length (s)	Species / Group	N° of birds	Rotor area cross	Collision	Behaviour	Edited by	User Notes	User Var	Azi.	Temp.	Hum.	Rain	Lux	Warning init	Warning duration (s)	Dissuasion init	Dissuasion duration (s)	Stop init	Stop duration (s)	Videos	Download	
6616	2015-05-24 12:18:27	27	Griffon vulture	1	NO	NO		DTB			0	33	39	0	7025.5	12:18:27	26	-	-	-	-			
6617	2015-05-24 12:18:53	9	Griffon vulture	1	NO	NO		DTB			0	33	38.9	0	7012	12:18:53	31	-	-	-	-			
6618	2015-05-24 12:27:07	3	Raptor	1	NO	NO		DTB			0	32.8	38	0	7093	-	-	12:27:07	27	-	-			
6619	2015-05-24 13:05:04	54	Griffon vulture	1	NO	NO		DTB			0	33.7	35	0	10027.7	13:05:56	26	13:05:05	50	13:05:05	90			
6620	2015-05-24 13:23:29	4	Raptor	1	NO	NO		DTB			0	34.6	34.1	0	9760.5	-	-	13:23:29	26	13:23:29	90			
6621	2015-05-24 13:29:27	15	Raptor	1	NO	NO		DTB			0	34.3	33.7	0	9201.7	13:29:27	39	-	-	-	-			
6622	2015-05-24 15:44:23	11	Griffon vulture	1	NO	NO		DTB			0	35.7	26.9	0	19827.4	15:44:23	5	15:44:28	30	15:44:29	90			
6623	2015-05-24 17:43:00	5	Griffon vulture	1	NO	NO		DTB			0	33.9	35.7	0	19535	17:43:00	27	-	-	-	-			
6624	2015-05-24 17:56:31	16	Raptor	1	NO	NO		DTB			0	33.4	36.5	0	19250.4	17:56:31	32	-	-	-	-			
6625	2015-05-24 19:35:52	4	Griffon vulture	1	NO	NO		DTB			0	32.5	40.3	0	18182	-	-	19:35:52	28	-	-			

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66

Figure 4.11: Example of data analyses

Moreover, during the platform operation activities, the same operators dedicated to the monitoring of marine mammals carry out birdlife monitoring and a part of the survey card will be dedicated to birds' assessment.

During the birdlife visual monitoring phase, any carcasses recovered on the platform or in adjacent areas that are easily accessible from the BGF, will be necessarily counted and identified at the specified level. Although carcass monitoring is a widely used technique for estimating the impact of turbines on birds by quantifying their collisions on land-based wind-farms, it is important to note that this technique is not easily applicable to the BGF platform. In fact, the logistics of the structure and of the study area within which to monitor the carcasses are strongly subject to atmospheric agents (winds, currents, wave motion), with the risk of underestimating the impact in a way that is difficult to quantify. For this reason, it has been decided to use the information from the collection of carcasses in order to have an additional source of elements to establish the species and age groups of individuals recovered, instead of counting the number of carcasses to estimate the number of specimens left in collisions.

4.2.4 Monitoring activities

4.2.4.1 Pre-installation survey

In order to obtain an assessment of potential environmental impacts on the biotic and abiotic compartments, a dedicated boat-based survey is conducted prior starting of the installation phase.

The pre-installation survey should be carried out at least two weeks before installation starts in order to have the most up-to-date and detailed baseline information for those environmental components not presenting a strict seasonal variability. For those other components, such as pelagic fauna, marine mammals and birds, a monitoring of at least one year, on a quarterly basis, would allow to obtain important information on seasonal variability. The pre-construction survey will collect data on the abiotic and biotic components identified in the previous paragraphs.. The pre-construction survey will collect data on the abiotic and biotic components identified in the previous paragraphs.

The following Table 4.1 shows the parameters, the technique and the frequency of the pre-installation monitoring carried out during a dedicated boat based survey.

Table 4.1: Pre-installation survey plan

Compartment	Parameters	Monitoring Technique	Frequency
Water	• Temperature • Salinity • Density; Current • Dissolved Particulate matter	One sample for each station presented in Figure 4.1 + 1 in the control point	On a quarterly basis starting from 1 year before installation
Sediment	• Physical • Chemical • Ecotoxicological	One sample for each station presented in Figure 4.1 + 1 in the control point	On a quarterly basis starting from 1 year before installation
Benthic fauna	• Presence/absence • Identification • Quantification	One sample for each station presented in Figure 4.1 (for macrozoobenthos) + 1 in the control point	On a quarterly basis starting from 1 year before installation
Pelagic fauna (fish and turtles)	• Presence/absence • Identification • Quantification	Visual observation from the boat	On a quarterly basis starting from 1 year before installation
Marine Mammals	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Passive acoustic detection from the boat	On a quarterly basis starting from 1 year before installation
Birds	• Presence/absence • Identification • Quantification	• Visual observation from the boat	On a quarterly basis starting from 1 year before installation

4.2.4.2 Installation phase

The installation phase requires short-term monitoring, so that potential impacts on environmental components in and around the platform can be assessed in a short time. Indicatively, the execution of 1 survey every week could represent a good example of short-term monitoring. By the way, more details on the monitoring frequency can be provided depending on the actual duration of the phase.

Table 4.1 shows the parameters, the technique and the frequency of the installation phase environmental monitoring activities.

Table 4.2: Environmental monitoring during the Installation phase

Compartment	Parameters	Monitoring Technique	Frequency
Water	• Temperature • Salinity • Density • Current • Dissolved Particulate matter	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/week
Sediment	• Physical • Chemical • Ecotoxicological	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/week
Benthic fauna	• Presence/absence • Identification • Quantification	• One sample for each station presented in Figure 2 (for macrozoobenthos) + 1 in the control point • ROV observation from BGF platform	• 1 survey/week
Pelagic fauna (fish and turtles)	• Presence/absence • Identification • Quantification	• Visual observation from the boat	• 1 survey/week

Compartment	Parameters	Monitoring Technique	Frequency
Marine Mammals	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Passive acoustic detection from the boat	• 1 survey/week
Birds	• Presence/absence • Identification • Quantification	• Visual observation from the boat	• 1 survey/week

4.2.4.3 Operational phase

The operational phase requires short-term monitoring in the first period in which the platform will start operating, while, subsequently, monitoring can be carried out with reduced frequency in order to observe the evolution of the situation over a long period. Indicatively the execution of 1 survey every month could represent a good example of short-term monitoring during the first 6 months of operation. After this period, indicatively the execution of 1 survey every 3 months could represent a good example of long-term monitoring.

Table 4.3 shows the parameters, the technique and the frequency of the operational phase environmental monitoring activities.

Table 4.3: Environmental monitoring during the operational phase

Compartment	Parameters	Monitoring Technique	Frequency
Water	• Temperature • Salinity • Density • Current • Dissolved Particulate matter	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase

Compartment	Parameters	Monitoring Technique	Frequency
Sediment	• Physical • Chemical • Ecotoxicological	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase
Benthic fauna	• Presence/absence • Identification • Quantification	• One sample for each station presented in Figure 2 (for macrozoobenthos) + 1 in the control point • ROV observation from BGF platform	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase
Pelagic fauna (fish and turtles)	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Visual observation by underwater dedicated cameras • Visual observation by aerial cameras	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Visually monitored by dedicated cameras and by the long distance surveillance cameras

Compartment	Parameters	Monitoring Technique	Frequency
Marine Mammals	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Passive acoustic detection from the boat • PAM by autonomous bottom recorder	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Visually monitored by dedicated cameras and by the long distance surveillance cameras • Acoustically monitored by the bottom recorder
Birds	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Visual observation from the BGF platform (video cameras)	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Constantly monitored by an automatic detection system

4.2.4.4 Decommissioning phase

The decommissioning phase includes monitoring aimed at verifying the restoration of the initial conditions. A survey must be carried out within the first 6 months of the plant's decommissioning (short term monitoring) and then once a year for the following 3 years (long term monitoring).

Table 4.4 shows the parameters, the technique and the frequency of the decommissioning phase environmental monitoring activities.

Table 4.4: Environmental monitoring during the decommissioning phase

Compartment	Parameters	Monitoring Technique	Frequency
Water	• Temperature • Salinity • Density • Current • Dissolved Particulate matter	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey during the first 6 months • 1 survey/year for next 3 years
Sediment	• Physical • Chemical • Ecotoxicological	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey during the first 6 months • 1 survey/year for next 3 years
Benthic fauna	• Presence/absence • Identification • Quantification	• One sample for each station presented in Figure 2 (for macrozoobenthos) + 1 in the control point	• 1 survey during the first 6 months • 1 survey/year for next 3 years
Pelagic fauna (fish and turtles)	• Presence/absence • Identification • Quantification	• Visual observation from the boat	• 1 survey during the first 6 months • 1 survey/year for next 3 years
Marine Mammals	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Passive acoustic detection from the boat	• 1 survey during the first 6 months • 1 survey/year for next 3 years

Compartment	Parameters	Monitoring Technique	Frequency
Birds	• Presence/absence • Identification • Quantification	• Visual observation from the boat	• 1 survey during the first 6 months • 1 survey/year for next 3 years

5 RISK ANALYSIS

This chapter integrates the previously developed monitoring plan by presenting a risk-based approach. This improves the interpretation of the monitoring plan aimed at prioritizing the actions outlined, in order to support the identification of the major environmental criticalities for the BGF platform, taking into account in which phase of the life cycle of the platform they are expected, the magnitude predictable and the location where they could occur. In addition, for each phase and for each monitoring station, the minimum requirements concerning possible monitoring actions to mitigate the expected impacts are outlined.

At status, the integration of a risk-based approach and the environmental impact assessment is not currently guided in detail nor systematically implemented in the European MOI context. Nevertheless, in the wider context of the “Technical guidance on monitoring for the Marine Strategy Framework Directive” [R16], the importance of prioritizing the monitoring actions and of taking into account risk considerations when performing environmental monitoring is mentioned. Even though the coverage and the aim of the monitoring actions described within the Directive are different from the purpose of the monitoring actions outlined for the BGF, the concepts illustrated in the Technical Guidance are theoretically applicable to each monitoring program, and thus they are considered as a basis to develop the risk analysis of the BGF deployment and operations.

The risk-based approach implemented for this study is constituted by a prioritized risk analysis, which can be considered as the entry point for the development of a prioritized monitoring strategy, , as well as which data are required to better characterize the knowledge about vulnerabilities. Such analysis reflects the contents outlined in the monitoring plan.

The outputs obtained in this chapter, as for the case of the monitoring plan, are not site specific, but generally applicable. This approach is considered indeed as relevant, because, in most cases, it is expected that major potential impacts caused by the BGF platform depend on the configuration of the platform itself rather than on the specific location where the platform is installed. Certainly, site-specific features influence the potential realization of the impacts as well as their extent.

Table 5.1 shows the outlined monitoring plan, including the prioritized risk-based assessment results. Specifically, for each lifecycle phase, expected impacts for different monitoring stations are recalled and associated to a certain level of magnitude and a minimum monitoring action to guarantee timely identification / quantification of impacts, together with the definition of suitable mitigation measures.

For each phase and location, the magnitude is estimated on the basis of the Environmental Impact Assessment (EIA) carried out in the deliverable D4.1 [RD 1] as well as from general literature analysis.

The pre-installation survey phase is excluded from the assessment as it is scoped to the baseline characterization before any intervention on the site.

Table 5.1: Monitoring plan and prioritized risk assessment

Phase	Impact	Magnitude	Monitoring station	Minimum monitoring action
Installation and decommissioning	Water	very low	all stations	sampling
	Sediment	low	BGF	sampling
		very low	all the other stations	sampling
	Benthic fauna	very low	all stations	sampling
	Pelagic fauna (fish and turtles)	very low	all the stations	sampling
	Marine Mammals	very low	all the stations	visual/acoustic detection
	Birds	very low	all the stations	visual observation
Operation	Water	high	BGF	sampling
		medium	A, B, C, D, E, F, G, H	sampling
		low	all the other stations	sampling
	Sediment	medium	BGF, A, B, C, D, E, F, G, H	sampling
		low	all the other stations	sampling
	Benthic fauna	high	BGF	ROV observation and sampling
		medium	A, B, C, D, E, F, G, H	ROV observation and sampling
		low	all the other stations	ROV observation and sampling

Phase	Impact	Magnitude	Monitoring station	Minimum monitoring action
	Pelagic fauna (fish and turtles)	low	all the stations	visual observation
	Marine Mammals	low	all the stations	visual/acoustic detection
	Birds	high	BGF	visual observation / automatic detection
		low	all the other stations	visual observation

6 DATA PROCESSING MODEL

This chapter describes useful procedures for data analysis that can be exploited for the monitoring program defined for the BGF platform. The definition of these procedures is mainly based on the type of sensors that are available on the platform itself, extensively described in D2.4 “Aquaculture automation & security and integration with renewable energy production systems preliminary design report” [R19] and on the type of outputs that they are expected to provide. Such series of model is intended as a support for the development of the integrated control system of the platform, allowing the implementation of the functions needed to support proper environmental monitoring in the medium-long term. For those additional instruments foreseen within the monitoring plan, guidelines for data management have been already described (Ch. 4).

In detail, the main goal of a generic data processing model is indeed to ensure that all the data needed are properly collected, in a standardized way, with the aim of generating relevant information, while unnecessary information is disregarded.

Data processing models are commonly implemented for the monitoring of several industrial activities and complex plant operations. Even though the general framework of these models remains the same, from one application to another, the analyses performed can vary (e.g.: in type, in resolution, in accuracy, etc.) depending on the needs of the specific application. They are commonly exploited also for the purpose of environmental monitoring,

The main scope of the chapter is, thus, to identify simple methodologies for an effective interpretation of data available from the records performed by the platform’s sensors, from an environmental monitoring perspective. The definition of the methodology takes into account the fact that data obtained from the monitoring on the platform are complemented by the data measured in the other stations foreseen by the monitoring plan, which present lower resolution and quality.

To this purpose, a brief analysis of the automation and control systems foreseen on the BGF platform is carried out, in order to understand which of them may be exploited for the aims of the environmental monitoring plan.

It is highlighted that the type of data processing performed can be more or less refined and accurate depending on the type of instrument considered, i.e.: probes actually provide long and continuous data series, suitable for data analysis, while other equipment such as cameras can be exploited for environmental monitoring purpose only with support of non-automatic operations.

6.1 Processing models for existing automation and control systems

Below, the main items of the BGF platform automation and control systems that are a source of potentially useful data for the monitoring of environmental effects of the installation are summarized (Table 6.1) and the correspondent type of data processing is indicated.

Table 6.1: Main automation and control systems for environmental monitoring

System	Rationale	Processing model type
Water state system, Aquaculture automation system, Fish state monitoring system	• analysis of water conditions to secure fish welfare • monitoring of the environment surrounding the cages • reduction of human efforts during daily management of fish-farming process • guarantee of the maximum fish welfare, based on the control of biometric variables and management of safety devices for the fish farm	Numeric data processing
Remote operated vehicles	• possibility of performing various remote operations (e.g.: seabed analysis, performance of small jobs through hydraulic manipulators, etc.)	Image/Video processing
Surveillance system	• real time picture of activities and vessels approaching the platform	Image/Video processing

From the analysis of sensors to be used in environmental monitoring, it appears that those that produce data series to be processed are associated to monitoring of water quality, which is not among the main concerns emerged from the analysis of expected environmental impacts.

In the next sections, for each of the systems identified as relevant, an insight about the specific instruments installed on the platform and about the type of outputs that they provide is given, to allow the development of the processing model.

6.1.1 Processing model for water state system, aquaculture, automation system, fish state monitoring system

The relevant instruments for these systems are:

- acoustic current profilers;
- multi-parametric probe or multiple single probes measuring the different parameters (water oxygen probe, water temperature probe, water pH probe, water conductivity probe).

The relevant outputs for these systems are:

- sea temperature;
- dissolved oxygen;
- salinity;
- pH;
- nitrogen, including ammonia;
- chlorophyll;
- torbidity.

All the outputs are analog and provided automatically and continuously (i.e.: with very low frequency, in the order of seconds) by the instrumentations with which the platform is equipped. The frequency of the measurements can be set taking into account the need of data resolution for the correct functioning of renewable energy systems and proper wellbeing of the fish.

More specifically, standard probes can be connected directly to a PC via USB cable provided. This allows real time data-monitoring, recording of data on local storage and automatic instrument calibration. Data storage consists in the creation of data loggers with a pre-defined frequency (e.g.: 2-second frequency). The logged data is saved as a TAB delimited file, which can be opened in any spreadsheet application such as Excel. Figure 6.1 shows an example of user-interface for real time monitoring and storage of data recorded by the probe.

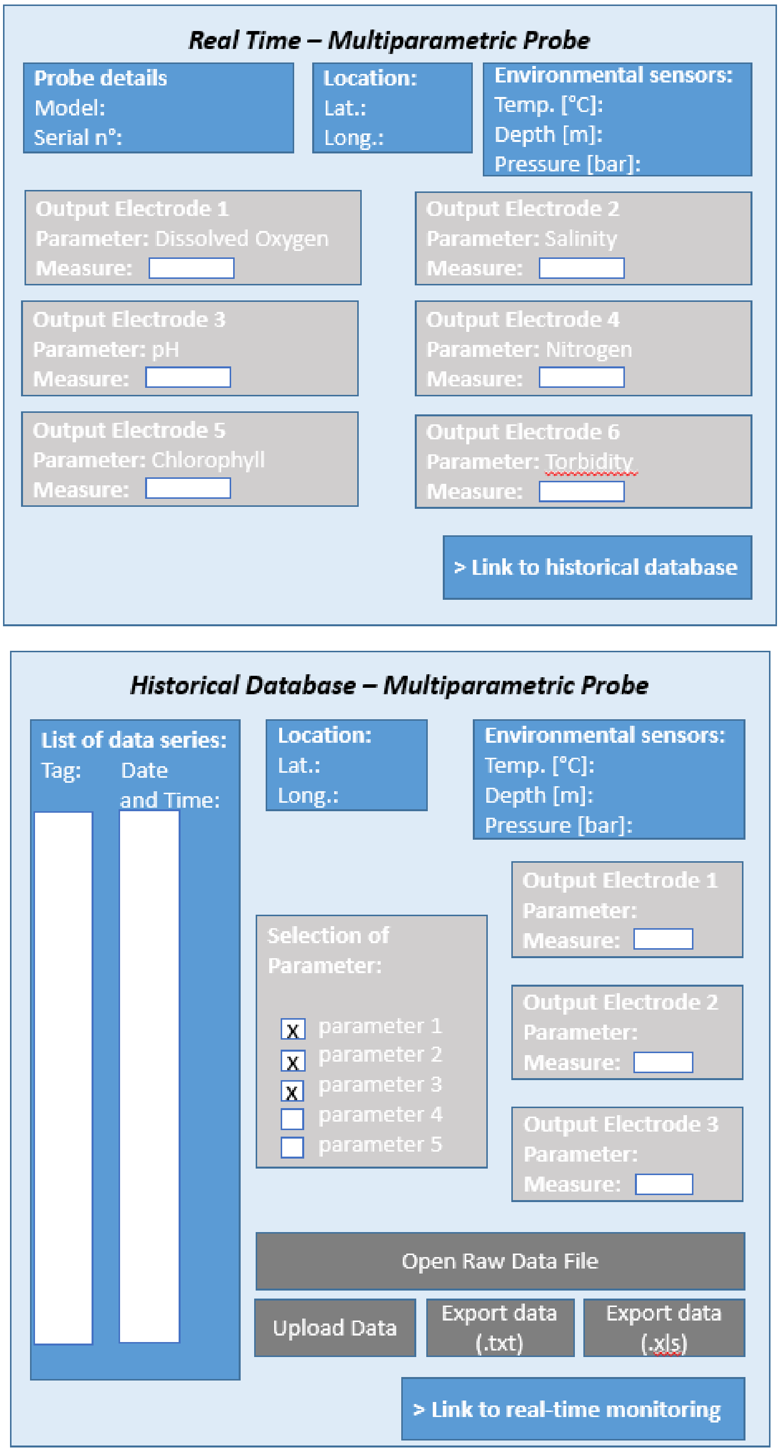

Figure 6.1: Example of user interface for probes (own elaboration)

The signals are to be automatically transmitted to the offshore and onshore control rooms as analog signals, used as inputs to the platform control system, which guarantees their immediate presentation and interpretation to the appointed staff, which is expected to visualize and check them in real time, either from the control room located onboard or from the onshore station.

The data processing plan for these types of data in an environmental monitoring perspective is proposed considering a direct analysis of raw data measured by the sensors, with the aim of possibly integrating the procedure within the overall control system of BGF platform.

However, it is highlighted that commercial software able to perform such tasks exists. Commonly, they are flexible, allowing the possibility of importing standard format data (xls., doc., etc.) and compatibility with the most used versions of common operating systems.

Raw data representing the outputs of the aforementioned measurements are to be imported in a data analysis software (e.g.: Matlab, Phyton, R), which can be commonly be interfaced with log files in text or excel format.

The desired frequency for environmental monitoring is considered as 1 month, in line with what already proposed in the environmental monitoring plan.

In order to obtain data of water state parameters with such frequency, an algorithm able to group all the data for each month (e.g.: in a matrix) and to calculate their average is to be programmed.

Monthly values of recoded water state parameters shall be exported as .xls or similar formats and stored until at least the decommissioning phase. If needed, they can be compressed to limit space requirements.

As additional analyses to interpret collected data, clear plotting of the trend of values of each parameter in time, to be compared with correspondent values before construction and installation of the platform. Deviations from the reference state can be also plotted for monitoring purposes.

For each monitored parameter, criteria to evaluate its acceptability should be introduced. To this purpose, the implementation of warning rules based on environmental regulations applicable to the site where the BGF platform is installed and/or additional thresholds estimated and provided by environmental experts based on site-specific features – as acquired during the pre-installation campaigns - and on the precise purpose of the monitoring activities. Such thresholds should take into account not only significant punctual deviations or anomalies from expected values, the arising of anomalous trends in the long perspective, as well as main actions performed for the BGF management along the correspondent timeframe (e.g.: fish feeding operations, energy production regime), which can affect the measured parameters.

The process previously described in illustrated in Figure 6.2 below.

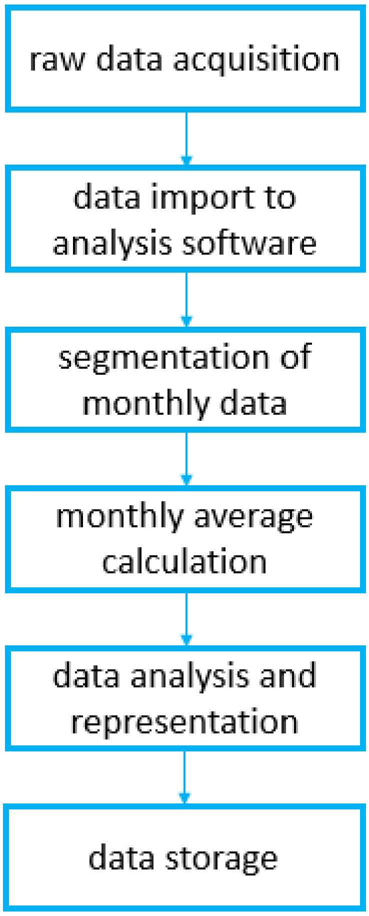

Figure 6.2: Data processing model

Considering that the installation of the probes is foreseen in the location of each cage, the data processing model is to be applied only to the outputs of one probe, in order to avoid the need of analysis and storage of data that are not relevant. The probe selected to provide the data for this type of analysis should be the one where the most severe impacts are expected.

As far as the other measurements for water state monitoring foreseen by the monitoring plan are concerned, such as those in the surroundings of the platform, data storage should be performed manually, for examples by creating an Excel file reporting, for each measurement location, time of measurement and values of each measured parameter.

After properly aligning the frequency of the measurements, such values can be processed by the data analysis software exactly as done by input gathered from existing probes.

6.1.2 Processing model for remoted operated vehicles

A Remote Operated Vehicle (ROV) is a portable device that can be managed by an operator from the Control Room. It can be equipped with several built-in features, including advanced camera systems and sensors to perform various monitoring tasks.

The BGF platform, as per current design, is equipped with two ROVs, the first one being dedicated to cleaning operations and the second one dedicated to generic inspection tasks.

In detail, the ROV for cleaning operations is equipped with one camera to visualize the net and the lower parts of the concrete caissons, navigation sensors, a scanning sensor for the seabed analysis around the anchors. The ROV for inspection has also hydraulic manipulators used for simple jobs, like net checking, etc.

Information provided by these ROVs is mainly in terms of images in the area of the BGF platform. Even though it is not straightforwardly intended for environmental monitoring, such images produce qualitative knowledge that may be exploited to observe medium-long term macro transformations in the surroundings of the platform and to inform specific environmental monitoring activities.

Additional equipment could be added to expand the device's capabilities, including:

- mechanical arm for specimens' collection. Collected specimens may be analyzed directly onboard, within the control room if the necessary instruments are available, or may be transferred onshore for laboratory analysis. Nevertheless, considering the significant presence of automatic instruments already installed in the proximity of the cages, this type of practice should be implemented only occasionally, in case specific information is needed.
- acoustic sensors (e.g.: hydrophones), which can detect sound levels in the area of the BGF platform and can support an improvement of knowledge about noise emissions generated by the BGF installation, including the operation of its energy generation systems;
- instruments (e.g.: probes) that measure water clarity, water temperature, water density, light penetration, and temperature to be used to perform measurements outside the cages and at the distance foreseen by the monitoring plan, where currently installed sensors cannot be effective.

In case it is foreseen to use the existing ROV also for environmental monitoring purposes, it shall be ensured that the umbilical for electricity transmission can be unplugged from the platform and plugged on the dedicated generator installed on the boat to be used for performing environmental monitoring in the stations foreseen in the surrounding of the platform.

Main details about each inspection performed with the ROV shall be systematically recorded in an Excel file, including personnel performing the inspection, location of the inspection, time of inspection and main parameters observed (qualitative and quantitative) in order to carry out an exhaustive high-level monitoring database, especially of benthic communities, as foreseen by the monitoring plan.

In addition to this high-level kind of data processing, a more specific analysis of images/videos recorded during the inspection is to be systematically implemented.

For some ROVs existing on the market, the possibility of interface with open-source software is guaranteed. Data transfer from the ROV can be done either manually, by plugging the internal memory of the ROV to the desired laptop, or remotely by the dedicated software, in case the instrument is set for remote data transfer.

However, in general, due to limitations in wireless technologies, communication is usually fed through a tether/umbilical. The transmission mediums for communications are metallic conductors or fibre optics. The latter, are beginning to become more prevalent in inspection-class ROVs.

Considering that inspection ROVs commonly use multiple HD cameras and/or sonar systems, along with control and navigation equipment, it is important that a large bandwidth is provided for data throughput.

If possible, the procedure analyzing acquired images/videos can be implemented through a tailored and automatic algorithm of image processing. Indeed, even though it is foreseen that 24-hour working staff is dedicated to the platform, at least a partial automatization of such process (e.g.: marking all the objects or videos of potential interest) can lead to reduction of human efforts as well as to an increase of accuracy of collected data, avoiding potential bottlenecks related to the need of processing a wide number of images.

To this purpose, image-processing techniques aim at facilitating and automatizing the interpretation of acquired data and at extrapolating desired information. They can be implemented at various levels, from a mere enhancement of image quality, to the extrapolation of features or the identification of specific objects. A number of software for image processing are available and include already pre-set algorithms to perform standard actions.

For the specific purpose of environmental monitoring, the most desirable application of image processing is object detection, i.e.: a computer vision technique for locating instances of objects in images or videos. Object detection algorithms typically leverage machine learning or deep learning to produce meaningful results. Such technique is currently used in applications such as detection for automatic driving or surveillance systems [R20].

Despite the fact that is fact underwater images are known to be degraded due to a number of factors such as turbidity, floating particles, and light attenuation in the medium, specific algorithms for the purpose of marine species detection from video recorded by ROVs exists, and have been demonstrated as a realistic alternative to manual annotation from image observation. As an example, for detection, a saliency-based approach has been tested with positive results [R22]: the method consists indeed in detecting, locating and classifying into the main biological taxonomies. Additionally, machine learning assisted image annotation methods have been proposed in literature [R23] to allow human observers to quickly annotate large image collections, by automating the process of object detection and by generating annotation candidates, highlighting regions showing and classifying object of potential interest.

The aforementioned methods can be embedded into software for end-users, referred to as underwater image annotation software (e.g.: BIIGLE 2.0[1]), possibly enabling the collection of inputs for different experts. Considering the high specificity of image processing software, specific for underwater image

[1] https://www.biigle.de/

processing, it is not excluded that commercial software would be linked within the integrated control system developed for the platform, without the burden of creating an in-house software with the same functions. However, at a later stage, having tested the overall functioning and the use made of the software, the possibility of developing specific software for image processing at platform level should be evaluated.

Typical software presents user-friendly interfaces, where users can, for instance, collect and share their projects. Within each project, the user is allowed to perform the image analyses, as well as access to other functionalities such as adjusting the basic quality of the images (e.g.: brightness, contrast, saturation,), or locating observations in a geospatial context [R21].

Interfaces usually include a dashboard showing the project associated to the specific user account. Each project can be opened and edited, according to user needs.

Images in Figure 6.3 below provide an idea about the different interfaces – corresponding to different functions that are available to an annotation software end-user.

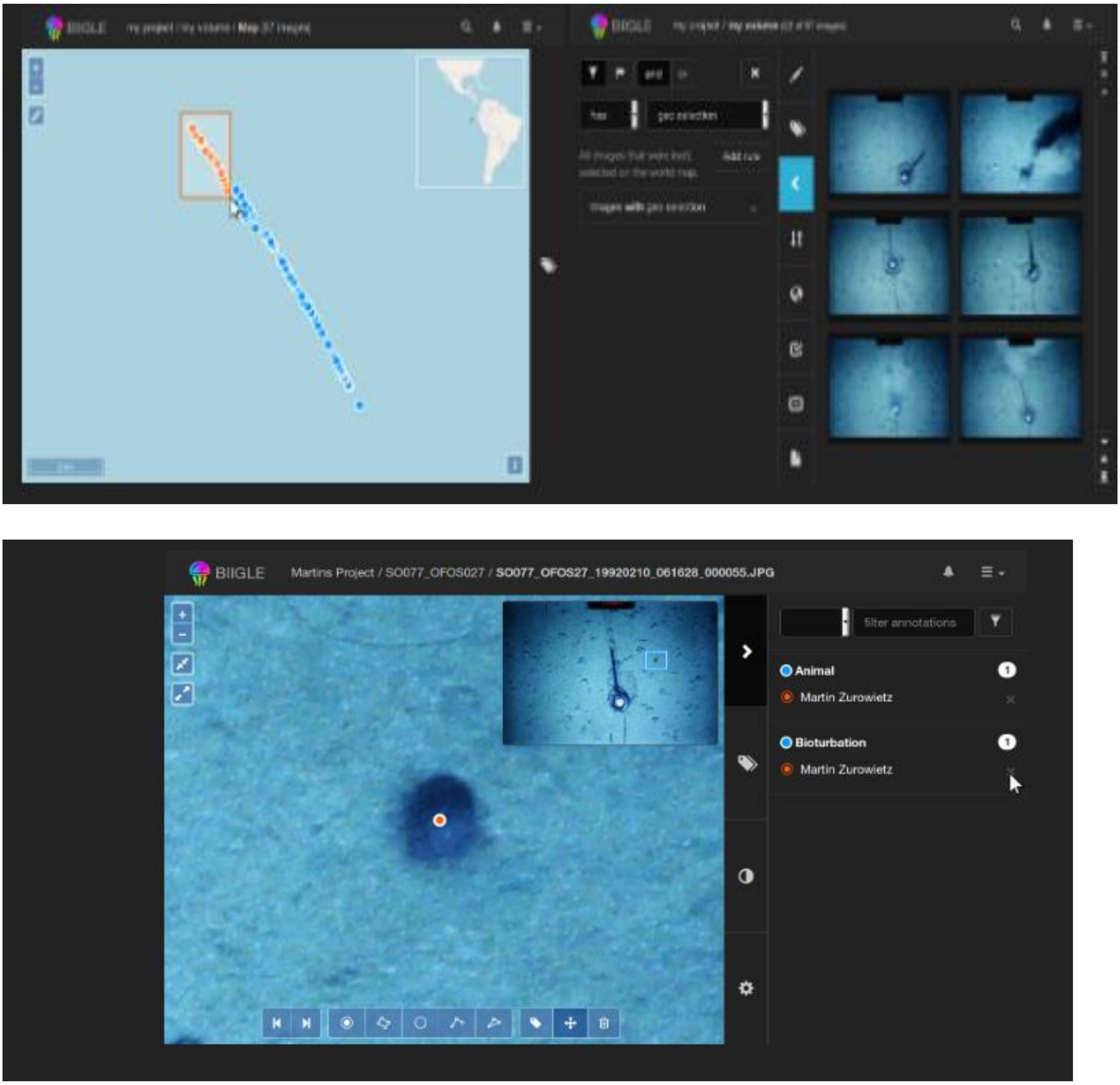

Figure 6.3: Examples of annotation software user-interfaces (geo-referenced observations, above – labelling of observation, below)

Image screening can be realized into two different modes: manually, in case the user browses and screens the images freely, suitable in case only limited volumes are investigated and if figure have sufficient contrast with respect to background or automatically, in case the system performs image analysis automatically, providing as output small patches showing objects of interest. The last step of the procedure is to label the object of interests included in the images. A label is defined as some kind of semantic category like a habitat classification, a morph type or taxon for an organism. Labels can be assigned manually by the user or automatically, thanks to machine learning techniques, assign annotation to each object. In the latter case, annotations should be checked and validated by an expert staff member. Labels are included in so-called label-trees, which are collection of labels that may be flat or in a tree-like structure. This can be a taxonomy, a custom classification scheme or something entirely different – either manually created by the end-user or

The software is capable of creating annotations about the type of objects of interest; nevertheless, an operator, to validate the automatic collection of data, should review them. Conversely, the user can decide – in case of small projects to be analyzed or other specific needs – to manually label each object. In both cases, labels refer to a so-called “label tree”, which includes a pre-defined set of labels, organized into vertical and horizontal relationships, according to their mutual connections. Pre-set label trees can be imported from available databases, such as the world register of marine species[2].

The manual labelling process can be also implemented for videos.

The labels that are referred to for the annotation of the objects of interest within a project provide clear boundaries and indication about the level of accuracy of the annotation itself, outlining which objects are observed and recorded for monitoring.

The identification of the most suitable process for labeling depends on various factors, such as:

- evidence of major criticalities in the installation sites;
- affordable availability of experts for data analysis.

A typical exportable output is a representation of the number and location of the objects of interest classified within a volume; i.e.: a histogram counting the occurrence of labels of each annotation in a volume, displayed as bar chart (.xls format).

Thus, despite a human effort is always a necessary step of the process, tools to speed up the entire image processing operation exists, and they allow the concentration of human efforts on the mere classification of detected objects of interest.

For the specific case of BGF, at least one environmental expert could be dedicated to a detailed software-aided analysis of the images periodically recorded (according to the provisions of the monitoring plan illustrated in the previous sections) with the inspection ROV in the selected monitoring stations. Data storage should be guaranteed only for the sequences of images presenting classified objects of interest for environmental monitoring purposes. The process previously described in illustrated in Figure 6.4 below.

[2] http://www.marinespecies.org/

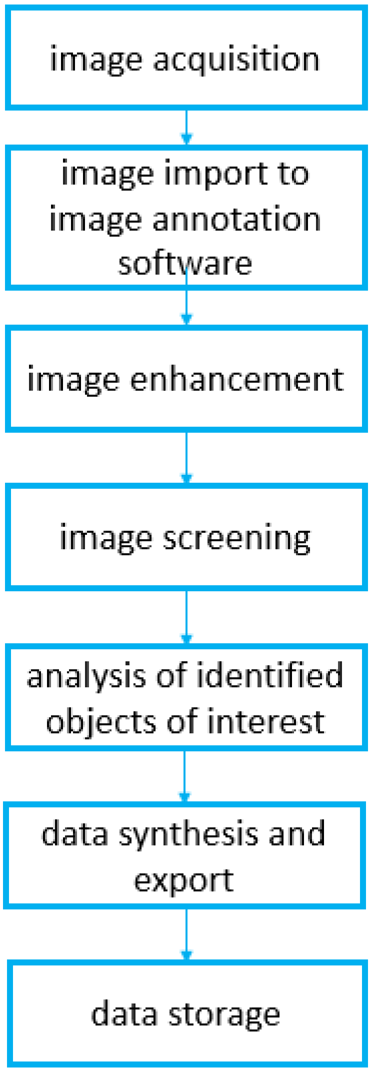

Figure 6.4: Image processing model

6.1.3 Processing model for surveillance system

The surveillance system is constituted by the External Surveillance and Security System (ESSS) and the Internal Surveillance and Security System (ISSS).

Surveillance and security data are managed by the Local Control Room, under the monitoring of the Remote Control Room, which receives processed data in real time.

The ESSS exploits the integration of information of the surveillance radars, AIS and long-distance cameras to provide an accurate surveillance of maritime traffic and to identify eventual unexpected events (accidental or deliberate actions).

In the case of ESSS, the long-range radar (visibility from 20 m to 2 km from the platform) is responsible for detecting any vessel in the nearness of the platform, as well as its movement pattern. The video obtained by the camera is exploited by a convolutional neural network specially designed and trained for the purpose of vessel detection and identification.

The ISSS is a smart security network of cameras to implement access control of operators and surveillance of accuracy in carrying out tasks in safe conditions, thus promoting adequate behavior during platforms operations.

The surveillance system can be exploited from an environmental perspective to create information about the presence and the behavior of bird species in the area of the platform. In detail, images produced by the ISSS can support the understanding of birds' attractiveness with respect to lights, components of the platform and aquaculture, while images produced by the ESSS can support the estimation of avoidance or collision rates, as well as the quantification of frequency and size of birds flying across the platform.

The storage of previously described information can require the implementation of a manual procedure, allowing keeping record and track of the relevant observations, including information about the number and type of birds. Additional information including details about parameters that may be reasonably correlated to birds' behavior (e.g.: lights turned on) shall be included in the dataset. This data processing model is compatible with current setup, foreseeing the presence of a full-time operator surveilling outputs of the cameras.

Along with the implementation of the procedure, operators shall guarantee that images recorded in correspondence of a relevant event from an environmental perspective (e.g.: migration of birds across the platform) are stored for an amount of time that allow that they are checked and analyzed by a dedicated expert. This latter can support the process of increasing knowledge about the impacts of the BGF platform on the environment. In this perspective, the storing capacity should be sized on the expected frequency of the analyses of recorded images of the appointed staff member (or viceversa).

However, an enhancement of this task is reached – as for the case described for processing of images gathered from the camera of the ROV – by automating the image analysis process to enable a more sustainable long-term monitoring, based on the same theoretical concepts previously introduced. Birds' detection by using security cameras has already been realized in case of airports

The same data processing model can be used to store and record monitoring activities of pelagic fauna and marine mammal approaching the platform, whenever visible from the surveillance systems.

7 CONCLUSIONS

This document analyses strategies to allow a close monitoring of environmental impacts of the Blue Growth Platform, in order to identify best management practice along the Platform's life cycle.

Thus, based on the results of the environmental impact assessments developed for the three reference sites in D4.1, a general monitoring plan is outlined, and it represents the core of this document. The plan is defined for the pre-installation, installation, operation and decommissioning phase respectively, in order to cover both the short and long-term perspective. The monitoring plan for the operation addresses the monitoring of the most relevant impact expected during life cycle and, thus, it is reported below:

Environmental monitoring during Operation phase

Compartment	Parameters	Monitoring Technique	Frequency
Water	• Temperature • Salinity • Density • Current • Dissolved Particulate matter	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase
Sediment	• Physical • Chemical • Ecotoxicological	• One sample for each station presented in Figure 4.1 + 1 in the control point	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase

Compartment	Parameters	Monitoring Technique	Frequency
Benthic fauna	• Presence/absence • Identification • Quantification	• One sample for each station presented in Figure 2 (for macrozoobenthos) + 1 in the control point • ROV observation from BGF platform	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase
Pelagic fauna (fish and turtles)	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Visual observation by underwater dedicated cameras • Visual observation by aerial cameras	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Visually monitored by dedicated cameras and by the long distance surveillance cameras

Compartment	Parameters	Monitoring Technique	Frequency
Marine Mammals	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Passive acoustic detection from the boat • PAM by autonomous bottom recorder	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Visually monitored by dedicated cameras and by the long distance surveillance cameras • Acoustically monitored by the bottom recorder
Birds	• Presence/absence • Identification • Quantification	• Visual observation from the boat • Visual observation from the BGF platform (video cameras)	• 1 survey/month during the first 6 months of the phase (short term); • 1 survey every 3 months for the remaining time of the phase • Constantly monitored by an automatic detection system

In addition, a risk analysis is proposed in order to prioritize the action outlined in the monitoring plan, , in order to support the identification of the major environmental criticalities for the BGF platform, taking into account in which phase of the life cycle of the platform they are expected, the magnitude expected and the location where they can occur. In parallel, minimum monitoring actions (in terms of associated costs and burdens) suggested to mitigate the impacts are outlined.

Finally, a set of data processing models has been defined to ensure that all the data recorded by the sensors installed on the platform and needed for environmental monitoring are properly collected, analyzed and stored. Specifically, guidelines for data management are provided, focusing of processing of numeric data, as those recorded by probes, as well as on image analysis, useful for the interpretation of data collected by cameras and ROVs.

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Annex A. Data sheet

Document Title **DATA SHEET - Bird Detection System**	Project **The Blue Growth Farm**

General Characteristics	
Variable	**Design characteristics**
Detectable bird Species/Groups	All bird Species/Groups (identified through the review of bird flight video and audio recordings)
Installation Site	Offshore Wind Turbine (WT)
Main components	HD cameras: 4-8 for each WT (for day detection) / thermal cameras (for night detection)
	Environmental sensors: light, temperature, humidity
	Cabinet (1/WTG): Analysis Unit, Detection Software, Electrical and Lighting Protection Systems and Communications Hardware
	Mounting system + cables and connection
Dimension and Weight	50x65-130x25 cm, 10-20 kg
Power supply	external - 110-250 AC monophasic 50/60Hz
Power consumption	55-95 W
Operating conditions	Day and Night
Additional features	weather protection of outdoor and cabinet components
Communications	Wind Farm Network/Mobile Router 4G/ADSL/Optic Fiber/ Satellite Internet.
Surveillance area	360° around WT and radius from 25 m to 320 m (to be calibrated on bird wingspan)
Bird flight detectability	>80% (day detection)
Bird flight traceability	Video and audio recordings of every bird flight stored in online Data Analysis Platform
	

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File Name: Bird detection system datasheet	Sheet	1	of	1

Document Title **DATA SHEET - Hydrophone**	Project **The Blue Growth Farm**

General Characteristics	
Variable	**Design characteristics**
Frequency Range (±3dB)	0.008-250 kHz
Transducer Sensitivity	-187 to -200 dB, re 1V/µPa
Preamplifier Gain	20 - 33 dB
Power Supply	5-32 Vdc
Max Opearting Depth	up to 900 m
Operating temperature range	-40 to 85 °C
Dimensions	90-120 mm (lenght), 15-25 mm (diameter)
Directionality	Omni directionality below 10 Hz
	

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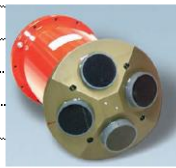
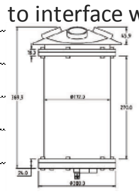
File Name: Hydrophone data sheet	Sheet	1	of	1

Document Title	Project
DATA SHEET - Acoustic Current Profiler	**The Blue Growth Farm**

General Characteristics

Variable	**Design characteristics**
Standard depth	800 m
Maximum range for water profiling	100 m
Maximum cell size	4 m
Weight in air	16 Kg (9 Kg without battery)
Frequency	600kHz
Bottom tracking options - max altitude	130m
Bottom tracking options - min altitude	0,5m
Power supply - max. transmit	100W
Power supply - min. transmit	30W
Receiver mode / sleep mode	0,8W / 7mW
Hardware characteristics	Transducer 4 Beam Convex (22 degrees angle) Housing: Anodized aluminum and plastics Communication: RS422 or RS232 Internal compact flash card: 1 GB
Data acquisition SW	Compatibile with common operating systems
Data acquisition SW capabilities	real time monitoring, data analysis and display
Interface to other sensors	Data fusion function to interface with third party sensors (RS232 s port)





Sensing data charateristics

	Frequency	**Accuracy**	**Cell size**	**Max water vel**	**n. of cells**
Pressure		0,25%			
Velocity	600KHz	0,25% ± 2	0,5-4 m	20 Knots	170
Wave	Generation of wave parameters in both time and frequency domains, including wave heights (significant wave height, approximate significant wave height, macimum wave height, H10 and mean wave height)				
maximum range	60m				
wave heigh resolution	1 cm				
wave height accuracy	4 cm				
wave direction resolution	0,1 degree				
wave direction accuracy	2 degree				

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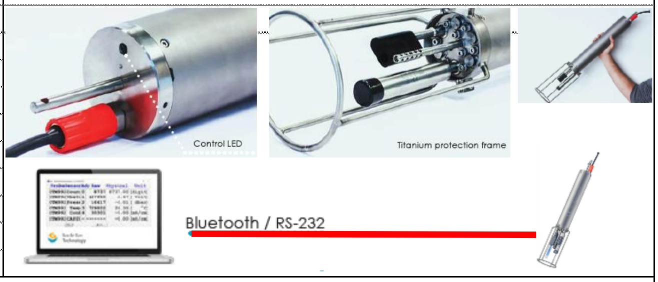
File Name: water state equipment data sheet	Sheet	1	of	1

Document Title **DATA SHEET - Multiparameter probe integrated sensing**	Project **The Blue Growth Farm**

General Characteristics

Variable	**Design characteristics**
Depth range	up to 200 m
Weight	low
Housing	Non-corrosive titanium
Sensors accomodation	up to 10
Measurement typology	on line (standard RS-232 connection used for programming, data output, and data acquisition. The microprocessor controls the 16 bit analog to digital converters that have as many channels as required by sensing capacity (up to 10)).
Power supply	external
Data acquisition SW	Microsoft Windows based
Sensing capacity	
Conductivity (C)	
Pressure (depth)	
Temperature (T)	
Turbidity	
Oxygen	
pH	
Redox (ORP)	
Fluorometer	



Sensing charateristics

Sensor typology	**Technology**	**Range**	**Accuracy**	**Resolution**	**Response time**
Conductivity	7-pole-cell	0 – 70 mS/cm 0 – 300 mS/cm	± 0.002 mS/cm ± 0.010 mS/cm	0.005 mS/cm	150 ms
Pressure	piezo resistive	5, 10, 20, 50, 100, 200 bar	up to 0.05 % full scale in the range of 5-35°C	0.002 % full scale	150 ms 150 ms
Temperature	Pt 100 4-pole	-2 – 36 °C -2 – 60 °C	± 0.002 °C ± 0.005 °C	0.0005 °C 0.0005 °C	150 ms
Oxygen	optical	0 – 250 % sat. 0 – 20 mg/l	± 2 % sat. ± 2 % sat.	0.01 % sat. 0.01 % sat.	2 s
Turbidity	90 ° back scatter	0 – 25 FTU 0 – 125 FTU 0 – 500 FTU 0 – 4000 FTU		0.1 FTU / NTU	100 ms
pH	combined electrode	4 – 10 pH 0 – 14 pH	± 0.02 pH	0.0002 pH	1 s
Redox (ORP)	combined electrode	± 2 Volt	± 20 mV	1.0 mV	1 s
Fluorometer	CDOM / FDOM, Chlorophyll A, Fluorescein Dye, Oil-Crude, Oil-Fine, Optical Brighteners, Phycocyanin, Phycoerythrin, PTSA Dye, Rhodamine Dye, Tryptophan				

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