UNIVERSITY OF TROMSØ UIT

Faculty of Biosciences, Fisheries and Economics

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Recreational Fisheries, Unreported Commercial Catches and Marine Protected Areas

Alf Ring Kleiven

A dissertation for the degree of
Philosophiae Doctor

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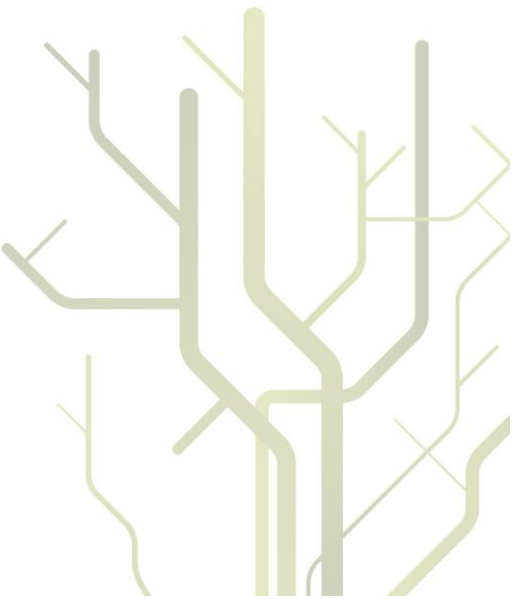

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Preface

Sunday 25 November 1906, southern Atlantic ocean: ”*Finally we got some wind. Everything on board is the same, so there is not much to write about. On Friday, Otto fished an albatross. The sail maker was fishing yesterday. He had a big one on the bait, but the line snapped and it disappeared. I got the head of the first fish he caught. It is now stuffed and finished.*

Helene Karoline Larsen, 19 years old

The words of the young lady are from my great grandmother’s diary. She circumnavigated the world with her father, a sail ship captain, during 1906-1908. After growing up on a small fisher island, she tells about all the experiences on the seven seas: being tied to the mast in a storm, navigating through icebergs and catching large fishes and albatrosses. A lot has changed in 100 years, but albatrosses are still caught as by-catch by longliners to such a degree that the species is threatened with extinction. During these 100 years, fish stocks have been fished down to a fraction of what my great grandmother experienced. We are struggling more than ever to take care of the blue ocean.

It must be in my blood, I love sailing and the mysterious life the ocean contains. This led me into marine biology at University of Bergen. I owe my student friends a great thanks, having the astonishing ability to balance partying and studies through some memorable years. I would not be where I am today without the enthusiasm of the late Roger Bennett who receives my greatest appreciation for guiding me into the world of integrated coastal zone management at the University of Bergen. Going to Australia for a master’s degree at James Cook University, gave me brand new perspectives on ocean management and conservation. Being in Townsville in the middle of the re-zoning of the Great Barrier Reef Marine National Park was an inspiring experience. It was a fantastic adventure to have shared the years in Australia with my travel- and student companion Even Moland. Who could have known that our ideas and dreams created while we cruised the Great Barrier Reef with our sailboat “S/Y Ringreven”, should lead us to Flødevigen research station with neighbouring offices working on PhD’s in tightly bound projects!

I am indebted to Jan Atle Knutsen, the brain behind the first lobster reserves in Norway. The creation of the reserves opened many doors and exciting research questions. My thankfulness

goes to all my colleagues at the Flødevigen research station, who have been eager to help out and have given me many happy days.

This thesis represents an interdisciplinary and cross-institutional effort. I owe my supervisor, Svein Jentoft, at the University of Tromsø great thanks for bringing social science into my PhD. My supervisors at the Institute of Marine Research, Esben Moland Olsen and Jon Helge Vølstad have both done a fantastic job in guiding me through the mysterious ways of recreational fishing survey techniques. I am grateful for my supervisor's clever thoughts and comments.

My mum and dad have been my strongest supporters through my years of studies. You were always there to support me when I lost the belief in my own capabilities. And you were even able to repeatedly convince me that I got some sort of talent. My relative and good friend, Alf Ulland, deserves my thanks for daring to employ a young academic as his fishing mate for half a year. The first hand experience of being a commercial fisher has given me an invaluable perspective within my research field.

This work could not have been fulfilled without the positive responses and help from recreational fishers filling out catch diaries and eager to tell me about the latest catch in phone interviews. The huge data set collected by the catch diaries is important in order to follow the development in the lobster population and the fishery in the following years.

Into my second year of the PhD, an amazing girl became my colleague, then my fiancée and together we were able to produce the loveliest baby on the planet. Mona, you have made the last years the most fantastic part of my life. Thank you for being my girl and the mother of Ask. You have without doubt given me a pleasurable and busy life outside my PhD.

Fishery resource management is an increasingly complex issue, and expectedly even more complex in the coastal zone than in the open ocean when it comes to biodiversity and the diversity of different stakeholder groups. Fishery management has to involve tradeoffs and interactions within and between nature and society[1]. There has been voiced a need for a broader approach than the traditional disciplinary approaches in order to solve such management problems (Wickson et al. 2006). Fishery management is clearly about regulating human activities rather than regulating the fish itself. However, advice on how human activities should be regulated is often provided by specialists in fish biology. In order to achieve a sustainable fishery, there is a need to integrate knowledge of human behaviour and the resources concerned. Humans are part of the ecosystem and when implementing ecosystem-based approaches to fishery management, it is clearly a need to consider and involve all stakeholders concerned[1]. Throughout the work with this PhD thesis I have tried to examine the issues in an interdisciplinary framework in order to obtain a holistic view of the issues concerning lobster management in coastal Skagerrak. Basically, the problem of concern has been the red-listed European lobster (*Homarus gammarus*) in Norwegian waters. Lobster has a strong cultural importance for many people along the coastal Skagerrak. In that way, the status of the lobster population does affect both the recreational and commercial fishers as well as a set of other stakeholders. It is therefore a need to gain knowledge about both the stakeholders and the resources in question. Who are the stakeholders? How do they interact with the resources concerned? How do they interact and participate in management processes? How are the lobster population responding to the human activities? These are large and challenging questions and each question could be the focus of a PhD thesis in itself. I have tried to integrate all these questions into my thesis. In many respects, social and natural science inhabit two different cultures, even how to present a thesis is based on differing traditions. I have tried to balance my thesis in conjunction with these different traditions. It is up to the reader to evaluate the degree to which I have been successful in this regard.

Alf Ring Kleiven, Arendal, June 18th 2010

[1]Francis RC, Hixon MA, Clarke ME, Murawski SA, Ralston S. 2007. Fisheries management - Ten commandments for ecosystem-based fisheries scientists. Fisheries 32: 217-233.

[2]Wickson F, Carew AL, Russell AW. 2006. Transdisciplinary research: characteristics, quandaries and quality. Futures 38: 1046-1059.

Contents

Abstract

The implementation of four experimental lobster reserves in Norway in 2006 highlighted a set of important questions regarding lobster management. This thesis presents a study on the management and fishery of the European lobster (*Homarus gammarus*) in Skagerrak. Firstly, the implementation process of the lobster reserves was analysed. It revealed that local stakeholders, such as recreational fishers, were positive to the use of reserves for management of lobster. However, they were not involved in the implementation process. By reviewing existing literature regarding recreational fisheries, we show that recreational fishers behave differently than commercial fishers. Recreational fishers are not dependent on making profit from the fishery and the value of recreational fishing to those who engage in it is a combination of catch and experience value. The latter implies that recreational fishers can continue fishing when stocks are at a low level, in the same way as subsidised commercial fisheries. We termed this self-subsidising: A fishery as one in which fishers subsidise themselves through an economic investment in gear and time from their non-fishery based earnings. Further, methods to estimate recreational, commercial and total effort and catch were developed. A probability-based strip transect survey method was developed and used to estimate the recreational and commercial effort in the fishery. The survey revealed that recreational fishers outnumber commercial fishers, contributing to 2/3 of the total effort (number of traps) during the season. Lastly, we collaborated with recreational fishers that reported catch and effort through catch diaries. Test validation from a random sample of fishers showed that the catch rate from those who filled out catch diaries could be considered as representative for the recreational lobster fishing population in the study area. We also found that mean recreational catch rates could be considered as representative for the catch rates in the commercial fishery. Our estimates show that recreational fishers represent 65 % of the total landings in the study area. In addition, 77 % of the lobsters caught by commercial fishers remain unreported. Hence, total catch from the recreational and commercial fishery combined, was estimated to be 14 times higher than the officially reported landings. The main conclusion in this thesis is that the lobster fishery can be considered unregulated: there are no quotas, no total effort regulations and no registry of participation from neither commercial nor recreational fisheries. The lack of data information may lead to mismanagement of the lobster fishery with the risk of further population reduction. Further, the positive attitude towards the lobster reserves, as expressed from the local stakeholders,

clearly shows the potential in using lobster reserves as an important tool in the management of the European lobster in coastal Skagerrak. Implementation of more lobster reserves should strive to achieve stronger stakeholder involvement from the early start of the process in order to incorporate local user knowledge and ensure legitimacy of new reserves.

List of papers

Paper I Pettersen, A.R., E. Moland, E. Moland Olsen and J.A. Knutsen. 2009. Lobster reserves in coastal Skagerrak - An integrated analysis of the implementation process. Pages 178-188 in E. Dahl, E. Moksness and J. Støttrup, editors. Coastal Zone Management. Wiley-Blackwell Publishing, London.

Paper II Kleiven, A.R., E. Moland and U.R. Sumaila. Recreational fishing as a self-subsidising activity: Implications for sustainability of targeted fish stocks. (*Manuscript*)

Paper III Kleiven, A.R., E. Moland Olsen and J.H. Vølstad. Estimating Recreational and commercial fishing effort for European lobster (*Homarus gammarus*) by strip transect sampling. (*Manuscript*)

Paper IV Kleiven, A.R., E. Moland Olsen and J.H. Vølstad. Total catch an order of magnitude above officially reported landings for a red-listed marine species. (*Manuscript*)

Introduction

Overexploitation of the worlds fishery resources has gained increased attention the last decade (Jackson et al. 2001; Pauly et al. 2002; Myers and Worm 2003; Lotze and Worm 2009; Worm et al. 2009). There has been argued that heavy fishing pressure has lead to removal of top predators (Jackson et al. 2001; Myers and Worm 2003), in which the fishing industry turn over to targeting lower trophic levels (Pauly et al. 1998). Overcapacity in the fishing fleet, financed by subsidies, is identified as one of the most important driving forces for the continued overharvest (Sumaila et al. 2007). Further, illegal fishing is of global concern, which has been estimated to be between 11 and 26 million tonnes (Agnew et al. 2009). In general, illegal, unreported and unregulated (IUU) fishing is identified as a major threat to the world fish stocks and has become important on the international fisheries management agenda (Le Gallic and Cox 2006).

The main focus related to the global fish crisis has been towards the commercial fishing sector. Pauly (2009) argued that government scientists often focus on commercial fisheries even when small scale and recreational fisheries land the bulk of the catch. These fisheries are mostly conducted in near shore areas. Collection of catch data in small scale and recreational fisheries is more challenging than in large fisheries where the industry is more organised (Pauly 2009). In addition, there are challenges related to collecting biological probability-based information in order to get reliable stock estimates. As for the Norwegian coast, it has become evident that coastal cod populations (*Gadus Morhua*) can be structured into genetically distinct populations at a small geographically scale (tens of kilometres) (Knutsen et al. 2003) with different life-history traits (Olsen et al. 2004). Traditional stock assessment tools, such as trawl surveys, are usually developed for fish stocks in the open ocean and are not easily applied to coastal fish populations (Lunde et al. 2008).

Growing attention has been directed towards the impacts of recreational fishing (McPhee et al. 2002; Coleman et al. 2004; Cooke and Cowx 2004; Lewin et al. 2006). In their review, Lewin et al. (2006) argued that there is growing evidence that recreational fishing can lead to a decline of fish populations. Cooke and Cowx (2004) argued that a failure to recognise the potential effects of recreational fisheries could put ecologically and economically important resources at risk. A number of case studies have highlighted the importance of recreational fishing as a significant contributor to fishing mortality. In the US, Coleman et al. (2004)

found that recreational fisheries accounted for 24 % of the catch from populations of concern (i.e. overfished or experiencing overfishing). Furthermore, it is observed that recreational catch is high compared to commercial for many high valued overfished species (McPhee et al. 2002; Schroeder and Love 2002; Coleman et al. 2004). As for Norwegian coastal fisheries, there has been no reliable estimate available for the landings of recreational fishers. Recreational fishing is increasingly recognised as an important challenge for management, leading to a discussion on how to involve this sector in the management programs (Robertson and Caporossi 2003; Sutinen and Johnston 2003; Arlinghaus and Mehner 2005; Cooke and Cowx 2006; Sutton 2006, Granek et al. 2008). Recreational fishing activities are highly diverse, stretching from sport fishing to food gathering. A general definition of recreational fishing is "all fishing activities not conducted for commercial fishing purposes" (Pawson et al. 2008). Further, it can be argued that "recreational fishing does not include sale of catch" (Pawson et al. 2008). In Norway, the management authorities have made rules for how much fish recreational fishers are allowed to sell and Norway operates with official landing statistics from recreational fishers that sell catch legally. Based on the definitions above, there is reason to argue that when recreational fishers sell their catch, they are operating commercially and should not be considered as recreational fishers. I will in this thesis use the FAO Code of Practise for Recreational Fisheries definition of recreational fisheries: "Fishing of aquatic animals that do not constitute the individual primary resource to meet nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets" (Pawson et al. 2008).

There are evidently some apparent differences between commercial and recreational fishers. While commercial fishers often are organised and registered, recreational fishers are more often an unregistered heterogeneous group. The commercial fishers sell their catch and are more or less dependent on catch for income. In general, there is thus reason to argue that the main motivation for a commercial fisher is to make economic revenue of the catch. On the other hand, the recreational fisher's motivation to fish is based on a multitude of factors, such as enjoying a quality environment and feeling a sense of freedom (Holland and Ditton 1992). Several studies have shown that non-catch motivations are more important than the catch, where the primary motivations do not have to involve catch and eating fish (Arlinghaus 2006). In coastal fisheries, where recreational fishers are an important component of the fishing activity there is a need to identify a broad spectre of their activity. Their motivation to

fish, the catch composition and their perceptions to existing management measures are all important factors in order to achieve a successful management of recreational fisheries. The challenge facing management is how to conserve fish stocks on a small geographical scale where (i) the stock assessments are poor, (ii) there are no reliable catch estimates and (iii) the users are not well defined.

Marine Protected Areas (MPAs) has been advocated as a promising tool to combat overfishing in coastal areas (Halpern and Warner 2002; Russ 2002; Gell and Roberts 2003; Russ and Zeller 2003; Lester et al. 2009). MPAs come in many forms and definitions. They can range from no-take marine reserves (where all extractive activities are forbidden) to areas with fewer restrictions (such as areas protected from trawling). It is argued that MPAs have the potential to protect marine ecosystems from complex ecosystem effects of human exploitation (Gell and Roberts 2003; Rudd et al. 2003; Baskett et al. 2005). MPAs usually have both biological and social goals. While biological goals can be restoration of habitats, protection of endangered species and spawning sites, social goals can be increased revenue from the resources and tourism, as well as empowering coastal communities (Christie et al. 2003).

MPAs have the potential to trigger both the curiosity of the biological and social scientist. The biologist may see a MPA as a conservation tool for biological diversity (Lester et al. 2009) and as a fishery management tool that can increase catches in areas open to fishing (Abesamis et al. 2006; Goni et al. 2010), as well as an insurance against failed fisheries management (Russ 2002). The social scientist can be triggered by the curiosity on how stakeholders are involved and affected (Himes 2007; Sutton and Tobin 2009) as well as the governance of the MPAs (Jentoft et al. 2007; Sanchirico et al. 2010). Social research on MPAs might include sociology, political science, cultural anthropology, economics, legal studies and geography (Christie et al. 2003). MPAs can be seen as a connection between the social and natural system with the aim to reach a sustainable co-existence between nature and man.

Although MPAs are clearly not the single and simple answer to an ecosystem based management approach (Cicin-Sain and Belfiore 2005; Murawski 2007), they should be viewed as an integral part of ecosystem based fisheries management and a critical component of successful rebuilding efforts (Lubchenco et al. 2003; Francis et al. 2007; Pauly 2009;

Worm et al. 2009). Within MPAs that are fully protected from extractive activities, it is expected that fishing mortality is reduced, leading to increased density, mean size and age, biomass and reproductive potential of target species (Russ 2002; Lubchenco et al. 2003). These expected effects within MPAs have been repeatedly confirmed the last decade (Murawski et al. 2000; Halpern and Warner 2002; Evans and Russ 2004; Williamson et al. 2004; Lester et al. 2009). In order for the MPAs to have a positive effect for fisheries, the increase in density, size and biomass should lead to a net export of adults (spillover effect), eggs and larvae (recruitment effect) from the MPAs to the fished areas (Russ 2002; Lubchenco et al. 2003). Spillover from MPAs to fished areas have been found in many regions (Rowe 2001; Gell and Roberts 2003; Kelly and MacDiarmid 2003; Kaunda-Arara and Rose 2004; Follesa et al. 2009; Stobart et al. 2009). Recent studies have documented net spillover effects for a number of species (Russ et al. 2004; Abesamis et al. 2006; Goni et al. 2010). Net spillover means that the emigration from the reserve is higher than the immigration into the reserve from surrounding fished areas. The effects of net larval dispersal from MPAs to fished areas are the most challenging to study, and has been mostly investigated by modelling (Cudney-Bueno et al. 2009, but see Pelc et al. 2009).

It is argued that MPA design and its effects tend to be viewed from a biological perspective, with the risk of overlooking the social side, which might lead to failure for the MPAs to reach the management targets (Christie et al. 2003). Implementation of MPAs often generates opposition by stakeholders, since the regulations affect their access to resources (Banks and Skilleter 2010). It is therefore important that all stakeholders in the local community are able to have a say in the process. Stakeholders are not a homogenous group. Steel et al. (2006) divides stakeholders into the following groups: Scientists, managers, members of interest groups (e.g. recreational and commercial organisations), “attentive public” (e.g. those who participated in the process) and the general public. Different stakeholder groups may have different legitimacy, power and urgency for the resources concerned, which can affect their influence on management processes (Mikalsen and Jentoft 2001). A social science research agenda has emerged the past years looking at the stakeholder’s influence, attitudes and perceptions towards MPAs (Suman et al. 1999; Stump and Kriwoken 2006; Jones 2008; Mangi and Austen 2008; Sutton and Tobin 2009). Further, Jentoft et al. (2007) presented a governance system analysis for MPAs, which could be seen as a methodological contribution for future research on MPAs in the context of social science.

The implementation and management of MPAs can both be conducted by a top-down or bottom-up approach dependent on which institution or social system that uses the management tool (Jentoft 2007). A top-down approach would typically be an implementation process where the government control the process from start to end, where minimal influence and power are given to stakeholders. A typical bottom-up approach would be a MPA process where local communities are directly involved and have influence in the whole process. In contrast to quota settings, a MPA establishment process can be initiated by local stakeholders. Different solutions might be found in different communities/ geographical areas dependent on the natural resources, the use of the resources and community structure. However, the local community get access to a tool that can decide where different extractive and development activities can take place and not. For instance, if the community is concerned about the habitats and fishery resources, it can establish MPAs in order to protect these systems. When establishing MPAs in local coastal areas, a top-down approach is not recommended, and can easily lead to "paper parks" with low legitimacy from the stakeholders (Leigh Kessler, 2004). Such processes are in need of stakeholder involvement and participation in order to obtain legitimacy by the users. However, involvement may range from local initiatives and designation to governmental-led planning where key stakeholders participate in the process (Brody 1998). Brody (1998) further argues that a bottom-up approach can be viewed as a desirable model to adopt when establishing MPAs. Often, an establishment process is neither a bottom-up nor a top-down, but rather something in between.

Participatory processes are not an easy task. They are known to be complicated, with a lot of different interests being involved, and may lead to delays in the decision-making (Leigh Kessler 2004). However, by stakeholder involvement, the management will be able to achieve a higher integration of scientific knowledge with local user knowledge. It is argued that participation from people with a stake in the resource increases the level of understanding and the level of support for marine protection, while it reduces the potential for conflicts and the need for enforcement (see Leigh Kessler (2004) for further references). Management authorities have the responsibility to act if the marine ecosystem is at stake. However, there has been argued that good governance is in need of stakeholder participation at the lowest possible level (subsidiarity principle) (Bekres 2007), which would mean that management authorities should seek to involve local communities and give the local

communities as much responsibility and power as possible. Management authorities should then further provide expertise and knowledge, playing the role as an advisor in the MPA planning process. As for Norway, with a strong and well organised central authority, a balance has to be found between the local and central power in a co-management regime.

Recreational fishers should expectedly have a stake when coastal MPAs are to be implemented. However, in the Norwegian management system they have been viewed as latent stakeholders with low urgency and power but with increasing legitimacy (Mikalsen and Jentoft 2001). The heterogeneous and unorganised nature of recreational fishing and the lack of knowledge regarding the activities challenges the traditional ways of involving stakeholders in fishery management. Nevertheless, ignoring recreational fishers as an important stakeholder group might lead to MPA management failures.

Research questions

Four experimental lobster reserves were established along the Norwegian Skagerrak coast in 2006. The main argument for the implementation was based on biological curiosity: how do a lobster population respond when harvesting is excluded from the area? On the other hand, the implementation of experimental lobster reserves also raised important management questions regarding user involvement and the need to identify key stakeholders. The implementation process was highly focused on collaboration with commercial fishers. Conversely, there were strong indications that recreational fishing is a significant part of the lobster fishery in this area. Recreational fishers could be affected by the implementation of coastal reserves. There is a lack of previous studies, both in socio-economic and biological contexts, on marine recreational fishing in Norway. The lobster fishery was seen as an excellent candidate in order to analyse a recreational fishery in Norway. It is a popular fishery with long historical traditions and it is only fished by one type of gear (traps) in a short season (October-November). The lobster is listed as ‘near threatened’ in the national red list (Oug et al. 2006), and CPUE has been at low levels for decades (Fig. 1). In my thesis I have aimed to look at the recreational lobster fishery in coastal Skagerrak in an interdisciplinary way. If more lobster reserves are to be implemented along the Norwegian coast (NDN 2009, Schulze and Karlsen 2009, Aanonsen 2009), there is a need to understand the recreational fishery, both the

nature of the activity, the recreational fisher's interest in management processes and their part in the catch.

The fishery for European lobster (*Homarus gammarus*) (hereafter: lobster) in Norway has a long tradition in coastal Skagerrak. In 1876, more than 1100 tons of lobsters were officially landed in Norway (SSB 2010). Already at this time, the public debate regarding management of lobsters and the decrease in stocks were publicly discussed. In 1848 a new law was introduced, prohibiting fishing of lobster in summer (Dannevig 1936).

Dannevig (1936) argued that in the early days of the fishery, lobsters must have been as plentiful as crabs were in the 1900s, and that the fishing techniques were not able to catch lobster at greater depths, thus protecting them from the fishery. While trying to estimate the stock size of lobster at his time, Dannevig assumed that there were a substantial amount of lobsters outside the traditional fishing areas. He defined these areas as refugia that were protected from the fishing and played an important role in maintaining the stock. The lack of technology hindered fishermen in catching lobster in exposed areas and at greater depths. Today, both the recreational and commercial fishers have access to more advanced technology (GPS, echo-sounder, weather forecasts etc.), more powerful boats and heavier gear, and are thus expectedly able to catch lobster in any area within its range.

The lobster fishery was for a long period of time a lucrative fishery, in which a substantial proportion of the local population of fishers and farmers participated. The official lobster landings in Norway from 1928 to 2009 show a decrease through time (Fig 1). However, there are large uncertainties regarding these statistics due to potential sale outside the legal market by commercial fishers and the fact that recreational catch is not accounted for. There has been no available data regarding these matters in the Norwegian lobster fishery. The Institute of Marine Research (IMR) has collaborated with a selection of commercial fishers since 1928 in order to collect yearly CPUE-data. At the same time, the Norwegian Directorate for Fisheries have collected official landings. By combining these estimates, we could estimate the effort (E=C/CPUE). Let's assume that the CPUE-data from commercial fishers are representative and reliable (see Fig 1). Then the calculations should be right if it is also assumed that all lobster catches went through official landings. Catch, CPUE and effort remains high until the 1960s. In the 1960s, official landings drop significantly. While the reported landings in 1960 were 787 tons, the landings in 1970 were 210 tons (73% reduction). CPUE also did decrease

during the same time period, but not to the same extent. CPUE in 1960 and 1970 was 0.17 and 0.13 lobsters per trap day^{-1} respectively (24% reduction).

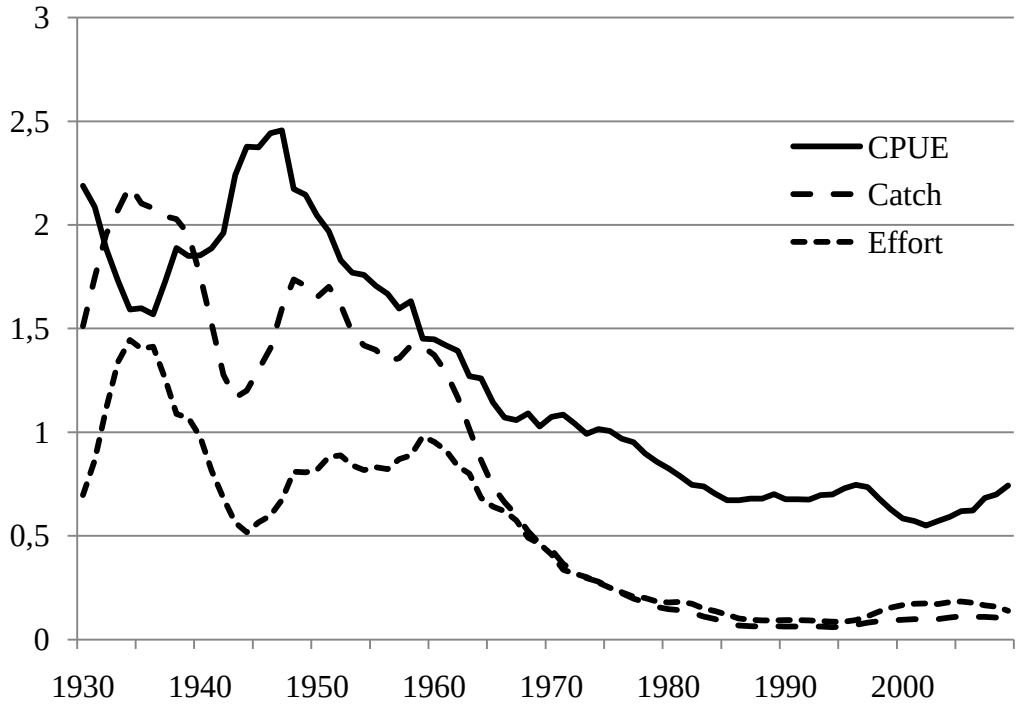

Figure 1. Official commercial lobster landings (500 tons) and CPUE (lobsters per trap day^{-1}) reported by a selected panels of commercial fishers in Norway from 1928 to 2009. Effort is given as Catch/CPUE. Effort calculation is based on the assumption that all lobster landings are officially reported. All the three time series were smoothed by computing the 5-year moving average. Because of the smoothing of the data, there is reason to stress that the long term trends can be considered as more reliable than the development from year to year. Source: Statistics Norway and Institute of Marine Research.

One hypothesis could be that the reduction in CPUE reached a level where it was not longer an economic gain from the fishery, leading to a collapse in the commercial lobster fishery in Norway. However, with such small fishing effort since the 1960s, one would expect that the lobster population would have a fair chance to rebuild. Another hypothesis could be that larger proportions of the catches are becoming unreported in the 1960s. Recreational fishing could be expected to be growing in these years, and commercial fishers might have started to sell more of their catch on the black market. Combining these two hypotheses might be necessary to explain the reduction in official catches in the 1960s. There are no available statistics regarding the total number of commercial fishers participating in the lobster fishery.

However, the total number of registered fishers in the area where it is fished for lobster was reduced by 30 % in the 1960s (SSB 2010). This could explain some of the fall in landings. There has been no available information regarding unreported illegal trade of lobsters and recreational landings. The work presented in this thesis has tested and developed a set of techniques in order to estimate the unreported catches in the Norwegian fishery for European lobster.

Lobster fishing regulations. New regulations for the lobster fishery were introduced before the 2008 season. Previously, commercial fishers had been allowed to fish with an unlimited number of traps. In 2008, the maximum number of traps was set at 100. The maximum number of traps for recreational fishers was reduced from 20 to 10. Additionally, egg-bearing females became protected and the minimum size limit was increased from 24 to 25 cm total length (TL), as measured from the tip of the rostrum to the end of the telson. The lobster season was shortened by one month (1 October to 31 November). Escape vents in the traps were introduced as a requirement. Traps are the only allowed gear when fishing for lobster, and divers are not allowed to catch lobster (NMFCA 2009). Commercial fishers are by law obliged to deliver their lobster catches through their own sales organisations, from which the resultant statistics is known as the official landings.

Figure 2. The experimental lobster reserves established in Norwegian Skagerrak in 2006. Capitol R and C denote reserves and control areas, respectively (Paper I).

In September 2006, four lobster reserves were established along the Skagerrak coast. These are Flødevigen (1 km^2), Risør (0.6 km^2), Bolærne (0.7 km^2) and Kvernskjær (0.5 km^2) (Fig. 2). Inside these reserves, it is illegal to fish with standing gear. The objective of the reserves is to understand how lobster populations develop within limited areas when the fishery is

excluded and thus test the potential of MPAs in future lobster management (Paper I). In his PhD-thesis, Moland (2010) argued that these moderately small lobster reserves are able to protect fractions of the lobster population, due to observations of long term site-fidelity observed in resident lobsters.

Research questions. The general objective of this study has been to investigate the fishery and management of European lobster (Homarus gammarus) in coastal Skagerrak, Norway, with a special emphasis on the recreational fishery and lobster reserves.

The research questions were:

1. How were recreational fishers and other local stakeholders included in the implementation process of the lobster reserves, how were they affected and what are their expectations of the effects? (Paper I)

2. What characterises the recreational fisher? What type of management implications are found with regards to recreational fishing versus commercial fishing? (Paper II)

3. How large is the recreational compared to the commercial effort in the lobster fishery? What type of methodology should be applied to estimate recreational and commercial effort? (Paper III)

4. What is the total catch of lobster in recreational fisheries compared to commercial fisheries? How does total catch compare to official landings? (Paper IV)

Summary of papers

Paper I

Stakeholder participation, especially by resource users, is found vital to a successful MPA management regime (Mascia 2003; Fernandes et al. 2005). By participating in the management process, stakeholders are more likely to acknowledge the benefits of protected the areas, take credit for the designation and enforce the regulations they establish (Leigh Kessler 2004). Four experimental lobster reserves were established along coastal Skagerrak, Norway, in 2006. In the event of future implementation processes of MPAs in Norway, there was a need to evaluate the implementation process of the newly established lobster reserves. Commercial fishers were involved at an early stage and asked to suggest potential areas. When reviewing background documents for the implementation process, it was not found any information surrounding recreational fisher's involvement in the process. How did they perceive the lobster reserves? Had they been involved and how would they like to be involved in future processes? In paper I we aimed to integrate natural and social science to obtain a complete understanding of the implementation process, in order to achieve a complete understanding of the potential of lobster reserves in coastal Skagerrak. While the biological selection criteria were found to be met, recreational fishers had neither been informed nor involved in the implementation process. Nevertheless, the recreational fishers responding to the questionnaire showed a positive attitude towards the use of reserves as a tool to manage lobster. In the event of using MPAs as a future management tool in coastal Norway, more species and larger areas might be considered, increasing the risk of conflict if not all stakeholder groups are involved in the process. The study documents the need to develop and establish appropriate tools to involve unorganised recreational fishers, as well as commercial fishers, in future MPA planning processes.

Paper II

There are fundamental differences between a recreational and a commercial fisher. A commercial fisher fish for profit, a recreational fisher do not. If the commercial fisher has more expenses than revenue from the fishery, the activity would stop as long as it is not subsidised. On the other hand, the recreational fisher may have a number of reasons to go fishing, both catch and non-catch related (Holland and Ditton 1992; Arlinghaus 2006).

Recreational fishers use money from outside the fishing sector for equipment and time to go fishing. Thus, while commercial fishers bring excess money out from the fishery and into the broader society, recreational fishers do the opposite and bring money from the outer society and into the fishery. The consequence is that recreational fishers can spend a whole day catching one fish without fear of bankruptcy. In paper II, we argue that recreational fisheries should be viewed as a self-subsidising fishery and that management needs to consider these innate forces in the activity when management tools are considered. We defined a self-subsidising fishery as a fishery as one in which fishers subsidise themselves through an economic investment in gear and time from their non-fishery based earnings.

Paper III and IV

The knowledge regarding total catch in the lobster fishery has been limited. The Institute of Marine Research (IMR) has collaborated with a selection of commercial fishers since 1928 in order to collect CPUE data. Commercial fishers are obliged to deliver their catches through their sales organisation, which is known as the official landings. However, recreational catches are not included in official landing statistics. There are also indications that commercial fishers sell some of their catch outside the legal marked. In order to estimate total catch, data on effort and CPUE has to be collected. Paper III describes a probability-based strip transect method to estimate commercial, recreational, and hence total effort. The study area was the Agder counties (Southern Skagerrak) except the area west of the south cape, Lindesnes. Transects were run for five different weeks throughout the lobstering season. A calibration study was conducted to adjust for transect width and detectability. Mean number of lobster traps per km^2 and associated variance was estimated by a ratio-estimator using bootstrapping, with transects as primary sampling units. Post-stratification of the counts by depth (by 10 meter depth intervals) combined with GIS mapping improved the precision of the estimated density of lobster traps and increased the effective sample size of transects up to by 22-44 %. Estimated total effort for the first week was 48.95 (SE 3.11) traps per km^2, decreasing to 5.96 (SE 0.79) in the 8th (and last) week of the lobstering season. Recreational fishers were found to account for 2/3 of the total effort in the lobster fishery. The dominance of recreational fishers pinpoints the need for management to consider recreational fisheries in order to achieve a sustainable management of the lobster population.

Paper IV estimates total landings by commercial and recreational fishers. Recreational lobster fishers were recruited to keep a catch diary throughout the lobstering season. Seventy-seven lobster diaries were returned at the end of the lobster fishing season. We compared the the catch rate between the recruited diarists and a random selection of fishers collected in field (Paper III). The results showed that the reports from the recruited diarists could be considered as representative for the recreational lobster fishing population in the area. In addition, it was found that the diaries could be used to estimate catches by commercial fishers. We estimated that recreational catch account for 65% of the total catch in the study area. Moreover, our estimates show that only a small proportion (23%) of the commercial lobster landings are sold through the legal market and thus documented. In total, true catches of lobster is found to be nearly 14 times higher than the official landings.

Discussion

The initiative for the creation of lobster reserves was taken by the management authorities and the Institute of Marine Research (IMR). This could be considered as the 'step zero', the initial phase of the MPA implementation process. It has been argued that these initial steps can determine the outcome of the process (Chuenpagdee and Jentoft 2007). Step zero was an informal process, where the first official documents were the selection criteria for the lobster reserves. Commercial fishers were invited to nominate potential areas to be protected based on a set of selection criteria. The same type of process, on a completely different scale, is found for the re-zoning of the Great Barrier Reef Marine Park in Australia. Here, the aims were defined by the government in cooperation with scientists. These aims could be reached in many ways, and all stakeholders were given the opportunity to suggest areas for different zoning purposes. The management authorities received more than 30 000 formally submitted comments from stakeholders and organisations, which were analysed and entered into the database (Fernandez et al. 2005). A survey conducted three years after the implementation revealed that the majority of the recreational fishers found the rezoning to be 'a good idea' and supported the 2004 zoning plan (Sutton and Tobin 2009). In contrast to the process in Australia, management authorities in Norway seem to have aimed at organisations in their involvement process, where commercial fishers were the main target. Unlike commercial fishers, recreational fishers are mostly an unorganised group. Involvement of recreational

fishers, and other local stakeholders, would require additional participation efforts. Interestingly, our survey did not find any opposition against the lobster reserves among the local stakeholders, even though they were not involved in the implementation process. However, a substantial part (46 %) of those who fished showed an interest in participating in future MPA planning processes. The preferred ways to get involved was through information letters and local media. Information letters and media is one way communication with meagre possibilities for the local stakeholders to actively participate in the process. The results indicate that local stakeholders are not familiar with direct involvement in management processes. For instance, marine recreational fishers have not been recognised as an important stakeholder in the management of marine resources in Norway (Mikalsen and Jentoft 2001). Accordingly, management authorities, such as the Directorate of Fisheries, have historically put little attention on involving recreational fishers in their consultative processes. However, when developing new management plans for lobster (NDF 2007) and coastal cod (NDF 2009), the Directorate of Fisheries organised open public hearing meetings along the coast. These meetings, some of which I attended, attracted recreational fishers as well as commercial fishers. In 2009, two coastal municipalities (Kragerø and Lillesand) initiated local hearing processes in order to establish reserves for lobster and cod (Schulze and Karlsen 2009; Aanonsen 2009). These local initiatives led to a debate between local stakeholders in the media and might be a development towards an increase in the awareness of the local community when it comes to management of local marine resources. Jentoft (2000) argued that "...viable fish stocks require viable fisheries communities". Could these local initiatives contribute to a sustainable management of local resources? The initiatives from local communities may indicate a development towards a co-management regime with regards to management of local marine resources. Co-management can be viewed as collaboration between local stakeholders and the state in order to manage a certain common. It means that the government delegate, or share, rights and responsibilities with e.g. local stakeholders and fishers (Jentoft and Kristoffersen 1989; Plummer and FitzGibbon 2004). Jentoft (2004) argued that co-management can not come without empowerment. Empowerment give user groups and stakeholders access to the management decision making processes. With increasing power, the individual can enhance its ability to predict, control and participate in society.

Co-management and empowerment are strongly linked to and dependent on each other (Jentoft 2004). If local communities and stakeholders, such as recreational fishers in coastal Skagerrak, should be able to have a say in the management of the local fishery resources, they need to become empowered. Today's management decisions with focus on stock assessments, quotas and technical regulations decided by central authorities on a national level do not give local communities much power. The way the system of stock assessments and quotas are designed is not well adapted for co-management. Local communities have meagre influence and limited power in the decision making process. Looking at MPAs, the potential for co-management might be higher. The experimental lobster reserves described in this thesis were established from an interaction between local and higher levels of government and commercial fishing organisations. However, the initiative came from outside the local community (researchers and management authorities). In order to achieve a co-management regime of future MPAs, it should be a main goal that the local communities get more control of the implementation process. Scientists and managers should on the other hand seek to be advisors and facilitators in the process. It is no guarantee that co-management and empowerment of local communities will lead to a more sustainable management of the local marine resources. As for Norway, with a strong and well organised central authority, a balance has to be found between the local and central power in a co-management regime. A balance of power and influence might be the best option to meet national and local goals for the marine resources. It will therefore be of interest to researchers to follow and analyse the local MPA initiatives in Kragerø and Lillesand in order to understand the potential of co-management of MPAs in Norway. In addition, a collaborative project between the local municipality of Tvedestrand, the Norwegian Directorate of Fisheries and IMR has been initiated in order to develop a zoning plan in the coastal areas for Tvedestrand (Itvedestrand 2009). This process involves central governmental agencies in collaboration with local governments from the very beginning of the process. These different projects represent a unique opportunity to evaluate the potential of co-management of MPAs in coastal Skagerrak.

As identified in Paper I, recreational fishers were not involved in the implementation process, even though they had a stake in the resources and areas concerned. Research on marine recreational fisheries in Norway has been limited in both social and natural science. There are evidently some apparent differences between commercial and recreational fishers. In paper II,

we reviewed the literature in order to contrast the nature of recreational fisheries with commercial fisheries. By defining recreational fishing activities as self-subsidised, we pinpoint on a series of management challenges that does not fit well with the management tools implemented to control commercial fisheries. Recreational fisheries in Norway may serve as an example.

Limited research has been conducted on marine recreational fisheries in Norway. In a phone survey conducted by Hallenstvedt and Wulff (2004), 42 % of the respondents informed that they had fished in the sea in 2003. However, the study did not fully cover the population of recreational fishers and could for example have been affected by recall bias. Survey methodology will be further explored later in the discussion (see below). In the time period from 1970-2003, ten national recreational fishing surveys have been conducted in Norway. Catch statistics were not included in these surveys, except the Hallenstvedt and Wulff (2004) report which operated with a one year recall period. There are some uncertainties related to the recreational fisher surveys since there are some differences in methodology, but the long term trends should be seen as more reliable than comparing any one year to another (Vorkinn et al. 1997). The estimated proportion of marine recreational fishers in the Norwegian population has been estimated to be between 37 and 44 % from 1970 to 1996 (Vorkinn et al. 1997). In a survey regarding outdoor activities in Norway conducted in 1996, 42 % informed that they had fished in the sea the latest year. In the same survey, 34 % informed that they had been skiing in the mountains (trip lasting more than 3 hours) and 7 % had been hunting small game (Vorkinn et al. 1997). These results show that marine recreational fishing is a popular activity in Norway. However, data information regarding regional participation, economic value and catch are sparse. The target population for the surveys described above were Norwegian citizens or legal residents. There has been a growing recreational fishing tourism industry in Norway, where tourists from other countries come to Norway to fish. A probability-based survey covering 445 identified tourists fishing businesses in Norway were conducted in 2009, where catch and effort was estimated for these businesses (Vølstad et al. 2010). Foreign tourists fishing in Norway may only use handheld tackle when fishing in the sea (NDFa). The regulations of Norwegian recreational fishers (Norwegian citizen or legal resident) can be termed liberal when comparing the regulations with other highly developed fisheries nations such as USA (NOAA 2005) and Australia (anonymous 2010a). A single recreational fisher is allowed to fish with up to 210 m of gillnets, a long-line with 300 hooks

and 20 pots and traps in addition to regular line and rod (Lovdata 2010). The recreational fisher is allowed to sell the catch, as long as the value does not exceed 50 000 NKR per year (approx $ 7 500 US) and catch of cod does not exceed 2000 kg (NDF 2010b). Minimum size limits were introduced in 2010 for a selection of marine species (NMFCA 2009). However, if the fisher identifies the fish as dead or not able to survive, it can be brought home and eaten (NDF 2010c). The consequence of this is that a recreational fisher that keeps undersized fish bears minimal, if any, risk of being prosecuted for illegal fishing. Recreational fishery in Norway can be termed an open-access fishery, and it is expected that a large proportion of the population are participating in the activity. Considering the self-subsidising nature of recreational fisheries, the liberal regulations and the high participation rate in Norway, it might be reason to expect that recreational fisheries can put coastal resources at risk. Some popular coastal target species, such as coastal cod (*Gadus morhua*) and lobster (*H. gammarus*) are listed in the national red list (Nedreaas et al. 2006; Oug et al. 2006). As long as a commercial fishery is not subsidised and the prices of the target species remain stable, commercial fishing effort would be expected to be reduced if stocks decline. Due to the self-subsidising forces in recreational fisheries there might be reason to expect that recreational fishing effort would not respond in the same manner as in the commercial fishery. This is what we might have detected in Paper III, where the recreational effort in the lobster fishery is found to be twice as high as the commercial effort. Data collected from the commercial fishery shows that CPUE has been at low levels since the 1970s. Unfortunately there are no historical records on the effort in neither the commercial nor the recreational lobster fishery. However, it is reason to expect that commercial fishing effort has declined since the 1970s. The low catch rates may have reduced the effort in the commercial fishing sector. Lobster fishing has a high cultural value for many coastal inhabitants along the Skagerrak coast (Knutsen et al. 2009). Due to the shifting baseline syndrome (Pauly 1995), recreational fishers might be satisfied with a historically low catch rate and continue to fish as long as the activity satisfy their experience value. They are in no danger of going bankrupt and recreational fishers can continue the hunt for the over-harvested lobster. Hence, the fishing effort has the potential to keep over-harvested stocks at low levels. Specifically, recreational fisheries accounted for 4 % of the entire landings in the United States in 2002 (Coleman et al. 2004). For populations of concern (i.e. overfished or experiencing overfishing), the study by Coleman et al. (2004) found that recreational catch was 23 % of the total catch.

Estimating effort and catches in recreational fisheries. The nature of recreational fishing makes the choice of methodologies for surveying this activity challenging. The number of participants in the activity is usually higher, more diverse and diffuse than for commercial fisheries. Some recreational fishers are less avid, while others fish more often (NRC 2006). NRC (2006) argued that recreational surveys in the US may be the most complex national surveys currently conducted.

In order to estimate total catch (C) in diffused recreational fisheries, it is essential to collect information regarding Effort (E) and Catch Per Unit Effort (CPUE). A phone survey might theoretically reach all potential fishers, but it would yield a poor estimate of catch due to challenges regarding species identification and the need to recall size and number of fish for each trip (NRC 2006). More often, CPUE data is collected by intercept and creel surveys, where fishers are asked about the time spent fishing and catch information (see e.g. Vølstad et al. 2006; Rangel and Erzini 2007; Beckley et al. 2008). The interviewers/researchers can count and measure the fish, thus improving the accuracy of CPUE compared to phone interviews where recall bias is an issue and species identification cannot be confirmed. The combination of effort estimates from phone surveys and CPUE estimates from intercept surveys result in an estimate of total catch $(C = CPUE \times E)$. Intercept surveys are often conducted at access points such as marinas, fishing piers or boat ramps where many recreational fishers pass through after they have completed a fishing trip. In many countries, such as the US and Australia, trailer boats are often used and the recreational fishers can be intercepted when and where they are launching or taking up their boat at boat ramps.

Traditionally, surveys of effort have been based on random phone surveys, such as the study by Hallenstvedt and Wulff (2004) described above. In phone interviews, where interviewees for example are selected randomly from the white pages or through random digit dialling (RDD) (NRC 2006), there is a risk of not reaching the whole target population. In Norway for example, an unknown proportion of recreational fishers are foreign fishing tourists (Vølstad 2010). A national phone survey would not be able to account for these fishers. NRC (2006) pinpointed that a list frame sampling method, such as a phone book, could suffer from overcoverage since not all households contain anglers, and undercoverage since some anglers do not live in the area or are not listed in the phone book. In addition, it is a risk for duplication if a household has more than one phone number. Another challenge is recall bias. Recall bias is a type of systematic error resulting from the respondent's inability to remember

the correct answer. Two independent surveys on recreational fishing in New Zealand conducted in 1996 and 2000 revealed a difference of 300 % in fisher prevalence between these two phone surveys. Accordingly, the catch estimates for different species were as well 2 to 6 times higher in 2000 compared to the 1996 survey. Kearney (2002) observed a large difference between the number of people that said they had fished the last year and the actual number that did. In phone interviews, a large proportion of respondents said they had fished the last year, but with the follow up by fish diaries the participation rate appeared to be much lower. Kearney (2002) argued further that "...the large number of diarists who said they fished in the last year and thought they would fish in the next, who did not fish ... strongly suggests that "telescoping" is a real problem for interview assessment of recreational fishing and this problem could be worse as the period of recall is extended". Telescoping can be understood as the respondent's potential to remember longer than the recall period it is asked for. E.g. if a person is asked about how many fishing trips he/she conducted the last year, activities from before the period in question might be included in the answer. The recreational fishery for lobster (*Jasus edwardsii*) and abalone (*Haliotis rubra and H. Laevigata*) in Tasmania, Australia, was investigated by both recall interviews and telephone diary surveys within the same season (Lyle and Morton 2004). Recall interviews were based on phone interviews where the recreational fisher was asked about effort and catch for the last fishing season (November-August). The telephone-diary survey asked eligible respondents to participate in a diary survey, where the participants were continuously followed up by phone interviews at least once a month throughout the fishing season. It is argued that a telephone-diary survey would have less recall bias than a recall survey (Baharthah 2006). Lyle and Morton (2004) showed that the recall estimates of catch and effort were consistently higher than the estimates from the telephone-diary surveys. Effort was 1.27 times higher while catch was 1.4 times higher for the lobster fishery, while it was 2.24 and 2.19 times higher respectively, for the abalone fishery. Baharthah (2006) analysed three different survey methods for the Western rock lobster (*Panulirus cygnus*) recreational fishery in Western Australia. She found that mail survey estimates of effort and catch were more than twice as high as the telephone-diary survey estimate. Further, the effort and catch from the telephone recall survey was as well significantly higher than the telephone-diary survey. In the lobster survey presented in this thesis, we did not observe any differences between those who filled out daily catch diary and those who filled out the mail based questionnaire at the end of the season. However, the recall period was only 2 months in a

highly specialised fishery. Baharthah (2006) argued that telephone-recall surveys can suffer from recall bias when the recall period is longer than two months. Our survey had such a short recall period that the risk of recall bias was minimised. The Norwegian recreational telephone one-year recall survey conducted by Hallenstvedt and Wulff (2004) and other Norwegian recall surveys (Vorkinn et al. 1997) might have suffered from recall bias and telescoping. However, in order to test this hypothesis, there is a need to perform parallel surveys such as those conducted in Australia. A future Norwegian recreational survey should be expected to be extremely challenging due to the long coastline, scattered population structure, high number of foreign fishing tourists and the liberal recreational regulations. Conducting reliable effort and catch estimates in a fishery on a large unregistered scattered group of fishers with exceptionally liberal regulations would require a professional team, careful planning and predictable economic resources.

Recreational lobster fisheries. Recreational lobster fisheries for lobster have been researched in different countries. Davis (1977) described the challenge of estimating recreational fishing for lobster in Florida, where he found creel surveys logistically impossible. There were too many access points and difficulties in identifying potential fishermen. Davis (1977) therefore used protected areas to evaluate the effects of recreational fishing on the spiny lobster (*Panulirus argus*) population. In another later attempt to estimate the spiny lobster recreational fishery in the same area in Florida, annual harvest from the park was estimated by multiplying the number of boats engaged in the fishery times mean number of fishing days for each boat and the mean daily catch (Davis and Dodrill 1989). In 1991, licence requirement was introduced for recreational fishers targeting lobster in Florida Keys (Muller et al. 2000). Iacchei et al. (2005) also used the opportunity represented by MPAs to evaluate direct impacts of commercial and recreational fishing on spiny lobster (*Panulirus interruptus*) in California, US. They had access to compare an area dominated by commercial fishing, a recreationally fished area and an invertebrate no-take area. In other countries, there are license requirements for recreational lobster fishing. With a comprehensive license system that covers a large portion of recreational fishers, more cost-effective surveys on recreational fishing can be conducted, and the potential for more accurate estimates are higher. In South Africa, Cockcroft and Mackenzie (1997) used a multistage telephone interview of permit holders through season to estimate effort and catch for west coast rock lobster (*Jasus Lalandii*). They found that recreational catch increased from 7 % of total allowable

commercial catch in 1992-1993 to 25 % in 1995-1996. In Tasmania, Australia, the number of persons with lobster licenses increased by 80 % from mid 1990's to 2002-2003. Since 1995, a periodically telephone-diary survey has been undertaken to estimate the recreational catch through time (Lyle et al. 2005). The researchers found that the recreational catch had increased significantly and was 12 % of the total allowable catch in the 2002-2003 season. Muller et al. (2000) estimated the recreational landings to be 23 % of the total landings in the Florida Keys in the 1999-2000 season. There seems to be a general global trend of increased participation by recreational lobster fishers and a growing recognition that the recreational fishing sector should be accounted for in stock assessments, ecological impacts of fishing, and resource sharing and -access (Lyle et al. 2005).

The survey methodology presented in this thesis (Paper III) is a novel new way of estimating recreational fishing effort. By using probability-based strip transects to estimate effort we are able to avoid the issue of recall bias and other typical problems regarding list frame sampling methods as described above. This method is not applicable to all types of recreational fisheries. The lobster fishery is highly specialised where it is only allowed to use traps with buoys attached, and the season lasts for only two months. The use of random phone surveys to obtain effort and catch data from recreational lobster fishers would be costly due to the expected small proportion of the population participating in the fishery (Griffiths et al. 2010). We recruited recreational fishers to a panel that provided data on catch and effort through diaries (Paper IV). The recruitment was based on name dropping and snowball sampling in order to obtain a sufficient sample size. However, this a non-random sampling method in which the recruited reporters might not be representative for the whole fishing population. To test the assumption that the recruited reporters were representative for the recreational lobster fishing population was reasonable, we also contacted a random sample of fishers identified from marked buoys during the field strip transect survey (Paper III). The dramatic change in CPUE through time made phone interviews challenging, because it was necessary to obtain catch data for exact dates, which could be difficult to recall for fishers. We were able to conduct a phone survey after the first week of the season for Aust-Agder (eastern part of the study area). However, the data collected from West-Agder (the western part) were conducted over a few days after two weeks of the fishing season. Due to high variation in catch between days, the data obtained from these interviews were not suited to be compared with catch diaries. This is evident in Fig. 3, where daily CPUE for the first two weeks of the lobstering

season are presented. The first day of the fishing season has by far the highest CPUE and then the catch rate decreases relatively steady in the following days. It is therefore highly important to collect catch information at one specific day in order to avoid bias in the CPUE estimate.

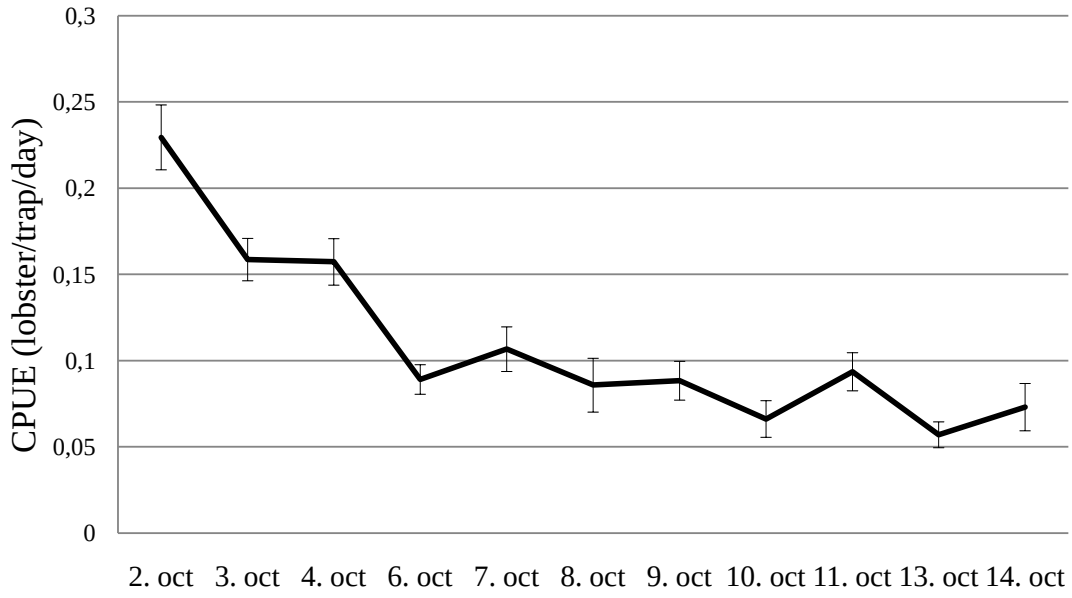

Figure 3. Daily CPUE (lobster per trap day^{-1}) for the first two weeks of the lobster fishing season for all southern Norway (Hordaland to Østfold). Traps are deployed 1 October and the first hauls are conducted 2 October. Sundays are excluded since it is illegal to haul traps on Sundays in parts of the study area (Skagerrak).

Management implications of the presented findings

Even though there exists an effort limitation per fisher in the lobster fishery (maximum 10 traps for recreational and 100 traps for commercial fishers), total effort limitation is absent. It is therefore a potential for increased effort if there is an increase in the number of recreational- and commercial fishers participating in the fishery. A lobster fishery without total effort and/or quota regulations, and no available data on participation and catch, put the resources concerned at risk. Our estimate of total catch compared to the official landings should be considered as a serious challenge for the Norwegian management authorities. The

complete lack of recreational catch data, which is expected to be high for more species than lobster, will make sustainable management of coastal resources a difficult task.

When introducing new management regulations for lobster in 2008, the Norwegian Ministry for Fisheries and Coastal Affairs expressed a management target of 10 lobsters per 100 traps as a mean for the season (NMFCA 2008). Management targets based on CPUE alone can be highly problematic. As an example, in the new management plan for lobster (introduced in 2008) was the season shortened by one month (December). In a fishery, such as the lobster fishery, where CPUE decreases through time within season, a shortening of the season is likely to increase the CPUE independent of the development of the target population. When calculating the weekly catch rate in the lobster fishery it became obvious that catch rates are by far highest in the beginning of the season and decrease through time. The fishery has the potential to fish out a high proportion of the catchable lobsters in very few days, and appear to be more like a depletion experiment rather than a sustainable fishery (see Fig 3 and 4). Mean CPUE for the season does not necessarily give good information of how many lobsters that are left after the fishing season. This can be seen in Fig. 4, where we compare weekly CPUE from catch diaries obtained from recreational fishers in 2008 (n = 97) and 2009 (n = 168) for the whole of southern Norway (Hordaland to Østfold).

While CPUE was significantly higher in 2009 than in 2008 in the first weeks of the season, the catch rate decreased towards the end of the season. In the later weeks, CPUE was at the same level as in 2008. The difference between these two years might be explained as differences in catchability between the years and/or an increase in the target lobster population. However, when catch rates are similar in the end of the season for both years, there might be reason to argue that the population of lobster left after these two seasons would be similar. These findings may be interpreted as symptomatic of a fishery that might not be concurrent with the rebuilding plan as expressed by the management authorities.

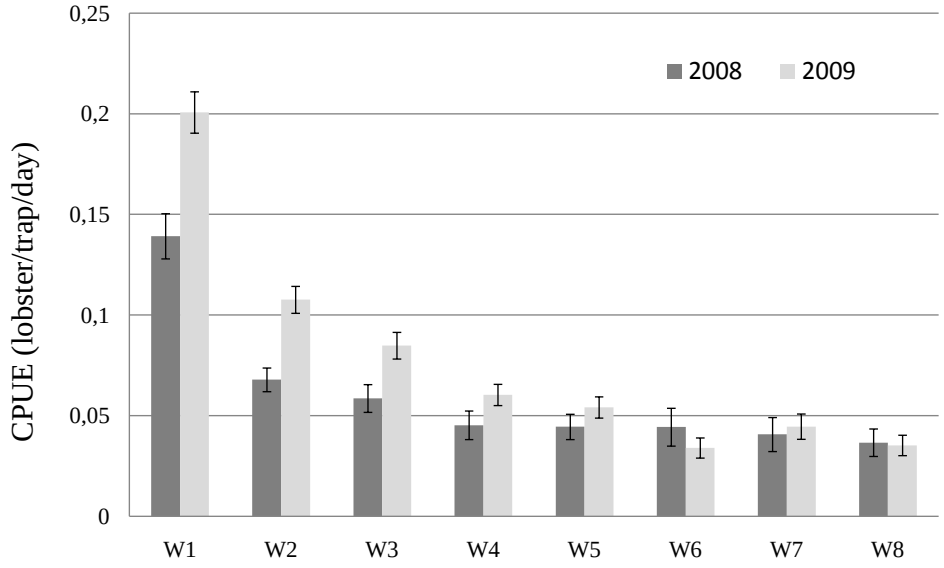

Figure 4. Mean weekly CPUE (lobster per trap day^{-1}) for 2008 and 2009 from Hordaland to Østfold (all of southern Norway). While CPUE was significantly higher in 2009 compared to 2008 in the first weeks of the lobster fishing season, CPUE is on the same level the last weeks of the season.

A limit of total effort and/or a total allowable catch for both recreational (TARC) and commercial fisheries (TACC) would be one option in order to achieve a sustainable lobster fishery. This, however, is in reality impossible to introduce under today's management regime. A limit of total effort or TARC and TACC would require basic knowledge of the number of participants in the fishery and their catch for both recreational and commercial fishers. Introduction of TARC and TACC can be a challenging task because it has to be made decisions regarding resource sharing between the recreational and commercial fishing sectors (Borch 2010). Such a process has been tried out in New Zealand, creating heavy conflicts among recreational and commercial fishers. Borch (2010) discussed the challenges of implementing recreational fisheries into modern fishery management systems. Recreational fishers often take their access to the resources for granted, it is a poorly defined unorganised sector and has limited institutional power in the existing management systems. As found in our stakeholder survey regarding the lobster reserves (Paper I), recreational fishers were not consulted in the process and they have, arguably, little tradition in participating in such

processes. However, the dominance of recreational catch in the lobster fishery in the Agder counties (Paper IV) cannot be ignored if a sustainable fishery is to be achieved. Therefore, the critical first step needed is to implement robust data collection frameworks for recreational lobster fisheries. To collect catch data cost efficiently and precisely, the introduction of a license system should be considered in the recreational fishery for lobster. In the hearing process regarding the new lobster regulations in 2008, the Norwegian Recreational and Small-Scale Association stated (NRSSO 2008): "We recommend an introduction of a marking and registration system for the lobster fishery. Such a system will give a better overview of the participation as well as catch and effort in the lobster fishery. It will as well help the control of the fishery" (in Norwegian, translated by the author). Inviting representatives from the recreational fishing sector from the start of such a process will increase the probability for a common understanding, knowledge transfer, finding appropriate solutions and increase the legitimacy for the management decisions.

The high international profile to combat Illegal, Unreported and Unregulated (IUU) fishing shown by the Norwegian government when managing the oceanic fish stocks seems not to be relevant for coastal resources such as lobster. Commercial unreported catches, most likely sold on the black market, should be considered as a serious management problem and should be characterised as IUU-fishing. In order to give precise management advice, researchers need to know the total fishing mortality. The results presented herein indicate that official landings are just a fraction of the total catch (Paper IV). The commercial fishing industry has to report their catches in order to achieve a sustainable fishery for the future.

When considering the existing management regime, it is necessary to discuss the use of lobster reserves in order to secure the lobster population. A network of marine reserves along the coast would have the potential to secure a part of the lobster population from fishing (Moland 2010). Implementation of reserves affects local stakeholders such as recreational and commercial small-scale fishers. The positive attitude toward the existing lobster reserves, as expressed by the stakeholders in our survey (Paper I), shows a potential for a successful introduction of lobster reserves along coastal Skagerrak. In order to use lobster reserves as a management tool there is a need for larger and more numerous areas than the relatively small and few experimental lobster reserves existing today. Accordingly, a higher potential for conflict is present in the event of introduction of a network of reserves for lobster and other species. The ongoing zoning processes along the Skagerrak coast can be important in order to

understand the best way of implementing lobster reserves. Involving local stakeholders from the early stage in the process and secure their influence in the implementation process will expectedly reduce conflict and increase the legitimacy of the potential reserves.

General conclusions and recommendations for future work

Officially reported landings statistics for lobster in Norway should not be used to evaluate the lobster stock development. Together, recreational catches and unreported catches from the commercial fishing sector constitute the vast majority of the total catch. Moreover, there are no indications that official landings represent a static proportion of the total landings. There are negligible regulations of effort in the lobster fishery and no registry of neither commercial nor recreational fishers participating in the fishery.

The survey area for this PhD covered only a part of the lobster fishing area in Norway. In order to estimate the catches in other regions of Norway there is a need to improve the strip transect survey method and adapt to different coastal systems. The complexity of the coastline on the west coast, with long fjords, large islands and steep coastlines, represents new challenges for survey design. The coastline in inner Skagerrak is comparable to outer Skagerrak where the survey described herein was conducted. Field personnel conducting strip transect surveys have to be focused on keeping the same transect width through the whole survey. Our survey showed that nearly all lobster fishers participate from the beginning of the season. There was no significant difference in effort between the first and second week of the season, indicating that the majority of fishers participate for more than one week. Given the assumption that fishers behave the same way in other areas of Norway, a future effort survey should cover a two week survey period. In a future survey, information should be collected from a random selection of fishers from the surveyed weeks. Effort for the parts of the fishing season not covered by a survey could be estimated by phone interviews of the randomly selected fishers to obtain information regarding their fishing activity throughout the season.

As long as there is no existing registry of recreational lobster fishers, lobster diaries from recruited fishers can be seen as a good alternative to estimate CPUE. It is important to control for their representativity for the general lobster fishing population. Phone based interviews have to be conducted often and timely since catch changes within a short time frame (daily).

Collection of CPUE from commercial fishers should be expanded. A complete list of commercial fishers participating in the lobster fishery would be very helpful for data collection.

The self-subsidising forces of recreational fishers might explain why recreational fishers are able to dominate the effort and catch of an over-fished red-listed species. The newly acquired knowledge of the dominance of recreational fishers in the lobster fishery presented herein highlights the need for management to include recreational fisheries in stock assessments and decision making processes. The nature of recreational fishing activities, as opposed to commercial, has to be considered when management tools are evaluated, how these regulations are communicated and how recreational fishers should be involved in management processes.

Marine protected areas (MPAs), designed to protect lobsters, have the potential to be an important management tool in an unregulated fishery. As shown in this thesis, the user groups showed a positive attitude towards the implementation of lobster reserves. The results indicate a high social potential for the use of lobster reserves as a management tool in coastal Skagerrak. Given that the experimental lobster reserves have a positive biological effect, as found for other lobster species elsewhere (Paper I), MPAs for lobsters would be able to protect components of the lobster population from over-harvesting. It is therefore a need for research to follow up the new MPA initiatives taken by local communities in Skagerrak to gain local knowledge regarding the potential of co-management when implementing MPAs in coastal Norway.

The target species in this study was European lobster. However, the proportion of the population fishing for lobster should be considered marginal compared to the proportion of the population targeting other marine coastal species, such as the red listed cod (*Gadus morhua*). There is thus a need for a national recreational survey targeting catches off a broad spectrum of species to get a comprehensive overview of the impact of recreational fishing on coastal fish populations in Norway. Managing the coastal fisheries in Norway without catch data from recreational fisheries may lead to serious mismanagement, further depletion and potential collapse of coastal resources.

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