TECHNICAL BRIEF

ULTFARMS

Harmonised Recommendations for Production Systems



Authors:
Jens Kjerulf Petersen, Kasper D. Meyer, Tim Staufenberger, Jacob Nimz, Jakob Becker, Eva Strothotte, Mieke Eggermont, Annelies Declercq, Emma Huijben

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INTRODUCTION & PROJECT CONTEXT

The ULTFARMS project moves beyond the current application of Low-Trophic Aquaculture (LTA) systems with novel engineering, technical, ecological, and biological processes to optimize production in harsh offshore conditions, low salinities, and their integration within Offshore Wind Farms (OWFs). The project works with research and industry partners to develop and operate six innovative Low-Trophic Aquaculture Pilots (LTAPs) across the North and Baltic Seas.

Member State	Name of OWF	LTA Production
Belgium	Belwind	Seaweed – Oysters
The Netherlands	Borssele	Mussels
Germany	FINO2	Seaweed
Germany	FINO3	Seaweed – Mussels – Oysters
Denmark	Anholt	Seaweed – Mussels
Denmark	Samsø	Mussels



MULTI-USE & GENERAL OFFSHORE CONSIDERATIONS

01. MULTI-USE & SPATIAL PLANNING

From a spatial planning perspective, the integration of aquaculture infrastructure is considerably easier if aquaculture requirements are considered during the early phases of wind farm planning, design, and construction. Retrofitting aquaculture systems into already operational wind farms is technically possible but more complex, and not yet legally feasible in some countries.

Recommendation 1:

Aquaculture requirements are ideally considered during the concept and design phase of offshore wind farms e.g., through legal mechanisms, to facilitate integration of LTA production systems, where permitted.

02. GENERAL CONSIDERATIONS OFFSHORE

When selecting an area for LTA production offshore, several factors are important to consider, such as the primary production level (available nutrients) of the area, physical forcing, other maritime activities, access to electricity, and the distance to port. Long distances result in long travel time and high fuel costs.

Offshore LTA production requires much more durable and robust equipment compared to nearshore production. Dominant wind and current direction are important guidelines for orientation. Wave height must always be taken into account when working offshore, as windfarm safety requirements set limits on the wave conditions under which operations may take place. It also plays a role in decisions such as how deep below the surface grow-out structures are deployed.

Recommendation 2:

An offshore LTA-unit should be located not too far from the nearest service hub or harbour to save time and energy costs.

Recommendation 3:

From a technical perspective, ensure that the grow-out structures are parallel to the dominant forcing direction, paying due attention to the balance between physical stress on structures and biological productivity. Note that a biological perspective should be also be assessed, as the optimal orientation also depends on the cultivated species, current strength, and food availability along the longline.

BLUE MUSSEL PRODUCTION

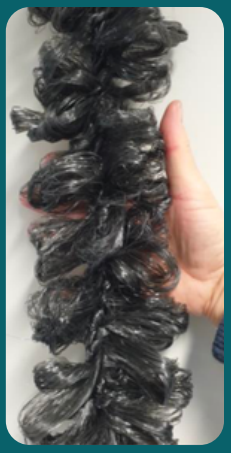
03. BLUE MUSSEL CULTIVATION SYSTEMS

Production methods

Blue mussel production was cultivated using three methods:

1. Longlines and droppers with socking.
2. Longlines and droppers with no socking.
3. Tube systems with nets.

Options 2 and 3 provide the fewest number of working days at sea in the production area. Working with longlines requires regular maintenance related to adding or removing buoys in relation to mussel growth and biomass increase.





Socking and Deployment Protocols

- **Spat Collectors:** Deployed in spring/early summer in loops with weights stripped to the bottom to prevent entanglement before mussel settlement.
- **Socking Processing:** When mussels reach 20–30 mm, they are stripped from collectors, sorted by size, and socked using a core, for example made of used, cut-up trawl nets, surrounded by a cotton sock. Using sustainable or recyclable materials where available is recommended. Socking must take place onboard the vessel to withstand offshore logistics.
- **Tube Systems:** Nets (recommended 12–16 mm size with 150–250 mesh size) are deployed simultaneously with spat collectors. Under heavy spatfall, it is necessary to thin out mussels before winter to allow growth to full sellable size.

Recommendation 4:

When producing offshore, socking of mussels must take place onboard the boat and not on land.

Recommendation 5:

When producing offshore, longlines and tubes should be submerged, to reduce physical stress on the system and prevent damage from ship traffic

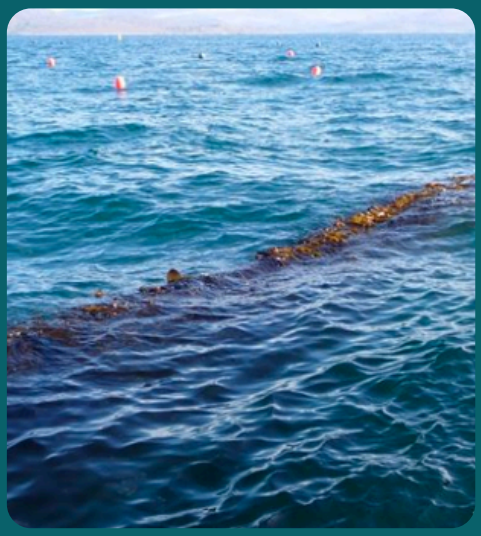
SEAWEED PRODUCTION

04. OFFSHORE SEAWEED CULTIVATION

Offshore seaweed production typically follows a longline or net approach. Cultivation systems are normally submerged to reduce exposure to wave action and prevent damage from vessel traffic.

Seeding Techniques

- **Pre-cultivated Algae Twine:** Wound around longlines and nets. This can yield higher growth, but due to intensive handling, it is primarily recommended for longlines.
- **Seedling Solutions:** Sprayed directly onto nets or longlines. This is the best option for net cultivation but can be prone to yield loss due to harsh conditions during and directly after spraying. A hatchery phase after spraying has also proven effective.
- **Biosecurity:** Algae must be local to the region to prevent the introduction of non-native species, propagated in specialised hatcheries to align with regional growth cycles.



Logistical Challenges

If seeding must take place during winter to cater to the growth cycle of cold-adapted algae like kelp, operational weather windows can become extremely scarce.





Recommendation 6:

Choose your method of seeding according to cultivation type and obtain locally sourced algae in close cooperation with algae hatcheries.

Recommendation 7:

Offshore deployments require unique weather windows: plan accordingly, design system and schedule with redundancy but with as few trips as possible.

General Production Principle:

The ideal (cost-effective) offshore production system requires only installation and harvest and no restocking nor maintenance.

VESSELS & AUTOMATION

05. VESSEL LOGISTICS & REQUIREMENTS

Offshore aquaculture systems require specialized vessel concepts capable of supporting multiple operations: deployment of cultivation systems, line/tube maintenance, harvesting, and infrastructure inspection. Efficient vessel logistics are essential to reduce operational costs and ensure safe working conditions.

- **Deck Design:** Flexible configurations and modular deck layouts allow equipment to be rapidly adapted between maintenance and harvesting tasks.
- **Minimum Specifications:** Vessels must be a minimum of 15 meters in length, equipped with cranes and heavy-duty gear for hauling longlines, and possess sufficient deck space to safely handle anchors, buoys, and equipment.
- **Safety Distances:** Operating near wind turbines introduces technical challenges regarding safety distances and service boat access. Dynamic positioning systems are required for most operations and are generally recommended.



06. AUTOMATED SYSTEMS

In harsh environments with few operational weather windows, autonomous or remotely operated systems support routine duties:

- Mounted gauge and depth sensors with online connectivity to land operators.
- Moored environmental loggers connected via satellite transmission.

Recommendation 8:

Vessel designs for offshore aquaculture operations should include modular deck configurations and equipment interfaces to support different operations.

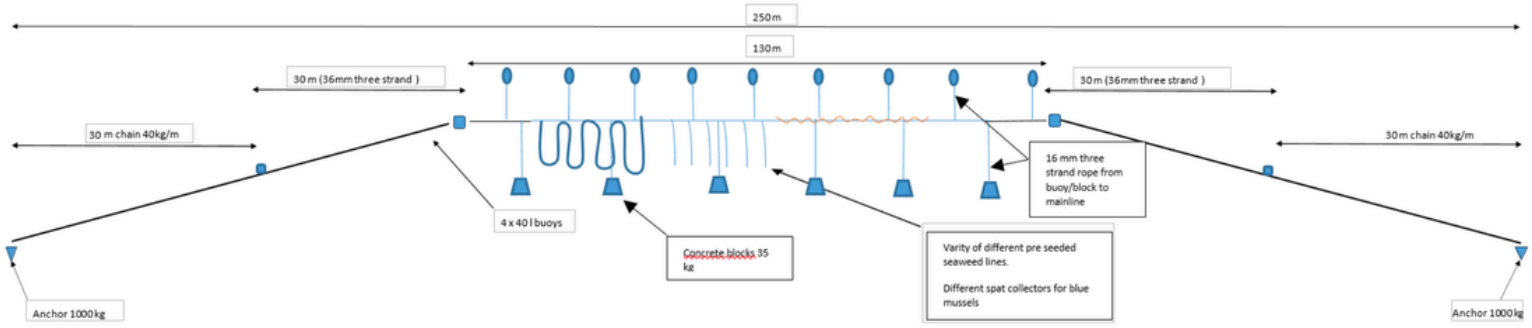
Recommendation 9:

Automated systems are a valuable tool for manned vessels to support monitoring, inspection and environmental assessment tasks.

LONGLINES, TUBES & ANCHORING SETUP

07. LONGLINE UNIT LAYOUT

Bivalves and seaweed production utilise longline systems built for high structural stability. An example of a standard configuration consists of a 130-meter main line with a diameter of 36mm, completely submerged to avoid surface damage.



Longline set-up for growing mussels and seaweed. The measures indicated in the figure are for water depths of 15-20 m. Measures should always be adapted to local conditions.



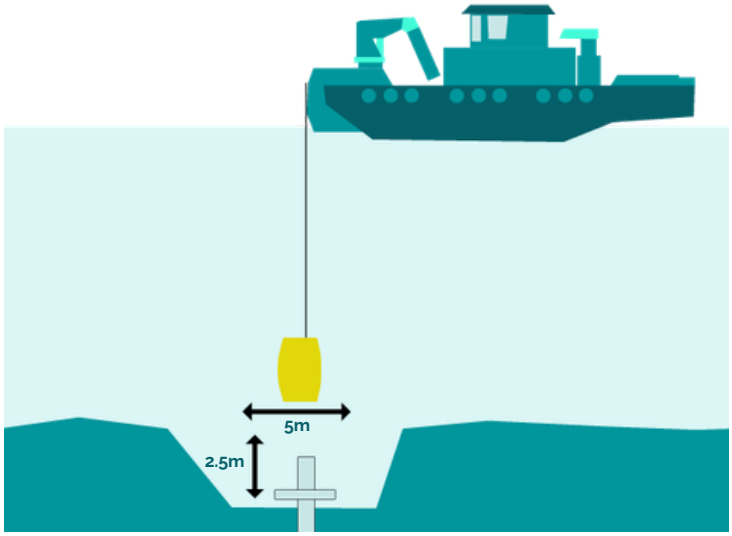
#	DESCRIPTION
10	Rope 36mm, 30m
11	Trawl Float 3x6liter
12	Shackle 12 ton
13	Stud link chain 40kg/m
14	Shackle 12 ton
15	Flip anchor 1000 kgs
16	Back rope 30mm 30m
17	Buoy Ø600 mm

Standard Mooring Baseline: Flip Anchors

For standard installations, open-ocean forces demand robust traditional mooring engineering. The baseline system utilizes a **1000 kg** flip anchor connected via 30 meters of stud link chain cable (weighing approximately **40 kg/m**) and heavy-duty 12-ton shackles. This configuration is adapted for typical water depths of 15–20 meters, should consider the currents of the area, and requires an annual or biennial structural safety inspection.

LONGLINES, TUBES & ANCHORING SETUP

08. ALTERNATIVE ANCHORING: SCREW ANCHORS





Where sediment conditions and weather windows allow, drilled-in screw anchors are a highly reliable anchoring option. These consist of heavy-duty screw units drilled directly into sandy or muddy bottom types using specialized subsea equipment. When deploying these systems, design configurations must be adapted strictly to local sediment characteristics, as not all bottom types are suited for screw installations.

Recommendation 10:

Buoys should generally be submerged, as surface buoys are prone to damage or being lost. Use of 80 L PE plastic buoys is recommended. To keep the longline straight in the water column, 10–15 kg weighted blocks can be used.

Recommendation 11:

When cultivating offshore, adapt material to withstand harsh conditions, use redundancy when designing anchoring.

Recommendation 12:

Screw anchors are the most reliable anchoring option but their design should be adapted to local sediment conditions. Not all sediment types are suited for screw anchors.

OYSTER CULTIVATION (*Ostrea edulis*)

09. SEABED CAGE - & ACOUSTIC RETRIEVAL SYSTEMS

Conventional oyster farming methods designed for sheltered coastal environments, such as bag systems on tidal flat racks, suspended longline lanterns, or surface flipping baskets, are entirely unsuitable for offshore environments due to extreme wave exposure and current velocities.
The validated offshore approach utilises reinforced cage structures placed directly on the seabed, where multiple oyster baskets are stacked within a rigid frame providing mechanical protection.

On-bottom cultivation system

Cages are elevated 30–50 cm above the sediment surface using specially designed feet that partially penetrate the sediment, ensuring stability while preventing the structure from sinking or being buried in soft substrate. Cage bases are further weighted internally for stability.



Acoustic Retrieval Mechanism

To minimise collision risks with shipping or wind farm vessels, these subsea cages incorporate acoustic remote-release technology. Upon receiving an acoustic command from the surface vessel, a buoy connected to a recovery line is released and floats to the surface, allowing the crew to safely haul and retrieve the cage without needing permanent surface infrastructure.



Recommendation 13:

Conventional oyster farming systems designed for sheltered coastal environments should generally not be deployed in offshore locations due to insufficient structural stability and excessive maintenance requirements.

Recommendation 14:

When using seabed cages as the cultivation structure, they should be designed with elevated support feet to improve stability and prevent burial in soft sediments.

Recommendation 15:

Offshore oyster cage systems should incorporate acoustic remote-release mechanisms to enable retrieval without permanent surface infrastructure. Moreover, the buoy design should take into consideration the extra weight that builds up on buoys as a result of fouling over time.

OYSTER CULTIVATION (*Ostrea edulis*)

10. BIOSECURITY & SPECIES SELECTION

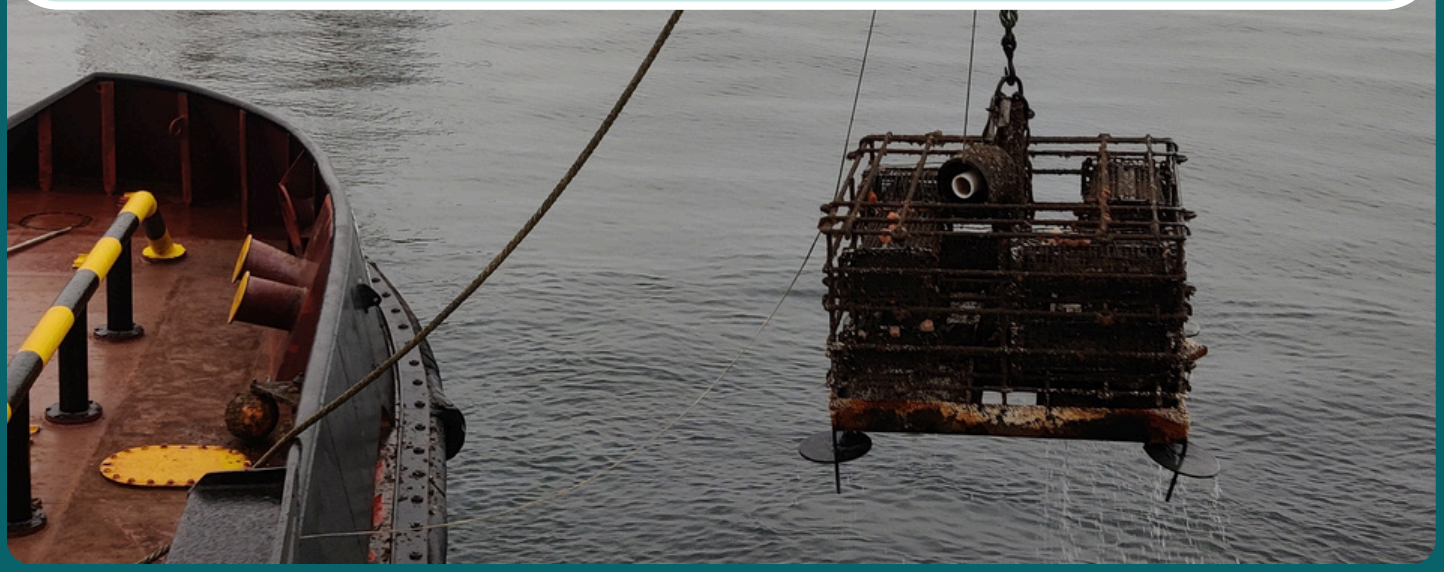
Managing the biological risks of offshore production requires strict biosecurity protocols and careful monitoring of ecosystem interactions over multi-year culture cycles.



- **Species Selection:** Operations must strictly source native European flat oyster (*Ostrea edulis*) spat for the North Sea region. Spat must be verified to be free of diseases and pathogens, and test negative for the presence of *Bonamia* and *Marteilia* to prevent devastating regional outbreaks.
- **Biofouling & Nutrient Flow:** Fouling organisms can rapidly colonize cage baskets and choke out water exchange. System designs must utilize holding structures that are as wide-mazed as possible to maintain critical nutrient inflow even after fouling settles.
- **Predation Pressures:** Since oyster culture spans multiple years, all life-cycle phases of predators must be accounted for (e.g., large crabs that enter the system as tiny zooplankton and grow to full size inside the protective cage).

Recommendation 16:

Only use European flat oyster (*Ostrea edulis*) spat which has tested negative for the presence of *Bonamia* and *Marteilia*.



Technical Summary: 16 Recommendations

This master checklist compiles the operational requirements established by the ULTFARMS consortium practitioners based on cross-pilot demonstrations. Use this section for rapid cross-referencing, deployment tracking, and multi-use compliance audits.

SPATIAL & ENVIRONMENTAL PLANNING



- [ ] **Rec. 1:**
Integrate aquaculture requirements early during the concept and design phase of offshore wind farms (e.g., via legal frameworks) to streamline spatial sharing.
- [ ] **Rec. 3:**
Position grow-out structures parallel to the dominant environmental forcing direction, balancing physical structural limits with biological yield.
- [ ] **Rec. 2:**
Locate offshore LTA-units within a logical distance from the nearest service hub or harbour to minimize transit times and energy expenditure.





MUSSEL & SEAWEED PRODUCTION LOGISTICS

- [ ] **Rec. 4:**
Complete all mussel sorting and socking operations directly onboard the vessel rather than attempting land-based logistics.
- [ ] **Rec. 5:**
Submerge headlines and growing media entirely below the surface to protect equipment from extreme offshore wave action.
- [ ] **Rec. 6:**
Tailor seeding methods (twine winding vs. spray solutions) to your cultivation setup and secure regional, hatchery-sourced strains.
- [ ] **Rec. 7:**
Design systems with high structural redundancy and schedule deployments tightly around limited winter weather windows to minimize offshore trips.

Technical Summary: 16 Recommendations

VESSELS & MARITIME OPERATIONS



- [ ] **Rec. 8:**
Build or charter vessels with modular deck layouts and standard equipment interfaces to easily transition between hauling, maintenance, and harvesting.

- [ ] **Rec. 9:**
Integrate automated systems (e.g., online gauge sensors, satellite-linked environmental loggers) to assist crews with monitoring and risk assessment.

ENGINEERING & MOORING INFRASTRUCTURE



- [ ] **Rec. 10:**
Utilise fully submerged 80 L PE plastic buoys paired with 10–15 kg weighted positioning blocks to keep longlines straight and prevent surface asset loss.

- [ ] **Rec. 11:**
Specify and source high-durability marine materials designed to survive open-ocean forces, utilising multi-point redundancy in your mooring layouts.

- [ ] **Rec. 12:**
Deploy drilled-in screw anchors as a highly reliable mooring baseline, provided local bottom sediment surveys confirm they are compatible.



Technical Summary: 16 Recommendations

OFFSHORE OYSTER SYSTEMS

- [ ] **Rec. 13:**
Do not deploy conventional coastal oyster gear (e.g., surface baskets, floating lanterns) offshore due to structural failure and unmanageable maintenance costs.

- [ ] **Rec. 14:**
When using seabed cage systems, ensure that they are heavily reinforced and engineered with elevated support feet to resist currents and prevent the oysters from being buried in soft sediment.

- [ ] **Rec. 15:**
Offshore oyster cage systems should incorporate acoustic remote-release mechanisms to enable retrieval without permanent surface infrastructure. The buoy design should also take into consideration the extra weight that builds up on buoys as a result of fouling over time.

- [ ] **Rec. 16:**
To safeguard regional marine biosecurity, restrict all cultivation stock exclusively to European flat oyster (Ostrea edulis) spat which has tested negative for the presence of *Bonamia* and *Marteilia* and other diseases.



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