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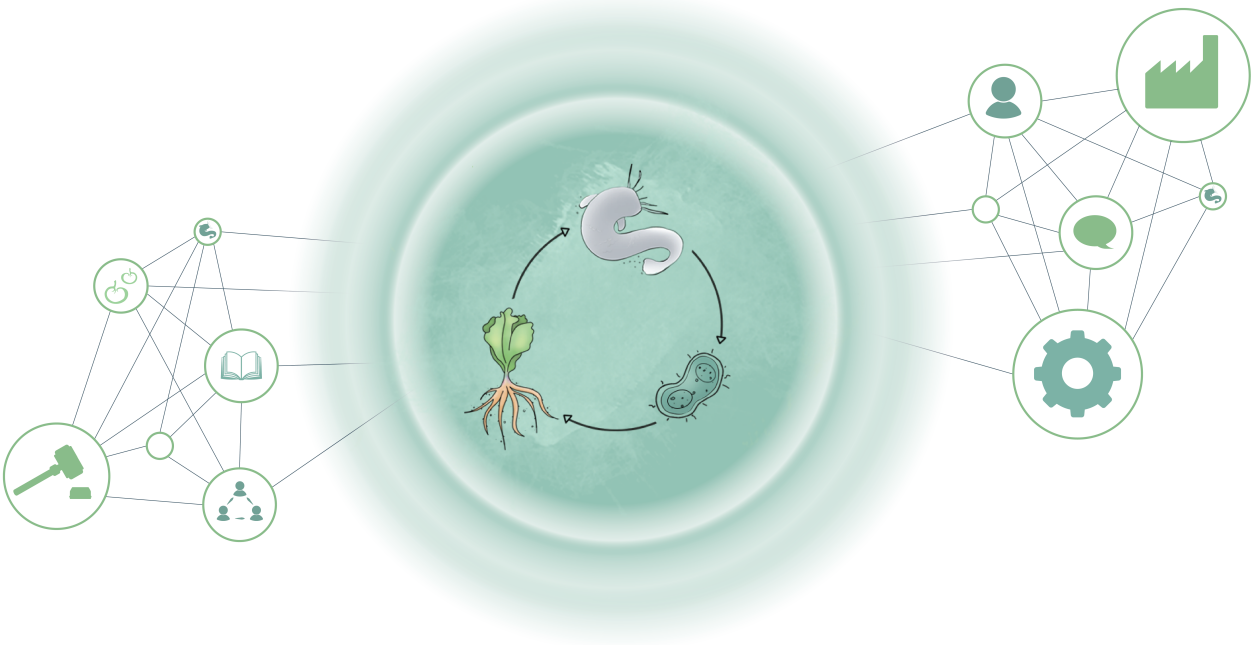

Upscaling of the Aquaponic Niche

Guiding Swedish Niche Actors to Foster Sustainable Food System Transitions

Master's thesis in Industrial Design Engineering

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Abstract

The Swedish food system requires changes to become sustainable. Our current way of producing and consuming food has brought challenges, for example, regarding food security, overfertilization of water courses and exploitation of the sea. Aquaponics, a closed-system food production technology integrating the concepts of aquaculture, i.e. fish farming, and hydroponics, i.e. farming of vegetables in soilless medium, is an emerging technology addressing some of these sustainability issues. Therefore, the thesis aimed at exploring how an upscale of the Swedish aquaponic niche could be facilitated, and thus initiate change within the current food regime.

The thesis was conducted in three phases and builded upon a theoretical framework consisting of Multi-Level Perspective, Strategic Niche Management and Design Thinking. The first phase intended to understand the current aquaponic niche within the Swedish food system. Data was gathered through conducting interviews and focus groups with stakeholders and thereafter analysed through an affinity diagram, a stakeholder mapping and a force field mapping. The result implies that a potential upscale of the aquaponic niche is a complex matter, as the thesis identified 21 categories of stakeholders and 60 enabling and restraining forces affecting an upscale. In the second phase, the aim was to explore how the niche can be guided to facilitate an upscale. Building upon the system understanding gained, twelve guidelines, guiding the niche towards an upscale, and five areas of opportunity, suggested as contexts for actors to apply their guidelines and create experiments, was suggested. Moreover, the third phase aimed at exploring how an individual niche actor, exemplified by the aquaponic producer Pond Fish & Greens, might contribute to the facilitation of an upscale through the design of experiments. To achieve this, the result from the prior phases was combined with design thinking and resulted in five concepts of experiments and a suggested suitable point of intervention, providing a first step for Pond Fish & Greens to facilitate an upscale of the niche.

The results and findings of this thesis are believed to be of interest to actors within or with a relationship to the aquaponic niche, e.g. aquaponic producers, authorities and potential collaborators. Moreover, through providing an example of a process guiding a niche to facilitate an upscale, it can as well provide implications for others interested in upscaling.

Keywords: Aquaponics, Design Thinking, Experiments, Food System, Multi-Level perspective, Strategic Niche Management, Sustainable Transitions, Upscaling

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Frida Edstam & Johanna Frisk, Gothenburg, June 16, 2021

Vocabulary

Aquaponics	a food production system in which the waste produced by farmed fish supplies the nutrients for plants grown in soil less medium upon which the water returns purified to the fish tanks
Aquaculture	farming of aquatic organisms in water environments
Hydroponics	the process of growing plants in soilless mediums
Horticulture	plant agriculture
Upscaling	the process in which niche experiments can come to influence or transform regimes
Experiments	pilot or demonstration plants where learning and testing of real-life experiences can be conducted

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1. Introduction

Food supply is currently a weak link in our aspirations towards a sustainable and resilient coexistence. Although the current food system has succeeded with securing high levels of food supply and food safety, it has simultaneously brough sustainability issues that, if continued, will endanger natural resources, our health, the climate and the economy (Group of Chief Scientific Advisors, 2020). Amongst others, the current way of consuming and producing food has brought environmental issues such as overfertilization of watercourses, exploitations of the sea and large emissions deriving from an increase in consumption of animal protein (Franke et al., 2018). Moreover, as well on a national level it has brought challenges, amongst others, regarding the Swedish food security. As imports reduce the amount of food produced nationally, the high amount of imported food in Sweden causes a recognized need for food security in times of war or crises (LRF, 2019). However, as well in times of peace a low food security presents issues, as it affects the possibilities of sustainable food production and work opportunities (LRF, 2020).

A sustainable food system can be described as a system that delivers food security and nutrition for people today without compromising the economic, social or environmental bases to generate food for future generations (Group of Chief Scientific Advisors, 2020). Thus, to become sustainable, the current food system requires changes (Kuylenstierna et al., 2019). Although a recognized need for system changes, the opinions and ideas of how a sustainable food system might be designed and how to get there is not universally agreed upon. Even so, there is a broad scientific consensus on what is needed for changing the current system into a sustainable food system; reduce food loss and waste, foster changes towards better diets for health and environment and maintaining agricultural yields and efficiency while simultaneously decreasing the negative impact on biodiversity, soil, water and air (Group of Chief Scientific Advisors, 2020).

One emerging technology claiming to have the potential of tackling some of these sustainability issues is aquaponics. Aquaponics is a closed-system food production technology, integrating the concepts of aquaculture, i.e. fish farming, and hydroponics, i.e. farming of vegetables in soil-less media (Love et al., 2015; Rakocy et al., 2004). The technology is built by the coexistence of greens and fishes efficiently re-using the nutritions deriving from fish feed and fish feces as nutritions for the greens (Rakocy et al., 2004). Aquaponics is discussed to have potential to improve sustainability in terms of both food security and as an alternative to the aquatic protein deriving from fisheries and aquaculture (Kloas et al., 2015; Tisdell, 1999). With fish being the animal protein with the highest feed conversion ratio compared to chicken, beef, pork and sheep, it is claimed to be a protein source with high potential of sustainability (Röös, 2014; Franke et al., 2018). However, fisheries as well as aquaculture face sustainability challenges, for example, contributing to eutrophication, overfishing and destruction of ecosystems (Franke et al., 2018), making aquaponics an interesting alternative.

Based on the recognized need for changes in the food system and the argument that aquaponics has the potential of improving sustainability, it altogether implies the importance of exploring the possibilities with aquaponic technology to influence the current Swedish food regime. The aquaponic technology in Sweden can currently be defined as part of a technological niche, i.e. the incubation room in which novelties are protected from the mainstream market selection (Geels, 2005; Raven, 2005). However, through the process of upscaling, such a niche can come to influence the regime (Jolly et al., 2012). Thus, to improve the sustainability of the Swedish food system it is essential to understand how an upscale of the current Swedish aquaponic niche can be managed.

1.1. Aim and Research Question

Based on the issues presented above, this thesis aims to explore how an upscale of the Swedish aquaponic niche can be facilitated, and thus contribute to sustainable development of the Swedish food system through impacting the current food-regime. This aim is partly achieved through utilizing the Swedish aquaponic producer Pond Fish & Greens, from here on referred to as Pond, exemplifying one actor within the Swedish aquaponic niche. Setting out to answer the thesis aim, the following four research questions are posed and addressed during the thesis:

1. Who are the stakeholders affecting an upscale of the aquaponic niche?
2. What are the enabling and restraining forces affecting the possibilities to scale up the aquaponic niche?
3. How might aquaponic niche actors be guided towards facilitating an upscale?
4. How might Pond, exemplifying an actor within the aquaponic niche, contribute to an upscale through the design of experiments?

1.2. Report Disposition

This report is structured into seven chapters. After the introduction in Chapter 1, Chapter 2 and Chapter 3 presents the background and the theoretical framework utilized as a base for the thesis. Further, Chapter 4 presents a description of the process and methods used performing the thesis. The method is divided into three sections, presenting the methods utilized in the three different phases; system understanding, navigating niche formation and designing a set of experiments. Similarly, in Chapter 5 the analysis and result of the thesis is presented according to the three phases, as visualised in Figure 1. Firstly, it explains the understanding gained about the current aquaponic niche within the Swedish food system in Phase 1. Secondly, it builds upon the understanding gained and in Phase 2 elaborates on how the general aquaponic niche might be guided to navigate niche formation and facilitate niche upscaling. Thirdly, Phase 3 explores how an individual niche actor, exemplified by Pond, might contribute to niche upscaling through the design of a set of experiments. Chapter 6 provides a discussion of the results by reconnecting to the posed questions, elaborate on implications and present suggested further work. Lastly, Chapter 7 summarises the report briefly and concludes the main findings.

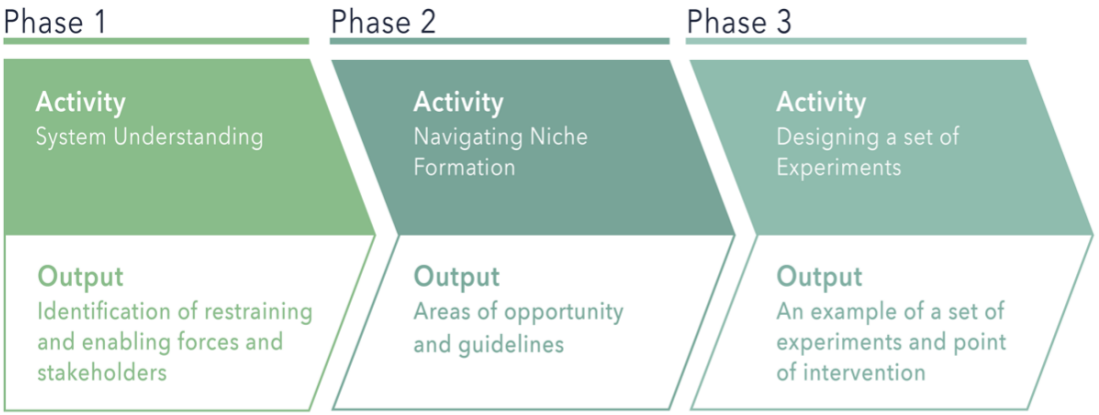


Figure 1.
Activities and outputs

2. Aquaponics and the Swedish food system

This chapter expands on the background of the thesis through elaborating on the Swedish food system, its sustainability issues and ambitions for change. Moreover, it presents aquaponic technology as part of a transition towards a more sustainable food system and the aquaponic producer Pond, exemplifying one niche actor within the aquaponic niche.

2.1. The current swedish food system

A food system can be described as *"the interconnected system of everything and everybody that influences, and is influenced by, the activities involved in bringing food from farm to fork and beyond."* (Centre for Food Policy, 2019, p.1). That is, the food system involves everything from production, transportation, manufacturing, retailing, consumption and disposal of food (Kuylenstierna et al., 2019). Taking a closer look at the Swedish food system, with an emphasis on aquatic protein and greens, several factors can be highlighted to describe the current Swedish food regime. Figure 2. concludes identified relevant regime characteristics, further elaborated on in the following section.

Independent of where in the world food is being produced, the development of the food industry follows similar patterns - from systems building on local conditions, to large scale, specialised and centralised systems (Almena et al., 2019; Naturskyddsföreningen, 2013) dependent on fossil fuels, fertilizers and chemical pesticides (Woods et al., 2010; Naturskyddsföreningen, 2013). Similarly, as well the manufacturing and retailing industry in Sweden is nowadays often characterized by large scale and centralised systems. Although conventional agricultural production dominates in Sweden, organic agricultural production has grown into another important production practice being signified by its different view upon pesticides and fertilizers (Naturskyddsföreningen, 2013; SLU, 2017). Moreover, the EU policies are to a large extent shaping the food production within the Swedish system (Kuylenstierna et al., 2019), for example, controlling what products can be labeled as ecologically produced (KRAV, 2020).

Independent of where in the world food is being produced, the development of the food industry follows similar patterns - from systems building on local conditions, to large scale, specialised and centralised systems (Almena et al., 2019; Naturskyddsföreningen, 2013) dependent on fossil fuels, fertilizers and chemical pesticides (Woods et al., 2010; Naturskyddsföreningen, 2013). Similarly, also the manufacturing and retailing industry in Sweden is nowadays often characterized by large scale and centralised systems. Although conventional agricultural production dominates in Sweden, organic agricultural production has grown into an important production practice, signified by its different view upon pesticides and fertilizers (Naturskyddsföreningen, 2013; SLU, 2017). Moreover, EU policies to a large extent shape the Swedish food production system (Kuylenstierna et al., 2019), for example, controlling what products can be labeled as ecologically produced (KRAV, 2020).

Studying the origin of the seafood produced within Sweden, 75 percent originates from commercial fishing while 14 percent originates from aquaculture, i.e. farming of fish (Borthwick et al., 2019). Within the Swedish aquaculture sector fish is most commonly farmed in freshwater, with cage farming being the most utilized technique and rainbow trout being the fish mainly produced (Länsstyrelsen, n.d.; Jordbruksverket, 2021).

Another characterizing factor within the Swedish food regime is the many middlehands present between producer and consumer. According to Björklund et.al. (2008) the normal distribution chains in the Swedish food system often include a production chain consisting of several actors, each responsible for one part of the chain, sharing the profit. Starting with the farmer, the produced food is often transported between food refiners, wholesale and stores before reaching the consumer.

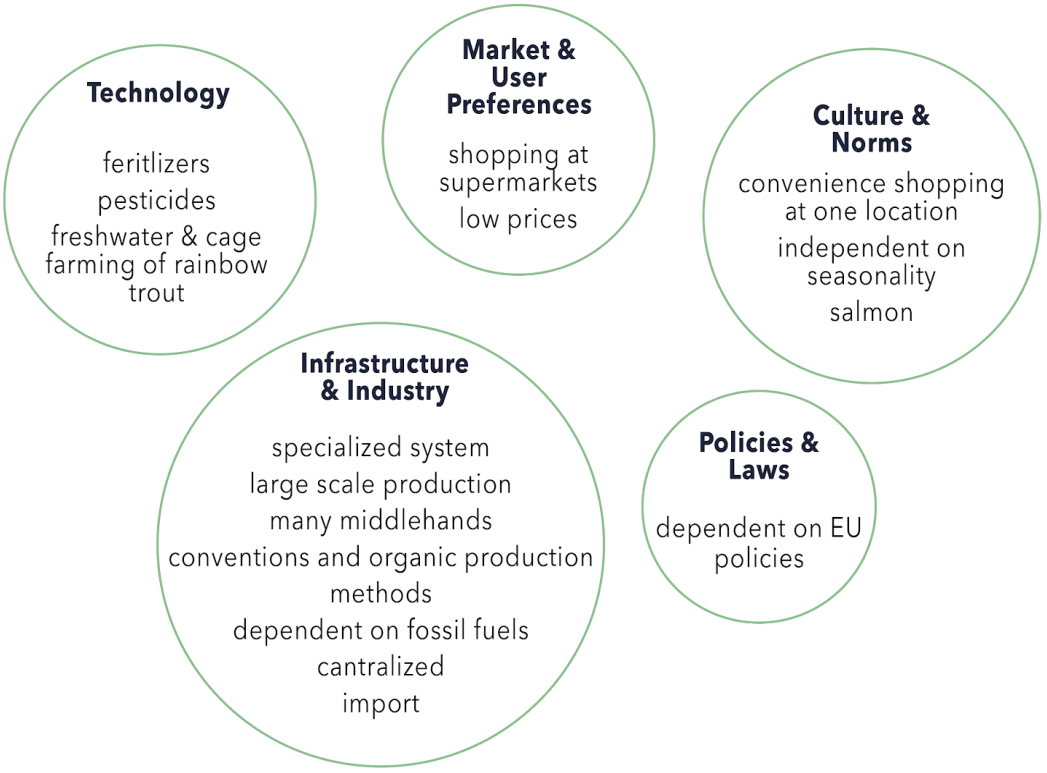


Figure 2.
Swedish food regime

Supermarkets are to a large extent controlling the Swedish food market, with the three largest actors together controlling 78 percent of the market (Eriksson et al., 2016). Thus, the customers are generally accustomed to the convenience of purchasing food at low prices, independent of season and at one location (Smith, 2010). Moreover, the supermarkets connect the Swedish consumers to a global food market, providing the consumers with a wide range of products, independent of season (Kuylenstierna et al., 2019). Lantbrukarnas Riksförbund (2020) highlights that the Swedish farmers in the early 1990s produced 75% of the food consumed in Sweden. As of today, the self-sufficiency ratio has decreased into 50%, leaving the Swedish food system dependent on import. The ratio of imported seafood in Sweden is also high, as approximately two thirds of the consumed seafood is being imported (Borthwick et al., 2019). Salmon, almost exclusively imported from Norway, is the most consumed seafood within the Swedish market.

2.2. Sustainability issues in the system

Although the current food system has succeeded with securing high levels of food supply and food safety it has simultaneously brought sustainability issues that, if continued, will endanger natural resources, our health, the climate and the economy (Group of Chief Scientific Advisors, 2020).

Regarding ecological sustainability, the current food system contributes to environmental problems such as overfertilization and pollution of watercourses, seas and lakes; emissions of greenhouse gases; exploitations of the sea; emergence of animal and plant diseases and reduced biodiversity (Franke et al., 2018). Sustainability issues within the food system can be derived from all parts of the value chain; from production issues such as overfertilization, greenhouse gas emissions and use of unsustainable feed, to consumption issues such as an increase in intake of animal protein, leading to larger emissions compared to vegetable proteins (Franke et al., 2018). Another sustainability challenge within food production and consumption concerns a lack of resource efficiency as the current economic system uses the linear economic model “take-produce-consume-discard” (Jurgilevich et al., 2016). Because of this, there is a high amount of waste created within the food system as it often does not imply utilization of, for example, by-products. However, the ecological sustainability issues within the food system moves beyond production and consumption of food. For example it also includes infrastructural issues, as well in need of being addressed (König et al., 2018). As the current food system is specialized and decentralised this affects where, in relation to the consumers, the food is being produced. For example, food produced in proximity to the consumers reduces the need for transportation.

Similarly, the production of aquatic protein within the Swedish food system faces sustainability challenges. With the fish stocks already reaching 85 percent of the biological limit (Velings, 2015), it is troublesome that the demand of fish worldwide is expected to increase from 80 million tonnes in 2013 to 93 million tonnes in 2030 (The World Bank, 2013).

Thus, with overfishing being a problem, it is interesting to highlight alternative production of aquatic protein. However, aquaculture currently also faces sustainability challenges since farming of fish in oceans or lakes contributes to overfertilization and pollution as feed, antibiotics and feces end up in the aquatic environment (Franke et al., 2018). The largest environmental impact within aquaculture derives from the production of inputs such as fish feed (Jordbruksverket et al., 2013). However, it is important to highlight that the environmental impact of the feed differs. For example, herbivores or omnivores, fed with vegetable protein, generally cause less impact than feed for omnivores or carnivores, fed with animal protein from other fish or animals. According to (Franke et al., 2018), a lot of the farmed fish are fed by wild-caught fish, thus, as well contributing to overfishing, loss of biodiversity and disturbance of ecosystems within the oceans.

The challenges within the current food system go beyond ecological sustainability. Currently in Sweden, the profitability of food producers and farmers is challenging, as the percentage of profit reaching the producer is limited (Lind et al., 2019). Of the money a consumer spends on food, nine percent ends up at the producer. Due to a decrease of food prices and increase of production costs, this is a significantly lower share than in the mid 1990s when almost the double ended up with the producer. Another challenge present within Sweden regards food security. The high amount of imported food within the Swedish food system is problematic as a high import reduces the amount of food produced nationally, causing problems in times of war or crises (LRF, 2019). However, as well in times of peace, a higher self sufficiency ratio is beneficial as it creates possibilities of sustainable production, work opportunities and export of food (LRF, 2020).

2.3. AMBITIONS OF AN ALTERNATIVE SYSTEM

Acknowledging the sustainability issues present within the current food system, as previously presented, it is interesting to on the other hand elaborate on a sustainable food system. According to FAO (2018, p.1), a sustainable food system can be described as a system that "*delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised.*". Although there is a recognized need for changes for the current food system to become sustainable, the opinions and ideas of how a sustainable food system might be designed and managed are not universally agreed upon (Group of Chief Scientific Advisors, 2020; Kuylenstierna et al., 2019). However, there is a broad scientific consensus on what is needed for changing the current system into a sustainable food system; reduce food loss and waste, foster changes towards better diets for health and environment and maintaining agricultural yields and efficiency while simultaneously decreasing the negative impact on biodiversity, soil, water and air (Group of Chief Scientific Advisors, 2020).

The need of transforming the current system into a more sustainable and resilient food system is recognized by a wide range of stakeholders and ambitions for change are evident on multiple levels in society, both on a global level as well as in Sweden (Franke et.al., 2018; Kuylenstierna et.al., 2019). One example of ambitions for change on a global level is the UN Sustainable Development goals (SDGs), in many ways linked to the food system (Koehring, 2019). In 2015 all member states of the United Nations adopted the 2030 Agenda for Sustainable Development, including the 17 Sustainable Development Goals (SDGs), that provides a shared plan aiming for sustainability both for people and the planet, as well now as in the future (United Nations, n.d.). Briefly studying the SDGs, the thesis group can connect several to the food systems, as well argued by Koehring (2019). For example, SDG 2 Zero Hunger strives to improve food security and promote sustainable agriculture. It includes targets aiming at by 2030 having doubled the productivity and incomes of small-scale food producers, implementing resilient agricultural practices, helping maintain ecosystems and increasing the investment in infrastructure at rural areas and agricultural research. Other SDGs are also related to food systems, for example, SDG 14 Life Below Water, aiming to sustainable usage of the oceans, and SDG 12 Responsible consumption and production, aiming to ensure sustainable consumption and production patterns.

As well on a national level there are ambitions for change. For example, the Swedish government has the main responsibility of realizing the UN SDGs, with the help of actors within all levels of society (Franke et al., 2018). Moreover, Sweden has developed environmental goals, among several has a strong connection to the food system. For example, Sweden aims to secure a rich agricultural landscape, restrict climate impact and end overfertilization. Sweden has also developed a national food strategy, aiming at by 2030 e.g. increasing the overall food produced, contributing to an increase in self-sufficiency, increasing the amount of locally and organically produced and consumed food and making it easier for consumers to make conscious choices (Government Offices of Sweden, 2017).

Not only within the state are ambitions for change needed. For example, to be able to reach the goals of the Swedish national food strategy, the Government Offices of Sweden (2017) highlights the importance of involvement and effort made by all companies, organisations and stakeholders along the food chain to be able to successfully realize the strategy. It could be argued that ambitions for change to some extent already are present among these actors. For example, contributing to an increase in the organic food produced and consumed, the producers and consumers themselves have an impact. Indicated by an increase of the land utilized for organic food production and the organic food consumed, an increase in ambitions for consuming more organic food seems to be present both amongst producers and consumers (Naturvårdsverket, n.d.; Jordbruksverket, 2019). For example, between the years 2017 and 2018, the land utilized for organic food production increased by 6 percent (Jordbruksverket, 2019), and between 2004 to 2017 the consumed organic food increased by 5,6 percent (Naturvårdsverket, n.d). Similarly, a study made by Jordbruksverket in 2015 shows that the amount of consumers consuming locally produced food as much as possible has increased from 45 to 61 percent between the year 2011 to 2014 (Lööv et.al., 2015).

2.4. AQUAPONICS

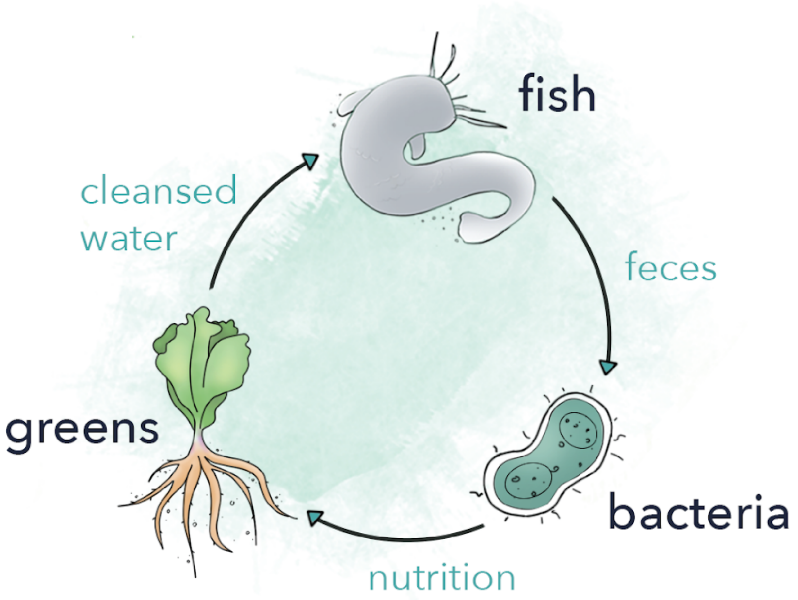
Protein consumption is increasing, due to a growing middle class, and together with an increasing population Velings (2015) calculates that in the year 2050 the world will require 70 % more protein sources than today. With fish being the animal protein with the highest feed conversion ratio compared to chicken, beef, pork and sheep, it is claimed to be one protein source with high potential of sustainability (Röös, 2014; Franke et.al., 2018). As current means of producing aquatic protein facing sustainability challenges, it is interesting to explore alternatives.

One rather new technology, with roots in ancient times, claiming to have the potential of providing solutions to some of the sustainability issues within the current food system, is the aquaponic technology (König et al., 2018). Aquaponics is a closed-system food production technology, integrating the concepts of aquaculture, i.e. fish farming, and hydroponics, i.e. farming of vegetables in soil-less media (Love et al., 2015; Rakocy et al., 2004). The technology is built on the coexistence of greens and fish, efficiently re-using the nutritions derived from fish feed and feces as nutritions for the greens (Rakocy et al., 2004). Through filters, the ammonia from the fish water is converted into nutrients, upon which the water is recirculated into the fish tanks (The Aquaponic Source, 2020), visualised in Figure 3. Moreover, the technology can be applied in a diverse set of contexts, ranging from commercial or community based urban food production to rural industrial-scale production (König et al., 2016).

Foremost, aquaponics is discussed to have the potential to improve sustainability as an alternative to the aquatic protein deriving from fisheries and aquaculture (Kloas et al., 2015). Similarly, König et al.(2016) argues that producing food in circular aquaponic systems results

in a significant reduction of environmental impacts, in comparison to the common plant production and fish farming of today, as it does not to the same extent contribute to soil erosion and pollution of the soil and groundwater. Apart from claiming to be a nutrient and water-efficient production method, it as well can be operated with close to zero waste as the small amount of waste produced, foremost in the form of sludge, can be composted into valuable products. Moreover, aquaponics is argued to have the potential of contributing to increased food security (König et al., 2016; Kloas et al., 2015). For example, König et al.(2016) argues that aquaponics applied in urban areas has the potential of increasing food production within cities and thus contribute to overall increasing food security. Moreover, aquaponic is argued to have the potential of contributing to sustainability through other means than only as sustainable food production. For example, it is argued to fulfill a purpose being an educational tool within schools, providing a better indoor climate being interior greening or as a unit in social institutions (König et al., 2016).

Figure 3.
Aquaponic system



Although aquaponic is argued to have the potential of being a sustainable option, it currently faces sustainable as well as economic issues. König et al. (2016) conclude that aquaponic systems can only be managed sustainably with a thorough knowledge of the individual components of fish, greens and bacteria as well as on a system level. With the interrelations between these three being highly complex and interdependent (Tyson et al., 2011), this presents a challenge to achieve sustainable and profitable systems. Moreover, it is a labour-intensive technology, in need of daily monitoring, and competes with conventionally grown products, as well presenting challenges regarding profitability (König et al., 2016). The importance of future research is highlighted by König et al. (2016) for this quite new and quickly developing technology to understand and assess its full sustainable potential. Amongst others, future research is needed on achieving maximum yield through successful cycling of nutrients and pH levels, technological advancements and alternative fish feeds.

2.5. The aquaponic niche actor Pond

This section presents the niche actor utilized as a starting point in this thesis when aiming at exploring how an individual niche actor can contribute to facilitating an upscale through the design of experiments. The actor addressed is the aquaponic producer Pond. Further, the company and one of its business concepts are presented.

Pond is a small company located on the West Coast of Sweden, focusing on urban food production, especially aquaponic technology solutions, as a means to increase food security by providing land-based food options (N. Wennberg, personal communication, march 11, 2021). Since 2014 Pond has been part of developing, building and running multiple fish farms, often combined with vegetables, in urban context within the region of Västra Götaland. In 2014 Pond developed its first aquaponic facility in the urban area Slakthusområdet, Gothenburg, together with a network of actors aiming at creating an ecological center in the currently empty factory premises within the neighbourhood (Stadsjord, n.d.). Apart from filling the urban void with food production, Pond aimed at involving citizens as well as politicians in dialogue on food culture, sustainability and food security as a means to increase the knowledge within these areas. As of today, Pond has moved out of the facilities in Slakthusområdet and has establishments at the sustainability hub Garveriet, Floda, where fish is being produced and sold to private persons both at the hub's restaurant as well as at its Fish shop (Öhman, 2020). In order to secure competence to take care of Ponds facilities, Pond promotes competence from the neighbourhood (Wennberg, 2019). In Ponds current facilities, they have been training young people from the neighbourhood, refugees (Wennberg, 2019) and people taking part in activity work programs (Sik, 2020), i.e. a service providing meaningful activities based on an individual's abilities. Moreover, Pond is currently working with expansions and collaborations as well in Sweden as across borders (Wennberg, 2019). One idea being explored is the use of standard containers as a means to provide modular and scalable aquaponic units.

Figure 4.
Season 5 (Greenhouse Living, n.d.) and container concept (Berg & Pond, 2020)

The idea of a modular container concept is partly based on the winning entry, Season 5, in the competition Urban Food From Residual Heat in 2017 (TailorMade, n.d.). During the competition, Niklas Wennberg, CEO at Pond, was a part of the winning team, contributing with his knowledge of sustainable and urban aquaponic production. Season 5 is a scalable and modular urban food production unit, combining fish farming in shipping containers with vegetable farming at greenhouses on top of the containers. Focusing mainly on the aquacultural part of Season 5, Pond is developing a mobile and modular land-based aquaculture unit, fitting fish tanks and connected tools required to run the production into standard containers (N. Wennberg, personal communication, december 12, 2020). Although currently at concept stage, it is built upon the technology and knowledge from Ponds established production facilities. The advantages of focusing on shipping containers, implicating modularity and mobility, are many. Being scalable and flexible increases the ability to fit a modular production unit into a variety of contexts, independent of size (Greenhouse Living et al., 2020). Further, a modular container is easy to build at a site but it is also easy to disassemble and remove. Thus, being a non-permanent method of building, it allows for temporary building permits and makes it suitable for temporarily non-used urban or rural spaces. So far, Pond's container unit represents micro-scale food production, with a capacity of producing 2-20 tonnes of fish a year (N. Wennberg, personal communication, march 11, 2021). However, as utilizing containers implies a flexible solution, it can be either scaled up or down to fit into the context of interest.

3. Theoretical Framework

The theoretical framework for this thesis builds upon theories on system understanding and design thinking. The theories used are Design Thinking, Multi-level Perspective (MLP), and Strategic Niche Management (SNM). In the following chapter, the theories will be further described and concluded by presenting takeaways on how the theories will contribute to the thesis process.

3.1. Design Thinking

The term design thinking first appeared during the 1960s when design methodology was launched as a subject (Cross, 2007), shifting the attention from the artefacts of design to the general process of designing (Ryan, 2014). Thus, design thinking is not only applicable to product developers but may as well be applied when generating service solutions, processes, governance models or business strategies (Conway et al., 2017). Ryan (2014) defines design thinking as a normative, user-centred and iterative approach to innovations. Moreover, Owen, (2006) presents characteristics argued important in design thinking, amongst others; human-centred focus, environmental-centred concerns, ability to visualise, ability to use language as a tool, systemic vision, tolerance for ambiguity and affinity for teamwork. The process of design thinking is not universally agreed upon, although Wölbling et al. (2012) present one example of a process in five steps; understanding the problem, processing data, ideating solutions, prototyping and testing.

In recent years, researchers and practitioners have been starting to explore the combination of design thinking and systems thinking (e.g., Ryan, 2014; Design Council, 2021; Conway et al., 2017). For example, Conway et al., (2017) conclude that while design thinking has been proven successful when creating new products and services, it still needs to be explored how it can support innovations attempting to scale and impact systemic change. Thus, augmenting design thinking with a systems thinking approach is suggested to ensure that the dimension of a systemic understanding and impact as well is recognised.

3.2. Multi-level Perspective

The Multi-level Perspective is a theory on how to understand and structure socio-technical systems and system innovations. It consists of three levels; the macro-level formed by socio-technical landscapes; the meso-level by socio-technical regimes; and the micro-level by technological niches (Geels, 2005).

Macro-level: Socio-technical Landscape

The landscape refers to both material and immaterial aspects affecting the socio-technical development of the wide exogenous environment (Raven, 2005). These aspects could be e.g. cultural aspects, macro-economic aspects or environmental changes, as well as material infrastructural changes such as highways and cities. The landscape works as a base and background for the socio-technical system and may not be directly affected by actors (Geels, 2005). When changes occur in the landscape, it results in pressure on the regime (Geels & Schot, 2007) which often leads to a change in the socio-technical regime.

Meso-level: Socio-technical Regimes

A socio-technical regime is a dynamic concept of structures of rules set by different social groups of certain technological systems or artefacts (Raven, 2005). The terms of 'rules' explain the body of the regime and cover all from engineering practices to product characteristics and production processes (Rip & Kemp, 1998). Geels (2005) adds the aspects of 'social groups' to further explain the complex configuration of the regime. The social groups include all actors who may affect the elements and linkages within the socio-technical system. These groups may be all from research departments, to the finance sector, to end-users . In order to understand the concept and to structure a certain system, the regimes are possible to explain by categorizing aspects into socio-technical characteristics (ST-characteristics); technology, market and user preferences, culture and norms, policies and laws, knowledge and science, and infrastructure and industry (e.g. Geels & Kemp (2000); Geels, 2005)

Micro-level: Technological Niches

The niches are special application domains, where radical innovation may occur (Geels, 2005), protected from the context in the regime (Raven, 2005). In other words, since radical novelties are initially fragile, they need to emerge in so-called 'protected spaces', separated from the mainstream market selection. Niches do therefore function as 'incubation rooms' (Geels, 2005). These incubation rooms are important for the development of learning processes and social networks which in turn are important for the radical innovations to grow.

3.3. Strategic niche management

Strategic Niche Management (SNM) is a theory foremost applied as a policy tool or research model. It has been used to understand how new sustainable technologies are introduced focusing on societal experiments. The theory was born because of the questions of why most environmentally improved technologies never become large enough to work commercially (Raven, 2005). Kemp et al. (1998) put emphasis on how governments can work as facilitators to steer transitions, but they also explain that different actors may apply SNM to manage sustainable change.

3.3.1. Societal experiments

The SNM literature has drawn from former literature on niches and innovations and suggests that niches do not naturally exist but have to be created, or formated. To create them, the SNM suggests societal experiments to be conducted, giving room for the innovations to evolve and improve (Kemp et al., 1998; Raven, 2005). Sengers et al., (2019) mean that experiments are important in the process of learning and shall reflect the socio-technical configurations of society to be representative and useful for structural transitions of socio-technical systems. Experiments could be described as pilot or demonstration plants where learning and testing of real-life experiences can be conducted (Raven, 2005). Therefore they have an opportunity to develop since they often are protected from the societal rules existing in the regime. Thus, they face fewer societal obstacles and are e.g. sometimes subsidised by authorities (Kemp et al., 1998).

3.3.2. Three aspects of niche formation

Along with the experiments, three important aspects of how to succeed with the creation of a niche have been identified by Schot et al., (1996) according to Raven (2005); the communication of visions and expectations from the actors, the creation of social networks promoting the experiments, and the learning processes within the niche. To form a niche, it is suitable to acknowledge how the three aspects interrelate, e.g. changes in one aspect result in changes in the others. Based on Raven (2005) Figure 5 demonstrates the connections of how the aspects are dependent on each other and how this impacts new design, incremental design or no change of the experiment.

Expectations & Visions

For a niche development it is crucial to have successfully articulated expectations and visions for the future since it demonstrates a certain direction and legitimates the protected space (Geels & Schot, 2008). Geels & Schot (2008) draws from earlier literature by Elzen et al., (1996) and Hoogma et al. (2002), summarized three aspects for the expectations to contribute to a successful niche development; they should be *specific* because general expectations may not guide the development enough; they should have a *high quality* to be competitive; and they should be *more robust* which means to be agreed among actors within the niche.

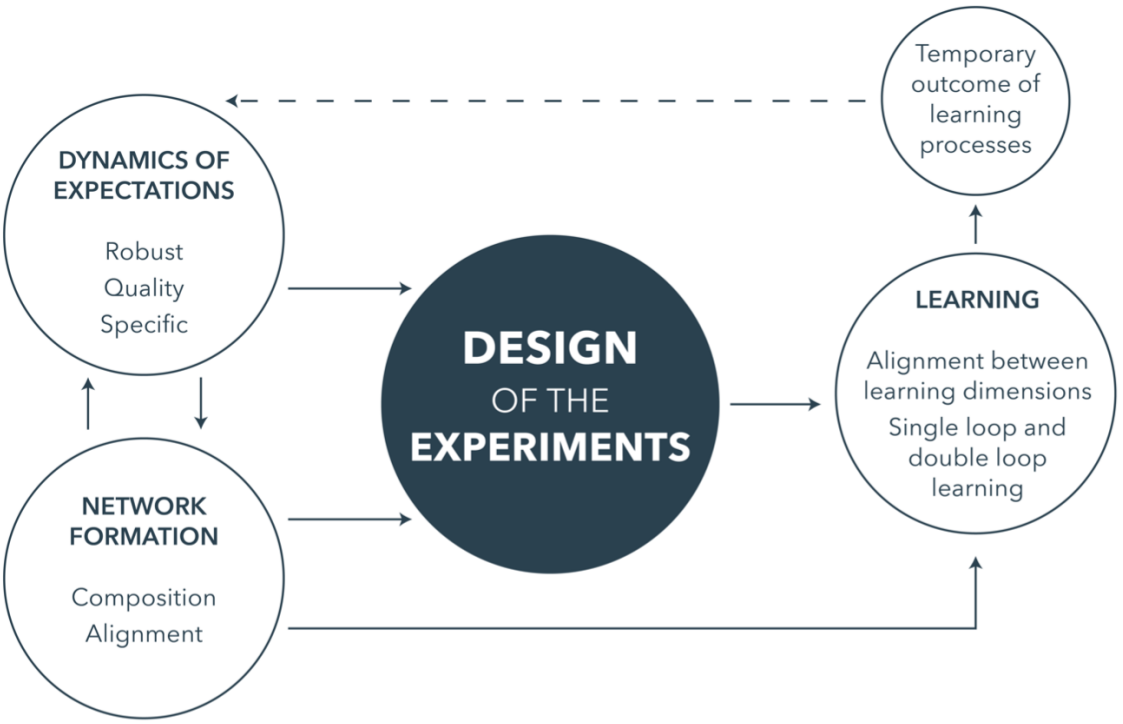


Figure 5.
Dynamics in internal niche processes (based on Raven, 2005)

Network Formation

The creation and enforcement of a strong social network is important for the development of the niche. This network facilitates for actors to grow and create good connections, it creates a window for the new innovation to develop further, and enables for the existence of necessary resources (Geels & Schot, 2008). The type of actors varies from societal groups and policy makers to users and producers. They are important to bring forward the expectations and rules within the niche (Raven, 2005). Likewise, Geels & Schot (2008) continued on the literature by Elzen et al. (1996) and Hoogma et al. (2002) and summarized two aspects which are important for the social networks; *deep networks* is important because it creates space for the involved actors to develop or rearrange within their organisation; and *broad networks* to contribute with different views from a large number of stakeholders, including not directly dependent stakeholders since they may give necessary insights. Hoogma et al. (2002) also discuss the importance of a variety of actors since established actors, compared to new actors, are more influenced by the regime and may therefore contribute to more successful navigation of the niche formation. Furthermore, Raven (2005) explains how an experiment may contribute to network formation and writes that experiments have mostly used already existing networks. Existing networks have established and working channels that the experiment can take advantage of.

Learning processes

Learning processes from different levels are important for niche developments (Kemp et al., 1998). These learning processes may be divided into seven areas, similarly to the ST-characteristics; societal and environmental effects, regulations and government policy, industry and production networks, infrastructure and maintenance networks, cultural and symbolic meaning, market and user preferences and technical aspects and design specifications (Geels & Schot, 2008). Experiments can be constructed to nurture learning within the development in order for the niche to develop successfully (Raven, 2005). Furthermore, Hoogma et al. (2002) established relationships between the process of learning and the actor-network and concluded that there is a higher possibility of market niche creation if the actor selection is wider, even including both outsiders and users, and thus contributes to a more encompassing learning process.

3.3.3 Four patterns of niche formation

Out of the internal niche formation process and the experiment cycle, see Figure 5., four patterns of niche formation appear (Hoogma et al., 2002). These are technological niche proliferation, development of market niches, regime transformation and technological or market niche extinction (Hoogma et al., 2002; Raven, 2005).

Firstly, the technological niche proliferation emerges if the internal niche process results in various new experiments. However, the technology is not stable enough to be sufficiently competitive and therefore the 'protected space' needs to be continuously maintained (Raven, 2005). Secondly, the pattern of development of market niches occurs if a technology has reached economic sustainability and consists of technological niches merging into one or more market niches. A market niche is a niche possible to impact and influence the regime since the novel technology of the market niche has an advantage over the established technology in the regime (Hoogma et al., 2002). However, the niches are not yet visible in the regime and only a few actors rearrange into this new technology (Raven, 2005). Similarly, the process in which niche experiments can come to influence or transform a regime, through activities embedding the experiment in regime level structures, is by others called upscaling (Jolly et al., 2012). Thirdly, through the pattern of regime transformation, a new dominant technology emerges, hence the regime transforms (Raven, 2005). This happens if new technologies transfer, via technological and market niches, into the dominant technology. It results in a changed regime even though most often many aspects from the old regime remain. The last pattern of niche formation occurs if the niche is not successfully developed and accordingly returns to a R&D option again.

3.3.4 Debated shortcomings of SNM

Literature reveals some debated shortcomings with the SNM theory. For example, Raven (2005) debates the theory's simplicity, not including enough internal and external forces. Moreover, both Raven and Hoogma et al. questioned whether the theory is applicable as a tool for transition, since transitions are such complex phenomenons (Hoogma et al., 2002), and since there is a lack of literature and research on how to steer experimentation management over longer periods of time (Raven, 2005). Furthermore, the number and spread of experiments during the niche formation process is a challenging and debated subject. For example, Hoogma et al. (2002) mean that experiments do not contribute enough to change the regime since they do not affect actors sufficiently, of which other incentives should contribute, and that a variety of experiments has been shown necessary.

3.4. Application of theories

The thesis will be characterized by a design thinking approach, e.g. inspiring the process. While combining design thinking with a systems perspective, MLP and SNM will be applied. The MLP will foremost be used to understand the current food system, and to structure interviews and results. The definition of niche and regime as well as the ST-characteristics are most important. Similarly, since the aim of the thesis is to manage an upscale of the aquaponic niche, SNM will be applied while structuring results, analysis and the process of niche formation. Most important for the thesis are the three aspects of niche formation, the process of upscaling, and the definition of societal experiments. In addition, the debated shortcomings of the theory will be considered.

4. Method

This chapter presents the methods applied during the thesis. The chapter is divided into three main sections, Phase 1, Phase 2 & Phase 3, and presents the methods accordingly. Phase 1 presents methods utilized for data gathering and data analysis, aiming at understanding the aquaponic niche within the current food system. Phase 2 presents the methods used when aiming at providing guidance for aquaponic actors to navigate niche formation. Lastly, Phase 3 presents methods aiming at exploring and exemplifying how an individual niche actor might contribute to the facilitation of an upscale. Figure 6 presents a graphical representation of the steps and methods applied in the thesis.

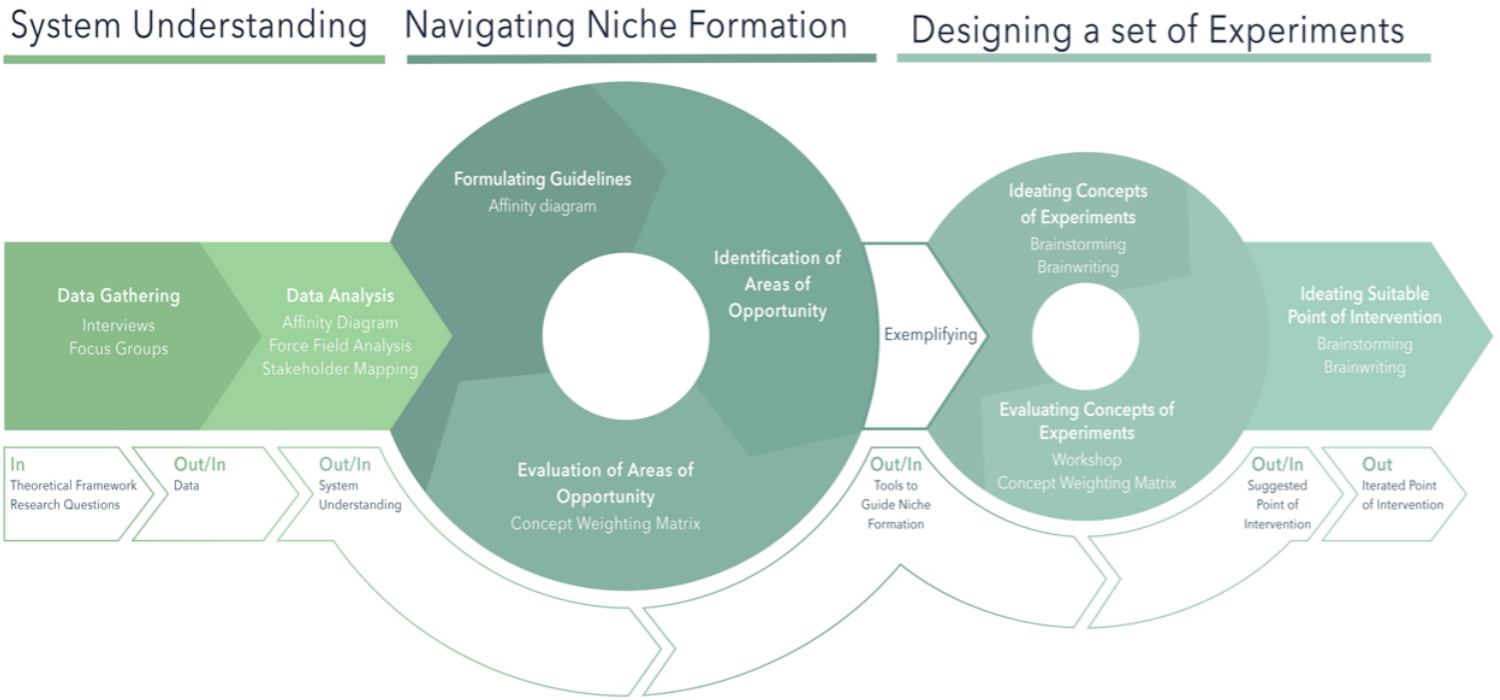


Figure 6.
Project process and main outcomes

4.1. Phase 1: System Understanding

With the aquaponic niche within the current Swedish food system as its setting of research, Phase 1 aimed at understanding the current system through mapping stakeholders and their relationships and identifying forces restraining and enabling an upscale of the niche. Further, the methods utilized to gather and analyze the data are presented.

4.1.1 Data gathering

Data was gathered performing interviews and focus groups. Further, these methods as well as their applicability in Phase 1 are presented.

4.1.1.1. Interviews

Setting out to understand the system, interviews were conducted with a variety of actors within, or with a relationship to, the aquaponic niche. All interviews were held as online video meetings and were documented by audio recordings, later transcribed to enable data analysis. The interviews were of semi-structured character with open-ended questions, allowing the interviews to provide depth and new perspectives but also allowing comparison and analysis of the answers (Leech, 2002). To structure the interviews, a question template was used (Appendix A.).

Table 1. Conducted interviews

Interview No.	Actor	Participants
1	Aquaculture actor	Founder
2	Aquaponic producer	Owner Owner
3	Aquaponic producer	Owner
4	Aquaponic producer	Manager
5	Aquaponic research	Researcher
6	Seafood Restaurant	Chef
7	Supermarket	Owner
8	Fish store	Manager
9	Sustainability Hub with aquaponics	Kitchen manager Investor Facility Owner
10	The Swedish Board of Agriculture	Authority employee Authority employee Authority employee
11	Vattenbrukscentrum Ost	Researcher

In total, eleven interviews of approximately one hour each were conducted in Phase 1, with fifteen participants. The first stakeholders were selected aiming at including a broad variety of actors from both market, civil society and state, see Table 1. Moreover, the aim was to include actors from the aquaponic as well as from relevant related fields such as aquaculture. All actors had some previous knowledge and relationship to the aquaponic technology and aquaponic producers. The initial selection was complemented as interviewed stakeholders were asked for recommendations on others relevant to interview, setting the foundation for further selection.

4.2.1.2 Focus groups

To capture perspectives of potential customers, two focus groups were held as online video meetings, with in total seven participants, as visualised in Table 2. A focus group is often defined as a method aiming at gathering qualitative data through a group discussion with a specific focus (Hylander, 1998). Foremost, the aim was to identify and validate forces affecting change deriving from the experience of potential consumers and customers of fish and greens produced in the aquaponic system. The focus group was of semi-structured character with open-ended questions (Leech, 2002), and followed a semi-structured question template (Appendix B.).

As the aim was not to generalize, nor compare the result, but rather collect a brief understanding of potential forces affecting change, a representative and statistical selection was not considered necessary (Hylander, 1998). The selection for the two focus groups was made using the snowballing technique, where others' were asked to identify potential participants (Tursunovic, 2002). Further, focus groups are often created according to a rather homogeneous selection with certain characteristics focused upon when composing the groups (Hylander, 1998). Aquaponic food being relatively new to the market, the selection was made to gather data from individuals with low or no previous knowledge of aquaponics but with a high likelihood of purchasing aquaponic food. The first focus group was set up by participants with a high interest in sustainable food and/or commonly purchasing food directly from the producers whilst the other group consisted of participants with some interest in sustainable food and some in purchasing food directly from the consumers.

Table 2.
Conducted focusgroups

Focus group No.	Theme	Participant Characteristics
1	highly potential consumers	1.1. prioritizes organic and localy produced food
		1.2. often consumes directly from producer
		1.3. often consumes directly from producer
2	potential consumers	2.1. prefers high quality fish from fish stores
		2.2. sometimes buys organic and from producer
		2.3. often prioritizes price and availability of store
		2.4. often prioritizes price and availability of store

The focus group was divided into two parts. The first part consisted of a general discussion of what factors are important when purchasing food, for example, at a supermarket, at a restaurant or at a farmers market. The second part of the focus group was built around the scenario of a customer having the option of purchasing aquaponically produced food. According to (Hylander, 1998), a scenario is one way of uniting a focus group around a common focus and discussion. The participants in the two focus groups were approached by the scenario at three times, with three levels of knowledge; with brief theoretical knowledge of aquaponics, and after a session with questions and answers simulating a dialogue with the producer. The purpose of this was to learn about potential enabling and restraining forces amongst customers with different levels of knowledge. As a tool to communicate knowledge visually to the participants, pictures and illustrations were used.

4.1.2. Data analysis

Further the data analysis methods are presented; stakeholder onion diagram, affinity diagram and force field diagram.

4.1.2.1. Stakeholder mapping using a Stakeholder Onion Diagram

Studying the aquaponic niche within Sweden there are several actors with a relation to the niche, apart from the aquaponic producers themselves. These actors, so-called stakeholders, are defined as someone who affects decisions made within a project or someone who gains or loses something of a project, e.g. financial, functional or status (Alexander & Robertson, 2004). Aiming at understanding the system of the aquaponic niche, understanding the stakeholders, their relationship and their role in the system is believed to be important. Thus, a Stakeholder Onion Diagram was used to map and visualise the stakeholders in relation to an aquaponic food producer.

To identify stakeholders the thesis group created a first draft of a map, based on previous knowledge and experience, aiming at identifying a first set of stakeholders. Utilizing these identified stakeholders as a starting point the stakeholder onion diagram was further evaluated and updated through the stakeholder interviews.

A stakeholder onion diagram visualises the relationship between a project, or in this case an aquaponic food producer, and its stakeholders (Alexander & Robertson, 2004). Basing the diagram of this analysis on the diagram created by Czischke (2018) the diagram visualises stakeholders according to three levels of involvement, as involvement increases closer to the center of the chart, and according to three different types of relationship, visualised by arrows. Further, it as well bases the diagram on three domains to which the stakeholders belong; the market, the state and the civil society.

The relationships between the project and its stakeholders are mapped according to three levels of involvement surrounding the project; primary stakeholders, secondary stakeholders and the wider environment (Czischke, 2018).

- Primary stakeholders: Stakeholders with significant influence, strong legitimacy and/or strong control over resources. Involved on a day-to-day basis.
- Secondary stakeholders: Stakeholders that play an important role in the project, but are not involved in day-to-day operations.
- Wider environment: Individuals or organisations that are indirectly affected but whose actions and competence provide a framework for the project.

To visualise as well the relationship between the stakeholders in the diagram, arrows were used to visualise three different types of relationships (Czischke, 2018).

- Strong collaboration relationship: Relationships related to day-to-day operational aspects and actors who are mutually interdependent.
- Ad-hoc collaboration relationship: Relationships limited to more specific means.
- Indirect relationship: Latent or implicit relationships, often with a connection to laws or regulations.

4.1.2.2. Thematic analysis through Affinity Diagram

Having gathered data through the use of focus groups and interviews the transcript was analysed using an affinity diagram. An affinity diagram, or K-J analysis as it as well is known by, is a way to organize field data and reveal common issues and themes (Holtzblatt & Beyer, 2017). The data is transferred onto, for example, sticky notes and grouped into categories, often consisting of 4-6 pieces of data, describing a specific issue or point. It is often built bottom-up and starts without predefined categories to allow new knowledge and insights to be gained. The identified categories can further be arranged into larger areas of interest.

The purpose of using Affinity Diagram in this thesis was to analyse the data collected through interviews and focus groups. As the data was collected in a semi-structural manner, using Affinity Diagram enabled a way to structure the data through clustering it and visualizing patterns and themes. This was done through collecting interesting information from the transcripts on sticky notes, upon which they were grouped as patterns of enabling and restraining forces for change emerged. In a second round of analysis, the forces were grouped into the six characteristics of a socio-technical system (see Section 3.2.), see Fig. 7.

Figure 7.
Affinity diagram in progress

4.1.2.3. Visualisation of forces affecting change through Force Field Analysis

To further analyse and visualise the forces identified in the Affinity Diagram, a Force Field Analysis was used. Force Field Analysis is a method that maps out and visualises forces favouring and resisting a proposed change, in this case, an upscale of the aquaponic niche (Thomas, 1985). The forces favouring and resisting change are represented by arrows or vectors opposed to one another in the diagram (e.g. see Section 5.1.2.). The length of the arrows can be used as a representation of the relative strength of the forces. Change and movement within a system can either be achieved by increasing the forces for change or reducing the forces opposing the change.

In this thesis, the Force Field Analysis was used with the purpose of visualising the enabling and restraining forces affecting an upscale of the aquaponic niche. Unlike how Thomas (1985) utilizes the length of the arrows to represent the relative strength of the forces affecting change, the length in this case instead represents the number of actors directly or indirectly mentioning a certain force. As a result, one step in the diagram represents one interview or focus group. Thus, instead of showing the relative strength of the forces, this diagram rather shows how widespread the awareness and knowledge about a certain force is amongst the interviewed actors.

4.2. Phase 2: Navigating niche formation

The purpose of Phase 2 was to study how to guide the niche actors to navigate niche formation, and thus facilitating an upscale of the aquaponic niche. Thus, the research setting focuses on the aquaponic niche within the current Swedish food system. Further, the methods applied to generate guidelines and identify and evaluate areas of opportunity are presented.

4.2.1. Formulating guidelines to facilitate an upscale

With the purpose of identifying what might be needed from the aquaponic niche to either increase the enabling forces or reduce the restraining forces and thus, facilitate movement within the system (Thomas, 1985), the identified forces from Phase 1 were further analyzed. Much similar to the Affinity Diagram applied to conduct a thematic analysis of the interviews, this was done through grouping the forces into themes and areas formulated as guidelines of how to potentially facilitate an upscale of the aquaponic niche. The identified guidelines were further analysed in a second round and grouped into groups of guidelines. Grouping the guidelines, the three processes of Strategic Niche Management (see Section 3.3.2.), expectations & visions, social networks and learning processes, were used as a starting point.

4.2.2 Identification of areas of opportunity

The interviews conducted with stakeholders not only generated a general system understanding but discussions with stakeholders were also held on potentially new directions of the Swedish aquaponic niche, new actors to include and unexplored areas with potential. Having transcribed the interviews, these new ideas were gathered. Doing so, four potential areas of opportunity were identified in which the aquaponic niche could continue to develop to facilitate an upscale.

4.2.3. Evaluation of areas of opportunity

Aiming at mapping how the four identified areas of opportunity relates to the set of guidelines created, an evaluation was done using a concept weighting matrix (Wikberg Nilsson et.al., 2015). Concept weighting is done to evaluate and rank concepts using a matrix in which the concepts are placed on one axis and relevant criteria decided upon on the other axis. In this case, the areas of opportunity were the concepts and evaluated against the guidelines, utilized as the criteria. Performing the method, each concept is compared to each criterion and given a score indicating how well it is fulfilled. In this case, the thesis group assigned scores ranging from 1-3, illustrating how much focus the area of opportunity potentially puts on addressing each guideline. If applicable, the points can be summarised into final scores for each of the concepts by summarizing the points for each concept and divide it by the number of criteria utilized (Wikberg Nilsson et al., 2015). As the aim of the evaluation was to evaluate the areas towards the guidelines, rather than evaluating them towards one another, these final scores were not applicable during this stage of the process but instead applied when evaluating the concepts developed for Pond to identify a suitable point of intervention (see Section 4.3.2.).

As a final step of the method of creating a concept weighting matrix analysis of weak spots can be made (Wikberg Nilsson et al., 2015). This is done by identifying the spots in each concept where the points are low and secure that these spots are addressed in the final concept. Based on the idea of a weak spot analysis, this thesis instead identified the guidelines in which none of the identified areas of opportunity had a high focus. Based on these identified unaddressed guidelines, a fifth area of opportunity was added to secure that the areas in combination had a high focus on all guidelines.

4.3. Phase 3: Designing a set of experiments

While Phase 2 aimed at guiding the general niche towards an upscale, the purpose of Phase 3 is to exemplify and further explore how an individual niche actor might contribute to an upscale. Thus, the focus of the research shifts onto the aquaponic producer Pond and their current business, exemplifying a specific niche actor within the aquaponic niche. Further, the methods applied when exploring how this specific actor can contribute to an upscale are presented.

4.3.1. Ideation of concepts of experiments for Pond

Aiming at exploring and exemplifying how one actor within the aquaponic niche, in this case Pond, can utilize the areas of opportunity and the guidelines to contribute to an upscaling of the aquaponic niche, concepts of five experiments were developed. The experiments were based on the business idea of Pond and each one mapped to one specific area of opportunity.

Aiming at developing concepts based on Ponds business, three interviews were held to gain an understanding of Pond, their drives and values and learn about their current business and ongoing collaborations. The interviews were of semi-structured character (Leech, 2002) and each aimed at exploring a certain theme of interest, see Table 3. The interviews lasted approximately 45 minutes and were all held as online video meetings.

Table 3.
Exploratory interviews

Interview No.	Theme	Participants
1	General understanding of business	Owner
2	Collaborations and projects in Sweden	Owner
3	Projects Abroad	Owner
		Intern
		Intern

With a base in the understanding gained through the interviews, concepts were ideated during an ideation session utilizing brainstorming and brainwriting. Brainstorming is a method aiming at generating a large number of ideas by stimulating the participants' creativity through sharing ideas (Wikberg Nilsson et al., 2015). In order to do so, the importance of aiming at a quantity of wild and crazy ideas, instead of qualitative ideas, and group climate characterized by safety and non-critique is highlighted. Building upon the same ideas, braindrawing instead utilizes sketches and therefore potentially stimulates other perspectives and ideas (Wikberg Nilsson et al., 2015). A brainstorming or brainwriting session can be set up in a variety of ways, however often circulates around predefined themes or questions. In this case, the session was divided into five parts, each part focusing upon ideating concepts addressing one area of opportunity. During each part, focus was as well put on addressing the guidelines related to each area of opportunity. Each area was firstly individually ideated upon, using a combination of text and sketches (see Figure 8.), for approximately thirty minutes. Afterwards, the ideas were shared within the thesis group and combined into five concepts further visualised.

4.3.2. Evaluating concepts in a workshop

To explore which of the five concepts had the highest possibility of being successfully implemented and maintained by Pond, while still having the potential of facilitating an upscale of the niche, the thesis group and Pond together evaluated the concepts.

The evaluation was done during a one and a half hour workshop session, held as an online video meeting, in which the CEO of Pond was invited as an expert of their current business. A workshop is a collaborative working meeting aiming at exploring a certain area of interest (Wikberg Nilsson et al., 2015). A workshop can be arranged in a variety of ways, however in this case it utilized a concept weighting matrix as its starting point. As previously described in Section 4.2.3., a concept weighting matrix places the concepts on one axis and evaluation criteria on the other axis (Wikberg Nilsson et al., 2015). Thus, relevant evaluation criteria was firstly decided upon together. However, to ensure that the concepts ability to facilitate niche upscaling was not neglected, the criterion of how well the concept addressed the guidelines was already decided upon and rated by the thesis group. Apart from this pre-set criterion, each concept was evaluated against each of the criteria using an interactive matrix (see Appendix C) and assigned with scores ranging from 1-3. Lastly, the final score for each concept was summarised. As one criterion was regarded as more important by Pond, the impact of this score was doubled to ensure a fair final score.

Figure 8.
Ideas from ideation session

With a base in the final score for each concept, together with recommendations from Pond, a concept was chosen to further develop.

4.3.3. Ideation of suggested point of intervention

Based on the result from the workshop with Pond, the suggested point of intervention was further ideated upon. This was done by combining one concept with elements from another complementary concept, aiming at creating a final concept with an improved possibility of targeting guidelines as well as criteria used in the evaluation matrix (see Section 4.3.2.). Similar to when ideating concepts, the ideation of the suggested point of intervention was done using the methods brainstorming and brainwriting (Wikberg Nilsson et al., 2015).

5. Results & Analysis

This chapter contains results and analysis of the thesis work, divided into three parts. Phase 1 regards the system understanding, Phase 2 explores how actors might navigate niche formation and Phase 3 focuses on exemplifying by designing a set of experiments based on the aquaponic producer Pond.

5.1. Phase 1: System understanding

The first phase of the project aimed at understanding the socio-technical food system where the aquaponic niche is a part. This concluded in a mapping of the stakeholders involved or relevant to the system, and forces affecting change within the system. Further, the result and analysis of the second phase is presented.

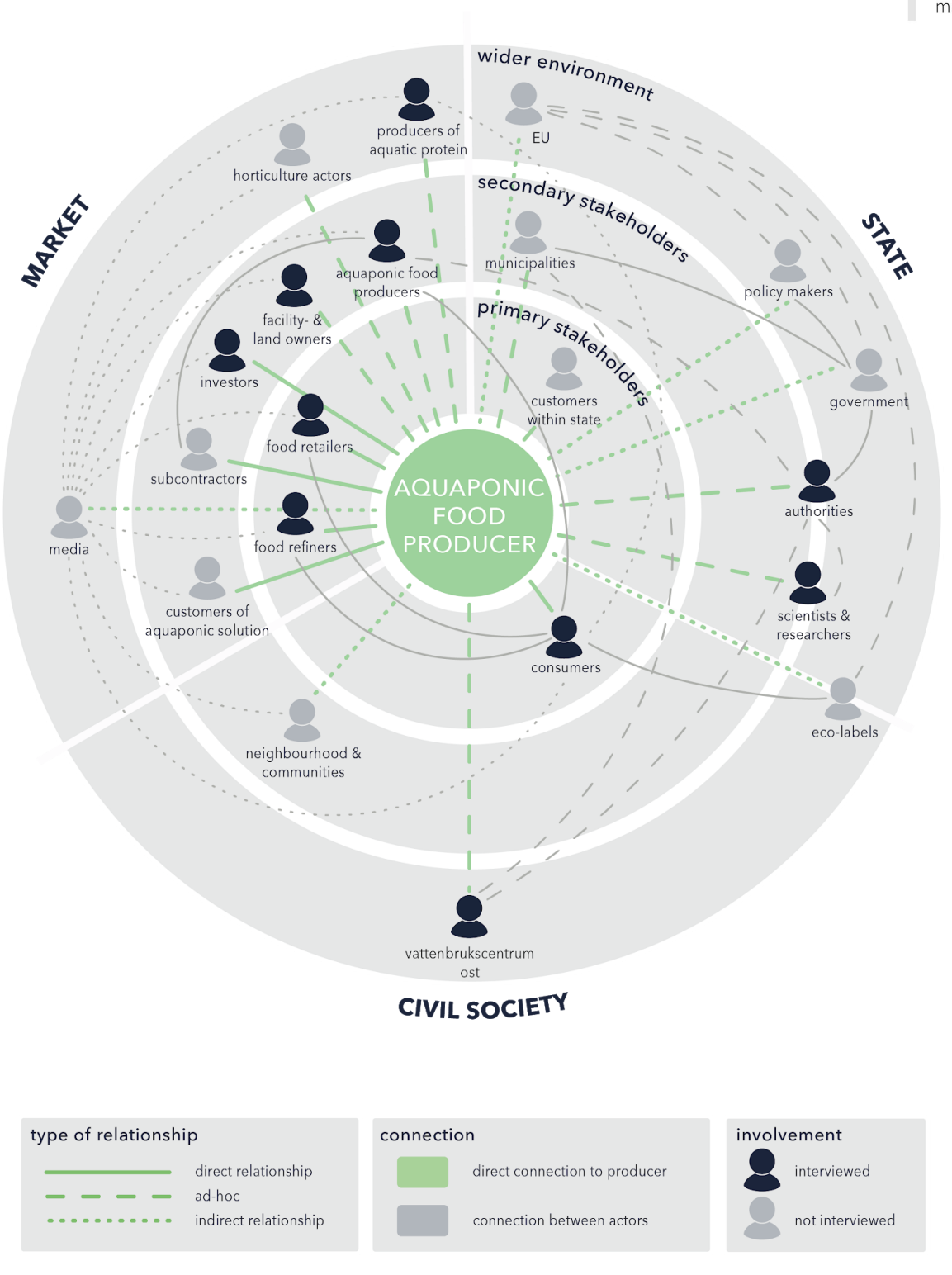
5.1.1. Mapping of stakeholders

Within the aquaponic food system there are several actors who affect or in other manners are relevant. The semi-structured interviews with stakeholders resulted in a deeper understanding of who these actors are, what sector they are part of, their connection to the core aquaponic food producer, and how they interrelate. The stakeholder mapping is illustrated in a stakeholder onion diagram, see Figure 9., presenting the stakeholders and the connections that are considered most important when aiming at understanding the system. The diagram as well shows which stakeholders have been participating in interviews. Following, a description of each actor and their relationships to one another is presented according to the three levels of involvement; primary stakeholders, secondary stakeholders and the wider environment.

5.1.1.1. Aquaponic food producer

The stakeholder diagram is analyzed placing the aquaponic food producers in its center. Being the owner of the production facilities, they are perceived as the primary force pushing the niche forward. Their main focus is to produce fish and greens through utilizing aquaponic technology, thus, providing an alternative to current food productions. Additional focuses are as well present among the producers, e.g. knowledge sharing and research collaborations.

Figure 9.
Stakeholder mapping



5.1.1.2. Primary stakeholders

The thesis identified four primary stakeholders who may be involved in a day-to-day operation with the core aquaponic food producer. Moreover, all primary stakeholders have a direct relationship to the core aquaponic food producer meaning they are mutually dependent and have a high frequency of involvement. All primary stakeholders are customers of the raw product from the core aquaponic food producer.

Consumers

The consumers include people who consume the fish and greens produced by the aquaponic food producer. They could, for example, be end-customers purchasing the fish and greens or visitors at restaurants or events. The consumers' relation to the core aquaponic food producer is strong since they are in direct and often continuous contact with the product. Consumer-behaviour affects the business, for example in the number of purchases, just as the communication from the producer affects the perceptions of the fish and greens for the consumer. The consumers have, apart from a direct relationship to the core aquaponic food producer, also strong relations to food refiners and retailers as well as eco-labels. Likewise, the refiners and retailers of aquaponic food are just as dependent on the consumers as the aquaponic food producer is. Moreover, eco-labelling seems to impact many consumers since it gives promises of ethically produced and eco-friendly food, which many consumers request according to several of the interviewed stakeholders.

Food refiners

Food refiners consist of stakeholders such as restaurants and other companies refining food, for example, a company selling pre-cooked meals. These actors are customers, although not the end-customers, purchasing the produced aquaponic raw product. According to several of the interviewed stakeholders, significant for many food refiners is a demand for continuous delivery of the product. This may be challenging, but also beneficial since it may induce agreements with the aquaponic food producer, entailing repeated purchases and ensuring future sales-channel. Thus, they are very valuable collaborators according to the interviewed stakeholders. The food refiners have a direct relationship to the consumers, since the consumers purchase their product, and to the core aquaponic food producer since they buy the raw product from them.

Food retailers

Supermarkets or niched stores such as fish stores, are examples of food retailers who may sell the produced fish and greens. The food retailers vary in type, size and location. Like the food refiners, the food retailers are in direct relationship to the consumers and the core stakeholder because they are mutually dependent on a strong relationship. The core aquaponic food producer may as well sell their own products by entailing a producer to consumer strategy and sales channel, thus, taking on the role as food retailer as well as aquaponic producer.

Customers within state

This group is similar to the food refiners but do specifically target consumers within the public sector instead of e.g. civil visitors at restaurants. The customers within the state are e.g. schools, hospitals or public companies. They may include larger segments of individuals, e.g. universities or hospital restaurants, and can therefore be very important for the aquaponic producer since they ensure strong sales channels. Further, they usually come with public agreements and procurements.

5.1.1.3. Secondary stakeholders

During the thesis, nine secondary stakeholders were identified which are important for the core stakeholder but not involved on a day-to-day basis. The majority of the relationships between a secondary stakeholder and the aquaponic food producer within this system is ad-hoc, however both direct and indirect relationships exist as well.

Municipalities

The municipality in which an aquaponic producer is located may have relations to the aquaponic producer, foremost regarding regulations and permissions. Due to the decision making position, the boards of the municipalities have some power over the aquaponic producer. At the same time, the aquaponic producer has opportunities to influence the boards and their decisions through creating knowledge and awareness. Similarly, other aquaponic producers and the aquacultural non-profit organisation might influence the municipalities through creating knowledge and awareness. Moreover, since the municipalities are not involved daily with the aquaponic producer and because they have different dependency on each other, their relation is ad-hoc.

Governmental agencies

Swedish governmental agencies, such as agencies specialized in agriculture, ocean and water, and food, are placed between being a secondary stakeholder and the wider environment since their role in the aquaponic projects varies. Just as the municipalities, the agencies have an impact through matters regarding regulations and permissions, but may also function as enablers regarding subsidies, guidance and support. They are normally not involved daily with the aquaponic producer and altogether the relationship to the aquaponic producer is ad-hoc. Moreover, the agencies have a direct relationship to the government, maintaining the law and specialized knowledge, and ad-hoc relations to the aquacultural non-profit organisation, and scientists and researchers since they collaborate in education and knowledge sharing, just as developing the technology.

Scientists & Researchers

Like the agencies, this group is positioned between being a secondary stakeholder and the wider environment since they can play an important part for the stakeholders, just as they may direct and support the technology with a framework from a distance. They could propose new business strategies, as well as improvements of the technology, beneficially for

the current food system to transfer into higher sustainability levels. Since the scientists and researchers often are involved in limited projects or as temporary counsellors, their relations to the aquaponic producer is ad-hoc, even though the relations at times with daily collaborations may be direct.

Neighbourhoods

Neighbourhoods are defined as groups of people or organisations that are not in direct contact with the aquaponic producer as consumers but will be affected by their presence. For example, the neighbourhood might be affected as the aquaponic producer spreads knowledge and awareness. Their presence may as well impact how individuals move around the neighbourhood, and may potentially attract new groups to the site. The neighbourhood actors may therefore be indirectly involved day-to-day with the aquaponic producer since they are not necessarily in direct contact purchasing the product.

Customers of aquaponic solution

The aquaponic producer not only has the possibility of selling the produced food, but also the production system and knowledge about the technology as such. Thus, stakeholders who may buy the technological solution are defined as customers of the aquaponic solution. They are positioned as a secondary stakeholder as they are not involved daily, but rather occasionally when selling solutions or knowledge. However, a one-time purchase of the technology may for example shift into a leasing contract which makes the secondary stakeholder position debatable. Nevertheless, they have a direct relationship with the aquaponic producer since they are mutually dependent on each other while managing the trade.

Subcontractors

All actors who deliver products or services to the core stakeholder to make the business possible are defined as subcontractors. It could be both subcontractors involved daily as well as more seldomly. They are positioned as secondary stakeholders, although their involvement and their interdependency might vary. One example of an important subcontractor is companies delivering spawn. Although not involved daily, the system is highly dependent on them. Other subcontractors are, for example, fish feed suppliers or waste disposal businesses. Generally, their relationship with the aquaponic producer is direct since they are strong and on operational aspects involved day-to-day in the business. Similarly, they also have a direct connection to other aquaponic protein producers.

Investors

Investors are essential for the aquaponic producer if there is a lack of capital. The investors could include public or organisational fundings as well as private investments. If the aquaponic producer itself has enough capital, this stakeholder will expire. The investors will not be involved in the daily business, but on the other hand, they will have mutual interests with the aquaponic producer in economic terms which makes the relationship direct.

Facility- & land owners

Facility- and landowners are highly important for the aquaponic producer since they provide the space for the production. However, the owner may as well be the aquaponic producer itself, if the aquaponic producer already owns the land or facility. An external facility- or landowner is a secondary stakeholder since its terms will be present daily although not involved in operational aspects. Further, the relationship to the aquaponic producer is ad-hoc since it is limited to specific means regarding facility- or land matters.

Other aquaponic food producers

There are currently a few aquaponic food producers in Sweden, but the interviews revealed hopes for an increase in the number of actors. These aquaponic food producers have similar prerequisites as the core aquaponic producer and therefore might have similar relationships to stakeholders such as subcontractors, media and authorities. However, other stakeholders are not necessarily shared with the core aquaponic producer. For example, the investor and the customers might differ between the aquaponic producers. The relationship between the core aquaponic producer and other aquaponic producers is ad-hoc, although varies depending on, for example, the frequency of collaboration. However, the other aquaponic food producers will not likely be involved day-to-day and are therefore secondary stakeholders.

5.1.1.4. Wider environment

The stakeholders in the wider environment are spread over different sectors and have various levels of power and influence over contextual matters as well as laws and regulations. The relationships to the aquaponic producer are never direct, but the actions made in the wider environment still affects the aquaponic producer significantly through providing a framework.

EU

The European Union holds laws and regulations the national government inherits and upholds, thus, providing a framework for the aquaponic producer. Although rarely in direct contact with the aquaponic producer, their relationship is indirect. Moreover, the relationship to the government, policymakers and some eco-labels are ad-hoc since they are in contact more frequently.

Policymakers

Policymakers are most often members of the state sector with strong relations to the government, although might as well be members of development- or strategy departments at companies. They are not frequently involved with the aquaponic producer but may affect them significantly with their policy-making, therefore they have an indirect relationship to the aquaponic producer. The policy-making could, for example, include more emphasis on R&D departments, new subsidies or tax reductions, focus on network creation or knowledge and information spread. Moreover, they are also dependent on EU regulations.

Government

The government is the stakeholder setting laws and regulations, but may also provide fundings and policymaking. The government delegates certain matters to authorities, agencies and municipalities and is therefore seldomly in direct contact with the aquaponic producer. However, the aquaponic producer will be heavily affected by actions and decisions made by the government. The government is also in relation with the European Union, upholding international regulations.

Eco-label organisations

There are currently several eco-labels on the market. Their role is most often to determine ecology, ethics and social sustainability of products and services, making them framework providers within the wider environment. During interviews, KRAV is the label most frequently discussed, although currently not available for land-based fish farming. Thus, there are, according to the interviewees, no generally well-known label enlightening environmental or ecological sustainability applicable for aquaponic technology and production. Moreover, the consumers are in direct relation with the Eco-labels since they share interests in defining the sustainability of products, and are very dependent on each other. The connection to the EU is also interesting since KRAV, for example, is based on EU terms.

Vattenbrukscentrum Ost

This stakeholder is a non-profit organisation with the interest of developing aquaculture and water use. Since their main focus is not on aquaponics solely, but rather on improving the prerequisites for aquaculture, they and the aquaponic producer have a limited exchange and do therefore claim an ad-hoc relation. On the other hand, their competence will support the aquaponic producer and the system even though they are not involved day-to-day, which is why they belong to the wider environment. Moreover, they have ad-hoc relations with authorities since they educate these groups.

Media

Stakeholders within the media include journalists and reporters, using different channels such as papers, TV or internet to communicate. They belong to the wider environment since they provide an indirect framework for the society, and thereby the aquaponic producer, with their actions and choices of focal points. Like the government, the media will affect all stakeholders in the diagram since they often reach many readers and listeners, but more seldomly are in contact with each stakeholder which makes the relation to the stakeholders indirect.

Horticulture Actors

The stakeholders defined as horticulture actors include actors such as vegetable farmers, plant nurseries and hydroponic farmers. Currently, they are competitors, since they already provide customers with greens and therefore have an indirect relation to the aquaponic producer. However, several of the interviewed aquaponic actors expressed interest in establishing more direct relationships by initiating collaborations with horticulture actors.

Producers of aquatic protein

Just as the horticulture actors, the relations to producers of aquatic protein is indirect since they are currently competitors. Likewise, the interviewed aquaponic and aquacultural actors also expressed interest in a collaborative future. As highlighted by interviewees, these actors and the aquaponic producer usually produce different types of aquatic protein, but might still share the same consumers purchasing fish. Therefore the aquatic producers share a connection to the same consumers as the aquaponic producer indirectly.

5.1.2. Forces affecting change

The Force field diagram maps forces affecting change within the studied system. The forces are divided into six groups, replicated from the socio-technical characteristics found in the Multi-level perspective theory. Each group includes forces both *enabling change* and *restraining change.* The length of each bar represents how many of the interviewees mentioned the force. Each focus group counts as one voice instead of replicating the participant quantity. Some forces, replicated by curvy bars in Figure 10., are defined to be dynamic as the forces are created due to an increase or decrease of a certain aspect, e.g. an increased interest among actors.

5.1.2.1. Infrastructure & Industry

Forces positioned in the infrastructure and industry category regards communication, collaboration and distribution.

Enabling forces

During both interviews and focus groups, a Interest for producer-consumer distribution was highlighted. Producer-consumer distribution means fewer middle hands as the consumer instead may meet the producer directly. Several interviewees mentioned both the increase of the number of actors focusing on this business type, as well as their size. One aquaponic producer said: *"I mean, Reko-circles [producer-consumer distributor] has gone from 300 000 customers to 700 000 customers in one and a half years."* Contradictory, it was also discussed that there is a lack of these channels for producer-business and the opportunities for scaling up this distribution type.

As the aquaponic is a combination of the technologies of aquaculture and horticulture in one system, several actors discussed the possibility of linking actors from these two fields to collaborate or learn from each other. This led to a force of the possibility of Linking aquaculture and horticulture. For example, one researcher emphasized the possibilities of linking these two fields: *"I started to work on this ten years ago, and what I tried to do was linking actors from the aquaculture field and the horticulture field"*. On the other hand, the researcher continued: *"I noticed that here in Germany horticulture actors are very reluctant",* which demonstrates the possible complications within such collaborations.

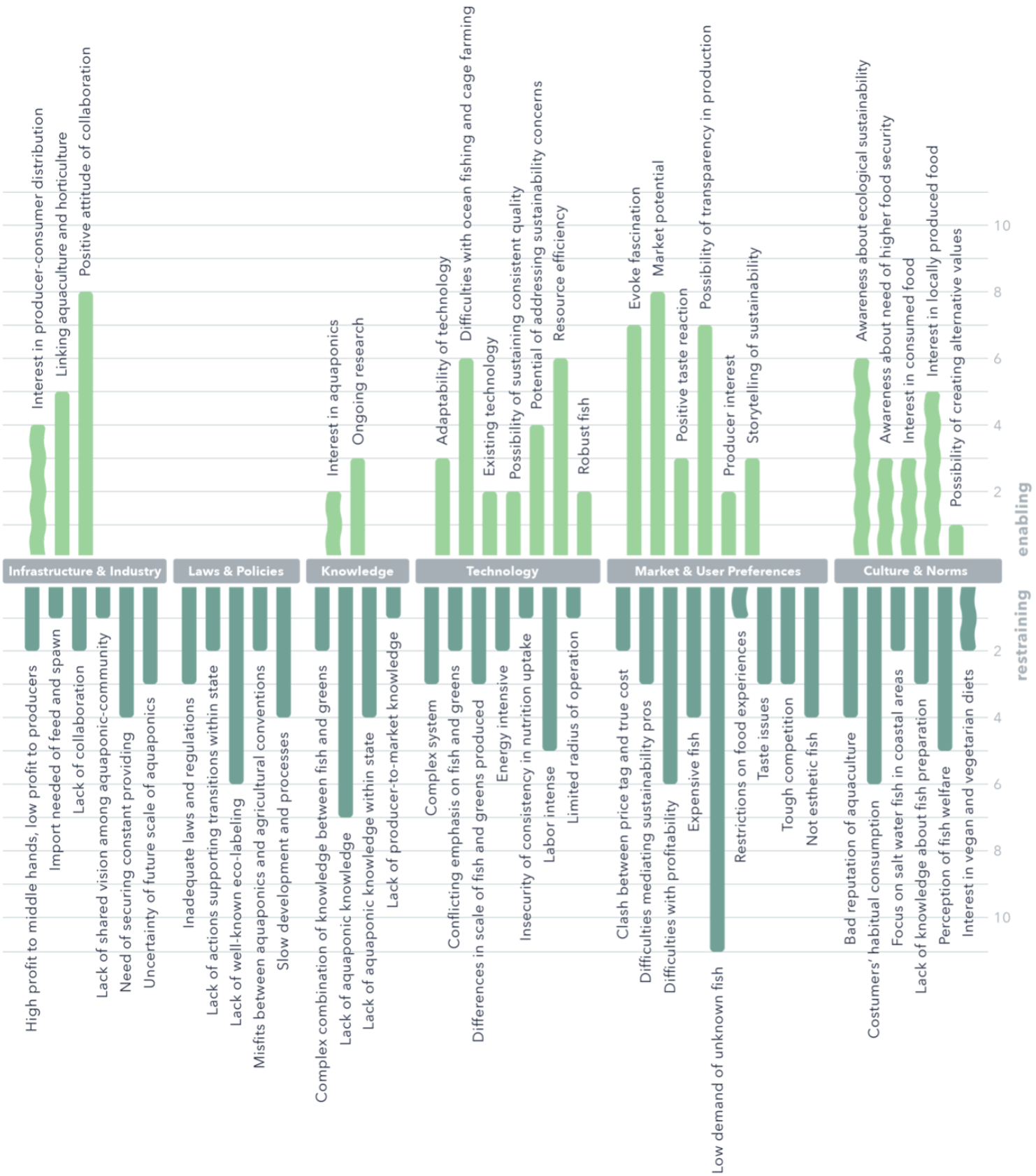


Figure 10.

Forces affecting the upscale of aquaponics

One of the most widespread forces highlighted by many actors was the **Positive attitude of collaboration**, within the aquaponic niche as well as with aquaculture actors, authorities and researchers. The overall sense was that no actors were against collaboration, and most of them saw collaboration before competition. A researcher elaborated further on the benefits of a broad collaboration: *"I believe in trying to connect all in the industry, not only in aquaponics or RAS [...]. It is such a small industry in Sweden, so I believe all would benefit from this. Because if it would count as aquaculture, then the ones farming in cages would benefit from it".* In addition, sharing learning experiences and together reducing costs were some of the benefits brought up. An aquaponic producer said: *"It is easier towards authorities if you have started a community or network where you collaborate and where you can take on problems together".*

Restraining forces

One restraining force related to the enabling force of *Growing interest for producer-consumer distribution* is **High profit to middle-hands, low profit to producers.** The general market system existing today is based on a certain chain of purchases and costs. This is expressed during interviews to often lead to high profit to middle hands and low profit to producers, limiting existing producers as well as new entrants. One aquaponic producer emphasised: *"Our principle is that if you are more local, you can aim directly at the customer. Then more money can end up with them who do the work, not only to middle hands".*

Another force that might limit the Swedish aquaponic market is the **Import needed of feed and spawn**. Currently in Sweden, there is no producer of the fish spawn requested by aquaponic actors, which makes the industry dependent on import. One aquaponic producer described the supply of spawn: *"It is not too simple in Sweden, it is easier in other countries''.* On the other hand, this may not bring any trouble, as long as the relations remain stable and smooth. Moreover, there are some similar questions related to feed, and the same producer commented: *"...it is not sustainable to buy this fish feed with a lot of fish in it, even though feed for Tilapia [a fish species] contains much less compared to salmon. And there is no production of feed in Sweden either''.* However, it is discussed during interviews that research is held in Sweden to find alternative methods for feed production.

A restraining force underpinning the enabling force of *positive attitude of collaboration* is the current **Lack of collaboration.** For example, one aquaponic producer described a lack of collaborative initiatives and commented on the communication between actors: *"You do not talk".* These collaborative issues also include cage farmers and aquaculture actors, which is described to affect aquaponic actors as well. One researcher elaborated: *"In the aquaculture field there is some friction between cage farmers and actors who have been in the business for a long time".* The researcher further described an example of an established aquaculture actor who currently faces issues: *"They have had large problems from the big companies who want nothing less than for them to simply fail. The companies look at it as a system which threatens their business."*

The interviews revealed a difference among actors in vision and ideas of the future for the aquaponic niche, implying the force **Lack of shared vision among the aquaponic community.** For example, one researcher described how *"I already observed that the actors have different ideas about what the technology looks like in the future"*. As an example, the researcher further mentioned how approaches differ between actors: *"What I observed in the dynamic in the aquaponics network is that they are still diverse approaches. Also on where to put the emphasis, on the fish or the plants".* The force is defined as restraining since, according to the theory of Strategic Niche Management (see Section 3.3.2), a niche needs to have specific and highly qualitative expressed expectations and visions. They should also be more robust, meaning it is more successful if many actors within the niche are agreeing upon them. In addition, an **Uncertainty of future scale of aquaponics** is present among actors. One producer commented on the complicated future of production-scale: *"I also believe small-scale is good. I think it is successful if we have small-scaled [productions] too. But I think it is wishful thinking to believe that small-scale will be dominant in the future",* and continued: *"We need industrial scale".* An aquatic producer expressed a different view: *"I believe aquaponics is most suitable for smaller productions [...] I think it is a very good development."*

Another restraining force in the industry category is the **Need of securing constant providing** as restaurants, food refiners or supermarkets often require constant providing. One aquacultural producer mentioned a typical request from customers: *"If it shall be on the menu, we need to get fresh fish every week".* A reseller as well described the problems with the uneven provision: *"What happens with the shelf? If a new product arrives which can be delivered all year round - well, then the other will lose because we never want an empty shelf".* Although defined as a restraining force, it is also highlighted by interviewees that an aquaponic facility has huge potential of securing constant providing since it is not dependent on e.g. weather situations or current catch.

5.1.2.2. Policies & laws

This group includes forces related to laws, regulations and policies. As visualised in Figure 10., no enabling forces were identified within this category. This is since no comments from the interviewees evolved around enabling forces related to legal and regulatory matters.

Restraining forces

Several interviewees emphasized the importance of labelling products to prove an ecologically, environmentally and socially sustainable production. The ecological label discussed was the KRAV certificate, but likewise its impossibility of being used in aquaponic technology. Therefore, present for the aquaponic community is the **Lack of well-known eco-labelling** suitable for aquaponics. An existing challenge is that aquaponic production can currently not be counted as ecological. One aquaponic producer said: *"There is this problem that it can't be classified as ecological because closed-loop systems are not included"*. Another aquaponic producer reflected upon how the existing certificates might not reflect the actual benefits of the technology, giving false impressions to the customers:

> *"it is important for the public sector to fight for real definitions and not say that Clarias is as good as trawled crayfish. Or even that it is better with trawled crayfish because it is environmentally certified and land based fish farming can't be certified."*.

Contradictory, it was discussed whether a label even is required from the public, or if the technology itself or the information given to the customers directly in the store, may bring enough information of sustainability. However, most interviewees from the focus groups commented on the importance and reliability of certified products, and said they preferred them.

Interviewed actors expressed a need for the authorities within Sweden as well as abroad to take action to deal with the impossibility of eco-labelling aquaponic production: *"We build our whole systems on EU legislations. It is not until the EU changes this..."* Similarly, a general Lack of actions supporting transition within state emerged during interviews. One aquaponic producer expressed the possibilities with legal impacts, and commented on needed actions for environmentally advantageous technologies: *"We can make regulations on what is allowed to do. We have done it before, prohibited lead in gasoline [...] and CFCs in refrigerators [...] We must do so with other things as well".*

In addition, the process of taking action within the state often comes with Slow development and processes. The aquatic protein producer said: *"It is the slow system that exists which is an obstacle for us [...] and authorities and regulations have not understood that it has to happen rather fast".*

Furthermore, there also exist problems around Inadequate laws and regulations regarding aquaponics. The agency gave an example:

> *"It is important to remember the complicated regulations, especially for fish. [...] it is demanded from animal protection laws to be able to demonstrate a theoretical education when you are responsible for the fish. But there is nowhere any demand for what the education must contain".*

In addition, an existing Misfit between aquaponics and agricultural conventions adds upon the problems with regulatory processes. One researcher described:

> *"Many who produce in this way stand between producing fish and greens, so it gets strange when filling in your permissions. You produce both [...] The papers you should fill in, it is rather comical, they are made for agriculture. You should fill in how many stables you have. It is rather strange".*

Another researcher further elaborated on the existing misfits: *"Aquaponics has also difficulties that it is so high-tech that it is difficult to link it to a stream of agriculture innovation systems,*

because some people think it is not agriculture, it is food production". Moreover, the agency expressed their future thoughts: *"Conditions must be created to make it easier to get permission for this type of circular flow of nutrients than what exists today [...] We could probably clarify the laws about what it takes to get permission to farm fish".*

5.1.2.3. Knowledge

This category includes forces regarding knowledge and science about aquaponics, the combination of fish and greens, and sales-channels.

Enabling forces

Although the aquaponic technology and actors still are rather unknown among the larger public, there is an increasing **Interest in aquaponics** within society. One aquaponic producer commented on interest from potential producers as well as the general public: *"There is a huge interest right now, many organisations run fishing projects such as aquaponics [...]. We have many study visits from these groups. The general public also starts to show interest".* The producer also described how the interest from politicians "*increases all the time".* Moreover, the interviewed agency themselves predicted a future of working more with aquaponics: *"we will start trying to be better in aquaponics [...] We want to learn more and feel we need to increase our competence to be able to contribute more. It is definitely something we talk about"*

For the technology to develop, research is important. During interviews, several **Ongoing research** projects within the aquaponic niche emerged. For example, one producer said: *"Right now we have product development and research projects which aim to remove the traditional fish feed".* Furthermore, other currently explored research topics discussed during interviews was the storage of fertilizers and linking horticulture and aquaculture.

Restraining forces

Although there is an increasing *interest in aquaponics,* there is still **Lack of aquaponic knowledge.** The lack of knowledge was problematized by several interviewees and it appears to exist among the general public as well as among the aquaponic producers themselves. One researcher described the low spread of knowledge among the population: *"not many know about aquaponics"*. The interviewed agency explained problems with lack of knowledge about fish care among the producers: *"Warning, warning, it is actually animals we talk about. Many I come in contact with think: 'only add some fish and then we connect the systems'. But it takes a lot of knowledge to make these animals live well".* Furthermore, it appears to be a **Lack of producer-to-market knowledge,** presenting a challenge for aquaponic producers out of a business perspective. As described by a researcher: *"A challenge for many actors is to start selling. They don't often think about the end, that this has to reach the customer. [...] How shall you get this to the market? What logistics?"*

Similar to the existing general *lack of aquaponic knowledge,* the same problems occur in **Lack of aquaponic knowledge within state.** The interviewees highlighted the importance of knowledge within authorities since they have strong decisive positions and may affect change beneficially. One researcher commented on the current gap of information: *"It exists among them we believe should know. I am thinking, some decision-makers who work within the municipalities should have a good perception, but don't have it".* The researcher continued and stressed the lack of knowledge even regarding aquaculture in general: *"Because most don't even know what aquaculture is".* On the other hand, understanding of the difficulties for authorities was also emphasized. One producer said: *" it is not easy to grasp something new, they have their heads and desks filled with everything else".* In addition, the interviewed agency themselves expressed interest in aquaponics and were optimistic about a future of working more with aquaponics: *"we will start trying to be better in aquaponics [...] We want to learn more and feel we need to increase our competence to be able to contribute more. It is definitely something we talk about"*

A challenge in knowledge sharing and understanding of the technology, both within the state and among actors, is the **Complex combination of knowledge between fish and greens**. A researcher said: *"It is definitely a limitation in knowledge, both within administrators who manage permissions, but also for the practitioners. You don't only need to know about the greens, but also the fish".*

5.1.2.4. Technology

All forces regarding aquaponic technology and production are included in the category of technology.

Enabling forces

According to the interviews, aquaponics has been struggling with undeveloped technologies and systems but have improved during the last decades. As described by one producer: *"When we returned we realised that aquaponics had developed and that you nowadays actually can start up without yourself having to experiment in all areas."*. Therefore, there is an enabling force of **Existing technology** contributing to the development of the industry. Moreover, interviewees also mentioned beneficial development in other applicable technologies, e.g. the solar panel industry. Still, the technology needs to continue improving and one researcher elaborated on the difference between more established technologies and the aquaponic technology: *"The other [industries] are so established in Sweden [...], you can buy a system and start without needing to think so much about it. Since it [aquaponics] is new, it might be a problem."*

The interviews revealed several applications and variants of aquaponic production, demonstrating the **Adaptability of technology**. Actors running small-scale aquaponic facilities as well as actors planning to implement large-scale industries were interviewed. The diversity within aquaponics was described by one producer as *"Large-scale and small-scale, urban and rural. Everything simultaneously".*

The interviews also elaborated on the technology's **Possibility of sustaining consistent quality** and exemplified one producer who has experienced improvements in the fish production: *"Now we have control over it and it has a consistent quality".* Another chef showed belief in the technology while comparing it to fish auctions and ocean fishing: "*Exactly, here you can probably get consistent quality all the time, if you find the key in the farming".*

One force contributing to the possibility of sustaining constant quality is the **Robust fish** often used in aquaponic systems**.** *"Clarias, pangasius and tilapia are extremely easily farmed [...] They can withstand nearly anything",* said a producer. The producer continued emphasising the importance of robust and less sensitive fish if something occurs, e.g. if the greens' nutrition uptake is decreased. Moreover, the robustness also contributes to the sustainability of the system since there is less risk of wasting fish or greens produced.

As described, aquaponic technology might be a good solution to some of the food production challenges existing and there is great belief in its **Potential of addressing sustainability concerns.** *"It is not like aquaponic solves all problems, but aquaponics can solve some of the problems"*, said one producer. A researcher addressed the potential of aquaponics as a sustainable alternative: *"if you can succeed with marketing aquaponics as a sustainable way of producing this fish [...] then it is a win, absolutely!"*. Another researcher further elaborated on the potential in the sustainability promises sold by the aquaponic technology, engaging investors and customers.

One area in which the technology has the potential of addressing sustainability concerns regards the **Difficulties with ocean fishing and cage farming.** *"Right now the fish farming industry is in a shift. From the ocean and up on land. Farming in the ocean is deeply unmodern and very soiling, overfertilizing etcetera. There are grand problems with fish and diseases'',* was quoted from one aquatic protein producer. Another producer added: *"We know the oceans are overfished. It doesn't work anymore [...] We know, the Baltic sea is overfertilized".* This opens possibilities for aquaculture and land-based fish farming.

The aquaponic technology is advantageous regarding how efficiently it may use waste and resources to produce fish and greens. The **Resource efficiency** in aquaponics is exemplified by one producer: *"seeing a waste or a byproduct as an asset instead of a problem"*. Essential is the feed conversion ratio, described by one producer: *"1 kilo of feed gives approximately 1 kilo of fish, and may also give 10 kilos of greens".* Another benefit of the resource efficiency of the technology is the water use, explained by a researcher: *"It is a very efficient way of producing both fish and greens in a way that saves water".*

Restraining forces

Several interviewees described the aquaponic system as a **Complex system** since it involves both farming fish, growing greens, running a business as well as managing technology. The problems seem to occur especially in the initiation of production. The interviewed agency described problems about fish care the fish farmers may meet: *"I have heard about fish farmers who have started with fish and who maybe had other animals or greens before. They said they did not know what they were doing in the first years…".* The entrepreneurial risk when entering new areas of business demanding new technological and farming abilities was also discussed. A researcher commented: *"I think many of these entrepreneurs who have these business perspectives, underestimate what it means to run a farm".* Moreover, a large-scale producer further explained the complexity arising when recirculating a lot of water: *"When you increase the circularity level, the complexity increases drastically. A lot of things happen and there is a lot to think about to do it right".* In contradiction, one interviewed producer, running a small-scale aquaponic system, instead expressed the simplicity of the system: *"It is very simple and only to start up. It works, the fish thrive and the greens grow".* Thus, it is interesting to acknowledge the different perspectives of complexity existing within the niche.

In addition to the complexity, the system is also **Energy intensive**: *"It requires a large energy supply",* as explained by the agencies. The energy used while warming the water tanks is also highlighted by a producer: *"If you are having these exotic fish in Sweden they need heat"*. Further, the agency brought up collaborations that could be initiated to bridge the heating issues: *"You could reduce costs by applying some sort of agreement with the industry where you can take advantage of energy waste".*

Moreover, the system is described as **Labor intensive**. A researcher said: *"It is a lot of labour needed in aquaponics compared to a regular fish farm. A lot of the fish farms can be automated and it is a bit harder in aquaponics".* An aquaponic producer added the difficulties related to a small-scale system: *"It takes a lot of time to make it work. It is manual, it is not possible to make it work commercially on that scale [...] You have to do it as a hobby".*

As aquaponics requires recirculation of water, one actor implied the challenge of **Limited radius of operation**, i.e. fish tanks and greens need to be placed relatively close to one another to manage the recirculation. The actor explained: *"We are locked in nutrition transported by water, demanding the greens to be relatively closely located"*. Further, the actor elaborated on how this might cause problems in environments and sites with a lack of space, for example cities, where instead a separation would be suitable.

Since aquaponics implies the production of two types of food, thus requiring knowledge in two fields, a **Conflicting emphasis on fish and greens** was mentioned by several actors. One researcher described the *"diverse approaches on where to put the emphasis, on the fish or the plants"* in the aquaponic network. This was as well prominent among the interviewed actors, as an emphasis often was put on either the production of fish or greens.

Related to the simultaneous production of both fish and greens, the **Differences in scale of fish and greens produced** was problematized by several interviewees. The production facility requires a much larger scale of greens than fish produced if the greens are to single-handedly manage the uptake of fish feces. Thus, a researcher elaborated: *"then the main product is no longer the fish, but the greens".* This was mentioned in the interviews as a problem for actors who want a focus on fish production, but still are interested in aquaponics. One producer of seawater fish exemplified a similar problem in seawater systems: *"We can't just clean our water with algae, because that would require a huge algae farm"*. Furthermore, one producer described a challenge with the **Insecurity of consistency in nutrition uptake** if the greens are single-handedly managing the nutrition uptake: *"It would be like when we have harvested the greens, we have to stop feeding our fish".* Therefore the producer continued: *"We must actually dimension our biofilters to manage fully without algae".*

5.1.2.5. Market & user preferences

This category highlights forces related to the market of the aquaponic technology as well as user preferences revealed during the interviews.

Enabling forces

The interviews showed a **Market potential** for aquaponic technology, establishing the technology's potential of growing into a market niche. The agency said: *"I believe the market exists for this type of production. Many want to buy sustainably produced food, and in aquaponics there is definitely a circular thinking in the production".* The current import of fish is also discussed and it is concluded by a researcher that *"We import a lot of fish [...] so there is still room in the market for many who produce fish".* As an example of market potential, one food reseller highlighted the absence of smoked eel, a dish traditionally eaten during holidays, and explained that Clarias have an opportunity of replacing it since it *"actually tastes like it".*

In addition, several interviewees talk about the increased **Producer interest**. There are e.g. *"many organisations running fishing projects as aquaponics and aquaculture and we have many study visits from these groups",* as exemplified by a producer. As well the agencies highlight the producer interests and add *"It is very trendy. Many are curious about this type of production".* Another researcher emphasised the increased interest in aquaculture in general: *"There is a huge interest. There are some really large who are about to start but there are many small too [...]. That means they are under the 40 tonnes limit [of fish produced]".*

As the interviews demonstrated, aquaponic technology has a **Possibility of transparency in production**, e.g. due to its tight, circular system, the possibility of local production and producer pride of sustainable technology. Simultaneously, several interviewees emphasize the importance of using communication of knowledge to get customers and other actors to understand the technology. Therefore, using transparency as a communication tool seemed

to be of favour for many producers. One producer elaborated on the importance for customers to know the origin of the products they buy and continued: *"We believe in being very open about what we are doing, and share experiences''.* A researcher discussed the usage of transparency regarding the fish welfare while demonstrating a production facility, and exemplified that it might be beneficial to create a more visually attractive fish farm because *"even if you know it has nothing to do with the fish, it always looks better for the public that the fish lives well".* Interestingly, one participant in the focus group elaborated on transparency and believed in a production where the producer is *"very open and makes a thing about it; 'come and see how our fish are doing' [...] Then I believe you trust them even more".* This shows how the force of transparency may be used to benefit the technology, but also that it has to be handled with care to present information in a fair way.

In addition, the possible **Storytelling of sustainability** was also highlighted as important when communicating the benefits of the technology. Storytelling was defined in the interviews as stories of sustainability and origin of the products. The importance of storytelling when selling was described by a producer: *"You sell more and more stories. A kind of feeling that 'this is good' [...] if you have a story of sustainability, local production and so on, then it's amazing".* This possibility seems to be important for both restaurants as well as other end customers.

While marketing the aquaponic technology, the force to **Evoke fascination** is of importance. Many interviewees emphasize on the reaction most people get when they are presented with aquaponic technology. One researcher exemplified a reaction: *"Wow, is it possible to do this? [...] Don't you add anything? The plants grow simply in water?"*, the researcher further adds: *"For many it is amazing and I think so too. It is an extraordinary way of producing food".* A refiner built on the consequences of fascination and elaborated on the benefits for a restaurant to present a new product on their menu: *"They will think it is superb to get something new, something exciting, something to compete with".*

Finally, the force of **Positive taste reaction** when tasting the fish is an enabler for the future of the production. Beneficially, both people working with aquaponics as well as newly introduced people seem to have positive reactions. A food reseller talked about the taste and said: *"It is a very fine fish, and it is very tasty".* Another producer added: *"every time I serve the fish, everyone is so happy".*

Restraining forces

While discussing sustainability problems on societal levels, the **Clash between price tag and true cost** emerged. The price tag represents what customers pay for the produced food, while the true cost represents the societal and environmental impacts of the production. The interviews problematized the clash when the negative effect on society is higher than what the customer pays. A producer described the problem by exemplifying: *"If I destroy life for future generations, it should be shown in the price tag".* The system and economic problems could currently, according to the producer, be described with a structure where the polluters

do not pay. Since aquaponic technology produces products with a high emphasis on sustainability, this force is defined as restraining and something most aquaponic actors probably will face.

The general perception of aquaponics seems to demonstrate a high belief in the sustainability of the technology. However, there also seem to exist **Difficulties mediating sustainability pros.** The focus groups brought up questions on how sustainable the technology really is, since the visual perception of a shown production facility was very high-tech and not aligned with their thoughts on usual sustainable productions. Moreover, the agency also emphasized the difficulties some producers have while mediating sustainability. They described: *"Many, when we question them a bit and ask 'how is it sustainable?' and 'how is it environmentally friendly?', they have a hard time showing it".*

Similarly to other forces regarding economic matters, all interviewees elaborated on the **Difficulties with profitability**. The interviews emphasized two particular situations when the profitability is most crucial; during the initiation of production and in small-scale productions. One small-scale producer said: *"It is hard to see any economy in it since both the spawn and the feed are too expensive".* Another producer commented on a larger production initiation: *"It will be very profitable but it is hard in the beginning since it demands quite a lot of capital to start".* Moreover, the agencies added:

> *"A great challenge is to reach the market competitively. How to get profitable? […] At the same time as you compete with the aquaculture and the fish industry, you compete with commercially grown vegetables. And that is a great challenge, I think".*

Similarly, other interviewees talked about the **Tough competition** present for current aquaponic actors as well as new entrants. One researcher elaborated on the possible difficulties aquaponic actors may face if new large-scaled aquaculture farms enter the market as "*they will be way too big and outrival all small actors"*. In addition, the agency explained current competition in the vegetable market: *"You compete in the exact same market as the ones growing tomatoes elsewhere […] They are also your competition so it has to have just as good price and quality as they do".*

Furthermore, the interviews established how the **Expensive fish** is restraining the business. One refiner of Clarias discussed: *"We will never make it trendy if we sell it for a very high price. I believe, maybe not subsidize it but if you can sell it at a beneficial price, you can get the society to produce it".* A potential customer from the focus groups commented accordingly: *"If they say it costs 350 SEK/kg, I will leave, I will go to another place. So it can't cost too much […]. The price has a great impact".*

There are moreover some restraining forces related to the fish, making the production and distribution more difficult. Interviewees mention the problem of a **Low demand of unknown fish**. One producer commented: *"It is like everything else, there has to be a demand".* A refiner of the fish discussed the low interest of the fish and the lack of hype as problems while a producer exemplified a common customer-reaction to this new type of fish: *"I don't know what that is''.* The same experiences had been present for a reseller of the fish who mentioned the importance of marketing the fish to a larger audience: *"If you see some things all the time, it may become a natural reasoning for people".* Furthermore, the esthetics of the fish seems to be an issue when selling and preparing the fish. Some interviewees comment on the **Not esthetic fish** and its difference to peoples' usual mental models of what a fish looks like. A reseller exemplified: *"Many say it doesn't look like a usual fish, so many are a bit afraid of their looks".* Another reseller continued: *"You have to sell it in files. You can't have it [not filead] on the counter".* Contradictory, several interviewees from the focus groups said they did not care about the looks, they had eaten worse before, and one commented: *"It wouldn't surprise me if the majority of people in the world eat these kinds of fish".* However, there seem to be some **Taste issues** present, even though there simultaneously exist present *positive taste reactions.* As a food refiner reflected, freshwater fish sometimes have the perception of giving a taste of mud.

Finally, one force restraining many actions within society as of today is the current pandemic and the following **Restrictions on food experiences**. During interviews, it was discussed how knowledge sharing and demonstration of food and taste is restricted and how this changes the possibilities of marketing new fish. For example, since restaurant experiences have been affected, a challenge has emerged as they serve as suitable channels for new taste to reach the public. One reseller of fish discussed: *"One downside I see now is covid while it simultaneously may be difficult to scale up as it is".*

5.1.2.6. Culture & norms

Forces coming from cultural conditions and norms present in the society, are described in this category. As seen in Figure 10., several of these forces are marked dynamic. This mirrors how societal trends commute.

Enabling forces

Several interviewees highlight how the increasing **Awareness about ecological sustainability** is an enabling force. One reseller of food expressed the current perception from the public: *"Today it is super-hip. It is rather so so if you don't do it".* Similarly, a producer commented: *"It has been a trend for a long time now [...] Sustainability is huge".* Another producer established the force dynamics by discussing the food trend: *"People do more and more understand that we have to do something about this".* Similarly, there is an increasing **Interest in locally produced food.** *"This about local production is also a strong trend",* was expressed by a producer. Elaborately, a reseller with a high focus on food production discussed: *"Actually, I believe it is more important with local production than ecology. Suddenly you understand the effects of carbon dioxide emission. It is easy for a person to understand how*

far food has travelled". Even the increasing **Interest in consumed food** is in favour of aquaponic technology, since according to a reseller: *"it is important to mediate the health effects for people and what it means to produce this".* The reseller continued talking about the increasing amount of knowledge about fish among people: *"You notice there are a lot more people who are interested and know more about fish and crayfish than five-ten years ago. You are more conscious about what you consume".* A refiner added: *"You want to learn new things, find new flavours, this interest of what actually is on the plate has increased tremendously in society".*

The **Awareness about need of higher food security** seems to be increasing according to the interviews. The agency elaborated on the current pandemic: *"It has created an increased awareness about the food chain being fragile sometimes and that self-provision has come back into the spotlight".* Several other producers agreed on the need for higher food security and had this argument as a cornerstone of their business.

Finally, interviewees also discussed the **Possibility of creating alternative values** emerging when new aquaponic productions are initiated. These values fluctuate from creating new work opportunities to more sustainable productions. As exemplified by one producer, aquaponics can, apart from food production, as well be about "*social values, pedagogical values and circularity".* Further, the producer elaborated on even making alternative values profitable: *"We would say it is possible to reach profitability in a 10 tonnes facility, but then the production must generate more than only fish. It must be a pedagogic institution where you talk about society. That is advantageous".*

Restraining forces

According to the interviews, a general **Bad reputation of aquaculture** is a problem reaching from over forty years back in time. One researcher elaborated: *"Many have a negative image of aquaculture, especially cage farms and salmon farms etcetera".* The interviews further discussed how consumers may react, and the researcher continued by exemplifying what some say: *"No, I would never eat farmed fish because it is gene-modified".* In addition, this subject was discussed in the focus groups and one participant questioned: *"Fish farming is linked to quite some additives and chemicals to the fish. Is it the same in aquaponics? Or is it less chemicals?".* Meanwhile, the technology has changed during the years and a significant reduction in chemicals and additives according to the interviewees is clear, the old reputation seems to still be occasionally present.

Since aquaponic technology involves farming and keeping animals, the **Perception of fish welfare** is determined as an important force. In general, it was reflected upon how fish will be seen as individuals more and more. One researcher said: *"You have to start thinking about welfare and not only their physiological health and their growth but also their mental health".* The researcher continued and elaborated on how the ethics will be questioned. In addition, the agency also highlighted the problem that many seem to believe that fish can be treated without special care: *"It is actually animals we talk about [...] It takes a lot to make these animals live well".* This issue was also discussed in the focus groups and first perceptions

from participants evolved around productions looking artificial and cramped. Interestingly, one participant reflected upon farmed fish: *"If I could choose wild-caught fish instead, I would have bought it, because it feels better if the fish may live naturally rather than being farmed".* Furthermore, another participant added: *"We put human values on the living standards of fish",* and continued explaining why the fish tanks should be larger and more similar to their natural habitat: *"Out of a humanistic and philosophic perspective, we think they would like it better".*

The **Customers' habitual consumption** was established as a force both reseller and customers themselves have to deal with to change a normative behaviour and enable a change in food consumed. A producer with experience of working in the food industry commented: *"To change people's behaviour is very cumbersome, it is not easy. If you ask people 'Are you open to changes and willing to try new food?', then 99% say 'yes, I'd love to'. But they go to the store and buy the same food anyways".* Another reseller continued in the same pattern: *"They have their thinking but you have to try to make them think and maybe change course".* For example, a participant from the focus groups determined one type of habitual action: *"I always buy fish at a fish reseller".*

Furthermore, the interviews revealed a tendency to a general **Focus on saltwater fish in coastal areas** where there is saltwater. Accordingly, one refiner usually working in coastal areas elaborated on how freshwater fish seldomly is a part of their menu and discussed behaviour from people: *"It is probably just in peoples' minds. On the west coast you eat crayfish from the sea and on the east coast you eat crayfish from lakes".* Another producer commented on how the general agenda of aquaculture in the west coast has been aiming at saltwater production and continued: *"Then it is interesting to hear what people think if freshwater systems have a future and may be valuable".*

Another trend several interviewees highlighted was the increasing **Interest in vegan and vegetarian diets**. The discussions evolved on how the fish might not be favoured by vegetarians and how vegans might perceive the greens being grown in a circular system where fish is a part. One producer discussed: *"If 'fish eating' people become vegetarians, then people don't eat fish".* Determinedly, a participant from the focus group elaborated on veganism: *"I am wondering, if a vegan got to know that the vegetables have been grown in connection with fish production, maybe they would not be very committed".*

Another trend commented by some interviewees was the **Lack of knowledge about fish preparation** in general as well as in detail regarding fish suitable for aquaponic production. *"People don't know how to prepare fish",* explained a refiner about fish in general and specified the problem related to typical aquaponic fish: *"People don't know how to handle it".* Similarly, a producer added: *"If you ask people if they wish to eat more fish they say 'yes I would like to eat more fish' and then nothing happens because they don't know how to".*

5.2. Phase 2: Navigating niche formation

The second phase of the project aimed at further exploring how an upscale of the aquaponic niche can be facilitated. With a focus on the aquaponic niche in general, this section presents the findings of how an upscale of the aquaponic niche can be navigated. The conclusion is a set of guidelines, serving as a guide for how to facilitate upscale, and five identified areas of opportunity, potentially serving as contexts for addressing the identified guidelines.

5.2.1. Guidelines to facilitate an upscale of the niche

This section presents guidelines that can be used by the aquaponic niche as a guide for facilitating niche upscaling. The guidelines are based on the identified enabling and restraining forces (see Section 5.1.2.) and may serve as a guide for how to either increase the enabling forces or reduce the restraining forces, thus, creating movement within the system (Thomas, 1985), in this case, movement in the form of niche upscaling. Visualized in Figure 11 are the twelve guidelines, divided into five themes; network formation, learning processes, articulation of expectations & visions, interplay with the regime and strategies for aquaponic businesses. Three of these themes are inspired by the three processes of Strategic Niche Management (SNM) (see Section 3.3.2.), while the two other themes are identified by the thesis group.

Network formation

Aiming at facilitating niche upscaling, formation of the aquaponic network is believed to be of great importance. Similarly, SNM highlights the importance of network formation as it, according to Geels & Schot (2008), facilitates for actors to grow and creates a window for the new innovation to develop further. One of the identified guidelines relates to network formation; facilitate collaborations.

The guideline **Facilitate collaborations** highlights the importance of collaboration within the niche as well as between the niche and other sectors to facilitate niche upscaling. As emerged during interviews, there are currently factors related to collaborations both enabling and restraining an upscale of the aquaponic niche. Among the forces enabling change is a generally *positive attitude towards collaboration*s within the niche and opportunities arising as aquaponics is *linking aquaculture and horticultur*e. Building upon the existing enabling forces, the restraining force of a *current lack of collaboration* is reduced. This altogether induces movement within the system.

Network formation

Facilitate collaborations

−	+
Lack of collaboration	Positive attitude of collaboration
	Linking aquaculture and horticulture

Articulation of Expectations & Visions

Align visions with network

−	+
Lack of shared vision among aquaponic-community	
Uncertainty of future scale of aquaponics	
Conflicting emphasis on fish and greens	

Learning processes

Strive to improve aquaponic system

−	+
Limited radius of operation	Need of securing constant providing
Complex system	Import needed of feed and spawn
Energy intensive	Division between fish and greens produced
Taste issues	Insecurity of consistency in nutrition uptake
Labor intense	Ongoing research
Difficulties with profitability	

Continue to learn

−	+
Complex combination of knowledge between fish and greens	
Lack of producer-to-market knowledge	

Share knowledge

−	+
Lack of aquaponic knowledge	
Perception of fish welfare	
Bad reputation of aquaculture	
Lack of knowledge about fish preparation	

Interplay with the regime

Foster authority dialogues

−	+
Inadequate laws and regulations	
Misfits between aquaponics and agricultural conventions	
Slow development and processes	
Lack of actions supporting transitions within state	
Lack of aquaponic knowledge within state	

Challenge norms

−	+
Not esthetic fish	
Low demand of unknown fish	
Clash between price tag and true cost	
Focus on salt water fish in costal areas	
Costumers habitual consumption	

Utilize societal interests and events

−	+
Restrictions on food experiences	Interest in aquaponics
Interest in vegan and vegetarian diets	Market potential
	Evoke fascination
	Producer interest
	Awareness about need of higher food security
	Interest about consumed food
	Interest in locally prod. food

Strategies for aquaponic businesses

Communicate values and benefits

−	+
Difficulties mediating sustainability pros	Potential of addressing sustainability concerns
	Storytelling of sustainability
	Possibility of creating alternative values
	Difficulties with ocean fishing and cage farming

Utilize strenghts of aquaponic technology

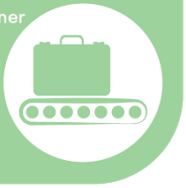
−	+
	Adaptability of technology
	Robust fish
	Resource efficiency
	Existing technology
	Possibility of sustaining consistent quality
	Positive taste reaction

Uphold transparency in production

−	+
	Possibility of transparency in production

Explore business strategy and distribution channels

−	+
High profit to middle hands, low profit to producers	Interest in producer-consumer distribution
Difficulties with profitability	
Conflicting emphasis on fish and greens	
Expensive	
Clash between price tag and true cost	
Tough competition	



Interplay with the regime

Aiming at niche upscaling, which potentially may influence the regime (Jolly et al., 2012), the interplay between the aquaponic niche and the food regime becomes interesting. Three guidelines are included in this category, inviting the niche actors to both challenge and involve the existing regime; foster authority dialogues, utilize societal interests and events and challenge norms.

Aiming at influencing the regime, **foster authority dialogues** is an important guideline. Authorities are important actors within the current food regime, currently posing several challenges restraining an upscale of the aquaponic niche. For example, authorities are affecting restraining forces such as *inadequate laws and regulations, slow development and processes* and *lack of actions supporting transitions within state.* Thus, the contribution of all niche actors to foster authority dialogues is important when aiming at reducing these restraining forces while simultaneously inviting a key regime player to be involved in the niche.

Another important guideline aiming at influencing the regime is for the niche to **challenge norms.** As emerged during interviews, several restraining forces affecting the upscale of the aquaponic niche derived from societal norms, e.g. *unesthetic fish, focus on saltwater fish in coastal areas* and *clash between pricetag and true cost*. Thus, the aquaponic niche should altogether aim at challenging the norms to create opportunities for the niche to influence the regime.

However, there are not only general opinions within society appearing as restraining forces for the aquaponic niche. There are as well societal interests and events beneficial for the niche. Thus, **utilize societal interests and events** is a third guideline encouraging the aquaponic niche to benefit from these interests and events. For example, during interviews several actors highlighted an increased *interest in aquaponics*, the potential of aquaponics to *evoke fascination* amongst people being introduced to the technology and an increased *interest in locally produced food.* These examples all serve as potential opportunities for the aquaponic niche to utilize societal interest to facilitate an upscale.

Strategies for aquaponic businesses

Lastly, while categorising the guidelines a fifth category appeared with guidelines specifically related to strategies for aquaponic businesses. Four guidelines were identified within this category; encouraging aquaponic business to communicate values and benefits, uphold transparency in production, utilize strengths of aquaponic technology and explore business strategy and distribution channels.

Figure 11.
Guidelines guiding actors to navigate niche formation

Firstly, the guideline **communicate values and benefits** encourages aquaponic actors to spread knowledge about the benefits and values of the aquaponic technology. As there is currently a force restraining the upscale related to *difficulties mediating sustainability pros*, actors need to highlight the potential of aquaponics and build upon enabling forces such as *storytelling of sustainability* and *potential of addressing sustainability concerns.* Doing so might, according to the interviews, serve as a great marketing opportunity when designing experiments utilizing aquaponic technology.

One enabling force frequently discussed during interviews was the *possibility of transparency in production*, e.g. since it strengthens the reliability of fair productions. Thus, encouraging aquaponic producers to take on a strategy that enables the producers to **uphold transparency in production** is believed to be beneficial when aiming at facilitating niche upscaling. However, it is important to highlight the necessity of balancing transparency with knowledge.

A third guideline, related to strategies, is encouraging aquaponic producers to **utilize strengths of aquaponic technology.** Among the enabling forces identified, several addresses the many strengths existing within the aquaponic technology, e.g. *adaptability of technology, resource efficiency* and *possibility of sustaining consistent quality.* Thus, while encouraging the actors related to aquaponic business and experiments to utilize these strengths, these enabling forces will be utilized.

Lastly, even though there are many strengths within aquaponic technology there are as well areas in need of further explorations to develop the niche. Analysing the forces, the business channels and distribution strategies of aquaponic producers were identified as two such areas in need of further exploration. Thus, the guideline **explore business strategy and distribution channels** encourage aquaponic businesses to explore these areas further, hopefully contributing to overcoming restraining forces such as *high profit to middle hands, difficulties with profitability* and *tough competition.*

5.2.2. Areas of opportunity

While aiming at facilitating an upscale of the aquaponic niche, it is of interest to define areas of opportunity together with guidelines. These areas can serve as contexts in which the aquaponic niche can innovate to address the guidelines. The interviews with stakeholders resulted in four identified areas of opportunity. The fifth area of opportunity presented, network formation, was added by the thesis group to secure the potential addressment of all guidelines (see Section 4.2.3.). Arguments and ideas underpinning this area of opportunity could be found within interviews. This section further elaborates the five areas of opportunity.

Collaborate with existing horticulture producers

As aquaponic farming is a combination of both aquaculture and hydroponics, the technology has the potential of complementing and adding value to both existing industries.

Thus, further exploring how aquaponic technology has the potential of contributing with fish, nutrition and circularity within horticulture is of interest. The idea of linking actors from the horticulture and aquaculture field is present within research, although sometimes an opportunity missed by the aquaponic niche actors themselves. An interviewed researcher described how these ideas had been present within research for several years, although added that:

> *"the aquaponic actors were so fascinated by the promises of their technology that they did not really think of what it would mean for an existing horticulture entrepreneur to build the next greenhouse with an aquaponic approach."*

However, several interviewed actors appeared to be well aware of this area of opportunity and stressed the potential of finding new collaborators and areas of use in the horticulture field. One of the interviewed aquaponic producers described how interest has been shown from Swedish horticulture actors in adding fish farming into their existing hydroponic production.

Another opportunity mentioned by an aquaponic producer is a described collaboration in the Netherlands where a fish producer and a plant nursery are collaborating. This example highlights that the opportunity of collaborating with horticulture not only addresses existing aquaponic actors but also invites new actors from the horticulture and aquaculture sector into the aquaponic niche. Further, the aquaponic producer described the win-win in these kinds of collaborations: *"If you are a fish producer, you are not so interested in farming salad, and if you are a vegetable farmer - you are not so interested in building a fish farm. But connecting these two would be a win-win."*.

Based on the interest expressed by, and expressed to, the interviewed actors it is interesting to further explore how this area of opportunity can be innovated within and how collaborations with existing horticulture actors can be set up.

Collaborate with existing producers of aquatic protein

Both the wild fishing sector as well as the aquaculture sector currently face challenges (see Section 2.2.). With overfishing being a great environmental problem, it is of importance to produce aquatic protein by other means than wild fishing. However freshwater cage farming, which is the currently most frequently utilized technique in Sweden, also faces environmental problems, for example, related to eutrophication and pollution. Due to the presence of these challenges, it is interesting to further explore how aquaponics could contribute as part of a solution.

Similar to how aquaponics can be implemented in collaboration with existing horticulture actors, several of the interviewed actors highlighted the opportunity of aquaponics to collaborate with actors in the aquaculture and wild fishing sector. An interviewee from the Swedish Board of Agriculture stressed the opportunities with collaborations between aquaculture and horticulture: *"Aquaculture is fighting to get permission to emit fertilizers and if it is possible to combine with horticulture technology instead, who uses the fertilizers, even that process will be easier".* Similarly, other actors highlighted the opportunity of collaborating with the wild fishing industry. According to several of the interviewed actors, interest has been shown from the wild fishing sector in exploring the potential with aquaponics, and especially land-based aquaculture. For example, one actor within the aquaculture sector described;

> "*Fishermen are thinking about future generations, what shall our children and grandchildren do for a living? They see that wild-caught fish is uncertain, [...] one year they get to fish for herring and the next year they don't. They see this [land-based aquaculture] as safer and think it is super interesting. "*

Although one challenge with implementing collaborations with actors within aquaculture, discussed during interviews, may be that these actors mainly have an interest in producing aquatic protein. As expressed by one aquaponic producer: "*if you are a fish producer, you are not so interested in producing salad"*. Even so, it is interesting to further explore how this area of opportunity can be utilized to design experiments balancing the different interests among different actors while simultaneously contributing to niche upscaling.

Enabling research and innovation

Research and innovation is an important contributor to the development of the aquaponic niche. One aquaponic producer described how the technology in the aquaponic niche has developed in recent years:

> *"We've been familiar with aquaponics for quite some time, but for starters the technology did not feel mature enough. When we returned we realised that aquaponics had developed and that you nowadays actually can start up without yourself having to experiment in all areas.".*

Even though this indicates how a lot has happened in the aquaponic niche during recent years, interviewed actors still stress the importance of development to address challenges through collaborations with researchers. For example, the interviews presented ongoing research and experimentation within areas such as feed, farming substrate and storage of residual nutrition. There is thus a continuous need for research and innovation within the aquaponic niche to continue to develop.

Spreading knowledge and awareness through public presence

Although increasing, there is still a general lack of awareness within society about aquaponic technology as well as its values and benefits. Lack of awareness and knowledge exists among potential customers and potential producers as well as among authorities and politicians. According to an interviewed researcher, one potential way to create awareness is to focus on marketing aquaponics to the general public: "*Just out with the message. And then the politicians will get the message too. They are part of the public society.*" For example, several interviewees discuss the idea of placing an aquaponic unit at an accessible and frequently visited public place. The Swedish Board of Agriculture discussed: *"you can put it at a square somewhere and show that here we are producing the food and this is where the fish and greens come from."*

If succeeding in creating increased awareness within the general society, many opportunities may arise within the aquaponic niche. As stated by one researcher; *"As long as everyone knows about it it gets easier. If there is a market requesting the aquaponic products, laws and policies will follow"* Thus, further experimenting with spreading knowledge and awareness through public presence is believed to be interesting.

Build network forums

Fostering collaborations and sharing of knowledge within the aquaponic niche is addressed as highly important, although somewhat tricky, by the interviewed actors. As implied by the interviews, a generally positive attitude towards collaborations between the aquaponic, aquaculture and horticulture sector appears to exist. Simultaneously, a lack of collaborations within and between the sectors is expressed. An aquaponic producer described challenges with collaborations: *"You want collaboration, but you do not want to share".* Similarly, another interviewee addressed the same topic: *"Sometimes people want to hold on to their ideas, but I believe in sharing ideas with everyone. [...] If you should write every recipe in the world with this fish it would take a huge effort".* Thus, experimenting with how to foster collaborations is believed to be interesting.

One opportunity, brought up by several of the interviewed actors, is the creation of aquaponic networks, creating a shared space for sought collaborations and knowledge-sharing. One aquaponic actor described the lack of such networks: *"Who is really organizing aquaculture and aquaponics? You can find a few actors, but they do not have any impact at all really. No regional or national reach."*. Further exploring the idea of aquaponic network formation, is believed to be interesting to seize opportunities arising when enabling collaborations within the aquaponic niche. As described by one aquaponic producer: *"We want to collaborate with as many as possible to be able to transform the system [...]. Because we think it is easier to work together to transform the system than doing it yourself."*

5.2.3. Evaluation of areas of opportunity

Having identified five areas of opportunity it is of interest to evaluate how potential experiments innovated within these areas correspond to the guidelines. As visualised in Figure 12., each area was given a score ranging from low (1) to high (3), indicating the probability of an experiment within this area to address the guidelines. This section further presents the result of the evaluation.

The first area of opportunity, **collaborate with existing horticulture producers,** focuses on forming collaborations with the horticulture sector. By inviting actors to the aquaponic niche, the guideline *facilitate collaborations* has a high probability of being addressed. As horticulture actors already are a part of the regime within the current food system, forming new collaborations with these established regime actors might as well enable opportunities to *explore business strategy and distribution channels.* For example, this could be achieved through utilizing the horticulture actors' existing distribution channels and customer segments. Further, the area as well addresses the guideline *utilize strength of aquaponic technology* as it utilizes the existing technology of aquaponics and its focus on resource efficiency as a means to provide their production facilities with fertilizers.

Similarly to collaborations with horticulture, as well experiments innovated upon within the second area of opportunity **collaborate with existing producers of aquatic protein** is believed to have a high potential of addressing the guidelines *facilitate collaborations, explore business strategy and distribution channels* and *utilize strengths of aquaponic technology* as it invites collaborations with an already established regime-actor. This area of opportunity as well *challenge norms* to a great extent, for example, as it provides the possibility of increasing production and potentially the demand of a currently unknown and unesthetic freshwater fish. Further, challenging two common means of producing aquatic protein, wild fishing and cage farming, through instead marketing and producing aquatic protein produced on land, the area can foster innovations with a strong focus on *communicating values and benefits.* For example, the potential for aquaponic technology to provide a solution to current difficulties with ocean fishing and cage farming can be utilized.

Instead of focusing on facilitating new collaborations to induce new productions, the third area of opportunity **enable research and innovation** rather focus on the creation of knowledge. This as well affects the guidelines which potentially could be addressed by an experiment within this areas, as it foremost has a high probability of addressing the guideline *strive to improve aquaponic system.*

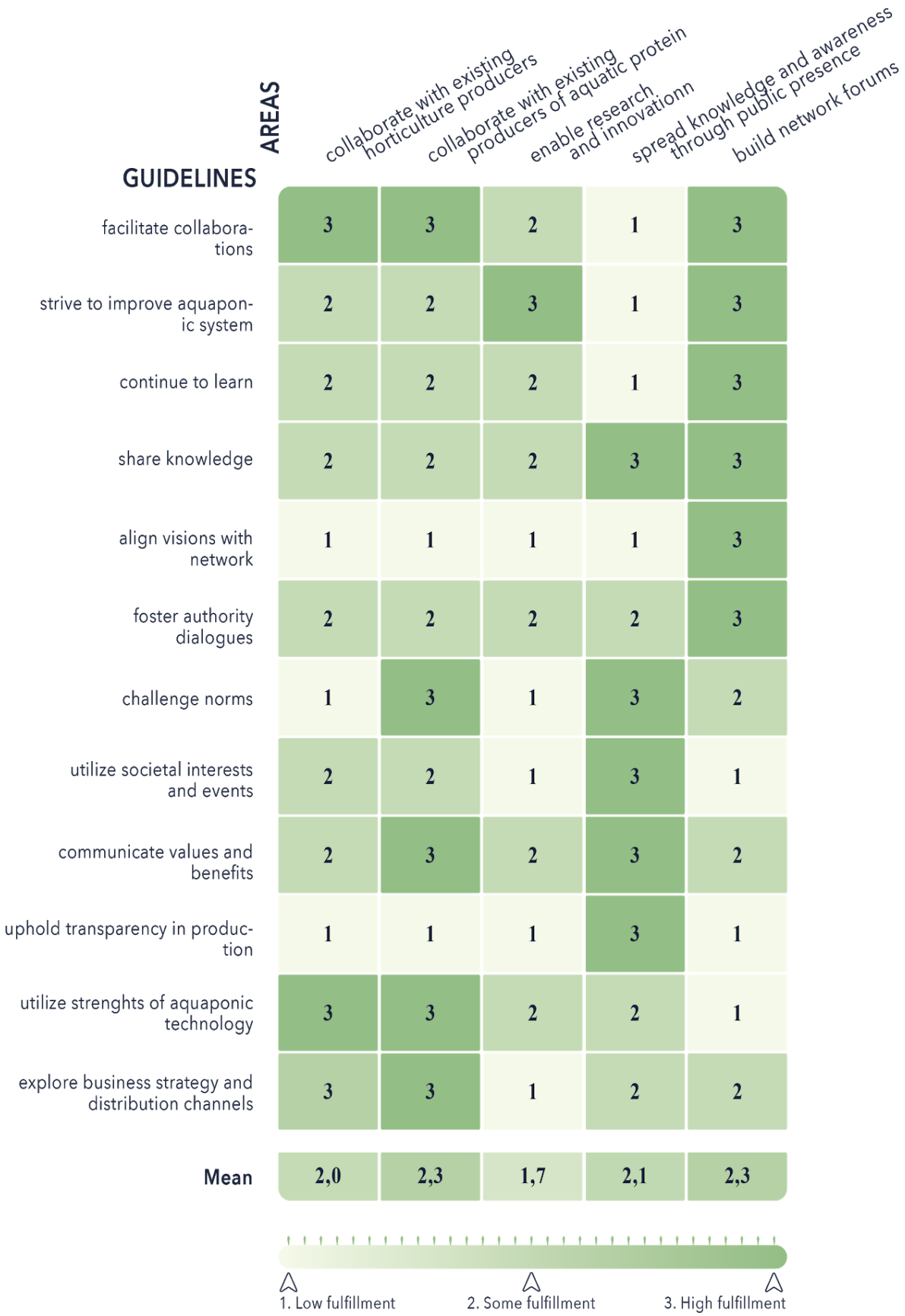


Figure 12.
Evaluation of areas of opportunity

Similar to the area enabling research and innovation, the fourth area of opportunity **spread knowledge and awareness through public presence** as well fosters experiments focusing on knowledge. However, instead of producing new knowledge, this area rather focuses on spreading the knowledge to the general public. Thus, it has a strong probability of addressing the guidelines *share knowledge, uphold transparency in production* and *communicate values and benefits.* Further, this area is believed to be able to both *utilize societal interests and events* and *challenge norms* as it aims at spreading awareness of a norm-breaking means of producing food while simultaneously utilizing increasing societal interests about, for example, food security and locally produced food.

Lastly, the fifth area of opportunity, **build network forum**, differs from the four other areas as it neither focuses on facilitating collaborations to induce productions nor creating or spreading knowledge. Instead, this area of opportunity aims to serve as a context that can facilitate an upscale of the niche through fostering the collaboration and knowledge sharing between actors with relation to, interest in, or potential future interest in the aquaponic niche. Thus, this area of opportunity addresses guidelines such as *share knowledge, facilitate collaborations, continue to learn* and *strive to improve aquaponic system.* Moreover, this area of opportunity is the only area of opportunity with a high potential of fostering experiments addressing the guidelines *align visions within the network* and *foster authority dialogues* as it might provide a platform for the involved actors to align their visions and unite their efforts to influence authorities.

While evaluating each of the areas of opportunity against the guidelines, it can be argued that it is not possible to facilitate niche formation through the development of only one experiment within one area of opportunity. As the areas of opportunity to different extent have the potential of fostering experiments addressing the different guidelines, it is believed that a set of experiments, each experiment relating to a different area of opportunity, is preferable to successfully facilitate an upscale. Further, not all these experiments need to derive from one single actor. Instead, a collaboration within the niche, where different actors set up experiments that in different ways contribute to niche upscaling, is advisable.

5.3. Phase 3: Designing a set of experiments

Aiming at exploring and exemplifying how one actor within the aquaponic niche might facilitate an upscale through the design of experiments, this section builds upon the previous results and utilizes the aquaponic producer Pond as an example. Through applying the areas of opportunity and guidelines, five concepts of experiments are developed, together forming a set of experiments. Further, an evaluation of the concepts is presented, concluding in the identification of a suitable point of intervention.

5.3.1. Concepts of experiments

The five concepts presented in this section are examples of experiments, based on Ponds current business, that in different ways might facilitate developments contributing to an upscale of the aquaponic niche. Each concept maps towards an identified area of opportunity, and thus, foremost focuses on addressing the related guidelines (see Section 5.2.3.). Four of the concepts are based on Ponds container concept (see Section 2.5.), whilst the fifth concept, Swedish Aquaponic Association, relates to Pond as an actor within the aquaponic network. Following, each of the concepts will be presented.

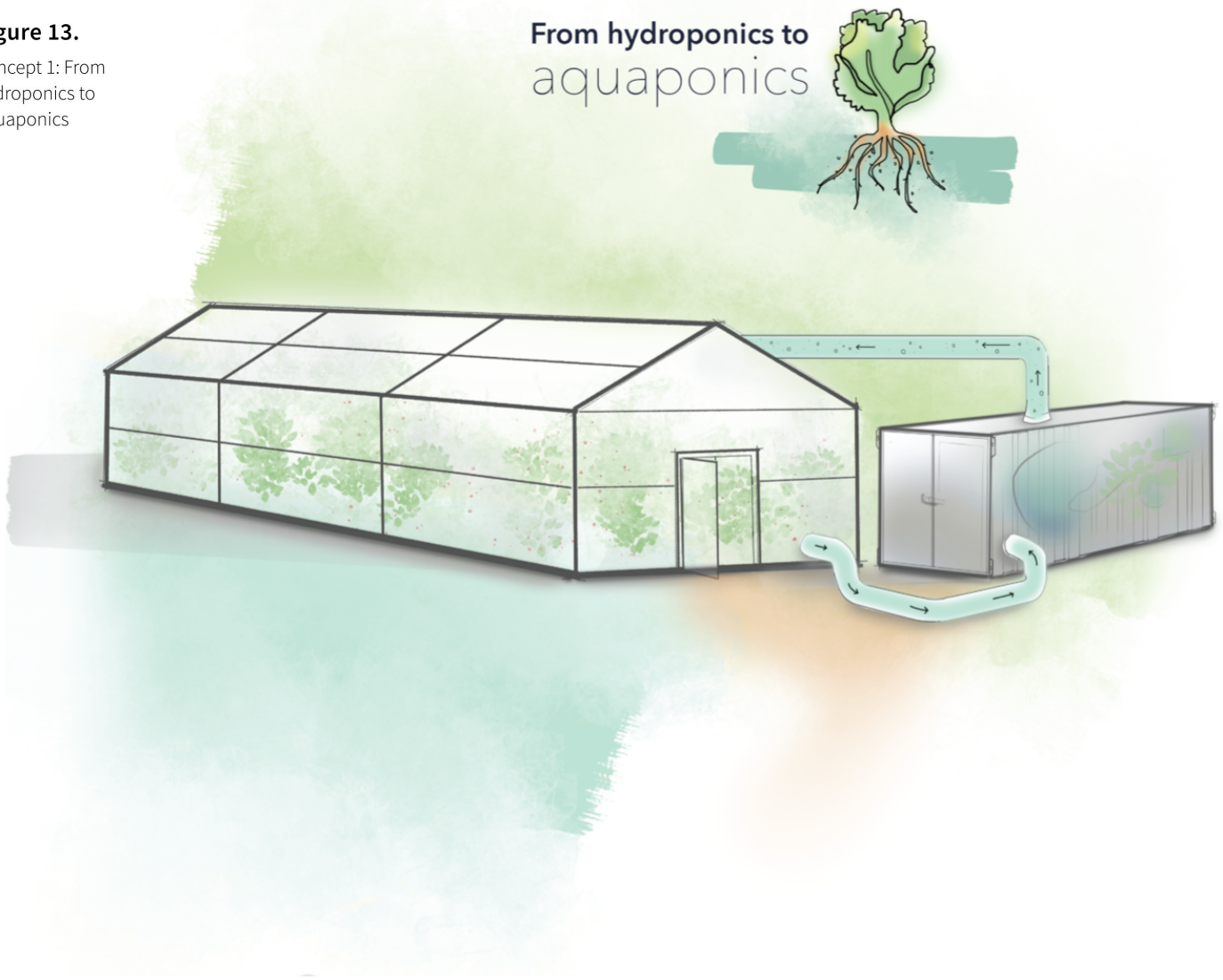
From hydroponics to aquaponics

The concept From hydroponics to aquaponics is based on the area of opportunity *collaborating with existing horticulture producers*. The concept introduces a collaboration with an existing horticulture producer producing vegetables through hydroponic technology. Initiating collaborations with the horticulture sector through firstly approaching hydroponic actors, already applying hydroponics, is believed interesting as these actors already are familiar with producing vegetables in soil-less-media. Thus, the knowledge and system changes needed to shift into aquaponic production are believed to be less challenging than for a farmer producing vegetables in soil.

Aiming at complementing the business of a rural horticulture farmer, producing vegetables through hydroponic technology, the concept From hydroponics to aquaponics adds fish into the farmer's current systems, as visualised in Figure 13. The context is defined by an already existing hydroponic set-up, where vegetables are grown in large greenhouses using nutrition purchased from subcontractors. Adding on a line of containers with fish tanks, dimensioned according to the vegetable production, instead provides the farmer with the possibility to produce the fertilizer needed. Simultaneously, a new business opportunity emerges in selling fish. Being an add on to an already existing business within the food sector, there is as well an already existing network of resellers and distributors. Utilizing this, the farmer mainly sells the fish produced to already established business contacts such as local restaurants and supermarkets but also the local farmers markets, which the farmer regularly participates in. However, fish production being a new area of expertise for the farmer, there is a lack of knowledge in implementing and maintaining an aquaponic system. Thus, the knowledge of Pond is needed, both during implementation and start-up, but occasionally as well in the long term in case of problems or unexpected events.

Figure 13.

Concept 1: From hydroponics to aquaponics



Benefits

An already established hydroponic system easen implementation.

Low amount of extra space needed when adding fish production to an existing production of greens.

Existing knowledge about vegetable production.

Existing network of reseller, distributors and consumers of food.

Increases the amount of produced aquaponic food available at the market.

Challenges

Lack of knowledge about fish production.

Need to adapt to new rules and regulations when adding fish into the system.

From wild fishing to aquaculture

Based on the identified area of opportunity *collaborating with existing producers of aquatic protein,* the concept From wild fishing to aquaculture targets wild fisheries. As previously discussed, one potential challenge within this area of opportunity is the potential lack of interest from wild fisheries to produce vegetables (see Section 5.2.2.). Moreover, there are currently actors within the aquaponic niche questioning the definition of aquaponics described as tight loops within a limited radius of operation:

> *"Aquaponics is really about tight systems where you do not dissipate energy and nutrients. Then, it becomes interesting when you allow aquaponics to include systems where you store nutrients [...]. Where aquaponics is allowed to be defined broader than these tight loops".*

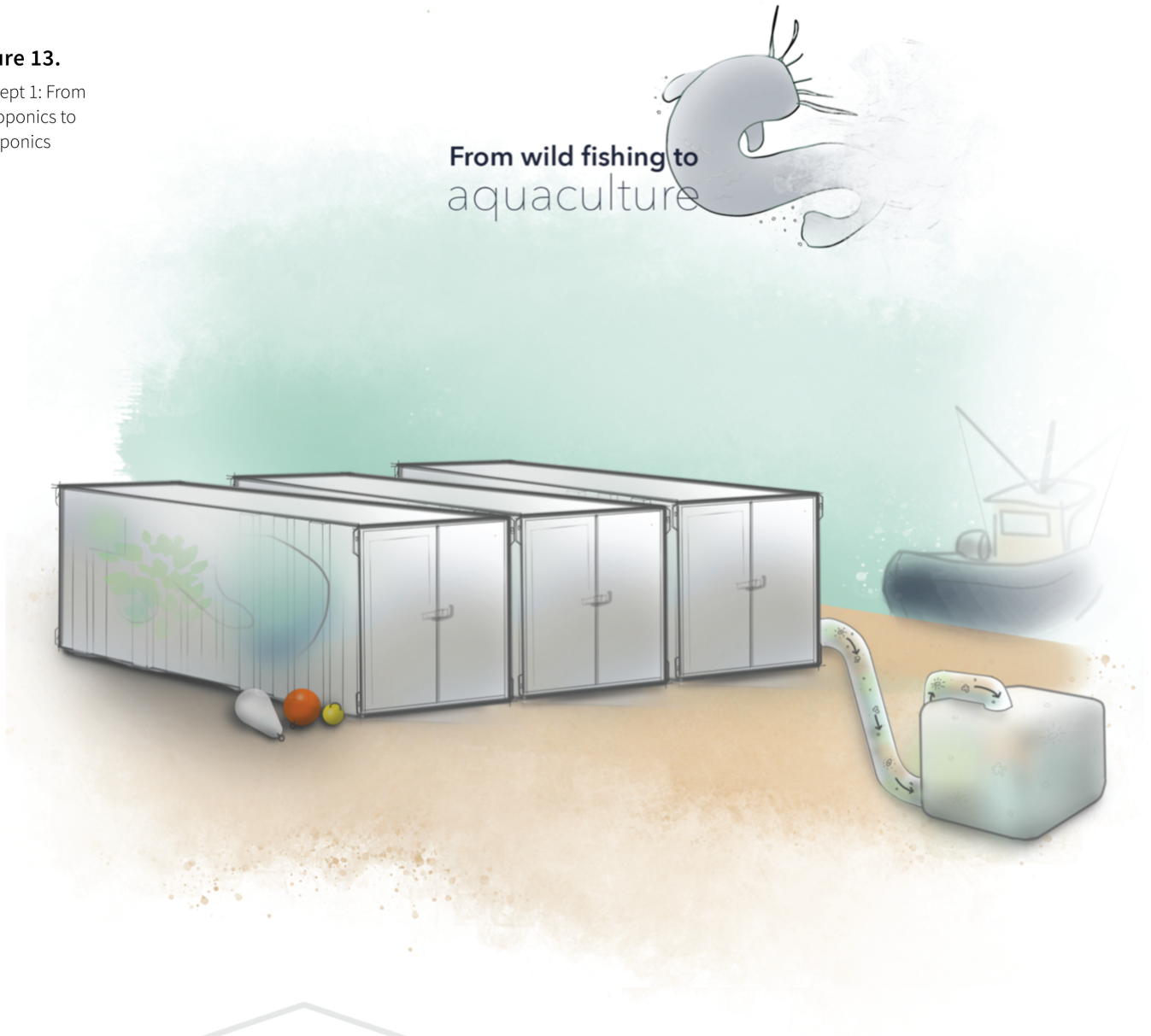
Thus, one potential way of initiating collaborations with the aquaculture sector could therefore be to redefine what aquaponics actually is. Building upon this idea, From wild fishing to aquaculture introduces a land-based aquaculture system, borrowing the mentality of circularity and no-waste from aquaponics, while focusing on producing sustainable aquatic protein.

From wild fishing to aquaculture aims at adding land-based, recirculating, aquacultural systems into the current business of wild fisheries, as visualised in Figure 13. Being a complement, rather than a substitute, to the current business of the addressed wild fishery, this concept consists of a rural land-based aquaculture farm located right at the harbour where the company currently operates. As the wild fishery has aquatic protein production as their main interest, the unit focuses on the production of fish and fertilizers, the latter being sold to nearby farmers. Thus, it is by definition not an aquaponic unit but borrows the idea of sustainable food production, circularity and no-waste mentality from the aquaponic technology as the nutrition from the fish waters is withdrawn from the system and re-used by local farmers, allowing the cleansed fish water to recirculate. Focusing on fish production, the fish produced is distributed to local supermarkets and fish shops as well as restaurants, building upon the existing network of the wild fishery. Moreover, it is possible to open up for events inviting local residents to gain knowledge, insight and sensory experience of ocean fishing as well as land-based production of aquatic protein right at the production site.

For starters, the concept is designed as a small-scale production line, producing up to 40 tons of fish each year. According to the interviews, introducing a production line this small allows for an easier permit application process although simultaneously allowing the fishery to learn about the technology of fish farming. To aid the implementation and learning process, both the container concept and the knowledge needed for the setup and maintenance can be leased by Pond to the fishery. Further on, if the concept and business model is proven successful, it is possible to both upscale as well as buy the concept.

Figure 13.

Concept 1: From hydroponics to aquaponics



Benefits

Due to overfishing, wild fisheries may need future business-opportunities.

Wild fisheries, being a large industry with existing land, have the potential of producing a lot of aquatic protein.

Knowledge already exists about aquatic protein.

Existing network with customers, e.g. supermarkets, restaurants and fish shops.

Challenges

Shifting from ocean fishing to partly land-based production methods requires a shift in mindset and culture.

Potential mismatch between current routines and for running an aquaculture farm.

Lack of knowledge about farming fish.

Challenges the current definition of aquaponics.

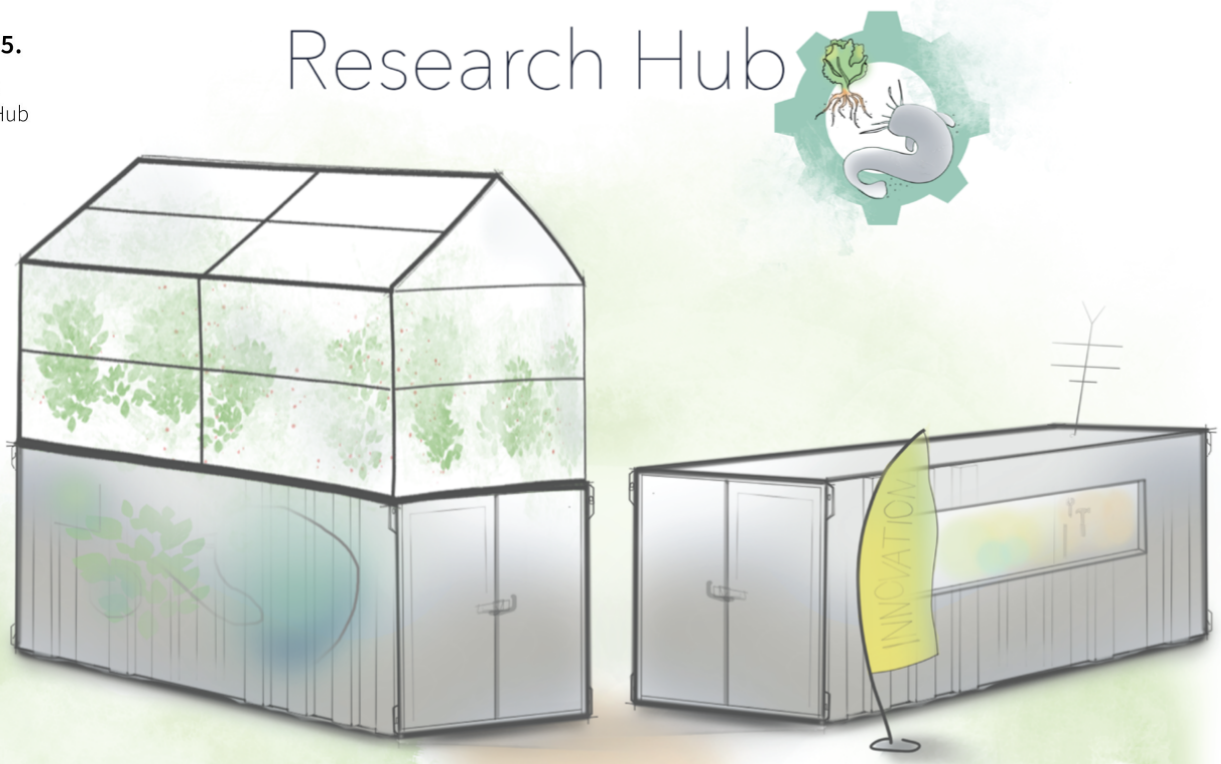
Potential difficulties marketing and selling fresh-water fish in saltwater coastal areas.

Research Hub

Sprung from the area of opportunity *enabling research and innovation* the Research Hub explores the opportunity of collaborating with researchers to further promote research and innovation. Being located in the urban context of a campus area, the Research Hub aims at triggering research and innovation through placing a small-scale aquaponic unit, provided by Pond, right in the center of research and development, as visualised in Figure 15. As the focus is set on facilitating learnings about how to improve the aquaponic system and technology, the unit is built up by a modular container, producing fish, and a greenhouse, providing a space for vegetable farming. The research hub has the potential of hosting multiple research projects, and thus demands flexibility as the needs vary between the projects. Accordingly, an extra container is added to provide a flexible space adaptable to ongoing research projects, and the modularity of the container concept as well allows for up-scaling of the hub by further adding containers.

Being a research hub, the aim is as well to share research through, for example, hosting lectures, workshops and seminars. The proximity to the campus serves as a great benefit since facilities serving this purpose are present. Another advantage of being located at the campus is the proximity to students, as it serves as a great possibility of encouraging student projects and sparking interest amongst a future generation of researchers. However, by-passers and residents of surrounding residential areas as well occupy the campus area. To share knowledge and create awareness amongst them all, information is shared outside the hub on the ongoing research as well as of aquaponics in general.

Figure 15.
Concept 3:
Research Hub



Benefits

Located at the center of research and development which might trigger research projects and student collaborations.

Financially protected space allows for larger margins of ”failure”

Challenges

Researching aquatic protein may cause an ethical challenge considering animal rights and animal experiments. Puts high demand on communication.

When focus is put on ongoing research projects, it may cause challenges with the distribution of the food produced.

Potential challenges with long-sightedness, as projects finances may be limited and short-termed.

Neighbourhood Center

The concept Neighbourhood Center utilizes the area of opportunity *spreading knowledge and awareness through public presence* as its starting point. Consisting of a small-scale aquaponic unit, with the purpose of demonstrating the technology rather than producing fish and greens, the concept will be located at the center of an urban neighbourhood, as visualised in Figure 16. Thus, the context is defined by proximity to a variety of local actors and communities, as well as a lot of movement of people, and invites a wide range of citizens to learn about aquaponics. Further, being an urban center, access to space is limited. Therefore, a small-scale aquaponic unit is suitable to use as it can be adapted to a variety of city environments.

The unit will consist of one container and a greenhouse, producing fish and greens, but will primarily focus on information sharing through exhibition-like areas sharing a brief introduction of the aquaponic technology as well as its benefits and challenges. In parallel with knowledge-sharing, the exhibition areas offers the visitors a glimpse into the containers and greenhouses. Even though being small-scaled, the production unit and exhibition areas need daily care-taking. Being located in a neighbourhood, there is a possibility of using local competence as day-to-day keepers. For example, people who are taking part in daily activity programs could be included as an important part of the keeping of the facilities, similar to Ponds existing production facilities.

To further contribute to the spreading of knowledge and awareness, events will regularly be held where the visitors or by-passers, for example, can have a chat with the aquaponic farmer, enter the production site or participate in a workshop or lecture in the outdoor classroom. Tasting experiences is as well an important part of the aquaponic experience. Thus, it is advisable to create the opportunity for the visitors to as well purchase the produced food. Collaborations could for example be made with adjacent restaurants, food trucks and supermarkets where it is possible to purchase the food. Being a small scale production unit, collaborations with other aquaponics producers could be made to ensure constant providing of Clarias and vegetables to the local resellers.

Figure 16.

Concept 4: Neighbourhood centre

Benefits

Potential of creating knowledge and awareness among a wide range of people on topics such as aquaponics, aquaculture, hydroponics and sustainable food consumption.

Allows for transparency in production.

Contributes to expand the customer segment.

Possibility of utilizing urban voids.

Challenges

Complex network of actors needed for a successful experiment.

Uncertainties of finance, ownership and maintenance of the concept.

With the main focus being the production of knowledge, profitability may be a challenge.

Lack of space in urban areas.

Swedish aquaponic association

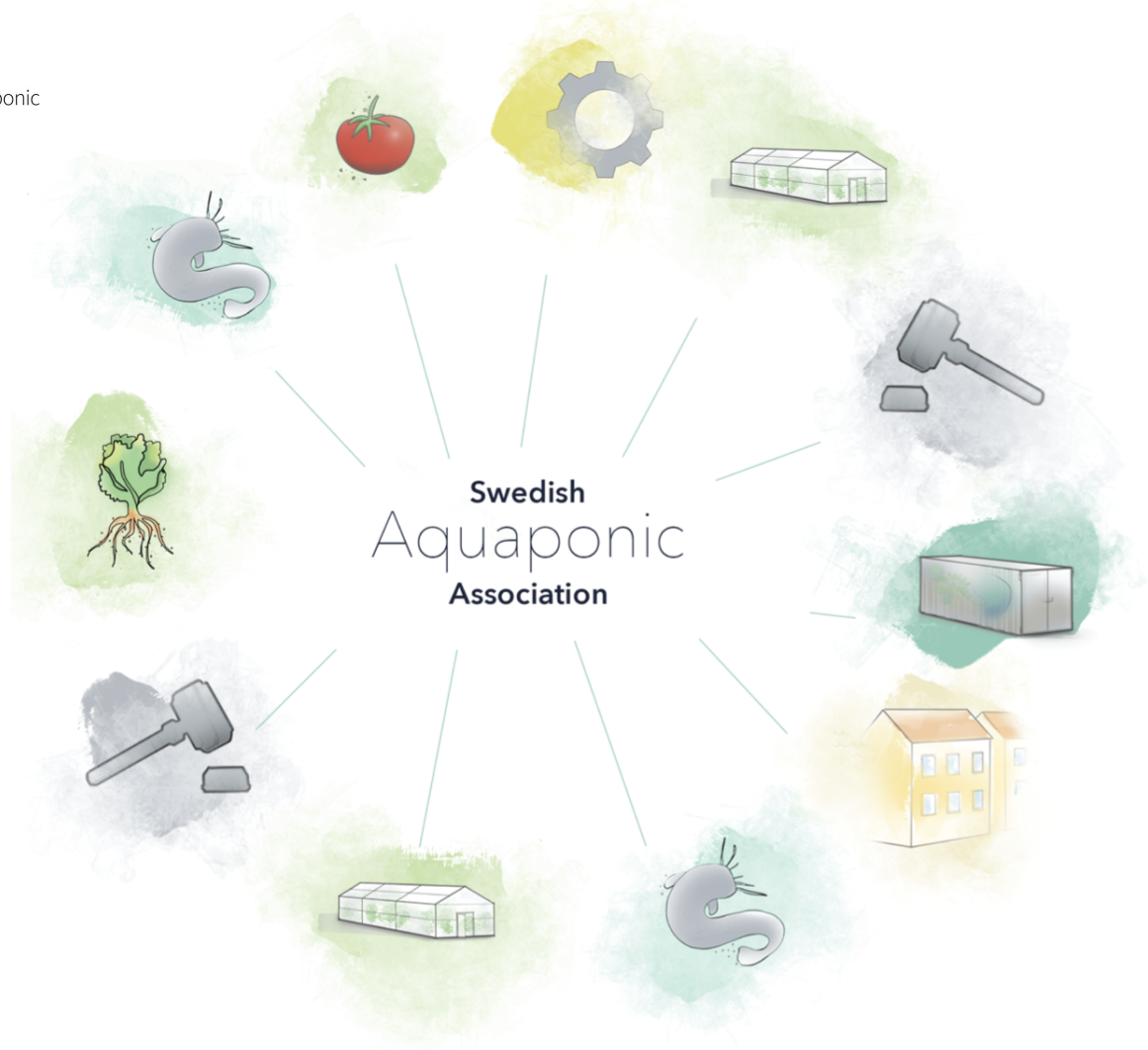
Building upon the area of opportunity, *network formation*, The Swedish aquaponic association has its starting point in the experienced lack of collaborations within the Swedish aquaponic niche.

The concept is a non-profit trade association, co-founded by the aquaponic actors within Sweden, as represented in Figure 17.. It aims to facilitate collaborations amongst aquaponic producers and together conduct advocacy work and share knowledge about aquaponics and its benefits to potential consumers as well as politicians, both within Sweden and the EU. Through collaboration, the association aims at facilitating system-changes towards more circular and sustainable food production methods. The association is led by a board of elected individuals representing a variety of actors within the field. Each member pays a yearly membership fee that helps finance the association and its activities.

To facilitate a space for knowledge sharing and diffusion of knowledge among the niche actors, the association arranges activities such as a yearly aquaponic conference, webinars, study visits and lectures in which the members can participate. Amongst the activities are both activities only for members but also activities open to the public, depending on the topic and the aim. The association also arranges regular online-discussions, where aquaponic actors meet up and share thoughts and ideas. Occasionally, the association arranges online meetings with other aquaponic associations around the world to be able to collaborate, share knowledge, learn and connect as well across borders. The activities are announced through the association's web page, which also serves as the main communication channel.

Figure 17.

Concept 5: Swedish aquaponic association



Benefits

Has the potential to foster collaborations and dialogues both within the network but also with the public sector, private sector and the state.

Support learning and knowledge sharing.

Potential of larger advocacy if the sector unites forces.

Challenges

Potential struggles with creating a climate supporting knowledge sharing and transparency rather than competition.

Lots of engagement and pro bono work needed already from the start, whilst value is created over time.

5.3.2. Evaluating concepts of experiments

This section presents the evaluation of the five concepts, aiming at identifying low hanging fruits, i.e. the most easily achieved concept, both based on Ponds business interests as well as the possibility of addressing the guidelines (see Section 5.2.3.), thus, potentially facilitating niche upscaling. Thus, the eight criteria represent both these aspects and are further described in Appendix C. With a base in the eight criteria, the five experiments were graded together with Pond on a scale from 1-3, from low to high fulfilment, as visualised in Figure 18. Further, based on the result of the evaluation and discussions with Pond, a concept was suggested as a suitable point of intervention for Pond.

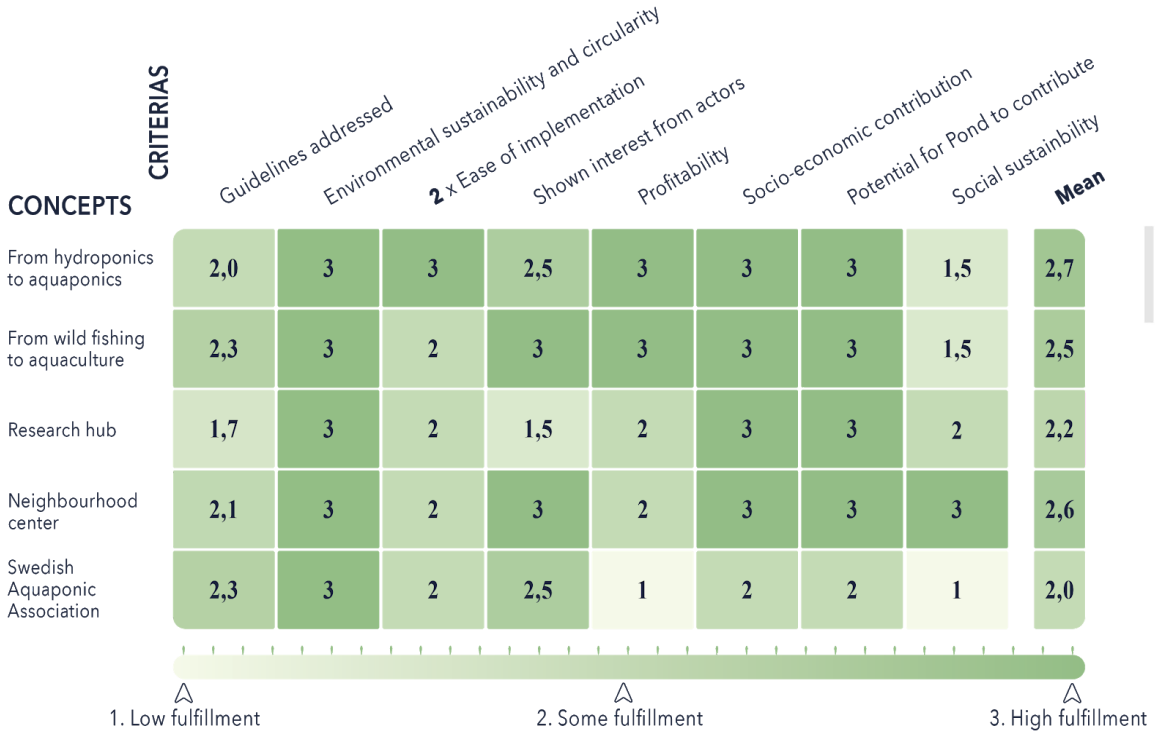


Figure 18.
Evaluating concepts of experiments

The concept **From hydroponics to aquaponics** received the highest total score among the five concepts. One benefit highlighted by Pond is that the horticulture sector already is a strong sector within the current regime: *"there are a lot of [horticulture] actors already with good finances"*. Thus, inviting existing regime actors to collaborate, both ease of implementation and profitability has a high potential of fulfilment. However, its contribution to social sustainability, a factor regarded as important by Pond, was questioned: "*the traditional side of horticulture is that it is not visitable, it is not inclusive and there are very few employees''*. The low scores on social sustainability leave room for improvements. Moreover, the concept has relatively high adressment of the guidelines, e.g. as it facilitates collaborations and explores business strategies and distribution channels. In conclusion, the concept is argued to have a high potential of contributing to an upscale of the niche while simultaneously having a general high potential of addressing Ponds interests, making it a suitable point of intervention.

Similar to the concept From hydroponics to aquaponics, the concept **From wild fishing to aquaculture** as well creates opportunities for food production through collaborations with existing regime actors, resulting in high addressment of profitability and ease of implementation. The similarity between these concepts is described by Pond: "*these two have a special character, more towards business and larger scales"*. Unlike the horticulture sector, the wild fishing industry is characterized by few but large actors: *"a bit complicated with wild fishing is that there are relatively few fishing operations in Sweden. On the other hand, these ones are big with good finances*." According to Pond, this might make the ease of implementation somewhat more challenging as there are fewer actors present to approach. However, if succeeding in collaborations with one of these large actors, there is a high potential of impact. Another interesting aspect highlighted by Pond during the workshop is the concept's high addressment of environmental sustainability. Although this concept focuses less on circularity compared to e.g. the concept From hydroponics to aquaponics, the benefits for the environment compared to the current wild fishing industry is very high: *"What are you replacing with this kind of fish production? That replacement may be more important than the contribution from collaborating with horticulture"*. Moreover, considering the addressment of the guidelines, this concept shares the highest mean of fulfilment. Thus, it is argued that From wild fishing to aquaculture has a high potential of both contributing to niche upscaling and addressing Ponds interests.

The concept **Research Hub** is believed to have a high addressment of factors such as environmental sustainability, socio-economic contribution and potential for Pond to contribute. However, it is believed to have a somewhat lower possibility of addressing Ponds interest among the evaluated concepts. One challenge emerging during the workshop was its potential difficulties with profitability. Even though research is believed to be highly important for economic growth over time, difficulties with short term profitability are discussed: "*What is research worth? One could reason that it mainly costs a lot of money. [...] It is not very easy to make money out of it.".* Another challenge implied is the somewhat lower interest shown by researchers, compared to other addressed actors: "*there is not much interest shown from researchers. But it could be that we have not addressed the researchers in this way [providing research hubs]".* Further, Pond argues that their contribution to research is mainly through providing them with contexts of aquaponic productions: *"we have the production facilities. We believe it to be important to research not only in research labs, but as well in production".* Concluding, the concept Research Hub can be argued to have the potential to contribute to a niche upscale, and as well somewhat answers to Ponds interest. However, the opportunities of research and innovation to facilitate a niche upscale might be better approached by Pond through supporting research possibilities in other contexts than the proposed concept.

In contrast to the two concepts focusing on initiating production and collaborations with the existing horticulture and wild fishing sector, the concept **Neighbourhood center** rather has its main focus in knowledge sharing and education. Although this is a great benefit with the Neighbourhood center, resulting in high fulfilment of guidelines and socio-economic

contribution, it also serves as a drawback for the potential profitability and ease of implementation. As described by Pond, *"It is not possible to motivate the investment out of only a production perspective. Pedagogy needs to have an essential role as well".* As further discussed by Pond, "*there is perhaps somewhat less resources available to finance the expertise needed*, *making this somewhat harder"* resulting in lower addressment of profitability as well as ease of implementation. One benefit of this concept, discussed during the workshop, is its potential in contributing to social sustainability and social inclusion. As described by Pond: *"This can actually be a space for people in a marginalized existence and without any employment. It could serve as a way for them to get back to their own life and role in society."* Concluding, the concept Neighbourhood center is believed to have good potential both to contribute to niche upscaling as well as addressing the interests of Pond.

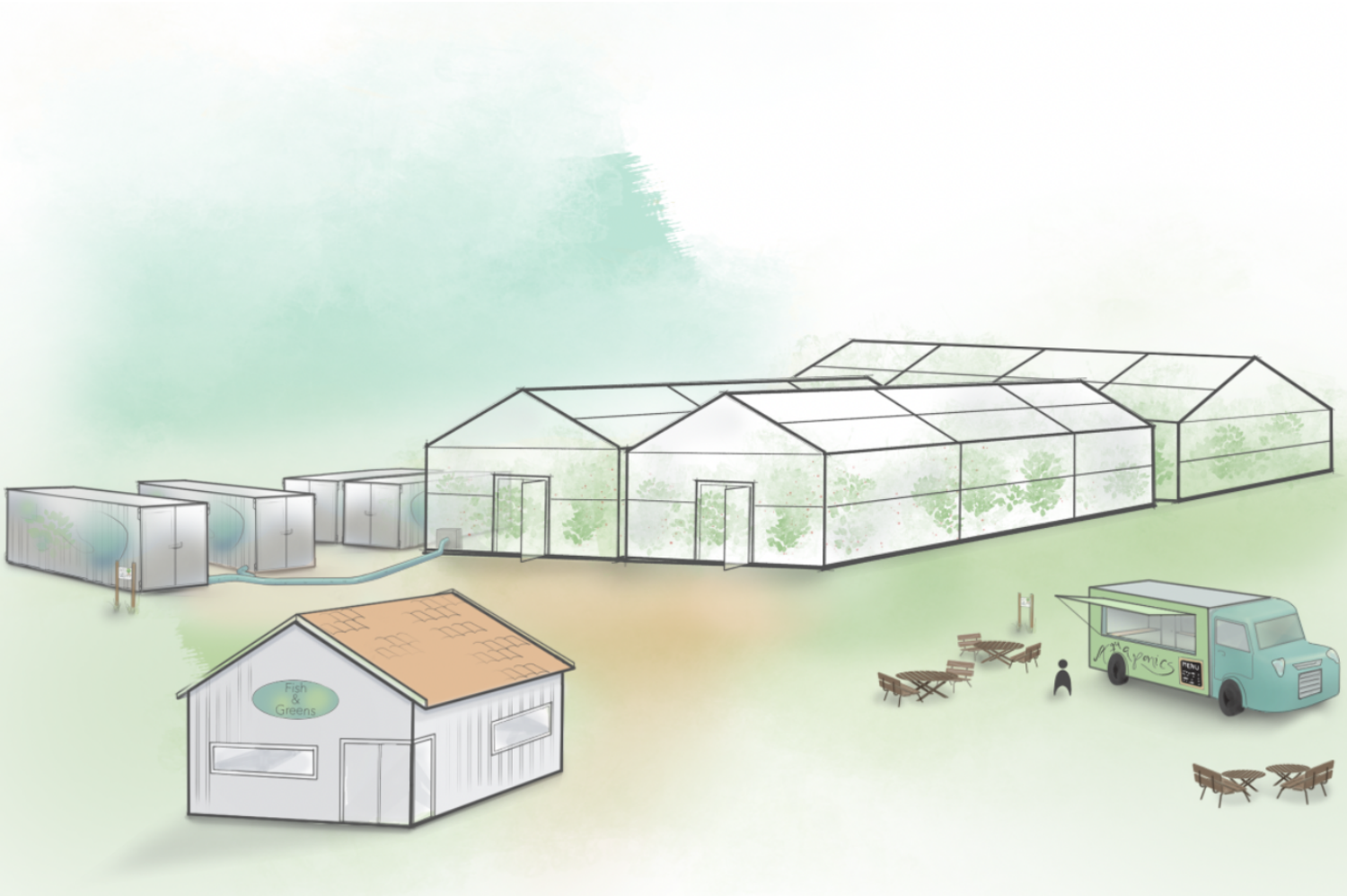
Lastly, the concept Swedish Aquaponic Association differs from the four other concepts as it focuses on Pond as an actor within the aquaponic niche rather than their business ideas. The creation of an association is described by Pond as "*really important to get a development within the industry"* and it shares the highest addressment of the guidelines. Even so, it is the concept receiving the lowest mean score. Among others, this is described to be due to challenges with ease of implementation and profitability: *"Running an association is tiring and it has low profitability".* Moreover, the association is believed to create a low potential in contribution for many actors within the niche as *"the ones working now, they have a lack of resources and do not have time. They truly want this, but they really do not have time. "*. Thus, it could be argued that this concept could be a highly important contributor to niche upscaling by fostering knowledge sharing, authority dialogues and alignment of visions within the network. However, due to the current characteristics of the niche, there might be difficulties finding initiators and actors taking ownership of such a network.

Based on the results of the evaluation and discussions with Pond, the concept from Hydroponics to Aquaponics was identified as a low hanging fruit suitable point of intervention for Pond to enable niche upscaling while simultaneously addressing their own interests. However, the evaluation revealed a few drawbacks of the concept, foremost concerning a lack of social sustainability and knowledge sharing. As described by Pond, *"you have the potential of adding both the social aspect and pedagogy, but now it is business producing a lot of food that is the main focus for hydroponics to aquaponics".* Thus, the concept will be merged with elements from the Neighbourhood center to include elements of social sustainability as well as knowledge sharing.

Figure 19.
Concept of suitable point of intervention

5.3.3. Suitable point of intervention for Pond

Based on the evaluation and discussions with Pond (see Section 5.3.2.) a combination of the concepts Hydroponics to Aquaponics and Neighbourhood center was identified as a suggested suitable point of intervention for Pond. Thus, sprung from a collaboration between Pond, providing a solution of aquaculture, and a Swedish Hydroponic farmer, with existing hydroponic production, this concept consists of an aquaponic system in where tomatoes, being produced in large greenhouses, are fertilized by the generated nutrition from the fish Clarias, being produced in a set of standard containers placed in connection to the greenhouses, as visualised in Figure 19. Thus, this concept presents the possibility of producing food in an aquaponic system. Moreover, the concept includes elements such as a cafe, a farm shop, exhibition areas, school programs and programs providing work opportunities and collaborations with people currently outside the labour market. Therefore, it also presents possibilities of spreading knowledge and awareness and addressing social inclusion.



Production and distribution of aquaponic food

The main goal of this concept is to increase the production and distribution of vegetables and fish produced with aquaponic technology on the Swedish food market. The production is divided into two parts; providing tomatoes as well as the fish Clarias. As in the concept *From hydroponics to aquaponics,* as well this concept adds on the fish production to the production of tomatoes to replace the currently utilized fertilizers with the generated nutrition from the fish production. Thus, apart from the tomatoes currently being produced and sold by the farmer, the fish are added to the business.

There are several possible channels for distributing the produced fish and vegetables. Since the horticulture actor being an already established regime actor, there are already existing distribution channels and collaborations with, e.g. wholesale, supermarkets and restaurants where the tomatoes are currently being sold. Thus, aiming at as well distributing the produced fish, these sale channels could be utilized. The produced food can as well be distributed directly to the consumer, serving as a complementary sales channel that allows for a larger profit for the producer. Through suggesting elements such as a farm shop, the possibilities for customers to pick their own tomatoes, and a cafe, part of the distribution of fish as well as vegetables can be managed directly to the consumers.

Spreading knowledge and awareness

A sub-goal of the concept is to, similar to the concept *Neighbourhood center,* spread knowledge and awareness about aquaponic technology and its values and benefits to the general public. Through providing the production of both fish and greens in direct proximity, the concept provides the opportunities of sharing a brief understanding of the circularity in aquaponic food production. However, unlike the concept *Neighbourhood center,* a farm might not be a location frequently visited, providing a potential challenge while spreading knowledge and awareness. Even so, through adding elements such as a farm shop, pick-your-own opportunities and a cafe, the farm also has the possibility of being not only a production facility but as well a destination for day trips and tourism. Further, it is also possible to invite groups with potential interest, e.g. schools, to learn more about aquaponics and sustainable food production. Initiating these elements will further enable opportunities of spreading knowledge and awareness, not only beneficial for the niche development but as well for the farmer as an increased amount of visitors provide further opportunities for businesses.

Aiming at spreading knowledge and awareness amongst the visitors of the farm, both knowledge about the fish, the circularity and the tomato production are being communicated. For starters, presenting an overview of the aquaponic technology and knowledge on the fish production as such, an exhibition area in relation to the fish containers is set up, visualised in Figure 20. The exhibition area is designed to guide the visitors in two steps; demonstrating a transparent production while complementing it with knowledge to understand what is being viewed. Thus, the visitors are firstly encountered with an exhibition sharing knowledge about topics such as sustainability challenges within the

food system, the aquaponic technology and the fish and vegetables produced. Secondly, having gained an understanding of the production method, the visitor is offered a glimpse through an opening in the container wall and into the fish production. By providing the visitors with the knowledge, for example about the fish and its preferences, before guiding them to have a glimpse into the system, they will more likely have the knowledge to understand what they see. Thus their interpretations and understanding of the system will be affected by the knowledge shared, avoiding assumptions and misinterpretations. Further, to as well offer an insight into the circularity of water and nutrition in aquaponics, the visitors can follow the flow of water, from the fish containers into the greenhouses through transparent pipes. Having arrived at the greenhouses, the visitors can follow the water inside and have a look inside one of the greenhouses.

Figure 20.
Exhibition areas

Social inclusion

Another sub-goal of this concept, as well partly addressed in the concept *Neighbourhood center* is that of contributing to social inclusion through aiming at creating a place inviting everyone, independent of for example age, abilities or origin.

Expanding the current business of a horticulture farmer to include as well the production of fish, but as well to include elements such as a cafe and a farm shop, new work opportunities will be created. In Ponds aquaponic production facilities in Lerum and Göteborg (see Section 2.5.), people that are currently outside the labour market have been invited to take part in the business. For example, people taking part in activity work programs and people having arrived in Sweden in recent years are involved in the day-to-day operation of the facility. Similarly, aiming at social inclusion, the work opportunities arising when implementing this concept can be utilized to invite these groups as part of the business. Further, this kind of concept might as well invite other groups in society to take part in and learn from farming in general and aquaculture as such. For example, through opening up the business for and inviting groups such as school classes as well as politicians, knowledge and insights are shared and a space for people to learn and evolve is created.

6. Discussion

This chapter reconnects to the aim of the research and aims at discussing the research questions posed by highlighting the main findings. Further, it discusses the limitations of the thesis, its implications for practice and research and suggests further work.

6.1. Fulfillment of Aim and Research Questions

This thesis aimed at exploring how an upscale of the Swedish aquaponic niche can be facilitated. Aiming at fulfilling the aim, four research questions were posed and are further discussed in this section.

6.1.1. Stakeholders affecting an upscale of the niche

Knowledge for addressing the first research question, **Who are the stakeholders affecting an upscale of the aquaponic niche?,** was gained by gathering data from stakeholder interviews which were further analysed and visualized through a stakeholder onion diagram. Doing so, the question was answered by identifying 21 different stakeholder-groups, with different levels of involvement and different connections to one another.

The 21 categories of stakeholders are found within the three domains; state, market and civil society, and are as well identified within all three levels of involvement. Further, the majority of them have direct or ad hoc relationships with several of the involved stakeholders, indicating interdependencies among the stakeholders. However, media, a stakeholder within the wider environment, appears to be the one stakeholder where only indirect relationships are identified. Through providing a framework for several of the aquaponic niche actors, media is believed to be an important actor affecting the possibilities to upscale. However, only being indirectly affected by the actors within the aquaponic niche, there is a lack of mutual dependency. Thus, for the aquaponic niche to find ways to interact and impact Media to a larger extent is believed interesting to further explore, as it might serve as an opportunity to increase the potential of upscaling. For example, a stronger connection to media could help in diffusing the knowledge and awareness about aquaponics and its benefits amongst potential customers, collaborators and investors as well as the state.

As of today, a few of the identified stakeholders carry an active role in facilitating an upscale of the aquaponic technology. Among the stakeholders, mainly the aquaponic food producers themselves and Vattenbrukscentrum Ost is believed to actively strive for an upscale of the technology. However, as well other involved stakeholders, e.g. consumers, authorities, food retailers and food refiners, have a positive attitude towards an upscale of the technology, but are currently somewhat less engaged in a potential upscaling. Thus, for the aquaponic producers and Vattenbrukscentrum to build on the relationships with these actors, to engage as well others in the aims for an upscale, is believed an important step. For example, further engaging actors within the state domain is believed crucial as they provide an important framework for the aquaponic niche.

6.1.2. Forces affecting possibilities of scaling up

The second research question, **What are the enabling and restraining forces affecting the possibilities of scaling up the aquaponic niche?,** was addressed by gathering data from stakeholder interviews and focus groups, analyzed using an affinity diagram bringing up relevant themes, and visualised in a force field mapping that highlighted enabling and restraining forces. Doing so, the question was answered through a representation of the current restraining and enabling forces, as pictured and expressed by the actors involved in the thesis

In total, sixty enabling or restraining forces affecting an upscale of the aquaponic niche were identified according to six categories; *infrastructure & industry, laws & policies, knowledge, technology, market & user preferences* and *cultures & norms.* These six categories correspond to the six characteristics of a socio-technical system (see Section 3.2.) and forces were found within all of them. This indicated a variety in nature of the forces found and may point towards a broad coverage of forces enabling and restraining change in the thesis. Moreover, the forces identified were analysed out of their occurrence in interviews. Among the most frequently occurring enabling forces, thus expressed by the largest number of interviewed stakeholders, was *positive attitude of collaborations, market potential, fascination creation* and *possibility of transparency in production.* On the other hand, the most frequently discussed restraining forces were *low demand of unknown fish, lack of aquaponic knowledge, lack of well-known eco-labelling, difficulties with profitability* and *customers habitual consumption.* Being occurrence-based, these forces are not by default the forces with the highest impact on restraining or enabling change. Even so, indicating what forces are on the top of the actors' minds, they could be argued to be forces frequently encountered, and thus presenting important challenges and opportunities.

Among the sixty forces identified, nine were identified to originate from changes occurring in society, thus from a decrease or increase of a factor regarded as important by the stakeholders. These forces primarily regard changes in interests and awareness among the general public, for example, increases in *interest in producer-consumer distribution* and *awareness about need of higher food security.* The occurrence of these forces originating from

current movements, highlights the importance of this analysis and visualisation, representing a snapshot of the present situation. Even though these forces marked as dynamic arise due to movements, all forces found in this thesis are or can be subjects of change.

6.1.3.Guiding niche actors towards an upscale

The third research question was **How might the aquaponic niche actors be guided towards facilitating an upscale?.** This question was addressed through the development of guidelines, guiding the niche towards facilitating an upscale, and the identification of areas of opportunity, serving as a context in which an upscale could be facilitated through the implementation of experiments.

The guidelines were based on further analysis of the identified forces and aimed at helping the niche actors navigate the enabling and restraining forces affecting an upscale. In total, twelve guidelines were identified and divided into five themes; *network formation, learning processes, articulation of visions and expectations, interplay with the regime* and *strategies for aquaponic businesses.* Among the identified guidelines, several appeared to be in line with the three processes described by Strategic Niche Management (SNM) to be important factors for succeeding with the creation of niches; the communication of visions and expectations, the creation of social networks promoting the experiments and the learning processes within the niche (Raven, 2005); Schot et al., 1996). For example, the guideline *align visions within network* was in line with communication of visions and expectations, and the guidelines *share knowledge* and *strive to improve aquaponic system* are in line with learning processes within the niche. However, several guidelines were found not relating to the suggested processes of SNM. Thus, the two themes *interplay with the regime,* including guidelines aiming at drawing from or impacting the regime, and *strategies for aquaponic business,* including guidelines presenting strategies for actors designing aquaponic experiments, were added.

Moreover, the areas of opportunity identified were based on ideas and discussions during stakeholder interviews and aimed at serving as a context in which aquaponic experiments can be implemented to facilitate an upscale of the niche. Thus, these areas of opportunity served as opportunities in which the guidelines could be applied. In total, five areas of opportunity were identified. The first two areas, *collaborate with existing horticulture producers* and *collaborate with existing producers of aquatic protein,* regarded opportunities arising when inviting the aquaculture and horticulture sector to collaborate, thus, aiming at expanding the network of actors within the aquaponic niche. Suggesting these two areas of opportunity are in line with the SNM process *network formation,* as inviting new actors to the aquaponic niche contributes to the creation of broad networks according to Geels & Schot (2008). The third and fourth area of opportunity identified, *enabling research and innovation* and *spreading knowledge and awareness through public presence,* regards the creation and diffusion of knowledge. Thus, they create opportunities of facilitating *learning processes* within the niche, for example, regarding the areas *technical aspects and design specifications*

and *market and user preferences* as suggested by Geels & Schot (2008). Lastly, the fifth area of opportunity *build network forums* regards the creation of platforms for the niche to, for example, strengthen its networks, enabling diffusion of knowledge amongst the actors and unite their, e.g. authority dialogues. Thus, this area of opportunity provides an opportunity to address all three processes within SNM; *network formation, articulation of visions and expectations* and *learning processes.* In conclusion, it can be argued that all five areas of opportunities are relevant when guiding the niche actors towards an upscale. This claim can further be strengthened as the result, when evaluating the areas of opportunity towards the guidelines (see Section 5.2.1.3.), highlights the need of all areas of opportunity if aiming at addressing all guidelines.

6.1.4. Ponds contribution to an upscale

The fourth research question was **How might Pond, exemplifying an actor within the aquaponic niche, contribute to niche upscaling through the design of experiments?.** This was answered through developing and evaluating a concept of a set of experiments, based on Pond's role as a niche actor and aquaponic producer. In total, five concepts were developed; *from hydroponics to aquaponics, from wild fishing to aquaculture, Research Hub, Neighbourhood center* and *Swedish aquaponic association*. The concepts were based on the previously identified five areas of opportunity and guidelines guiding the niche towards facilitating an upscale. Thus, these experiments are all argued to have the potential to contribute to niche upscaling. Further, aiming at suggesting one experiment for Pond to start with, successful in addressing Pond's business interests as well as acting as a facilitator of niche upscaling, a concept of a point of intervention was identified through combining *from hydroponics to aquaponics* with *Neighbourhood center*.

Contribution to niche development

Ensuring that this thesis has answered the posed research question it is interesting elaborating on how the implementation of such a concept can come to contribute to niche upscaling. To facilitate an upscale, its contribution to either increasing the enabling forces or reducing the restraining forces, affecting an upscale of the aquaponic niche, are key. With the concept presented having a focus on production and collaboration as well as spreading of knowledge, the concept is argued to come to directly have an impact on several of the identified forces, as visualised in Figure 21.

Firstly, with the main goal of the concept being to produce aquaponic fish and greens through collaborating with a hydroponic farmer it utilizes the enabling forces of *linking aquaculture and horticulture* to initiate a collaboration. Doing so, this concept serves as a great example of how aquaponics can link these two existing sectors. Being an inspiration for other potential collaborators the concept is believed to contribute to an increase in the enabling force *linking aquaculture and horticulture* as well as an increase in *producer interest.* Moreover, through setting up a successful collaboration providing a good example, the enabling force *positive attitude of collaboration* and the restraining force *lack of collaboration* are as well believed to be positively affected.

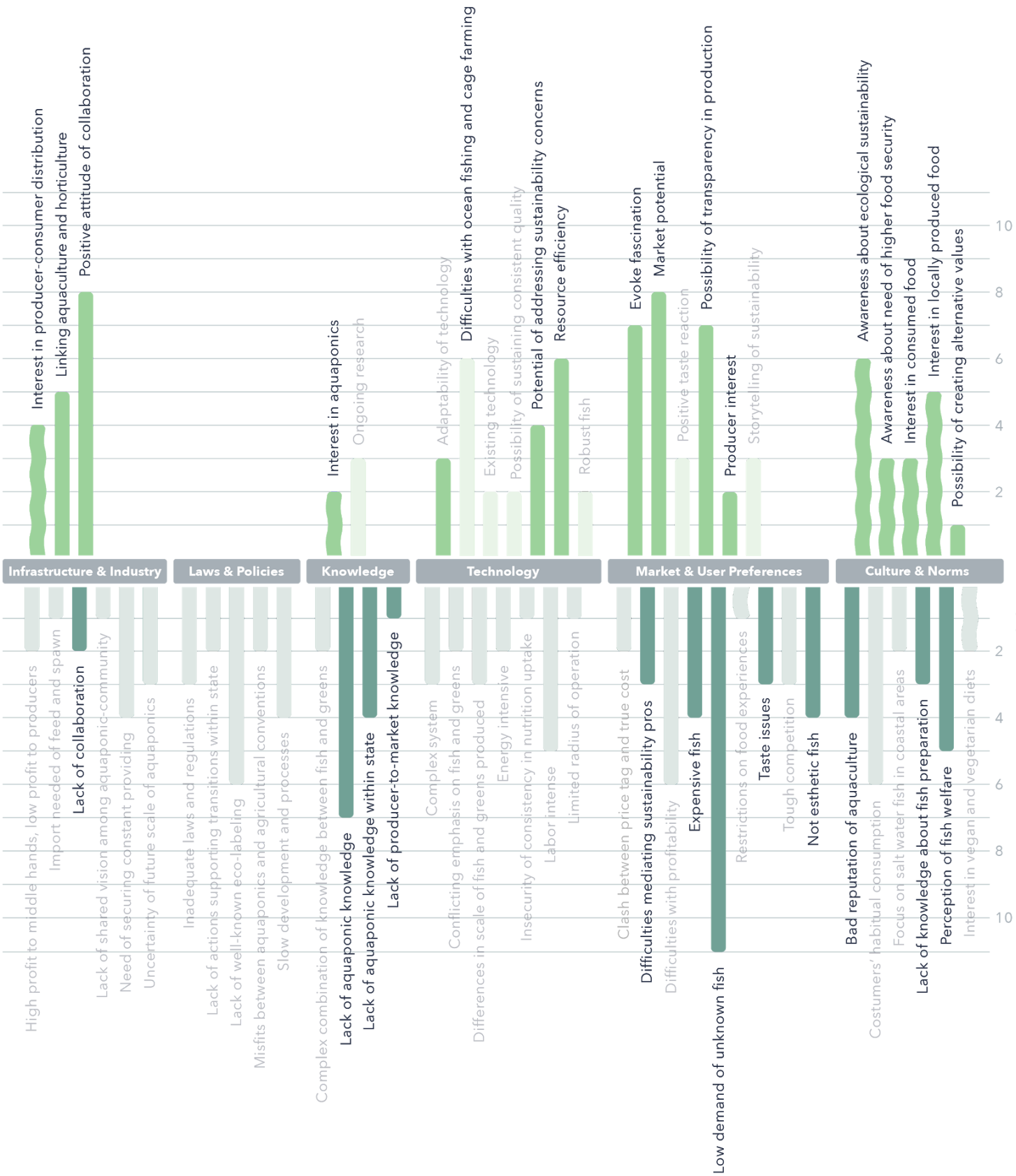


Figure 21.

Impact on identified forces for change

Moreover, setting up an aquaponic facility in collaboration with an existing actor within the horticulture sector, this concept expands the aquaponic niche to include as well the horticulture sector. Thus, the enabling forces *potential of addressing sustainability concerns* and *resource efficiency* is becoming even more relevant, as the concept provides an example of how aquaponics can increase resource efficiency and provide a solution to sustainability concerns as well within the horticulture sector. Doing so, these two enabling forces are believed to be further increased.

Further, the concept utilizes Pond's business concept of adding standard containers as facilities for fish production. Therefore, the concept is believed to further add to the *adaptability of the technology* by providing an example of how mobile standard containers can be utilized, for example, where there are issues regarding building permit applications, where the facilities are non-permanent or where there is a lack of space. Another area in which the concept is believed to add to niche development through providing a successful example is the *possibility of creating alternative values.* The concept addresses social values, for example, exemplifying how an aquaponic production can be inclusive and provide work opportunity, but as well pedagogical values, exemplifying how to combine production with spreading knowledge and awareness.

As another goal of the concept is to spread knowledge and awareness, the concept is furthermore believed to have the potential of contributing to sharing knowledge within society about topics such as aquaponics, aquaculture and fish preparation. Thus, it may have the potential of contributing to decreasing restraining forces such as *lack of aquaponic knowledge, bad reputation of aquaculture* and *lack of knowledge about fish preparation.* Further, aiming at spreading knowledge and awareness, the concept utilizes societal interests to communicate and evoke interest amongst its visitors. Enabling forces such as *interest in aquaponics, interest in producer-consumer distribution, increased interest in locally produced food, evoke fascination, increased interest about consumed food* and *increased awareness about need of higher food security* are all drawn upon. Doing so, this concept is believed to even further increase these interests among society, and thus, contributing to an increase among these enabling forces. General increased knowledge and interest among the general public altogether are believed to imply an increase in the *market potential* but as well a decrease in the restraining forces *low demand of unknown fish, expensive fish* and *unesthetic fish,* as the perceptions among the general society may be influenced.

However, the concept does not only share knowledge and awareness to the general public. Through implementing this concept, an experiment will be set up resulting in learning on topics regarding, for example, communicating aquaponics to the general public but also about distribution and marketing of aquaponic food. Serving as an experiment, this concept is believed to contribute with learnings to the niche regarding communication, for example, on how to successfully communicate the sustainability values and benefits of aquaponics and thus reducing the restraining force *difficulties mediating sustainability pros.* Moreover, it will contribute with learnings on how to balance a transparent production with knowledge, avoiding challenges with for example *perception of fish welfare.* Therefore, it will contribute to

the niche with an increased *possibility of transparency in production.* Moreover, the concept will not only provide the niche with knowledge regarding communication. Through experimenting with business strategies and distribution channels, e.g. farm-shop, pick-your-own and a café, the concept may as well provide learnings to the niche, decreasing the restraining force *lack of producer-to-market knowledge.*

Scenario of niche upscaling

As argued, if implementing an experiment such as the described concept of implementation, the forces enabling and restraining an upscale of the aquaponic niche may be affected. Aiming at exemplifying how this might come to affect the general aquaponic niche development it is interesting elaborating on a potential scenario. Further, as visualised in Figure 22., such a scenario is presented.

Figure 22.
Scenario of niche upscaling

Successfully implementing the concept of point of intervention suggested, regarding technology as well as business, the interest from other horticulture actors on setting up similar facilities grows. Eventually, several experiments where aquaculture is used in combination with horticulture is initiated. An increasing amount of experiments contribute to increasing diffusion of knowledge in society, but as well to an increase in producer interest. In time, as well current aquaculture actors and wild fisheries learn the potential of combining land-based fish production and production of greens, for example, to overcome issues with sustainability and legislation. This may lead to new initiations of experiments ranging from, for example, wild fisheries complementing their existing business with land-based production of Clarias, as exemplified in the concept *From wild fishing to aquaculture,* to land-based aquaculture farms adding greens into their production.

Moreover, the diffusing knowledge and awareness about aquaponic food may as well have an impact on research and collaborations between researchers and aquaponic food producers may be initiated, as exemplified in the concept *Research Hub.* Thus, the aquaponic niche continues developing. The aquaponic producers grow in number and in financial strength, due to increasing market potential and improved technology and business strategies, the potential for initiating networks grows. In time, several of the larger

aquaponic niche actors decided to collaborate to initiate an aquaponic network, as exemplified in the concept *Swedish aquaponic association.* The network invites aquaponic niche actors, stakeholders and actors with an interest in aquaponics, aquaculture and horticulture to collaborate. Thus, the network may come to contribute to, amongst other, improved authority dialogues as well as diffusion of knowledge and learnings amongst the niche actors themselves.

Altogether, as new actors get involved in the niche, the amount of experiments grows, the technology improves due to research collaborations, and knowledge and awareness diffuse amongst e.g. authorities, society in general and potential producers, the aquaponic niche becomes more established. In time, it may come to influence the current regime (see Section 2.1.) and its focus on producing aquatic protein through cage farming and wild fishing (Borthwick et al., 2019), by providing an alternative of production in circular aquaponic system. Moreover, it has the potential of challenging the current regime-characteristics of food import (Lantbrukarnas Riksförbund, 2020), shopping at supermarkets (Eriksson et al., 2016; Kuylenstierna et al., 2019), many middle-hands (Björklund et al, 2008) and low prices (Smith, 2010) as the aquaponic technology and the niche-actors, as exemplified in this thesis, have the potential of providing food locally and directly to the consumer while spreading awareness of, for example, the true cost of food.

6.2. Limitations & implications of method

As a means for this thesis to fulfil its aim and answer the research questions, the applied methods have been of great importance in shaping the result. Thus, discussing their impacts and limitations is crucial.

The data gathered in this thesis was qualitative and has been gathered through eleven semi-structured interviews and two focus groups. In total, 22 participants have been involved, representing ten of the twenty-one categories of stakeholders identified (see Section 5.1.1.) and visualised in Figure 9. Thus, the sample size of each category has been small as the focus was put on creating a broad understanding of factors affecting an upscale, representing the perspectives of several stakeholders involved, rather than a deep understanding representing the perspective of only one type of stakeholder. This may have had an impact on the result, as the factors identified are interpretations of the perspectives and beliefs of only one or a few representatives of each type of stakeholder. Even though the aim was a broad picture, not all stakeholders affecting an upscale have been involved. Thus, there might be forces perceived by excluded stakeholders, e.g. municipalities and horticulture actors, this thesis has not been able to identify. Even so, the data-gathering methods and its sample is believed successful in providing a general broad understanding of the forces affecting change, and thus sufficient in providing a base for the thesis to fulfil the aim and the main question '*how might an upscale of the Swedish aquaponic niche be facilitated?*'

Further, analysing the data gathered in interviews and focus groups, an affinity diagram was applied to identify forces affecting an upscale. The affinity diagram was performed by the thesis group and therefore builds on personal perspectives and assumptions. Thus, if a different group were to analyse the gathered data, it is possible for the themes and areas identified to be somewhat different. The same argumentation can be applied to the methods used to develop guidelines guiding niche upscaling, to identify areas of opportunity and to find and suggest a suitable point of intervention for Pond. However, building the results upon the data gathered in interviews, but also through including stakeholders, the result has been aligned and validated with the perspectives of the stakeholders.

Lastly, having been a thesis with a broad focus, both aiming at understanding the current system and how to potentially facilitate an upscale, a lot of methods have been applied. Doing so has been perceived as crucial to secure a wider understanding of the current niche, which acts as a base for exploring how an upscale can be facilitated. However, taking on a narrower approach, for example, simply focusing on the facilitation of an upscale through the design of experiments, additional focus could have been put on validating the concepts and suggested point of intervention with other users and stakeholders than Pond. For example, the suggested point of intervention could have been validated with horticulture producers. Currently, not having included validation, the actual feasibility of the five concepts as well as the suggested point of intervention can not fully be validated but remain to be explored by Pond. However, having based the concepts in guidelines and areas of opportunity deriving from interviews, and having validated them together with Pond, the result is argued to have a high likelihood of alignment with real contexts, users and stakeholders.

6.3. Implications

The thesis and its result may have implications to new practice as well as research. Following, potential implications are presented.

6.3.1. Merging design with a systems perspective

Building upon the acknowledged need among researchers and practitioners to combine design thinking with systems thinking (e.g. Ryan, 2014; Design Council, 2021; Conway et al., 2017) this thesis combined elements of design thinking with a systems perspective. Conway et al., (2017) highlight the importance of ensuring the dimension of a systemic understanding and the potential impact of design, to support innovations attempting to scale and impact systemic change. Similarly, this thesis was based on a broad system understanding, through mapping of stakeholders and forces, and acknowledged potential impacts of the design outcomes, for example, evaluating and reflecting upon the impact of the design concept on guidelines and forces for change.

Adopting a design thinking approach to facilitate an upscale aiming at system transitions within this thesis has been successful, both regarding design thinking as a process and as valuable characteristics of a design thinker's skills and mindset. Firstly, taking inspiration from design thinking processes (e.g. Wölbling et al., 2012) has created a good foundation for translating the system understanding of the problem into tangible innovations; e.g. guidelines, concept of a set of experiments and a suggested point of intervention. Moreover, the iterative characteristics of the design process have been important while conducting this thesis as the iterations made, e.g. when evaluating and redesigning experiments (see Section 5.3.2), have ensured that insights from all steps of the process have been incorporated and shaped the outputs. Secondly, several characteristics of design thinking skills and mindset, as presented by Owen (2006) has been proven applicable when aiming at facilitating an upscale within this thesis. For example, the *human-centred focus* and the *affinity of teamwork* are argued valuable when involving niche actors and acknowledging their interests and needs. Further, the *ability to visualise* and *ability to use language as a tool* is argued valuable when communicating guidelines as well as concepts to the niche actors involved, translating the findings of the thesis into an understanding amongst the stakeholders, who are the actual facilitators of an upscale. However arguably most beneficial is the *tolerance for ambiguity* and *systemic vision*, as taking on a systems perspective has proven to be holistic, complex and accompanied with uncertainties.

In summary, it can be concluded that this thesis has contributed with an example of how design thinking and a systems perspective can be successfully combined in the creation of concepts of innovations, with the potential of scaling up and impacting systemic change.

6.3.2. Implications for practice

The implications for practice will be discussed both regarding the implication of the process and the implication of the result of this thesis. Further, the implication is discussed according to application area; Pond, the aquaponic niche and the process of upscaling.

The thesis process and its way of applying methods and theory may foremost be used while structuring the upscale of a niche, such as the aquaponic niche. This implies that any actor aiming at the upscale of a niche may be inspired by the process. Through the thesis, the process was beneficially followed and is thus believed to have the potential of being a solid support. Summarizing the process, it consists of three phases, visualised in Figure 23. The phase system understanding is outlined by data gathering, to collect information, and data analysis, to structure the data. Secondly, navigating niche formation is outlined by a formulation of guidelines and areas of opportunity. The third phase regards the design of a set of experiments and identification of a point of intervention, with the potential of facilitating change. While it is argued that actors within any niche can take inspiration from the process as a whole, the aquaponic niche actors may foremost focus on the later parts of the process. As this thesis has provided a system understanding and guidance in navigating niche formation, other aquaponic actors can build upon this and focus on the process aiming at designing experiments and finding points of interventions.

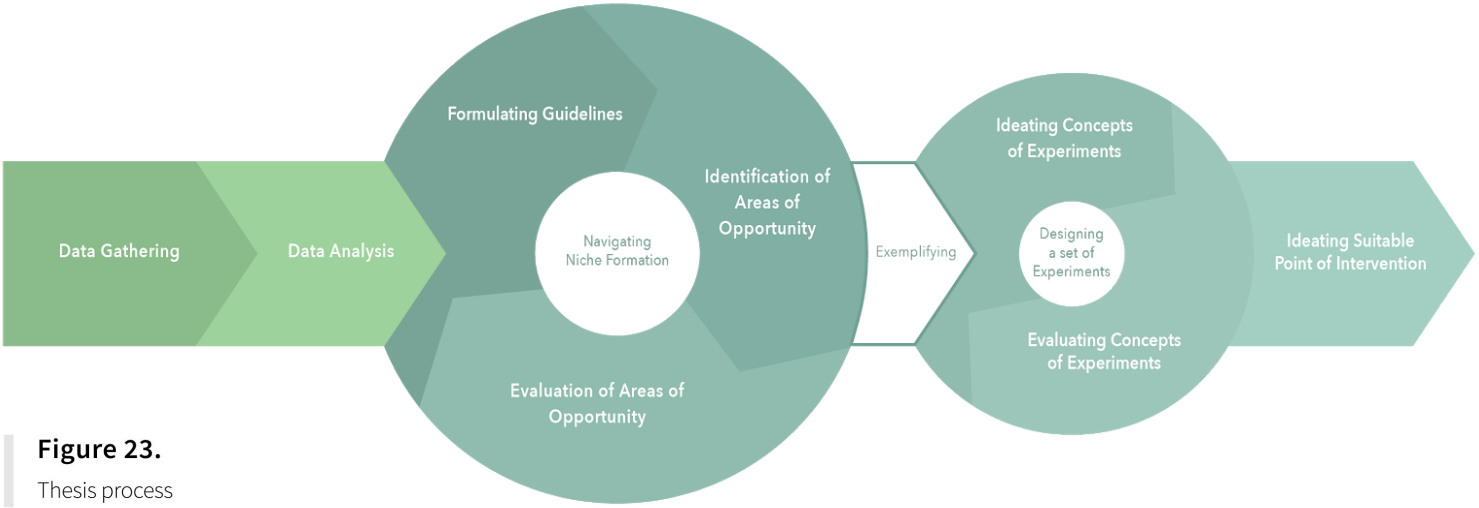


Figure 23.
Thesis process

The result of the thesis also suggests implications for practice. In particular for Pond, the designed set of experiments, the evaluation against criteria and the final suggestion of a suitable point of intervention are recommended implications for their continuous work. This result may also be used as inspiration for other niche actors. For the aquaponic niche and the different actors within, the result presenting a system understanding and navigation of niche formation may be used as a means of understanding the current system as well as a guidance for an upscale of the niche. Therefore, the result is just as important for the niche as a united movement, as it is for a single company.

6.3.3. Implications for research

This thesis was outlined by the Strategic Niche Management (SNM) and the Multi-level Perspective (MLP) as two theories aiming at understanding a system and system changes. While MLP was applied without adjustments, the application of SNM is important to discuss further. Firstly, literature demonstrated how the theory most often has been used as a research or policymaking tool (Raven, 2005). In this thesis, the models were used as a base and framework to build a strategy of how the aquaponic technology could reach a stronger niche structure aiming at challenging the current food regime. This has partly been questioned in literature as an inconvenience, e.g. due to the inability of single experiments to successfully reach a transition (Raven, 2005). The thesis took inspiration from literature that had been questioning the SNM as a transition tool (e.g. Raven, 2005; Hoogma et al., 2002), and implemented several and a variety of experiments which seems to have included more possibilities for the creation of a stronger niche. A variety of experiments have the potential of covering more and larger areas and the ability to deal with upcoming issues better than a few experiments do, which creates better opportunities for the niche to establish. Therefore, this thesis (see Section 5.2.3.), agrees with the literature (Hoogma et al., 2002), that a suitable variety of experiments are favourable while conducting a niche enforcement. Moreover, the literature (Hoogma et al., 2002; Raven, 2005) also suggests that more known cases where several experiments have been

consciously used to manage a niche development are in need. Since this thesis has attempted to propose a set of concept experiments to navigate niche upscaling, it may be seen as contributing to such a case.

Secondly, continuing on the discussion in Section 6.1.3. about the addition of two new processes while structuring the guidelines with support from the SNM theory, the thesis used the theory and extended it to serve the aim of this thesis. SNM proposes three aspects important while managing a niche transition; the network formation, learning processes and articulation of expectations and vision. For the upscaling of the aquaponic technology, the thesis suggests to add two more processes; interplay with the regime and explore business strategy. This addition seemed to be beneficial and was necessary since the guidelines included in the new, additional processes were not suitable to position in the three already existing processes in SNM. As a conclusion, the thesis suggests that the processes already included in the theory are of use while it simultaneously could be beneficial to add processes more suitable or even customized for the specific technology and niche.

6.4. Further work

This thesis has, apart from answering the research questions, as well contributed to the identification of new questions to pose. To answer these questions, further research and further work by Pond is suggested.

The process and result of this thesis suggest further research on the understanding of the system, the applicability of SNM as a tool for transition and the applied process of facilitating a niche upscale. Firstly, taking on a broad approach, this thesis presents a holistic picture of the aquaponic niche within the Swedish food system. Although perceived as beneficial, further research is suggested on a larger scale to fully understand the system, e.g. including more types of stakeholders and larger sample size to provide new perspectives. Moreover, the dynamics and interrelatedness of the identified forces and their relative strength, hindering or enabling an upscale, is suggested to further be researched aiming at deeper understanding. Secondly, this thesis utilizes SNM as a strategic approach, as discussed in Section 6.3.3. Utilizing SNM as a tool for transition is believed to be interesting to further explore since it may help future radical innovations turn into technology niches and finally market niches. Therefore, further research on SNM as a strategy approach is suggested, e.g. to understand its relevance, reliability, and areas of application. Lastly, this thesis has through its process suggested a way of working when facilitating niche upscaling that potentially could be developed and generalized, as discussed in Section 6.3.2. To do so, the process as such needs further developments and iterations to validate its applicability in relation to other niche actors as well as other niches aiming at upscaling.

Moreover, this thesis has contributed to the identification of a concept of a suggested point of intervention for Pond, however a concept far from finalized. Serving as a point of intervention, there is now a need of identifying the specific actors involved, e.g. a horticulture farmer and investors, and initiating collaborations. During this thesis, the focus has been put on addressing the guidelines of how to facilitate a niche upscaling and the interests of Pond. Thus, it is suggested that Pond, as a next step, acknowledges the interests and needs of all actors addressed and involves them in the process of designing the experiments, as suggested in Figure 24.

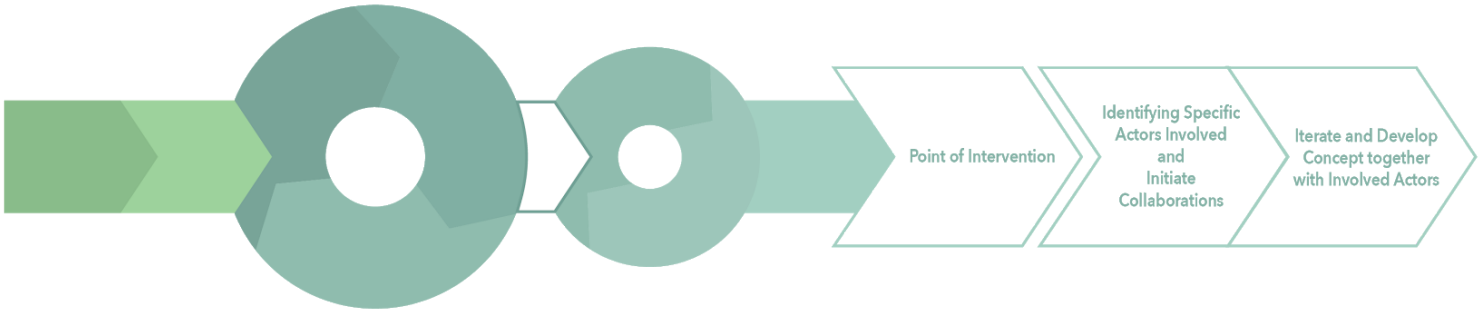


Figure 24.
Suggested continuation of process

7. Conclusion

Acknowledging that the current food system requires changes to become a sustainable food system, this thesis provides an understanding of how an upscale of the aquaponic niche can be facilitated to initiate change within the Swedish food regime. Aiming at guiding actors to facilitate such an upscale, the thesis provides an understanding of the current aquaponic niche, gained through qualitative data gathering and analysis of the perspectives of multiple stakeholders. Based on this understanding, tools to guide the niche in navigating the niche formation and a way forward for an individual niche actor are suggested. Through the process of this thesis insights and findings were provided, useful to build upon and draw from for the aquaponic niche and its actors as well as researchers and other niches. Further, the main findings are concluded:

- Mapping the stakeholders (RQ1) and the forces affecting the possibilities of an upscale (RQ2), a broad understanding of the current aquaponic niche within the Swedish food system was provided. Analysing the stakeholders, 21 stakeholders categories were found currently affecting an upscale of the niche. Moreover, sixty forces were found, either enabling or restraining an upscale.
- Facilitating an upscale, this thesis highlights the importance of creating several experiments and suggests the involvement of multiple actors. Generally guiding the niche towards an upscale (RQ3), 12 guidelines were identified with the potential of navigating niche formation. Five areas of opportunity, deriving from interviews, were concluded and suggested as contexts for actors to apply guidelines and create experiments.
- For Pond, exemplifying a niche actor, five concepts were created, forming a set of experiments (RQ4). Among the concepts, a combination of two was identified as a suitable point of intervention, suggesting a collaboration between Pond and a horticulture actor. This result provides a first step for Pond to facilitate niche upscaling.
- The process through which this thesis was conducted is on its own believed to be an important finding. Through combining design thinking with a systems approach, the process suggests a way of working within a niche to facilitate upscaling through the design of experiments. Although suggested to be further developed and validated, the process has been experienced as successful for this thesis.
- Applying Strategic Niche Management (SNM) as a tool for transition has resulted in insights related to such an application. Although proven successful, two additional processes were added in this thesis; *interplay with the regime* and *exploring business strategies*. Thus, the findings imply that it might be beneficial to extend the theory by including processes for the upscale of aquaponics.

Concluding, we hope that this thesis will contribute with insights, inspiration and new perspectives, deriving from results as well as the process. Doing so, we hope to guide many actors, interested in aquaponic technology as well as upscaling in general, to together aim at facilitating sustainable change.

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Appendix A - General Interviews

<table>
<tr><td colspan="2">Present ourselves
Explain that we wish to use the result in our report - ok? It will be anonymous!
Is it okay to record the interview to use as base for our analysis - only we will have access to it!
The interview will last about an hour.
We are objective and want honest answers. Our goal is to investigate and understand, therefore all type of information is relevant for us.
You can whenever you like interrupt the interview. Of course it is fine if you do not like to answer a question - just let us know.</td></tr>
<tr><td>Warm up
1. Who are you?
Tell us a little bit about your company. What are your visions?</td><td>Introduction
Insight about the interviewee</td></tr>
<tr><td>The food system
In our thesis we look at transition to a more sustainable food system, and we include the whole food chain: from producer to consumer.

We work with a framework describing the system out of six perspectives; infrastructure & industry, policies & laws, knowledge & science, technology, market & user preferences, and culture & norms. This we can use as inspiration.

2. What do you think is important to think of when you introduce new solutions which try to challenge and create change?</td><td>Barriers for niches
Out of their point of vision
Open question</td></tr>
<tr><td>Aquaponics
In our thesis we have chosen to specifically focus on the aquaponics possibilities to scale up and complement and challenge the food production like it looks today.

3. Do you have any thoughts about the potential role of aquaponics in the commercial food system?
Why? Why not? Upscaling possible? What does it take?

4. Do you think aquaponics can challenge the way we produce food today?
Why? Why not?

5. Do you see any forces or factors in society you believe can help aquaponics to be more established and grow?
Waves to ride? Movements in society?

6. What do you believe restrains aquaponic to get established and grow?
Bottle necks? Resistance? Barriers?

7. Aquaponics or circular RAS-farming, what are the advantages with aquaponics?</td><td>Understand possibilities
Open question</td></tr>
</table>

Do you think it is a disadvantage to not grow greens in direct contact? Maybe not all technical, but from a consumer perspective, societal perspective or similar?

We have met some different thoughts during the project we thought we could get your opinions on?

8. What do you think about large-scale and small-scale facilities respectively?
   Do you see any barriers or opportunities to use which are connected to the size of a farm?

9. What does the current collaboration look like in the aquaponic-sphere? Between aquaponics-aquaculture-horticulture?
   Is more collaboration something valuable?

10. City-, urban- or rural farms?
    Differences? Similarities? Better/worse?

11. Is there value in local production?
    Are there any values following that? What values do you see among consumers?

12. Do you have any thoughts on sales-channels? Direct-sales to customers? To restaurants?

13. (Do you value mobility or modularity?)
    Are there any wins in modular/mobile systems when it comes to new innovations?

Open questions

14. Do you have any thoughts on which actors are important to interview?

Tip
Open questions

Closure

Thank you for participating - it is very valuable with your inputs for us!
Eventually we will make more interviews longer in the project, for example to get input on developed solutions and concepts. Would you mind being contacted for such an interview?
Please get in touch if you have more questions or comments!

Appendix B - Focus groups

Introduction *Hi,* *How nice that you want to participate in this focus group!* *First of all we would like to say that everything you comment is of use for us! There is no right and wrong, relevant or irrelevant you could say. We have not chosen any side yet.* ● *We will ask some questions you can talk about and we believe it will take about 45 minutes, depending on your discussion.* ● *One of us will be the moderator and the other one will probably ask some questions or make some comments.* ● *If there is anything you do not like to answer, you may pass, and you can whenever you like leave the meeting. Since this is held on Zoom it may be difficult to say something sometimes, so we will maybe give the word to someone if it is necessary.* ● *In the report and thesis you will all be anonymous, but is it fine to use the result there?* ● *For us to be able to participate as much as possible we wonder if it is okay for you that we record this interview so we can go back and listen again? Everything will be erased afterwards.* ● *We will not tell you so much about what we are doing and the pros and cons, but we are happy to do so afterwards if you like. We prefer your first spontaneous reactions. Therefore we will not answer any questions in the beginning - but please ask questions and we will answer them later in the conversation!*	*Picture 1*
Warm up *We thought we could start with a round where everyone can tell us shortly about themselves and a fish or vegetable dish you find really tasty.*	
Questions 1. When you buy fish and greens - what factors are important for you while purchasing the food? What channels do you often buy from? Why?	*Picture 2 - what affects what kind of food you buy?*
2. *In our thesis we work with a special way of producing food called aquaponics.* Is there anyone who knows about aquaponic farming? *We tell about aquaponics: show illustration of the circularity? A circular system where everything is included.* *Mention the fish - fresh-water.* 3. What is your first reaction to this? Is food produced like this something you would like to buy? What factors could be enabling or restraining for you to buy this food?	*Picture 3 The circularity*
4. *Show images of the fish farm. The fish, the environment, the technology, the greens etc.* This is what an aquaponic farm looks like. What do you think about this? Positive reaction? Negative reactions?	*Picture 4 Aquaponic farm* *The greens*

- If we now ask the same question as before, what is the possibility that you now would buy the aquaponic farmed fish and greens? Is it different now when you have seen it from the inside, or just heard about it?	*The fish*
5. *We are specifically working with a concept called Fish in a Box where it is suggested to farm an african fish called Clarias small-scaled and locally. (Show picture of container and the fish).* - What do you think when you see this? What does it take for you to buy it? What might restrain you to buy this? - Do you think you would think differently depending on where you were offered to buy the fish? Directly from the producer, at the supermarket or at a restaurant for example? Why? What would it take for you to buy it directly from the producer? - Would your will in buying the produced food change if there was only fish, and the green production was placed elsewhere? How important is the green production's closeness? Why?	*Picture 5* *Fish in a box*
Pause for questions from participants *Do you have any questions so far?*	
6. What do you think about aquaponics now that we have talked about it for a while? If you would come in contact with it in the future - how do you think you would react and act?	
Show the sustainability if they wish *Show how sustainable it is. The circularity. Maybe tell more.*	*Picture 6*
Thank you! *Now we feel very happy. Is there anyone who would like to add something extra or has a question?* *We want to thank you a lot!*	*Picture 7*

Appendix C - Evaluation workshop

CONCEPTS	Guidelines addressed	Environmental sustainability and circularity	Ease of implementation	Shown interest	Economic sustainability	Potential for Pond to contribute	Social sustainability		Sum
Neighbourhood center	2.1	3 biokol, no waste	2 lite svår	3	2 3	3	3		2,6
Research hub	1.7	3	2	1,5	2 3	3	2		2,3
From wild fishing to aquaculture	2.3	3	2	3	3 3	3	1,5		2,6
From hydroponics to aquaponics	2.0	3	3	2,5	3 3	3	1,5		2,6
Swedish Aquaponic Association	1.9	3	2	2,5	1 2	2	1		1,9

viktig
samhällsekonomiskt
pedagogik
merga med neig.
starka näringar som är inkluderade redan
få men stora
men önskan att skapa

3: High fulfillment 2: Some fulfillment 1: Low fulfillment

The criterias

1. The numbers in the criteria of ***Guidelines addressed*** were recovered as calculated means from the former evaluation of areas of opportunity.
2. ***Environmental sustainability and circularity*** was added since it is one of the aquaponic technology's strengths and reasons for existence, which makes it very important. The concepts were given numbers as of their potential of fulfilling the criteria of being environmentally sustainable and circular in the future.
3. The criteria of ***Ease of implementation*** was especially important. The concepts were assigned numbers of how easy the container solution could be implemented in each possible context. Since the workshop concluded that this criteria was most important when finding the low hanging fruits, it was assigned to be counted twice in the summary.
4. Closely related to ease of implementation is the criteria ***Shown interest from actors***, which aims at describing from which areas actors had already been showing interest in the solutions from Pond, making the search for collaborators or customers shorter.
5. *Economic sustainability* was changed to ***profitability*** since it better explains the contain of the criteria. It focuses on the belief in how well the experiment would be profitable if set up.
6. When finding the lowest hanging fruit for a specific company, the ***Potential for Pond to contribute*** was essential. The concepts were evaluated upon the probability of how well Pond and the associated solutions could contribute to a successful experiment.
7. *Societal economic sustainability* was changed to ***Socio-economic contribution*** to better fit the purpose. It was added during the workshop and found necessary as a complement to profitability. This criteria was aimed at justifying how beneficially each experiment would contribute to a sustainable economy for the surrounding society. That could e.g. be either by creating work opportunities as well as drawing new attention to the site.
8. Finally, the criteria of ***Social sustainability*** was added to demonstrate how each concept would contribute to a better societal experience and social inclusion. E.g. educating people, building thriving life and sustaining welfare were included in this criteria.

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