Centre for Transdisciplinary Environmental Research
STOCKHOLM UNIVERSITY

Aquaculture in Sweden
towards a sustainable future?

Alexandra Berggren

**Natural Resource Management, Governance and Globalisation
Master's Thesis 2007:3**

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Natural Resource Management, Governance and Globalisation

a transdisciplinary programme held by the Centre for Transdisciplinary Environmental Research, CTM, at Stockholm University. The one-year programme consists of four courses and the writing of a Master's thesis on a subject related to at least one of the courses.

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Abstract

The thesis is about aquaculture as an alternative seafood source in Sweden. The problem is that the aquaculture is not ecologically, socially and economically sustainable. The aim was therefore to find out what the possibilities and barriers are for moving towards a more sustainable aquaculture by analysing the social and ecological system of aquaculture and five case studies (project and companies that focus on more sustainable aquaculture). The thesis examines three main questions that are: which factors affected the success and failures of the case studies, if the aquaculture system is in a desired or undesired state and if the state is resilient. The study is trans-disciplinary; using the framework of resilience and governance theory. The methods used were semi-structured interviews with stakeholders at different organisational and spatial levels, visits to two of the case studies and literature research. The analysis show that the most important factors that influenced the case studies were financial resources (EU-funding and investments), market knowledge and access, entrepreneurship, engagement, knowledge and practice, slow EU-funding process and difficulties in being eco-labelled. The state is undesired and not resilient and can transform to a desired state through building knowledge, create a common vision and goal with the help from social networks and using a policy-driven window of opportunity. Barriers for moving towards a more sustainable aquaculture are different opinions about the environmental impact from aquaculture, disputes about who has the responsibility for the development of the Swedish aquaculture and which direction it should go, farming being a local history, low accountability on the roles of the stakeholders, lack of strong non-governmental organisations and aquaculture having low priority. One way to manage these issues is through deliberation in stakeholder forums and social networks, where negotiation and debate can take place. Deliberation can also be a tool for a better implementation of aquaculture policies.

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List of abbrevations

EFF: European Fisheries Fund

FFPA: Fish Food Producers Association

FH: Fish Health AB

FIFG: Financial Instrument for Fisheries Guidance

ICSM: Integrated Coastal Zone Management

KRAV: eco-label and economical association that work for ecological farming, animal care and production

MA: Ministry of Agriculture

NFA: National Food Administration

NGO: Non-Governmental Organisation

NOAF: National Organisation of Aquaculture Farmers

NSP: National Strategic Plan for the fisheries sector

NVI: National Veterinary Institute

OP: Operative Programme

SBA: Swedish Board of Agriculture

SBF: Swedish Board of Fisheries

SEPA: Swedish Environmental Protection Agency

SES: Social-Ecological System

SF: Swedish Fish

SUAS: Swedish University of Agricultural Science

1. Introduction

1.1 Problem statement

1.1.1 Overfishing

In May year 2003 an article came out where scientists showed that overfishing leads to depletion of the marine species. 90% of large predatory fishes in the global ocean have disappeared (Myers and Worm 2003) and this may have serious top-down effects on the trophic levels in the ecosystem (Pauly et al. 1998).
The world population is increasing and are prospected to reach 9.2 billion in year 2050 (UN 2007). Together with increasing urbanization and rising per capita incomes, the world consumption of fish has tripled between year 1961 and 2001, from 28 to 96.3 million ton (FAO 2004).
Seafood (e.g. fish, molluscs, crustaceans and algae) is a major food source for the world population and will probably still be that in the future. This sets an increasing demand of the marine resources. Food consumption is increasing and people need to eat seafood due to the important nutrients (polyunsaturated fats, vitamins and minerals) that it contain (SLV 2007).

1.1.2. Aquaculture – the alternative to overfishing?

Aquaculture provides 50 % of the world fish production (FAO 2006), is an alternative seafood source to wild fisheries and generate income and employments. Aquaculture is a controlled and artificial system that is depending on the provision of ecosystem services from natural systems (such as fodder from wild fish, seed, land and water resources) and can therefore (often negatively) impact freshwater and marine ecosystems and the societies that depend on the aquaculture and contribute to the overfishing of the seas. It depends on which factors you look at (fig 1).

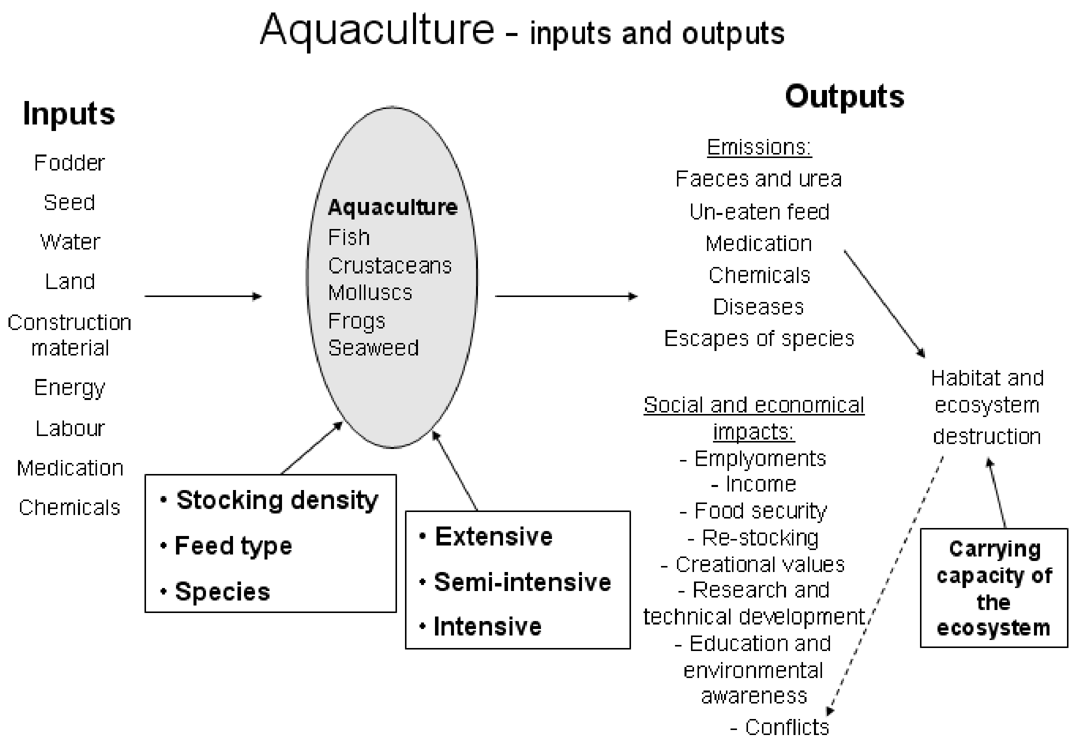

Fig 1. Aquaculture - inputs and outputs. The sustainability of aquaculture is decided by how the inputs (for ex. kind of species, type of fodder, density of the species, production type) generate outputs (emissions and social and economical impacts). The emissions impact the surrounding ecosystem depending on the carrying capacity of the (water) ecosystem (for ex. water circulation, the size and depth of the water course, level of nutrients in the water) and the receptivity of the species in the ecosystem. The social and economical impacts can be both positive in form of income but also negative in form of conflicts between different stakeholders.

In Sweden the environmental impacts (such as emissions of nutrients) from aquaculture have decreased, but is still a problem and the production is still mainly focused at carnivore fish farms (that uses wild fish as fodder). There are also conflicts between the farmers and the different interests that want to use the water resources.

1.1.3. Sustainable aquaculture

To develop a management and governance of the aquaculture in Sweden that is not filled with conflicts or environmental concerns, a framework of ecological, social and economical sustainable aquaculture should be used (Berg et al. 1996).

To be more ecological sustainable several steps are important to consider. The main areas are: more farming of species that are dependent on herbivorous feed, reduction of fish meal and fish oil in feed, integrated farming systems, reduced resource use (for ex. seed from own breeding fish and not from wild fish), avoidance of chemicals and medicals, recycling of nutrients (Folke and Kautsky 1992) and treatment and recirculation of the waste water (Naylor et al. 2000). This also incorporates regulations of the location of farms, minimize escapes of fish, make import of stock more safe to disease transmittance, funding for development of technique and secure the freshwater resources.

But it is also important with a management and governance of the aquaculture that makes the aquaculture socially and economically sustainable. Socially sustainable aquaculture is management that do not raise conflicts between resource users and that supports fair and equality between gender and different groups in the society. Economically sustainable aquaculture is a management where the aquaculture is financially viable and provides employments and income.

A sustainable aquaculture also incorporates other different conditions (Frankic and Hershner 2003) such as: a sustainability (or continuity) of supply and a continuity of quality of the inputs to the system, a consideration of the social, environmental and economic costs of providing the inputs (e.g., depletion of resources elsewhere), a long-term continuity (or sustainability) of production and the efficiency of conversion of resources into an useful product.

To prosper a more sustainable aquaculture the EU supports farming that is doing innovative measures and pilot projects that contributes to a more sustainable aquaculture (definition decided by the Swedish Board of Fisheries (SBF) (FV 2007) and the EU Commission directives (EC 2005)).

1.2 Aim

The aim of the thesis is to find out the possibilities and the barriers to evolve and develop a more sustainable aquaculture in Sweden.

To reach the aim two theoretical frameworks are being used in this study to analyse the aquaculture in Sweden; resilience and governance theory.
The resilience framework describes our world as different social-ecological systems (SES) and therefore the study is going to treat Sweden as a SES that is constituted of five case studies, the ecological services and goods that the Swedish aquaculture is depended on, the different stakeholders that are involved in management of the country's aquaculture and the governance structures that are existing in the system.
The resilience theory also describes the systems to be in desired or undesired states (providing or not providing the humans with wanted services and goods). The system can be resilient to changes; maintain the same function in times of stress and disturbances.
The governance theory will be used for analysing the social interactions, governance structures, mechanisms and processes that show how the actors in Sweden manage aquaculture and the ecosystem services and goods that supports and are affected by aquaculture.

So with other words the thesis explores the different economical, ecological and social factors that affect aquaculture in Sweden, to find out what possibilities and barriers to practice a more sustainable aquaculture are, in order to understand whether more sustainable aquaculture is a possible alternative to present aquaculture in Sweden.

The study focuses on different case studies (projects and companies) that are doing innovative measures such as developing techniques and farming species with the aim to minimize their environmental impact and developing their local community. These are described in chapter four. The case studies are representing a part of the local stakeholders in Sweden.

1.3 Research questions

The case studies that focus at more sustainable aquaculture in Sweden; what are the common /different factors that have helped them to succeed or preventing them from succeeding? Are there trade-offs and synergies between ecological, economical and social factors?

Is the aquaculture in Sweden in a desired or undesired state?
Is the state of the aquaculture resilient to changes, disturbances and stress?

1.4 Contribution

This study is contributing with a resilience framework and governance theory analysis of the aquaculture in Sweden. Usually resilience analysis is made on natural ecological systems (Folke 2006), but here it is done with a focus on aquaculture as a controlled and synthetic system. But the controlled system is still depending on the provision of services and goods from natural ecosystems and those are important to bring into the analysis.

The analysis will increase the knowledge about the social interactions between different stakeholders of aquaculture in Sweden and how this affects the possibilities for the enhancement of the sustainability of the aquaculture.

The study also has an aim of increasing the present knowledge about which possibilities and challenges there are in Sweden to reach a management and governance of a more sustainable aquaculture and give suggestions and directives on how the management and governance can be improved.

1.5 Background

1.5.1 The present situation of aquaculture in Sweden

Sweden has different aquaculture productions. The species that are farmed are rainbow trout (the mostly produced), char, eel, salmon, salmon trout, sea mussel and crayfish. The production of aquaculture in Sweden in year 2005 was 7320 ton; 4783 ton food fish, 1462 ton fish for stocking, 1069 ton mussels and 6 ton crayfish (SCB 2006). The total value of the aquaculture was 239 million SEK year 2005.
The aims of the farming are food production for direct consumption or processing, and fish for stocking that are used for other food fish farms or for output in Swedish waters for reconstructing aims or sport fishing activities.

Aquaculture in Sweden is an important source for income for people that live in rural areas, sparsely-populated areas and in the archipelago (JD 2000). In year 2005 there was 501 employees in the aquaculture industry (SCB 2006). Most of the Swedish production are owned by Åland companies, processed on Åland and exported to Finland (JD 2006), but also to Japan or are being sold to smoke houses. The rest goes to the local Swedish market, restaurants and supermarkets (JD 2000).

The development of the Swedish aquaculture is modest and rainbow trout farming has been on around 4000-5000 ton each year the latest ten years (fig 2). The production remains constant despite the fact that the food fish farms have decreased to half of how many they were twenty years ago (from around 300 to less then 150 farms) (fig 3). The sustained production depends mainly on a concentration of a few big companies that have productive and large-scale farms (JD 2006).

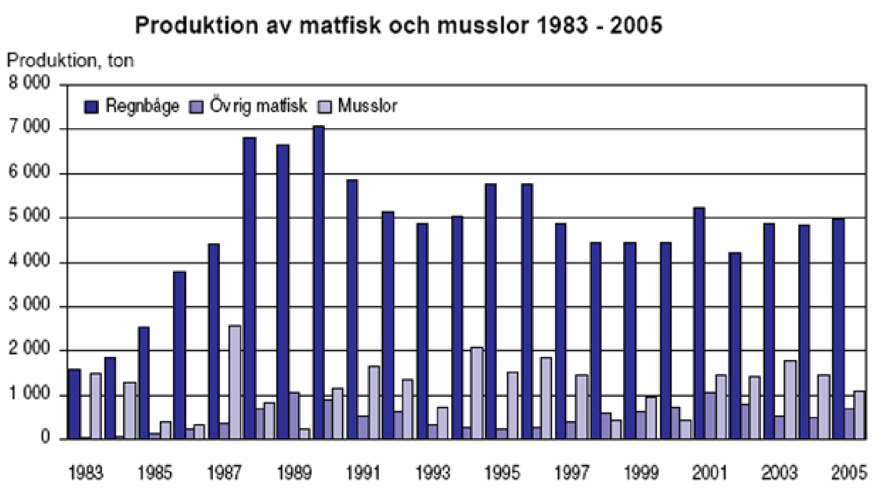

Fig. 2. Production in tones of food fish year 1983-2005. Rainbow trout ("regnbåge"), other food fish ("övrig matfisk") and mussels ("musslor"). (SCB, 2006)

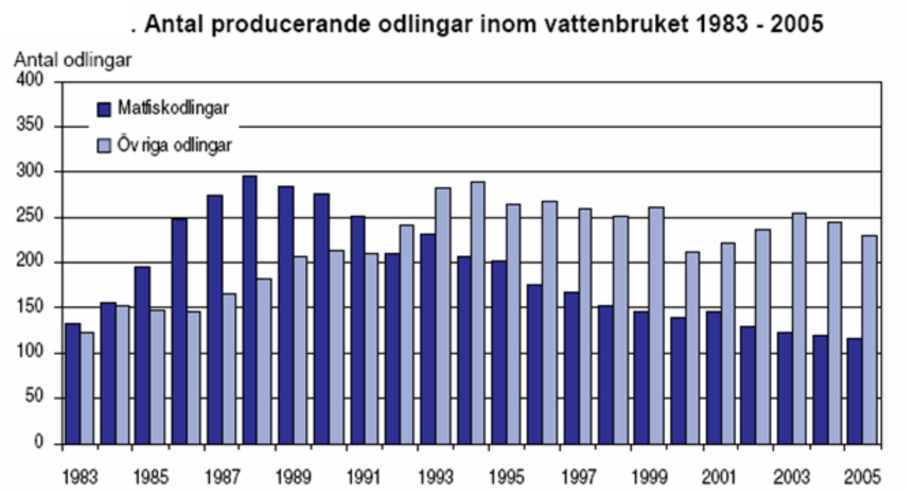

Fig. 3. Amount of productive aquaculture farms year 1983-2005. Food fish farms ("matfiskodlingar") have decreased since year 1988 and other farms ("övriga odlingar") have in general increased since the eighties (where farms with production of fish for stocking and mussel farms are the types that have increased the most the last five years). (SCB, 2006)

Food fish farming of salmon and salmon trout has disappeared (JD 2006). The farming of char has increased until year 2002 when it due to a suddenly warmer climate dropped to a production of the half amount. The industry is mainly in fresh water. The production of rainbow trout is concentrated to north of Sweden, Värmland and Dalsland, char mainly in north of Sweden, mussels on the west coast, crustaceans in the southern parts of Sweden and eel (that need high water temperatures) only in Skåne and Blekinge.

The companies that farm fish for output in freshwater have increased due to a stabile economical situation for those (JD 2006). Many companies have changed their production to this activity or combined it with their food fish production. The food fish companies that slaughtered their fish for freezing in the winter, are not left due to concurrency from Norwegian salmon production. Smaller productions (50 ton per year) have survived due to processing the products and selling these by themselves.

The mussel farming is done as an additional activity to other production. On the west coast of Sweden mussel farming are becoming a larger industry; now 600-800 ton / year (KMF 2006), estimates tells that it is going to be 50 000 ton / year and employ around hundred people in the future (Johansson 2007). The mussel farm can improve water quality and decrease eutrophication by uptake of nutrients (1000 ton mussels absorb 650 ton phosphorous and 10 ton nitrogen) (KMF 2006), provide seafood, fodder to poultry and pig and be used as agricultural fertilizer (Lindahl et al. 2005). The problem of periodical bio-toxins in mussels can be managed by management plans and new techniques.

The profitability is not enough to be depended only on mussel farming, mainly due to a too small market in Sweden, so the mussels are exported to Europe (JD 2006).

Through the years there have been conflicts between different stakeholders concerning water usage and aquaculture farms. The different interests are those who want to maintain the natural values in the area, land owners and recreational interests that do not want any disturbances from the farm (like bad smell or bad water quality), fisheries, industries, water cleaning plants and seafaring (Alanärä and Andersson 2000). The debates and conflicts are still flourishing and the intensive water based net pen aquaculture is controversial (Härdmark 2007).

According the Ministry of Agriculture (MA) Sweden has good natural conditions, a good local market, high technical knowledge, good fish health and has lowered their environmental impact (JD 2005). If the consumers demand more farmed fish, then the aquaculture has possibilities to develop niche products (which give higher prices). The aquaculture support to fishing tourism and sport fishing is also a possibility for a stabile and increasing market.

The MA also states that the barriers and weaknesses that Sweden has are cold and harsh climate (ice and hard winds make difficulties with net pen farming and too cold temperatures decreases the growth rate of the fish), high employment costs and a lack of private capital. This makes it difficult to meet the pressure from low-salary and neighboring countries. The writing also acknowledges that the strongest factors that have slowed the development of aquaculture in Sweden are the effluents of nutrients (that limits licensing of bigger productions) and low profitability.

1.5.2 Different scales and types of aquaculture

Aquaculture may be extensive, semi-intensive or intensive (Naylor et al. 2000). All forms base on keeping the fish in capture in dams, net pens (nets that are formed as big bags), ponds, containers or mussels and algae on ropes. In extensive aquaculture you exclude predators and competitors, in semi-extensive you enhance food supply, and in intensive you add nutrients and provide the best conditions for getting a maximum growth rate of the fish. The intensive aquaculture often mean intensification of animal density, inputs, wastes and risk for spread of diseases.

1.5.3 Aquaculture and fish fodder

Aquaculture may be a good alternative to reduce the pressure on wild fish stocks, but this is only valid if you farm herbivores (carp) or filter feeders (as molluscs, feeding on plankton or algae). The farming of carnivorous fish needs feed containing wild fish (which are for example herring, sand eel, mackerel and sardine (FV 2007), because fish protein and fish oil contains vital amino acids, fatty acids and energy (Naylor et al. 2000). This sets a pressure on wild fish stocks (Deutsh et al. 2007) and minimise the food supply of small pelagic fish for people and for marine predators that depends on these (Naylor et al. 2000).

Fish meal is also given to poultry and ruminants where a couple of hundred grams wild fish is needed to grow one kg of poultry or ruminants. But to grow one kg of marine finfish you need approximately 3.84 kg wild fish (Kautsky 2007).
This is not to confuse with feed conversion ratio, the amount of dry fodder the fish can convert to body mass, that in 1995 was approx. 1.1 in Sweden (1.1 kg dry fodder to grow 1 kg carnivore fish) (Jonsson and Alanärä 2000).

1.5.4 Alternative fodder to carnivore fish

Alternative to fish meal (protein) and fish oil in carnivore fish fodder can be "soy beans, corn, rapeseed, sunflower seeds, flaxseeds and wheat gluten" (Powell 2003) or krill and amphipods (small crustaceans) (Suontama et al. 2007).
The alternative fodder has to fit the demands of nutrients of different species, the digestibility of the fish of the nutrients (Watanabe 2002) and ingredient palatability (Glencross et al. 2007). The fodder of the perfect proportions and totally vegetable is right now very expensive (Powell 2003). Development of fodder is done by three big fish-feed companies in Norway (BioMar, Skretting and Ewos) that are doing research to reach an aim of replace fifty percent of the fish meal in feeds with alternative proteins to year 2010.

1.5.5 Aquaculture and emissions

The possible environmental effects of effluents (uneaten feed, feces, urea, medication, chemicals and diseases) from aquaculture are highly dependent on the carrying capacity of the water ecosystem (the amount of nutrients a water can manage without changing its state; water circulation, the size and depth of the river/lake/coast where the farms are situated, level of nutrients in the water) and on stocking density, feed type and which species are farmed (Wu 1995, Nordvarg and Johansson 2002, FAO 2006). In fish farms and shrimp aquaculture it is also important to consider the density of the cultured species and the water quality. To high quantities on a small area with bad circulation of the water can cause severe outbreaks of diseases and pollution problems (Funge-Smith and Briggs 1998).

Research on the environmental effects of Swedish fish farms has been reviewed in a report by the SBF (FV 2005) It shows that the emissions of phosphorus and nitrogen have decreased, from levels of 30 respectively 130 kg /ton produced fish around year 1975, to levels on 5.5 respectively 55 in year 2005. The decrease depends mainly on the increase in energy contents in the fodder, which reduce the amounts of fodder and with that a decrease in emissions of nitrogen and phosphorus (Jonsson and Alanärä 2000), effective use due to high fodder costs, but also on a decreasing amount of farming (FV 2005).

In year 2005 the total emissions of phosphorus and nitrogen from aquaculture was 40 respectively 350 ton (where 80% was released to fresh water and 20 % to marine waters) (FV 2005). In relation to the water effluents from humans year 2000; 3200 ton phosphorus and 60 100 ton nitrogen, the report states that the role of fish farms on eutrophication of waters are small. But if you apply the levels of nutrients (kg/ton produced fish) mentioned in the section above on a farm with a fish production of 100 ton per year it is the same as untreated human waste water from 1000 persons; 500 kg phosphorus and 5.5 ton nitrogen.
This means that the emissions from Swedish aquaculture have decreased but still exist and impact the marine ecosystem.

The impacts from aquaculture emissions are often seen in the local environment directly connected to the farms. Studies in the Baltic have shown that emissions from fish farms effect the environment around the fish farms in form of increased growth of algae, (Rönnberg et al. 1992), periphytic growth (Nordvarg and Johansson 2002) and increases in biomass and sediment (Lehtinen et al. 1998) which can lead to anoxic conditions, decrease of diversity in benthic communities and gas formation of methane and hydrogen sulphide (Ervik et al. 1997). In some areas in the Baltic this effect can become smaller if there is a greater water circulation and exchange. But the emissions still contribute with nutrients and bio mass to the Baltic Sea and to a certain extent to the present eutrophication of the sea.

There are waters in Sweden that can be appropriate for aquaculture, for example oligotrophic waters (that have low levels of nutrients and low biodiversity) like water plant reservoirs and lakes. These can be prospered by an increase in biodiversity (of for example different fish species) due to an increase in nutrients from emissions from fish farms (Wahlström 2000) and there is a wish for more studies on the effect of increased nutrient levels in medium productive lakes in Sweden that can be appropriate for aquaculture.
But an establishment of aquaculture should be done with consideration of the already existing, and sometimes rare, species in certain water ecosystems that do not exist in other types of waters.

Development of resistant bacteria in the sediment beneath cages may occur during use of antibiotics to treat farmed fish (Kerry et al. 1996). But in Sweden the levels of diseases and unsuitable fish species (that can cause problem bringing different diseases) have decreased the latest ten years (FV 2005) and the use of antibiotics has decreased from 40 gram /ton farmed fish year 1995 to 1-2 gram / ton farmed fish year 2003. This depends on a restrictive import of fish, no preventive use of antibiotics and preventive measures as for example control programs (FH 2007).

Escaped fish from farms can have large ecological impacts (Naylor et al 2001). Depending on the time of the escape, water status, size and age of the escaped fish and survival capacity of the escaped fish, domesticated farmed fish have genetic traits that can be inherited by wild fish, and make the wild fish less adaptable to natural ecosystems (FV 2002).

1.5.6 Aquaculture and breeding material

The use of wild-caught seed in aquaculture to stock farms can have impacts on wild fisheries. Large amounts of by-catches when collecting seeds can lead to depletions of important fisheries in the areas (Naylor et al. 2000).
In Sweden the seed for the farmed fish comes from both own breeding fishes and from roe that is taken from wild fishes (Wichardt 2007). The mostly produced species rainbow trout is only bred from own fishes at the farm (which have in some cases led to inbreeding and associated problems if it is not controlled). Herring and char is bred from own fishes and from wild fish. Salmon (for output in natural waters) and pike-perch is bred from wild fish. Eel (for food fish and output) is farmed from wild species (because there is no hatching technique available) and eel is a species that is now becoming extinct due a decreased amount of breeding and survival in the seas (restrictions are now done in Sweden) (FV 2007).

1.5.7 Integrated aquaculture

Integrated aquaculture can increase ecological and economical sustainability by an increased profit, production and nutrient uptake efficiency (Chopin et al. 2001). The system is substituted of several cages or ponds where you farm several species at the same time. An example can be that the waste water from fish goes to molluscs or to seaweed/plants that take up the excess feed and nutrients from the fish. The molluscs are later fed to the fish or other animals and the seaweed/plants can be sold.

2. Theoretical framework

The thesis has a trans-disciplinary approach, because a problem can be solved with the help from different disciplinary areas. Two frameworks are used in the analysis of the results, where the first is coming from the science of system ecology and the other from political science.

2.1 Resilience theory

2.1.1 Resilience

Carpenter et al. (2001) interpret social-ecological resilience of a system as: “(a) the amount of change the system can undergo (and implicitly, therefore, the amount of extrinsic force the system can sustain) and still remain within the same domain of attraction (that is, retain the same controls on structure and function); (b) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors); and (c) the degree to which the system can build the capacity to learn and adapt.”

2.1.2 Systems, memory and states

The world can be described in *ecological and social systems (SES)* that are linked to each other in different ways on different temporal and spatial scales (Holling, 1992). These systems have an ecological and *social memory*: “Memory is the accumulated experience and history of the system, and it provides context and sources for renewal, recombination, innovation, novelty and self-organisation following disturbance (Holling, 2001)” (Folke 2006). These systems may be *complex adaptive systems*, where the different parts of the system together have an emergent behaviour (you can not predict the future in the system by looking only at the parts) (Walker and Salt 2006).

The SES can exist in *different (multiple) basins of attraction* (Holling 1973), different states where the system has different functions and structures. A system can be in a desired state where it has a capacity to provide humans with *ecosystems services* (Daily 1997). If the system moves to another basin of attraction, due to for example human activity (that decreases the resilience by for ex. controlling natural variability) (Gunderson 2000), then it can come to an undesired state with less capacity to provide ecosystem services.

2.1.3 Diversity

The pressures that decrease resilience make the system more *vulnerable* to changes. Biological diversity (response- and functional diversity) (Walker and Salt 2006) and social diversity (Eriksen et al. 2005) can increase resilience by helping the ability in complex adaptive systems to self-organize in times of disturbances. Functional diversity is the amount of different functional groups in a system that fulfils different functions (for ex. trees and birds or aquaculture and fisheries). Response diversity is the diversity of responses to change and disturbances (such as different temperatures and water qualities) within the different functional groups (for ex. farming of different aquaculture species). The social diversity can be connected to *social resilience*; the ability of a social system, a human community for example, to withstand disturbances, such as natural disasters (Adger 2000).

2.1.4 Adaptability and transformability

But to be resilient in a robust way is not always desirable, a system may be in a undesired state and still be resilient.
Adaptability is something that are related to this; the capacity of the actors in a SES to influence the resilience of the system (Walker et al. 2004). This might mean making the system not to go into an undesirable state by *adaptive management* or to make the system go to a desirable state; *transformation*.

Adaptive management is to “learn to manage by change”, to be adaptive to changes, to predict what can happen and how to act in forehand (Gunderson et al. 1995). Lack of adaptability to environmental or social changes and stress, make a SES vulnerable (Adger 2006) and might make the system go to another state. Therefore *uncertainty*, risks and surprise are important factors to consider (Kates and Clark 1996).

Transformation is depending on the transformability of the system; “the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.” (Walker et al. 2004). Transformability also depends on the *adaptive capacity* and *adaptive governance* of the system (see further down).

The transformation goes through *tree phases*. Phase 1: preparing the system for change trough building knowledge about the ecosystem (or in this case: the aquaculture system with connected ecological and social systems), create a common vision and goal for the future in a comprehensive framework (a framework that gather the different perspectives and values from the stakeholders at different organisational levels) and collaboration and negotiation in social networks. Phase 2: using a window of opportunity (a situation that provides an opportunity for change, for example a new policy from the government that can give an incentive to change, so called “policy-driven” window of opportunity) and phase 3: building resilience of the new desired state (Olsson et al. 2004) (fig 4).

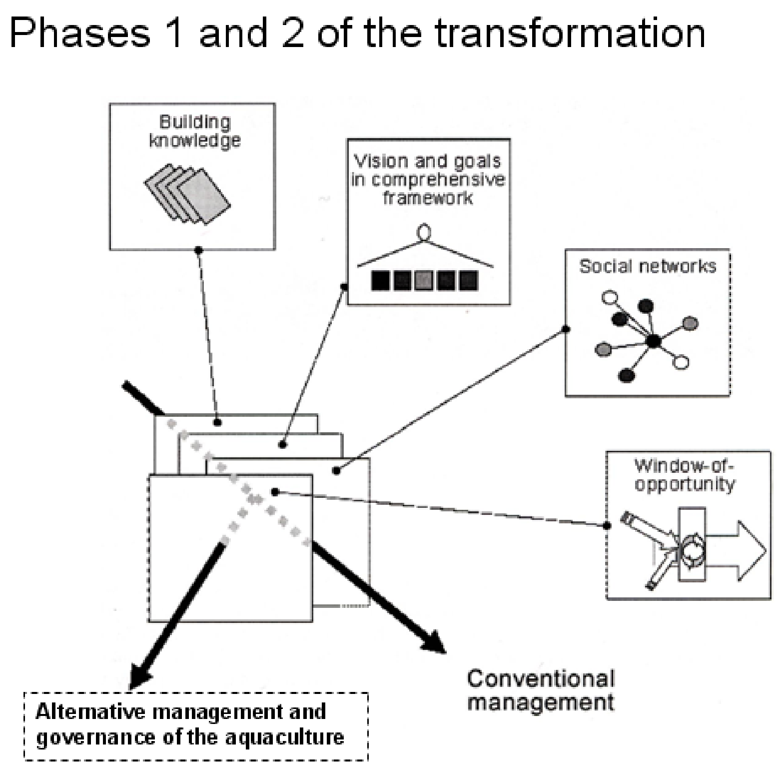

Fig. 4. Phase 1 and 2 of the transformation. The transformation of the present and conventional management and governance of aquaculture towards an alternative management and governance goes through phase 1 (building knowledge, vision and goals with the help from social networks) and phase 2 (using a window-of-opportunity). (Original from Olsson et al. 2004, edited by author)

Adaptive capacity incorporates *learning*; where the system learn, develop and share knowledge from mistakes and successes done in management of disturbances and unexpected situations (Folke et al. 2005). The adaptive capacity of a system are an ability to be open to new ideas and opportunities to lead the system on new trajectory, that may be more suitable in times of change (Folke 2006). Here is *innovation* also a vital quality that can help the system go towards a new state.

2.1.5 Adaptive governance

Adaptive management is related directly to the management of the ecosystem, while adaptive governance is related to the ecological system but also the social context. The definition might be summarised as follow: "Adaptive governance focuses on experimentation and learning, and it brings together research in institutions and organisations for collaboration, collective action, and conflict resolution in relation to natural resource and ecosystem management. The essential role of individuals needs to be recognised in this context (e.g., leadership, trust building, vision, and meaning); their social relations (e.g., actor groups, knowledge systems, social memory) and social networks serve as the web that tie together the adaptive governance system. It has cross-level and cross-scale activities and includes governmental policies that frame creativity. The notion of adaptation implies capacity to respond to change and even transform social-ecological systems into improved states." (Folke et al. 2005)

2.1.6 Social capital

Social capital is tightly connected to adaptive governance. Social capital facilitates collaboration; people dear to invest in collective actions, trusting that others will do so to (Pretty 2003). Trust-building can take time and might be difficult if there are already existing conflicts. But with trust the cost (time and money), of controlling what other people do, decreases. Factors that increases trust are reciprocity (exchanging goods or knowledge between stakeholders or develop long-time relations), common rules, norms and sanctions developed by the stakeholders together in consensus (increases the confidence to invest in the collective action) and connectedness (bonding, bridging and linking) among the stakeholders. Connectedness forms a network where bonding is the connection between actors with similar objective forming a group, bridging is making links between the different groups and linking is the ability of the groups to for example make contact with external agencies such as authorities.

2.2 Governance theory

2.2.1 Governance

The term governance has many definitions. The concept can be summarized as follow: "The governance concept points to the creation of a structure or an order which cannot be externally imposed but is the result of the interaction of a multiplicity of governing and each other influencing actors." (Kooiman and Van Vliet 1993, in Stoker 1998). According to Young (Young 1992 in Lebel et al. 2006) governance is the structures and processes by which societies share power, but also shapes individual and collective action. It is important to consider because it influences for example how we manage our natural resources and also determines the capacity to manage resilience.

The theory can be used for analysing the SES, by looking at social interactions and governance processes and governance mechanisms, to further come to a conclusion how the systems stakeholders manage the resilience of the system.

2.2.2 Attributes

Lebel et al. (fig 5 in appendix 1) have selected a couple of attributes of governance systems; *participation*, *deliberation* (debate, mediation, negotiation), *polycentric organization of authorities, multi-layered institutional arrangements, accountability and justice*.
Further the same authors then associate these attributes with the capacity to manage resilience; "*scale* to engage effectively with and handle multiple- and cross-scale dynamics", "*uncertainties* to anticipate and cope with uncertainties and surprises", "*fit* to design institutions which fit diverse social and ecological contexts", "*thresholds* to detect and navigate hard-to-reverse thresholds", "*knowledge* to combine and integrate different forms of knowledge", "*diversity* to maintain ecological and social diversity". This sets the grounds for the "degree to which the system is capable of self-organization, and the "degree to which the system is capable of learning and adapting".

To analyse the whole SES of the aquaculture in Sweden in this study, research has to be done about who the different stakeholders and actors are, at which different organisational and spatial levels they act and how they are connected to each other, and which essential ecosystem services and goods the aquaculture are depended on.

3. Methods

To answer the research questions and to find data different methods are used. These methods are based on two structural approaches. These give directives on which methods are used and why those methods are the most appropriate ones.

3.1 Methodological approaches

3.1.1 Ecological approach

The ecological approach is holistic; looking at the connections and interconnectedness between small individual parts of the world and the emerging function or property that they evolve together, constructing “a larger whole”. This can be connected to the resilience framework and the living of different stakeholders or species. The gathered sum of all the different qualities the stakeholders or species have creates a larger system with certain functions and structures.

3.1.2 Constructive approach

The constructive approach can be similar to the ecological approach. Constructivism is an approach that has a holistic and idealistic view of structures in the society. Constructivism means that structures are more then the sum of it parts (holism). The structures both constrain the actors and constructs the actors’ identities and interests. But the structure itself may also be formed by the actors and the interactions between the actors. The idealistic view in constructivism, say that social consciousness is the ground for society. The constructivists think that ideas such as norms, rules and knowledge is not only constraining our behaviour but also form our identities and interests. The interpretations and understandings of material forces, as natural resources and geography, are not formed by nature, but by ourselves and our consciousness (Barnett 2006).

This can be linked to governance theory where the governance structures and its mechanisms shape the actions of individuals and the collective.

3.2 Ways to find answers to the research questions

3.2.1 Navigation

To access information about which stakeholders I should contact I navigated through homepages (search words: fish farm, aquaculture, environmental friendly farm/aquaculture, ecological farm/aquaculture, sustainable farm/aquaculture) and phoned the SBF and KRAV (economical association that work for increased ecological farming, animal care and production). The SBF is the authority that has the major role in aquaculture issues in Sweden and manages the EU-support to aquaculture.

To know if I talked to relevant and enough amount of persons the study should continue its investigation. I tried to contact those persons that I was recommended from other stakeholders to contact, those that I felt might give me useful information or represented a certain interest and area in the aquaculture society. The authorities that are in some parts involved in management of licensing aquaculture production (for example the National Food Administration (NFA) and the Swedish Board of Agriculture (SBA)) have not been focused on because they never come up as important actors vital for my study and research questions.

3.2.2 Case studies

The study first had an aim of analysing the success of eco-labelled farms, but there are no such fish farms in Sweden. That led me to seek for farms that practiced or had practised an aquaculture that had the goal of more ecological, economical or social sustainable farming. The criteria that the case studies were chosen on were farming of alternative species of food fish (looking at food fish is chosen because it is farmed in most aquaculture farms in Sweden), using recirculating systems, prosper regional development and being KRAV-labelled. This led to crustaceans and mussels being less focused on.

Each experience from the case studies is unique and can be taken as a view that maybe not is general for all other farmers in Sweden, but it is still a reality and shows some of the factors that influence the development of aquaculture in Sweden.

I interviewed Abborrös, Mats Emilsson, on the phone. He is the leader of the project. I found Abborrös in connection to Östgös AB on the net. Several people talked about Östgös AB and the company's involvement with perch farming in new kinds of cages and I followed it up.

I visited Greenfish with Björn Lindén where I did a part of the interview and continued it on the phone later. He is the head of the company and contact person. I found him on the internet searching on ecological fish farm and by talking to Marc Wester on KRAV.

I also visited Kattastrand recirculation farm and Per-Erik Nygård where I did the interview. He is the person who owns the farm and has worked with the project mostly, but have other persons who helped him. I found him mainly by speaking to Cecilia Holmqvist on SBF.

The two visits gave me technical information of how the aquaculture systems work, but also a contact with the stakeholders that provides a feeling of how they work, why they do it and a sense for their values and concerns.

I did an interview with Mats Grönlund, The Aquaculture Project, on phone. He is one of three main persons that are contact persons and leaders. I found their project very late in the process.

Finally I interviewed Ulf Hallin that was a former eco-labelled farmer, on the phone. I got his name through Marc Wester, KRAV.

3.2.3 Semi-structured interviews

I did semi-structured interviews with the stakeholders in my case studies (Kvale 1997) to get information of what they do and why, how they manage ecological, economical and social issues and how they look at the future for themselves. The questionnaire contained questions about: technique, species, medication, ethics, fodder, fish escapes, energy, water resources, waste management, economical profitability, costs and incomes, market prospects like demand and consumers, the experience of the process of applying and receiving EU-support, their thought about getting eco-labelling certification, their networking and kind of contacts with other farmers abroad and in Sweden, scientists, authorities like SBF and the county boards, the Fish Health (fish diseases and health control organisation), non-governmental organisations (NGO) like the National Organisation for Aquaculture Farmers (NOAF), the former Food Fish Producers Association (FFPA), KRAV and Swedish Fish (SF) (a trade organisation promoting the demand for fish products, run by the fishing industry) and how their knowledge and experiences will be passed further to other stakeholders.
The interview with the former eco-labelled farmer contained questions about why he started, how it developed and why he did not continue.

I did semi-structured interviews with stakeholders on the local organisational level but also researchers, authorities, NGO´s and the industry that are on other organisational levels in the management and governance of the aquaculture. To do an analysis of which state the aquaculture in Sweden is in and whether it is resilient or not, I had to have knowledge and experiences from different stakeholders on different levels in the system. The interviews contained for example questions about which kind of interests and positions they have in the management and governance of aquaculture in Sweden, what kind of contacts and collaborations there is between different levels and stakeholders, and what they think about the future of the development of aquaculture in Sweden.

The interviews were written down and not recorded. This can have lead to misunderstanding of the informants or missed information. To be sure that the interviewees would not be quoted wrong and that some sensitive or private information would not be written, the texts were reviewed by the interviewees.

3.2.4 Literature and additional research

To inform me about research in aquaculture I read different articles and books. Governmental and university reports and investigations, statistics from the Central Bureau of Statistics and additional information from the SBF gave me information about which kind of and how much research is done in Sweden and to get a view of the status and production of aquaculture industry in Sweden. To get information of regulations and funding from the EU I complemented the research on the internet. This literature research was also a way to complement and control the data from the interviews (e.g. triangulation).

The methods are chosen to gather the smaller parts to a larger whole; the different values and perspectives of the stakeholders in the social, ecological and economical system together form the system of management and governance of aquaculture in Sweden.

4. Case studies

(Fig 6. in appendix 1)

4.1 Abborrös

Size and type of aquaculture: Seven locations, each producing approximately 30 ton fish per year, water based, dense cages, integrated and intensive.

Species: Perch *(Perca fluviatilis)* that is an omnivore (both herbivore and carnivore).

Owner and location: The project is a collaboration between scientists and several fishers in the archipelago south east of Norrköping. The leading person is Mats Emilsson.

Idea: The idea of the project is to farm perch in an ecological, economical and social sustainable way by testing different techniques and develop the employments and economy of the region. The technique, that is going to start spring/summer year 2007, is dense cages on the coast where the water is recirculated. These are 5 m in diameter. The waste water is collected on the bottom of the cage and pumped up to a container where heavier particles are separated. The water is then transported to channels where ropes float. On the ropes shells, barnacles and algae are growing and they filtrates the water. The water will be recirculated back to the fishes or can be led to a meadow that functions as a natural bio bed.

Input: The fish is fed with cod fodder but the project will try to develop alternative fodder that is suitable for perch and develop fodder with less fish protein. Perch larvae are received by Kattastrand recirculation farm.

Output: Fish, bio filter animals (fodder to poultry), algae (fodder to ruminants and pigs) and sludge (fertilizer to agriculture).

Water, energy, fish health: The channels receive energy from the sun and the water temperature increases. The warmer water can then be led back to the fishes and make the perch grow faster (optimum growth at around +20 degree Celsius). Experiments with suitable oxygen levels (with help from ex. the algae) and other fish health issues will be tested.

EU-funding: Yes.

4.2 The Aquaculture Project

Size and type of aquaculture: Small scale production, water based, dense cages and intensive.

Species: Perch *(Perca fluviatilis)*

Owner and location: The project is a collaboration between Vilhelmina, Åsele and Dorotea municipalities. It is led by three persons and Mats Grönlund, fisheries advisor, is one of them.

Idea: The project is constituted of different parts and (since one and a half year ago) one of them is farming of perch in dense cages (4-5 m in diameter) in lakes (fig.7 and 8) where the warmer water on the bottom of the cage is pumped up to higher levels in the water pillar. This creates a warmer water temperature that is suitable for the perch. They have not yet tried to pump up and use the nutrient rich waste water as fertilizer to agriculture due to a too small amount of fish in the cages (not enough assimilation of waste). Their main issues are if you can farm perch larvae in the cages, if it is possible to increase the growth of wild caught perch in net pens and which risks and possibilities there are to farm perch in the south of Lapland. The idea is to prosper a regional development from the fisheries and the farming of perch as a niche product. This will be done by generating employments, entrepreneurships and new business ideas from the project.

Input: The perch is fed with cod fodder. Young perch and larvae have been received from Östgös AB and from perch larvae in the own breeding project.

Output: Fish and waste water.

Water, energy, fish health: The waste water (fodder remnants, urea and faeces) is pumped from the bottom of the cage and then out to the lake. The perch like to live in shoals, but it has also cannibalistic behaviours that can impact the amount of fish in the farm. The perch can live in different water qualities, but grows best in clean and oxygen rich water. The perch in the project seems to be in good health.

EU-funding: Yes.

Fig. 7. Dense cage used by The Aquaculture Project. The cage is like a big dense bag which does not let in any water. The special plastic tissue is attached to a frame that is made of a floating material. (Photo: The Aquaculture Project, 2005)

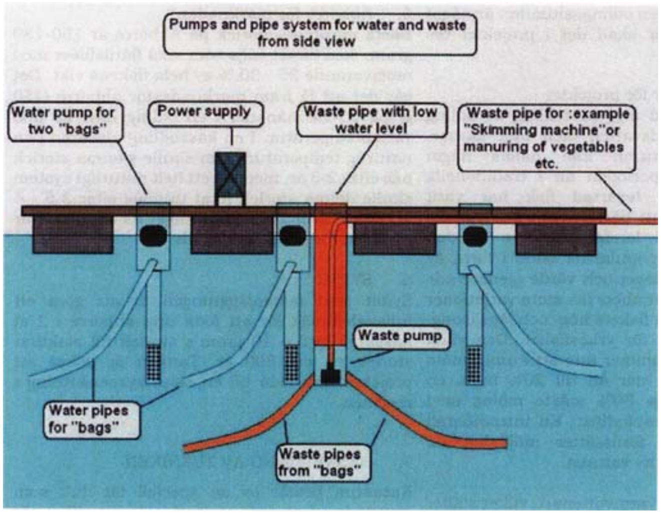

Fig. 8. Detail from dense cage used in The Aquaculture Project. Water goes to the cage (here called "bags") through pipes and the waste water is later pumped up to the outside of the cage. Water with a warmer temperature in the bottom of the cage can be pumped up to higher levels of the water pillar, which prosper the growth of the perch. The waste water can be treated with different techniques or be used as fertilizer to agriculture (which has not yet been tested in this project). (Picture: The Aquaculture Project, 2005)

4.3 Kattastrand recirculation farm

Size and type of aquaculture: 100 kg fish and a couple of tones vegetables per year, land based containers, integrated and intensive.

Species: Perch *(Perca fluviatilis)*

Owner and location: Per-Erik Nygård, Härnösand

Idea: The farm is a "bioponic system" (fig. 9 and 10). The waste water from the fish flows down to plant beds with pebbles and micro bacteria. The water becomes cleaned by the bacterial process and the uptake of nutrients by the plants. The water then goes back to the fish containers by the help from pumps. Per-Erik also does tests with developing fodder to wild caught perch.

Input: Fish fodder and fish fry (own breeding of perch larvae, but also gets perch from Abborrös)

Output: Fish, vegetables and evaporation of water.

Water, energy, fish health: The system is in a greenhouse where the energy from the sun helps the plants to grow and keeps an appropriate temperature in the building. When needed he use the warm air furnace that is fuelled with pellets. The fish water temperature is regulated by sun panels and makes the fish grow faster. Diseases haven't been a problem during the ten years that the farm has been going due mainly on no new incoming water that can bring diseases and total cleaning in the plant beds.

EU-funding: Yes

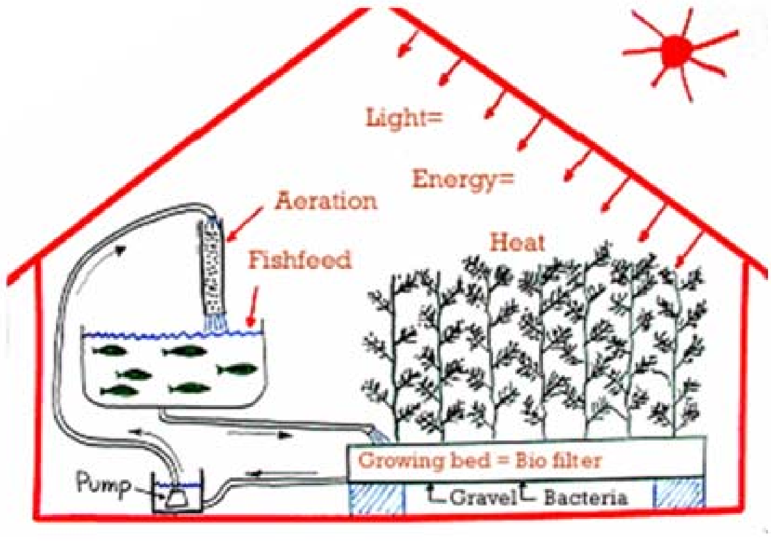

Fig. 9. The system in Kattastrand recirculation farm. The whole construction is situated in a green house that preserves energy and heat from the sun. The fish is fed in containers that are aerated. The waste water from the fish flows to a bed with pebbles and bacteria where it is cleaned. Vegetables grow in the bed, using phosphorus and nitrogen from the urea and faeces in the waste water. The clean water is then pumped back to the fish. (Picture: Kattastrand recirculation farm, 2006)

Fig. 10. Detail from the system in Kattastrand recirculating farm. The waste water flows from pipes down to a drain. The drain is perforated so the water can drip down on the bed of pebbles. The tomato plants stand in the bed and grow by using the nutrients from the waste water. The water is cleaned by bacteria in the bed and then pumped back to the containers with perch. (Photo: Berggren, 2007)

4.4 Greenfish

Size and type of aquaculture: 500 ton per year**,** land based containers and intensive.
Species: African sharptooth catfish (*Clarias gariepinus)* which is an omnivore. It grows fast and is full grown after six months.
Owner and location: Greenfish is lead by Björn Lindén, an aquarist with diverse background of different areas like biogeochemistry, industry and aquaculture.
The company has newly started a farm in Falkenberg after being in bankruptcy some time.
Idea: The system recirculates the waste water from the fishes through a system of biological and mechanical cleaning (similar to the processes in water purification plants), and the remaining sludge goes to agriculture (fig.11). The idea of the company is that the agricultural farmers receive a license for producing fish for Greenfish. The farmers invest in building the system and then produces the fish in their barns with own cerealia fodder (leguminous plants and linseed) and then use the sludge as fertilizer. Later they will start farming the carnivore Barramundi *(Lates calcarifer)* that can be fed with the preparation remnants from the catfish. That will reduce fodder costs and be more efficient.

Input: It is right now fed with cod fodder, but will be fed with KRAV-labelled corn and cerealia later on. The company have their own breeding stock.
Output: Evaporation, food products and sludge.
Water, energy, fish health: The water temperature (+22 degree Celsius) is supported by the energy from pumps, fish metabolism and a well isolated building. The cost of energy is beneath five percent of the total costs. The fish health is in a very good condition, due mainly on no new incoming water that can bring diseases and on the cleaning system of the water. The fish breaths air and like to live in dense shoals.
EU-funding: Yes.

Fig. 11. The recirculation system constructed by Greenfish. The system is placed inside a barn that is usually used for agricultural purposes. The fish is farmed in the containers in the front of the picture. Water is flowing through pipes to the basin. The waste water is then pumped to the biological and mechanical cleaning that is conducted in the containers in the back of the picture. The clean water is then pumped back to the fishes. The system is closed and uses a minimal input of water. (Photo: Berggren, 2007)

4.5 Gustavalax AB

Size and type of aquaculture: During 1999-2002 the farm had conventional farming parallel with KRAV-certified production (which was producing 60 ton per year), water based, net pens in a lake and intensive.
Species: Rainbow trout *(Oncorhynchus mykiss)*
Owner and location: Ulf Hallin, Hagfors
Idea: Eco-labelled production

Input: KRAV-approved fodder that come from wild natural resources that are managed sustainable, from resources that are not used for human consumption and from bi-products.
Output: Fish and emissions (see further down)
Water, energy, fish health: (see further down)
EU-funding: Have not applied for EU-funding.

The company followed the certification rules. The regulations and recommendations are for example that all fodder should in the first hand only be KRAV-approved fodder, the production shall be well documented and reported to KRAV, the farm has to be provided with good water conditions and not be situated near polluting sources, the surrounding environment shall be impacted of emissions in so small amounts as possible, only mechanical and biological measures to remove on-growth of organisms on the cages are possible, breeding material shall be KRAV-approved and recommended to be produced with preventions against inbreeding and strains adapted to local conditions, no genetically modified components shall be used in the production, growth stimulating agents, appetite stimulating agents, synthetic antioxidants, amino acids, preserving agents, synthetic colour agents and hormones are forbidden, preventive treatment with medication is not allowed (vaccination is recommended), the time of waiting before letting fish back after medication is the double to the national regulations, management plans and actions for preventing and controlling fish escapes shall be implemented and escapes shall be reported to KRAV, living fish can be transported maximum six hours and shall be overviewed by a person responsible for the health of the fish (KRAV 2006).

5. Analysis

5.1 Drivers and barriers

The interviews and visits of the different case studies showed many interesting results and emerging issues. There are different factors that influence the development of the projects and companies. Four of the case studies have started or are proceeding with their activities and productions and the fifth case study did not succeed to maintain a KRAV-certified production (which I write about in part 5.1.8). Some synergies and trade-offs between ecological, economical and social factors can be traced.

5.1.1 Capital and investors

A common factor for all the case studies is that capital is the most important factor that is needed to start and survive a project or company. It can be both a stress and driver: stress if you do not have it and a driver when you got it. When receiving EU-funding it is vital to invest with your own capital, because the funding is not paid out at once and it can be hard to immediately find other investors. The EU-funding has been a big support for all four cases (Gustavalax AB has not applied for support). Without it the projects and productions would not have come to a reality. This can contribute to a high vulnerability for the case studies.

As will be mentioned further down, it is important to have an ability to show to the investors and the admission of EU-support that your project and ideas are going to work. It can be an advantage if you can show that your project is already going, which has been experienced by the Kattastrand recirculation farm.

For Greenfish the investor “Teknikbrostiftelsen” (a foundation with official support, in corporation with universities and industry, aiming at commercialising scientific research and called Innovationsbron AB from year 2005) was an important financer in the beginning. ALMI Företagspartners AB (a company that help develop ideas to become profitable businesses) is collaborating with Teknikbrostiftelsen and have also helped Greenfish with financing. They can evaluate if companies has options for getting patent on their business. Patent is good if you want to have more capital in the company by proving that your company is secure for investors.

Abborrös was supported by Sparbanksstiftelsen Alfa (a foundation of a Swedish bank), Regionforbundet Östsam (municipalities and county councils) and Innovationsbron Östra Götaland AB.

5.1.2 Knowledge about the market

The perch farmers and Greenfish has a good knowledge about the demand for their products and have established contact with the market and some has contact with SF. According to a researcher on the SUAS, the demand for perch is not so big on the local market in the north part of Sweden, because the local people can fish the perch themselves from the lakes. But in the rest of Europe there is a big all-year-around demand for perch in suitable fillet sizes and restaurants and wholesalers are eager to receive both perch and African sharptooth catfish.

5.1.3 Entrepreneurs and leaders

A leader shall push the development of the project forward, by making people engaged in the project and by having the over all view of what has to be done. This also means to create a vision and meaning for the future. In for example the project Abborrös, Mats Emilsson has made the fishermen to have a future goal of getting more employments if they change their activities and try something new and different.
Entrepreneurship is also a kind of leadership. It is important with an ability of making networks with stakeholders and investors as in the example of Greenfish, where Björn Lindén created trust for his idea through making people feel that they wanted to invest time and money on the project.

5.1.4 Engagement and participation

To get people to work together towards a common goal there has to be engagement. This can for example been seen in Abborrös where the engagement of several fishermen is created by enhancing the possibility to participate in regular meetings and by creating meaning of the project. By long time interactions during several years in the society Mats Emilsson has created a trust for the project and accountability for the ideas. This trust and engagement can be a good tool for solving possible conflicts early in the process and in that way save time and money, with other words a synergy between social and economical factors.

Younger generations see the possible gains in changing their living, but the older generations have been harder to convince. But by showing that the project works, more people will probably join and support the project.

5.1.5 Knowledge systems

Knowledge is a central key and important factor in the development of the case studies. Different kinds of knowledge and different kind of systems providing knowledge has been shown in the study. Different techniques like water cleaning, cage building and perch farming techniques has been developed and tried out in collaboration between farmers and scientists.

Traditional knowledge is also important to manage and this can for example be seen in Abborrös and The Aquaculture Project, where people that manage fisheries (a skill of knowing how to deal with fish) participate in the aquaculture projects.

The Aquaculture Project has by networking with foreign perch farmers and scientists at the SUAS received knowledge about how to breed and farm perch, a knowledge that has not been very developed in Sweden.

Greenfish has gathered different areas of knowledge and expertise like economists, lawyers and leading scientists. That can be an advantage and a strength when dealing with different unexpected problems and changes (regarding not only aquaculture technique) which can occur during the process.

There is also collaboration between farmers (the Abborrös, The Aquaculture Project and Kattastrand recirculation farm) and the SUAS, with exchange of knowledge, experiences or perch larvae. This increases the social capital by reciprocity and trust, but also creates a connection between the theory and practice of the aquaculture research. According to a farmer (interv. 4), collaboration with universities and other farmers gives an increased authority and weight to the project.

Experimentation and learning from mistakes is also an important source to knowledge. It gives a capacity to know how to adapt with changes and to be flexible when something goes not according to your plans. There is a lot of evidence of innovation and testing ideas in the different case studies, especially Kattastrand recirculation farm where Per-Erik Nygård have worked and tested the technique practically for several years.
The experiences and knowledge from failures and mistakes by Gustavalax AB and the Aquaculture Project is important to govern in knowledge systems for future surprises and uncertainties that other farmers can be exposed to.

5.1.6 EU-funding during year 2000 to 2006 and the process of receiving the funding

The Financial Instrument for Fisheries Guidance (FIFG) was the fond for the development of fisheries and was one of EU four structural funds. It contributed to the realization of the EU common fisheries policy. The previous program period was year 2000-2006, where Sweden had a budget on 75.47 millions Euros (EC 2005) and 144 applications were made during the period (FV 2007). The rules and directives for measures are decided by the commission, but it is up to each country to decide where the funding should go. The state shall always support financially in the projects, and if the

support goes to investments that later will give yields, the farmer shall contribute with own capital (EU 2006).
Funding can for example be given to investments and improvements (the economic support is 20-40% and the contribution of private capital is 80-60%), pilot projects with sustainability aspects (a public receiver gets 50% EU-funding and 50% national public funding, a private receiver gets 50% EU-funding, 5% from SBF and have to invest at least 30% private capital) and for other measures in the interest of the aquaculture sector like education or networking (Holmquist 2007).

One of the biggest difficulties that have been mentioned in the interviews is the process of receiving EU-funding (interv. 1,2,3,4). The first step for applying for money is not the hardest part. The difficulties lie in receiving money when the admission has being admitted.

First you get an answer from the county board and the SBF that you can start the project. The decision of actually receiving the money comes later. It can mean that you have to go in with own investments in the beginning of the project to get the production started. If you do not have that money there is a risk that the project would not start at all. In the case of The Aquaculture Project the municipality helped with financing in the beginning.

The process is in general experienced as very long and slow, going through several steps. Receipts have to be shown for everything that has been invested in, and the rest of the money that have not been used, must be returned. Supervision of the projects is also a part that takes time. The project is controlled by examiners and the farmers can then answer on eventual critic. These opinions have also been raised by the SBF (interv. 16).

In the case of seeking support as a company some problems can emerge. There is a production demand from the industry which is not correlated with the slower process of EU-funding management, which can lead to bankruptcy of the company and according to a farmer several other farmers has been exposed for this (interv. 3). The same source mentions that there is also a mismatch between the paragraphs for getting money and the right valuation of the project in the beginning. The grants are admitted before checking the paragraphs, which can lead to that the company has to revise the applications once again, which is problematic and has occurred for several farmers.

The amount of applications has risen through the years, according to the SBF (interv. 16). The reason for this is unclear, it can depend on the available information on the SBF homepage or a communication of the information between the farmers. A worsen situation for the farmers in Sweden today might influence the need for more funding.

5.1.7 The problem of farming perch and finding the right perch fodder

The cases that have been farming perch, have all had difficulties with getting the egg to hatch and the larvae to survive. The fish is a domestic species but have not been farmed before in Sweden and there is a need for research on for ex. how to manage its behaviour (difficulties with cannibalism) and on larvae rearing. The cod fodder that right now is given to the fish is too fat. The perch need less fatty acid and more amino acids. Specially adapted fodder can be constructed but it is very expensive because it is only produced in small scales so far (interv. 2). There is a request from the farmers to the public sector that is asked to support more breeding projects and larvae rearing.
The cages used in The Aquaculture Project have been difficult to manage during bad weather conditions (interv. 4, 33) and it has also been hard to clean the cages and to catch the fish in a practical way.

5.1.8 The KRAV-certified farm

The reason for Gustavalax AB to start with certified production was that there was a demand for more ecological farms out in Europe, there were an interest from the food markets and that the farm wanted to try a new niche.

The fish was fed with KRAV-admitted fodder that was especially made for the farm. The fodder raised the price of the fish; ten percent of the total production cost was constituted

by the fodder. This made a trade-off between being ecological sustainable and economically viable. The result was that one of the big food markets withdrew and the production could not afford to proceed.
It is also experienced as very expensive to be certified (costs of certification and controls) (interv. 2,3,5), hard to fulfil the criteria (interv. 2), the own production is too small (interv. 4) and that there is lack of aquaculture knowledge at KRAV (interv. 5).

5.2 Is the aquaculture in Sweden in a desired or undesired state?

This analysis bases on a vision that the aquaculture in Sweden shall still exist today and in the future.

The criteria for how I think a desired state should be: provide aquaculture products in an ecological, economical and social sustainable way. That means using fodder that do not put a pressure on natural resources, no kinds of emissions, using seeds that are from own breeding species at the farm (without inbreeding) and not from wild captured species, a sustainable use of energy, no habitat or ecosystem destruction, a production that is economically viable and profitable, that give so many employments as possible, a use of water resources that do not give rise to stakeholder conflicts and fair and equal social conditions.

An undesired state is the opposite: no products at all or the products that are provided are produced in an ecological, economical and social unsustainable way.

Today I believe that the aquaculture industry in Sweden is in an undesired state. This is based on the following conditions: farming of carnivore fishes that are fed on fish based fodder, emissions (mostly nutrients) from net pens into waters, seed taken from wild fish and problems with inbreeding from own seed, small-scale farmers that do not have a viable and profitable production, a decreasing amount of employments especially in rural communities and conflicts between stakeholders over water usage.

5.3 Is the Swedish aquaculture resilient to changes, stress and disturbances?

If the ecological, economical and social system of aquaculture in Sweden would be resilient it would mean having an ability to learn and adapt to external and internal changes, stresses and disturbances and still maintain the same undesired state with its functions and structures.
Possible stresses can be a harsh climate (ice on water that impact the cages and low temperatures that can decrease the growth rate of the fish), low profitability being small-scale production, changes on the global market, changes in prices and supply of fish based or vegetable fodder, decrease in supply of seed from wild eels, but also as Kaiser and Stead propose in their article: an uncertainty of changing demand and supply of products, changing perception of consumers and the uncertainty of the changing values that are building the grounds for policy making in the society (Kaiser and Stead 2002).

My answer is that the resilience of the aquaculture in Sweden is affected by different factors depending on how you look at it.

The system is resilient towards low profitability and low temperatures through a diversity in activities and farmed species. The stress of low profitability when being a small-scale production (difficult to get permits for bigger productions due to hard environmental regulations) are managed by small-scale and family own companies by increasing income through processing the products themselves or by a combination of farming food fish and fish for stocking (that in turn can increase income by using the fish in sport fishing tourism). There is also farming of different kinds of species in Sweden and many of these are suitable for cold temperatures. This response diversity in farming activities and species increase resilience in the aquaculture system; farmers can maintain same function and structure despite the stresses.

The system is not resilient towards changes on the global market. It is difficult for the farmers to have a production that competes with foreign markets like Norway. The prices

of fish in Sweden are too high to be able to compete with the prices of fish from a country that can produce higher amounts to a lower price.
If the demand increases and consumer perception changes for other products (for ex. eco-labelled products) the aquaculture in Sweden has not yet prepared a supply for that change. Another factor to low resilience can be aquaculture policies that are now giving directives for development of a more sustainable aquaculture which can put a pressure on farmers to change their activities, which they are not prepared for.
There is also a lack of diversity in and flexible overlaps between generations within the aquaculture today, which will have an impact on the amount of active farmers in the future (interv. 12). This decreases the resilience towards retirements and mortality.

The conclusion is that the aquaculture is not totally resilient and that there are both possibilities and barriers to move from the undesired state towards a more desired one.

5.4 How to move towards a more sustainable aquaculture

5.4.1 Transformation to a desired state

The present state is not desirable. To move towards a new and more desired state the system has to go through a transformation, where the present and conventional management change towards an alternative management. The capacity to transform is decided by the adaptive capacity and adaptive governance of the system (see part 2.1.4 and 2.1.5). This together with building knowledge, vision and goals, social networks and a window of opportunity can make the system go towards an alternative direction (fig.4). I would also like to add participation, deliberation and accountability from the governance theory (fig.5 appendix 1) that are components essential for the ability to build knowledge, visions, social networks, trust between stakeholders and increase the legitimacy and chance for implementing and evolving a new governance of the alternative aquaculture management.

There are several factors that affect the transformability of the aquaculture in Sweden.

5.4.2 Building knowledge and a common vision

5.4.2.1 Research

Knowledge about ecosystem dynamics (in this case the knowledge how to manage aquaculture) should be build to help the society to progress. In Sweden there is applied research about a more sustainable aquaculture (some universities work together with the farmers) and this is financially supported by the state and by some part of the aquaculture industry (interv. 5, 16, 17).

Examples of the research are: alternative fodder development in SUAS, Uppsala, modelling and behavioural research on different species SUAS, Umeå, mussel farming at Tjärnö Marine Biological Laboratory and Kristineberg Marine Resource Station, technological development in the Royal Institute of Technology in Stockholm, University of Lund, University of Gothenburg and Chalmers Technological University, breeding research on Kälarne research station driven by the SBF and recirculating systems at the Kalix School of Renewable Resource Management). The universities are important for the knowledge building, but also for the distribution and information about the knowledge towards the farmers and the society.

5.4.2.2 The image and narrative of aquaculture

There are different arguments on how big environmental impact aquaculture has on Swedish waters between the different scientists. This affects both decision making and which kind of information that reaches the public.

Some farmers and scientists feel that the debate is unbalanced and perceives it as “narrow-minded, conservative and biased” and that there is an image and narrative of aquaculture being worse than it actually is (interv. 2, 12, 14, 26). The narrative comes mainly from aquaculture causing big environmental problems in the seventies and that remains in the social memory of the society. Some other researchers are critical to this view and believe that we still have to be more careful of the location of aquaculture and the fodder use (Kautsky et al. 2000).

5.4.2.3 Who has the responsibility of the development of aquaculture?

The different aquaculture stakeholders that have been interviewed state that somebody else, other than themselves, should drive the development. The SBF and the researchers thinks that the development depends on the industry, the farmers and the market (int. 18, 25); “We cannot make the industry, it have to make itself.”(int. 15). The industry and the researchers (in the same time) believe that the politicians and the authorities should support and push the issue (int. 2, 4, 12, 25, 33). In the issue of eco-labeled products, the producers blames that there is not any demand from consumers that can secure their production, and the buyers and consumers blame that there are not any existing and reliable production to buy (int. 32).

There is also the question of commercializing productions with more sustainable technique or management. There are arguments from researchers, SBF and the industry that new more sustainable technology is more expensive and harder to handle in big scale (int. 10, 16, 33). But one can also argue that the bigger producers are the ones that have the capital to invest in the technique and should do that. But then it becomes an issue about profitability.

There is an understanding that no body alone can be able to take the lead in the development and that there should be a joint force from all the actors. But the debate in the society about which the next step in the development is, is standing still due to this polarization in opinions of the different actors.

5.4.2.4 Innovation, “local history” and fear in investing

The importance of being innovative is that you have a capacity to be creative and adapt to changes or unexpected events, but also the ability to change towards a new and different direction. There is a perception of the farming in Sweden being a “local history” (int. 12). It means that there is stagnation in the development of the industry due to a tendency for farmers to only concern with their own production and continue it in the same way and at the same time having difficulties with making their production to something more profitable. There are no activities outside the farms that are innovative, like networking and changing experiences, and in that way increase the capacity to change.

This can be depending on that there is a fear in investing too much and trying different activities. New technique can be perceived as expensive and difficult to manage, and that it will be more costs than benefits (Boyd 2003). Farmers with traditional knowledge do not have the engagement or incentive to invest (int. 33). “The technique is not ready yet” which creates a fear for the risk of investing and trying something new. A suggestion is to clearly show if there can be economical gains from a more sustainable technique management (for example reducing stocking rate and better feed management can lead to “better water quality, less stress, faster growth, better feed conversion ratios and less waste produced”, thus increased profits and efficiency) (Boyd 2003).

A similar problem has been observed by a farmer (int. 3). He means that there is a shortage of investors, that there are too few owners of capital that can invest in aquaculture. There is fear and lack of experience to invest in the aquaculture sector because it is something unknown and have not been done in a big scale.

5.4.3 Deliberation

The credibility in the narrative and image of aquaculture and the question on who should push the development forward is not meant to be solved in this study. The biggest issue that influences the development of a more sustainable aquaculture is the question of the existence of aquaculture in general. These important discussions have to be discussed and deliberated in the society.

Deliberation is a process that is a part of Integrated Coastal Zone Management (ICZM) (Kaiser and Stead 2002). ICSM can be used in policy making and implementation and it is multidisciplinary (involvement of environment, technology, economy, politics, sociology, law and indigenous knowledge) and extended peer-reviewed work (involvement of other stakeholders and interests to add to the knowledge when uncertainties of science make it harder to solve the problem) and participatory and consultation mechanisms at and between different organisational levels (farmers, traders, authorities, NGOs) and spatial scales (local, regional, national and international) in for example consensus conferences. Open and transparent participatory discussions are an arena where the different stakeholders can express their needs and desires but also their capacities and how much they are prepared to involve in different management plans (Hugues-Dit-Ciles 2000). This can result in a better understanding of the values and backgrounds that lies behind arguments and create a platform from which the stakeholders can solve problems and decide what issues are important for them.

The deliberative process can be used as a tool for discussions and negotiations of which direction the aquaculture in Sweden should go and how it should be conducted. This in forums and other meeting forms, with the help from the MA that has the most powerful and political force to initiate and form the aquaculture agenda. This process should be conducted on all organisational levels and with the stakeholders from different interest groups.

5.4.4 Social networks

The aquaculture in Sweden has a network of stakeholders at different organisational and spatial scales and vertical and horizontal levels. These are being used to govern management of farms and for exchanging information and knowledge (fig.12 in appendix 1).

5.4.4.1 Bonding and bridging organisation

A bonding and bridging organisation can be useful for stakeholders that have the same interest and it can connect to other groups of stakeholders. An incentive for the farmers that want to work with sustainable issues, to make it through all difficulties with seeking money, trying new technique or other issues, would be to have an organization that offers help. The NOAF is an organisation that represents the interest of the aquaculture farmers towards authorities and decision makers and could be this bonding and bridging organisation. It could also manage a knowledge system to govern the experiences and knowledge of for example The Aquaculture Project and Gustavalax AB.

NOAF have problems with surviving the latest years due to a decreasing amount of farmers (that in turn depends on the difficulties with getting permits for bigger productions) and due to difficulties with making it economically. The leader Kaij Lundgren is now doing a new promotion of the NOAF and is trying to reach schools and universities for recruitment of younger generations. Unfortunately there is a perception from some farmers that NOAF is mostly focused on commercial farms (int. 2) and that they are not very innovative and new thinking (int. 3).

5.4.4.2 Linking organization

A producer organisation can be a way to connect the farmers with the market. The FFPA gathered thirteen rainbow fish producers in Sweden year 1998 with the mission to process and sell the products of the members within Sweden and on foreign markets. This through a close corporation with costumers, purveyors and processing companies. This can be a good thing according to Ulf Hallin (that got help from them during the time he was KRAV-certified) and there is now discussions of the formation of a similar organization for the mussel farmers (KMF 2006).

The association has gone into bankruptcy and does not exist anymore because many of the farms were sold to a company from Åland (int. 5).

5.4.4.3 Project group

The regulations, rules and processing for receiving aquaculture permits is right now a big problem with long process time, big costs for farmers, strict environmental criteria and difficult coordination and interpretation of the guidelines and regulations. This is now going to be discussed in a project group constituted of SUAS, NOAF, SBF, SEPA, NFA, NVI and MA (int. 20)

5.4.5 Policy-driven window of opportunity

5.4.5.1 The National Strategic Plan and the Operative Programme

The European Fisheries Fund has a budget for fisheries and aquaculture development that is going to be implemented through the National Strategic Plan (NSP) for the fisheries sector and the Operative Programme during year 2007-2013. One of the main focuses is to promote an ecological, economical and social sustainable development of fisheries and aquaculture. Many of the goals and measures are the same for fisheries and aquaculture and it is difficult to know when the document especially addresses aquaculture (in connection to this it has been commented on a hearing that the aquaculture is having a too small part in the NSP in comparison with wild fisheries (Olsson 2006).

5.4.5.2 Implementation and change of system

These policies are a way towards a new state of the aquaculture. The question is how it is going to be implemented and by who. Today the aquaculture is having a very low priority in society; one and a half employee on the SBF, one employee for both fisheries and aquaculture on the counties and as a part among many other issues (more high prioritized areas) agriculture, wild life and fisheries on the MA.

The implementation is also influenced by a perceived confusion of roles of authorities and other institutions. The accountability and coordination on who are doing what is not high. The SBV have a role both as a decision maker (int. 15) and as a supervisor of farmers that receive EU-funding (a bad combination according to one farmer (int. 3)).

SUAS perceive themselves as having (involuntarily) the role of both SEPA, SBF and NOAF. SEPA has resigned from aquaculture in general, according to one farmer, but SEPA in turn states that their role is to “looking at environmental impacts from the aquaculture” (int. 20).

To increase the chances of the policies to be implemented it is important to look at several factors (Kaiser and Stead 2002). The research and the policy have to not only work with and focus on technical and ecological issues, but also at economical, cultural and social perspectives. The research has to increase their trans-disciplinary work; integrating natural, social and political science. The values, interpretations of information, decisions and actions by individuals are influenced by “cultural, background and community structure” where they live. It is important to know about these dynamics in making new systems of governance, because it is only then that it is mostly likely that the policies will be accepted and integrated in the society.

Building knowledge (trans-disciplinary knowledge about what the problems are and how to solve them) and having a common vision, goal and meaning (which direction the new state of aquaculture has to move) can be created through deliberation (participation and discussion where narratives, fears and possibilities can be brought to the table) and together with a social network (that can manage and govern the knowledge and visions) and implementation of policies, the undesired state of aquaculture in Sweden can transform to a new desired state.

The transformation process will take time and a lot of work. And the probability is that there will be a change of the system “where the farmers of today are not going to be the same as in the future” (int. 33).

6. Discussion

In my first research question there are some subjective terms which can impact the results and analysis.
The definition of sustainable aquaculture is a term that is not clearly defined. This means that it opens up for all kinds of interpretations and no one is more right then the other. What seems sustainable today (such as feeding fish with agricultural plants) can be unsustainable in the future (ecosystem destruction due to large soy bean plantations). This also concerns the case studies and the term “succeed”, which is a highly subjective adjective that can be interpreted as succeeding to finance the project, start a production, be profitable or to reach the goals according to plan.

There is some critic regarding the resilience theory framework that the second and third question is based on.

Aquaculture is a constructed and controlled system that is not natural in the sense that ecosystems are. It is created by humans where the inputs and outputs are regulated and manipulated. The products of the system can be stimulated by different agents and the outcome can be perfect. Resilience theory as it is today is mostly often analysing natural ecosystems.

The definition of what a desired or undesired state is, is usually more easily to decide (and is something that have been done several times) for ecosystems that provides us with ecosystem goods and services. What an aquaculture system is providing us with is depending on who is asking and what kind of criteria you use (provision of materialistic goods or provision of a socially acceptable system). You can desire big productions and not counting in the environmental impacts, or you can desire both big productions and counting in that you want no environmental damage.

The border of my aquaculture as a SES is big and contain a lots of stakeholders and their interactions, but also a lot of different smaller SES (for example my case studies or other aquaculture farms). The resilience can be decided of the big system, but there can also be questions posed about the states and resilience of the smaller systems and of the case studies.

To decide the resilience of the whole system, analysis of all different parts and aspects are needed and demands a lot of different information. In this study it has not been possible to cover all aspects.

It is also important to ask the questions: which disturbances is a desired or undesired state of a system resilient towards? What is perceived as disturbance and stress in a social and economical system? For many SES stress and sources of possible disturbances can be uncertainties of supply and demand, risks in investments, changes in population, changes in people's private economy, conflicts and war due to inequity issues, stress from poverty, outbreaks of diseases, factors that threat peoples welfare and wellbeing and these drivers and factors act on, and originates from, local, regional or global scales.

It can be good to decide the relevance of asking the question "is the aquaculture system resilient?". What does that knowledge give us? In this case it can be relevant to know if the system is in an undesired state and not resilient. It can then be easier to move towards a desired state, than if it were undesired and resilient.

As I address sustainable development of aquaculture in this study it can be good to analyse how resilience fit in the concept of sustainable development. For me resilience has tools for increase for example social sustainability by conflict resolution. Social capital and adaptive governance creates trust, reciprocity, social networks and involves learning and experimentation through stakeholder collaboration. Social sustainability is then prospered by a decision making process that hopefully everyone can agree on and not lead to conflicts.

7. Conclusion

7.1 Conclusion

The wild fish resources in the world are overexploited while the world population is increasing. An alternative seafood source could be farming of species in aquaculture. But some types of aquaculture are not ecologically, socially and economically sustainable, which is a problem of the aquaculture in Sweden (emissions of nutrients, farming carnivore species with fodder containing wild fish, stakeholder conflicts, low profitability for small-scale farmers and decreasing employments in rural communities). The state of aquaculture in Sweden is undesired, but not totally resilient and there are possibilities and barriers for transforming the system towards a more desired state where the aquaculture is more sustainable.

A more sustainable aquaculture can be managed in alternative ways and this has been shown by or is going to be tested in the case studies: recirculating systems (project Abborrös and Greenfish) and integrated aquaculture (project Abborrös), eco-certified production (Gustavalax AB), farming omnivore or herbivore species (Greenfish) or by farming niche species and having a diverse set of activities (combination of farming, processing the products, sport fishing and fisheries) which create a regional development and increased income (The Aquaculture Project).

The case studies have shown that there are several important factors that influence the development of a more sustainable aquaculture. Investments and capital is vital for getting the projects and productions to start. Having good connections to the market and knowledge about the demand, supply and the dynamics on the market is the base for a successful business. A good entrepreneur- and leadership is important for building trust and engagement between stakeholders, vision and meaning for the participators and building trust for the project towards investors and the Swedish Board of Fisheries (EU-funding). There is a synergy between participation and good economy in the long run when you practise an early conflict resolution.

The researchers and farmers in Sweden have knowledge and practice of a more sustainable aquaculture management trough networking and collaborations, where problems and solutions are worked out.

The slow process of receiving EU-funding and the KRAV-certification can be seen as barriers and difficulties that make the aquaculture development slower. The KRAV-certification is expensive and there is a trade-off between environmental gains and economical difficulties where the higher-price products becomes hard to sell.

The transformation to a desired state goes through several phases.

Phase 1 is building knowledge about the aquaculture (trans-disciplinary research about what have to be solved and how to do it) and creating a common vision and goal of which direction the aquaculture in Sweden should go.

Difficulties in reaching this phase are the different perceptions and narratives of how the aquaculture is affecting the environment, the issues of who should take the responsibility of the aquaculture development (a dispute between farmers, industry, politicians, researchers and authorities), the phenomena of the “local history” and the fear in investing. These issues could be deliberated by the different stakeholders in forums, meetings and social networks. A way to easier solve some of the problems today in the aquaculture society could be by increasing the understanding of the background to the different values and perceptions that the stakeholders have.

The social networks that exist today could be increased by a stronger bonding and bridging aquaculture organisation and a stronger linking organisation that has a connection between the farmers and the rest of the industry and the market.

Phase 2 is using the new national policies as a window of opportunity to change the undesired state. This will only be implemented if the issues of aquaculture will be given higher priority in the society and by an increased accountability on the roles of the different stakeholders that are, or should be, involved in the aquaculture.

7.2 Suggestions for further research

The EU-funding is very vital for the farmers and the vision of a development of a more sustainable aquaculture in the EU common fisheries policy are implemented through the EU funding. Therefore it can be important to find out the divide between how much funding from the EU went to aquaculture respectively to innovative measures in aquaculture and aquaculture pilot projects in Sweden during for example the program period 2000-2006, by doing a survey of the decisions on applications.

The companies from Åland are having the dominating share of the production in Sweden. In which ways is that affecting the aquaculture industry in Sweden? How does that impact the regional development through amount of employments and who is being employed? The companies have big and commercial scale productions and therefore more capital than smaller productions, can that be a possibility or threat for a development of a more ecological, economical and social sustainable aquaculture?

The tradition and history of aquaculture in Sweden is different from the other Nordic countries where the aquaculture productions are much bigger and managed in other ways. This study could be done in the other countries where it could show whether or not the aquaculture systems are in desirable states and show what kind of possibilities and barriers there are for development of a more sustainable aquaculture in those countries.

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Appendix 1

Figures

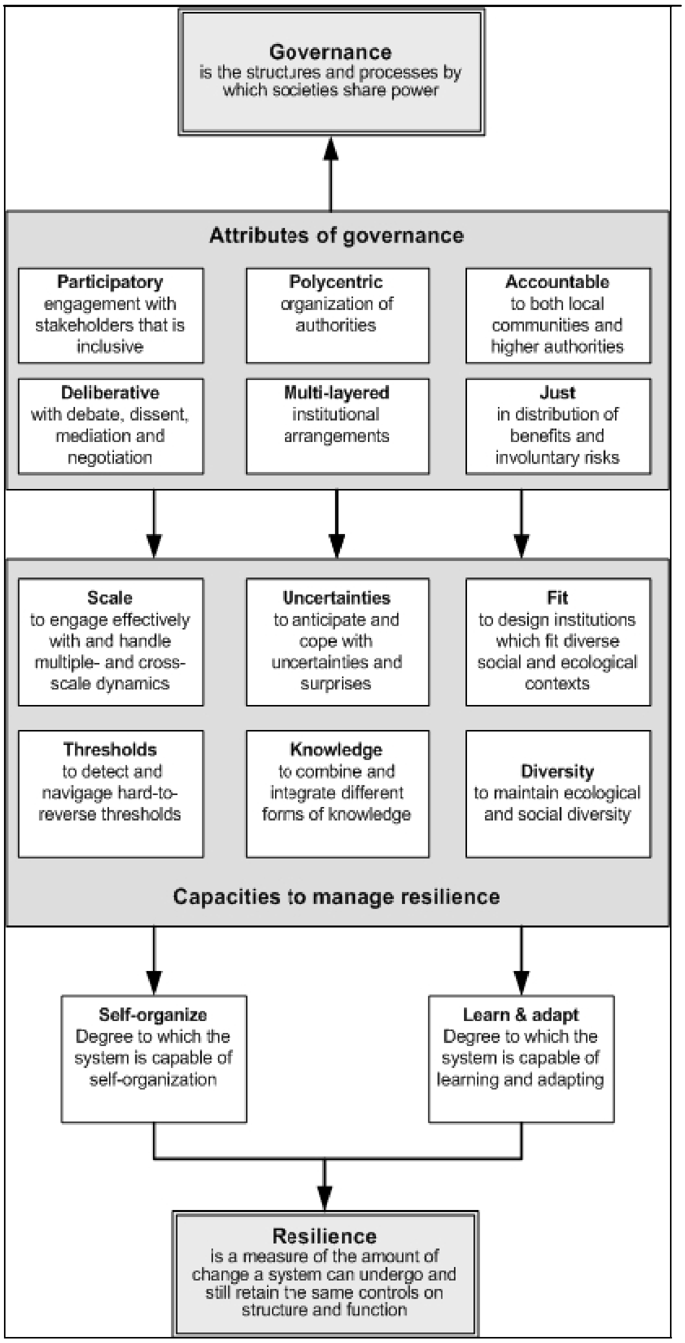

Fig. 5. Associations between selected attributes of governance systems and the capacity to manage resilience. (Lebel et al. 2006)

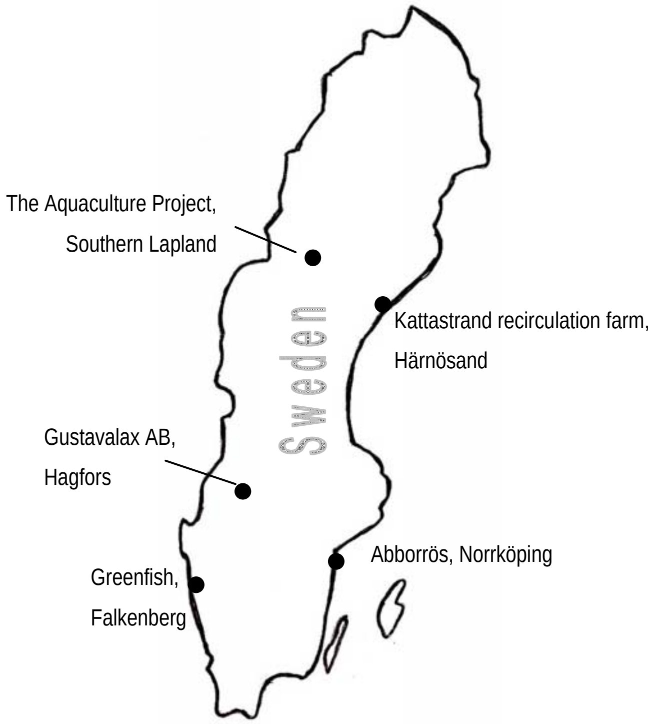

Fig.6. The location of the case studies in Sweden

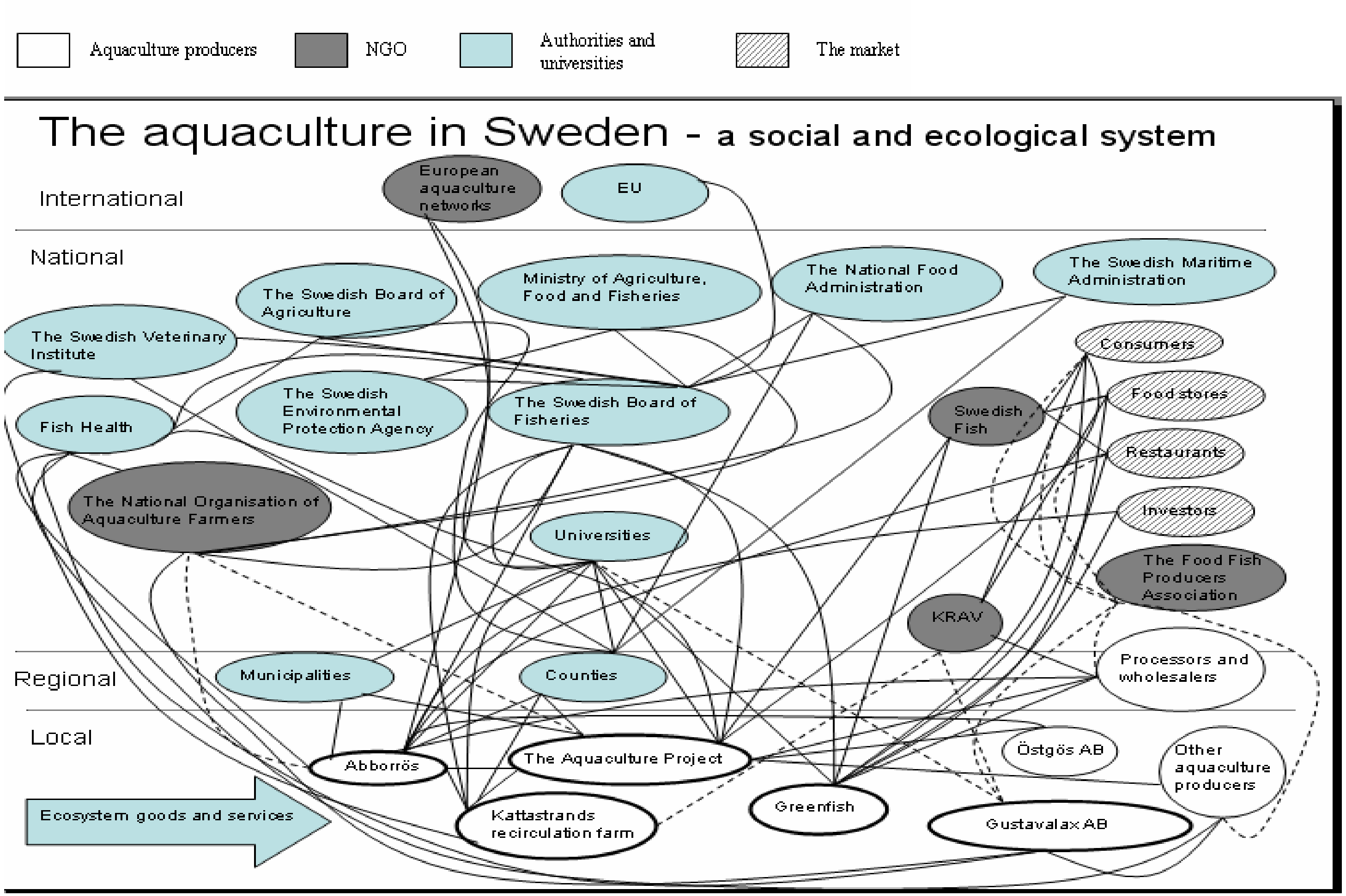

Fig. 12. The aquaculture in Sweden – a social and ecological system. The chart describes the social network between stakeholders in the system on different organizational and spatial levels. The case studies (thick black lines around the circles) are on local level, provided by ecosystem services and goods. The dotted lines are contacts that have been made earlier, but are presently not actual due to different reasons. The lines represent the connections that the actors have and these can be different kinds of connections: one time or regular communication, one way or both ways communication, "good" or "bad" communication (collaborations, corporations, reciprocity, trust, conflict etc.) or formal or informal communication.

Appendix 2

Interview list

Interview 1 – farmer

Interview 2 – farmer

Interview 3 – farmer

Interview 4 – farmer

Interview 5 – farmer

Interview 6 – scientist

Interview 10 – scientist

Interview 12 – NGO

Interview 14 – governmental organisation

Interview 15 – authority

Interview 16 – authority

Interview 17 – scientist

Interview 18 – scientist

Interview 20 – authority

Interview 25 – scientist

Interview 32 – NGO

Interview 33 – investor