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Fishery co-management; a sustainable way to develop fisheries?

A multi-disciplinary assessment of the fisheries in Lake Vättern, Sweden.

By: Audrey van Mastrigt S1773402

Preface

The internship is in context with the specialization Science, Business & Policy and the master Marine Biology at the University of Groningen. The internship was conducted at the Swedish University for Agricultural Sciences (SLU) Department for Aquatic Resources in collaboration with the EU GAP2 project. The internship took place over a period of 26 weeks from 10 January till 5 July and was supervised by Alfred Sandström (SLU), Franke van der Molen (University of Groningen), and Britas Klemens Eriksson (University of Groningen).

Acknowledgement

I would like to take this opportunity and express my sincere gratitude to my supervisor Alfred Sandström at the Department for Aquatic Resources, Swedish University of Agricultural Sciences, whom has guided me through the project from start to finish in Sweden. I would also like to thank my other supervisors Franke van der Molen and Britas Klemens Eriksson at the University of Groningen, your input, advice and encouragement have helped the project come to a good end product. The work was in part financed through support from the European Union's Seventh Framework through the Science and Society Programme project number 217639: Bridging the knowledge Gap between Fishermen and Science (GAP2). This work does not reflect the Commission's views and in no way anticipates its future policy in this area.

I would also like to show my appreciation to all of the staff at SLU department for Aquatic Resources for hosting me and for your kindness, which made me feel at home during my stay. Furthermore, I would like to thank the interviewees and the members of the Jönköping County Administrative board in particular, Beatrice Alenius, Måns Lindell and Michael Bergström for providing me with important information that was needed for the project to proceed.

Finally, I want to thank my friends and family for their support and encouraging words at times when I needed it most.

Summary

Mismanagement of fisheries is one of the main reasons for the critical situation fisheries face today. Therefore, there is a demand for new management strategies that can help to develop sustainable fisheries. One of these new upcoming governance approaches in fisheries is co-management. Co-management is a governance arrangement where resource users are involved in the decision making process. It aims to develop sustainable fisheries by integrating the ecology of the fishery system with the social and economic aspects associated with the fisheries. This is something that centralized 'top-down' management forms of governance have often failed to address. This study aims to assess whether co-management indeed does lead to more sustainable fisheries using Lake Vättern as its case study.

Lake Vättern is a unique, deep, oligotrophic lake situated in southern Sweden with a long tradition of both household and commercial fisheries. The fish catch statistics have shown a gradually declining trend since the 1970's. In the early 21st century, the commercially important Arctic char and whitefish reached alarmingly low levels due to over exploitation. As a consequence of these declining catches and poor stock statuses, an entire suite of new fisheries regulations was implemented. During this time period a co-management group was also founded by the Lake Vättern Water Society to bring stakeholders together and resolve ongoing conflicts. The new fisheries regulations have been considered successful, but an unanticipated problem arose. The fish populations have shown signs of recovering in Lake Vättern and are currently in better conditions, but the new regulations on commercial fisheries prevents the fishermen from exploiting some of the stocks. Due to the stringent fishing regulations and the high profit made off of crayfish, the fisheries have become mostly dependent on the exploitation of signal crayfish.

The co-management group has been a relatively successful arrangement as it is one of the three pilot projects that continued to exist after the trial period, from the six that were initiated. Clearly defined boundaries, a variety of stakeholders, a skilled chairman, a long-term vision and good communication about goals and means are characteristics that mark the success of the co-management arrangement. The sustainability of the fisheries in Lake Vättern was assessed using an interdisciplinary rapid appraisal technique (RAPFISH) analyzing the time period 1994-2012. Results from the RAPFISH show that the sustainability score of the commercial fishery in Lake Vättern has improved since the onset of the new regulations and the formation of the co-management group in 2004. The sustainability score mostly improved for the ecological and social aspects concerning the fishery. No apparent trends for economic and/or technological attributes were shown within this time frame. From the analysis it can be concluded that the co-management group mostly contributed to an enhanced social sustainability and possibly indirectly influenced the ecological sustainability. The positive trend in the ecological sustainability is best explained by the implementation of the new fishery regulations.

The future of Lake Vättern shows an increase in exploitation from recreational fishermen, a possible decrease in the crayfish population and the potential to exploit a larger variety of commercial fish species. My suggestion for the fishery in Lake Vättern to continue in a sustainable manner is to improve the economic environment of the fishery whilst conserving the fish stocks and maintaining a positive social environment. This can possibly be achieved by implementing methods that increase the profitability from the commercial fish species.

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Abbreviations

CAB: County Administrative Board

CFP: Common Fisheries Policy

CPUE: Catch per unit of effort

EMFF: European Marine and Fisheries Fund

FIFG: Financial Instrument of Fishery Guidance

LVWCS: Lake Vättern Water Conservation Society

SBF: Swedish board of fisheries

SLU: Swedish University of Agricultural Sciences

SwAM: Swedish Agency for Marine and Water Management

VVF: Vätternvårdsförbundet

1 Introduction

1.1 Incentives for project

The commercial fishery stocks in the European Union are in critical condition. There is a general decline in the quantities of mature fish since the 1970's, which corresponds with an increased abundance of fish taken annually (Commission of the European Communities 2001). Fish stocks are heavily exploited and if the fisheries will continue in the same manner fish stocks will face overexploitation or even depletion. This is also the case for Swedish fisheries. Both coastal and inland fisheries have experienced high mortality rates and declines in commercial fish stock populations. On a global scale inland fisheries have received little attention in the ongoing discussion of overexploitation of aquatic resources. However, harvest from inland fisheries has shown increasing trends in both developed as well as developing countries (Allan, et al. 2005). Some inland fisheries have show to trends where commercial fishing becomes increasingly economically less important, which causes them to divert away from commercial fishing and towards increased recreational fishing. Often recreational fishing is not well documented even though they contribute significantly to the total inland harvest (Allan, et al. 2005).

There have been many attempts to control these fisheries. However, few management schemes have been successful in managing the fisheries in sustainable way. The management strategies that were chosen often result in conflict and heavy discussions. The central 'top-down' management system is strongly criticized. In the past decade, there has been a shift in policy and objectives of fishery management from addressing only short-term interests such as maximizing annual catches and employment, to addressing both long and short-term interests such as long-term welfare and sustaining ecosystems (Pomeroy 2001). Thus, there is a trend where authority is transferred from fishery administration to user groups.

The fisheries in Lake Vättern can also relate to these trends of declining fish stocks and management decisions leading to increased conflict and discussions. The commercial catch of Arctic char and whitefish has been in decline since the 1970's. The combined catches of these two species went from 200-210 tons annually to 5-10 tons annually (Official catch statistics from Swedish Board of fisheries). As the commercial fish catch continues to decrease the recreational fish catch has shown to exceed that of the commercial fishery (Vätternvårdsförbundet 2012). Due to the decreasing abundance in catch of commercially important fish species while catch effort continued to increase, stringent regulations were enforced to remediate the fish stocks. Regulations were implemented for both the commercial fisheries as well as recreational fishers. The drastic changes led to a decline in traditional fisheries targeting whitefish and other commercially important fish species. This was also strongly mediated by the increased importance of the crayfish fisheries. The conflict that arose during the implementation and enforcement of these strict fishery regulations led to the formation of a co-management group in 2004/2005 founded by the Lake Vättern Water Society. This group aims to bring different stakeholders together to discuss and formulate advice on the management of Lake Vättern. This form of management uses a 'bottom-up' approach, allowing resource users to participate in the formulation of governance.

Ideally a collaborative management structure is preferred over centralized management, as it allows for increased transparency, a wider source of knowledge can be attained, regulations are more rational, conflict is reduced, regulations are more legitimate and there is compliance from the resource users (Symes 2006, Abdullah *et al*. 1998, Carlsson and Berkes 2005). Though co-management seems an ideal form of fishery management, it is also very complex and the level of involvement of stakeholders is dependent on the state of the situation. The Lake Vättern co-management group consists of a wide range of fisheries stakeholders from various organizations; resource users (commercial, recreational, subsistence, water-owners), national, regional and local authorities, environmental organizations and researchers. This project will aim to assess whether eight years of implementation of a co-management group, to regulate the fishery, has led to a more sustainable fishery in Lake Vättern.

1.2 Frame

The internship is in context with the specialization field Science, Business & Policy and the master Marine Biology at the University of Groningen. The goal of the internship is to integrate aspects of policy and management with scientific knowledge. This project had a more scientific approach therefore integrating 75% scientific aspects and 25% policy and management aspects. The final product will be an advice report. As part of the internship the intern works toward an end product, which can be implemented. The report will anticipate on the possibility of the implementation of the results or advice given. The internship took place over a period of 24 weeks from 10 January till 1 July and was supervised by Aflred Sandström, Franke van der Molen, and Britas Klemens Eriksson (Table 1).

Table 1. List of supervisors

Name	Institute	Function	Role in supervision
Alfred Sandström	SLU Institute of Aquatic Resources/ GAP2	Case study leader/ Scientist	Daily supervision
Britas Klemens Eriksson	University of Groningen department of Marine Benthic Ecology and Evolution	Scientist and teacher	Science teacher
Franke van der Molen	University of Groningen, Professional Training 'Science+ Business & Policy'	Teacher	SBP teacher

1.4 Central Question

Has a co-management form of governance led to more sustainable fisheries in Lake Vättern?

Sub Questions:

1. How sustainable is the commercial fishery ecologically, socially, economically and technologically?
2. How does the fishery on crayfish and the recreational fishery compare to that of the commercial fishery in Lake Vättern?
3. How has co-management contributed to the sustainability of the fisheries in the lake?
4. What elements are needed for a successful co-management arrangement?
5. What can the co-management group do to improve the sustainability of the fishery?

1.5 Aim and end product

The aim of this project is to evaluate the sustainability of fishery co-management in Lake Vättern using an interdisciplinary approach. The co-management arrangement will be assessed on the economic, social and ecological development of the fishery in Lake Vättern and whether this has led to sustainable fisheries.

The evaluation will assess whether the fishery in Lake Vättern has become more sustainable within the time period starting from 1994 till now. In this time period several changes in fishery governance have been made and the co-management group was formed. Using this assessment an advice/suggestions can be given on whether the co-management needs to improve on certain attributes that concern the development of fisheries and how the results can be used in developing more sustainable fisheries in the future.

1.6 Reading guide

To come to a complete assessment of the fishery in Lake Vättern and the co-management group, the report is comprised of both a qualitative analysis as well as a quantitative analysis. It starts with a general description of the case study, and then follows into the analysis of the co-management group and the fisheries of Lake Vättern. Finally, both analyses are integrated resulting in a critically formulated conclusion and a fitting advice. The advice will be directed at the Lake Vättern co-management group, but can also be used in a more general sense for other case studies that may want to initiate a co-management arrangement.

The following Chapter starts by giving a background on Lake Vättern, as the study area for this report. It describes the ecological structure of the lake and then goes on to describe the three different fisheries that were distinguished for this project which are as follow: commercial fish fishery, crayfish fishery and the recreational fishery. Finally, it describes the governance of Lake Vättern, which has been important for the development of the fishery to what it is today.

Chapter three is part of the qualitative assessment of the co-management arrangement. The chapter starts by describing what co-management is and places the co-management arrangement of Lake Vättern into context. After describing co-management in a more general sense, it goes on to describing the Lake Vättern co-management arrangement, and ends with a short analysis of the functioning of the co-management group over the past eight years of activity.

Chapter four is the start of the quantitative analysis of the fisheries in Lake Vättern. This chapter more thoroughly describes the method that was used to measure the sustainability of the fishery in Lake Vättern between 1994 and 2012.

The results from the RAPFISH analysis described in chapter four are shown in chapter five. This is followed by a discussion of the results, which will identify links with the qualitative analysis of the institutional organization.

Chapter six discusses the possible interventions or improvements that the co-management group can help facilitate, to allow for a more sustainable fishery in Lake Vättern. It primarily focuses on methods that aim to improve the sustainability in both the ecological, economic, social and technological dimension of the fishery, by increasing the value of the commercial fish species in Lake Vättern.

Finally, Chapter 7 will summarize the main conclusions that were drawn from this assessment and state the advice that followed from the assessment of the fisheries in Lake Vättern. The advice answers the central question, whether co-management has led to a more sustainable fishery in Lake Vättern. Then general conclusions are made about what factors are crucial for a successful co-management arrangement. Finally, an advice is given for the management of Lake Vättern, on how it can improve the sustainability of its fisheries.

2 Background

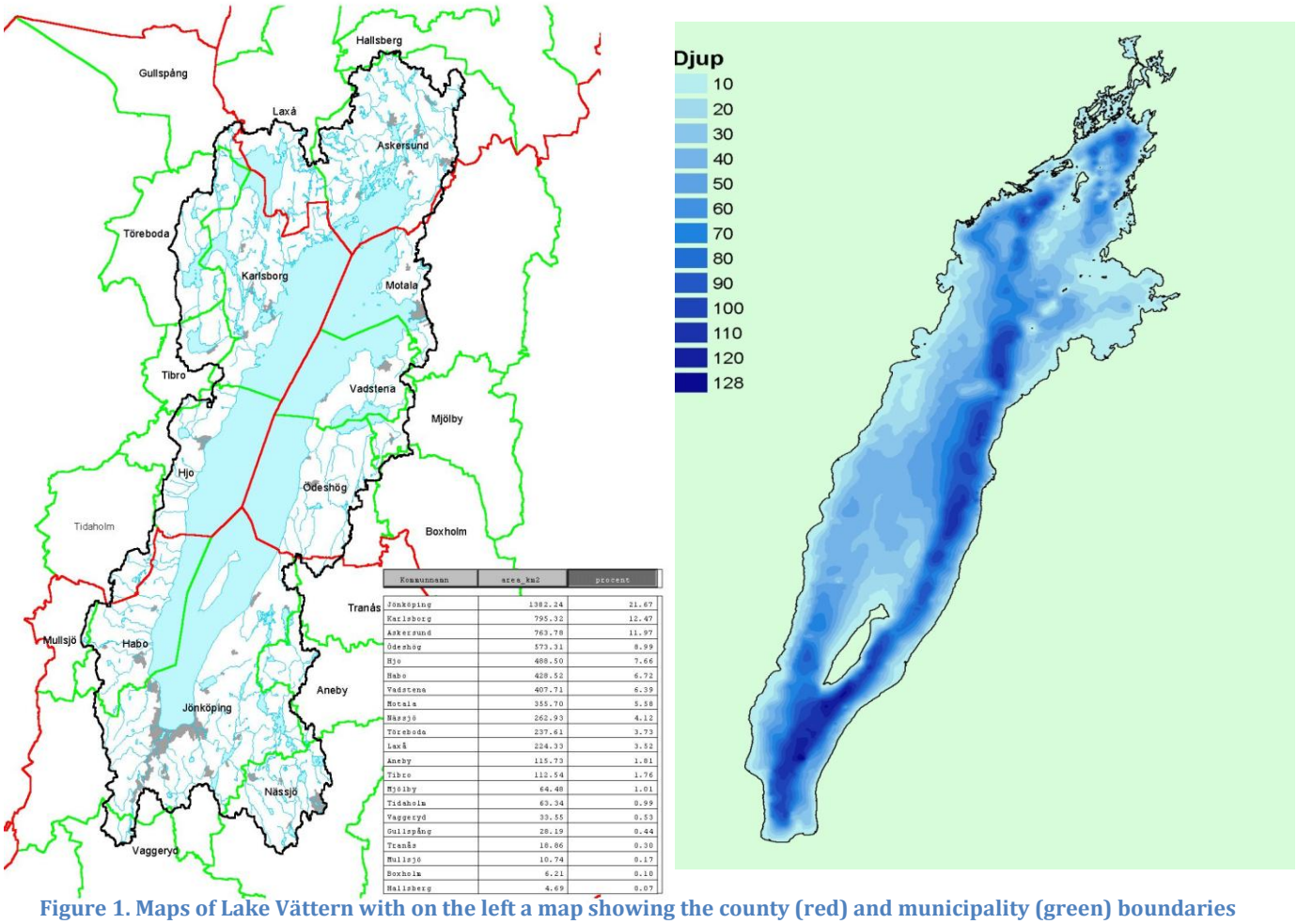
The project is based on assessing fishery co-management in Lake Vättern, Sweden. The following chapter will set the scene and describe the area in which the fisheries operate, the governance associated with the fishery and the different types of fisheries that are active on the lake and that were included in the analysis in this report.

2.1 Lake Vättern

Lake Vättern is situated in southern Sweden. It is Sweden's second largest lake and the 6th largest lake in Europe, as it stretches over a distance of 135 km from south to north (Table 2). It is a deep oligotrophic lake (Figure 1) that harbors 35 different fish species. The commercially important species that are found in Lake Vättern are mainly the fish species Arctic char (*Salvelinus alpinus alpinus*), burbot (*Lota lota*), perch (*Perca fluviatilis*), pike (*Esox Lucius*), salmon (*Salmo salar)*, trout (*Salmo trutta*), vendace (*Coregonus albula*), whitefish (*Coregonus lavaretus*) and most recently the crustacean, signal crayfish (*Pacifastacus leniusculus*) (Setzer 2012). The annual landings of the commercially important species have decreased in size dramatically with catches peaking between 200-290 tons in the 1960's to 70-100 tons in the 20th and 21st century, of which the majority of the catch comprise of signal crayfish, while whitefish catches have decreased from an average of 120 tons in the 1960's to an average of 7 tons in the past decade (Official data from the Swedish Board of Fisheries). The number of fishermen on Lake Vättern shows a similarly declining trend. At the end of the 1940's there were approximately 100 commercial fisherman and 400 part-time fishermen, this had already decreased to 40 commercial fishermen and 100 part-time fishermen in the 1970's. As of today the part time fishermen have disappeared completely, as a result of the changing fishery legislation in 1994 stating that all fishermen were obliged to have a license, and only 21 fishermen remained active on the lake today (Setzer 2012).

Table 2 A summary of the characteristics of Lake Vättern (Vätternvårdsförbundet 2012, Setzer 2012)

Maximum length	135 km
Maximum width	31 km
Average width	13.7 km
Coast line	516 km
Area	1912 km^2
Maximum depth	126 m
Mean depth	41 m
Volume	74 km^3
Catchment area	6360 km^2
Yearly Precipitation	500 mm/year
Yearly Evaporation	435 mm/year
Turnover time	60 years
Maximum visibility	17.7 m
Coordinates	58 24 'N 14 36 'E
Primary outflow	Motala ström that flows into the Baltic sea



Kommunnamn	area_km2	procent
Jönköping	1382.24	21.67
Karlsborg	795.32	12.47
Askersund	763.78	11.97
Ödeshög	573.31	8.99
Hjo	488.50	7.66
Habo	428.52	6.72
Vadstena	407.71	6.39
Motala	355.70	5.58
Nässjö	262.93	4.12
Töreboda	237.61	3.73
Laxå	224.33	3.52
Aneby	115.73	1.81
Tibro	112.54	1.76
Mjölby	64.48	1.01
Tidaholm	63.34	0.99
Vaggeryd	33.55	0.53
Gullspång	28.19	0.44
Tranås	18.86	0.30
Mullsjö	10.74	0.17
Boxholm	6.21	0.10
Hallsberg	4.69	0.07

Figure 1. Maps of Lake Vättern with on the left a map showing the county (red) and municipality (green) boundaries and on the Right a map showing the bathymetry (different depths) of the lake (Vätternvårdsförbundet, 2013; Anders)

2.2 Type of Fisheries in Lake Vättern

There are three categories of fishermen defined by law in Lake Vättern: recreational fishermen, professional fishermen and fishing rights owners. For this project the focus was mainly on the commercial fishery, which we have split into commercial fishing for fish and commercial fishing for crayfish, and recreational fishing. The following forms of fishing in Lake Vättern will be described below.

Commercial fishing

Professional fishermen are fishermen that fish with a commercial fishing license (Vätternsvårdsförbundet 2013). The commercial fishery in Lake Vättern is a small-scale fishery, which currently consists of 21 licensed fishermen. The fishermen fish on small fishing boats of less than eight meters in length and fish with passive gear mainly gill-nets and cages (for fishing on crayfish). Commercial fishery is a fulltime job for all of the fishermen and comprises of most if not all the family income. Initially, the fishery was primarily a multi-species fishery of which Arctic char and whitefish were one of the main targeted species. Since 1994, statistics have shown a decline in the catch of all commercial species and an increase in catch per unit of effort (CPUE). Since, the introduction of signal crayfish and changes in the fishery legislation, the fishery has taken on the character of a single species based fishery focusing primarily on the catch of signal crayfish in the

past decade (Figure 2). Recently signal crayfish catch statistics have also shown declining catches possibly reflecting that the stock is being overexploited.

Signal crayfish fishing

The profit made from the commercial fishery consists of 90% from signal crayfish. Signal crayfish (*Pasifastacus leniusculus*) from North America were introduced in Lake Vättern in 1969. Since then, the population has grown intensively and the supply of signal crayfish is very high. The signal crayfish cover an area of about 20% of the lake surface and the stock is estimated to be 3000 tons (Länsstyrelsen 2005). From 1999 and onwards, the commercial fishery on crayfish increased markedly. Signal crayfish is both an important species for the fishermen as well as an attraction that draws tourists and recreational fishermen to the lake. Recreational fishermen are only allowed to fish on crayfish five weekends of the year in the period that starts from the second Friday in August till the second Sunday in September (Vätternvårdsförbundet 2013). The increased intensity of fishing on crayfish has resulted in conflicts between recreational fishermen and commercial fishermen.

Recreational fishing

Recreational fishery has become increasingly important in Lake Vättern. According to the Swedish law, recreational fishery consists of tourists, anglers or sport fishermen and subsistence fishermen (Vätternvårdsförbundet 2013). Targeted fish species for recreational fisheries are mainly Arctic

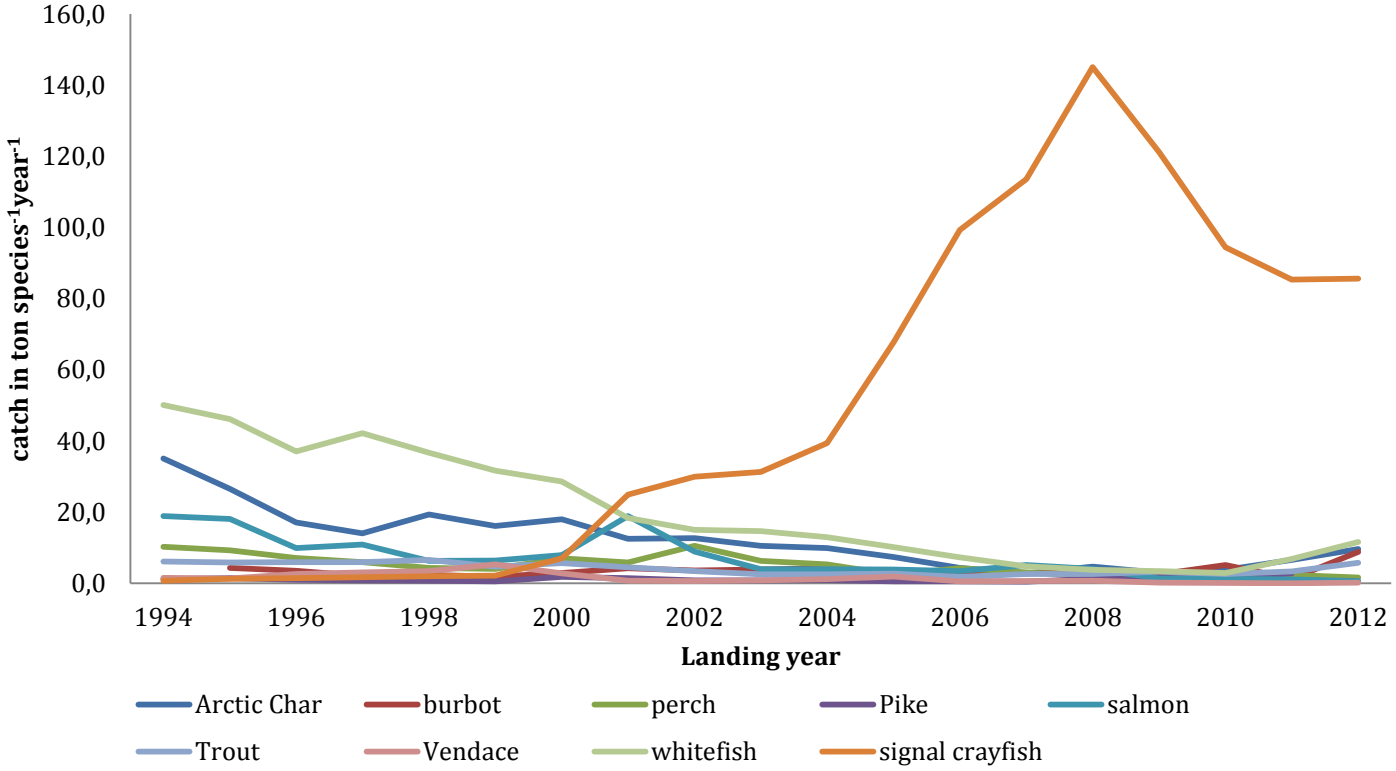


Figure 2. Graph showing the total catch of each commercially important species in ton for each year between 1994 and 2012.

char, trout and salmon. Various methods of fishing are used by anglers of which trolling, gill nets and 'utterfisker[1]', are the main methods used. Up until 1994 it was the task of the county administrative board to collect data on recreational fishery and thus annual catches were documented. In 1994 the law changed and the Board of Fisheries became responsible for monitoring commercial and recreational fisheries, and thus catch statistics were document on a national level. Since then, a few interview surveys have been done on the recreational fishery in Lake Vättern by the county administrative board in 2000, 2003 and 2010, to estimate the catch trends in recreational fishery (Vätternvårdsförbundet 2012).

The total catch from the recreational fisheries has exceeded the catch of the commercial fisheries in the past decade. In 2000 the estimated total recreational fish catch was 92 tons, while commercial fish catch was an estimated 77 tons. Recreational fishing accounted for 54% of the total catch and commercial fishery for 40 %. While in 1993, the recreational catch comprised of 40% of the total catch in Lake Vättern, thus showing a clear increase over time (Länsstyrelsen 2005). The socio-economic importance of recreational fisheries is estimated through the expense anglers devote to their leisure: licenses, fishing gear (mainly rods and lines) and other supplies (bait, clothes...), transportation, accommodation (European Commission 2006). In France, the amount spent is estimated to reach €200 to 250 per angler, and €350 to 400 in Ireland (European Commission 2006). In Sweden, it was estimated that the total expenditures from recreational fishermen, over the whole country in 2005, was approximately three thousand million (SCB 2005). Thus, recreational fishermen invest a relatively large amount on fishing each year and approximately 138,000 fishermen were active on the great lakes in Sweden (Vätternvårdsförbundet 2010).

2.3 Fisheries governance

Up until 1994 regional offices that belonged to county administration boards, regulated the fishery management. In order to have more coherent fishing rules, the management of fisheries was taken over in 1994 by the national authority. In 1994, the fishing legislation changed such that professional fishing was only allowed if you have obtained an official fishing license. This resulted in the loss of most fishermen that fished as a side occupation (Länsstyrelsen 2005). Then in 2004, stringent regulations were implemented regarding minimum legal size, closed periods, three protected areas and restrictions on bag size and use of equipment (FIFS 2004:37). The minimum size of catch for Arctic char has increased from 36 cm in 1960-1970's to 50 cm in 2007 (Setzer 2012).

According to Swedish policy, fisheries management needs to meet the criteria of social, economic and ecological sustainability. It states, in this policy, that a balance needs to be found between ecological sustainability, economic efficiency and social equity (SOU 1997/98:2; Piriz, 2004). In 2003 two new policies were adopted regarding marine and fishery strategies. They both called for a new strategy for the marine environment (SOU 2003:72) and fisheries (SOU 2003/04:51). The policies put emphasis on the development of local coastal fisheries, consultation and influence of stakeholders and testing of local collaborative management initiatives (also known as co-

[1] Uterfisker when literally translated it means 'otter fishing', however this method has nothing to do with fishing on otters. Utterfisker refers to an old fashioned way of trolling. It is a type a gear with which one can use several flies or lures (Wikipedia 2013).

management). The Swedish Board of Fisheries (SBF) was commissioned to take the lead and coordinate pilot projects. The Swedish government decided that pilot projects should be initiated in at least 5 catchment areas, two of which should be inland fisheries. One of these pilot projects was initiated in Lake Vättern and the Lake Vättern Water Conservation Society (LVWCS) founded a co-management group in 2005.

Lake Vättern borders four different counties and eight different municipalities in Sweden (Figure 1). The lake consists of both public open access waters as private waters. Private waters are considered the area of water that extends 300 meters from inland coast and 300 meters from the coast of island that are longer than 100 meters (Fiskeriverket, 2007).

For the recreational fishermen, regulations also became more stringent after 2004; a maximum of two Arctic char can be caught per day and in total only three fish may be caught. The sport fishermen are also restricted on the amount of hooks they are allowed to use and the type of fish gear. A maximum of ten rods per fishing trip is permitted.

3 Fishery co-management and user participation

The following chapter will describe what a co-management form of governance is and describe co-management according to the Lake Vättern case study. In short, fishery co-management is a bottom-up approach to managing fisheries, which evolved due to the criticism the central form of governance, had received in not achieving to manage the resource sustainably. Fishery co-management is in the general sense a power sharing arrangement between governmental authorities and the resources users. Co-management arrangements vary in the degree of legal mandate the stakeholders receive and in Lake Vättern has an advisory function. The Lake Vättern co-management group comprises of a wide variety of participants. The initial years of the co-management group were characterized by creating trust amongst participants and discussion on organization. Whereas, more recently, the discussions have been mostly on fishing and fishery regulations as well as other environmental issues concerning the lake. The Vättern co-management group has been successful, because it involved many stakeholders, had a good chairman and received long-term funding.

3.1 What is co-management?

In some cases, current governance regimes have failed to manage fishery systems sustainably. Where central forms of management have not succeeded in managing the stocks sustainably, there is a growing need for a new form of governance to allow for the recovery of fish stocks. Central forms of governance have often focused on improving the ecological status of the stocks, while failing to recognize the complex social and economic aspects that are associated with fisheries (Badjeck en Allison 2004). Co-management challenges the incentives of central governance, by dealing with fishing behavior at the local level and integrating the wealth of local ecological knowledge (LEK), by including resource users in the decision making process (Symes 2006). Co-management integrates ecology, economics and society (Pomeroy 2001). It is a form of governance, which has been widely used in managing of common-pool resources in developing countries. However, in recent years there is also an upcoming trend of user participation in small-scale fisheries in developed countries. Co-management can be characterized into two categories:

Government Leads				
		User Groups Lead		
Instructive Management centralized in government.	**Consultative** Government consult users but solely responsible for decision-making; controls the process.	**Cooperative** Government and users cooperate as equal partners in decision-making.	**Advisory** Users make decisions, based on government advice where necessary; government has a role in endorsing user-group decisions.	**Informative** User-group based management; government delegates authority for decision making to users who are only responsible for informing government on these decisions.
	CO-MANAGEMENT			

Figure 3.Typology of co-management arrangements (Badjeck en Allison 2004)

community-centered co-management and stakeholder-centered co-management (Pomeroy 2001). Where the latter form of management is usually found in fisheries in developed countries, which is the form that will be discussed further in this paper.

Many different definitions of co-management can be found in literature. The Worldbank refers to co-management as: 'the sharing of responsibilities, rights and duties between the primary stakeholders, in particular, local communities and the nation state, a decentralized approach to decision making that involves the local users in the decision-making process as equals with the nation-state'. The IUCN (1996) gives another definition and refers to co-management as 'a partnership in which government agencies, local communities and resource users, non-governmental organizations and other stakeholders negotiate as appropriate to each context, the authority and responsibility for the management of a specific area or set of resources'. Each definition tries to grasp the essence of co-management, which is generally described as a power sharing arrangement between the state and a community of resource users (Carlsson and Berkes 2005).

There is a hierarchy in co-management arrangements, which range from an organization where fishermen are slightly involved in decision making, to an arrangement where fishermen can design, implement and enforce laws. No one co-management arrangement is exactly the same, because the amount of authority given to the resource users is a political decision and arrangements need to be adapted to the region and resource in question (Pomeroy, 2001). The different forms of co-management and how they vary in degree of power that is given to the fishermen is illustrated (Figure 3). The first form of co-management, is where scientist and fishermen are reduced to providing authorities with information that they will use to form regulations. Communication in this form of co-management is mostly one-way (Jentoft and Mcay 1995). The second form of co-management, is where the resource users, in this case fisherman, have an advisory/consultative role. They can advise the government to implement certain regulations or change regulations, however the power/authority is still solely appointed to the government, which will make all final decisions. Finally, co-management can be where power and decision-making is shared between the government and user groups. A certain amount of responsibility is allocated to the producer organizations. In this form of management, the resource users can directly influence the governance. The co-management arrangement of Lake Vättern fits into the second category where fishermen and scientist have an advisory/consultative role, but can't directly influence the governance.

Co-management--- a power sharing arrangement between the state and a community of resource users (Carlsson and Berkes 2005).

3.1.1 Success of co-management

Co-management is in many cases already in place without it formerly being recognized as a co-management arrangement. There are many skeptical viewpoints on co-management and in some ways it might be represented as too idealistic to actually work in practice. However, when it is

exercised in the right way, it theoretically can have a number benefits compared to the old-fashioned centralized form of management. In the literature, examples such as projects initiated in Norway, Japan and Denmark have shown success (Nielsen and Vedsmand 1999).

Co-management allocates the responsibility and management at the local level of the resource being used. In this way knowledge about the resource is more directly accessible and decision-making is more *direct*. Ideally, a co-management structure is preferred over centralized management, because it increases transparency, a wider source of knowledge can be attained, regulations are more rational, conflict is reduced, regulations are more legitimate and there is increased compliance from the resource users (Symes 2006, Abdullah *et al*. 1998, Carlsson and Berkes 2005). Increased compliance and commitment from the resource users also leads to decreased transaction costs, thus making management more efficient (Symes and Phillipson 1999)

3.1.2 Limitations of Co-management

Though co-management has many benefits to managing a common resource such as fisheries, it is not suitable in every situation. Critics argue that reaching consensus amongst all participants is difficult and in some cases it is replaced by compromise. In such a situation, it has the risk that resource users still act out of self-interest. Pomeroy (2001) also argues that the incentive for individuals and communities to participate in co-management may not always be present. If this is the case, a co-management form of governance will not work.

Co-management is also thought to be a timely process and requires a multi-year effort, which can be very costly (Pomeroy 2001). However, when comparing a 'top-down' form of management with a 'bottom-up' approach, Hanna (1995) concludes, that even though a central form of governance may be cheaper initially it will have fewer benefits as to where a 'bottom up' approach can potentially give lasting returns (Nielsen & Vedsmand 1999). Therefore, co-management may be more costly in the initial phases but once it is properly implemented the costs of regulating the fisheries are reduced.

One other argument against co-management is that involving many different stakeholders, that have a connection to the fish resource, can make the institutional design quite complex. The complexity of the system, in some cases, might be too complex for resource users to understand and thus reduce the legitimacy of the arrangement (Jentoft and Mikalsen 2003). Jentoft and Mikalsen (2003) also argue that there is a discrepancy between the legal mandate and the responsibility the fishermen have for the effects of management. In the case of the Norwegian fishery, the fishermen receive quite a lot of power to influence the regulations, however they have no formal responsibility for the consequences of these decisions.

3.1.4 Property rights within co-management

Property rights play a central role when it comes to managing fisheries (Pomeroy 2001). Applying property rights as a management instrument gives the individual or community of resource users both the cost and benefits of the undertaken actions and therefore increases the incentive to conserve the fish stocks (Pomeroy 2001). Property rights gives the resource users the power to, use or manage the resource, sell it or grant it and take yield as harvest or rent it out (Badjeck en Allison 2004). It can be classified in four different categories depending on the level of access: open access,

state property, common property and private property (Berkes and Farvar 1989). In reality, however, property rights are more complex and may not exist exactly within these definitions. Applying property rights can have several inputs and outputs of which four are commonly mentioned: exclusivity, duration, security and transferability. The application of property rights is often imbedded in co-management regimes as co-management arrangements create a platform, which allows for strengthening of already existing property rights whether formal or informal.

Ways in which co-management can contribute to strengthening property rights and improving fishery management are setting of individual quotas or community quotas, specifying territorial user rights for fishing (TURFS), or fishing input rights (Shotton 2000).

Though strengthening property rights might seem like a good objective for fishery co-management, new right-based management regimes need to have overall support and legitimacy of the stakeholders. It should iteratively be built in within context and consultation, trust and institutional capacity building and they must remain sufficiently flexible to respond to future changes (Badjeck en Allison 2004).

Forms of property rights do exist in the commercial fishery of Lake Vättern as the professional fishermen are required to have a license. The fisher license promotes exclusivity by restricting the number of fishermen on the lake and limiting the fishermen on the type and amount of gear that they can use. Secondly, the area on the lake up to 300 meter from shore and 100 meters around an island is considered private waters. Restrictions on type of gear used still exist on the private waters, but no limit exists on the amount of gear that can be used. Some of the fishermen also own private waters and usually fish in these areas when there are many recreational fishermen out on the common waters in the summer (Johansson 2013, Sandström 2013). The areas of the lake outside of the private waters are considered open access areas, excluding the three protected areas that were implemented in 2004, where all types of fishing are restricted.

3.2 Co-management group Lake Vättern

After the implementation of new fishery policies in 2004 the Swedish Board of Fisheries (SBF), now known as the Swedish Agency of Marine and Water Management (SwAM), was commissioned to take the lead and coordinate collaborative management initiatives. The SBF initiated 6 pilot projects, two of which were inland fisheries including Lake Vättern. In 2005, the Lake Vättern Water Conservation Society (LVWCS) founded the Lake Vättern co-management group. The executive committee comprises of SwAM, LVWCS, Insjöfiskarna (commercial freshwater fishermen), Lake Vättern's Angling and Fish conservation Society (mainly subsistence fishermen), The fishing waters owners society, Sportfiskarna (sportsfishermen), Sveriges Fisketurism Företagare (fishing tourism guides), Kräftriket and Ekonomiska Förening (NGO, supporting crayfish fisheries, particularly its importance to tourism), two out of eight municipalities and two out of four representatives from the county administration boards (Vätternvårdsförbundet 2013). The previous participants and their incentives are later further described (Table 4). The co-management group acts as a forum where issues on fisheries can be addressed by the different stakeholders and in the long run formulate sustainable fishing strategies.

From the moment of initiation, the co-management group has undergone several changes in organizational structure. Organizational issues were a prominent topic during the first two years of the group. The co-management group was initially funded through the Financial Instrument of Fisheries Guidance (FIFG) during the period 2005-2006. In 2007, the group became a formalized part of the LVWCS and then became a working committee comprising of six different groups (Sandström & Norrgård, unpublished). The six working groups that were formed are: Rules and Regulations, Fishing controls, Investigation & Monitoring, Information & Communications, Fishing management in Vättern's tributaries and the Crayfish Group (Kräftgruppen). Each group will develop guideline materials and propose resolutions, so that a decision can be made jointly within the working committee. The working committee consists of representatives of each working group. In combination with the group becoming a formalized part of the LVWCS, new funding was received from the European Marine and Fisheries Fund (EMFF). Becoming an EMFF group means that the work from the working group committee should focus on sustaining and monitoring fish as well as focusing on the economic and entrepreneurial aspects of fishing (Lundholm & Crona, unpublished). In addition to receiving funding from the EMFF, the group received funding from the Seventh Framework Program, when they joined the EU GAP project in 2008. The GAP project enables the group to address participatory research issues (Alfred and Norrgård, unpublished).

The co-management group holds meetings 3 to 4 times annually at different locations around the lake. During the meetings, the topics that are discussed can be very diverse. They do not only focus on fishing and fishery regulations, but also environmental issues, conservation and other uses for exploitation of the lake (to name a few).

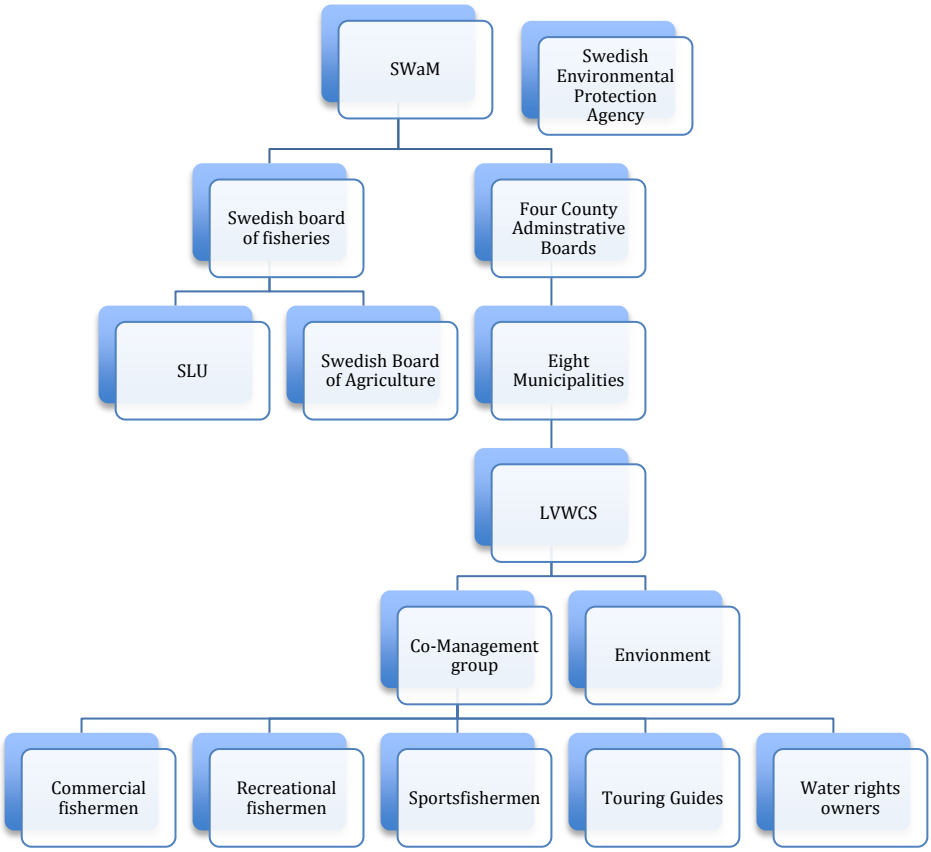


Figure 4. Diagram showing the structure of the fishery governance associated with Lake Vättern (adapted from Folkesson, 2010)

3.2.1 Activities of the co-management group

A consensus among all members of the committee has to be reached for a decision to be made. If consensus cannot be reached the issue is either postponed or rejected. Initially, there was a misunderstanding between the participants and the amount of legal mandate that they were given. The participants expected to be able to formulate new regulations, however the SBF was not able to allow this and meant for the CMI to serve as an advisory council. This might have caused for reduced motivation among the participants, however this obstacle is currently overcome.

Recently, a summary was made from the protocols from minutes of all the meetings that were held by the executive co-management committee between 2005 and 2012. From this analysis, it is possible to deduce what concrete decisions the group has made and how successful they were in terms of acceptance and implementation. This analysis could possibly help identify whether and how the co-management group has contributed to increasing the sustainability of the fishery in Lake Vättern.

Most decisions that were made, by the co-management group, were made in the period after 2007 when the co-management group had become a formalized part of the LVWCS. In the initial years, the co-management group had little effect or impact on the regulations regarding fishery regulations. These initial years were mostly characterized by discussing management and organizational structure, which would be essential for an efficient development of the co-

management group in the future. The period from 2005 till 2006 was also important for the participants to get to know each other and to build trust among the participants.

Over the years, many topics were discussed of which fishing rules and statuses of the fish stocks were a recurrent topic throughout all of the years. After 2007, other topics such as environmental issues, research, conflicts with other exploitation interests and habitat restorations were increasingly discussed.

In total, 85 decisions were made out of which 57 led to desirable results, the decisions regarded both changes in fishing rules and organizational issues. A total of nine proposals have been made to the national agency, regarding changes in the fisheries law for inland water. Four of the nine proposals have resulted in revisions of the regulations, three are pending and two have been rejected (Sandström and Norrgård, unpublished). The suggestions that have succeeded concerned rules on crayfish fishing, the number of days a net can soak in the lake without being emptied, and removing a paragraph concerning fishing with gillnets in deeper areas.

As mentioned above, the co-management group joined the EU Gap project in 2008. Joining the GAP project lead to an increased emphasis on collaborations between fishermen and scientists and approaches that help to facilitate participatory research. The outcomes of the GAP project will be further described in chapter 3.2.3.

Finally, economical topics of Lake Vättern are rarely discussed. When economy is a topic during the meetings, it concerns the annual budget for the co-management group or applying for external funding. Receiving long term funding is essential for the co-management group, to continue to exist and a long-term vision is needed for resolving issues. There is an external FLAG committee that focuses on measures that favor the long term economical development of the region that is related to the fishery i.e. through building better docks, manufacturing of fish and marketing (personal communication A. Sandström).

3.2.2 Functioning of the co-management group

Three of the six CMI continued after the trial period was over, of which the co-management group in Lake Vättern was one. Therefore, it can be assumed that they have found a successful and effective formula to manage the fisheries in this way. However, issues still need to be addressed for the long-term sustainability of the co-management group. To identify how the co-management group has functioned over the years, information was collected through the summary of the meeting minutes, interviews with several social scientists that have done prior research on the Lake Vättern CMI and use of prior articles written on Lake Vättern. Several recurrent themes were noticed on the positive and negative development of the co-management group. Overall the observations done on the co-management group do seem to support the literature written on collaborative governance in that it has led to increased legitimacy, compliance and reduced conflict (Pomeroy 2001, Symes 2006)

One of the main recurrent observations and key factors to maintaining this form of governance, was the building of trust (Lundholm and Crona in review). Before the co-management group was formed, there was little trust between the different stakeholders, which lead to increased conflicts

(Lundholm, 2013). Through the co-management group, a platform was created bringing the stakeholders together and allowing them to discuss different issues and try to resolve them. The building of trust did not immediately result but took time. Lundholm (2013) reflected back on the first meeting that she had 'never been more uncomfortable in her entire life', because of the tension that was in the room. After several meetings, the stakeholders got to know each other and a sense of trust was created. Now that the different parties had a better understanding of each other, the representatives from the different groups were in a better state to discuss and come to a compromise on how to resolve certain issues.

Another factor, that has been mentioned several times, is the role of the chairman within the co-management group (Lundholm and Crona in review, Sandström and Norrgård unpublished). First off al, the chairman is a politician with no prior knowledge or particular interest in fisheries; therefore he was seen as an unbiased participant, which the different members could confide in. Secondly, the chairman was good at mediating and leading the discussion by allowing every person to get an equal say on the matter.

Thirdly, the co-management group has created a platform in which knowledge and information is shared more efficiently between different groups. Before the co-management group was formed, Lake Vättern was in an 'institutional crisis', partly because of the uncertainty and differing views on the decline of the Arctic char stock. By sharing knowledge and information between fishermen and scientist, can clarify certain issues and increase the understanding of the resource (Lundholm and Crona in review).

Finally, long term funding is essential to maintain an institution (Pomeroy et al. 2001). The co-management group has received several forms of funding. For this type of governance to be effective a long-term view needs to be implemented. As mentioned before it takes time before this arrangement was fully functioning and trust was built between the stakeholders. Only after that was the group able to discuss other pressing issues on the agenda.

Up until now the positive development of the co-management group has been discussed, however there were also several recurrent concerns which were observed that might have lessened the functioning of the group. One of the key issues mentioned several times is the misunderstanding on the amount of legal mandate that was assigned to the co-management group (Lundholm and Crona in review, Jacobsen et al. 2011). The SWaM cannot delegate exercise of authority regarding e.g. license requests, conditions for protected areas, minimum catch size etc.; meaning that the SWaM cannot delegate the responsibility of fishery regulations and therefore not delegate this to the co-management group according to Swedish law (Fiskeriverket 2007). Some participants were under the impression that they would be able to directly influence the policies on fishery regulations; however this was not the case. The SBF, at the time, did not communicate this properly at the onset of the formation of the co-management group. When this was brought to the attention of the group, it decreased the motivation of several participants to continue. Even though this seemed to be a bump in the road, it did not break up the group. Some fishermen also identify that they are happy that someone else is responsible for enforcing the regulations.

Another criticism that the co-management group has received is the high representation of the Swedish authorities (Lundholm and Crona in review; Rova, et al. 2009; Jacobsen et al. 2011). Thus, making the co-management group more bureaucratic then it should be. Some fishermen also voiced this concern; however it doesn't seem to have had a negative effect on the efficiency of the co-management group. It rather makes the link between stakeholder and government shorter. One fisherman also mentioned that the communication and relationship with the county administrative board is very good.

Lastly, a recurring concern has been that the representatives of the different groups might not voice the views and wills of all the stakeholders (Lundholm 2013). This depends on the level of organization within the different fishery groups, which seem to be quite high around Lake Vättern. The commercial fishermen also have a committee. Approximately only half of the fishermen are however actually involved with this.

3.2.2 Facilitating participatory research

The co-management group joins the EU GAP project in 2008, which enabled the working group to address participatory research issues. One of the objectives of these tests is to increase ecological knowledge by broadening the source of information. This ultimately may lead to decreases in uncertainty about specific issues and in turn also reduce the conflicts, that might have been raised due to uncertainties. The main project that the GAP2 focuses on is the development of a selective whitefish fishery in Lake Vättern. This topic was chosen during one of the meetings allowing the stakeholders to suggest a topic, which they would be interested in. Two projects were suggested one by the commercial fishermen and the other by the recreational fishermen. In the end the majority voted for the selective whitefish project, which the commercial fishermen had brought forward. A total of 14 fishermen are currently actively participating within the project. The fishermen are positive about the collaboration with scientist and seem not to mind to invest extra time to help out with the project. The main incentive of the fishermen is that they can more easily fish on whitefish in the long run, which will also give them extra income (Carléns 2013, Grönlind, Grönlind and Gustafsson 2013, Johansson 2013). Overall, the collaboration between fishermen and scientists has been positively experienced (Carléns 2013, Grönlind, Grönlind and Gustafsson 2013, Johansson 2013). The fishermen that are involved are interested in learning new things about the resource from scientists and vice versa. The main incentive for fishermen to collaborate is out of self-interest this seems to also be an outcome in a Dutch GAP2 case working on self-sampling of flatfish (Kraan 2013). Thus, for the future of participatory research method topics need to be explored that both stakeholders have an interest in. For example, when trying to involve other stakeholders such as recreational fishermen or fishing rights owners. Involving these stakeholders is also difficult because of the low level of organization with in the groups.

Stakeholders	*Interests and Incentives*
1. **Swedish Agency of Marine and Water Management (SWaM/HaV)**	This is the national agency in Sweden that is responsible for foreseeing that common fish resources are managed sustainably. They are also responsible for implementation and regulation of fishery policies. They try to make fishing regulations as coherent as possible.
2. **County Administrative Boards (CAB)**	Four CABs surround the lake: Örebro, Östergötland, Jönklöping, Västrä Götland. The county administrative boards are responsible for environmental monitoring and supervision of the lake and they act in behalf of the SWaM. Their tasks are conducted in collaboration with Swedish University of Agricultural Sciences (SLU) and LVWCS.
3. **Lake Vättern Society of Water Conservation**	Work in collaboration with the (CAB). They are responsible to promote the maintenance of the ecosystem quality of the lake and coordinate monitoring, assessment and scientific data collection.
4. **Municipalities surrounding the lake**	There are 8 municipalities surrounding the lake (Askersund, Karlsborg, Motala, Vadstena, Ödeshög, Hjo, Habo and Jönköping) their main interest and concerns are on tourism that the lake and its resources bring to the area. Not all 8 municipalities attend the meeting, but one representative to reduce the amount of authorities that join in the meetings.
5. **Swedish University for Agricultural Sciences (SLU)**	Responsible for research and monitoring of fish stocks in Lake Vätttern. Their main interest is that fish stocks are maintained at a healthy level and that quality research and information is provided.
6. **Insjöfiskarna (freshwater fisherman)**	This is comprised of 20 licensed commercial fishermen of whom 19 are part of the co-management group. The commercial fishermen mostly have an economic incentive in participating in the co-management group.
7. **Lake Vättern's Angling and Fish Conservation Society**	Represents a large group of anglers that come to Lake Vättern for pleasure to fish. They have no commercial incentives but mostly wish to have a good fishing experience on the lake.
8. **The Fishing Waters Owners Society**	Want to make sure the fish stocks within their private waters are conserved.
9. **Sportsfiskarna (sport fishermen)**	The sport fishermen represent a large group in Sweden. They mostly fish for the experience and thus like to fish on large fish such as salmon and trout. Many sport fishermen also enjoy fishing on grayling. Their main incentives would be to keep the restocking of salmon and currently be allowed to continue fishing on grayling (communication with sprotsfiskarna representative).
10. **Sveriges Fisketurism Företagare (fishery tourism)**	To ensure a better balance between commercial fishing and fishing tourism, where authorities put more emphasis on the economic value of natural resources. It's about economic development and job creation through prudent management of fish stocks (Sveriges Fisketurism Företagare 2013)

Table 3. Represents the views and incentives of the different participants of the co-management working group.

4 Assessment

The aim of this project is to evaluate whether a co-management form of governance has led to more sustainable fisheries using Lake Vättern as a case study. Many fishery assessments focus on ecological sustainability and primarily perform complicated stock assessment analysis to determine the stock status (Pitcher and Preikshot 2001). Most of these stock assessment analysis look at ecological parameters and in a few cases economics is also taken into consideration. However, fisheries are influenced by changes in ecology and climate, economics but also social welfare and governance. To assess the sustainability of the fishery in Lake Vättern by taken these different fields into account a multidimensional rapid appraisal technique (RAPFISH) is used.

4.1 Sustainability in fisheries

Fisheries are part of a socio-ecological system and thus assessment of such a system requires an interdisciplinary approach. In practice, however, assessment of fisheries looking at ecological, economic and social criteria is scarce. Most studies are either resource based or integrate economics and ecology but often omit the social impacts (Pitcher and Preikshot 2001).

To be able to evaluate whether fisheries are sustainable, we would first need to define what sustainability is and how this can be measured. There are several definitions for sustainability. The most commonly known definition is found in the Brundtland report as; 'development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (WCED 1987). This definition of sustainability is too vague to link it to measurable attributes, thus the definition of sustainability needs to be further explored. Other definitions that followed after the WCED report focus mainly on the relationship between humans and natural resources. Such as the definition stated by Norton (1992): 'sustainability is a relationship between dynamic human economic systems and larger, dynamic, but normally slower changing ecological systems, such that human life can continue indefinitely, human individuals can flourish, and human cultures can develop—but also a relationship in which the effects of human activities remain within bounds so as not to destroy the health and integrity of self- organizing systems that provide the environmental context for these activities'. Solow (1991) gives a more economical definition of sustainability, stating that a system is only sustainable if the total capital is equal or greater in the next generation (Solow 1991).

'Sustainability is development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs'

Sustainability in a fisheries context has also been widely discussed. Adrianto et al. (2004) discusses the different paradigms in which sustainability of fishery is usually discussed. Sustainability is viewed from a conservational, rational and a social/community paradigm. According to these three perspectives sustainability should achieve a sustainable catch, be rational and economically efficient and preserve the way of life in a fishing community (Adrianto et al. 2005). According to Garcia et al. (2000), sustainable development in a global fisheries context should succeed in five

different criteria. First, the fishery should ensure food security globally. Second, the fishery ought to create competitive and profitable fishery harvesting and processing activities. Third, long-term viability of the resource needs to be ensured through these activities. Fourth, the wellbeing of the fishermen and fishery community needs to be cared for. Finally, the fishery should maintain the health and integrity of marine ecosystems for the benefit of other users (Garcia, et al. 2000). Bennet (2005) argues, that the fishery needs to maximize the costs of fishing and the value of the landed catch, which maximizes the resource rent (value of catch – cost of harvesting). In an economic context fishing effort should be maintained at maximum economic yield (Bennet 2005).

Therefore, according to the above argumentation, fishery sustainability should be defined widely (Adrianto et al. 2005). Fishery sustainability should concern resource conservation as well as integrate the social and economic aspects that are associated with the fishery system. Adrianto et al. (2005) states it quite nicely: 'while balancing of present and future catches is important---it is also important to pay attention to sustaining the process underlying the fishery'. To ensure the long-term sustainability of a fisheries this view needs to be integrated in management strategies.

4.2 RAPFISH Method

As described above, fisheries have a multi-dimensional character and to assess the sustainability of such activities it requires an integrative approach. To evaluate the sustainability, the case study will be assessed on its ecological viability, economic efficiency and social equity. To be able to integrate the analysis of the different disciplines a rapid appraisal technique (RAPFISH) was used as basis for the assessment and enables this case study to be easily compared to other case studies in the past, present and future. RAPFISH is a rapid appraisal technique designed to compare the sustainability of fisheries in an interdisciplinary manner (Pitcher and Preikshot 2001). RAPFISH analyzes the sustainability by a set of defined criteria (attributes) that are grouped within five dimensions (i.e. ecological, economic, social, technological and ethical), which are critical for the long-term viability of the fisheries (Pitcher and Preikshot 2001). For this study RAPFISH was applied to four of these dimensions and some of the attributes were changed to suit the case study better. A list can be found of the attributes and the respective scores that were assigned to them in Table 4.

Scores were given to each attribute using official catch statistics provided by the Swedish Board of Fisheries and in later years the SwAM, consultation with experts, interviews with fishermen and other stakeholders, and statistics found on Statistics Sweden (Statistiska centralbyån). Once all the attributes were scored and the matrixes completed, the Microsoft Excel software developed for RAPFISH was used to perform a multi-dimensional scaling (MDS) analysis. MDS reduces the N x M matrix of fisheries statistics for N fisheries and M attributes into a N x 2 dimensional space which has similar distance properties as the N x M statistics. (Kavanagh and Pitcher 2004). This method allows for an analytical assessment of measures that are very different from each other such as comparing social attributes with ecological attributes. In this 2D attribute space, one dimension (x-axis) is the score representing the sustainability status from 'bad' to 'good', and the other dimension (y-axis) represents other factors, unrelated to sustainability, which distinguishes the individual fisheries (Kavanagh and Pitcher 2004, Pitcher and Preikshot 2001).

Finally, a leverage analysis was performed on the attributes. A leveraging analysis shows the effect of removal of one attribute at a time of the overall ordination of fisheries (Kavanagh and Pitcher 2004). It calculates the sum of squares of the differences of the scores compared to those that are obtained with the full set of attributes. Thus for 'm' attributes, the RAPFISH analysis is run M+1 times, first with all the attributes and then M times with a different attribute removed with each iteration (Kavanagh and Pitcher 2004). This stepwise analysis results in a standard error, which expresses the leverage or sensitivity of each attribute on the sustainability score. The higher the standard error the greater the influence of the attribute has on the overall fisheries ordination. Thus the standard error represents the contribution of the attribute on how far the ordination is placed on the good or bad end of the scale.

4. 3 Scope

This project aimed to assess the fishery in Lake Vättern over the time period spanning between 1994 and 2012. This particular time period (1994-2012) was chosen due to data availability. There have also been substantial changes in governance and fishing intensity during this period making it especially interesting to study. The fishery in Lake Vättern was categorized into three different types; commercial, recreational and crayfish fisheries. Initially, the fisheries will be assessed separately and then compared in level of sustainability. The stock data for the commercial species is available per year throughout the entire period. However, for recreational fisheries the catch data was documented every year up to 1994 and after that a few assessments have been made in the years 2000, 2003 and 2010, through the use of interview surveys. It was decided to assess crayfish fisheries separately from the commercial fisheries, because the catch statistics on signal-crayfish fishery is not comparable to that of the commercial fish. The technological and social attributes will, however, be exactly the same for both the commercial fishery as crayfish fishery.

4.4 Assessment criteria

The scale used to score the attributes were similar compared to the scale suggested by Pitcher and Preikshot (2001), with the exception of a few criteria, which were excluded due to lack of data, and some were altered to suit the fishery in question better. The score reflects the average of the commercial fish species. It should be noted that when the reorganization took place at the Swedish Board of Fisheries the catch statistics were recorded differently compared to prior years. Initially, catches were reported each time the fishermen went out to fish, but after the reorganization the catch statistics were reported on a monthly basis. Per category there were between 9-12 attributes.

Exploitation status

The biological assessment of the fish species in Lake Vättern does not follow the standard FAO or ICES assessment. No exact stock size predictions are made on all the assessed species, thus I use a suite of CPUE indices to make a rough estimate of the exploitation status. Firstly, the average CPUE was calculated of all the commercial fish species using the official catch statistics on effort and catch per fishing trip. This data was complemented in the later part of the time series with data from a large-scale fish monitoring program that has been running since 2005. Data used from this program was mean catch per unit of effort (kg per gill-net and night) for each individual species.

Recruitment variability

The data on recruitment variability was not available for all commercial fish species thus an average was taken from four species (Arctic Char, whitefish, vendace and trout) for which it was calculated. It was assumed that the recruitment variability was the same over the whole time period.

Catch before maturity

Based on gillnet selectivity curves (Jonsson et al., in press). Size selection of fishing gear is described through selection curves, which are curves that are given for each size of fish for a specific species, the proportion of the population which is caught and retained by a unit operation of the gear (Hovgård en Lassen 2000). Gill-net selectivity master curves were derived using the SELECT concept (Pitcher, 1999) on data from the monitoring program that uses multi-mesh gill nets. The selectivity master curves relate retention of a specific fish species to the relative size of the fish and the relative size of the mesh of the gill-net. These, often binomial or normal fits, were used to measure the percentage of mature fish in the catch of the commercial fisheries using various mesh-sizes.

Price

The price of the fish was converted from SEK/kilo to $/kilo and corrected for the fluctuation in the value of SEK/$ for each year.

Species dependence

This attribute was added to the standard RAPFISH list and was scored between 0-2 depending on the number of species that dominated the catch. If the catch of the species was above 10% it was considered a main target species.

Trip length

The scale of the average fishing trip was adjusted from days at sea to hours on the lake as this was more suitable for the Lake Vättern fishery.

Illegal fishing

This attribute was originally categorized in the ethical dimension and for this project it was added to the social dimension. The score given per year was based on interviews with fishermen and other experts' perception on the status of illegal fishing. Most illegal fishing was associated with fishing on crayfish.

Table 4. List and definition of attributes used in the RAPFISH analysis (Pitcher, 2001) divided in to five disciplinary areas; ecological, economic, social, technological and governance. The attributes were scored through data that was acquired from official stock statistics, interviews with resource users and experts, statistics from Statistics Sweden and fishbase.org.

Attributes	Scale	Good	Bad	Notes
Ecological				
Catch Effort*	Kg/1000km net/day	1	6	Catch per unit of effort (fish fishery: kg/net crayfish: kg/cage)
Catch trend	0;1;2;	0	2	no change (0); small change (1); large change during (2)+-5 years
Exploitation status*	0;1;2;3	0	4	under-(0); under MSY (1); fully- = MSY (2); heavily- >MSY(3); or over-exploited >> MSY (4) (according to FAO scale)
Trophic level	average trophic level #	High (1)	Low (0)	Average trophic level of species in catch
Trophic level change	0;1;2	0	2	Is trophic level decreasing? No (0); slightly (1); rapidly (2)
Recruitment variability	0;1;2	0	2	COV; low<40% (0); medium 40-100% (1); or high >100% (2)
Size of fish caught*	0,1,2,3,4	4	0	Average fish size changed within +-5 years declined rapidly (0), declining (1), relatively stable(2), increasing (3), increasing rapidly (5)
Catch before maturity*	0;1;2	0	2	Percentage caught before maturity, none (0); some >30% (1); lots >60% (2)
Species caught	0;1;2	0	2	Including by-catch: low 1-10 (0); medium 10-100 (1); >100 (2)
Primary production	0;1;2;3	3	0	gC/m2/year: low 0-50 (0); medium 50-90 (1); 60-160 (2); very high >160 (3)
Economic				
Price*	0;1;2;3;4;5	5	0	Dollar/ton landed product; <250(0), 250-900(1); 900-1500 (2); 1500-3000 (3); 3000-6000 (4); >6000
Fisheries in GDP	0;1;2	2	0	Importance of fisheries in national economy; low (0); medium (1); high (2)
GDP/person	SEK/capita	High(1)	Low(0)	In region of fishery
Limited entry formal	0;1;2	2	0	Regulations on entry into fishery: none (0); some (1); lots (2)
Marketable right	0;1;2	2	0	Marketable right/quota/share? None (0); some (1); full ITQ (2)
Other income	0;1;2;3	0	3	In this fishery, fishing is mainly to: casual (0); part-time (1); seasonal (2); full-time (3)
Ownership	0;1;2	0	2	Profit from fishery mainly to: locals (0); mixed (1); foreigners (2)
Market	0;1;2	0	2	Market is principally: local/national (0); national/regional (1); international (2)
Subsidy	0;1;2	0	2	Are subsidies (including hidden) provided to support the fishery? No (0); somewhat (1); large subsidies (2)
Species dependence*	0;1;2	2	0	% of annual total value>10 %: 1 species (0); 2-4 (1); >4 (2)
Social				
Socialization of fishing *	0;1;2	2	0	% Fisherman work in a community; <1/3 (0); <2/3 (1); >2/3 (2)
Fishing community growth	0;1;2	0	2	Growth of local community over the past 10 years: <10% (0); 10-20%(1); >20%(2)
Fishing sector	0;1;2	0	2	Households in fishing in the local community: <1/3 (0); 1/3-2/3 (2); >2/3 (3)
Environmental knowledge	0;1;2	2	0	Level of Knowledge about environmental issues and the fishery: none (0); some (1); lots (2)
Education level	0;1;2	2	0	Education level compared to population average: below (0); at (1); above (2)
Conflict status	0;1;2	0	2	Level of conflict with other sectors: none (0); some (1); lots (2)
Fisher influence	0;1;2	2	0	Strength of direct fisher influence on actual fishery regulations: almost none (0); some (1); lots (2)
Fishing income	0;1;2	2	0	Fishing income as % of total family income: <50% (0); 50-80% (1); <80% (2)

Kin participation	0;1	1	0	Do kin sell and or process fish? No (0); Yes (1)
Equity in entry to fishery*	0;1;2	2	0	Is entry based on traditional/historical access/harvests? Not considered (0); considered (1); traditional indigenous fishery (2)
Illegal fishing	0;1;2	0	2	Illegal catching/poaching/transshipments: none (0); some (1); lots (2)
Technological				
Trip length*	hours	0	9	Average time per fishing trip
Landing sites	0;1;2	0	2	Are landing sites: dispersed (0); somewhat centralized (1); heavily centralized (2)
Pre-sale processing	0;1;2	2	0	Processing before sale, ex. Gutting, filleting: none (0); some (1); lots (2)
Use of ice	0;1;2;3	3	0	None (0); some (1); sophisticated (e.g. flash freezing, champagne ice)(2); live tanks (3)
Gear	0;1	0	1	Gear is: passive (0); active (1)
Selective fishing gear	0;1;2	2	0	Devices in gear to increase selectivity? Few (0); some (1); lost (2)
Vessel size	0;1;2	0	2	Average length of vessels: <8m (0); 8-17m (1); >17m (2)
Catching power	0;1;2	0	2	Have fishermen altered gear and vessel to increase catching power over past 5 years? No (0); somewhat (1); a lot, rapid increase (2)
Gear side effects	0;1;2	0	2	Does gear have undesirable side effects: no (0); some (1); a lot (2)

5 RAPFISH results and outcomes

The commercial fish fishery, commercial crayfish fishery and the recreational fishery were assessed using the RAPFISH method described in chapter four. Both a multidimensional scaling analysis and a leverage analysis was used to determine the sustainability score of the fishery and to determine which attributes most influenced the sustainability score. The results from this analysis show that Lake Vättern's commercial fishery is ecologically most sustainable compared to the economic and social sustainability. Both the ecological and social sustainability of the fishery has improved, which is possibly a combined result of the implementation of new fishing regulations and the decentralization of the governance by forming a co-management group.

5.1 Commercial fish fisheries

The results from the RAPFISH ordination are represented in figure 5, which shows the measured sustainability of the Lake Vättern multi-species fish fishery from 1994 till 2012, within the different dimensions. The ecological sustainability score ranges from 60% to 84% over the time period and shows an overall improvement. The score was lowest for the economic dimension, with values varying from 34%-38%. The economic sustainability was relatively stable over the years, but shows a slight decrease after 2005. The social sustainability score ranged from 55% to 67%, for which the time period from 2001-2005 received the lowest score (52%) the time period between 2007 and 2009 was the highest. Finally, the technological sustainability received an overall score of approximately 59%. Between 1994 and 2012 no large technological changes were observed.

A leverage analysis was performed on the different ordinations (Figure 6). The leverage scores represent the influence that the different attributes have on the sustainability score. The leverage

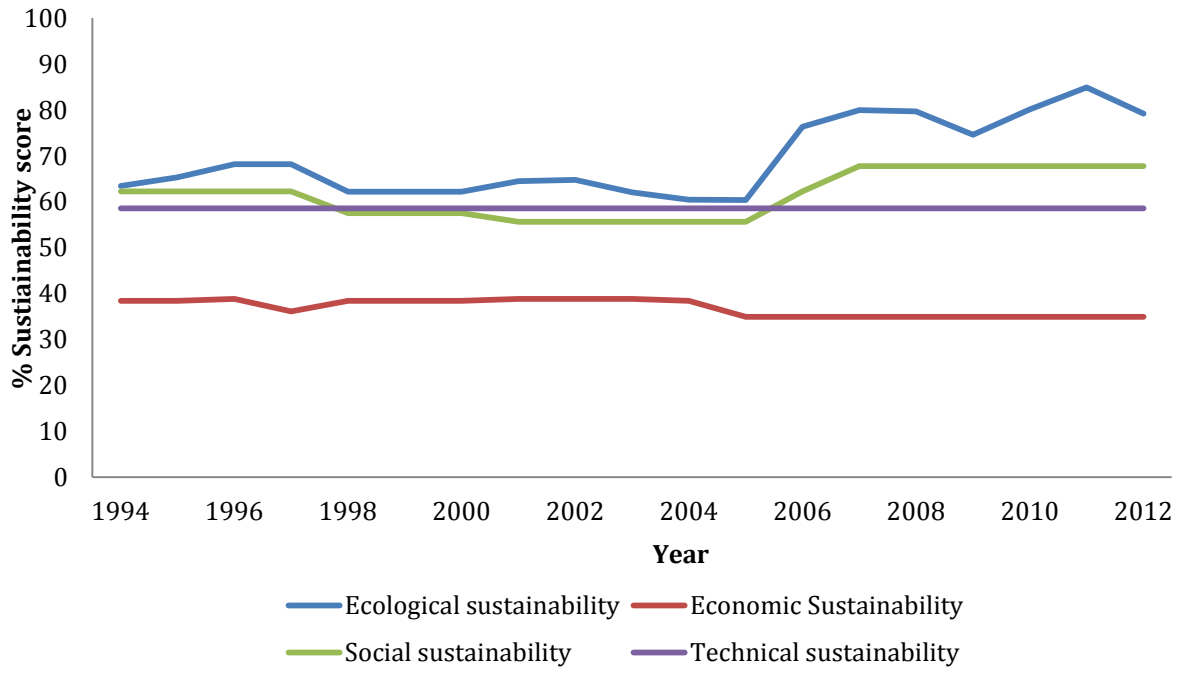


Figure 5. Represents the sustainability scores (y-axis) within the time period 1994-2012 of all four fields for the commercial fish fisheries.

analysis will help identify those attributes that had the most impact on the sustainability. From a management perspectives it can help identify which attributes had the most negative impact on the sustainability score and thus develop policy instruments aim to improve these attributes. For ecological sustainability, recruitment variability (see text box 'Recruitment variaibility') (SE ±6.4%) has the highest effect on the status of the fishery (figure 6). Recruitment variability is the variation in juvenile fish that are annual added to the population. Climate, predator and prey abundance and fishing exploitation can influence variation in recruitment (Kristiansen, et al. 2011). This is followed by the 'size of fish caught and 'trophic level change' (SE ±4.05%). Economic sustainability score is mostly driven by 'limited entry' and 'ownership' (SE ±6.1% and 5.8% respectively). Social sustainability has the highest leverage score for 'educational level' (SE ± 4.0%), followed closely by 'fishing sector' and 'environmental knowledge' (S.E. 3.5%). Finally the technological sustainability score is mostly influenced by 'gear', 'vessel size' and 'use of ice' (SE ± 3.4%, 3.1% and 2.8% respectively).

The high standard errors in the leverage analysis seem to be allocated to the attributes, which had the most extreme scores but showed the least variability between years. Thus, either the attribute scored had a bad score over the entire time period (e.g. recruitment variability was very high and thus received the worst possible score of 3) or a 'good' score (e.g. environmental knowledge which received the best possible score 2 and did not change over time). However, the attributes showing

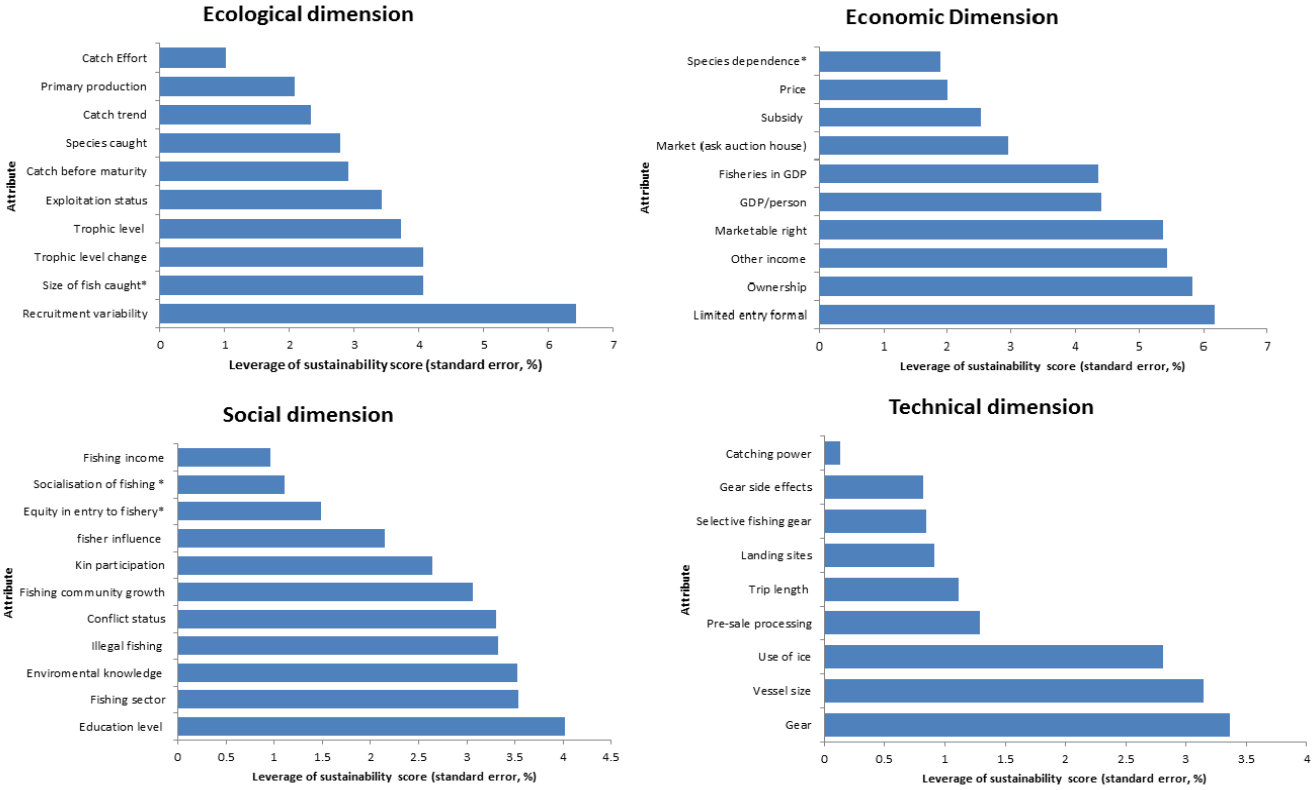


Figure 6. Leverage analysis of the commercial fish fisheries in Lake Vättern in the ecological, economic, social and technical field. The leverage was calculated as standard error of differences between scores obtained with and without including the attribute. The bars represent the standard error in percent on the sustainability axis from 'bad' to good' and has been sorted to show lowest to highest leverage score of the different attributes.

the most variability between the years are in some cases thought to be a better reflection of changing trends within the time period, which in turn will have had an impact on the ecological status of the fish stocks. These attributes are a good reflection of the market adaption that the fishery went through. The attributes that show this variability over time in the ecological dimension are 'catch effort ',' catch trend ', ' exploitation status' and 'size of fish'.

5.2 Crayfish fisheries

The fishery on signal crayfish has become increasingly important since the end of the 20th century and is now the most dominant target species comprising of 90% of the total commercial catch. Since signal crayfish have become such an important species and the fishery on this specific species has had consequences for the traditional fisheries it was assessed separately from the commercial fishery on finfish. Crayfish are also caught by different methods and thus the catch statistics are measured differently compared to the stocks of commercial fish species. For example, the effort is measured in cages/fisher/day, where as for the fish species it is in km net/fisher/day. The RAPFISH was only performed on the ecological dimension and economic dimension of the crayfish fishery

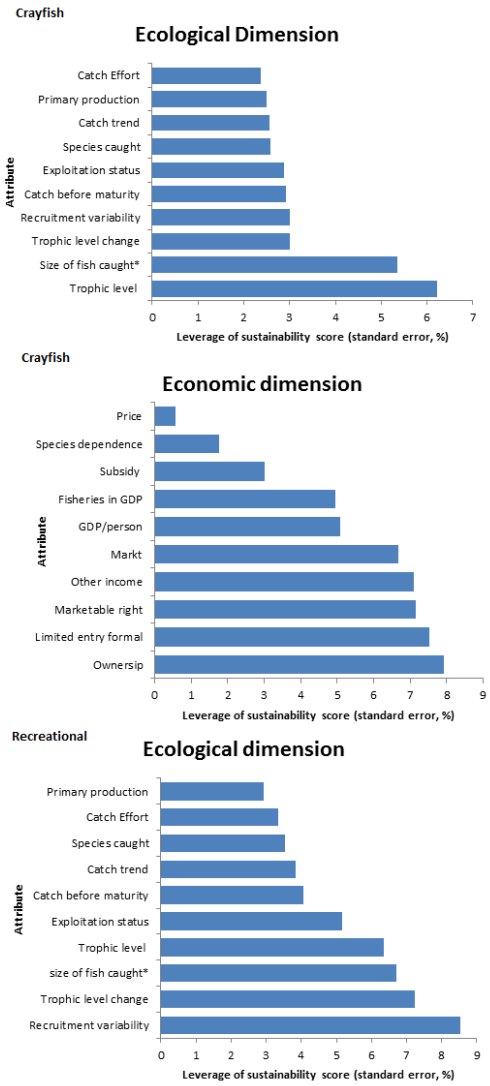


Figure 7. The leverage scores in % standard error with represent the amount of influence the attribute exerts on the sustainability score.

since the same commercial fishermen fish on the signal crayfish as the fish species in the lake; the social and technical dimensions are comparable to that of other the commercial fisheries. It is important to highlight the shift in focus from a variety of fish species to crayfish as it will have an effect on the future of the fishery.

The crayfish fishery has an ecological sustainability score between 71 % and 77%. When comparing it with the commercial finfish fisheries the crayfish fishery had a higher ecological sustainability than the commercial fishery up until 2006 (Fig. 8). After this time period, the commercial finfish fishery improved its ecological sustainability significantly, and thereby surpassed the crayfish fishery, according to the RAPFISH. The economic sustainability received a slightly higher sustainability score between 41-42 % compared to that of the commercial finfish fisheries and it also showed little variation over time.

The results from the leverage analysis show that 'Trophic level' and 'Size of fish caught' has the highest influence on the sustainability score (SE ± 6.2%, 5.3% respectively; Figure 7). The change in the crayfish fishery is best illustrated by the change in catch effort and catch trend. The catch of crayfish per unit effort (CPUE) has been increasing up until 2007 when the crayfish catches peaked (Fig. 2). After 2007 the CPUE and total catch decreased slightly either showing a declining trend or that the population has reached its maximum and the catches will stabilize.

The highest leverage score for attributes measuring economic sustainability was 'ownership', 'limited entry formal' and 'marketable right', which is almost comparable to the leverage score

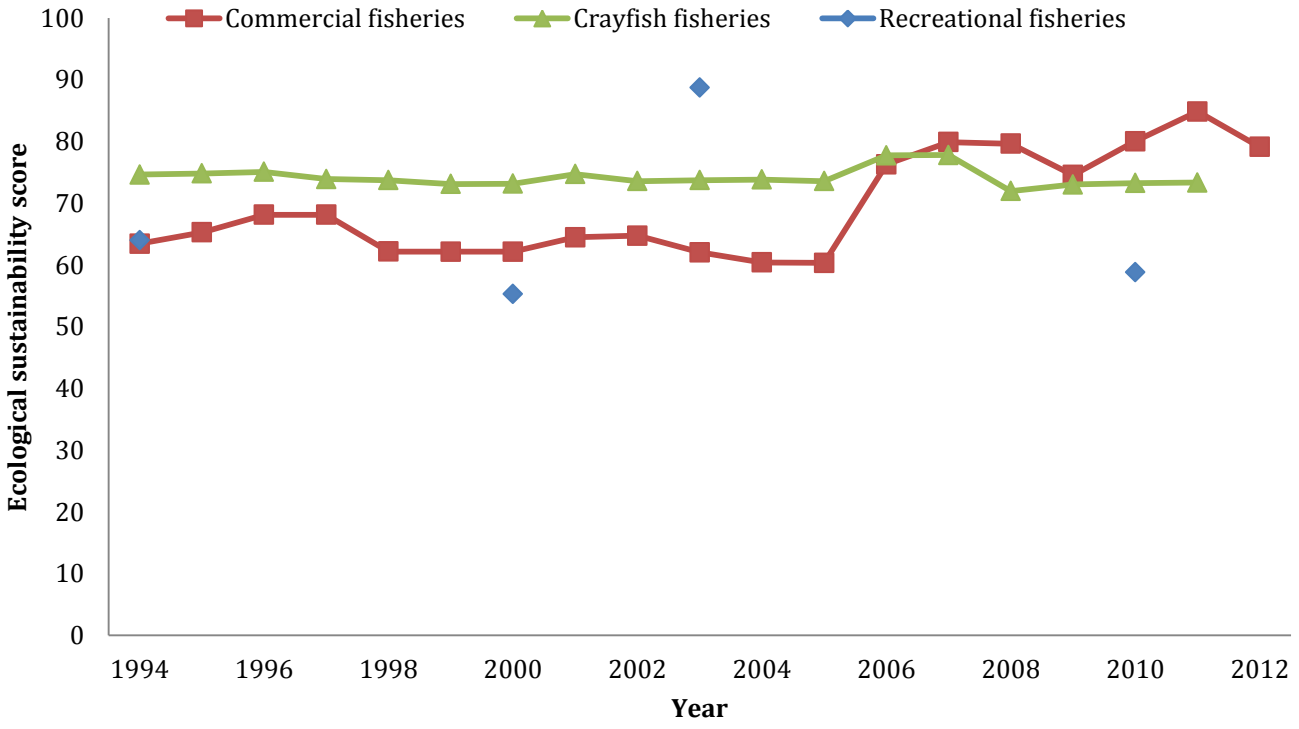


Figure 8. The ecological sustainability scores between 1994 and 2012 compared between the recreational fisheries, commercial fishery and crayfish fishery in Lake Vättern.

driving the economic sustainability for the commercial fish fishery.

5.3 Recreational fisheries

Data on recreational fisheries was not available for the entire time series. Thus the RAPFISH was based on four time points for which catch statistics were available: 1994, 2000, 2003 and 2010. Even though it was difficult to perform the same analysis on the recreational fishery as for the other forms of fishing on the lake it is important to take the recreational fishery into account. When comparing the total catch (excluding crayfish) the recreational fishermen catch in total more finfish than the commercial fishermen. Thus the impact of the recreational fishery on the ecological sustainability of the lake is equal if not larger than that of the commercial fishery.

It is difficult to assess whether there is a trend over time in the ecological sustainability since the number of data points is few. On average the ecological sustainability score of the recreational fishery is 66% and is therefore currently the least sustainable fishery compared to the commercial fishery and crayfish fishery (Figure 8). The low sustainability score possibly reflects the increased catch effort on the finfish, which exceeds that of the commercial finfish fisheries. When comparing scores given to each attribute between the years, there is little variation, however 2003 received a much higher sustainability score compared to the recreational fishery in 2000 while the only difference between the two years is that the catch trend decreased.

When performing a leverage analysis on the ecological attributes for the recreational fisheries recruitment variability has the highest standard error (S.E. 8.5%), followed by trophic level change and size of fish caught (S.E 7.2%, 6.7% respectfully; Figure 7).

5.4 Lake Vättern in a global context

One of benefits of the RAPFISH analysis is that it can be applied universally to assess different fisheries. By standardizing the method, it allows for a cross comparisons between fisheries around the world. To be able to place the fishery of Lake Vättern in a more global context, the average

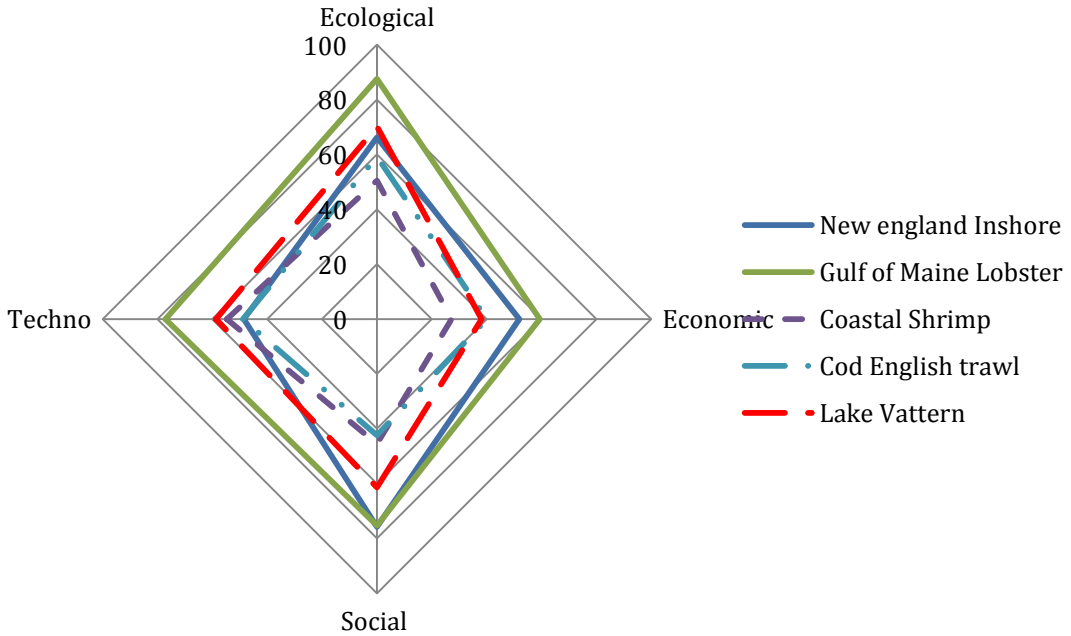


Figure 9. A kite diagram representing different fisheries that have also been assessed using the RAPFISH method

sustainability scores in each dimension were compared to other North Atlantic fisheries that have previously been assessed using the RAPFISH method (Alder, et al. 2000). Lake Vättern is in many ways very different from North Atlantic fisheries. The purpose of the analysis is to illustrate, how Lake Vättern's commercial fishery sustainability measures relatively compared to other fisheries (Figure 9). The comparison shows that Lake Vättern is ecologically and technologically more sustainable than many of the North Atlantic fisheries, but that it scores comparatively low in economical and social sustainability. Within the comparison group, the Gulf of Maine Lobster fishery is the most sustainable. In some ways the Gulf of Maine lobster fishery and Lake Vätterns fishery are alike. However, there are a few differences that have resulted in a higher sustainability score within each dimension for the lobster fishery. In the ecological dimension the fishery also suffers from a high recruitment variability, but scores well in most other attributes. For example, the lobster fishery has reduced all possible by catch and thus, it has very little discard. All the species are caught at maturity according to the RAPFISH and the size of the species caught has stayed relatively stable over the past 5 years. Economically the fishery, like Lake Vättern, is completely dependent on the income from the fisher. However, it contributes slightly more to national GDP and the fishery has implemented a full system of marketable right. This is either done through a marketable ITQ, CTQ or property rights system. When comparing the social sustainability, Lake Vättern does have fishermen fishing within a family or community and in some cases kin participate in processing fish. Therefore, Vättern has better scores for these attributes compared to the Gulf of Maine lobster fishery. However, the Gulf of Maine lobster fishery still has a higher social sustainability scorel. The higher sustainability score is possibly because the fishermen have more influence in the fishing regulations and according to the RAPFISH all level of conflict has been mitigated. Finally, the Gulf of main lobster has by far the best score in technological sustainability and this is reflected by the high dispersion of landing sites, use of highly selective gear and the gear that is used has little to none undesirable side effects.

Table 4. List of five different fisheries, which were also assessed using the RAPFISH method, including a short description of the fishery and the refrence from which the data was collected.

Fishery	Description	Reference
New England Inshore	Dredging, net and line fisheries for seasonally available stock such as groundfish, clams and herring; 1995	(Alder, et al. 2000)
Gulf of Maine Lobster	Small scale inshore pot trap fishery	(Alder, et al. 2000)
German Coastal Shrimp	Coastal shrimp fishery for human consumption; 1997 also a GAP2 project	(Alder, et al. 2000)
Cod English trawl	English trawl and seine cod fishery; 1990	(Alder, et al. 2000)
Red Sea Eritrea Trawl	Industrial trawl fishery in Eritrea around 2000	(Tesfamichael and Pitcher 2006)
Lake Vättern	Small scale multi species inland fishery in Sweden; 1994-2012	-

5.5 Integration

5.5.1 Ecological sustainability

The highest sustainability score was achieved within the ecological dimension of the Lake Vättern fisheries. Previous studies using RAPFISH have observed similar results. In these studies the ecological dimension also scored higher compared to the other dimension (Tesfamichael and Pitcher 2006). The results, described in the previous section, showed that ecological sustainability has increased over time with the greatest change occurring between 2005 and 2006. This could be a result of changed regulations that were implemented in 2004 or the implementation of the co-management initiative. The regulations increased the legal mesh size, which increased the selectivity of the nets. By increasing the mesh size the gear catches less small fish and more larger size specimens, thus it increases the size of fish caught. This indirectly will also reduce the chance of undersized, immature fish to be caught. Gill net selectivity surveys have shown that at a certain mesh size, the amount of fish caught before maturity decreases significantly (Jonsson et al., in press). Furthermore, stock assessment have also shown that the fish species have increased in size and density. Coincidently, the crayfish fishery also took off during this period further reducing the fishing pressure on the commercial finfish, which could have also lead to a more positive fish stock development.

Recruitment variability

Recruitment is the addition of new individuals to a population or to successive life-cycle stages within a population (Calley et al. 1996). Recruitment variability is the measure of the difference in the amount of juvenile species that are added to a population annually. The variation in fish recruitment can be driven by many factors and is often still poorly understood. Factors such as fisheries exploitation, habitat destruction, changes in climate and predator-prey abundance can be important drivers for recruitment (Kristiansen, et al. 2011).

Understanding variation in recruitment and population dynamics is important to be able to predict variation in fish production and develop better management regimes. Recruitment variability is expressed in coefficient of variance (COV). The lower the COV the more likely the next year will show similar results.

The attributes that caused the ecological sustainability to move toward the positive end of the scale was mostly due to an increase in the size of fish caught, the high average trophic level and the improved exploitation status. This is interpreted as a result of the implementation of the new fishery regulations in combination with market adaptation mechanisms.

The high recruitment variability (see text box Recruitment variability) of the fish species used in this part of the analyses has a negative impact on the ecological health of the fishery. The recruitment variability expressed as coefficient of variance (COV) has only been calculated for Arctic char (29%), whitefish (105.5%), trout (56%) and vendace (204%). From these four species the average recruitment variability was high. The high recruitment variability of whitefish and vendace can be a consequence of a high inter-specific competition (Personal communication A. Sandström). Since these two stocks are densely populated while the fishing pressure and predation

rate at the moment is a low, the species compete heavily. This competition can produce density-dependent dynamics inducing pulses in recruitment (Hamrin and Persson, 1986; Helminen and Saravala, 1994). The high variation in the amount of juveniles that are added to the population each year, makes it more difficult to make accurate stock predictions. High recruitment variability, thus, makes it more difficult to manage the fisheries. The recruitment variability cannot be influenced from a management perspective, but data collection on stock prediction can be improved to allow for a better understanding of the fish populations found in Lake Vättern. This also shows a weakness in the RAPFISH analysis since these density dependent mechanism will give a biased estimate of the sustainability.

The RAPFISH analysis does not show the causal relationship between the different variables; however, studies have shown socio-ecological feedbacks in fishery management, which do affect the sustainability of a fishery (Österblom, et al. 2011, Murillas, et al. 2008). To evaluate whether co-management directly had influence on the health of the fish stocks is difficult to determine. Fishery stocks can be affected by many factors and are often unpredictable (Ulltan 2002). However, changes in stock status usually show a lag in time after new management regimes or policies have been introduced. Some of the attributes have clearly received a better score due to changes in regulations and thus improving the ecological sustainability. The results of the institutional outcomes of the co-management group (Chapter 3.2.1) showed that the working committee had made several suggestions, towards the SBF, to change the fishery regulations. Four of them have led to actual alterations of the fisheries policy.

5.5.2 Economic sustainability

Trophic Level

Throphic Level (TL) is the position that an organism occupies in a food chain. Thus it reflects what it eats and what eats it. It is the integral count number of the number of consumption steps between a primary producer, which has a TL of 1 and that of the species (FAO 2008).

TL is usually determined by the de diet of the species and reflects the proportion of prey species found in the stomach.

Both the commercial finfish fisheries as well as the crayfish fisheries had the lowest sustainability score for the economic ordination relative to that of the other dimensions. The results from the RAPFISH showed that crayfish fishery had a slightly higher economic sustainability compared to the commercial finfish fisheries. This is mainly caused by the high profit that is made from the crayfish compared to that of the finfish.

The limited entry of new commercial fisherman and the local market to which the fish profit goes mostly determine the economic sustainability of the fishery. Since commercial fishermen had to have a fishing license by law in 1994 the number of fishermen on the lake reduced significantly. For a new fisherman to obtain a fishing license is not very easy. The fishermen must have a history in fishing and a new fisherman will only be able to enter the fishery in Vättern if another one leaves. By limiting the amount of licenses, the authorities regulate the number of commercial fishermen on

the lake and thus to some extent the effort of the fishery. Keeping the number of fishermen at a minimum regulates the fishing pressure. The commercial fisher is in that sense regulated sustainably, but no such regulations exist for recreational fishermen. Recreational fishermen can fish anywhere on the lake using a single rod and reel. When they use other forms of gear they are restricted to the common waters. Because of this, there is no limit on number of recreational fishermen that fish on the lake. If the recreational fishing industry continues to grow, it may lead to more uncertainty about the fish stocks since they are not obligated to report their catches.

Due to the crayfish fishery, the commercial fishery in Lake Vättern has been profitable for the commercial fishermen; however the fishery is of low importance to the national economy. The results from the RAPFISH showed that the absence of a marketable right and the fact that the fishing is a full-time activity for the fishermen reduced the economic sustainability. Other means of income can be important to have in case the resource might collapse due to overexploitation. And the profitability can be increased through after sales processing of the commercial fish species, which will be further explained in chapter six.

The low variation in economic sustainability shown through the RAPFISH analysis, suggests that here seems to be no direct influence of the change in governance on the economy of the fishery. The lack of discussions on the economics of the fishery by the co-management group (discussed in the chapter 3), also shows that the co-management group has had little influence on the economic sustainability. However, this could be a topic that the co-management group can focus on more now that the fish stocks are in a relatively more healthy state.

5.5.3 Social sustainability

When looking at Lake Vättern from a social perspective, the results from the RAPFISH show that the social sustainability has improved since 1994. The commercial fishery was least sustainable during the period 2001-2005, which was characterized by the institutional crisis that the fishery found itself in. Together with the ecological dimension the social ordination underwent several changes over the years.

The fishery is characterized by the low number of household that are engaged in the fishing sector , the high amount of environmental knowledge the fishermen are perceived to have and the decrease in conflict within the fishing sector, each contributing to a positive social sustainability score. Another attribute, which improved over the time period and contributed to an increased social sustainability, was the fact that the fishermen had more influence on fishery regulations compared to the previous years.

The attributes which contributed negatively towards a social sustainability was mainly the below average educational level and in some years the high level of conflict and illegal fishing. However, low educational level among fishermen is not unusual within the fishing industry (FAO 1998). Hence, it should be noted that the Lake Vättern fishermen might have a relatively low educational level on a national scale, but in a global perspective the educational level of the fishermen is above average (Garavito-Bermúdez et al. in review).

A study was recently done trying to describe fisher's ecological knowledge by using Lake Vättern as a case study (Garavito-Bermudez, in review). Garavito-Bermúdez et al. (in review) identified that the level of ecological knowledge was depended on the years of experience of the fishermen and the number of species they fish on. Hence, fishermen mainly fishing on crayfish had less knowledge of ecological interactions compared to fishermen that fished on a wider variety of fish species. However, all fishermen seem to have a substantial amount of ecological knowledge and also kept themselves educated by reading reports from the SBF and scientific articles. Fishermen also tended to develop hypothesis from their experience and knowledge that they had formed after reading reports and articles and often test these whilst out on the lake fishing (Garavito-Bermúdez, 2013). These results seem to correlate with the observations that were acquired during this project. From the interviews with fishermen, it became clear that they had knowledge of trophic level interactions and were also able to identify different causes for the changes in the fish population. For example, during one of the interviews the fisherman identified that the increase in certain fish species could be a result of multiple causes; change in fishing regulations, enforcing protected areas, changes in fishing pressure (Carléns 2013). While during another interview, the fisherman also talked about changes in fish populations due to changes in prey species. 'Arctic char and trout are dependent on the smelt population (Johansson 2013) '. In the second interview, the fishermen identified that the lack of nutrients affect the size of the fish population and that due to a peak in the nutrients, making the lake 'almost eutrophic, was the cause for the large catches in the 70s' and 80s' (Grönlind, Grönlind and Gustafsson 2013).

Finally, illegal fishing and conflict status have changed over the years and thus influenced the sustainability scores both positively and negatively. Illegal fishing was noted to be very high in 1998 which also resulted in a high amount of conflict. During this period the Arctic char stocks were in poor conditions, which led to heated discussion as to why this was happening and what should be done about it (Lundholm, 2013, Grönlind, Grönlind and Gustafsson 2013). The increase in popularity and demand of crayfish also led to more illegal fishing, especially between 2002-2005 when the crayfish catches peaked (Johansson 2013).

Co-management seems to have the most direct influence on the social sustainability. After the establishment of the co-management group, a few factors affecting the social sustainability improved such as the conflict status, the influence the fishermen have on the governance and the amount of illegal fishing. As mentioned earlier the co-management group formed a platform that enhanced the formation of trust between the stakeholders and increased the transparency of regulations. This resulted in a better compliance from the stakeholders a greater feeling of accountability for the resource at stake. These are social implications that in the long run will also improve the ecological health of the lake. The results are comparable to the socio-ecological feedback loops Österblom et.al. (2011) describes as a result of successful fishery management. It is also thought that a positive development of the fish stocks has led to a better compliance and helped maintain the co-management group (Österblom, et al. 2011, Sandström and Norrgård unpublished).

5.5.4 Technological sustainability

The technological dimension of the commercial fisheries showed no change between 1994 and 2012 and therefore received the same sustainability score for each year. Most of the major technical changes that make the fishery as it is today have occurred long before 1994. Small improvements, such as making gear more efficient, continuously occur but no changes that have substantial impact on the fishery.

The technical attributes that characterize the fishery and contribute to a good sustainability are the small vessels, the passive gear used and, since it is an inland fishery, making trips of maximum 8 hours a day. Furthermore, most attributes scored neither good nor bad. For example, the use of ice during a fishing trip: the fishermen do use some ice but they don't use sophisticated champagne ice or live tanks to preserve the catch in The use of such equipment would make the fishery more technologically sustainable according to the RAPFISH. Another example is the amount of before sales processing the fishermen do. On average they do some processing such as cleaning the fish, but most of the fishermen don't prepare the fish fully. The technological aspects of the fishery in Lake Vättern will not change much over time, as the fishery itself will remain a small-scale fishery. However, there are ongoing projects that aim to improve the selectivity of the gear. One of these projects is GAP2, which aims to find a method to fish on whitefish by minimizing the by-catch of undersized Arctic char.

6 Policy interventions to improve local sustainability

The fishery in Lake Vättern has shown an overall increase in sustainability since the introduction of new fishery regulations and the formation of a co-management group. When placing the commercial fishery of Lake Vättern in a global context it also seems to be doing relatively well, often having an average sustainability score compared to others that have been assessed using a RAPFISH analysis. This also shows that there is room to improve the sustainability of the fishery in Lake Vättern or the fishery can possibly learn from other case studies that are more sustainable. Potentially, the co-management group can contribute to this. As fisheries are dynamic, often unpredictable and the recreational fishery is becoming increasingly large, it is important for the co-management group to continue to strive for a most effective and sustainable management of the fishery on the lake. The following chapter will aim to give suggestions on ways the fishery sustainability can be improved according to the outcomes discussed in the previous section. From the results, I conclude that maximizing the value of the commercial finfish species will have the most potential to increase the sustainability in all the four measured dimensions. The section also contains a number of suggestions on how to improve the sustainability of the fishery from a management perspective.

6.1 Improving the economy of Lake Vättern's fishery

Economically the fishery in Lake Vättern is the least sustainable, according to the results from the RAPFISH analysis. The results show that the low score is mainly due to the lack of a marketable right and the income dependence of the fishermen on the fishing industry. However the fishery is profitable for the fishermen due to the crayfish. The economic sustainability of the recreational fishery was not assessed, however with the increase within the recreational fishery sector the recreational industry will increasingly compete for fish with the commercial sector. An increase in recreational fishing will also have further economic implications as recreational fishermen invest in fishing gear and spend money on travelling and accommodation. For Lake Vättern to become a more efficient and profitable fishery in the long term, it can strengthen the already existing property rights system by implementing some form of marketable right and/or increase the price of the fish species through other ways.

6.1.1 Strengthening the property rights system

A flexible form of fishing rights is thought to increase the incentive of the stakeholder to conserve the aquatic resource and at the same time increase the profitability of the fishing industry (Hentrich and Salomon 2005, Christy 1992). The European Committee also suggests, in a study done on the inland fisheries in 21 of the EU member states, to implement private fishing rights for commercial fishermen as a mean to mitigate conflicts between anglers and professional fishermen and resolve the difficulty for new entrants to join the commercial fishery (European Commission 2006). These fishing rights can also be leased to recreational fishermen, which is interesting from an economical point of view (European Commission 2006).

Property rights do exist in the commercial fishery of Lake Vättern (see chapter 3.1.4). The property rights include the commercial fishing license, restrictions on use of gear and private waters versus open access waters. Some of the fishermen also own private waters and usually fish in these areas when there are many recreational fishermen out on the common waters in the summer (Johansson

2013, Personal communication A Sandström). Other fishermen also rent the right to fish in private waters of farmers or industries around the lake (personal communication M. Bergström).

A study assessing the crayfish stock in common and private waters clearly showed that over time, and cumulative catch, the CPUE of the crayfish declined within the common waters but stayed stable in the private waters (personal communication A. Sandström). Fishermen are more prone to conserve the fish and crayfish stocks on their private waters and rather overexploit them in the common waters, which other studies have also confirmed (Christy 2000). Thus, extending the property rights that are already in place will increase the incentive of the fishermen to conserve the stock and increase the likelihood of a long-term socio-economical sustainable fishery. From the RAPFISH analysis marketable right received a low score and had a high negative impact on the economic sustainability. Thus, improving the marketable right in Lake Vättern will potentially increase the economic sustainability.

One form of exclusive negotiable fishing rights, which is commonly used in areas with a small fishing community and relatively static stocks (as is the case for Lake Vättern), is a more regionalized group based management system (GRF) based on territorial user rights (TURFS) (Hentrich and Salomon 2005, Christy 2000).

The setting of protected areas and technical provisions on fishing gear, are instruments that address overfishing and in the short-term have shown to improve the state of the stocks in Lake Vättern However, these regulations do not necessarily ensure the long-term sustainability of the fishery. Negotiable fishing rights, such as individual transferrable quota's (ITQ), have often arisen from co-management system. One example of this is the ITQ system that was developed in The Netherlands (Hentrich and Salomon 2005). Co-management systems allow for the implementation of such flexible management, because the co-management group is responsible for regulating the fishery in this manner. By giving the co-management group the responsibility of regulating the fishery, it could potentially limit cost of monitoring and more easily resolve potential conflicts regarding stock use (Christy 2000). Allowing resource users to self-regulate and monitor the system in Lake Vättern should be considered carefully, since it has been proven to be problematic in the past (Personal communication M. Bergström).

6.1.2 Before sales processing

Another way to increase the economic sustainability and increase the profitability of fish species is through stimulating more before sales processing. From my analysis, the Lake Vättern fishery appeared to do some before sales processing, but only basic things such a cleaning the fish. Before sales processing is a technological attribute. However, if the fishermen do more before sales processing it will have economic implications. The fishery will be economically more sustainable by improving the attribute of income dependence. Through diversification fishermen will be less dependent on the fish catch itself and thus making the system more resilient. Before sales processing also adds value to the catch. Through processing the fish, the shelf life of the fish will increase and consumers are willing to pay more for products that require little time to handle. Some of the fishermen have already invested in smoking facilities for the fish and some even have small restaurants and shops. Other modes of income can also be through attracting tourists. To attract tourists, facilities such as restaurants, or associated accommodation such as a bed and

breakfast, combined with arrangements enabling tourists to see and take part in traditional ways of fishing could help stimulate other forms of income.

The idea of increasing the value of the commercial fish species also allows for the fishermen to fish on different species through out the year. If the fishermen get a good value for the fish that they catch it can stimulate fishermen to target different fish species according to the season. Where as currently, the fishermen concentrate their fishing activity during the summer months when it is best time to fish on crayfish. It not only depends on the fishermen, but also the consumers. It is important the consumers are more aware of what they eat and that they pay a fair price for it. If there is a higher demand from the market for a variety of fish, it will also be reflected in the profit fishermen make from the fish. Some ways to improve both fishermen and consumer awareness in small-scale fisheries has been achieved through a method called 'integrated fisheries' (Vegter, 2013) which has been applied in Holland and 'community supportive fishing' in the United States. These are initiatives from fishermen that fish within a community. The fishermen aim to support small-scale fisheries by using sustainable fishing methods, fishing on a variety of species according to season and involve the local community to create awareness.

Adding value to fish through more before sales processing satisfies the increasing demand of consumers whom wish to buy ready made products or products that require little preparation before serving (FAO 2005). However, it also requires large investments in facilities such as buildings, equipment and requires large economic resources for marketing and promotion for production and distribution of products, which small companies may not possess (FAO 2005).

6.2 Improving the social status of the fishery in Vättern

6.2.1 Compliance of fishermen through strengthening of property rights

The introduction of TURF's is one way to reduce incentive of resource users to exploit the available stocks and exercise sustainable fishing methods that meet both biological needs of the fish populations as the market demand. Through this system, the fishermen are more willing to comply, which can reduce illegal-fishing trends further. This is one attribute, which had a negative impact on the social sustainability. Therefore, increasing compliance and reducing illegal fishing can increase the social sustainability.

6.2.2 Increasing knowledge

A high ecological knowledge, but an overall low educational level of the fishermen characterizes the fishery in Lake Vättern. From the RAPFISH can be concluded that a low educational level decreases the social sustainability score of the fishery. For the fishermen currently active on the lake this attribute will not change. However, for new entrants into the fishery, it could be a requirement to have a certain level of education or some form of training in a relative subject field that could contribute to the knowledge fishermen should require. However, since the entrance into the fishery is difficult and it is a slow process because of the limited number of fishermen on the lake, changes that aim to increase the educational level will not be achieved in the short-term.

If the fishermen are able to fish and make a good profit off of the commercial finfish species, there is an increased chance that more fishermen will fish on a more diverse selection of species during

different season. As discussed in the previous chapter (5.5.3), the knowledge that the fishermen posses is usually higher when fishermen fish on a variety of different species compared to fishermen that only target a single species (Garavito-Bermúdez et al. in review). Therefore, by making it possible and more attractive for fishermen to target a wider variety of species it could potentially increase the total knowledge of all the fishermen on the ecology of the lake. Currently, some fishermen only target crayfish. From the study done by Garavito-Bermúdez (in review), these fishermen seem to possess a substantially narrower vision on the ecosystem of the fish stocks then fishermen that have fished on a variety of species. Targeting only one species does not only pose a risk of the stock to collapse in the future but also limits the knowledge of the fishermen, which could contribute to a less sustainable exploitation.

6.3 Conserving the fish stocks sustainably

6.3.1 Implication of targeting more fish species

"You can't manage what you can't measure" is a well-known statement by Peter Drucker, management consultant, and which David Symes used to open his keynote speech at the Policy day for small-scale fisheries in Amsterdam. This problem of invisibility of the resource is both recognized by fishermen and managers regulating fisheries (Lundholm and Crona in review). All fisheries cope with this problem, however it is more important how fisheries deal with these uncertainties. The co-management group aims to address the problem of uncertainty by gathering the local ecological knowledge from the fishermen as well as stock assessment data provided by scientist. However, uncertainties will always be present within the fishery and a recurring issue when managing fisheries. Monitoring of species and stock statistics will need to be improved to allow for better management of the fishery in Lake Vättern.

This is also important when suggesting methods that increase the value of the commercial fish species. Increasing the value of the commercial fish species will give fishermen incentive for targeting a larger variety of fish. Increasing the species dependence of the fishermen would in turn also increase the fishing pressure on the commercial fish species, which could have negative implications whilst it is not done sustainably. Thus monitoring and stock statistics will help to develop regulations that will allow this to happen in the most sustainable way.

Currently, the fish stocks are showing improving trends and some have already reached a more healthy and stable state. Some fish species, such as whitefish, are shown to be so abundant that it has led to high interspecific competition, which in turn leads to a stunted growth. Therefore, increasing the fishing pressure on i.e. whitefish may also reduce the interspecific competition. This will in turn lead to an increase in the size of whitefish and thus making them more profitable. It is important to note that Arctic char, even though it is showing improving trends, is not fully recovered yet due to is low generation time (Fiskeriverket, 2007), therefore if fishing pressure is increased it will need to have little to no impact on the Arctic char population and other sensitive species. Therefore, there is an evident need to limit by-catches in the fisheries.

6.3.2 Better stock assessment through reporting of recreational fish catches

The number of recreational fishermen exceeds the number of commercial fishermen by far on Lake Vättern and is still showing an increasing trend. Before the initiation of the CMI, there were often

conflicts between the anglers and the professional fishermen. Form the analysis on the co-management group it was evident that these conflicts were addressed during the onset of the CMI. Recreational fishermen are not allowed to sell their catch; therefore there should not be any competition with the commercial fishermen on the market (European Commission 2006). However, some of their target species do overlap with the commercially important species. The anglers also fish in the same area as the commercial fishermen, because most of the lake is an open access area. Unlike the commercial fishermen, the recreational fishermen do not need to report their catches. These factors combined can result in potentially increasing conflicts in the future as the amount of uncertainty is increased. Recreational fishery also attracts tourism, which is good for the regional economy and should be continued to be stimulated. However, the recreational fishery needs to be more regulated to avoid conflict between anglers and commercial fishermen and to ensure the long-term sustainability of the commercial fishery. Since the recreational fishery contributes to a large amount of the harvest, reporting catches will also allow for better stock assessment of the fish species. A better stock assessment will in turn allow for more feasible regulations.

6. 4 Improving the technical sustainability of Vättern's fishery

6.4.1 Pre-sales processing

As mentioned earlier, one way to make the commercial fish species more profitable is by doing more pre-sales processing. The fishery in Lake Vättern scored in between good and bad on pre-sale processing and according to the RAPFISH this attribute slightly influences the technological sustainability in a negative way. However, from the analysis it came out less important then the selectivity of gear. Adding value to the catch can be through preparing and processing the fish through i.e. smoking, filleting, and other ways to increase shelf life. However, quality and health needs to be assured when fishermen build their own facilities to facilitate the processing and handling of fish. Therefore, it can be very costly for fishermen to invest in facilities for pre-sales processing, which could

6.4.2 Selective fishing

If the commercial fish species become more profitable, fishermen will start fishing more intensely on a higher variety of species. In this scenario, gear needs to be developed allowing for more selective fishing. Gear selectivity had a relatively high leverage score and thus, has quite a significant effect on the technological sustainability. Improving the selectivity of the gear can therefore contribute substantially to a higher technological sustainability of the fishery. The co-management group is already active in developing more selective fishing methods. Joining the GAP project in 2008 had several implications on enabling participatory research and developing methods for selective fishing (see chapter 3.2.). Scientists and commercial fishermen are in progress to enable fishing on whitefish also in deeper areas. Current regulations still prohibit this, but when a selective fishing method has been developed and proven successful, the co-management group will have a strong lobbying position to allow for a revision of the current policy.

So far the activities of GAP2 project has been concentrated on various ways to minimize the by-catch of undersized Arctic char. This work has consisted of several areas where scientists and fishermen collaborate. A new gear, never before tested in inland waters, the so called 'push-up

traps' have been tested. The trap was originally developed to minimize conflict between seals and fishermen in the Baltic Sea (Personal communication A Sandström). The traps have been constructed in such a way that they are easy to handle for a single fisherman and potentially will enhance the selectivity compared to other fishing methods (Personal communication A. Sandström). Other collaborations are 1) tests of optimal areas and time periods to minimize by-catch, 2) exchange of knowledge on whitefish ecomorphological variation and spawning areas and 3) an evaluation of release mortality of Arctic char in the recreational fisheries.

7 Conclusions & Advice

After a thorough assessment of the fishery in Lake Vättern we can conclude that the implementation of a co-management group, which had an advisory function within the Swedish governance, has led to an increase in sustainability. By applying a multi-disciplinary rapid appraisal technique, the sustainability of the fishery in Lake Vättern was measured within the time period from 1994 till 2012. Results show that both the ecological and social dimension of the commercial fish fishery has improved over time. While the technological and economic sustainability score displayed no major changes within the same time period. The driving force behind social sustainability was interpreted to be in part related to co-management, whereas the positive trend in the ecological sustainability of the fishery was mostly driven by changes in the fishery regulations that were implemented in 2004. However, social outcomes such as compliance from the resource users will indirectly also increase the ecological sustainability. Thus, the co-management group has led to an overall positive development of the commercial fishery in Lake Vättern.

The arrangement of the co-management group can take on many different forms and, therefore, it should be adapted to suit the specific situation that it is being used in. Experience from co-management arrangements can be very specific to the case study. However, there are some general conclusions that could be drawn from the current case study that have allowed for a successful co-management arrangement. Firstly, applying the co-management approach to a small-scale inland fishery set clear defined boundaries for the participants. Applying a co-management form of governance on a regional scale provides the participants with a sense of empowerment, because the distance to the decision making authority is shortened, which results in a more transparent decision making process. Secondly, the involvement of many different organizations even though criticized at first (Rova et al., 2009), allowed for the group to stay motivated and brought up many discussions. Due to the scale in which the fishery operates, it was possible to involve all the different stakeholders. Thirdly, a good mediating and unbiased chairman is important for a well-functioning co-management group. The chairman was skilled at leading discussions and created a good atmosphere during the meetings. This was crucial for the co-management group, because all the members were able to voice their opinions and conflicts were resolved in a friendly manner. Fourthly, a long-term vision is important as it takes time for, the different members to get to know each other, build trust between the members, changes in governance to occur and the fish stocks to portray changes. Finally, it is pivotal for the success of the co-management arrangement to have good communication on the goals and means of the group from the beginning. If the goals are not clearly communicated, or not all the members are in agreement, it could lead to decreased motivation and therefore be less efficient. When taking these outcomes into account, co-management, when exercised in the right way, does have its advantages compared to a centralized form of management.

Overall, Lake Vättern's fishery has shown positive trends. When comparing it with other studies, it scores higher than most fisheries. However, fisheries, such as the Gulf of Maine Lobster fishery, are more sustainable than Lake Vättern. In some aspects Lake Vättern can learn from this. Also the success of the governance on the fishery today does not ensure success in the future, because it is a continual process and the dynamic nature of the fish stocks needs to be accounted for. When

regarding the results, we can assess that the future of the fishery in Lake Vättern should aim to improve the economic environment of the fishery whilst conserving the fish stocks and maintaining a positive social environment. One way, which I suggest, that could make this possible, is through measures that aim to maximize the profit from the commercial fish species. Maximizing the profit of the commercial fish species can be done in several ways. In this paper I suggest that it can either be done through strengthening the property rights with the use of a flexible management system, or promoting other forms of income, such as establishing facilities for before sales processing. The co-management group will need to be responsible for defining the terms of the property rights and be responsible for regulating it. By deciding together on the terms of the property rights it can be formulated in such a way that it fits the situation. Involving the stakeholders in determining new forms of property right will make the regulations more legitimate. However, since the co-management doesn't have any legal mandate it can't officially enforce laws and therefore, it would be more of an agreement between the different stakeholders then a legally binding law. The co-management group has done this before by developing a management plans together for the lake. This management plan was made for the period between 2009 and 2013, and thus is ends this year. This could be a good opportunity to develop a new management plan in which new property rights are incorporated. For the co-management group to receive legal mandate changes will need to be made in the national Swedish law. This will not be something that can occur in the short term, but it could be something that will need to be done for the future.

The previous examples are a more economical approach to managing the fishery, but it also has the potential to improve the sustainability score within the other dimensions. By increasing the profit made from the commercial fish species, the fishermen will increase their catch on the different fish species. However, due to the current regulations this might not be possible, thus more selective fishing methods should be developed. The increase in profit made from the fish catch will need to be an initiative that comes forth from the fishermen and the community itself. However, the costs can be very high for investing in good facilities to process fish and attract tourist. This could potentially be a barrier for fishermen to start up a business. The regional authorities could help and give subsidies to fishermen that invest in building facilities to process fish. Also with a large share of recreational fishermen coming to Lake Vättern, a growing trend, it is important that methods are found in which both the commercial and recreational fishery can continue to co-exist. For example, proper documentation of the amount of fish caught by both the recreational and commercial fishermen is needed. This would need to be implemented by the regional authorities. They would need to make it obligatory for recreational fishermen to report their catch when they go out to fish on the lake. Up until 1994 this did happen, but due to the reorganization in management the national authority became responsible for this and started doing national surveys instead. To allow for better management and stock assessment all resource users should contribute to documenting stock statistics.

Vättern is a lake in which many different stakeholders make use of its resources. The co-management group has been an efficient platform to resolve conflicts between resource users with different interest and find solutions for which there is consensus between all parties. The commercial fishery in Lake Vättern will not grow any further in the number of fishermen; however the recreational fishery will continue to grow. Like other inland fisheries in Sweden the greatest

potential for the sustainability of the system, is to promote diversification of the industry through tourisms and develop more facilities for after sales processing, to maximize the profit made from the fishery without having to increase the fishing intensity substantially. Some measures might initially ask for large investments, which could be problematic if it is difficult to get access to credit. However, in the long run these investments could potentially pay themselves off and thus ensure the future sustainability of the fisheries in Lake Vättern.

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Appendix

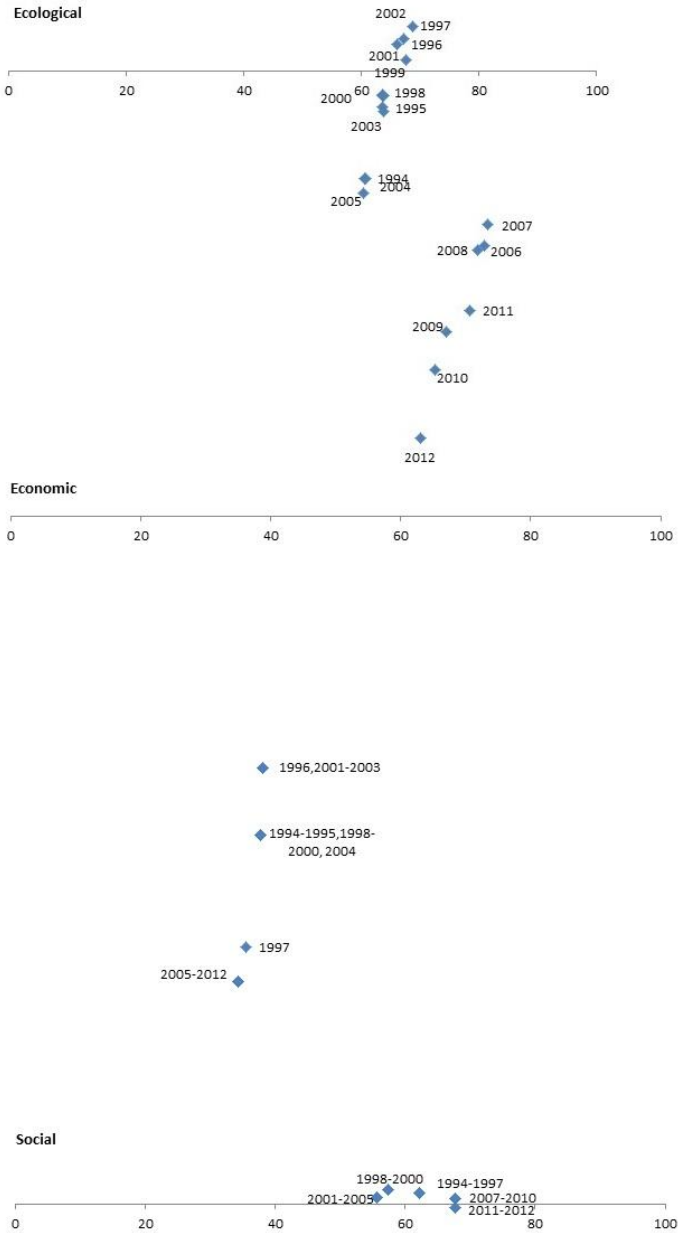
Appendix I

List of Interviewed people:

Cecilia Lundholm	Associate professor, director at the Centre for Teaching and learning at Stockholm University
Diana Garavito-Bermúdez	PhD student at the Department of Education at Stockholm University and Stockholm Resilience centre.
Beatrice Crona	Associate professor at Stockholm Resilience centre
Magnus Johansson	Independent fishermen
Alfred Sandström	Fishery biologist at Swedish University of Agricultural Sciences (SLU) at the department of aquatic resources.
Anders Carlen	Independent fishermen
Patrick Grönlind	Independent fishermen
Bernt Grönlind	Independent fishermen
Samuel Gustafsson	Independent fishermen
Alf Hultquist	Representative of the Recreational fishermen in the co-management working committee
Marloes Kraan	Social scientist, researcher and project leader at IMARES, The Netherlands

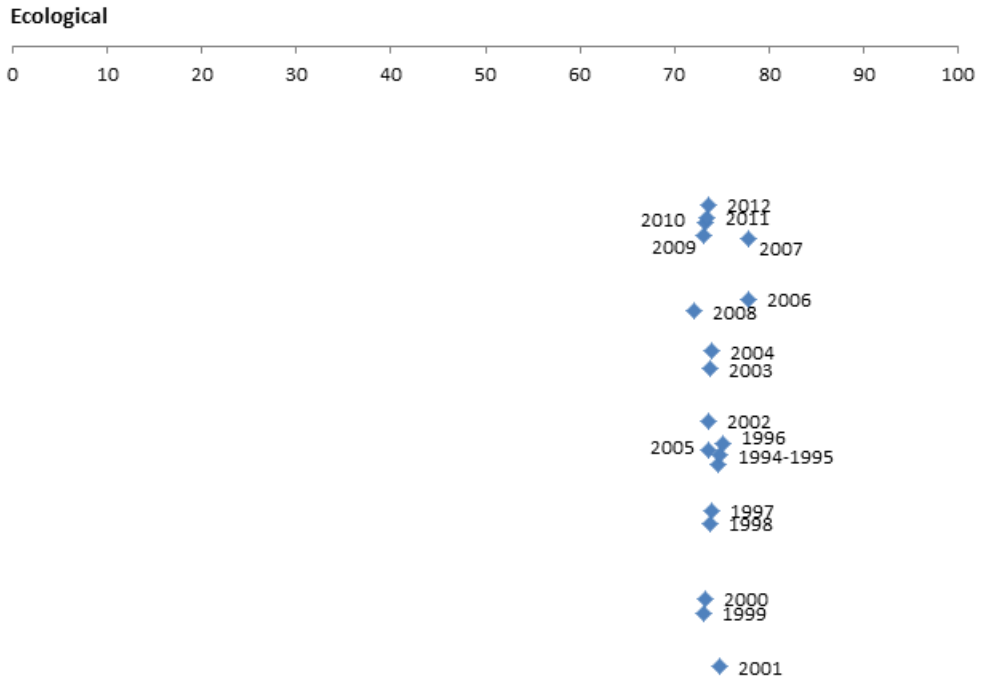
Appendix II

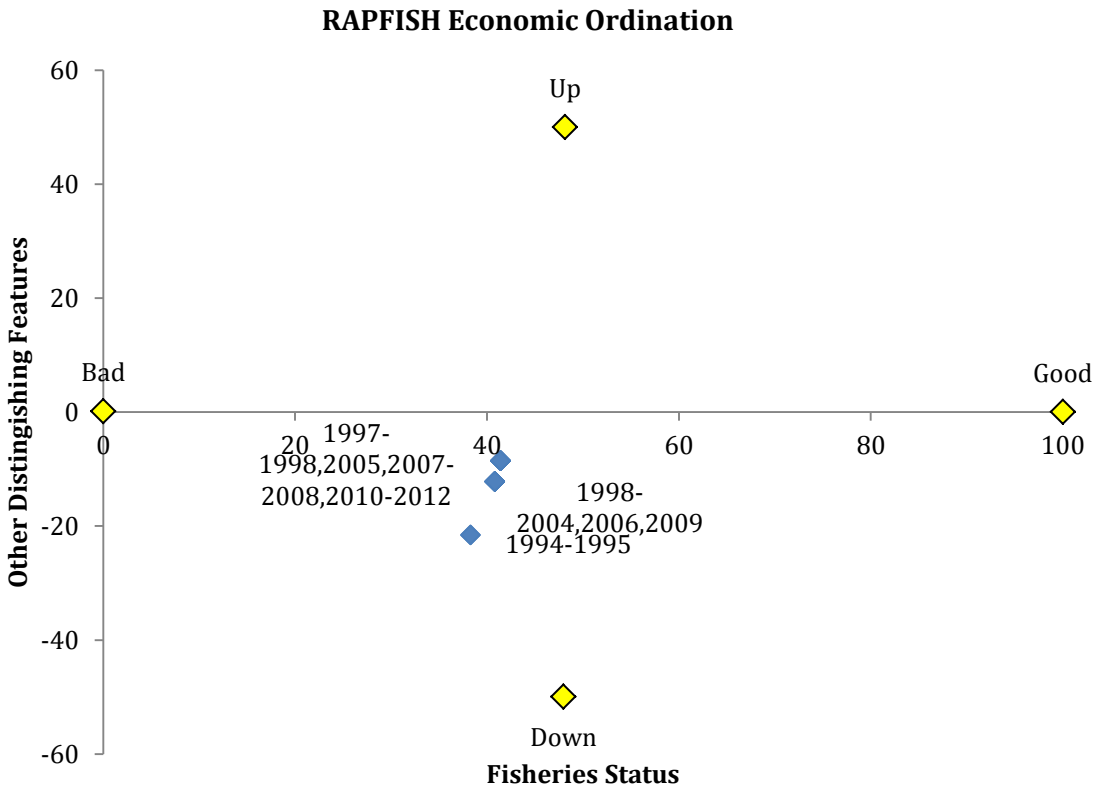
Ordination results from RAPFISH on the ecological, economic and social dimension of the commercial fishery:



Appendix III

RAPFISH ordination results for the ecological and economic dimension of the crayfish fishery





Appendix IV

Table with scores of the ecological attributes associated with the commercial fish fisheries

Year	Catch Effort	Catch trend	Exploitation status	Trophic level	TL change	Recruitment variability	Size of fish *	Catch > maturity	Species caught	Primary production
1994	1.8	1	1	1	0	2	2	1	0	3
1995	1.6	0.5	1	1	0	2	2	1	0	3
1996	1.6	0	1	1	0	2	2	1	0	3
1997	1.7	0	2	1	0	2	2	1	0	3
1998	1.4	0.5	2	1	0	2	2	1	0	3
1999	1.4	0.5	2	1	0	2	2	1	0	3
2000	1.4	0.5	2	1	0	2	2	1	0	3
2001	2.1	0	2	1	0	2	2	1	0	3
2002	1.6	0	2	1	0	2	2	1	0	3
2003	1.7	0.5	2	1	0	2	2	1	0	3
2004	1.8	1	2	1	0	2	2	1	0	3
2005	2.1	1	2	1	0	2	2	1	0	3
2006	2.6	0	1	1	0	2	3	0	0	3
2007	2.1	0	1	1	0	2	3	0	0	3
2008	2.4	0	1	1	0	2	3	0	0	3
2009	1.7	1	0	1	0	2	3	0	0	3
2010	2.5	1	0	1	0	2	3	0	0	3
2011	3.5	0	0	1	0	2	3	0	0	3
2012	4.2	1	0	1	0	2	3	0	0	3

Appendix V

Table representing the scores of the economic attributes of the commercial fisheries.

Year	Price	Fisheries in GDP	GDP/person	Limited entry	Marketable right	Other income	Ownership	Market	Subsidy	Species dependence*
1994	4	0	0	2	0	3	0	1	1	1
1995	4	0	0	2	0	3	0	1	1	1
1996	3	0	0	2	0	3	0	1	1	2
1997	3	0	0	2	0	3	0	1	1	1
1998	3	0	0	2	0	3	0	1	1	1
1999	3	0	0	2	0	3	0	1	1	1
2000	3	0	0	2	0	3	0	1	1	1
2001	3	0	0	2	0	3	0	1	1	2
2002	3	0	0	2	0	3	0	1	1	2
2003	3	0	0	2	0	3	0	1	1	2
2004	4	0	0	2	0	3	0	1	1	1
2005	4	0	0	2	0	3	0	1	1	0
2006	4	0	0	2	0	3	0	1	1	0
2007	4	0	0	2	0	3	0	1	1	0
2008	4	0	0	2	0	3	0	1	1	0
2009	4	0	0	2	0	3	0	1	1	0
2010	4	0	0	2	0	3	0	1	1	0
2011	4	0	0	2	0	3	0	1	1	0
2012	4	0	0	2	0	3	0	1	1	0

Appendix VI

Table representing the scores of the social attributes of the commercial fish fisheries.

Year	Socialization of fishing *	Community growth	Fishing sector	Environmental knowledge	Education level	Conflict status	fisher influence	Fishing income	Kin participation	Entry to fishery*	Illegal fishing
1994	1	0	0	2	0	1	1	1	1	1	1
1995	1	0	0	2	0	1	1	1	1	1	1
1996	1	0	0	2	0	1	1	1	1	1	1
1997	1	0	0	2	0	1	1	1	1	1	1
1998	1	0	0	2	0	2	1	1	1	1	1
1999	1	0	0	2	0	2	1	1	1	1	1
2000	1	0	0	2	0	2	1	1	1	1	1
2001	1	0	0	2	0	2	1	1	1	1	2
2002	1	0	0	2	0	2	1	1	1	1	2
2003	1	0	0	2	0	2	1	1	1	1	2
2004	1	0	0	2	0	2	1	1	1	1	2
2005	1	0	0	2	0	2	1	1	1	1	2
2006	1	0	0	2	0	1	1	1	1	1	1
2007	1	0	0	2	0	1	2	1	1	1	1
2008	1	0	0	2	0	1	2	1	1	1	1
2009	1	0	0	2	0	1	2	1	1	1	1
2010	1	0	0	2	0	1	2	1	1	1	1
2011	1	0	0	2	0	1	2	1	1	1	2
2012	1	0	0	2	0	1	2	1	1	1	2

Appendix VII

Table representing the scores of the technological attributes associated with the commercial fish fisheries.

Year	Trip length	Landing sites	Pre-sale processing	Use of ice	Gear	Selective fishing gear	Vessel size	Catching power	Gear side effects
1994	6.5	1	1	1	0	1	0	1	1
1995	6.5	1	1	1	0	1	0	1	1
1996	6.5	1	1	1	0	1	0	1	1
1997	6.5	1	1	1	0	1	0	1	1
1998	6.5	1	1	1	0	1	0	1	1
1999	6.5	1	1	1	0	1	0	1	1
2000	6.5	1	1	1	0	1	0	1	1
2001	6.5	1	1	1	0	1	0	1	1
2002	6.5	1	1	1	0	1	0	1	1
2003	6.5	1	1	1	0	1	0	1	1
2004	6.5	1	1	1	0	1	0	1	1
2005	6.5	1	1	1	0	1	0	1	1
2006	6.5	1	1	1	0	1	0	1	1
2007	6.5	1	1	1	0	1	0	1	1
2008	6.5	1	1	1	0	1	0	1	1
2009	6.5	1	1	1	0	1	0	1	1
2010	6.5	1	1	1	0	1	0	1	1
2011	6.5	1	1	1	0	1	0	1	1
2012	6.5	1	1	1	0	1	0	1	1

Appendix VIII

Table representing the ecological attribute scores associated with commercial crayfish fishery

Year	Catch Effort	Catch trend	Exploitation status	Trophic level	TL change	Recruitment variability	size of fish caught*	Catch > maturity	Species caught	Primary production
1994	3.6	2	0	0.5	0	0	2	0	0	3
1995	3.4	2	0	0.5	0	0	2	0	0	3
1996	3.1	2	0	0.5	0	0	2	0	0	3
1997	4.7	2	0	0.5	0	0	2	0	0	3
1998	5	2	0	0.5	0	0	2	0	0	3
1999	6.9	2	0	0.5	0	0	2	0	0	3
2000	6.6	2	0	0.5	0	0	2	0	0	3
2001	11.4	1	0	0.5	0	0	2	0	0	3
2002	7.3	1	0	0.5	0	0	2	0	0	3
2003	6.2	1	0	0.5	0	0	2	0	0	3
2004	5.8	1	0	0.5	0	0	2	0	0	3
2005	7.9	1	0	0.5	0	0	2	0	0	3
2006	7.7	0	0	0.5	0	0	2	0	0	3
2007	6.5	0	0	0.5	0	0	2	0	0	3
2008	5.2	0	1	0.5	0	0	2	0	0	3
2009	3.4	0	1	0.5	0	0	2	0	0	3
2010	3.1	0	1	0.5	0	0	2	0	0	3
2011	3	0	1	0.5	0	0	2	0	0	3
2012	2.7	0	1	0.5	0	0	2	0	0	3

Appendix IX

Table representing the ecological attribute scores associated with the recreational fishery in Vättern

Year	Catch Effort	Catch trend	Exploitation status	Trophic level	TL change	Recruitment variability	size of fish caught*	Catch > maturity	Species caught	Primary production
1993	1	0	1	1.0	0	2	2	2	0	3
2000	1	2	2	1.0	0	2	2	1	0	3
2003	1	1	2	1.0	0	2	2	1	0	3
2012	1	1	0	1.0	0	2	2	1	0	3