DELIVERABLE 1.1

BUSINESS AND INVESTMENT PLAN

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CONTENT

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1. EXECUTIVE SUMMARY

The document contains two business cases for mussel farming, which were prepared within the I3-funded project Baltic MUPPETS. One for the Western Baltic and one for the Central Baltic. Both business cases are added as annexes. The business cases focus on the industrial mussel production and processing of undersized blue mussels to pet food.

Undersized (less than 4.5 centimetres shell length) blue mussels are presently not economically used; according to EU directives, only mussels exceeding 4.5 centimetres in shell length can be used for human consumption. Nevertheless, if undersized mussels are a valuable source of proteins and other compounds, further economic use would increase the farming and thus the extraction of nutrients from the eutrophied water bodies of the Baltic Sea.

Mussels can be used in various ways; we focus on pet feed and, to a minor extent, on soil improvement. The main challenge is to find and develop attractive products and to define profitable markets, to make mussel products competitive with other, already existing, products, such as fish meal and mineral fertiliser.

2. INTRODUCTION

There are multiple advantages connected to mussel farming, among which the production of high-quality proteins and the uptake of nutrients are the most prominent. In addition, mussel production provides an additional source of jobs and income for the local population, serves as a habitat for various fish and invertebrate species and can also provide further resources such as calcium carbonate and fertiliser. Mussel farming is a relatively cheap, nature-based activity which imposes minimal stress on the surrounding environment. Thus, there are good reasons to foster mussel farming in the Baltic Sea. Baltic MUPPETS, as well as the previous Interreg Baltic project “Baltic Blue Growth”, are focusing on providing the required knowledge and economic base for further growth of this industry.

The Baltic Sea shows a strong gradient in its salinity (salt concentration) that decreases from the west to the east. Salinity plays a large role in the physiology of marine organisms, a consequence of which is the decrease in size and growth rate of mussels from west to east. As opposed to the so-called “Baltic Proper”, the water body in the centre of the Baltic is the salinity in the western part of the Baltic Sea (Danish and German coastal waters) high enough to provide good growth conditions and mussel reach sizes up to two to seven centimetres within two years (Fig. 1).

The differences in growth conditions and their economic consequences require different business plans for these very distinct regions.

The developed business cases address mussel farming in both the Western Baltic Sea and the Baltic Proper. In the Western Baltic, Danish companies operate 57 farms producing eight to ten thousand tonne annually (valued at about six million EUR), while in the Bay of Kiel, only small-scale production exists. In the Baltic Proper, the focus is on the Swedish east coast, where the company Ecopelag runs small farms and a pilot unit. Drawing on their data and experiences, the business plan outlines the conditions under which mussel farming in the Baltic Proper can become profitable.

While the mussel farms today produce primarily blue mussels for human consumption, an additional revenue stream could be realised by making use of the undersized mussels, which cannot be marketed as edible mussels. However, small mussels are as nutritious as large mussels, and can be used as animal feed, or more specifically as pet food, which has been identified as a target product. Various side-stream products can help to improve the cost/revenue balance and are also included in the financial calculations. Growing blue mussels is in principle a fairly easy process: Technical substrates, such as ropes or nets attached to a mooring system, are placed in the sea. Mussel larvae (spat) from natural parent populations will settle onto these substrates, thus no artificial reproduction effort is required. Furthermore, the mussels need no feed during production, as they feed on the microalgae in the water column. The mussels are then harvested and further processed into a marketable pet food.

3. METHODOLOGY

The business cases presented in this report were developed based on a combination of literature data, market research, and empirical data from existing mussel farms. Published studies and reports provided the scientific and technical background on mussel farming in the Baltic Sea region. Market research contributed insights into production costs, product values, and demand structures. In addition, real data from operating farms were incorporated to ensure that the assumptions and calculations reflect practical experience. Together, these sources formed the basis for outlining the economic feasibility and potential profitability of mussel farming under different regional conditions.

The two annexes describe the individual business cases for utilisation of under-sized mussels in the western Baltic Sea (annex I) and Baltic Proper (annex II) and are meant to be read separately. Hence the documents follow a similar structure with:

- **Introduction**
- Technical description*
- **Company and craft structure**
- **The products and their marketing**
- Finance planning (costs, revenues and captial demand)*
- **Risk asssessment**

Some sections are applicable for both business cases and are therefore very similar (highlighted above). Some follow the same internal structure, but numbers and details related to each geographical case are adapted (marked with a * above). All sections have been read and approved by regional experts.

4. GENERAL CONCLUSION

A clear outcome of the study is that the scale of production is decisive for the cost structure, and thus for selling price and attractiveness of a mussel-based product. According to the presented numbers, mussel production - and processing – must be in the range of at least several thousand tons per year. This requires mechanised processes. Among the potential markets, chicken feed and pond fish feed were identified as being particularly attractive. In addition, wet food products for dogs and cats are more profitable than dry products. Mussel meal remains still twice as expensive as fishmeal and – despite its high quality - will be hard to find customers.

Cooperation between farmers, harvesters and processing activities is mandatory! We advocate for a cooperative structure, based on trust and common interests.

In the Western Baltic, undersized mussels are usually a by-product of the production of larger mussels for human consumption. This might reduce production costs considerably, and has to be taken into account when designing a specific mussel farm.

As unusable mussels are usually thrown overboard and back into the sea, any use on land will decrease the nutrient load and will help to improve the water quality. In conclusion, in the Western Baltic, small mussels can and should be used.

The low salinity in the Baltic Proper limits the growth rate as well as the end size of blue mussels; a business model is therefore based on the valorisation of undersized mussels alone. It is concluded that specialised products for niche markets can provide a profitable business.


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ANNEX I: WESTERN BALTIC

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1. INTRODUCTION

The developed business case here focuses on the situation in the Western Baltic Sea. The example area is the Danish coastal waters, where the Danish companies run 57 farms with an annual production of 8-10,000 tonnes of mussels with a value of €6 million in the Limfjord and on the east coast of Jutland. The business case is also relevant for a farm in the Bay of Kiel, Germany, producing only a few tonnes per year.

While the mussel farms today produce primarily blue mussels for human consumption, an additional revenue stream could be realised by making use of the undersized mussels, which cannot be marketed as edible mussels. However, small mussels are as nutritious as large mussels, and can be used as animal feed, or more specifically as pet food, which has been identified as a target product. Various side-stream products can help to improve the cost/revenue balance and are also included in the financial calculations.

Growing blue mussels is in principle a fairly easy process: Technical substrates, such as ropes or nets attached to a mooring system, are placed in the sea. Mussel larvae (spat) from natural parent populations will settle onto these substrates, thus no artificial reproduction effort is required. Furthermore, the mussels need no feed during production, as they feed on the microalgae in the water column. The mussels are then harvested and further processed into a marketable pet food.

2. TECHNICAL DESCRIPTION (PRODUCTION)

Various steps are required from growing mussels in a farm to get a final product. The individual steps and their challenges are described below. In order to maximise efficiency, synergies should be identified and used, leading to a suggestion for the structure and cooperation between the different protagonists of the different crafts.

2.1 Location

The area we are focussing at is the western part of the Baltic Sea as well as the Limfjord. This area is sometimes described as Western Baltic, parts of it as Belt Sea, Kiel Bight, and – partially - the Kattegat. The important point is that the salinity, though reduced as compared to the world ocean (approximately 35 PSU) and also to the North Sea (around 32 PSU), is still above 15 PSU on average, providing very good growth conditions for blue mussels. East of this area, and divided by an underwater barrier between the German Darß and the Danish Gedser, salinity falls below 10 PSU limiting both mussel growth rate and maximum size. Another barrier exists

between Malmö and Copenhagen, preventing the influx of saline water from the Kattegat through the Öresund into the Baltic Sea.

Our partner within the MUPPETS project University of Tartu has revealed that the growth performance of mussels in this part of the Baltic Sea exceeds 128 tonnes per year calculated for ¼ ha standard mussel farm and is thus several times higher than in the eastern parts of the Baltic Sea.

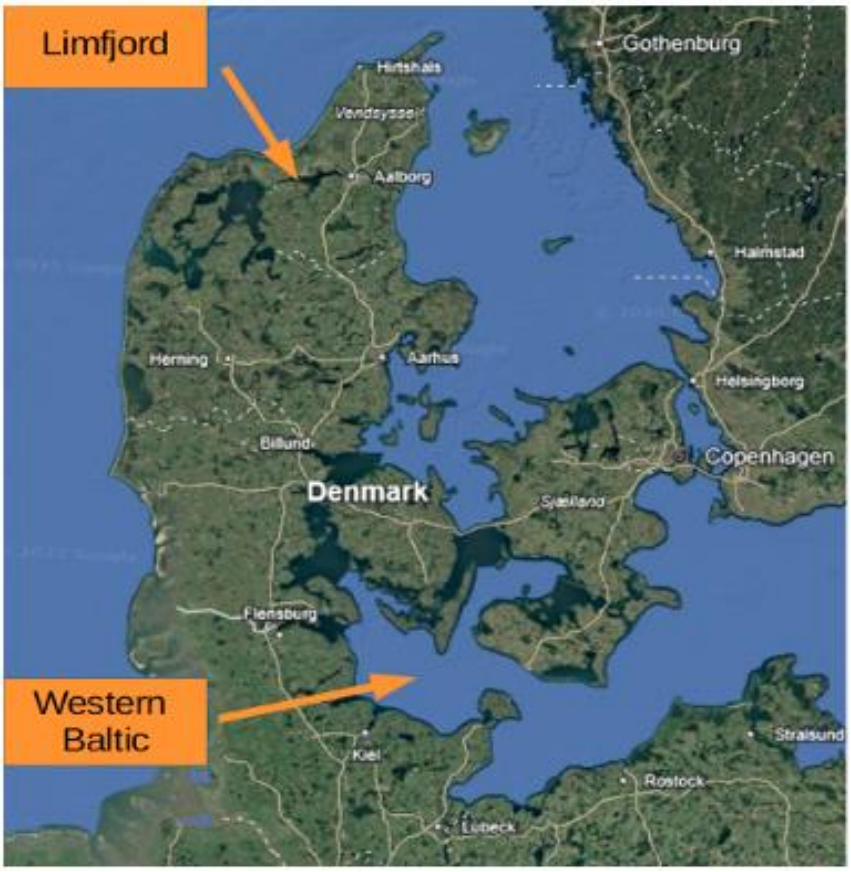

Figure 1. The area of Baltic proper. Source: Helcom.

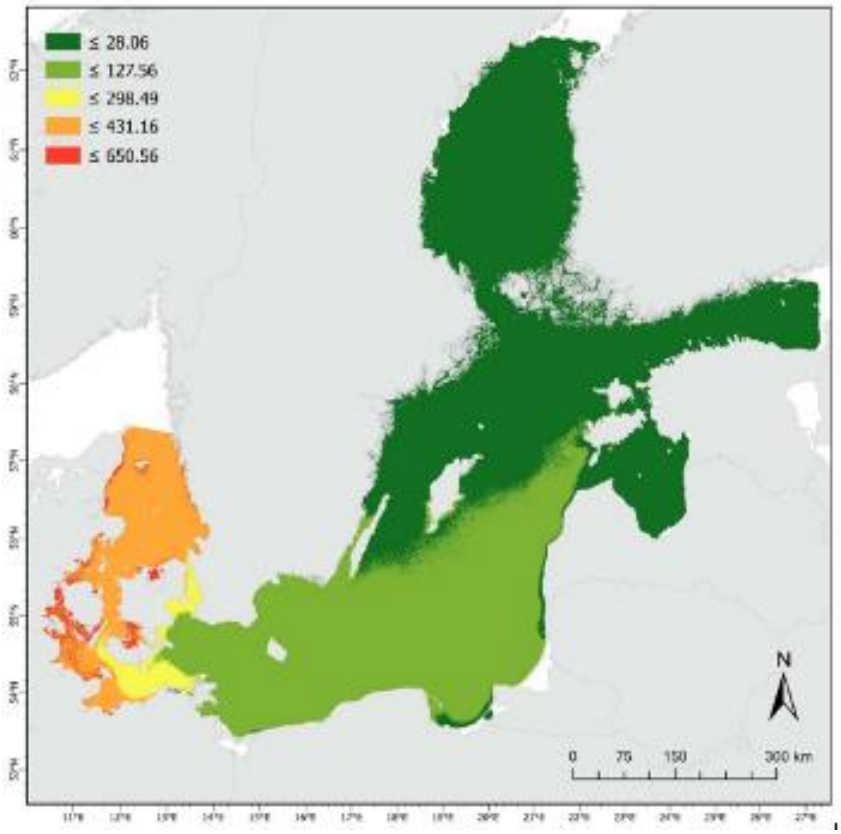

Figure 2. Mussel production potential in the Baltic Sea. Map provided by the Baltic MUPPETS partner U-Tartu. The colours indicate a yearly production of fresh mussels on the basis of a ¼ HA standard farm.

2.2 Mussel cultivation and harvesting technique

Mussel farming is a well-established technique which is common in many European and other coastal areas. Different environmental conditions lead to slightly varying regional methods, such as bouchaut-poles in the tidal areas of France, floating rafts in Spanish waters, longlines and smartfarm systems in North Sea and Baltic Sea.

All methods are based on natural reproduction, i.e. the cultivation takes advantage of the natural spat fall by offering artificial substrates to settle on. Due to the relatively low profit per volume harvested (further discussed in chapter 6), the economic solution is to produce large amounts, but with high quality. The only method presently available for producing large amounts of mussels with minimised human effort is Smart Farming.

Smart Farm AS is a Norwegian company that has developed a semi-automated system for the growth and harvesting of mussels. The system consists of vertical nets attached to polyethylene pipes for carrying the biomass and moorings to absorb active forces and necessary flexibility. The pipes have a standard length of 121 m, the depth of the nets is around 3-4 m, and the mesh size is around 16-30 cm, depending on the production conditions. We

calculate a price for a smart farm unit (including mooring and marker buoys, etc.) to be €20,000, and a duration time of 20 years (Ngyen et al. 2013).

At the end of the grow-out phase (1.5 to 2 years), a mechanical cleaner – somewhat similar to a car wash machine – scrubs the mussels from the nets and pumps the detached mussels on board a nearby ship. In the Limfjord, the mussels are thinned out in the autumn in order to avoid sinking of the system. The mussels will be harvested before the next settling, next spring, to avoid overgrowth of the mussel culture.

The harvesting machine and the boat are the biggest investments and should be in use as much as possible in order to get the best return on the investment. For the calculation, we assume costs of €1,000,000 for the ship, the harvester and the necessary equipment with a depreciation over 20 years. A harvesting machine can harvest up to 30 tonnes per hour. In this calculation, we assume 200 tonnes per day. The time for harvest will then be around three months. For the rest of the time, the boat and machine will be used for husbandry, maintenance like tensioning the anchors, cleaning the nets and submerging the units before winter, etc. The harvest capacity is then 20,000 tonnes per season (Ngyen et al. 2013), provided there is sufficient staff to work in two teams.

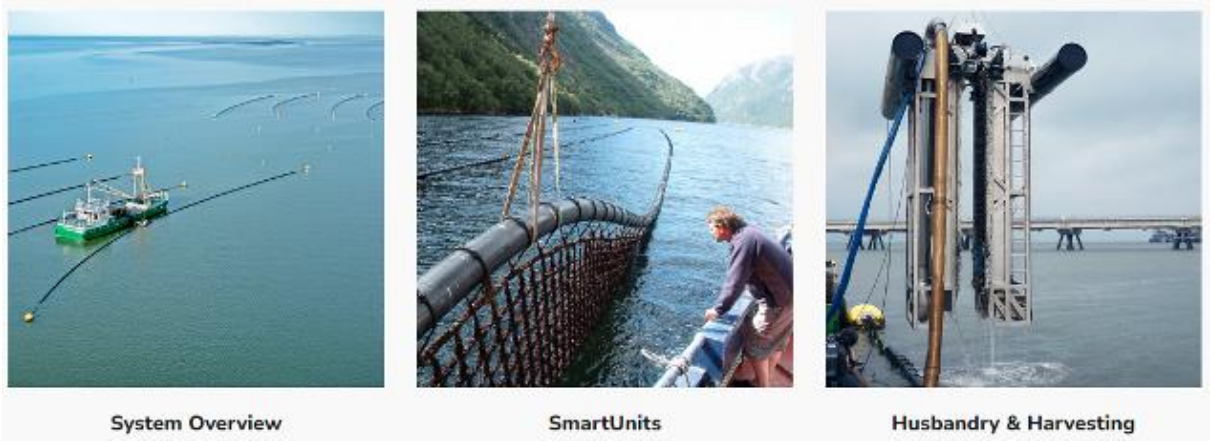

Figure 3. Photos of Smart Farms, retrieved from the website of Smart Farm AS.

2.3 Mussel processing

2.3.1 Declumping to deshelling

This step is considered to be the most difficult, costly and challenging. Various methods have been tested before (such as liquifying the meat by addition of enzymes, using the mussels as feed for black soldier fly larvae which are used for animal food) but today the most efficient and economic method is still he traditional cooking of mussels, which results in opening of the shells, followed by vigorous shaking (usually on a specially designed conveyer belt).

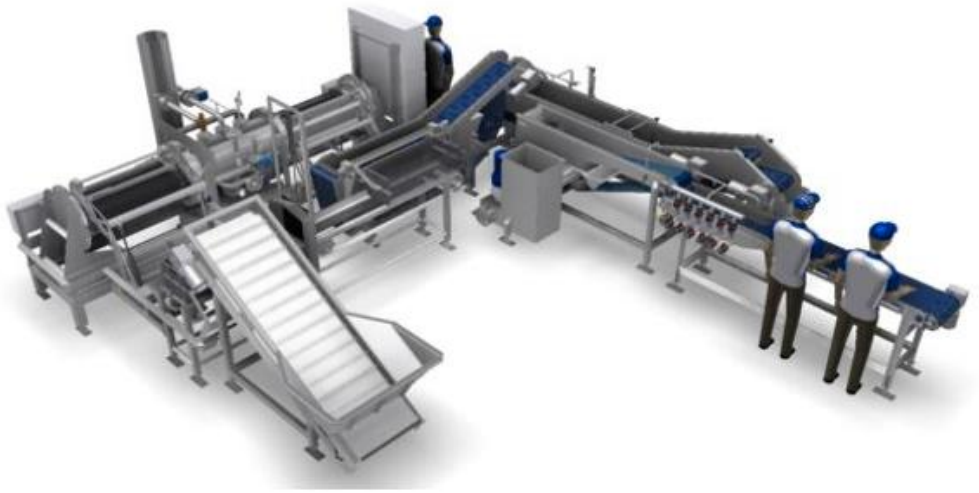

Figure 4. Schematic representation of a mussel processing chain according to the supplier Kramer (https://www.kramermachines.nl)

The mussels are fed into the process line by a Buffer-Dosing conveyor and are conveyed into the drum cleaner which declumps and cleans the mussels before entering the cooking line. The cleaned mussels are then transported to the pressure cooker where they are boiled and open their shells. The mussels are then shaken out of their shells by a passage over a shaker belt, while meat and shells are separated either by mechanical grading or by separation on the basis of the difference in density in a floatation tank.

2.3.2 Mussel meal

Many tests and surveys (Rasidi 2022, Weiss & Buck 2017; Steinberg et al. 2012) have shown that mussel meal is an equivalent replacement for fish meal. This holds particularly in the case of larger production, when variations in e.g., protein content can be equalised by mixing different fractions of the mussels in order to achieve a constant content. The process from a cooked mussel to mussel meals involves drying and grinding. There is commercially available equipment on the market. According to previous studies (CRM 2013), the material/processing costs are high, indicating that the material costs (i.e., the price of the mussels) are decisive for the profitability of the business. The required machinery consists of a dryer and a grinder.

2.3.3 Conservation and storage of mussels and mussel products

Fresh, living mussels can survive up to one week when kept in a cool place outside of the water (in which case they close their shells and minimise metabolism)

Frozen mussel meat can be stored for years without major deterioration of the valuable properties. However, freezing requires energy and space

Less space is required when **mussel meat** is **dried**, as the loss in water content decreases the volume by about 80%.

Grinding dried mussel meat results in **mussel meal** is shelf stable for several months in a dark and dry place. A gradual decay of unsaturated fatty acids limits the storage time to one year.

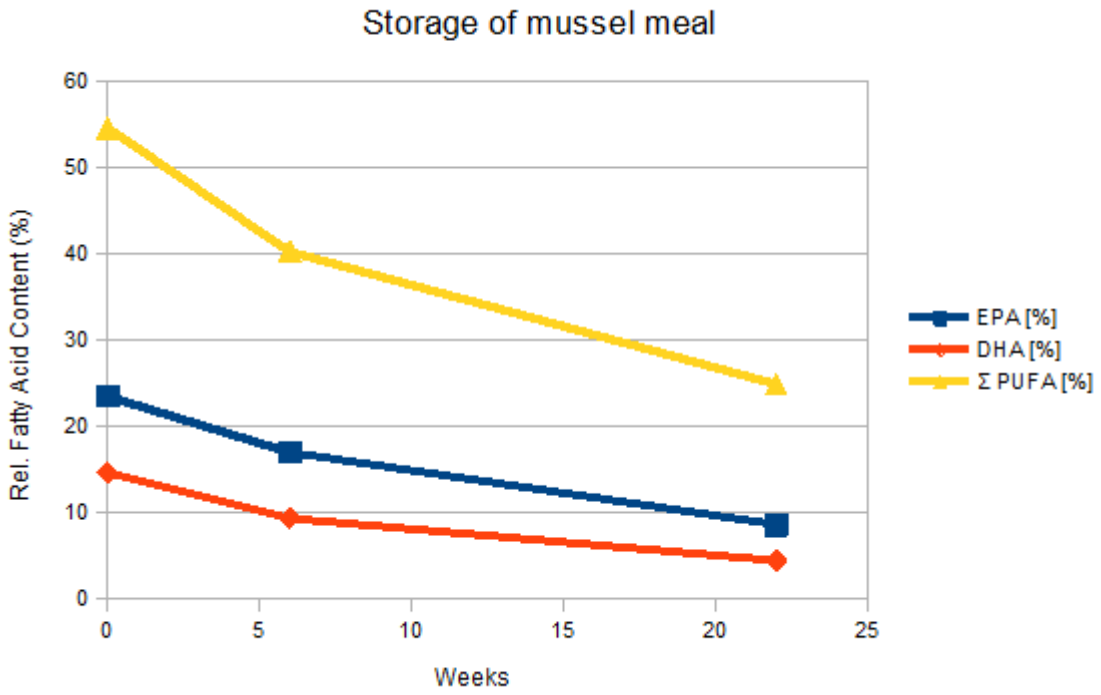

Figure 5. Shelf stability of unsaturated fatty acids in mussel meal (CRM 2013). The x-axis shows the time of stage in weeks, the y-axis indicates the relative fatty acid content of EPA, DHA and the sum of PUFAs.

3. COMPANY AND SECTOR STRUCTURE

To build a large-scale capacity for mussel production intended for feed, it is necessary to develop production (smart farms), maintenance and harvesting capacity, as well as transport and processing capacity, simultaneously. To reduce the costs of establishing maintenance and harvesting capacity, and to ensure a rapid build-up of mussel supply for the processing industry, collaboration between mussel producers is advisable.

For a profitable production site, a minimum volume (e.g. several 1000 tonnes per year, see chapter 6) is required, while an individual mussel farm plot is usually limited in size due to space limitations and environmental considerations. It can therefore be assumed that several farm plots are required to produce sufficiently for a medium to large-scale production of pet food. An additional advantage of the existence of a network of farm plots is that varying production of the individual farm plots caused by weather, predators, etc. (see chapter 7) can even out. As harvesting is a temporary activity, one harvesting unit (human resources and machinery) can serve several farms and the same holds for the transport of mussels. Therefore, a cooperation structure is required that optimises the use of capacity for each craft.

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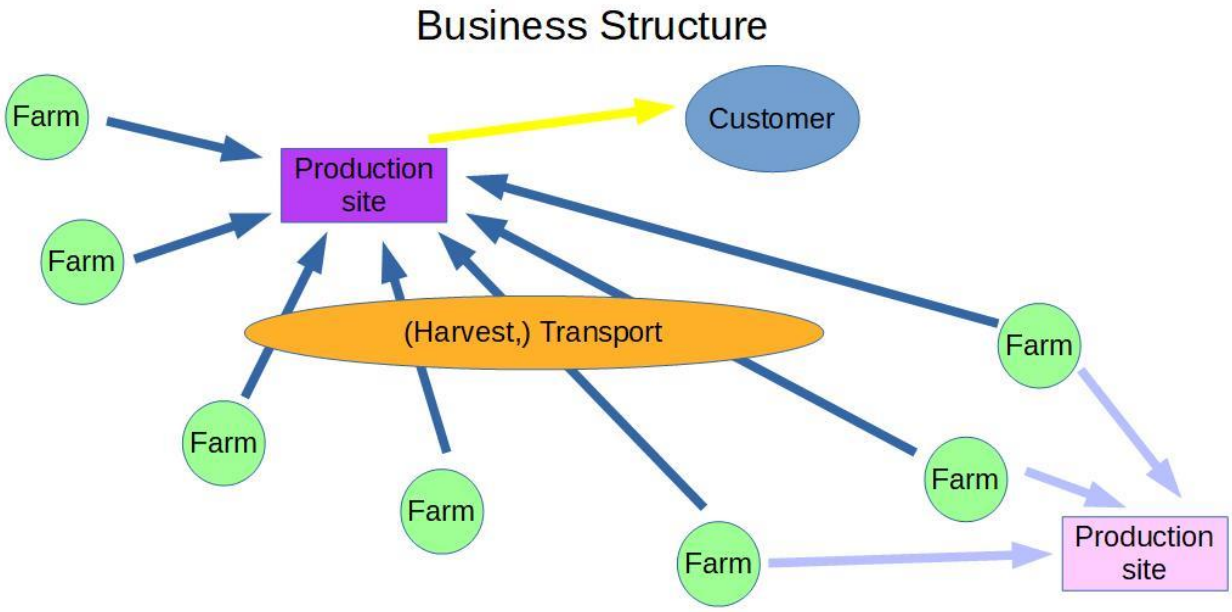

Figure 6. Scheme of structure of the sectors involved in mussel meal production. Depending on distances and capacities, additional processing sites can be integrated

Optimal ownership depends on the team and its qualifications. Different sectors and activities along the production line need to cooperate, and there are several ways for the organisation of this. We discuss here 2 different ownership models (centralised vs. decentralised), which represent the extremes of a field of organisational possibilities.

Centralised structure: The whole production chain from production at the mussel farm to the marketable product leaving the gate of the processing site is in one hand. The individual activities are performed by employees of this company.

Decentralised structure: The different sectors within the production chain act as individual and independent companies, e.g., one (or several) mussel farm companies, a harvest and transport company, and a mussel processing company.

There are various pros and cons to each of the structures: If the sectors are run by independent entities, the intrinsic motivation for each stakeholder is higher. However, there is the chance that an independent entity, which has run into economic difficulties, will eventually disappear – and could compromise the whole production chain in the long run.

Table 1. Pros (green) and cons (red) of centralised and decentralised sector structure

CENTRALISED	DECENTRALISED
Employee mindset	Entrepreneurial motivation
Shared risk	Farms might go bankrupt
Easy knowledge transfer	Limited knowledge transfer
Support for farms in case of problems	Problems in one entity could compromise the whole structure
Less Bureaucracy	Bureaucratic effort between companies

Nevertheless, we feel that the motivation is a paramount factor and tend towards the conclusion that a cooperation of several companies, each specialised in its specific field and with its own, intrinsic interest in success, is the preferred structure. We suggest that one or several farm companies, each with several farm plots, act as economic entities, while the centralised activities – harvesting, transport and processing- form another company. Possibly, harvesting and transport can also act economically independently. In Denmark, mussel farmers currently operate as relatively small units, all struggling to secure capital and generate profit in a challenging market. It is therefore not likely that mussel producers themselves will take the initiative to establish a centralised business that covers the entire value chain. Increasing fishmeal prices might lead to the development of closer cooperation between large fishmeal companies and mussel farmers.

The marketing team can be part of the processing company, but perhaps outsourcing is a more cost-efficient option.

4. THE PRODUCTS AND THEIR MARKETING

4.1 Benefits for customers

The mussel product is cheap, nutrient-rich, healthy and sustainably produced. It will be a stable and reliable resource less dependent on changing catch success and world market movements. The consumer will have a product of constant quality and will have the comfortable feeling that the product is not a burden to the environment.

4.2 Market analysis and competitors

It is apparent that customers of pet food like animals. Therefore, it should be a given that they are supportive of resources that cause less harm to the environment and to the well-being of sensitive animals.

A market analysis was performed on the basis of a literature review, a questionnaire and personal interviews.

4.2.1 Market development of the German pet industry – an overview

In 2023, the German pet industry continued its positive trend despite ongoing economic challenges. The stationary specialist trade and grocery retail sector recorded a total turnover of €5,616 billion, representing a year-on-year increase of 9.5%.

Within this figure:

- €4,495 billion was generated through the sale of prepared pet food,
- €1,121 billion came from pet supplies and accessories.

Additional revenue streams included:

- €1,316 billion from the online retail segment, and
- €161 million from the sale of wild bird feed.

Combining all distribution channels and product categories, the total market volume of the German pet industry in 2023 amounted to approximately €7.1 billion (*Source:* https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt).

The German pet food market is broadly segmented into five key product categories: dog food, cat food, ornamental bird food, ornamental fish food, and food for small mammals such as rabbits, guinea pigs, and hamsters.

Within this structure, the cat food segment consistently holds the largest share of the market, reflecting both the high number of domestic cats in Germany and the growing willingness of pet owners to invest in high-quality nutrition for their animals. The dog food segment ranks second in terms of market volume but also shows significant growth dynamics.

The graphic below illustrates the year-over-year increase in pet food sales in Germany over the period from 2019 to 2023. The data is based on the annual reports published by the Zentralverband Zoologischer Fachbetriebe Deutschlands e.V. (ZZF) and the Industrieverband Heimtierbedarf e.V. (IVH), two leading industry associations representing the German pet trade and pet supplies sector. According to these reports, the market for pet food in Germany experienced consistent and robust growth, with an average annual increase of approximately 8% compared to the previous year.

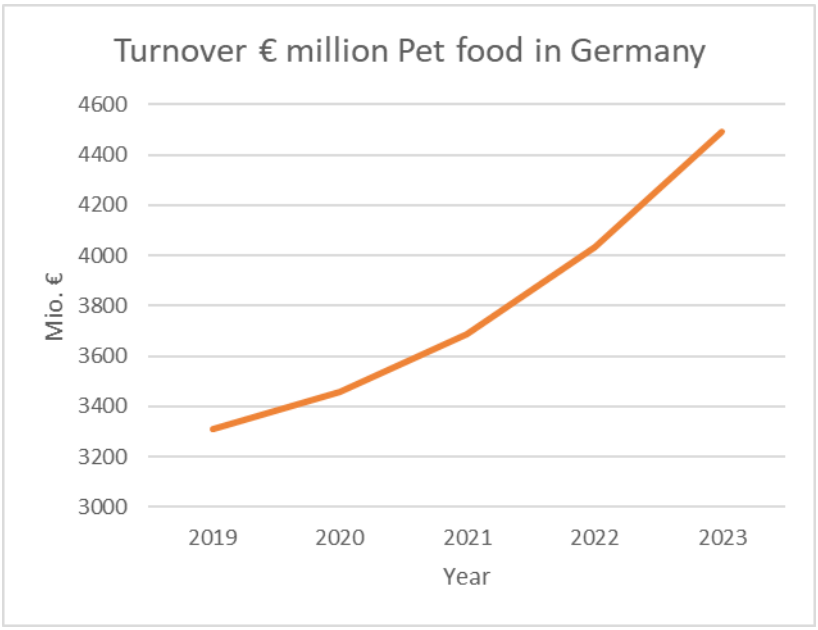

Figure 7. Turnover of pet food in Germany (in €).

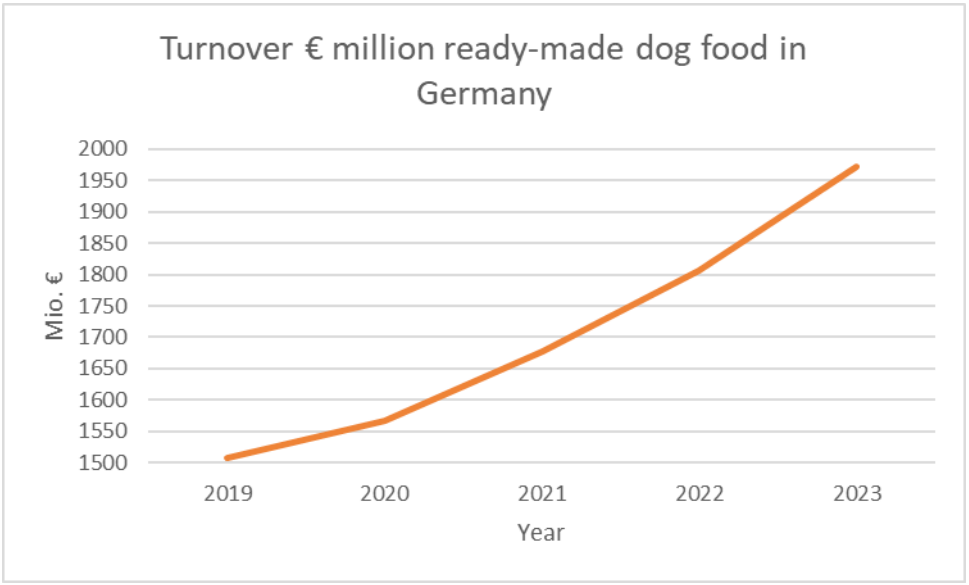

Figure 8. Turnover of dog food in Germany (in €).

An analysis of sales figures from 2019 to 2023 reveals a continuous and stable increase in revenue for dog food products. The average year-on-year percentage increase was approximately 7%. This upward trend underscores a sustained demand for both conventional and premium dog food options, driven by evolving consumer preferences, a rising focus on pet health and nutrition, and the ongoing humanisation of pets. The data suggests that the dog food market is not only resilient but also benefiting from long-term positive developments within the broader pet care industry. *(Source:* https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt*)*

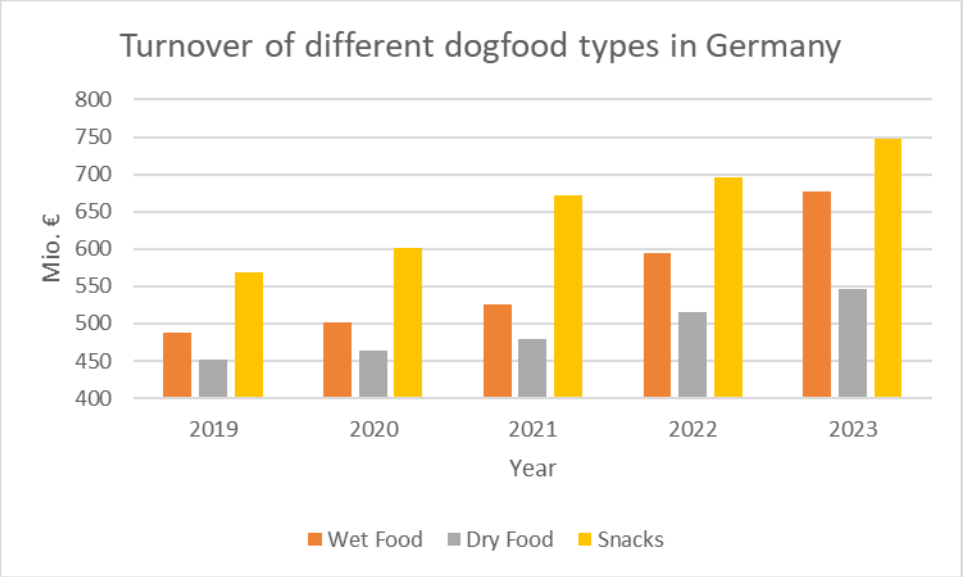

Figure 9. Turnover of various dog food types in Germany (in €).

The dog food segment can be further divided into three main product categories: wet food, dry food, and snacks. All three categories have shown positive sales growth in recent years.

Specifically, wet food experienced an average annual sales increase of 9%, while dry food grew by approximately 5% per year. The snacks category also saw a notable year-on-year growth of 7%. It is important to note, however, that snacks represent the highest-grossing category within the dog food segment, underlining their strong position in the market and the increasing trend of pet owners purchasing treats and functional snacks for their dogs.

(Source: https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt*).*

4.2.2 Summary of the results of a survey of German animal feed manufacturers

We developed a survey for German animal feed manufacturers. The questionnaire explores the potential use of mussel-based ingredients in pet food and is directed at companies within the animal feed industry. It begins by asking whether animal-based components, including fish, are currently used in their products, and in which categories (e.g., dog food, cat food, ornamental fish).

The core focus lies on whether respondents can envision incorporating a sustainably sourced mussel ingredient into their products and whether they would be willing to pay a premium for it. The survey also inquires about customer interest in sustainability, for instance, through questions about ingredient sourcing, and asks which quality criteria are considered most important for animal-based feed components (e.g., protein content, vitamins, calcium levels). Further questions address the preferred form of the mussel ingredient (e.g., powder, liquid, frozen pieces), the estimated purchase volume per year, and whether a higher calcium content would be acceptable.

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Finally, the questionnaire explores potential reservations or conditions for future use of mussel-based products, the market potential, and whether communicating the ecological benefits of sustainably farmed mussels would support product acceptance. Participants are also invited to provide additional comments or suggestions on the topic.

The survey was sent to twenty pet food producers by surface mail as well as by email. We had only three returns. All surveyed companies expressed a general openness to the use of mussel-based ingredients. Animal components, including fish, are already a regular part of their formulations, primarily in the production of dog and cat food. The idea of integrating a sustainable mussel-derived ingredient into future products was supported by all participants. Two of the three companies also indicated a willingness to pay a premium of between 15% and 50% for such ingredients. There was variation in the assessment of whether end customers are showing an increasing interest in sustainability. While one company reported observing this trend, the other two did not confirm such a development.

In terms of quality criteria for animal feed, clear priorities emerged: protein content, vitamins, amino acids, and trace elements were identified by all respondents as particularly important. Additional criteria, such as fat content, crude ash, crude fibre, or calcium levels, were considered relevant depending on the company.

Regarding the preferred form of mussel-based ingredients, two companies expressed interest in a dried powder, while one also showed interest in pureed and frozen variants. Estimated purchase volumes varied significantly—ranging from two to twenty tonnes per year—likely reflecting differences in company size and product portfolios.

An increased calcium content in the mussel product would be acceptable for two of the companies, with one explicitly stating an upper limit of 50%. The third company, however, rejected this option.

All participants viewed the ecological value of sustainably farmed mussels positively and would consider using them in feed products if they contributed to environmental benefits. It was also emphasised that transparent communication around sustainability, as well as improved consumer education, could enhance acceptance of such products. Two companies also identified a need for further research into health effects on pets as a key factor for future decisions.

Overall, the market readiness is viewed with cautious optimism: while specific timeframes were rarely provided, it became clear that niche products, with appropriate communication, could be implemented in the short term, whereas broader market penetration is expected to take several years.

In conclusion, the survey reveals clear potential for the use of sustainable mussel-based ingredients in pet food, driven by technical openness, differentiated market perspectives, and a strong emphasis on transparent communication.

4.2.3 Summary of interviews with pet food retailers

Surveyed companies were “Tierfutter Knutzen Kiel”, “BARF-Shop Kiel” and “Fressnapf Kiel”.

Knutzen responded as follows: Some customers occasionally express interest in alternative ingredients in pet food, particularly in dog food. In these cases, the focus is primarily on insect-based additives. A general trend toward sustainability, which was previously reflected in a greater willingness to pay higher prices, was clearly observable until around two years ago.

However, since the onset of inflationary pressures, this interest has noticeably declined. Nevertheless, there remains a fundamental openness to sustainable pet food and the integration of new and innovative feed components on the part of manufacturers.

BARF-Shop Kiel responded as follows: Current retail prices for frozen pet food range between €1.25 and €2.50 per 500 g, depending on the variety. (Beef blood represents the entry-level price at €1.25. Other common varieties include chicken, horse, turkey, rabbit, beef, rumen, and gullet meat—all offered in frozen form.)

There is no noticeable demand from customers for sustainable products in this segment. The use of mussel-based ingredients is generally considered a viable option. While sustainability is a relevant topic, it is clearly secondary to price considerations. For instance, the assortment includes an organic turkey ragout priced at €5.80 per 500 g, representing the upper price range.

In dried form, a mussel product would be especially attractive as a treat or snack. In this case, nutritional content is less important—taste and palatability are the deciding factors for customer acceptance. As a complete feed component, a frozen version would be appropriate. In this context, clear nutritional information and a well-communicated health benefit (e.g. for joints, coat, or immune system) would be essential. There are already whole, green-lipped mussels with shells available on the market, which are very well received by dogs—they are considered highly palatable and stimulating. For successful market integration, the mussel product should be either consistently available, ideally via wholesale, as is currently the case, or positioned as a seasonal highlight. A good example of this is dog ice cream in summer, which benefits from marketing strategies such as “Now available for a limited time only,” generating both attention and demand.

Fressnapf Kiel responded as follows: Purchasing is handled through the Fressnapf central office, which is generally open to new products. Regional items are included in the product range but require approval from the central office. One example is a cheese product for dogs from Schleswig-Holstein that was successfully listed. Individual stores are not authorised to make independent assortment decisions; all product listings and approvals are managed centrally. In the area of BARF (raw feeding) products, demand is steady but not particularly strong. Stores offer a freezer unit with various items, priced at €5.29 per kilo and €7.29 per kilo. Among these are shredded rabbit products packaged in plastic sausages.

Conclusion: The interviews reveal a general openness among retailers and manufacturers to sustainable and innovative ingredients like mussel-based components, despite a decline in consumer demand for sustainability due to inflation. While some customers show interest in alternative ingredients (e.g. insect-based), price remains the key decision factor. Mussel products are seen as viable, especially in dried form as treats, where taste matters more than nutritional value. For use as a complete feed, frozen formats would require clear nutritional

benefits. Two market strategies are considered promising: consistent availability via wholesale or seasonal product positioning (e.g. “limited time only”).

4.2.4 Summary of the interview with Tetra - the world’s leading ornamental fish food producer

There is a general interest in using mussel meal as a feed ingredient. However, clear quality and supply standards are essential for its integration into existing product lines. Most importantly, the product must offer consistent high quality, regardless of whether it originates from Germany, Denmark, Spain, or other countries.

A reliable and continuous supply is considered crucial. An annual purchase volume of up to 200 metric tonnes would be realistic, provided the product is approved for international markets, particularly in the EU, USA, and Russia. With regard to heavy metals, legal limits must be strictly observed and monitored. The specific regulatory frameworks of each country must be considered, with special attention to Russia, which has more stringent standards in some cases.

The product must also be microbiologically safe, meaning free from Salmonella and with low Enterococcus counts. In addition, it is recommended to include natural antioxidants, such as Vitamin E, in the formulation.

Key quality criteria for the product include:

- Protein content.
- Amino acid profile**.**
- Fatty acids, especially polyunsaturated types.
- Vitamins, with a focus **on** Vitamin K.
- Carotenoids as natural pigments and antioxidants.

A premium over fishmeal can be justified if supported by compelling arguments, particularly related to sustainability and ecosystem benefits. These elements provide strong marketing potential, especially in light of the shift away from fishmeal and the growing rejection of soy. Additionally, fish health is becoming an increasingly important issue, which could enable the use of health claims tied to fatty acid content, potentially even in combination with algae. A “bio” or organic certification is viewed positively, but not considered a decisive justification for a significantly higher price.

The price of mussel meal should be oriented toward the market price of fishmeal. A doubling of the price would likely be difficult to justify.

Product development for new feed formulations typically takes around one year. In the case of mussel meal, the development phase may be somewhat longer due to required testing. The product launch phase is estimated at around six months. The Interzoo trade fair is mentioned as a potential platform for product introduction.

The preferred product form is fine powder. Ideally, delivery would be made via silo trucks. Big bags are also acceptable; 20-kilo sacks are considered the least preferred option. Particle size is not critical for large-scale production, as the company is able to perform further grinding

internally. For small-scale or test batches, however, a particle size below 250 µm is required, as post-grinding is not possible. Approximately 200 kilos of mussel meal would be needed for initial testing.

Regarding calcium content, a distinction must be made: For fish feed, high calcium levels are undesirable, as they lower the overall protein content. In contrast, high calcium is beneficial for turtle feed. However, the company would not procure a single product for both species; in such cases, calcium would need to be supplied separately.

Concerning U.S. market approval, it is essential to verify whether the mussel species used (e.g., blue mussel) is included on the positive list for that market.

4.3 Marketing strategy: how to enter the market, how to reach the customers

Value proposition: The main value proposition is a good and healthy food for pets, e.g. dogs, cats, birds, rodents, ornamental fish, etc., that meets and exceeds requirements for nutritional value and health. The product is free of toxic substances and regulated in relation to food safety, it is well digestible and appetising, pelleted, shelf stable, traceable and can be applied according to need. It has a pleasant natural smell for pets and their masters. The product consists of natural ingredients only. The proteins are from sustainable sources, animal proteins are of marine origin, sustainably harvested and with a maximum of animal welfare. We stick to the word: “animal-friendly product for animals of animal lovers”. Most likely, price will not be the prime selling proposition, should the aim be not to exceed average prices of competitors by more than 20% (a surcharge of 20% is generally considered to be accepted by customers for trustworthy advantages for the environment and animal health).

Customers: We assume that people who have pets are animal lovers in general. Therefore, we see a main USP in the fact that all ingredients in the mussel-based pet food meet the highest standards, not only in the quality of the ingredients but also in animal welfare. Customers’ target group are environmental and animal welfare – conscious people.

Channels: A relatively small number of big chains (Fressnapf, Futterhaus, Zoo 24) accounts for the majority of the total turnover in the petfood sector in Germany. It will therefore be advised to start promotion events and activities there. BARF pet food (BARF = Biologically Appropriate Raw Food) is a fairly recent trend in Germany for organic and unprocessed animal food. Meanwhile, there is a multitude of shops that sell frozen meat and by-products of various animals (cow, pig, deer, duck, etc.).

4.4 Summary

There is considerable interest among producers and retailers in mussel products in pet food. No hesitation was found against using mussels as such. The sustainability aspects were well acknowledged, as well as potential health benefits. The price, however, is the most important factor for acceptance when exceeding niche markets and particularly responsible consumer groups.

5. FINANCE PLANNING: COSTS, REVENUES, CAPITAL DEMAND

In the following, we show cash flow examples of costs and revenues, calculated for increasing amounts of production. For the costs, we refer to offers from suppliers, market prices for raw products and the experience that exists within the Baltic MUPPETS consortium.

For the revenue we identified several product classes: Frozen fresh mussels (raw food), organic mussel meal, and side streams, consisting of mussel shells and for a - presently still price- and rewardless - environmental service. Revenues from sale of certificates for climate, nutrient extraction or biodiversity impact are not addressed, but may in the future be of importance; these types of revenues are dependent on political systems, and it is risky to take an investment with a depreciation profile for twenty years, as the political willingness can dry out.

The tables and graphs show the effect of upscaling and determine a minimum volume under which the production is simply futile. For the investments, we are calculating the depreciation over a timespan that has either been specified by the supplier or that is based on reasonable assumptions.

Staff costs are – as usual – high. In addition, they are particularly hard to estimate. Personal demand depends on the equipment used, or, rather, on the degree of automation of the equipment. Here is the most promising room to save on costs. Our estimates are intended to lean towards the conservative side.

5.1 Costs

In order to make the finance planning more transparent, we organise costs as they occur along the production chain. Each step adds on costs, and at each step some profit resp. salaries have to be generated.

Notwithstanding: The here estimated and calculated costs may differ according to salaries and specific local conditions (availability of infrastructure, boats, etc.) They should, nevertheless, give a realistic picture of the cost structure and the order of magnitude of expenses.

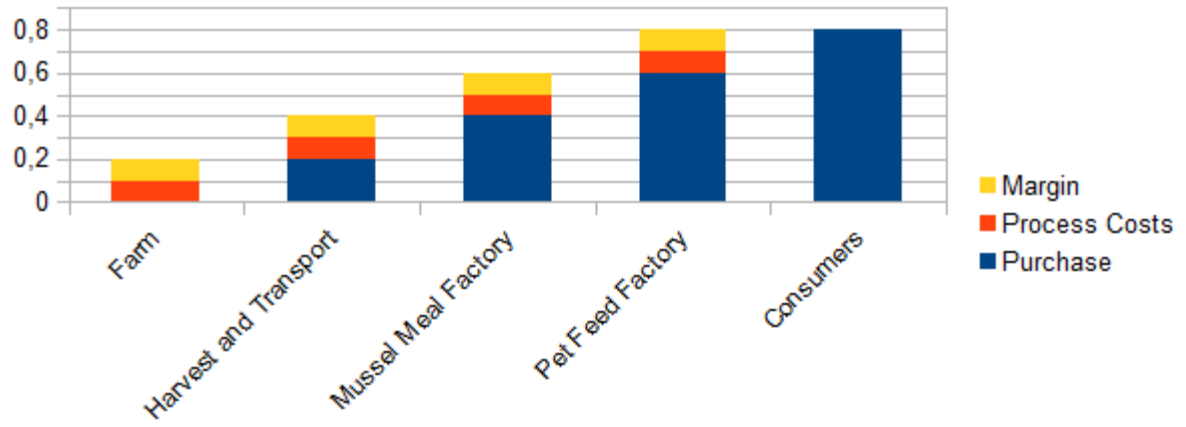

Figure 10. Costs along the production chain.

5.1.1 Costs of mussel farming

Costs for mussel farming arise from the following sectors: Investments in the farming equipment, staff costs and other generic costs. We assume that the farm operates with smart farming equipment. One smart farm unit – 120 meters of pipe and attached net with a depth of approximately 4 m, providing a length settling substrate of 6000 meters, costs €20,000. Required is also mooring equipment, the installation, marker buoys, and other items such as rope, shekels, etc. For working on the sea, a minimum of two people is required. The number of personnel depends on the size and production of the farm, see below.

General costs encompass rent for an office, telecommunication, insurance, mobility and other overhead categories. The following table shows the estimated costs of these categories.

Table 2. Costs of various categories in smart farming.

Item	Cost (€/unit)	Devaluation (1/y)
Material		
Farm units needed (20t/unit)		
Smart Farm units	20.000	15
Mooring and marker buys (€/unit)	5.250	15
Inspection boat		
Inspection boat(s) and dive equipm. (as	50.000	15
Fuel, insurance, repair etc.	~ 5 €/t prod.	
Personel		
CEO (per y)	70.000	
Worker (per y)	50.000	
Other		
Office (per y)	15.000	
Insurance	1.000	
Telecom	2.000	
Mobility	5.000	
Harvest		
Harvester (capacity 20.000t/y)	1.500.000	15
Fuel, insurance, repair etc.	~ 20 €/t prod.	
Staff (costs)	50.000	
Costs/kg fresh mussels		
Costs/kg without harvest		

In order to estimate a scaling effect, we calculate the costs per kilo of fresh mussels. It turns out that in a production range of more than 4,000 tonnes, the price per kilo of fresh mussels falls below €0.2.

Table 3. Costs of smart farm production for different production volumes.

Smart Farm Production (t/y)	10	20	40	100	200	400	600	800	1.000	1.500	2.000	2.750	4.000	10.000	20.000
Costs	**311.718**	**311.918**	**314.103**	**355.656**	**366.577**	**388.421**	**410.264**	**432.107**	**503.951**	**558.559**	**613.167**	**745.080**	**881.601**	**1.586.901**	**2.679.067**
Material	3.518	3.518	5.303	10.656	19.577	37.421	55.264	73.107	90.951	135.559	180.167	247.080	358.601	893.901	1.786.067
Farm units needed (20t/unit)	1,0	1	2	5	10	20	30	40	50	75	100	138	200	500	1.000
Smart Farm units	1.333	1.333	2.667	6.667	13.333	26.667	40.000	53.333	66.667	100.000	133.333	183.333	266.667	666.667	1.333.333
Mooring and marker buys (€/unit)	350	350	700	1.750	3.500	7.000	10.500	14.000	17.500	26.250	35.000	48.125	70.000	175.000	350.000
Inspection boat	4.433	4.433	4.533	4.833	5.333	6.333	7.333	8.333	12.667	15.167	17.667	21.417	27.667	71.000	161.000
Inspection boat(s) and dive equipm. (a	3.333	3.333	3.333	3.333	3.333	3.333	3.333	3.333	6.667	6.667	6.667	6.667	6.667	20.000	60.000
Fuel, insurance, repair etc.	1.100	1.100	1.200	1.500	2.000	3.000	4.000	5.000	6.000	8.500	11.000	14.750	21.000	51.000	101.000
Personel	85.000	85.000	85.000	120.000	120.000	120.000	120.000	120.000	170.000	170.000	170.000	170.000	170.000	220.000	220.000
CEO (per y)	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1	1	1
Worker (per y)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	2,0	2,0	2,0	2,0	2,0	3,0	3,0
Other	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000
Office (per y)	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Insurance	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Telecom	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Mobility	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Harvest	200.200	200.400	200.800	202.000	204.000	208.000	212.000	216.000	220.000	230.000	240.000	305.000	330.000	450.000	650.000
Harvester (capacity 20.000t/y)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Fuel, insurance, repair etc.	200	400	800	2.000	4.000	8.000	12.000	16.000	20.000	30.000	40.000	55.000	80.000	200.000	400.000
Staff (number)	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3
Staff (costs)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	150.000	150.000	150.000	150.000
Costs/kg fresh mussels	**31,62**	**15,60**	**7,85**	**3,56**	**1,83**	**0,97**	**0,68**	**0,54**	**0,50**	**0,37**	**0,31**	**0,27**	**0,22**	**0,16**	**0,13**
Costs/kg without harvest	*11,60*	*5,80*	*2,95*	*1,58*	*0,84*	*0,47*	*0,34*	*0,28*	*0,30*	*0,23*	*0,20*	*0,17*	*0,14*	*0,12*	*0,11*

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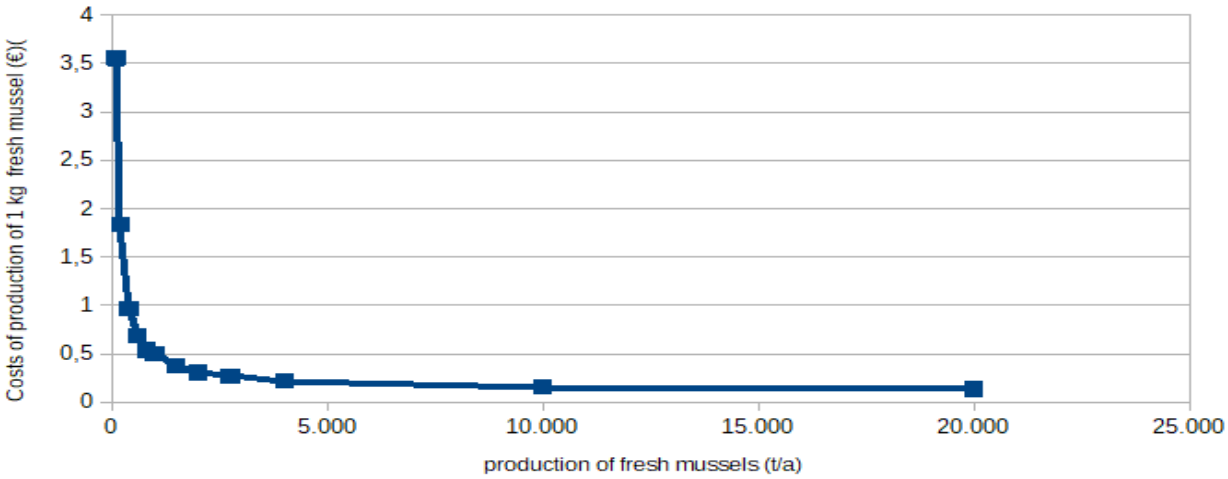

Figure 11. Upscaling effect of costs to produce 1 kilo of fresh mussels from 100 to 20,000 tonnes.

5.1.2 Costs for mussel transport

Prices for cooling transport fall in a range of 550€ basic price plus 30€/tonnes per 100 kilometres, adding another approx. 0.03 € / kilo fresh mussels.

5.1.3 Costs that occur in the processing facility

The costs as well as the revenues of the processing facility fall into the categories:

1. Building.
2. Technical installation.
3. Office.
4. Personal.
5. Marginal costs (mussel acquisition, brine salt, chemicals for cleaning, repairs and spare parts, controllers, alarm service, pest control, etc.).

Table 4. Costs of various categories in mussel processing

Costs	Costs	Deval. (y)
Building		
Under roof / required area	0.1 m^2/ t prod.	m^2
Under roof /costs	120	€/m^2
Outside space required	0.1 m^2/ t prod.	
Outside space / costs	60	€/m^2
Energy	0,01	
Mashinery		
Washer/Declumper (32500€, 5 years)	32.500	5
Steam Generator (41544€, 3 years)	41.544	3
Boiler, Rest of process line (157,356€, 3 years)	157.356	3
Chemicals, repaires, spare parts, etc. (0.9 €/t)	0,9	€/t prod.
Personel		
CEO costs	70.000	per y
Technician costs	50.000	per y
Office		
Office rent (15.000 €/y)	15.000	per y
Heating, Electricity, water etc. (2500 €/y)	2.500	per y
Telecom(2000€/y)	2.000	per y
Mobility (5000 €/y)	5.000	per y
Insurance (1000 €/y)	1.000	per y

For the building, we assume a space under the roof, as well as an approximately equally large space outside for parking, delivery, and cleaning treatment if required. The specific space requirements depend on the assumed production volume unit. In order to estimate a realistic production scale, we estimate costs for a range of 10 to 20,000 tonnes of fresh mussels. As always, we refer to publicly available figures and always lean toward a more conservative side. Any discount or cheaper versions will increase the profitability of the business.

Table 5. Costs of mussel processing for different production volumes

Production (t fresh mussels/y)	10	20	40	100	200	400	600	800	1.000	1.500	2.000	2.750	4.000	10.000	20.000
Costs	**262.859**	**262.918**	**263.036**	**263.390**	**298.980**	**300.160**	**355.340**	**355.520**	**378.200**	**381.150**	**393.850**	**409.025**	**438.400**	**714.500**	**1.008.500**
Building	**19550**	**19600**	**19700**	**20000**	**20500**	**21500**	**21500**	**21500**	**44000**	**46500**	**58750**	**72250**	**98000**	**245000**	**490000**
Under roof / required area	100	100	100	100	100	100	100	100	200	200	250	300	400	1000	2000
Under roof /costs	12000	12000	12000	12000	12000	12000	12000	12000	24000	24000	30000	36000	48000	120000	240000
Outside space	100	100	100	100	100	100	100	100	200	200	250	300	400	1000	2000
Outside space / costs	6000	6000	6000	6000	6000	6000	6000	6000	12000	12000	15000	18000	24000	60000	120000
Energy	50	100	200	500	1000	2000	2000	2000	5000	7500	10000	13750	20000	50000	100000
Rent	1500	1500	1500	1500	1500	1500	1500	1500	3000	3000	3750	4500	6000	15000	30000
Mashinery	**72809**	**72818**	**72836**	**72890**	**72980**	**73160**	**73340**	**73520**	**73700**	**74150**	**74600**	**76275**	**79900**	**154000**	**203000**
Washer/Declumper (32500€, 5 years)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	7500	10000	20000	40000
Steam Generator (41544€, 3 years)	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	50000	70000
Boiler, Rest of process line (157,356€, 3 years)	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	75000	75000
Chemicals, repaires, spare parts, etc. (0.9 €/t)	9	18	36	90	180	360	540	720	900	1350	1800	2475	3600	9000	18000
Personel	**145000**	**145000**	**145000**	**145000**	**180000**	**180000**	**235000**	**235000**	**235000**	**235000**	**235000**	**235000**	**235000**	**290000**	**290000**
CEO	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1	1
CEO costs	35000	35000	35000	35000	70000	70000	70000	70000	70000	70000	70000	70000	70000	70000	70000
Technician number	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4
Technician costs	110000	110000	110000	110000	110000	110000	165000	165000	165000	165000	165000	165000	165000	220000	220000
Office	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**
Office rent (15,000 €/y)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Heating, Electricity, water etc. (2500 €/y)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Telecom(2000€/y)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mobility (5000 €/y)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Insurance (1000 €/y)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Costs €/kg fresh mussels	**26,29**	**13,15**	**6,58**	**2,63**	**1,49**	**0,75**	**0,59**	**0,44**	**0,38**	**0,25**	**0,20**	**0,15**	**0,11**	**0,07**	**0,05**

The building must provide space for the production chain, consisting of feeder, washer/declumper, boiler and shaker belt, but also storage space for frozen and/or dried products, an office space, bathroom(s) and kitchen, a social room, etc. We assume costs for office and administration to be €25,500 per year.

Marginal costs (excluding the purchase of the mussels) consists of various materials such as brine salt, chemicals for cleaning, repair and spare parts, controllers, alarm service, pest control etc, energy, costs for the building (rent), the technical installations (washer/declumper, steam generator, boiler, rest of process line (shaker belt), staff costs (technician, CEO), costs for the office (rent, heating, electricity, water), insurance, telecommunication and mobility.

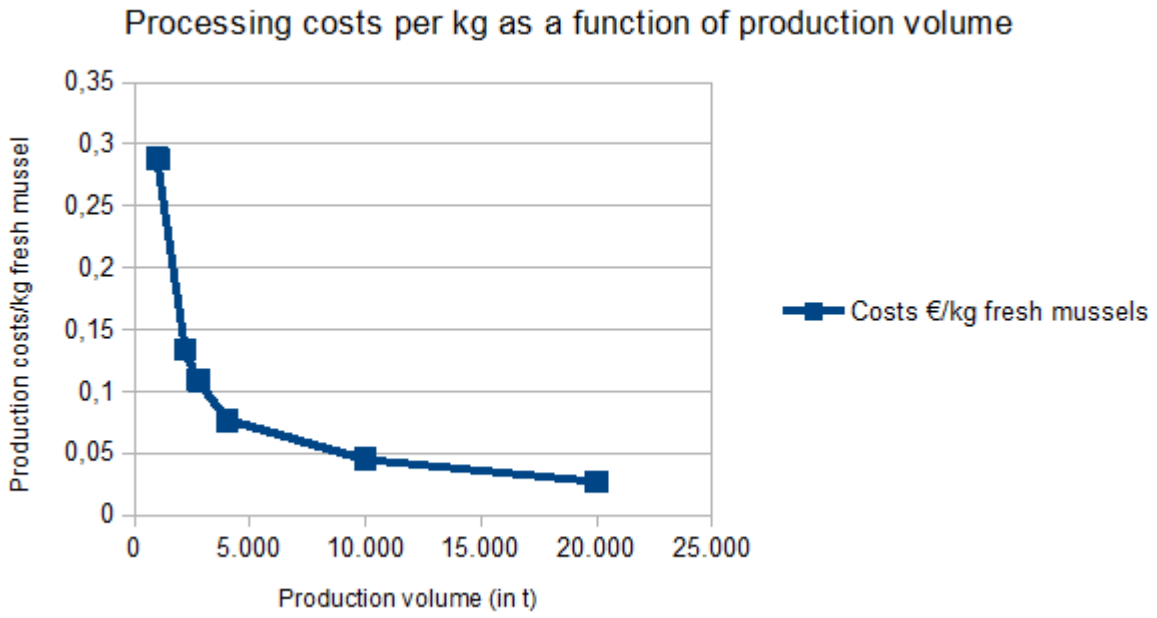

Figure 12. Mussel processing costs from fresh mussels to mussel meal as a function of production volume.

5.1.4 Combined costs- production of deshelled mussel meat

In the following, an overview of total costs from mussel production in a farm, through harvest, transport and processing, including declumping, deshelling, separation, drying and grinding, is presented. The calculation is based on a stand-alone production. If undersized mussels are collected during the thinning process, part of the farming costs are reduced to some extent (roughly 50%). It becomes very apparent that the costs decrease drastically when production increases.

In the next chapter, some light will be shed on potential revenues. It should be mentioned here already that the mass of mussels harvested does not equal the mass of any processed mussel product, due to the water and shell content of fresh mussels.

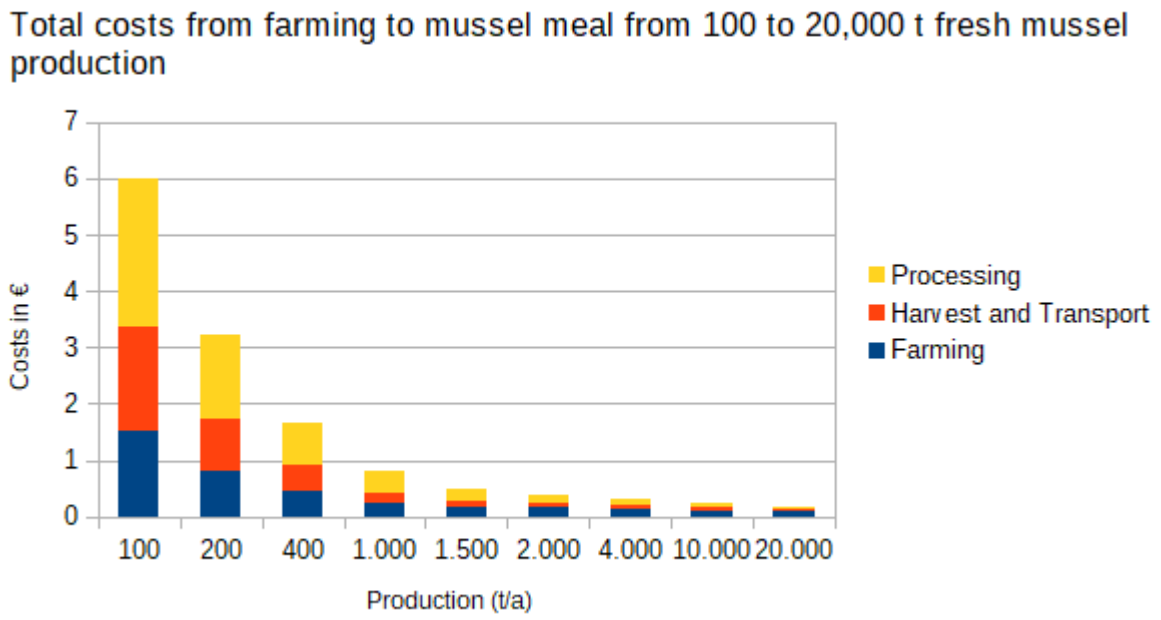

Figure 13. Total costs per kilo fresh mussel from 100 to 20,000 tonnes production per year.

5.2 Revenues and profit

We consider here the production of mini mussels as an add-on to the core business of a mussel farm in the western part of the Baltic Sea, which is the production of mussels for human consumption. Therefore, the use of small mussels is not essential for the farm but might provide an additional income. We therefore set the farming costs of the mini mussels to zero, and, as they are harvested together with the big mussels, the harvest and transport costs are an additional 50% of the costs for the big mussels.

On this base we estimate potential revenues for various products generated on the basis of small mussels, and an estimate for which, and in what order of magnitude, this additional production is profitable.

The profit of a business is the difference between the revenue, or sales, of a good, and the costs invested to produce the particular good. As has been shown in the section above, upscaling plays a major role as it decreases the costs per unit considerably. However, we have to keep in mind that the capacity of the European market to absorb these products has limits.

For the revenue we identified – and partially developed within the Muppets project - several products:

- Mussel meal as a replacement for conventional fish meal.
- Organic mussel meal.
- Pond fish feed from freeze-dried mussel meat.
- Dried mussel meat dried for chicken (as mealworms or black soldier fly substitute).
- Hobby chicken feed (cooked and dried, including shell).

- Sustainable Baltic mussel shells as food additive for chicken.
- Raw mussel meat frozen (“BARF”).
- Dog/cat food production in Sweden (Ecopelag).
- Dog/cat food own production in Germany (KMF / CAU).
- Fertiliser (dry and ground).
- Environmental services.

The profits estimated here are calculated on the basis of production costs and average market price; they do not encompass marketing activities or margins of intermediaries, which account for roughly 30% of the selling price.

5.2.1 Mussel meal

Mussel meal has proven to have almost identical composition as fish meal (Weiss and Buck 2017, Steinberg 2011, Rasidi 2022) and can thus be a sustainable substitute for the conventional fish meal, which to a large part still stems from traditional (and unsustainable) fisheries. According to the FAO (2024), about 15 million tonnes of fish are converted into fish meal annually.

Therefore, mussel meal has to compete with fishmeal in price. We defined two fractions of fish meal, which only differ in the price, one in the price range of the world market of fish meal, and the other with a surcharge of 50% for organic production. As the absorption of the world market is almost unlimited, for the organic market, we assume a capacity of 500 tonnes in the Northern and Western part of Europe.

A similar table as above reveals that even at a high production (of 10,000 tonnes of fresh mussels per year) and a relatively high price of €2.70 per kilo product will not be profitable. The reason is that a multitude (factor 15.5) of fresh mussel biomass is needed to produce the dry mussel meal. Only approx. 40% off a cooked Baltic mussel consists of meat, which is not completely extractable from the shells, as part of the adductor muscle tends to stick to the shell. The drying process reduces the weight of the meat by another 80 %, so that at the end, 15.6 kilos of fresh mussels are needed in order to produce one kilo of mussel meal. The processing (cooking, deshelling, drying, grinding adds more costs (see above) and adds even more costs. There is a slight chance that selling “organic” mussel meal in large quantities might be profitable.

Table 6. Costs and profits of dry mussel meal.

Mussel meal		„Conventional“ mussel meal	„Organic“ mussel meal
Market capacity (t/y)		100.000	500
Equivalent fresh mussels (t/y)		1.562.500	7.813
Factor (kg fresh mussel / kg product)		15,6	15,6
Market price of product (€/kg)		1,80	2,70
Price range (€)			
Production 400 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,26	0,26
	Processing costs fresh to meat(in €)	0,71	0,71
	Processing costs meat to meal (in €)	0,36	0,36
	Sum costs kg mussels (in €)	1,32	1,32
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	20,70	20,70
	Profit (in € per kg product)	***-18,90***	***-18,00***
Production 2750 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,04	0,04
	Processing costs fresh to meat(in €)	0,14	0,14
	Processing costs meat to meal (in €)	0,11	0,11
	Sum costs kg mussels (in €)	0,29	0,29
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	4,50	4,50
	Profit (in € per kg product)	***-2,70***	***-1,80***
Production 10000 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,02	0,02
	Processing costs fresh to meat(in €)	0,07	0,07
	Processing costs meat to meal (in €)	0,06	0,06
	Sum costs kg mussels (in €)	0,15	0,15
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	2,34	2,34
	Profit (in € per kg product)	***-0,54***	***0,36***

5.2.2 Pond fish feed

An interesting consumer segment that has been identified is operators of fishponds for private or part-time fish keepers. Since the market price for food is rather high (€5 -€15 per kilo) we see a good chance for a profitable product when mussel production reaches about 1,000 tonnes annually. The main part of the food consists of deshelled and processed mussel meat,

an extra of 1.50 per kilo of food has been estimated for other ingredients such as vitamins, etc.

Table 7. Costs and profits of dry mussel meal

Fish pond feed from dried mussel meat		
Market capacity (t/y)		200
Equivalent fresh mussels (t/y)		1.563
Factor (kg fresh mussel / kg product)		7,8
Market price of product (€/kg)		10
Price range (€)		5,00 -15,00
Production 400 t / year	Farm costs (in €)	0,00
	Harvest and Transport costs (in €)	0,26
	Processing costs fresh to meat(in €)	0,71
	Processing costs meat to dried meat (in €)	0,36
	Sum costs kg mussels (in €)	1,32
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	11,85
	Profit (in € per kg product)	***-1,85***
Production 2750 t / year	Farm costs (in €)	0,00
	Harvest and Transport costs (in €)	0,04
	Processing costs fresh to meat(in €)	0,14
	Processing costs meat to dried meat (in €)	0,11
	Sum costs kg mussels (in €)	0,29
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	3,75
	Profit (in € per kg product)	***6,25***
Production 10000 t / year	Farm costs (in €)	0,00
	Harvest and Transport costs (in €)	0,02
	Processing costs fresh to meat(in €)	0,07
	Processing costs meat to dried meat (in €)	0,06
	Sum costs kg mussels (in €)	0,15
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	2,67
	Profit (in € per kg product)	***7,33***

5.2.3 Chicken food, and chicken food additives

Private chicken farming in the backyard is getting increasingly popular in Europe; according to German law, for instance, between 3 and 20 chickens (and one rooster) can be kept in a private backyard. Chickens need feed, and especially a source of chalk in order to produce the shells of the eggs. In Baltic MUPPETS, we identified 3 types of food resp. food additives for chicken:

1. Ground and dried mussel meat as a replacement for mealworms or black soldier fly larvae

2. Cooked, dried and ground whole mussels. These provide 100% of the required calcium, about 42% of the required protein, and 17% of the required fat. The rest has to be added from other sources, we estimate a price of 1.00 € additional costs per kilo product for the supplementary ingredients (corn, maize, gluten, plant-based proteins, fat, vitamins, spore elements and appetisers)
3. Ground shells as chalk (calcium carbonate) addition to other chicken feed

The cost/revenue table shown in the next table reveals that a production above 1000 tonnes of fresh mussels can be profitable, particularly in the case of dried meat as a substitute for other animal protein sources. A particular advantage is given in the fact that dried mussel meat can be combined with the sale of the remaining shells, which would result in a profit of more than 5.00 € per kilo of fresh mussel produced.

5.2.4 Dog/cat food

Three different product options have been developed and discussed during Baltic MUPPETS:

1. A raw food, consisting of pre-boiled mussel meat. Raw dog food is a significant trend in Germany. Sources are various animal products (beef, rabbit, pork, different kinds of birds, deer, etc. Market research (see above) has indicated that mussels are an interesting material provided that the costs are comparable to other sources. The only process steps required in order to produce raw dog (or cat) food are freezing the meat afterwards.
2. Ecopelag, as well as a consortium of Kieler Meeresfarm (KMF) and the University of Kiel (CAU), has developed a dog food recipe. The experience of Ecopelag who started developing dog food recipes in 2024, shows that costs and revenue for the production of wet and dry food differ considerably. Selling prices of dry feed range from 150 to 400 SEK per kilo (€15 to €40 per kilo), for wet feed between 100 and 250 SEK (€15 to €25 per kilo). The loss of mass during the drying process and the additional energy and equipment costs for drying render the production of dry food less promising; emphasis is laid upon further development of wet food, both for dogs and cats.
3. An interesting product with a very high profit is a dog treat also developed by Ecopelag in Sweden. These dog snacks are produced from dried mussel meat only and sold in small units for a relatively high price. The extent of the market is yet to be found out. Further information on this product is given in Annex 2, business planning for the Central Baltic.

Table 8. Costs and profits of dry mussel meal.

Chicken food on the base of blue mussels		Dried mussel meat for chicken	Chicken feed (cocked and dried, including shell)	Mussels shells as chicken food additive	Dried mussels shells as side stream product
Market capacity (t/y)		500	500	10.000	10.000
Equivalent fresh mussels (t/y)		7.813	605	30.000	30.000
Factor (kg fresh mussel / kg product)		15,6	1,2	3,0	3,0
Market price of product (€/kg)		7,50	1,50	2,00	2,00
Price range (€)		5,00 – 10,00	2,00 – 3,00	1,00	1,00
Production 400 t / year	Farm costs (in €)	0,00	0,00	0,00	0,00
	Harvest and Transport costs (in €)	0,26	0,26	0,26	0,00
	Processing costs fresh to meat(in €)	0,71	0,71	0,71	0,00
	Processing costs meat to dried meat (in €)	0,36	0,36	0,36	0,36
	Sum costs kg mussels (in €)	1,32	1,32	1,32	0,36
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	20,70	1,60	3,97	1,07
	Profit (in € per kg product)	***-13,20***	***-0,10***	***-1,97***	***0,93***
Production 2750 t / year	Farm costs (in €)	0,00	0,00	0,00	0,00
	Harvest and Transport costs (in €)	0,04	0,04	0,04	0,00
	Processing costs fresh to meat(in €)	0,14	0,14	0,14	0,00
	Processing costs meat to dried meat (in €)	0,11	0,11	0,11	0,11
	Sum costs kg mussels (in €)	0,29	0,29	0,29	0,11
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	4,50	0,35	0,86	0,32
	Profit (in € per kg product)	***3,00***	***1,15***	***1,14***	***1,68***
Production 10000 t / year	Farm costs (in €)	0,00	0,00	0,00	0,00
	Harvest and Transport costs (in €)	0,02	0,02	0,02	0,00
	Processing costs fresh to meat(in €)	0,07	0,07	0,07	0,00
	Processing costs meat to dried meat (in €)	0,06	0,06	0,06	0,06
	Sum costs kg mussels (in €)	0,15	0,15	0,15	0,06
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	2,34	0,18	0,45	0,19
	Profit (in € per kg product)	***5,16***	***1,32***	***1,55***	***1,81***

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Table 9. Costs and profits of dog resp. cat food.

Dog / cat food		Raw mussel meat („BARF“)	Dog / cat food (recipe CAU)
Market capacity (t/y)		500	500
Equivalent fresh mussels (t/y)		1.563	3.906
Factor (kg fresh mussel / kg product)		3,1	7,8
Market price of product (€/kg)		2,00	5,00
Price range (€)			
Production 400 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,26	0,26
	Processing costs fresh to meat(in €)	0,71	0,71
	Processing costs meat to dried meat (in €)		0,36
	Sum costs kg mussels (in €)	0,97	1,32
	Additional costs (€/kg product)	0,00	1,50
	Sum costs kg product (in €)	3,02	11,85
	Profit (in € per kg product)	***-1,02***	***-6,85***
Production 2750 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,04	0,04
	Processing costs fresh to meat(in €)	0,14	0,14
	Processing costs meat to dried meat (in €)		0,11
	Sum costs kg mussels (in €)	0,18	0,29
	Additional costs (€/kg product)	0,00	1,50
	Sum costs kg product (in €)	0,57	3,75
	Profit (in € per kg product)	***1,43***	***1,25***
Production 10000 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,02	0,02
	Processing costs fresh to meat(in €)	0,07	0,07
	Processing costs meat to dried meat (in €)		0,06
	Sum costs kg mussels (in €)	0,09	0,15
	Additional costs (€/kg product)	0,00	1,50
	Sum costs kg product (in €)	0,27	2,67
	Profit (in € per kg product)	***1,73***	***2,33***

5.2.5 Fertilizer/soil improvement

Fertiliser is another product that has successfully been tested in Sweden, in a cooperation between Ecopelag and the company Grobruket. First experience with soil improvement shows promising results. Mainly, the shells are used, which are sold for approximately SEK 23 per kilo (€2.30 per kilo). Soil improvement: The shells that are separated during cooking will primarily be used for soil improvement. The 24,000 kilos are estimated to be sold for approximately SEK 23 per kilo (price adjusted for the cost of complementary ingredients) and thus generate SEK 575,000.

Table 10. Costs and profits of mussel-based soil improvement.

Ferztilizer (dry and ground)		Fertilizer whole mussel	Shells for soil improvement as by product
Market capacity (t/y)		1.000	1.000
Equivalent fresh mussels (t/y)		2.419	3.000
Factor (kg fresh mussel / kg product)		2,4	3,0
Market price of product (€/kg)		2,00	2,30
Price range (€)		1,50 – 7,50	
Production 400 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,26	0,00
	Processing costs fresh to meat(in €)	0,71	0,00
	Processing costs meat to dried meat (in €)	0,36	0,36
	Sum costs kg mussels (in €)	1,32	0,36
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	3,21	1,07
	Profit (in € per kg product)	***-1,21***	***1,23***
Production 2750 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,04	0,00
	Processing costs fresh to meat(in €)	0,14	0,00
	Processing costs meat to dried meat (in €)	0,11	0,11
	Sum costs kg mussels (in €)	0,29	0,11
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	0,70	0,32
	Profit (in € per kg product)	***1,30***	***1,98***
Production 10000 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,02	0,00
	Processing costs fresh to meat(in €)	0,07	0,00
	Processing costs meat to dried meat (in €)	0,06	0,06
	Sum costs kg mussels (in €)	0,15	0,06
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	0,36	0,19
	Profit (in € per kg product)	***1,64***	***2,11***

5.2.6. Environmental services

A scheme for financial compensation for environmental services is not in force for the time being. In some locations, there seem to be compensation efforts, but only voluntarily. Several attempts for a compulsory compensation scheme have been made and are still in development. However, at present, there is a lack of political will.

According to a study of Mewes (2012), about €20 needs to be invested for the extraction from water resp. The avoidance of input into a water body per kilo of nitrogen. The average content of nitrogen in a fresh mussel is 1% (weight). We therefore calculate a compensation price of €0.20 per kilo fresh mussels produced, which, if adequately compensated, would mean an extra benefit of €0.20 per kilo harvested mussel without any additional effort.

It turns out that, based on €0.20 per kilo mussels, respectively €20 per kilo nitrogen extracted, mussel farming only for this purpose turns out not to be economically viable. However, an existing compensation scheme for nutrient retention provided, the farming of mussels would create an extra income of (in this example) €0.20 per kilo fresh mussels harvested, without any further required activity other than recording and verifying. These €0.20 could make a difference in the business case.

Table 11. Costs and profits of mussel farming as an environmental service.

Environmental services		**Nutrient uptake**	**Nutrient uptake additional (side stream)**
Market capacity (t/y)		10.000	10.000
Equivalent fresh mussels (t/y)		1.000.000	1.000.000
Factor (kg fresh mussel / kg product)		100	100
Market price of product (€/kg)		20,00	20,00
Price range (€)			
Production 400 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,26	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat (in €)	0,00	0,00
	Sum costs kg mussels (in €)	0,26	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	25,50	0,00
	Profit (in € per kg product)	***-5,50***	***20,00***
Production 2750 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,04	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat (in €)	0,00	0,00
	Sum costs kg mussels (in €)	0,04	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	3,92	0,00
	Profit (in € per kg product)	***16,08***	***20,00***
Production 10000 t / year	Farm costs (in €)	0,00	0,00
	Harvest and Transport costs (in €)	0,02	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat (in €)	0,00	0,00
	Sum costs kg mussels (in €)	0,02	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	1,51	0,00
	Profit (in € per kg product)	***18,49***	***20,00***

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5.2.7 Summary of revenue and profit

Considering the costs to produce the various products, it becomes apparent that the use of small mussels is profitable when produced in larger quantities (way above 1000 t fresh mussels/year) and as an ingredient in pet food in a fairly high-priced sector. Particularly, food for fish in private fishponds, as well as hobby chicken husbandry, seem to be economically interesting.

The following table shows the profit (both per kilo product and per kilo mussels) of the eight most promising mussel-based products for the pet food market. For a more realistic picture, we subtracted 30% of the profit for marketing efforts or provisions for intermediates.

Table 12. Promising mussel-based pet food products.

Product	**Assumed market capacity (t/a)**	**Factor**	**Profit**			**Profit**		
			(€/kg product)			**(€/kg mussel)**		
Mussel production			*400 t/a*	*2,750 t/a*	*10,000 t/a*	*400 t/a*	*2,750 t/a*	*10,000 t/a*
Fish pond feed from dried mussel meat	200	7,8	-1,3	4,38	5,13	-0,17	0,56	0,66
Dried mussel meat for chicken	500	15,6	-9,24	2,1	3,61	-0,59	0,13	0,23
Dog / cat food (recipe CAU)	500	7,8	-4,8	0,88	1,63	-0,61	0,11	0,21
Dog / cat food (recipe CAU)	1.000	3	0,86	1,39	1,48	0,29	0,46	0,49
Raw mussel meat („BARF“)	500	3,1	-0,71	1	1,21	-0,23	0,32	0,39
Fertilizer whole mussel	1.000	2,4	-0,85	0,91	1,15	-0,35	0,38	0,48
Mussels shells as chicken food additive	10.000	3	-1,38	0,8	1,09	-0,46	0,27	0,36
Chicken feed (cocked and dried, including shell)	500	1,2	-0,07	0,81	0,92	-0,06	0,67	0,77

6. RISK ASSESSMENT (BEST-CASE VS. WORST-CASE SCENARIOS)

Risks exist in the form of environmental risks, technical risks, societal risks and economic risks. Each of these risk categories will be described in some detail below, and possibilities for mitigation are discussed.

6.1 Environmental risks

- Harsh weather has the potential to physically destroy the farm and moorings. Events like this occur often, and presumably even more so as the climate changes. Mitigation is investing in sturdy equipment (floats, moorings, ropes, etc.).
- Predators pose a permanent risk for mussel farms. First and foremost, in the form of diving ducks (Eider ducks), which can empty a complete mussel farm in a short time. The best solution today is a fence (costs around 40€/meter), which prevents Eider ducks from landing.
- Harmful algae blooms, particularly the shellfish poison-producing species (*Alexandrium*, *Gymnodinium,* etc.), can render the harvest unsellable. Mitigation is possible by employing cleaning facilities (temporary onshore housing) and repeated testing until the disappearance of the toxin.
- Ocean acidification and global warming can lead to decreased productivity and a compromised food chain. Though this is rather a long-term issue, farmers might consider alternative species.

Other risks are marine pollution events, for example, caused by oil spills or shipping hazards.

6.2 Technical risks

- The risk of equipment failure at sea (vessels, harvesting devices, etc.) is low and can probably be fixed in a reasonable time, as boats and smart farms are standard devices.
- A greater technical risk exists in the processing of the harvested mussels, particularly if the de-shelling turns out to be more expensive than planned, or frequent machine-fails.
- If the transport chain from farm to production site fails, there is the risk of deteriorating (rotting) material.

6.3 Societal risks

- Competition for space, for instance, by the installation of nature protected areas, naval exercise areas or shipping lanes.
- A serious risk is the lack of public acceptance of the adjacent population and/or tourists.
- Vandalism and robbery are not impossible, but improbable.

- A huge – however improbable – risk is the outbreak of a bellicose situation or terrorism.

6.4 Economic risk

- A small risk might be a lack of acceptance of mussel ingredients in pet feed.
- A significant problem arises when production costs turn out to be too high, and mussel ingredients turn out to be unfeasible for pet feed producers.

6.5 Risk assessment

In the following table, we estimate the risks as a function of severity and probability of occurrence. We also add strategies to mitigate the risks. For each risk, the probability of occurrence as well as the severity in the case of occurrence was estimated. These factors were combined according to the following rules:

Table 13. Risk estimate as a function of probability and severity.

Probability	Severness	Result
low	low	very low
low	medium	low
low	high	medium
medium	low	low
medium	medium	medium
medium	high	high
high	low	medium
high	medium	high
high	high	very high

Main risks (resulting in “high” and “very high”) are the presence of eider ducks, and the economic risks of an unfavourable ratio of costs/revenue, as well as insufficient market success

It shows that the main risks for small mussel farming and processing are i) environmental (weather, predators) and ii) economic issues (too high costs/prices and lacking consumer acceptance). The environmental constraints can at least partially be tackled by improved equipment (costs). As for the production costs, the optimal production volume has to be reached at each step within the production chain to maximise effectiveness. Upscaling is also an important step, which is closely connected to market success. Marketing is key here.

Table 14. Risks and potential mitigation measures.

Risk		Probability	Severness	Result	Mitigation measure
Environmental risks:					
	Bad weather	medium	high	high	Fortify constructon
	Predators	high	high	very high	Eider fence
	Harmful algae	medium	medium	medium	frequent checks, delay harvest
	Climate change	medium	low	low	n.a.
	Polluted water	low	high	medium	choose better site, n.a.
Technical risks					
	Equipment failure at sea	low	medium	low	improve equipment
	Equipment failure during processing	medium	medium	medium	Improve equipment, redundancies
	Transport chain fails	low	low	very low	n.a.
Societal risks					
	Competition for space	low	medium	low	Thorough site selection
	Lack of public acceptance of farm	medium	medium	medium	Public information
	Vandalism and robbery	low	high	medium	n.a.
	War, terrorism	very low	high	low	n.a.
Economic risk					
	Mussel ingredients unsuitable for pet feed	low	medium	low	Thorough tests and market research
	Production costs too high	medium	high	high	Improve business planning
	Lack of consumer acceptance	medium	high	high	Improve Marketing

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Baltic
MUPPETS

DELIVERABLE 1.1

BUSINESS AND INVESTMENT PLAN

ANNEX II: BALTIC PROPER

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CONTENT

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1. INTRODUCTION

The developed business case here focuses on the Situation on the Baltic proper. The example area is the Swedish East coast, where some smaller farms and a pilot production unit are in place, all operated by the Swedish company Ecopelag. This company is presently the only active protagonist of mussel farming in this area. We are referring to their data and experiences in many cases.

The business plan here will show that and – more specifically - under which conditions mussel farming in the Baltic Proper can be profitable. This includes the production side (costs) as well as the revenue side. The core business idea is the production of blue mussels and their conversion into a marketable product. The target production area is the central Baltic Sea, where, as explained above, the maximum size of blue mussels is generally considered to be too small for human consumption (< 4 cm shell length). However, small mussels contain as valuable ingredients as large mussels, which can be used as animal feed, or, more specifically, for pet food, which has been identified as a target product. Various side-stream products can help to improve the cost/revenue balance and are also included in the financial calculations.

Growing blue mussels is, in principle, a fairly easy process: Technical substrates, such as ropes or nets attached to a mooring system, are placed in the sea. Mussel larvae (spat) from natural parent populations will settle onto these substrates; no artificial reproduction effort is required. The mussels are then harvested and further processed into a marketable petfood.

2. TECHNICAL DESCRIPTION (PRODUCTION)

Various steps are required from growing mussels in a farm to the final product. The individual steps and their challenges are described below. In order to maximise efficiency synergistics should be identified and used, leading to a suggestion for the structure and cooperation between the different protagonists of the different crafts.

2.1. The location

The Baltic proper encompasses the sea between the central and southern Swedish east coast, southern Finland, Estonia, Latvia, Lithuania and Poland, shown in the following map.

Figure 1. The area of the Baltic proper. Source: Helcom.

Our partner within the MUPPETS project University of Tartu has revealed that the growth performance of mussels in this part of the Baltic Sea is well below 128 tonnes per year calculated for 0.25 hectare standard mussel farm and is thus several times lower than in the western parts of the Baltic Sea. The larger available space, which, in combination with the relatively low production costs compensate this disadvantage at least partly. Preferably, mussel cultivation would take place at coastal areas of Latvia, Estonia and southern Sweden, as well as at the Åland isles.

The base of the here presented business plan and the calculation therein is a pilot case in Sweden, where the non-profit association Ecopelag is running several mussel farms and a pilot facility to cook and deshell mussels.

Due to the lower salinity in the Baltic proper (approximately 7 PSU in the Gotland area, 7,5-8 in the Bornholm area and 5-6 in the Åland Sea area), blue mussels reach a maximum size of less than 4 cm, a size class which – for the time being - cannot be marketed for human consumption. Therefore, there is no commercial farming activity along the east coast of Sweden. Driven by the ecological benefits of mussel farming, Ecopelag tries to explore growth potential and techniques to make use of this resource, which, of course, consists of biomass equally valuable as in big mussels. In the Baltic Proper, it takes about 2 years for the mussels to reach the target size of up to 4 cm, the major part being between 2.5 and 3.5 cm. All mussels

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down to a size of 1 cm shell length are used in the process. This business plan aims to estimate the economic side of this endeavour.

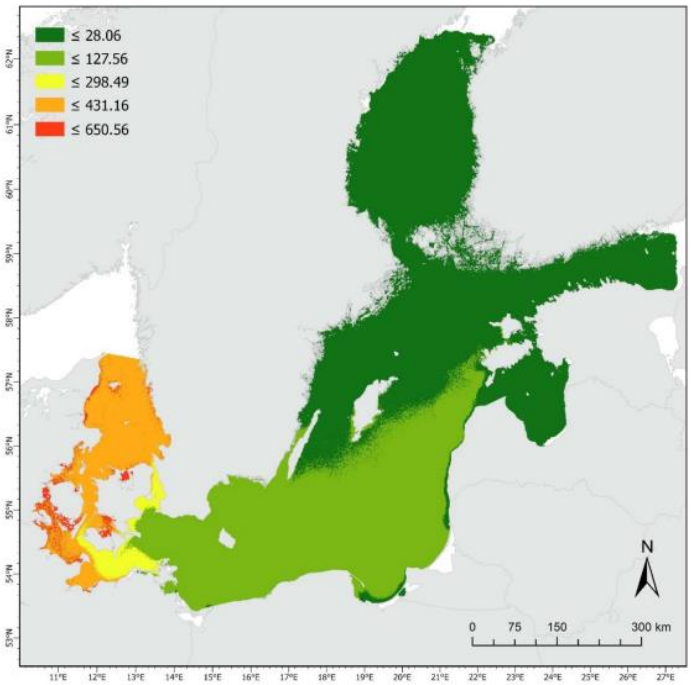

Figure 2. Mussel production potential in the Baltic Sea. Map provided by the University of Tartu.

2.2. Mussel cultivation and harvesting technique

Mussel farming is a well-established technique which is common in many European and other coastal areas. Different environmental conditions lead to slightly varying regional methods, such as bouchaut-poles in the tidal areas of France, floating rafts in Spanish waters, longlines and smartfarm systems in the North Sea and Baltic Sea.

Presently, Ecopelag operates with a traditional longline system. The Substrates that are used are so-called fuzzy ropes. These are ropes with a central thread and lots of hairy fibres hanging off, on which the mussel seed settles. No further thinning is employed, as the mussels grow out to their final size (up to 4 cm) on the same substrate.

For larger mussel production, a mechanised system with minimised human effort can be employed. Smart Farm AS is a Norwegian company that has developed a semi-automated system for the growth and harvesting of mussels. The system consists of vertical nets attached to polyethylene pipes for carrying the biomass and moorings to absorb active forces and necessary flexibility. For harvesting, a mechanical cleaner – similar to a car wash machine – scrubs the mussels of the nets and pumps the detached mussels on board a nearby ship. The higher investment costs of Smart Farming are compensated by reduced staff costs; a comparison of the costs of these systems depending on the production volume is discussed in Chapter 6.

Figure 3. One type of fuzzy rope used by Ecopelag. Photo by Maya Miltell.

2.3. Transport and logistics

Mussel transporters have to be registered in a national system and, upon control, have to show a log of transported goods and the performance of in-between cleaning routines. Before transport, the mussels must be properly packed by a company with the necessary permits for commercial handling of mussels. The mussel farm company must also keep a record of all the transports and transporters used for live mussels.

2.4 Mussel processing

2.4.1 Declumping to deshelling

Before entering a process line, the mussels have to be declumped and cleaned. This step is sometimes (so in the case of Ecopelag) already performed on the harvester boat. The cleaned mussels are then transported to the pressure cooker, where they are boiled and open their shells. Separation of meat and shells is generally the most difficult, costly and challenging step. Various methods have been tested before (such as liquifying the meat by addition of enzymes, use as feed for black soldier fly larvae which are then used for animal food) but today the most efficient and economic method is still he traditional cooking of mussels (which

results in opening of the shells), followed by vigorous shaking (usually on a specially designed conveyer belt), or as in the case of Ecopelag, a tumbling water stream in the flotation tank.

2.4.2 Mussel meal

Many tests and surveys (Rasidi 2022, Weiss & Buck 2017; Steinberg et al. 2012) have shown that mussel meal is an equivalent replacement for fish meal. The process from a cooked mussel to mussel meals involves drying and grinding. There is commercially available equipment on the market. According to previous studies (CRM 2013), the material and processing costs are high, indicating that the material costs (i.e. the price of the mussels) are decisive for the profitability of the business. Machinery required is a dryer and a grinder.

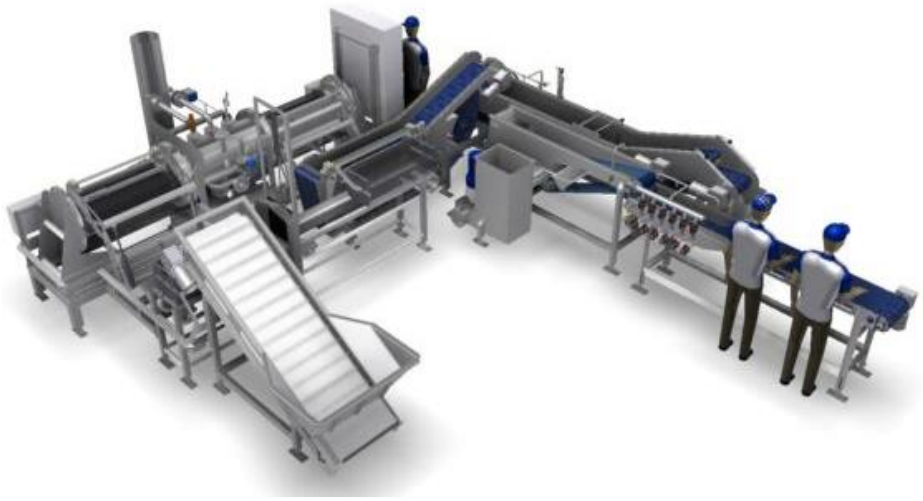

Figure 4. Schematic representation of a mussel processing chain according to the company Kramer.

2.4.3 Conservation and storage of mussels and mussel products

Fresh, living mussels can survive up to one week when kept in a cool place outside of the water (in which case they close their shells and minimise metabolism). Frozen mussel meat can be stored for years without major deterioration of the valuable properties. However, freezing requires energy and space. Less space is required when mussel meat is dried, as the loss in water content decreases the volume by about 80%. Grinding dried mussel meat results in mussel meal that is shelf-stable for several months in a dark and dry place. A gradual decay of unsaturated fatty acids limits the storage time to one year.

3. COMPANY AND CRAFT STRUCTURE

3.1 Company and sector structure

To build a large-scale capacity for mussel production intended for feed, it is necessary to develop production (farming), maintenance and harvesting capacity, as well as transport and processing capacity simultaneously. To reduce the costs of establishing maintenance and harvesting capacity, and to ensure a rapid build-up of mussel supply for the processing industry, collaboration between mussel producers is advisable.

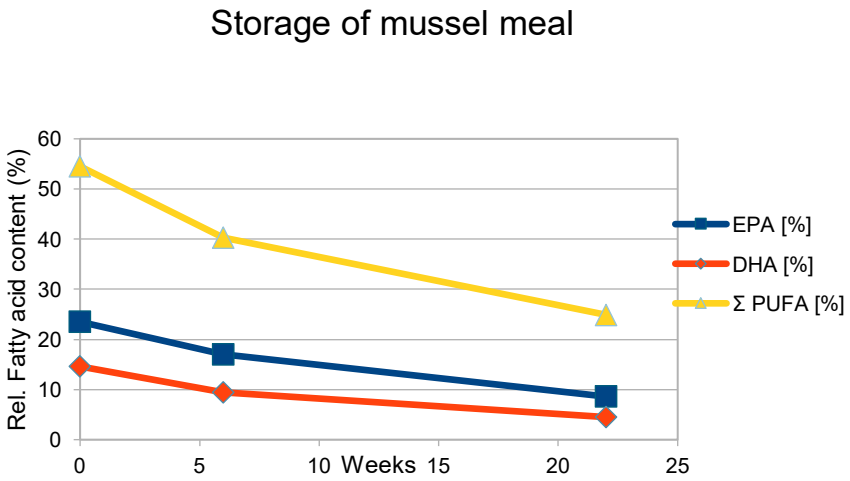

Figure 5. Shelf stability of unsaturated fatty acids in mussel meal (CRM 2013). The x-axis shows the time of storage in weeks, the y-axis indicates the relative fatty acid content of EPA, DHA and the sum of PUFAs.

For a profitable production site, a minimum volume (e.g. several thousand tonnes per year, see chapter 6) is required, while an individual mussel farm plot is usually limited in size due to space limitations and environmental considerations. Therefore, it can be assumed that several farm plots are required to produce sufficient quantities for a medium to large-scale production of pet food. An additional advantage of the existence of a network of farm plots is that varying production of the individual farm plots caused by weather, predators, etc. (see chapter 7) can even out.

As harvesting is a temporary activity, one harvesting unit (human resources and machinery) can serve several farms and the same holds for the transport of mussels. Therefore, a cooperation structure is required that optimises the use of capacity for each craft.

Optimal ownership depends on the team and its particular qualifications. Different sectors and activities along the production line need to cooperate, and there are several ways for the

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organisation of this. We discuss here 2 different ownership models (centralised vs. decentralised), which represent the extremes of a field of organisational possibilities.

Centralised structure: The whole production chain from production at the mussel farm to the marketable product leaving the gate of the processing site is in one hand. The individual activities are performed by employees of this company.

Decentralised structure: The different sectors within the production chain act as individual and independent companies, e.g. one (or several) mussel farm companies, a harvest and transport company, a mussel processing company.

There are various pros and cons to each of the structures: If the sectors are run by independent entities, the intrinsic motivation for each stakeholder is higher. However, there is the chance that an independent entity, which has run into economic difficulties, will eventually disappear – and could compromise the whole production chain in the long run.

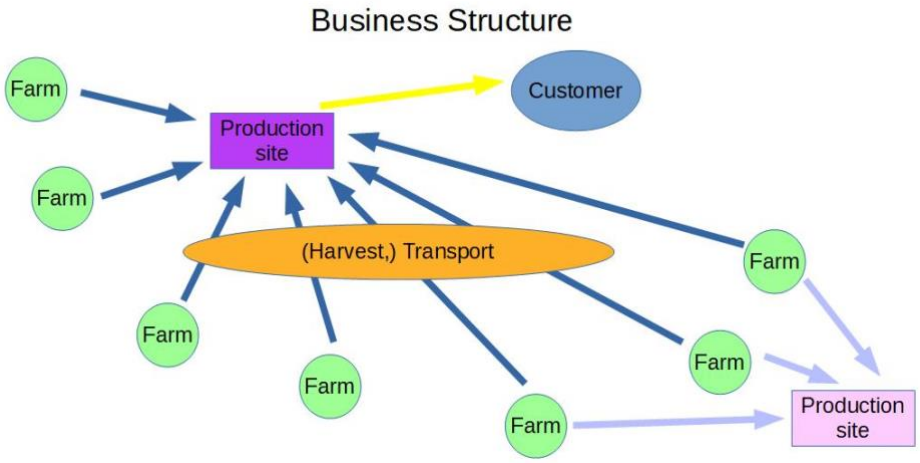

Figure 6. Scheme of structure of the sectors involved in mussel meal production. Depending on distances and capacities, additional processing site can be integrated.

Table 1. Pros (green) and cons (red) of centralised and decentralised sector structure.

centralised	decentralised
employee mindset	entrepreneurial motivation
shared risk	farms might go bankrupt
knowledge transfer easy	limited knowledge transfer
supports farms when problems	Problems in one entity can compromise whole structure
less bureacraty	bureaucratic effort between companies

Nevertheless, we feel that the motivation is a paramount factor and tend towards the conclusion that a cooperation of several companies, each specialised in its specific field and with its own, intrinsic interest in success, is the preferred structure. We suggest that one or several farm companies, each with several farm plots, act as economic entities, while the centralised activities – harvesting, transport and processing- form another company. Possibly, harvesting and transport can also act economically independently. In Denmark, mussel farmers currently operate as relatively small units, all struggling to secure capital and generate profit in a challenging market. It is therefore not likely that mussel producers themselves will take the initiative to establish a centralised business that covers the entire value chain. Increasing fishmeal prices might lead to the development of closer cooperation between large fishmeal companies and mussel farmers. The marketing team can be part of the processing company, but perhaps outsourcing is a more cost-efficient option.

4. THE PRODUCTS AND THEIR MARKETING

4.1 Benefits for customers

The mussel product is cheap, nutrient-rich, healthy and sustainably produced. It will be a stable and reliable resource less dependent on changing catch success and world market movements. The consumer will have a product of constant quality and will have the comfortable feeling that the product is not a burden to the environment.

4.2 Market analysis and competitors

It is apparent that customers of pet food like animals. Therefor it should be a given that they are supportive of resources that cause less harm to the environment and to the well-being of sensitive animals. A market analysis was performed on the basis of literature review, a questionaire and personal interviews.

4.2.1 Market development of the German pet industry – an overview

In 2023, the German pet industry continued its positive trend despite ongoing economic challenges. The stationary specialist trade and grocery retail sector recorded a total turnover of €5.616 billion, representing a year-on-year increase of 9.5%.

Within this figure:

- €4.495 billion was generated through the sale of prepared pet food,
- €1.121 billion came from pet supplies and accessories.

Additional revenue streams included:

- €1.316 billion from the online retail segment, and
- €161 million from the sale of wild bird feed.

Combining all distribution channels and product categories, the total market volume of the German pet industry in 2023 amounted to approximately €7.1 billion (Source: https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt).

The German pet food market is broadly segmented into five key product categories: dog food, cat food, ornamental bird food, ornamental fish food, and food for small mammals such as rabbits, guinea pigs, and hamsters. Within this structure, the cat food segment consistently holds the largest share of the market, reflecting both the high number of domestic cats in Germany and the growing willingness of pet owners to invest in high-quality nutrition for their animals. The dog food segment ranks second in terms of market volume but also shows significant growth dynamics.

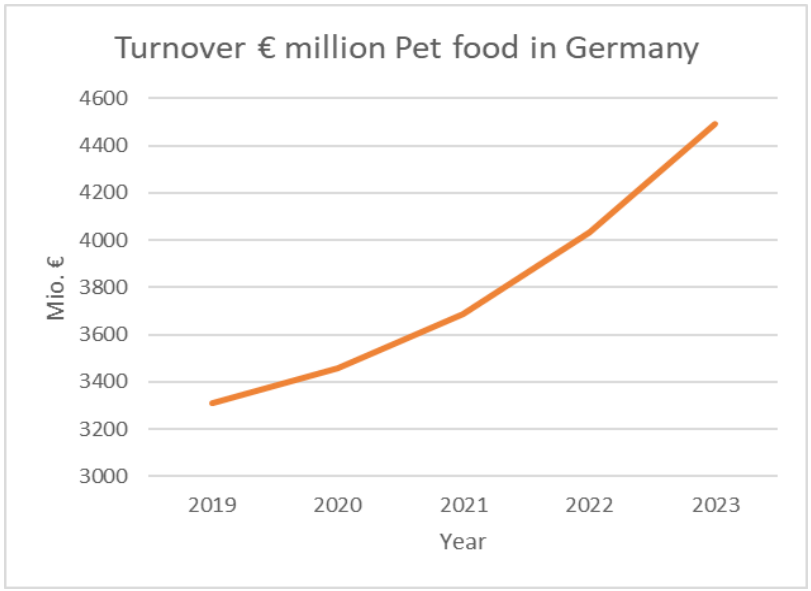

Figure 7. Turnover of pet food in Germany (in € million/year). Source: ZZF.

The graphic illustrates the year-over-year increase in pet food sales in Germany over the period from 2019 to 2023. The data is based on the annual reports published by the Zentralverband Zoologischer Fachbetriebe Deutschlands e.V. (ZZF) and the Industrieverband Heimtierbedarf e.V. (IVH), two leading industry associations representing the German pet trade and pet supplies sector. According to these reports, the market for pet food in Germany experienced consistent and robust growth, with an average annual increase of approximately 8% compared to the previous year

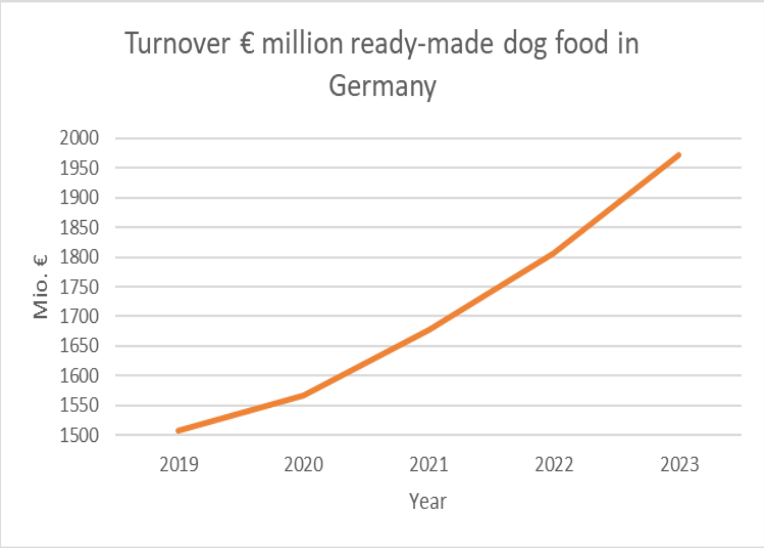

Figure 8. Turnover of dog food in Germany (in Mio €/year). Source: ZZF

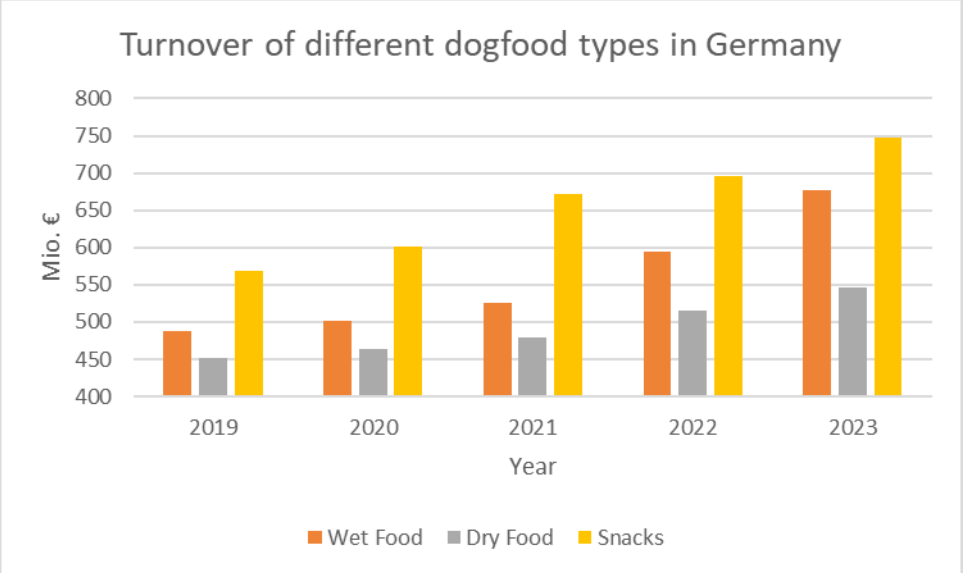

Figure 9. Turnover of different types of dog food in Germany (in Mio €/year). Source: ZZF

An analysis of sales figures from 2019 to 2023 reveals a continuous and stable increase in revenue for dog food products. The average year-on-year percentage increase was approximately 7%. This upward trend underscores a sustained demand for both conventional and premium dog food options, driven by evolving consumer preferences, a rising focus on pet health and nutrition, and the ongoing humanisation of pets. The data suggests that the dog food market is not only resilient but also benefiting from long-term positive developments within the broader pet care industry. (Source: https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt)

The dog food segment can be further divided into three main product categories: wet food, dry food, and snacks. All three categories have shown positive sales growth in recent years.

Specifically, wet food experienced an average annual sales increase of 9%, while dry food grew by approximately 5% per year. The snacks category also saw a notable year-on-year growth of 7%. It is important to note, however, that snacks represent the highest-grossing category within the dog food segment, underlining their strong position in the market and the increasing trend of pet owners purchasing treats and functional snacks for their dogs (Source: https://www.zzf.de/marktdaten/der-deutsche-heimtiermarkt).

4.2.2 Summary of the results of a survey of German animal feed manufacturers

We developed a survey for German animal feed manufacturers. The questionnaire explores the potential use of mussel-based ingredients in pet food and is directed at companies within the animal feed industry. It begins by asking whether animal-based components – including fish – are currently used in their products, and in which categories (e.g., dog food, cat food, ornamental fish).

The core focus lies on whether respondents can envision incorporating a sustainably sourced mussel ingredient into their products and whether they would be willing to pay a premium for it. The survey also inquires about customer interest in sustainability, for instance, through questions about ingredient sourcing, and asks which quality criteria are considered most important for animal-based feed components (e.g., protein content, vitamins, calcium levels). Further questions address the preferred form of the mussel ingredient (e.g., powder, liquid, frozen pieces), the estimated purchase volume per year, and whether a higher calcium content would be acceptable.

Finally, the questionnaire explores potential reservations or conditions for future use of mussel-based products, the market potential, and whether communicating the ecological benefits of sustainably farmed mussels would support product acceptance. Participants are also invited to provide additional comments or suggestions on the topic.

The survey was sent to twenty pet food producers by surface mail as well as by email. We had only 3 returns. All surveyed companies expressed a general openness to the use of mussel-based ingredients. Animal components, including fish, are already a regular part of their formulations—primarily in the production of dog and cat food. The idea of integrating a sustainable mussel-derived ingredient into future products was supported by all participants. Two of the three companies also indicated a willingness to pay a premium of between 15%

and 50% for such ingredients. There was variation in the assessment of whether end customers are showing an increasing interest in sustainability. While one company reported observing this trend, the other two did not confirm such a development.

In terms of quality criteria for animal feed, clear priorities emerged: protein content, vitamins, amino acids, and trace elements were identified by all respondents as particularly important. Additional criteria, such as fat content, crude ash, crude fibre, or calcium levels, were considered relevant depending on the company.

Regarding the preferred form of mussel-based ingredients, two companies expressed interest in a dried powder, while one also showed interest in pureed and frozen variants. Estimated purchase volumes varied significantly—ranging from two to twenty tonnes per year—likely reflecting differences in company size and product portfolios.

An increased calcium content in the mussel product would be acceptable for two of the companies, with one explicitly stating an upper limit of 50%. The third company, however, rejected this option.

All participants viewed the ecological value of sustainably farmed mussels positively and would consider using them in feed products if they contributed to environmental benefits. It was also emphasised that transparent communication around sustainability, as well as improved consumer education, could enhance acceptance of such products. Two companies also identified a need for further research into health effects on pets as a key factor for future decisions.

Overall, the market readiness is viewed with cautious optimism: while specific timeframes were rarely provided, it became clear that niche products—with appropriate communication—could be implemented in the short term, whereas broader market penetration is expected to take several years.

In conclusion, the survey reveals clear potential for the use of sustainable mussel-based ingredients in pet food—driven by technical openness, differentiated market perspectives, and a strong emphasis on transparent communication.

4.2.3 Summary of interviews with pet food retailers

Surveyed companies were “Tierfutter Knutzen Kiel”, “BARF-Shop Kiel” and “Fressnapf Kiel”.

Knutzen responded as follows: Some customers occasionally express interest in alternative ingredients in pet food, particularly in dog food. In these cases, the focus is primarily on insect-based additives. A general trend toward sustainability, which was previously reflected in a greater willingness to pay higher prices, was clearly observable until around two years ago. However, since the onset of inflationary pressures, this interest has noticeably declined. Nevertheless, there remains a fundamental openness to sustainable pet food and the integration of new and innovative feed components on the part of manufacturers.

BARF-Shop Kiel responded as follows: Current retail prices for frozen pet food range between €1.25 and €2.50 per 500 g, depending on the variety. (Beef blood represents the entry-level

price at €1.25. Other common varieties include chicken, horse, turkey, rabbit, beef, rumen, and gullet meat—all offered in frozen form.)

There is no noticeable demand from customers for sustainable products in this segment. The use of mussel-based ingredients is generally considered a viable option. While sustainability is a relevant topic, it is clearly secondary to price considerations. For instance, the assortment includes an organic turkey ragout priced at €5.80 per 500 g, representing the upper price range.

In dried form, a mussel product would be especially attractive as a treat or snack. In this case, nutritional content is less important—taste and palatability are the deciding factors for customer acceptance. As a complete feed component, a frozen version would be appropriate. In this context, clear nutritional information and a well-communicated health benefit (e.g. for joints, coat, or immune system) would be essential. There are already whole green-lipped mussels with shells available on the market, which are very well received by dogs—they are considered highly palatable and stimulating. For successful market integration, the mussel product should be either consistently available—ideally via wholesale, as is currently the case—or positioned as a seasonal highlight. A good example of this is dog ice cream in summer, which benefits from marketing strategies such as "Now available for a limited time only," generating both attention and demand.

Fressnapf Kiel responded as follows: Purchasing is handled through the Fressnapf central office, which is generally open to new products. Regional items are included in the product range but require approval from the central office. One example is a cheese product for dogs from Schleswig-Holstein that was successfully listed. Individual stores are not authorised to make independent assortment decisions—all product listings and approvals are managed centrally. In the area of BARF (raw feeding) products, demand is steady but not particularly strong. Stores offer a freezer unit with various items, priced at €5.29 per kilo and €7.29 per kilo. Among these are shredded rabbit products packaged in plastic sausages.

Conclusion: The interviews reveal a general openness among retailers and manufacturers to sustainable and innovative ingredients like mussel-based components, despite a decline in consumer demand for sustainability due to inflation. While some customers show interest in alternative ingredients (e.g. insect-based), price remains the key decision factor. Mussel products are seen as viable, especially in dried form as treats, where taste matters more than nutritional value. For use as a complete feed, frozen formats would require clear nutritional benefits. Two market strategies are considered promising: consistent availability via wholesale or seasonal product positioning (e.g. "limited time only").

4.2.4. Summary of the interview with Tetra - the world's leading ornamental fish food producer

There is a general interest in using mussel meal as a feed ingredient. However, clear quality and supply standards are essential for its integration into existing product lines. Most importantly, the product must offer consistent high quality, regardless of whether it originates from Germany, Denmark, Spain, or other countries.

A reliable and continuous supply is considered crucial. An annual purchase volume of up to 200 metric tonnes would be realistic, provided the product is approved for international

markets, particularly in the EU, USA, and Russia. With regard to heavy metals, legal limits must be strictly observed and monitored. The specific regulatory frameworks of each country must be considered, with special attention to Russia, which has more stringent standards in some cases.

The product must also be microbiologically safe, meaning free from Salmonella and with low Enterococcus counts. In addition, it is recommended to include natural antioxidants, such as Vitamin E, in the formulation.

Key quality criteria for the product include:

- Protein content
- Amino acid profile
- Fatty acids, especially polyunsaturated types
- Vitamins, with a focus on Vitamin K
- Carotenoids as natural pigments and antioxidants

A premium over fishmeal can be justified if supported by compelling arguments, particularly related to sustainability and ecosystem benefits. These elements provide strong marketing potential, especially in light of the shift away from fishmeal and the growing rejection of soy. Additionally, fish health is becoming an increasingly important issue, which could enable the use of health claims tied to fatty acid content—potentially even in combination with algae. A "bio" or organic certification is viewed positively, but not considered a decisive justification for a significantly higher price.

The price of mussel meal should be oriented toward the market price of fishmeal. A doubling of the price would likely be difficult to justify.

Product development for new feed formulations typically takes around one year. In the case of mussel meal, the development phase may be somewhat longer due to required testing. The product launch phase is estimated at around six months. The Interzoo trade fair is mentioned as a potential platform for product introduction.

The preferred product form is fine powder. Ideally, delivery would be made via silo trucks. Big bags are also acceptable; 20 kilosacks are considered the least preferred option. Particle size is not critical for large-scale production, as the company is able to perform further grinding internally. For small-scale or test batches, however, a particle size below 250 µm is required, as post-grinding is not possible. Approximately 200 kiloof mussel meal would be needed for initial testing.

Regarding calcium content, a distinction must be made: For fish feed, high calcium levels are undesirable, as they lower the overall protein content. In contrast, high calcium is beneficial for turtle feed. However, the company would not procure a single product for both species—in such cases, calcium would need to be supplied separately.

Concerning U.S. market approval, it is essential to verify whether the mussel species used (e.g., blue mussel) is included on the positive list for that market.

4.3 Marketing strategy: how to enter the market, how to reach the customers

The main value proposition is a good and healthy food for pets, e.g. dogs, cats, birds, rodents, ornamental fish, that meets and exceeds requirements for nutritional value and health. The product is free of toxic substances and regulated in relation to food safety, it is well digestible and appetising, pelleted, shelf stable, traceable and can be applied according to need. It has e a pleasant natural smell for pets and their masters. The product consists of natural ingredients only. The proteins are from sustainable sources, animal proteins are of marine origin, sustainably harvested and with a maximum of animal welfare. We stick to the word: “animal-friendly product for animals of animal lovers”.

Most likely, price will not be the prime selling proposition, should the aim be not to exceed average prices of competitors by more than 20% (a surcharge of 20% is generally considered to be accepted by customers for trustworthy advantages for the environment and animal health).

Most likely, price will not be the prime selling proposition, should the aim be not to exceed average prices of competitors by more than 20% (a surcharge of 20% is generally considered to be accepted by customers for trustworthy advantages for the environment and animal health).

Customers: We assume that people who have pets are animal lovers in general. Therefore, we see a main USP in the fact that all ingredients in the mussel-based pet food have the highest standards, not only in the quality of the ingredients but also in animal welfare. The customers’ target group are environmental and animal welfare – conscious people.

Channels: A relatively small number of big chains (Fressnapf, Vitakraft etc.) accounts for more than x% of the total turnover in the petfood sector in Germany. It will therefore be advised to start promotion events and activities there.

BARF pet food stars (BARF = Biologically Appropriate Raw Food) is a fairly recent trend in Germany for organic and unprocessed animal food. Meanwhile, there are x shops that sell frozen meat and offal of various animals (cow, pig, deer, duck, etc.).

4.4 Summary

There is considerable interest among producers and retailers in mussel products in pet food. No hesitation was found against using mussels as such. The sustainability aspects were well acknowledged, as well as potential health benefits. The price, however, is the most important factor for acceptance when exceeding niche markets and particularly responsible consumer groups.

5. FINANCE PLANNING: COSTS, REVENUES, CAPITAL DEMAND

In the following, we show cash flow examples of costs and revenues, calculated for increasing amounts of production. For the costs, we refer to offers from suppliers, market prices for raw products and the experience that exists within the Muppets consortium.

For the revenue, we identified several product classes: Frozen fresh mussels (raw food), organic mussel meal, and side streams, consisting of mussel shells and presently still priceless environmental service. Revenues from the sale of certificates for climate, nutrient extraction or biodiversity impact are not addressed, but may in the future be of importance; these types of revenues are dependent on political systems, and it is risky to take an investment with a depreciation profile for twenty years, as the political willingness can dry out.

The tables and graphs show the effect of upscaling and determine a minimum volume under which the production is simply futile. For the investments, we are calculating the depreciation over a timespan that has either been specified by the supplier or that is based on reasonable assumptions.

Staff costs are, as usual, high and particularly hard to estimate. Personal demand depends on the equipment used, or, rather, on the degree of automation of the equipment. Here is the most promising room to save on costs. Our estimates are intended to lean towards the conservative side.

5.1 Costs

In order to make the finance planning more transparent, we organise costs as they occur along the production chain. Each step adds on costs, and at each step, some profit has to be generated.

Notwithstanding: The here estimated and calculated costs may differ according to salaries and specific local conditions (availability of infrastructure, boats, etc.) They should, nevertheless, give a realistic picture of the cost structure and the order of magnitude of expenses.

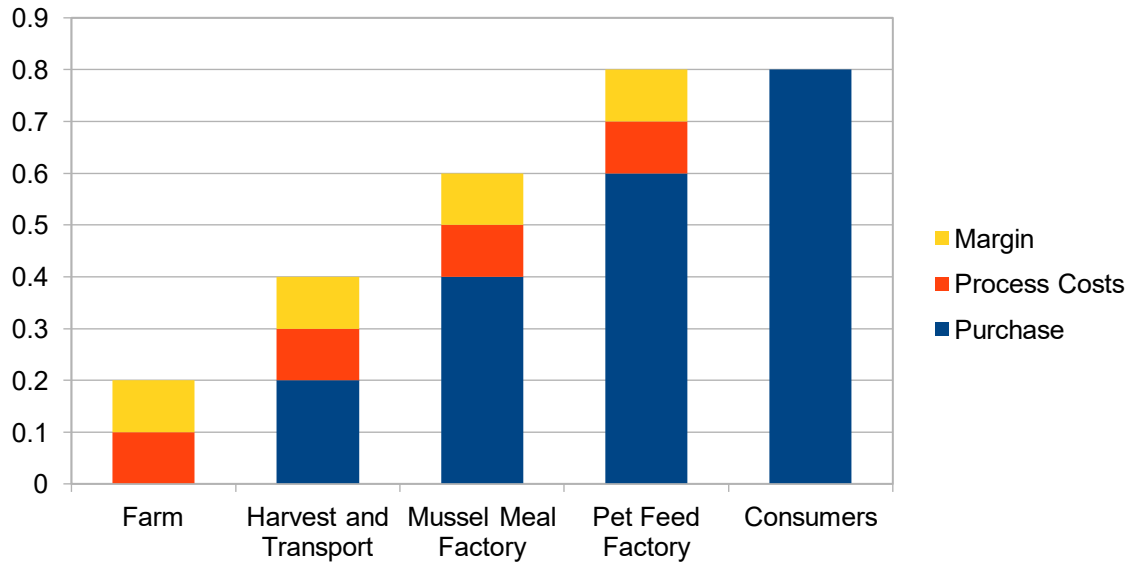

Figure 10. Costs along the production chain.

5.1.1 Costs of mussel farming

Longline Farm

Costs for mussel farming arise from the following sectors: Investments in the farming equipment, Staff costs, running costs and other generic costs.

Presently, Ecopelag operates with a traditional longline system. The Substrates used are so-called fuzzy ropes. These are ropes with a central thread and lots of hairy fibres hanging off, on which the mussel seed settles. No further thinning is employed, as the mussels grow out to their final size (~ 4 cm) on the same substrate.

Figure 11. Example of a fuzzy rope, here a sample from the company Hampidjan.

In order to estimate a scale effect, we calculate the costs per kilo of fresh mussels. It turns out that in a production range of > 2,000 t, the prices per kilo fresh mussels fall below 30 eurocents. The following table shows the costs for developing and harvesting fresh produce as a function of the production volume.

Smart Farming

Smart Farm AS is a Norwegian company that has developed a semi-automated system for the growth and harvesting of mussels. The system consists of vertical nets attached to polyethylene pipes for carrying the biomass and moorings to absorb active forces and necessary flexibility. The pipes have a standard length of 100 m, the depth of the nets is around 5 m, and the mesh size is around 20 cm. We calculate a price for a smart farm unit (including mooring and marker buoys, etc.) to be 20,000 €, and a duration time of 20 years (Nguyen et al. 2013).

At the end of the grow-out phase (1.5 to 2 years), a mechanical cleaner – somehow similar to a car wash machine – scrubs the mussels from the nets and pumps the detached mussels on board a nearby ship.

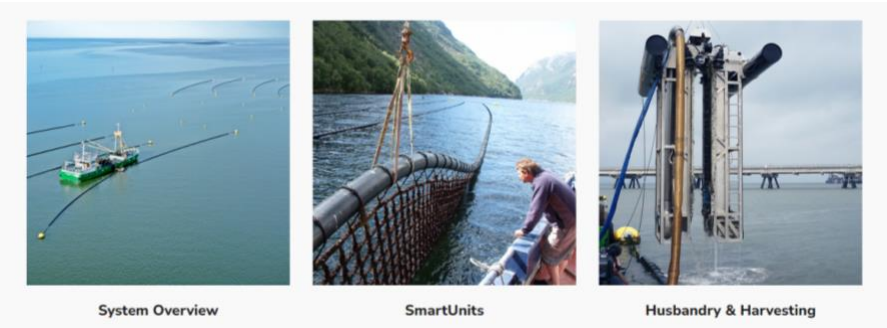

Figure 12. Photos of Smart Farms, retrieved from the Website of Smart Farm AS.

Table 2. Basic assumptions for the cost estimation of longline farming with fuzzy rope.

FUZZY ROPE PRODUCTION COSTS (T)			
Material	Cost (€/unit)	Cost (€/t production)	Devaluation (/y)
Mooring, marker bouys		500	20
Floats	€20/piece		10
Longlines, etc.	0,20 €/m	40	5
Substrates (CTR) (5 lkg/m, 0,2 €/m)	0,2€/m	40	3
Personel			
CEO (per y)	70000		per y
Worker (per y)	50000		per y
Service Boat			
No of boats			
Service boat, dive equipment	50000		15
Fuel, insurance, repair etc.		20	
Other			
Office	15000		per y
Insurance	1000		per y
Telecom	2000		per y
Mobility	5000		per y

Table 3. Costs for longline mussel production and harvest as a function of the production volume.

Christmas tree rope															
Production (t)	**10**	**20**	**40**	**100**	**200**	**400**	**600**	**800**	**1.000**	**1.500**	**2.000**	**2.750**	**4.000**	**10.000**	**20.000**
Costs	**150.547**	**151.760**	**154.187**	**196.467**	**208.600**	**232.867**	**282.133**	**331.400**	**380.667**	**494.500**	**608.333**	**754.083**	**963.667**	**1.879.667**	**3.406.333**
Material	**1.213**	**2.427**	**4.853**	**12.133**	**24.267**	**48.533**	**72.800**	**97.067**	**121.333**	**182.000**	**242.667**	**333.667**	**485.333**	**1.213.333**	**2.426.667**
Mooring, marker bouys	250	500	1.000	2.500	5.000	10.000	15.000	20.000	25.000	37.500	50.000	68.750	100.000	250.000	500.000
Floats	750	1.500	3.000	7.500	15.000	30.000	45.000	60.000	75.000	112.500	150.000	206.250	300.000	750.000	1.500.000
Longlines, etc.	80	160	320	800	1.600	3.200	4.800	6.400	8.000	12.000	16.000	22.000	32.000	80.000	160.000
Substrates (CTR) (5 lkg/m, 0,2 €/m)	133	267	533	1.333	2.667	5.333	8.000	10.667	13.333	20.000	26.667	36.667	53.333	133.333	266.667
Personel	**120.000**	**120.000**	**120.000**	**145.000**	**145.000**	**145.000**	**170.000**	**195.000**	**220.000**	**270.000**	**320.000**	**370.000**	**420.000**	**570.000**	**820.000**
CEO (per y)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Worker (per y)	1,0	1,0	1,0	1,5	1,5	1,5	2,0	2,5	3,0	4,0	5,0	6,0	7,0	10,0	15,0
Other	**23.000**	**23.000**	**23.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**	**33.000**
Office	15.000	15.000	15.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
Insurance	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Telecom	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Mobility	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Service Boat	**6.333**	**6.333**	**6.333**	**6.333**	**6.333**	**6.333**	**6.333**	**6.333**	**6.333**	**9.500**	**12.667**	**17.417**	**25.333**	**63.333**	**126.667**
No of boats	1	1	1	1	1	1	1	1	1	2	2	3	4	10	20
Service boat, dive equipment	3.333	3.333	3.333	3.333	3.333	3.333	3.333	3.333	3.333	5.000	6.667	9.167	13.333	33.333	66.667
Fuel, insurance, repair etc.	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	4.500	6.000	8.250	12.000	30.000	60.000
Costs/kg fresh mussels	**15,05**	**7,59**	**3,85**	**1,96**	**1,04**	**0,58**	**0,47**	**0,41**	**0,38**	**0,33**	**0,30**	**0,27**	**0,24**	**0,19**	**0,17**

The harvesting machine and the boat are the biggest investments and should be in use as much as possible in order to get the best return on the investment. For the calculation, we assume costs of €1,000,000 for the ship, the harvester and the necessary equipment with a depreciation over 20 years. A harvesting machine can harvest up to 30 tonnes per hour. In this calculation, we assume 200 tonnes per day. The time for harvest will then be around three months. For the rest of the time, the boat and machine will be used for husbandry, maintenance like tensioning the anchors, cleaning the nets and submerging the units before winter, etc. The harvest capacity is then 20,000 tonnes per season (Nguyen et al. 2013).

Comparing the costs of Christmas Tree Rope vs. Smart Farming

We assume that the farm operates with smart farming equipment. One smart farm unit – 100m of pipe and attached net with e depth of approx. 5 m, providing a length settling substrate of 6000 m, costs 15,000€. Required is also mooring equipment, the installation, marker buoys, and other items such as rope, shekels, etc. For working on the sea, a minimum of 2 people is required. The number of personnel depends on the size and production of the farm, see below General costs encompass rent for an office, telecommunication, insurance, mobility and other overhead categories. The following table shows the estimated costs of these categories.

In conclusion: Exceeding about 2000 tonnes of annual production, smart farming becomes more economic than longline farming.

Table 4. Costs for smart farm mussel production and harvest as a function of the production volume

Smart Farm Production (t/y)	10	20	40	100	200	400	600	800	1.000	1.500	2.000	2.750	4.000	10.000	20.000
Costs	**311.718**	**311.918**	**314.103**	**355.656**	**366.577**	**388.421**	**410.264**	**432.107**	**503.951**	**558.559**	**613.167**	**745.080**	**881.601**	**1.586.901**	**2.679.067**
Material	**3.518**	**3.518**	**5.303**	**10.656**	**19.577**	**37.421**	**55.264**	**73.107**	**90.951**	**135.559**	**180.167**	**247.080**	**358.601**	**893.901**	**1.786.067**
Farm units needed (20t/unit)	1,0	1	2	5	10	20	30	40	50	75	100	138	200	500	1.000
Smart Farm units	1.333	1.333	2.667	6.667	13.333	26.667	40.000	53.333	66.667	100.000	133.333	183.333	266.667	666.667	1.333.333
Mooring and marker buys (€/unit)	350	350	700	1.750	3.500	7.000	10.500	14.000	17.500	26.250	35.000	48.125	70.000	175.000	350.000
Inspection boat	**4.433**	**4.433**	**4.533**	**4.833**	**5.333**	**6.333**	**7.333**	**8.333**	**12.667**	**15.167**	**17.667**	**21.417**	**27.667**	**71.000**	**161.000**
Inspection boat(s) and dive equipm. (a	3.333	3.333	3.333	3.333	3.333	3.333	3.333	3.333	6.667	6.667	6.667	6.667	6.667	20.000	60.000
Fuel, insurance, repair etc.	1.100	1.100	1.200	1.500	2.000	3.000	4.000	5.000	6.000	8.500	11.000	14.750	21.000	51.000	101.000
Personel	**85.000**	**85.000**	**85.000**	**120.000**	**120.000**	**120.000**	**120.000**	**120.000**	**170.000**	**170.000**	**170.000**	**170.000**	**170.000**	**220.000**	**220.000**
CEO (per y)	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1	1	1
Worker (per y)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	2,0	2,0	2,0	2,0	2,0	3,0	3,0
Other	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**	**23.000**
Office (per y)	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Insurance	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Telecom	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Mobility	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Harvest	**200.200**	**200.400**	**200.800**	**202.000**	**204.000**	**208.000**	**212.000**	**216.000**	**220.000**	**230.000**	**240.000**	**305.000**	**330.000**	**450.000**	**650.000**
Harvester (capacity 20.000t/y)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Fuel, insurance, repair etc.	200	400	800	2.000	4.000	8.000	12.000	16.000	20.000	30.000	40.000	55.000	80.000	200.000	400.000
Staff (number)	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3
Staff (costs)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	150.000	150.000	150.000	150.000
Costs/kg fresh mussels	**31,62**	**15,60**	**7,85**	**3,56**	**1,83**	**0,97**	**0,68**	**0,54**	**0,50**	**0,37**	**0,31**	**0,27**	**0,22**	**0,16**	**0,13**
Costs/kg without harvest	***11,60***	***5,80***	***2,95***	***1,58***	***0,84***	***0,47***	***0,34***	***0,28***	***0,30***	***0,23***	***0,20***	***0,17***	***0,14***	***0,12***	***0,11***

5.1.2 Costs occurring in the processing facility

The next step in the production chain from fresh mussels to pet food is the facility where mussels are deshelled and, depending on the later use, ground and dried to mussel meal. The current most economical way to deshell blue mussels is cooking. Here, we discuss a facility to turn fresh mussels into mussel meal.

The costs as well as the revenues of the processing facility fall into the categories

- Building
- Technical Installation
- Office
- Personal

Marginal Costs (mussel acquisition, brine salt, chemicals for cleaning, electricity, repairs and spare parts, controllers, alarm service, pest control, etc.)

For the building, we assume a space under the roof, as well as an approximately equally large space outside for parking, delivery, and cleaning treatment if required. The specific space requirements depend on the assumed production volume unit. In order to estimate a realistic production scale, we estimate costs for a range from 10 to 20,000 tonnes of fresh mussels. As always, we refer to publicly available figures and always lean toward a more conservative side. Any discount or cheaper versions will increase the profitability of the business.

The building must provide space for the production chain, consisting of feeder, washer /declumper (if not installed on board of the pram), boiler and shaker belt, but also storage space for frozen and/or dried products, an office space, bathroom(s) and kitchen, a social room, etc.

Marginal costs (excluding the purchase of the mussels) consists of various materials such as brine salt, chemicals for cleaning, repaire and spare parts, controllers, alarm service, pest control etc, energy, costs for the building (rent), the technical installations (washer/declumper, steam generator, boiler, feeder, shaker belt and – if required – dryer and grinder etc.). Staff

costs account for a CEO and technicians, costs for the office (rent, heating, electricity, water), insurance, telecommunication and mobility.

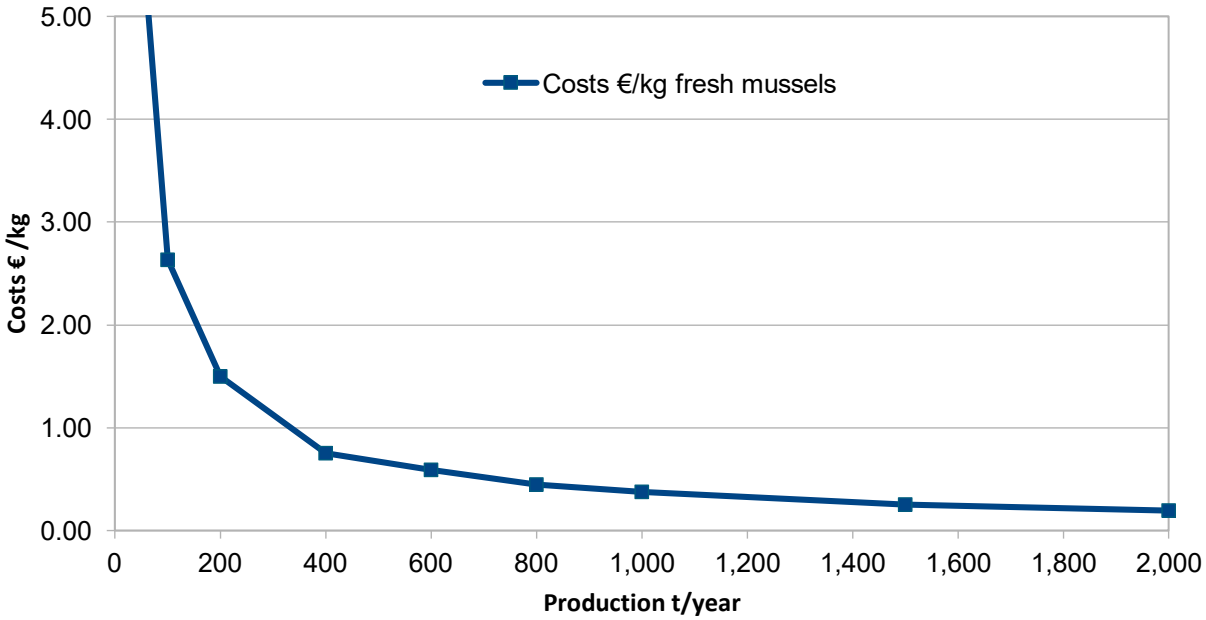

Figure 13. Estimated costs for processing fresh mussels to mussel meat.

Fig.13 shows decreasing costs for processing fresh mussels to mussel meal. The price per kilo of fresh mussel processed decreases below €0.10 when reaching a production volume of over 4000 tonnes of fresh mussels annually. Assumed is a meat content of 40% of the fresh mussel weigh of which only 50% can be extracted, and a water content of 80% of the meat weight.

Table 5. Costs for processing fresh mussels to mussel meal as a function of production volume. A production volume of 2750 tonnes of fresh mussels is equivalent to the capacity of the processing unit of Ecopelag when working in two teams

Production (t fresh mussels/y)	**10**	**20**	**40**	**100**	**200**	**400**	**600**	**800**	**1.000**	**1.500**	**2.000**	**2.750**	**4.000**	**10.000**	**20.000**
Costs	**262.859**	**262.918**	**263.036**	**263.390**	**298.980**	**300.160**	**355.340**	**355.520**	**378.200**	**381.150**	**393.850**	**409.025**	**438.400**	**714.500**	**1.008.500**
Building	**19550**	**19600**	**19700**	**20000**	**20500**	**21500**	**21500**	**21500**	**44000**	**46500**	**58750**	**72250**	**98000**	**245000**	**490000**
Under roof / required area	100	100	100	100	100	100	100	100	200	200	250	300	400	1000	2000
Under roof /costs	12000	12000	12000	12000	12000	12000	12000	12000	24000	24000	30000	36000	48000	120000	240000
Outside space	100	100	100	100	100	100	100	100	200	200	250	300	400	1000	2000
Outside space / costs	6000	6000	6000	6000	6000	6000	6000	6000	12000	12000	15000	18000	24000	60000	120000
Energy	50	100	200	500	1000	2000	2000	2000	5000	7500	10000	13750	20000	50000	100000
Rent	1500	1500	1500	1500	1500	1500	1500	1500	3000	3000	3750	4500	6000	15000	30000
Mashinery	**72809**	**72818**	**72836**	**72890**	**72980**	**73160**	**73340**	**73520**	**73700**	**74150**	**74600**	**76275**	**79900**	**154000**	**203000**
Washer/Declumper (32500€, 5 years)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	7500	10000	20000	40000
Steam Generator (41544€, 3 years)	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	13848	50000	70000
Boiler, Rest of process line (157,356€, 3 years)	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	52452	75000	75000
Chemicals, repaires, spare parts, etc. (0.9 €/t)	9	18	36	90	180	360	540	720	900	1350	1800	2475	3600	9000	18000
Personel	**145000**	**145000**	**145000**	**145000**	**180000**	**180000**	**235000**	**235000**	**235000**	**235000**	**235000**	**235000**	**235000**	**290000**	**290000**
CEO	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1	1
CEO costs	35000	35000	35000	35000	70000	70000	70000	70000	70000	70000	70000	70000	70000	70000	70000
Technician number	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4
Technician costs	110000	110000	110000	110000	110000	110000	165000	165000	165000	165000	165000	165000	165000	220000	220000
Office	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**	**25500**
Office rent (15,000 €/y)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Heating, Electricity, water etc. (2500 €/y)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Telecom(2000€/y)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mobility (5000 €/y)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Insurance (1000 €/y)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Costs €/kg fresh mussels	**26,29**	**13,15**	**6,58**	**2,63**	**1,49**	**0,75**	**0,59**	**0,44**	**0,38**	**0,25**	**0,20**	**0,15**	**0,11**	**0,07**	**0,05**

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5.1.3 Transport

Prices for cooling transport fall in a range of €550 basic price plus €30 per tonne per 100 km, adding another approximately €0.04 per kilo fresh mussels

5.1.4 Summary of costs

The following table shows the total costs for the mussel meat from the Baltic proper for a pet food. Depending on further processing and use, additional steps (drying, grinding, mixing, etc.) are required to achieve a marketable product, which are estimated in the following chapter 6.2.

Table 6. Total costs for the production of a dried pet food. component from mussels farmed in the Baltic proper.

Production (t/y)	**10**	**20**	**40**	**100**	**200**	**400**	**600**	**800**	**1.000**	**1.500**	**2.000**	**2.750**	**4.000**	**10.000**	**20.000**
Farming	15,05	7,59	3,85	1,96	1,04	0,58	0,47	0,41	0,38	0,33	0,30	0,27	0,24	0,19	0,17
Transport	6,17	3,09	1,55	0,62	0,56	0,41	0,52	0,52	0,47	0,35	0,28	0,23	0,17	0,08	0,04
Processing	26,29	13,15	6,58	2,63	1,49	0,75	0,59	0,44	0,38	0,25	0,20	0,15	0,11	0,07	0,05
Tot costs (€/kg fresh mussels)	**47,51**	**23,82**	**11,98**	**5,22**	**3,10**	**1,74**	**1,59**	**1,38**	**1,22**	**0,93**	**0,79**	**0,65**	**0,52**	**0,33**	**0,26**

5.2 Revenues and profit

In the following, we will shed light on potential revenues for various products generated based on small mussels, and an estimate of which, and in what order of magnitude, this additional production is profitable

The profit of a business is the difference between the revenue or sales of a good and the costs invested to produce the good. As has been shown in the section above, upscaling plays a major role as it decreases the costs per unit. However, we have to keep in mind that the capacity of the European market to absorb these products has limits.

- For the revenue, we identified and partially developed several products:
- Raw mussels, unprocessed
- Mussel meal as a replacement for conventional fish meal
- Organic mussel meal
- Pond fish feed from freeze-dried mussel meat
- Dried mussel meat dried for chicken (as mealworms or black soldier fly substitute)
- Hobby Chicken feed (cooked and dried, including shell)
- Sustainable Baltic mussel shells as a food additive for chicken
- Raw mussel meat frozen (“BARF”)
- Dog/cat food production in Sweden (Ecopelag)
- Dog/cat food own production in Germany (KMF / CAU)
- Fertiliser (dry and ground)
- Environmental services

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5.2.1 Unprocessed mussels

Unprocessed raw mussels serve as a comparison, as they are presently, due to their small size, unsuitable for human consumption. No further processing or additives are required after farming and harvesting. The market capacity is large, and there might be an opportunity to develop a product for human consumption in future. Based on the cost tables in previous sectors, the profitability can be represented in the following table to the right.

Table 7. Costs and revenues for unprocessed mussels.

Raw mussels unprocessed		
Market capacity (t/y)		100.000
Equivalent fresh mussels (t/y)		100.000
Factor (kg fresh mussel/kg product)		1
Market price of product (€/kg)		1,00
Price range (€)		0,8 – 1,2
Production 400 t / year	Farm costs (in €)	0,97
	Harvest and Transport costs (in €)	0,41
	Processing costs fresh to meat(in €)	0,00
	Processing costs meat to meal (in €)	0,00
	Sum costs kg mussels (in €)	1,38
	Additional costs (€/kg product)	0,00
	Sum costs kg product (in €)	1,38
	Profit (in € per kg product)	***-0,38***
Production 2750 t / year	Farm costs (in €)	0,27
	Harvest and Transport costs (in €)	0,23
	Processing costs fresh to meat(in €)	0,00
	Processing costs meat to meal (in €)	0,00
	Sum costs kg mussels (in €)	0,50
	Additional costs (€/kg product)	0,00
	Sum costs kg product (in €)	0,50
	Profit (in € per kg product)	***0,50***
Production 10000 t / year	Farm costs (in €)	0,16
	Harvest and Transport costs (in €)	0,08
	Processing costs fresh to meat(in €)	0,00
	Processing costs meat to meal (in €)	0,00
	Sum costs kg mussels (in €)	0,23
	Additional costs (€/kg product)	0,00
	Sum costs kg product (in €)	0,23
	Profit (in € per kg product)	***0,77***

5.2.2 Mussel meal

Mussel meal has proven to have almost identical composition as fish meal (Weiss and Buck 2017, Steinberg 2011, Rasidi 2022) and can thus be a sustainable substitute for the conventional fish meal, which, to a large part, still stems from traditional (and unsustainable) fisheries. According to the FAO (2024), about 15 million tonnes of fish are converted into fish meal annually.

Therefore, mussel meal has to compete with fishmeal in price. We defined 2 fractions of fish meal, which only differ in the price, one in the price range of the world market of fish meal, the other with a surcharge of 50% for organic production. As the absorption of the world market is almost unlimited, for the organic market we assume a capacity of 500 tonnes in the Northern and Western part of Europe.

A similar table as above reveals that even at a high production (of 10,000 tonnes of fresh mussels per year) and a relatively high price of €2.70 per kilo product will not be profitable.

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Table 8. Percentage of usable ingredients of blue mussels (numbers can differ depending on region and condition status of the mussels).

Total meat content in a mussel	40,00 %	of fresh mussel
Extractable meat	80,00 %	of total meat
Dry mass meat	20,00 %	of extractable meat
Shell mass	33,33 %	of fresh mussel
Dry mussel	41,33 %	Shell plus dry meat
Percent mussel in in petfood	50,00 %	of meat

The reason is that a multitude (factor 15.5) of fresh mussel biomass is needed to produce the dry mussel meal. Only approx. 40% off a cooked Baltic mussel consists of meat, which is not completely extractable from the shells, as part of the adductor muscle tends to stick to the shell. The drying process reduces the weight of the meat by another 80 %, so that at the end 15,6 kilo of fresh mussels are needed in order to produce 1 kilo of mussel meal. The processing (cooking, deshelling, drying, grinding adds more costs (see above), and adds even more costs.

The following table shows costs and revenues for mussel meal. Mussel meal competes directly with fish meal – in table 9 labelled as “conventional” mussel meal. We optimistically assume a potential surcharge of 50% for certified organic mussel meal. It turns out that even under optimal conditions and a high production volume, the production of mussel meal, neither “conventional” nor “organic”, will not be profitable for the B2B sector.

Table 9. Costs and revenues for mussel meal as a replacement for fish meal - "conventional" and "organic"

Mussel meal		„Conventional“ mussel meal	„Organic“ mussel meal
Market capacity (t/y)		100.000	500
Equivalent fresh mussels (t/y)		1.562.500	7.813
Factor (kg fresh mussel / kg product)		15,6	15,6
Market price of product (€/kg)		1,80	2,70
Price range (€)			
Production 400 t / year	Farm costs (in €)	0,97	0,97
	Harvest and Transport costs (in €)	0,41	0,41
	Processing costs fresh to meat(in €)	0,71	0,71
	Processing costs meat to meal (in €)	0,36	0,36
	Sum costs kg mussels (in €)	2,45	2,45
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	38,27	38,27
	Profit (in € per kg product)	***-36,47***	***-35,57***
Production 2750 t / year	Farm costs (in €)	0,27	0,27
	Harvest and Transport costs (in €)	0,23	0,23
	Processing costs fresh to meat(in €)	0,14	0,14
	Processing costs meat to meal (in €)	0,11	0,11
	Sum costs kg mussels (in €)	0,75	0,75
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	11,66	11,66
	Profit (in € per kg product)	***-9,86***	***-8,96***
Production 10000 t / year	Farm costs (in €)	0,16	0,16
	Harvest and Transport costs (in €)	0,08	0,08
	Processing costs fresh to meat(in €)	0,07	0,07
	Processing costs meat to meal (in €)	0,06	0,06
	Sum costs kg mussels (in €)	0,37	0,37
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	5,76	5,76
	Profit (in € per kg product)	***-3,96***	***-3,06***

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5.2.3. Pond fish feed

An interesting consumer segment that has been identified is operators of fishponds for private or part-time fish keepers. Since the market price for pond-fish food is rather high (€5-€15 per kilo), we see a good chance for a profitable product when mussel production reaches about 1,000 tonnes annually. The main part of the food consists of deshelled and processed mussel meat, an extra of 1.50 per kilo of food has been estimated for other ingredients such as vitamins, flavors etc.

The market capacity has been estimated for organic and sustainable food compositions. Market price is calculated without packaging, marketing and delivery.

Table 10. Costs and revenues for pond fish.

Fish pond feed from dried mussel meat		
Market capacity (t/y)		200
Equivalent fresh mussels (t/y)		1.563
Factor (kg fresh mussel / kg product)		7,8
Market price of product (€/kg)		10
Price range (€)		5,00 -15,00
Production 400 t / year	Farm costs (in €)	0,97
	Harvest and Transport costs (in €)	0,41
	Processing costs fresh to meat(in €)	0,71
	Processing costs meat to dried meat (in €)	0,36
	Sum costs kg mussels (in €)	2,45
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	20,63
	Profit (in € per kg product)	***-10,63***
Production 2750 t / year	Farm costs (in €)	0,27
	Harvest and Transport costs (in €)	0,23
	Processing costs fresh to meat(in €)	0,14
	Processing costs meat to dried meat (in €)	0,11
	Sum costs kg mussels (in €)	0,75
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	7,33
	Profit (in € per kg product)	***2,67***
Production 10000 t / year	Farm costs (in €)	0,16
	Harvest and Transport costs (in €)	0,08
	Processing costs fresh to meat(in €)	0,07
	Processing costs meat to dried meat (in €)	0,06
	Sum costs kg mussels (in €)	0,37
	Additional costs (€/kg product)	1,50
	Sum costs kg product (in €)	4,38
	Profit (in € per kg product)	***5,62***

5.2.4 Chicken food, and chicken food additives

Private chicken farming in the backyard is getting increasingly popular in Europe. According to German law, for instance, between 3 and 20 chickens (and one rooster) can be kept in a private backyard. Chickens need feed, and especially a source of chalk to produce the shells of the eggs. In the muppets project wee identified 3 types of food resp. food additives for chicken:

1. Ground and dried mussel meat as a replacement for mealworms or black soldier fly larvae

2. Cooked, dried, and ground whole mussels. These provide 100% of the required calcium, about 42% of the required protein, and 17% of the required fat. The rest has to be added from other sources, we estimate a price of €1 additional costs per kilo product for the supplementary ingredients (corn, maize, gluten, plant-based proteins, fat, vitamins, spore elements and appetisers)

3. Ground shells as chalk (calcium carbonate) addition to other chicken feed

The cost/revenue table shown in the next table reveals that a production above 1000 tonnes of fresh mussels can be profitable, particularly in the case of dried meat as a substitute for other animal protein sources. A particular advantage is given in the fact that dried mussel meat can be combined with the sale of the remaining shells, which would result in a profit of nearly €3 per kilo of fresh mussel produced.

5.2.5 Dog/cat food

Three different product options have been developed and discussed during Baltic MUPPETS:

1. A raw food, consisting of preboiled mussel meat. Raw dog food is a significant trend in Germany. Sources are various animal products (beef, rabbit, pork, different kinds of birds, deer, etc. Market research (see above) has indicated that mussels are an interesting material provided that the costs are comparable to other sources.

2. Dog snacks are a product developed by our Swedish Partners the company Ecopelag AB. This product has by far the highest profit margin of all the discussed products. It is sold in bags of 30-75 grams for approximately €11 per 100 grams. According to the experience of our Swedish partners, the interest is fairly good compared to similar products. It is currently sold through the Swedish E-commerce platform Apotea, but other channels can be developed.

3. The University of Kiel, together with the SME Kieler Meeresfarm are currently developing a pet food recipe. The idea is a modular dry basic food which is to be specified according to the target animals (pond fish, cats, dogs, juveniles, elderly, etc.). The food consists of approximately 50% of mussel meat and 50% of other ingredients. A comparable food composition is also developed by Ecopelag in an early stage. We therefore refer to the Kiel approach in the example given in Table 12.

Table 11. Costs and revenues for different products used in hobby chicken husbandry.

		Dried mussel meat for chicken	Chicken feed (cocked and dried, including shell)	Mussels shells as chicken food additive	Dried mussels shells as side stream product
Market capacity (t/y)		500	500	10.000	10.000
Equivalent fresh mussels (t/y)		7.813	605	30.000	30.000
Factor (kg fresh mussel / kg product)		15,6	1,2	3,0	3,0
Market price of product (€/kg)		7,50	1,50	2,00	2,00
Price range (€)		5,00 – 10,00	2,00 – 3,00	1,00	1,00
Production 400 t / year	Farm costs (in €)	0,97	0,97	0,97	0,00
	Harvest and Transport costs (in €)	0,41	0,41	0,41	0,00
	Processing costs fresh to meat(in €)	0,71	0,71	0,71	0,00
	Processing costs meat to dried meat (in €)	0,36	0,36	0,36	0,36
	Sum costs kg mussels (in €)	2,45	2,45	2,45	0,36
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	38,27	2,96	7,35	1,07
	Profit (in € per kg product)	***-30,77***	***-1,46***	***-5,35***	***0,93***
Production 2750 t / year	Farm costs (in €)	0,27	0,27	0,27	0,00
	Harvest and Transport costs (in €)	0,23	0,23	0,23	0,00
	Processing costs fresh to meat(in €)	0,14	0,14	0,14	0,00
	Processing costs meat to dried meat (in €)	0,11	0,11	0,11	0,11
	Sum costs kg mussels (in €)	0,75	0,75	0,75	0,11
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	11,66	0,90	2,24	0,32
	Profit (in € per kg product)	***-4,16***	***0,60***	***-0,24***	***1,68***
Production 10000 t / year	Farm costs (in €)	0,16	0,16	0,16	0,00
	Harvest and Transport costs (in €)	0,08	0,08	0,08	0,00
	Processing costs fresh to meat(in €)	0,07	0,07	0,07	0,00
	Processing costs meat to dried meat (in €)	0,06	0,06	0,06	0,06
	Sum costs kg mussels (in €)	0,37	0,37	0,37	0,06
	Additional costs (€/kg product)	0,00	0,00	0,00	0,00
	Sum costs kg product (in €)	5,76	0,45	1,11	0,19
	Profit (in € per kg product)	***1,74***	***1,05***	***0,89***	***1,81***

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Table 12. Costs and revenues of different dog food products.

Product		Raw mussel meat („BARF“)	Dog snacks (recipe Ecopelag)	Dog / cat food (recipe CAU)
Market capacity (t/y)		500	10	500
Equivalent fresh mussels (t/y)		1.563	156	3.906
Factor (kg fresh mussel / kg product)		3,1	15,6	7,8
Market price of product (€/kg)		2,00	110,00	5,00
Price range (€)		80,00 – 140,00		
Production 400 t / year	Farm costs (in €)	0,97	0,97	0,97
	Harvest and Transport costs (in €)	0,41	0,41	0,41
	Processing costs fresh to meat(in €)	0,71	0,71	0,71
	Processing costs meat to dried meat (in €)	0,00	0,36	0,36
	Sum costs kg mussels (in €)	2,09	2,45	2,45
	Additional costs (€/kg product)	0,00	0,00	1,50
	Sum costs kg product (in €)	6,54	38,27	20,63
	Profit (in € per kg product)	***-4,54***	***71,73***	***-15,63***
Production 2750 t / year	Farm costs (in €)	0,27	0,27	0,27
	Harvest and Transport costs (in €)	0,23	0,23	0,23
	Processing costs fresh to meat(in €)	0,14	0,14	0,14
	Processing costs meat to dried meat (in €)	0,11	0,11	0,11
	Sum costs kg mussels (in €)	0,75	0,75	0,75
	Additional costs (€/kg product)	0,00	0,00	1,50
	Sum costs kg product (in €)	2,33	11,66	7,33
	Profit (in € per kg product)	***-0,33***	***98,34***	***-2,33***
Production 10000 t / year	Farm costs (in €)	0,16	0,16	0,16
	Harvest and Transport costs (in €)	0,08	0,08	0,08
	Processing costs fresh to meat(in €)	0,07	0,07	0,07
	Processing costs meat to dried meat (in €)	0,06	0,06	0,06
	Sum costs kg mussels (in €)	0,37	0,37	0,37
	Additional costs (€/kg product)	0,00	0,00	1,50
	Sum costs kg product (in €)	1,15	5,76	4,38
	Profit (in € per kg product)	***0,85***	***104,24***	***0,62***

5.2.6 Fertilizer

Fertiliser is another product that has successfully been tested in Sweden, in a cooperation between Ecopelag and the company Grobruket. There are basically 2 types of soil improvement available, the first one being whole mussels, dried and coarsely ground, and the second one being only shells in order to elevate the soil pH. Particularly, using a shell product as by product can be a promising business.

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Table 13. Cost and revenues of fertilizer on the base of mussels.

Ferztilizer (dry and ground)		Fertilizer whole mussel	Shells for soil improvement as by product
Market capacity (t/y)		1.000	1.000
Equivalent fresh mussels (t/y)		2.419	3.000
Factor (kg fresh mussel / kg product)		2,4	3,0
Market price of product (€/kg)		2,00	2,30
Price range (€)		1,50 – 7,50	
Production 400 t / year	Farm costs (in €)	0,97	0,00
	Harvest and Transport costs (in €)	0,41	0,00
	Processing costs fresh to meat(in €)	0,71	0,00
	Processing costs meat to dried meat (in	0,36	0,36
	Sum costs kg mussels (in €)	2,45	0,36
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	5,93	1,07
	Profit (in € per kg product)	***-3,93***	***1,23***
Production 2750 t / year	Farm costs (in €)	0,27	0,00
	Harvest and Transport costs (in €)	0,23	0,00
	Processing costs fresh to meat(in €)	0,14	0,00
	Processing costs meat to dried meat (in	0,11	0,11
	Sum costs kg mussels (in €)	0,75	0,11
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	1,81	0,32
	Profit (in € per kg product)	***0,19***	***1,98***
Production 10000 t / year	Farm costs (in €)	0,16	0,00
	Harvest and Transport costs (in €)	0,08	0,00
	Processing costs fresh to meat(in €)	0,07	0,00
	Processing costs meat to dried meat (in	0,06	0,06
	Sum costs kg mussels (in €)	0,37	0,06
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	0,89	0,19
	Profit (in € per kg product)	***1,11***	***2,11***

5.2.7 Environmental services

A scheme for financial compensation for environmental services is not in force for the time being. In some locations, there seem to be compensation efforts, but only on a voluntary basis. Several attempts for a compulsory compensation scheme have been made and are still in development. However, at present, there is a lack of political will.

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Avoiding the input or extracting nutrients from the water body is costly. Mewes (2006 a and b) has quantified costs of various methods and in different regions, which, of course, resulted in a huge spread of costs. Here we apply a mean of €20 per kilo of nitrogen extracted or avoided. The average content of nitrogen in a fresh mussel is 1% (weight). We therefore calculate a compensation price of €0.20 per kilo of fresh mussels produced, which, if adequately compensated, would mean an extra benefit of €0.20 per kilo of harvested mussels without any additional effort.

Table 14. Costs and benefits of monetarizing the nutrient retention potential of mussel farming.

		Nutrient uptake	Nutrient uptake additional (side stream)
Market capacity (t/y)		10.000	10.000
Equivalent fresh mussels (t/y)		1.000.000	1.000.000
Factor (kg fresh mussel / kg product)		100	100
Market price of product (€/kg)		20,00	20,00
Price range (€)			
Production 400 t / year	Farm costs (in €)	0,97	0,00
	Harvest and Transport costs (in €)	0,41	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat	0,00	0,00
	Sum costs kg mussels (in €)	1,38	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	137,92	0,00
	Profit (in € per kg product)	***-117,92***	***20,00***
Production 2750 t / year	Farm costs (in €)	0,27	0,00
	Harvest and Transport costs (in €)	0,23	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat	0,00	0,00
	Sum costs kg mussels (in €)	0,50	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	49,74	0,00
	Profit (in € per kg product)	***-29,74***	***20,00***
Production 10000 t / year	Farm costs (in €)	0,16	0,00
	Harvest and Transport costs (in €)	0,08	0,00
	Processing costs fresh to meat(in €)	0,00	0,00
	Processing costs meat to dried meat	0,00	0,00
	Sum costs kg mussels (in €)	0,23	0,00
	Additional costs (€/kg product)	0,00	0,00
	Sum costs kg product (in €)	23,39	0,00
	Profit (in € per kg product)	***-3,39***	***20,00***

5.2.8 Summary of revenue and profit

Considering the costs for the production of the various products, it becomes apparent that the use of small mussels in general is only profitable when produced in larger quantities (way above 1,000 tonnes fresh mussels/year) and as an ingredient in pet food in a fairly high price sector. An exception is the use in fish pond feed, and, more than anything else, the production of dog snacks!

The following table gives an overview of the anticipated profits of the most promising mussel-based products for the pet food market after subtracting 30% for either B2B clients or marketing effort in the case of running an own (e-)shop. Examples are given for the described products and for production volumes of 400 t, 2,750tonnesand 10,000tonnesannually (mussel fresh weight).

Table 15. Summary of costs and benefits of promising products.

PRODUCT	Assumed market capacity (t/a)	Factor	Profit per kilo product			Profit per kilo mussel		
Production (t/year)			400tonnes	2,750	10,000	400	2,750	10,000
Dog snacks (recipe Ecopelag)	10	15,6	50,21	68,84	72,97	3,22	4,41	4,68
Pond fish feed from dried mussel meat	200	7,8	-7,44	1,87	3,93	-0,95	0,24	0,50
Dried mussel meat for chicken	500	15,6	-21,54	-2,91	1,22	-1,38	-0,19	0,08
Fertilizer whole mussel	1.000	2,4	-2,75	0,14	0,78	-1,14	0,06	0,32
Chicken feed (cocked and dried, including shell)	500	1,2	-1,02	0,42	0,74	-0,85	0,35	0,61
Mussels shells as chicken food additive	10.000	3	-3,74	-0,17	0,63	-1,25	-0,06	0,21
Raw mussel meat (“BARF“)	500	3,1	-3,18	-0,23	0,59	-1,02	-0,07	0,19
Raw mussels unprocessed	10.000	1	-0,27	0,35	0,54	-0,27	0,35	0,54
Dog / cat food (recipe CAU)	500	7,8	-10,94	-1,63	0,43	-1,40	-0,21	0,06

5.3. The path of growth

Producing in a profitable way requires a production volume of several 1000 tonnes of fresh mussels and happens within an order of magnitude that requires either a considerable investment or a good credit rating, both being conditions that are not necessarily a given for startups. Therefore, this chapter tries to describe a pathway to growing a business from the very beginning to a larger operation, which is profitable from the start.

The required amount of fresh mussels per unit marketable product differs according to the product. We assume here a maximum production potential in the Baltic Sea of 20,000 tonnes per year. The following graph shows – from top to bottom - the sequence of profitable products and the required amount of fresh mussels, up to an assumed potential production volume in the Baltic Sea of 20,000 tonnes per year.

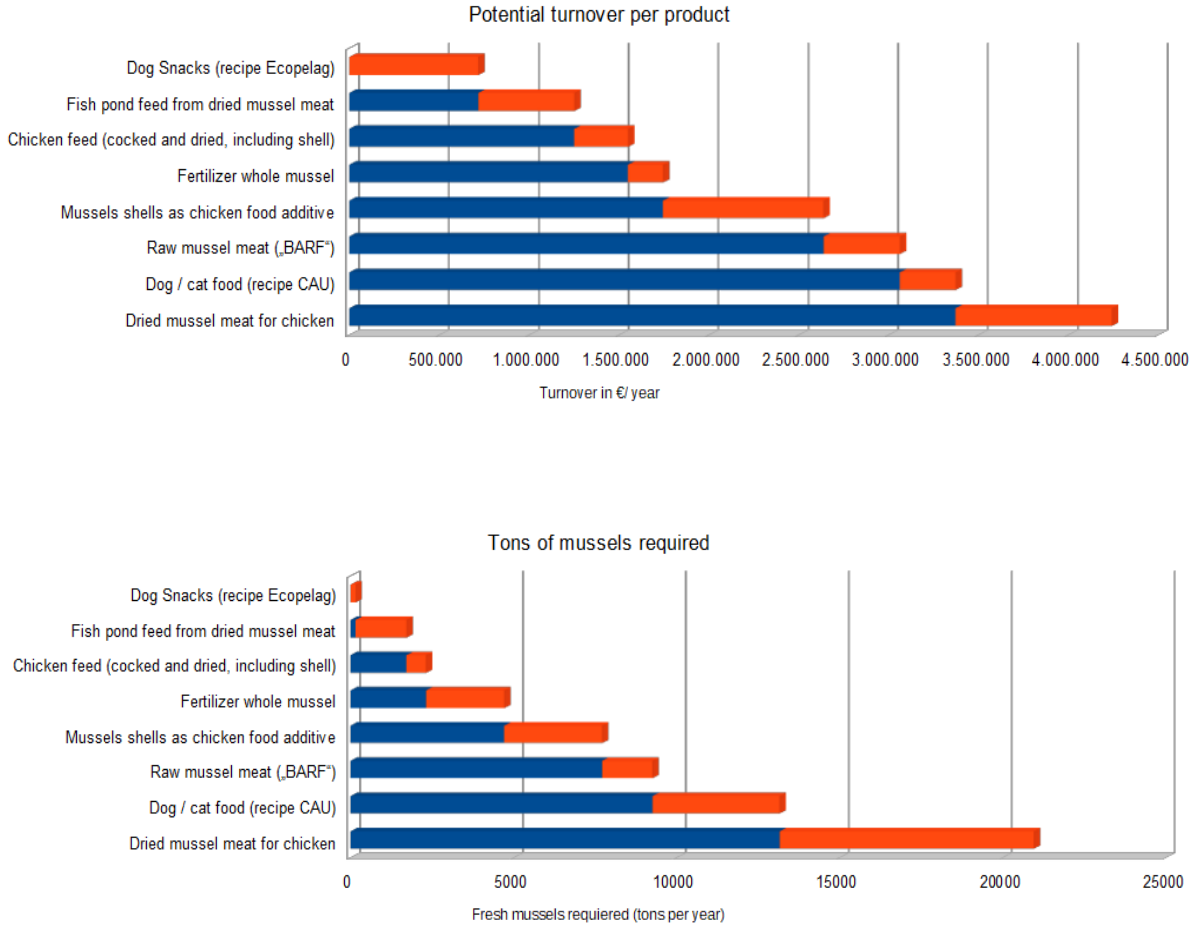

Figure 14 a and b: Suggestion for a sequence of product generation from farmed Baltic mussels according to market potential and mussel farming potential. The graph shows in orange the additional turnover resp. required mass of fresh mussels for each product group

A startup or a company with limited resources will likely start with a smaller production and high-value products. The company would thus start with producing dog snacks, being the most lucrative product and sell it either to a pet food store (or chain), or market it in its own e-shop. Similar or comparable high-priced products might also be developed in other places. However, as always in the world of high-priced products, the potential market is limited to a comparatively small group of customers. In the presented study, we assume the potential market volume to be 10 tonnes of snacks per year (150,000 snacks of 65 grams each), which would be equivalent to 156 tonnes of fresh mussels. By the time the market is saturated, the next profitable product can be tackled; in that case, pond fish food. Again, assuming a potential market of 200 tonnes per year, another 1560 tonnes of mussels would be required. Similarly, the subsequent products will be produced, which will give additional profit; however, with decreasing profit per unit of fresh mussels, until the maximum amount of mussel production in the Baltic Sea is reached (in the here presented approach 20,000 tonnes per year).

An additional sale of shells is profitable when the shells are a side stream product that do not account for additional costs for farming, harvesting, transport and deshelling. Mussel shells can be sold for soil improvement, and also as a chicken food additive. In the latter case, however, additional costs for the sterilisation of the mussel shells will occur.

A “product” of great interest would be a compensation for the improvement of water quality. There is no legal system yet in force to regulate this topic. A theoretical compensation of €0.20 per kilo of harvested mussels has been estimated on the basis of comparable costs for nutrient (nitrogen) reduction in the water by various methods (Mewes 2006). A potential nutrient compensation scheme would further improve the profitability of mussel farming. As the compensation would not require any additional effort except for documentation and verification of the amount of harvest, the additional €0.20 would make a significant difference in the whole budget of mussel farming.

6. RISK ASSESSMENT (BEST-CASE VS. WORST-CASE SCENARIOS)

Risks exist in the form of environmental risks, technical risks, societal risks and economic risks. Each of these risk categories will be described in some detail below, and possibilities for mitigation are discussed.

6.1 Environmental risks

Harsh weather has the potential to physically destroy the farm and moorings. Events like this occur often, and presumably even more so as the climate changes. Mitigation is investing in sturdy equipment (floats, moorings, ropes, etc.).

Predators pose a permanent risk for mussel farms. First and foremost, in the form of diving ducks (Eider ducks), which can empty a complete mussel farm in a short time. The best solution today is a fence (costs around €40 per meter), which prevents Eider ducks from landing.

Harmful algae blooms, particularly the shellfish poison-producing species (Alexandrium, Gymnodinium etc.), can render the harvest unsellable. There are ways to clean the mussels (keeping them in flow through systems for several days to weeks), but they are costly and time-consuming

Ocean acidification and global warming can lead to decreased productivity and a compromised food chain. Though this is rather a long-term issue, farmers might consider alternative species.

Another risk is pollution, e.g. an oil spill or, shipping hazards (burning freighters as recently)

6.2 Technical risks

The risk of equipment failure at sea (vessels, harvesting devices, etc.) is low and can probably be fixed in a reasonable time, as boats and smart farms are standard devices.

A greater technical risk exists in the processing of the harvested mussels, particularly if the de-shelling turns out to be more expensive than planned, or if the machine frequently fails. Mitigation

If the transport chain from farm to production site fails, there is the risk of deteriorating (rotting) material.

6.3 societal risks

Particularly in regions with a dense population, competition for space can be an issue. Competing interests are tourist sites, pleasure shipping, nature protected areas, naval exercise areas or shipping lanes, etc.

A serious risk is the lack of public acceptance of the adjacent population and/or tourists.

Vandalism and robbery are not impossible, but improbable

A huge, however improbable, risk is the outbreak of a bellicose situation or terrorism

6.4 Economic risk

A risk might be a lack of acceptance of mussel ingredients in pet feed, but the results on inquiries indicate that this risk is rather low.

A more significant problem arises when production costs turn out to be too high, and mussel ingredients turn out to be unfeasible for pet feed producers

6.5 Risk assessment

In the following table we estimate the risks as a function of severeness and probability of occurrence of a given incident. We also add strategies to mitigate the risks. For each individual

risk, the probability of occurrence as well as the severity in the case of occurrence was estimated. These factors were combined according to the following rules:

Table 16. Estimating the risk by merging severeness and probability of occurrence of incidents.

Probability	Severness	Result
low	low	very low
low	medium	low
low	high	medium
medium	low	low
medium	medium	medium
medium	high	high
high	low	medium
high	medium	high
high	high	very high

Main risks (resulting in “high” and “very high”) are the presence of eider ducks, and the economic risks of an unfavourable ratio of costs/revenue, as well as insufficient market success.

Table 17. Risks and their resp. mitigation measures for mussel farming and processing.

Risk		Probability	Severness	Result	Mitigation measure
10.1 Environmental risks:					
	Bad weather	medium	high	high	Fortify constructon
	Predators	high	high	very high	Eider fence
	Harmful algae	medium	medium	medium	frequent checks, delay harvest
	Climate change	medium	low	low	n.a.
	Polluted water	low	high	medium	choose better site, n.a.
10.2. Technical risks					
	Equipment failure at sea	low	medium	low	improve equipment
	Equipment failure during processing	medium	medium	medium	Improve equipment, redundancies
	Transport chain fails	low	low	very low	n.a.
10.3. Societal risks					
	Competition for space	low	medium	low	Thorough site selection
	Lack of public acceptance of farm	medium	medium	medium	Public information
	Vandalism and robbery	low	high	medium	n.a.
	War, terrorism	very low	high	low	n.a.
10.4. Economic risk					
	Mussel ingredients unsuitable for pet feed	low	medium	low	Thorough tests and market research
	Production costs too high	medium	high	high	Improve business planning
	Lock of consumer acceptance	medium	high	high	Improve Marketing

It becomes apparent that the main risks for small mussel farming and processing are i) environmental (weather, predators) and ii) economic issues (too high costs/prices and lacking consumer acceptance). The environmental constraints can – at least partially - be tackled by improved equipment (costs!). As for the production costs, the optimal production volume has to be reached at each step within the production chain to maximise efficacy. Upscaling is also an important step, which is closely connected to market success. Marketing is key here!

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7. WORKING PROCEDURE (GANTT CHART)

The following chart shows a possible workplan for the first three years of farm operation.

Optimistically, we assume that the permissions for the farm(s) as well as for the production site can be issued within 3 months. In order to save time, both applications should be submitted in parallel. While a mussel farm can be installed with approximately 3 months, the building of a processing unit and the installation of the technical equipment, including running-in, will probably require about one year.

Table 18. Timeline (Gantt chart) for installing mussel farms and processing units.

Sector	Activity	Year	Year 1												Year 2												Year 3											
		Month	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
		Month	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
Mussel farming																																						
	Explore potential sites, permissions																																					
	Installation of farms																																					
	Upscaling of farms resp. new farms																																					
	Exposure of Substrates (Nets)																																					
Harvesting and Transport																																						
	Harvesting (at farm site)																																					
	Transport from farm to processing plant																																					
Processing																																						
	Find site and get permissions																																					
	Bulding facility																																					
	Installing process line																																					
	Initiation of process line																																					
	Start of regular production																																					
	Upscaling steps																																					
Marketing																																						
	Web site																																					
	Physical presence in conferences etc.																																					
	Social media																																					
	CRM																																					

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