DELIVERABLE 1.8

BUSINESS MODEL FOR ECOSYSTEM SERVICE OF SMALL MUSSELS

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SUMMARY

In 2025, The Danish government decided to phase out mussel fishery on the east coast of Jutland within eight years. This decision means that mussel fishing by dredging must be transitioned to the cultivation of mussels in the water column and in bottom cultures.

The decision of the Danish government to prohibit bottom dredging in the marine areas around the Great Belt and the Little Belt and the southernmost part of Kattegat creates an opportunity for a new planning model for mussel production which combines food production and marine restoration. The planning model facilitates the quick phasing out of dredging for wild mussels and replaces it with a sustainable culture bank production of mussel spat and a grow-out phase, in which mussels are cultivated in bottom cultures and harvested gently. In this way, the production of mussels is combined with marine restoration via the formation of biogenic reefs. Marine areas are divided into different zones designated for the establishment of biogenic reefs, stone reefs, and culture banks, and some areas are designated specifically for the restoration of healthy marine ecosystems. An increased cultivation of these areas is expected as the water quality improves. Mussel banks in cultivated and non-cultivated areas improve the water quality by filtering the water and extract nutrients. The improved water quality creates new habitats for plants and animals.

This planning model aligns with the government's goal of phasing out dredging and promoting increased biodiversity and improved water quality. The transition into culture bank production requires a total investment of DKK 70M (EUR 9,3 M) over a period of five years. To implement this planning model, it will be necessary to revise the rules for mussel cultivation to ensure scalable and sustainable production. This planning model demonstrates how food production and the protection of nature can go hand in hand in ensuring a future-proof sea management.

1. BACKGROUND

The political agreement "A new direction for Danish fishery" ("En ny kurs for dansk fiskeri") from July 2nd, 2025, paves the way for significant changes in the Danish mussel sector, bringing both challenges and new possibilities for mussel fishing. The ban on dredging in the marine areas around the Great Belt and the Little Belt and parts of Kattegat on the East Coast of Jutland in Denmark means that fishing rights to wild mussel populations are discontinued with an eight-year notice (Fig. 1). Due to the principle of predictable regulation and responsible governance, there will however be transitional opportunities for the fishermen.

The agreement offers financial compensation with the condition that the fishermen give up their fishing permits, and new permits are given for the establishment of production via breeding in the water column and in culture banks. This is a concrete way of preserving and developing the vocation with a lessened impact on the marine ecosystems.

Another central element in the transition process is that the fishermen may take part as entrepreneurs in marine restoration projects and lay mussels in biogenic reefs. As such, their

knowledge and equipment become a resource in the efforts for improved marine environments. This introduces new sources of income and creates synergy between caring for nature and caring for the vocation, driven by the market and volunteerism rather than prohibitions and centralised detail management. A simplification and revision of the rules for mussel fishing and cultivation and a reopening for new permits is also expected as soon as 2026. This gives the mussel fishermen a real foundation for future developments, and it supports innovation in a sector that is under financial pressure. In this way, the agreement creates opportunities for vocational continuity and future growth without compromising the consideration for nature and climate.

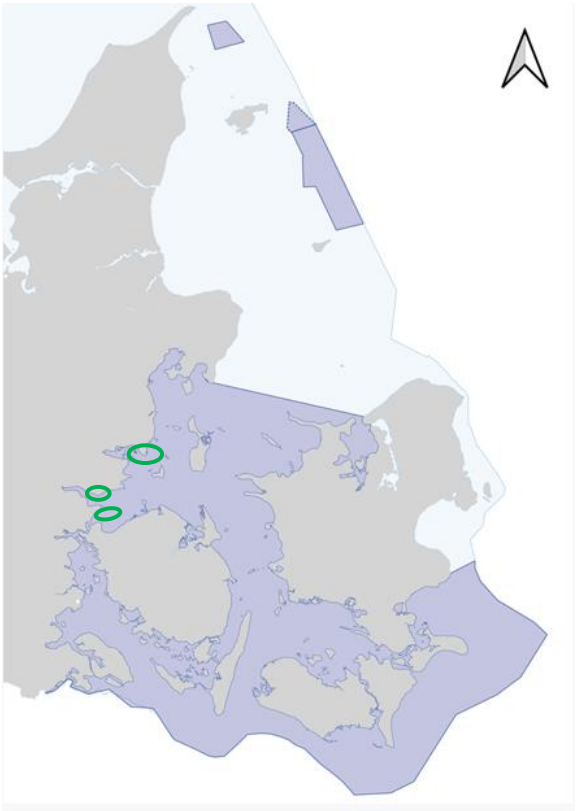

Figure 1: The areas suggested by the government parties to be closed for mussel fishing.

As part of the I3 project Baltic MUPPETS, co-financed by the EU, Blue Research has drafted a development plan for a transitional model, where fishing for wild mussel populations is suspended in the short term, new business opportunities are developed for cultivation of common mussels in bottom cultures, and fishermen may participate as entrepreneurs in marine restoration projects. This plan includes a governance model with an appropriate balance between the production of mussels in bottom cultures and the designation of areas for active natural restoration using biogenic reefs, stone reefs, and the establishment of eelgrass beds. The plan's primary focus is the cultivation of culture banks and the establishment of biogenic reefs with blue mussels. The nutrient catch of a mussel production (carbon, nitrogen and phosphorous uptake) has been valorised in D1.5, and this report describes a specific business model for the Danish case given the political background.

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2. POLITICAL GOALS FOR ECOSYSTEM SERVICES

For several years, there has been a political goal in Denmark of reducing the practice of fishing with dredging equipment, and the government's proposal for prohibiting fishing with dredging equipment in the marine areas around the Great Belt and the Little Belt and the southernmost part of Kattegat contains several political steps in this direction. In a sub-agreement in the Finance Act of 2022, it was in December 2021 decided to prohibit trawling in the Little Belt, the Great Belt and the strait between Langeland and Funen. However, this agreement has not yet been implemented. In the agreement on the Danish Maritime Spatial Plan of June 2023, it was therefore decided to shut down fishing with bottom trawling equipment in Flensburg Fjord, Vejle Fjord and Kalø Vig. The agreement also sets aside DKK 75M for the transition of fishing through to 2030 (LINK to agreement). The Ocean Institute (Tænketanken Hav) recommends a step-wise development and implementation of environmentally sustainable solutions for reaching the goal of fully phasing out dredging by 2035 (The Ocean Institute, 2024) The area planning suggested in this document aligns with the government's proposal for ending the use of dredging equipment (LINK), as fishing for wild mussel populations ceases and is replaced by the establishment of culture banks. Mussels will be harvested using a light dredger every 2-3 years. This impact will be much lower in comparison with the impact of current fishing practices (see Intensity of Fishery 2013-2018 LINK), due to the reduced area of the impacted area. The plan also supports the goal of designating the nature park Svanegrunden (see Nature Park Svanegrund LINK) as an area with no fishing activity.

3. PRIOR CULTURE BANK TRIALS IN THE AREA

The report "Culture bank project with seeding of blue mussels produced on long lines", ("Kulturbankeprojekt med udlægning af blåmuslinger produceret på langline"), published by DTU Aqua in 2013 (Dolmer et al. 2013) documents a trial in which blue mussels produced in nets in the water column in the Limfjord were seeded in culture banks in As Vig and Horsens Bay. The project's aim was to test whether this combination of water column production and bottom cultivation could create a stable, sustainable and commercially viable model mussel cultivation in the future.

The results clearly show that it is very possible to establish a successful production of consumable blue mussels in bottom culture based on spat produced on nets. The seeded mussels exhibited fast growth and developed a significantly larger percentage of meat than common for wild mussels. They also developed a significantly thicker shell, which improves durability and makes the mussels attractive on the market, where shellfish are evaluated based on appearance, weight, and ease of use. Initially, there was a high mortality rate which is an issue that must be handled before commercial-scale production can be initiated.

The high quality of the produced mussels is expected to elicit a higher price point, and it opens the door to new markets, including retail, restaurants, and export. This form of production also has a lower impact on the environment, and it can be employed in areas with extensive requirements for environmental protection. Experience shows that spat can be transferred

from long lines to culture banks without significant losses and that the technology can be scaled up using existing equipment and vessels.

The report contains detailed model studies to evaluate the potential for establishing culture banks with mussels in As Vig and on the East Coast of Jutland between the Little Belt and Aarhus Bay based on local conditions, including currents, sedimentation, and the concentration of nutrients. The models predicted how the seeding of mussels would impact the local ecosystems and the extent to which the mussels could maintain good growth and survival in the chosen culture banks. The model calculations show that there are physical and biological conditions well-suited for bottom cultivation. The currents were strong enough to ensure a good supply of food for the mussels, but not so strong that the mussels could not stay in place on the seabed. The sedimentation rate was low enough that there was no risk that the mussels would be buried or that organic material would accumulate to a detrimental degree. In relation to a culture bank production in As Vig, it is concluded that *"mapping of the potential for mussel production in the southwestern areas of Kattegat shows that the area by As Vig is not optimal due to a lack of food sources for the mussels. The food sources may be increased by approx. 50% by placing the culture bank in a better location, e.g., north of Endelave, in the northern parts of the Little Belt, or in other smaller locations in the southwestern Kattegat."*

To develop bottom cultivation, it would be necessary to carry out a trial production in an area with a greater production potential (see Appendix 1).

4. PLANNING MODEL

This document suggests a management model, in which protection and restoration of marine nature is integrated with a sustainable and gentle production of mussels. This production also entails a phasing-out of dredging for blue mussels. We suggest that this model is used in three areas (see Fig. 2 – green marked areas). The rest of the areas closed for dredging by the government are kept free of bottom culture production.

The plan includes a combination of commercial bottom cultivation and mussels in fixed plots and different type of active and passive marine habitat restoration planned according to the robustness and structure of the habitats, including the pristine natural habitat distribution. In Table 1 the potential positive, negative and unknown effect of different types of marine habitat restoration are listed.

Table 1: Overview of positive and negative effects of different types of marine habitat restoration and mussel cultivation, as well as matters not yet clarified, including financing. Note that combinations of measures can have bigger impact by enhancing each other's function.

Use	Positive effect on the ecosystem	Negative effect on the ecosystem	Matters not yet clarified and financing
Biogenic reefs	Water clarification and eutrophication mitigation. This can enhance biodiversity, e.g. distribution of macrophytes like eel grass, macro algae and other species. carbon sequestration.	In rare cases, deoxygenation occurs in these areas. Deoxygenation may result in a higher mortality and the release of nutrients.	The seeding of blue mussels in biogenic reefs may be partially financed by the mussel producer, depending on the overall economy in the culture bank production. The seeding of blue mussels may in the initial phase be carried out using line-grown mussels from the Limfiord. It should be analysed in further detail whether seeding mussels from another area can cause a spreading of foreign genetic material. The area's carrying capacity in relation to total biomass of mussels must be assessed.
Stone reefs	Biodiversity enhancement by habitat provision. Water quality improvement and eutrophication mitigation through establishment of bivalves on the reef.	If stone reefs are established in areas where stone reefs have previously existed, no negative effects are to be expected.	The financing is not yet clarified. The structure of the stone reefs is to be determined. It may be individual stones or close formations of stones, possibly with the creation of caverns.

Use	Positive effect on the ecosystem	Negative effect on the ecosystem	Matters not yet clarified and financing
Areas kept free from activity	These areas will achieve a passive nature restoration when kept free from mechanical disturbances in combination with a decreased discharge of nutrients.	None	None
Bottom culture established in parts of the designated cells	The mussels' filtration will clarify the water and contribute to neutralising the effects of eutrophication. As such, the mussels will promote the distribution of eel grass and macro algae in the adjacent cells.	The mussels must be harvested with a light dredger after 2-3 years. The harvesting will be targeted at the culture banks in each individual cell.	Culture banks is a known technology and the production will be commercial with a plan for production and business. The current management of mussel production in bottom culture (BEK no. 116 of 29/22/2021) allows each person/company to own two culture banks of 15 ha. In order to develop culture bank production as a central element of a business, this framework must be revised, so that there is no limit to the amount of culture banks an individual or business may own (with the condition of a duty of application), and so that the size is regulated in accordance with the sustainability of each area. The area's carrying capacity in relation to total biomass of mussels must be assessed.

To illustrate the management model for the three areas, management of the area between As Vig and Endelave is detailed below. The text contains direct links to the underlying data. A management system is established in which the marine area between Endelave and As Vig is divided into a matrix, and each cell is selected for specific protection, used for marine restoration, or for food production (Table 2 and Figure 2). The size of each cell is 660 x 660m. The management system includes active regulation to ensure that nature restoration and food production are integrated. The management alone cannot ensure the improvement of the ecological condition in the area, and it must be supplemented by a reduction in the discharge of nutrients in the area.

In the area, dredging for wild mussels will cease, and the production of mussels will be limited to a smaller area. Here, the mussels will be grown in bottom cultures and harvested 2-3 years after seeding.

Table 2: Legend for management matrix (Fig.2)

	Areas where biogenic reefs with blue mussels are established. Dredging will be prohibited in these areas. The biogenic reefs are mainly established around areas where stone reefs are established or where the currents are good.
	Areas where stone reefs are established. The stone reefs will be established in places of existing reefs (see Types of Marine Nature) or in former areas of stone fishing (see Centre for Marine Restoration**Error! Reference source not found.**
	Areas where culture banks can be established. The mussels are harvested after 2-3 years with dredging equipment. The production is planned in order so that there is always a biomass of 15,000 t blue mussels, meaning that 5-7,000 t blue mussels can be harvested each year. Parts of these cells may be used for culture banks, and other areas may be undisturbed. The parts in use depend on the carrying capacity of the area. The culture bank areas will be established in areas designated for bottom culture production in the Marine Spatial Plan (see the Marine Spatial Plan: areas designated as culture banks LINK) The areas in the Marine Spatial Plan overlap with areas designated by Natura 2000 (see Natura 2000). In connection with the approval of the Marine Spatial Plan, a general assessment concludes that the culture banks are not in conflict with the Natura 2000 designations. It will however be necessary to carry out detailed assessments for specific projects and with direct consideration of the grounds for designation in each individual area.
	Areas kept free of all activities. In shallow waters, a passive restoration of eel grass is expected. No areas have been designated for active restoration of eel grass beds, as this requires further maturation of the technology.

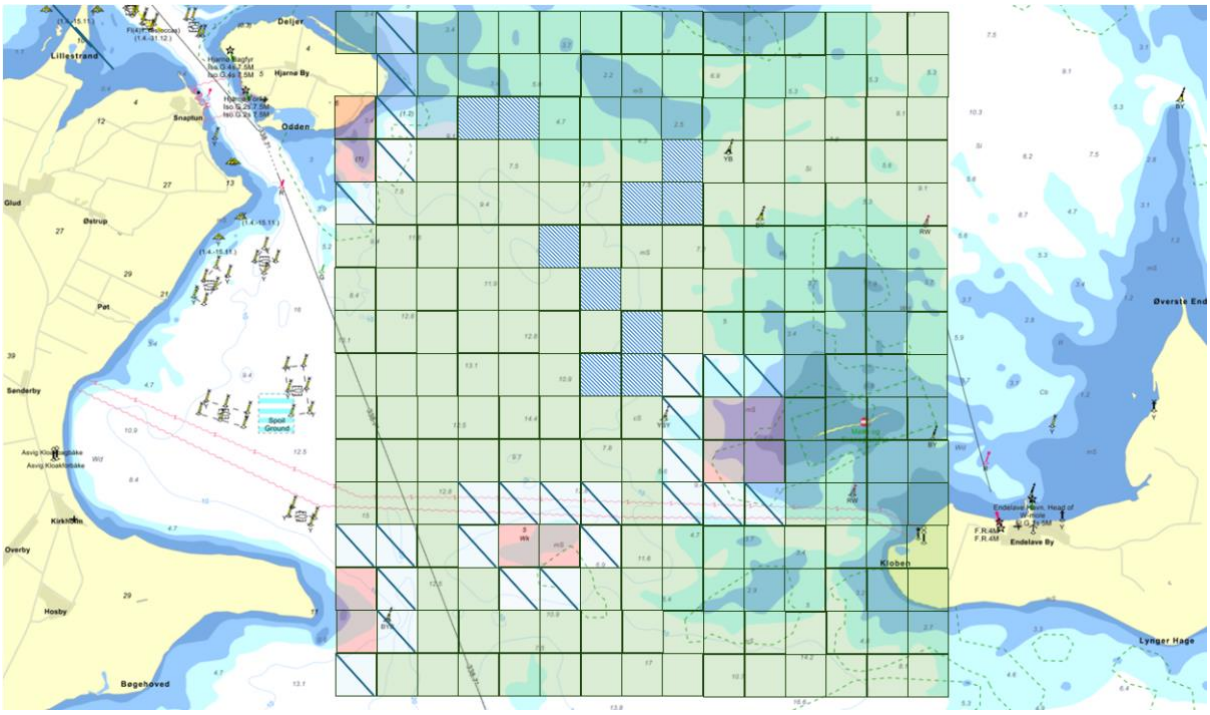

Figure 2: Management matrix. The map shows the area between As Vig and Endelave with the designated cells. Explanations for each cell type can be found in Table 1.

5. UNDERLYING DATA

In order to draw up the zone matrix of the area shown in Fig 2., extensive data has been analysed. In the following, we show an overview of the data sources which have contributed to the zoning.

Stone fishing (Centre for Marine Restoration) - LINK. Stone fishing (the removal of large stones from the seabed for construction works) took place in Denmark from the late 19th century and well into the 20th century. In practice, it largely ceased during the 1990s, and in 1999 it was de facto stopped and legally prohibited from 2009 as part of stronger marine environmental protection measures. The ban was introduced because stone reefs are important habitats for fish, seaweed, and bottom-dwelling organisms. Removing the stones had significant negative impacts on biodiversity and coastal stability.

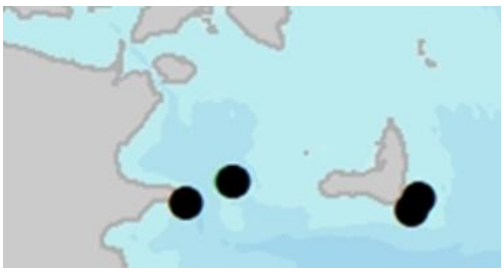

Figure 3: Registrations of stone fishing in the area.

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Natura 2000 - LINK

Parts of the area where culture banks will be established have been designated as a Natura 2000 area (area shaded in green).

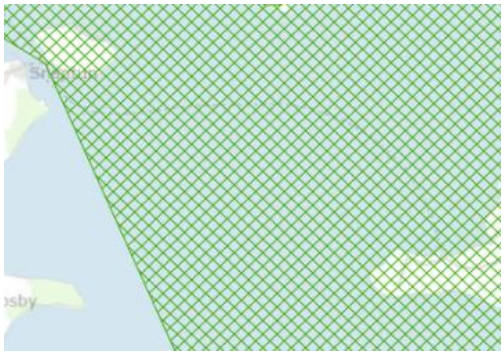

Figure 4: Natura 2000 coverage of the area.

Marine Nature Types - LINK

In the registration of types of nature, occurences of stone reefs have been registered in a large number of localities in the area.

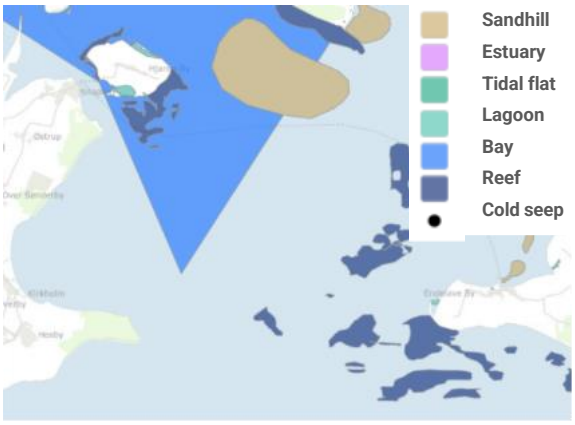

Figure 5: Marine nature types in the area.

Depth limit for eel grass - LINK

219 Århus Bay south, Samsø, and the northern marine area surrounding the Great Belt and the Small Belt 8.5 m

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The Marine Spatial Plan: areas designated for culture banks - LINK

In the Marine Spatial Plan, areas are designated for either biogenic reefs, where no dredging is allowed, or for culture banks, where the mussels are harvested after 2-3 years with a light dredger. As such, the area planning is limited to the current designations in relation to the establishment of bottom culture.

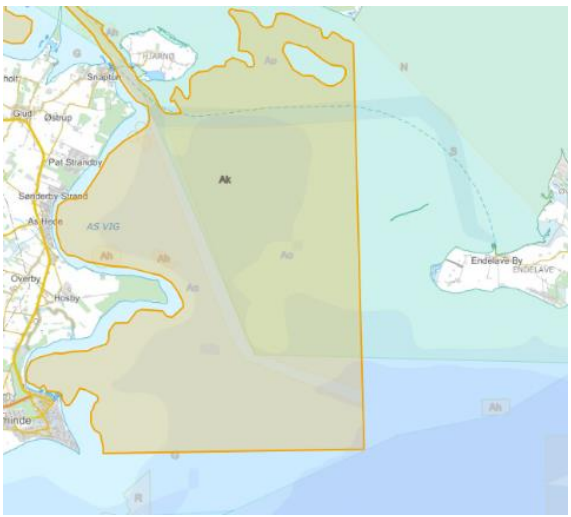

Figure 6: Areas designated for culture bank in the marine spatial plan.

The Marine Spatial Plan: areas designated for cultivation in the water column - LINK

A large part of the area has been designated for cultivation in the water column. As such, it will be possible within the area planning framework to establish local mussel production with cultivation on long lines or using the SmartFarm system. This production can be supplemented with seeding of mussels from other areas, assuming it can be documented that this does not entail a risk of spreading foreign species.

Figure 7: Areas designated for cultivation in water column in the marine spatial plan.

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Particles for filterfeeders - LINK

The Danish Hydraulic Institute has modelled the concentration for filter feeders, that can be used to assess food basis for bottom cultivation of blue mussels. The data is accumulated within a year (2011-2012). This work was done in connection with investigations of the possibilities for establishing bottom cultivation on the eastern coast of Jutland. The investigations are based on a specific test production in As Vig, where blue mussel spat grown in nets in the Limfjord was seeded.

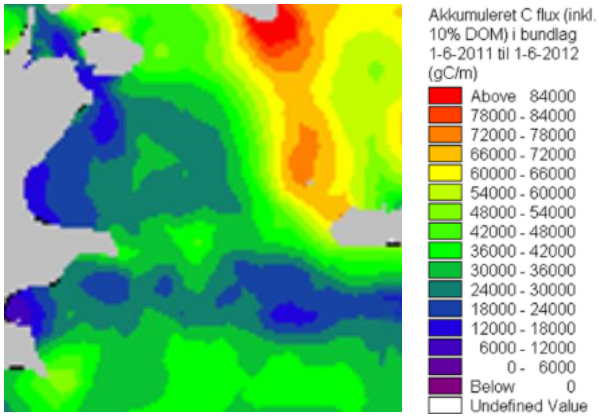

Figure 8: particles for seabed cultivation of mussels.

Nature Park Svanegrund - LINK

A series of private initiators and the municipalities of Odder, Samsø, Hedensted, and Horsens.

Danish Nature Parks is the quality approval of the Danish Outdoor Council, and it designates continuous areas of nature that live up to certain requirements regarding quality and development in nature and outdoor facilities. To join the scheme, the following requirements must be fulfilled: A minimum 50% of the nature park must be protected nature. As dredging for wild mussel populations is ceased and the area used for bottom culture is limited, this goal can be reached.

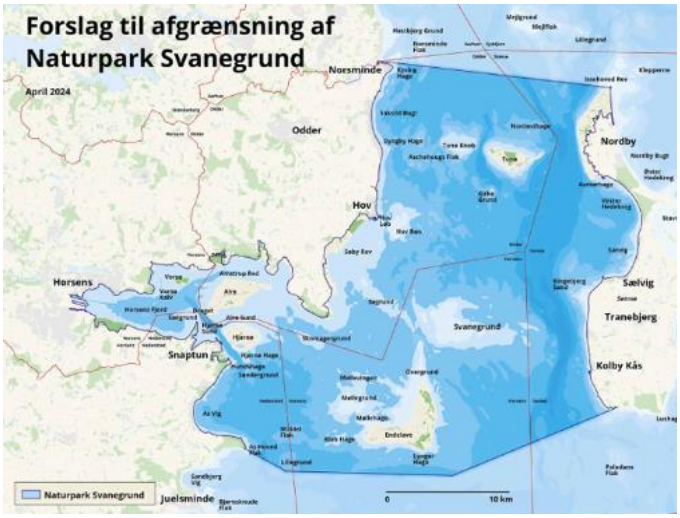

Figure 9: Suggestion for Svanegrund delimitation.

Fishery intensity 2013-2018 - LINK

The fishery intensity with dredging equipment in squares of 100x100m according to position data for Danish fishing vessels.

Figure 10: Fishery intensity in the area 2013-2018. Green is low, yellow medium and orange most intense.

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FINANCING

We have assessed that three vessels will be needed for bottom cultivation in the three suggested areas. These vessels will support a yearly production of 3-5,000 tonnes blue mussels in each of the three areas as well the seeding of mussels in the cells where biogenic reefs will be established. The three vessels may be mussel fishing vessels, which can be modified for the seeding of mussels and for gentle harvesting of mussels with a light dredger.

In itself, the transition from dredging-based fishing to the cultivation of mussels in culture banks results in some financial insecurity for the mussel companies, and financial support will be necessary for the development and optimisation of this production. The production will also require the establishment of spat production for seeding in the culture banks. Below is an overview of the direct costs of transitioning from dredging-based fishing to the cultivation of mussels. The total costs are more than 70 million danish kronor (DKK) (EUR 9.3 million) over a period of five years. Partial financing may come from the governmental compensation for ceased mussel dredging.

Table 3: Overview of the direct costs of transitioning from dredging-based fishing to the cultivation of mussels.

Expenses	DKK (million)
Purchase/conversion of three vessels for the culture bank cultivation and for the purposes of seeding the spat and harvesting saleable mussels.	15
Establishment of nine mussel productions in the Limfjord which will produce 10-15,000 t mussel spat for seeding each year. The purchase of harvesting vessels, on-land facilities, etc.	50-60M
Investment in development and documentation of culture bank cultivation and marketing of new products.	5
Total	**70-80**

Annex I describes a 10-year investment and operational budget for the transition, wherein the transition to a business model in which mussels are seeded in culture banks for both food production and for marine restoration is assumed. The investment budget assumes that the political agreement “A new direction for Danish fishery” can supply DKK 13 million to support the quick phasing-out of fishing for wild mussel population and DKK 15 million for the transition from mussel fishing to low-trophic aquaculture. Significant financial support is a prerequisite for the transition into bottom cultivation. The period for return on investment is nine years, making it a high-risk investment. With support from the framework of the new agreement, the period for return on investment is reduced to seven years, which still makes it high-risk, but it makes the business model more realistic.

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APPENDIX I

The investment and operational budget for a company that seeds up to 10,000 tonnes blue mussels in bottom cultures and sells mussels for marine restoration.

Budget preconditions

	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031
Price for 100 pipes (million DKK)	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Mussel production per pipe (t)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Number of staff per 100 pipes	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Salaries, operations, logistics per employee (million DKK)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Depreciation of pipes (year)	10	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Depreciation of machines (year)	5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Share of mussels for marine restoration	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sales of mussels for marine restoration (DKK/kg)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sales of culture mussels for consumption (DKK/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Mussel production in culture banks (P/B) and saleable share	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Investment budget

	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031	Total
New establishment of pipes (each)	250	300	0	0	0	0	0	0	0	0	
Accumulated number of pipes	250	550	550	550	550	550	550	550	550	550	
Investment in pipes (million DKK)	22.5	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50
Investment in machines and vessels (million DKK)	10	6	3	1	2	2	2	2	2	2	32
Total investment (million DKK)	**33**	**33**	**3**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**82**
Accumulated investment (million DKK)	33	66	69	70	72	74	76	78	80	82	
Potential support (million DKK)	28	0	0	0	0	0	0	0	0	0	
Annual net investment	5	33	3	1	2	2	2	2	2	2	54
Accumulated investment after support (million DKK)	5	38	41	42	44	46	48	50	52	54	

Profit budget

	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031	Total
Mussel production (t)	5000	11000	11000	11000	11000	11000	11000	11000	11000	11000	
Staff for mussel production (number)	2.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	
Sales of mussels for marine restoration (t)	1000	2200	2200	2200	2200	2200	2200	2200	2200	2200	
Sales of mussels for marine restoration (million DKK)	0.70	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	
Sales of mussels for consumption (t)	0	0	0	1600	3520	4400	4400	4400	4400	4400	
Sales of mussels for consumption (million DKK)	0	0	0	8	18	22	22	22	22	22	
Total turnover (million DKK)	0.7	1.5	1.5	9.5	19.1	23.5	23.5	23.5	23.5	23.5	
Salaries, operations, and logistics (million DKK)	2	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	41.6
Salaries for managers and administration (million DKK)	1	1	2	2	2	2	2	2	2	2	
EBITDA (million DKK)	-2	-4	-5	3	13	17	17	17	17	17	91
Depreciation of pipes (million DKK)	2.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	46.8
Depreciation of machines (million DKK)	2	3	4	4	4	3	2	2	2	2	28
EBIT (million DKK)	**-7**	**-12**	**-14**	**-6**	**3**	**9**	**10**	**10**	**10**	**10**	**16**

Liquidity budget with no support

	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031	Total
EBITDA (million DKK)	-2	-4	-5	3	13	17	17	17	17	17	91
Investments with no support (million DKK)	-33	-33	-3	-1	-2	-2	-2	-2	-2	-2	-82
Annual effect on liquidity (million DKK)	**-35**	**-37**	**-8**	**2**	**11**	**15**	**15**	**15**	**15**	**15**	**9**
Accumulated liquidity (million DKK)	-35	-72	-80	-77	-67	-52	-36	-21	-6	9	

Liquidity budget with support

	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031	Total
EBITDA (million DKK)	-2	-4	-5	3	13	17	17	17	17	17	91
Investments with support (million DKK)	-5	-33	-3	-1	-2	-2	-2	-2	-2	-2	-54
Annual effect on liquidity (million DKK)	**-7**	**-37**	**-8**	**2**	**11**	**15**	**15**	**15**	**15**	**15**	37
Accumulated liquidity (million DKK)	-7	-44	-52	-49	-39	-24	-8	7	22	37	

Co-funded by the European Union