Catch-and-release of Atlantic cod (*Gadus morhua*) in recreational fisheries

Keno Ferter

Dissertation for the degree of philosophiae doctor (PhD)

at the University of Bergen

2015

Dissertation date: 26.06.2015

Year: 2015

Title: **Catch-and-release of Atlantic cod (*Gadus morhua*) in recreational fisheries**

Author: Keno Ferter

Print: AIT OSLO AS / University of Bergen

"Angling is somewhat like poetry, men are to be born so: I mean, with inclinations to it, though both may be heightened by discourse and practice"

- Izaak Walton, *The Compleat Angler* (1653-1655), Part I, chapter 1

Scientific environment

The work for this doctoral thesis was carried out under a partnership between the University of Bergen (Department of Biology; Fisheries Ecology and Aquaculture Research Group) and the Institute of Marine Research (Fishery Dynamics Research Group).

Funding for this doctoral thesis was provided by the University of Bergen and by the Institute of Marine Research (Project: “Kartlegging av turistfiske”).

Acknowledgements

This PhD thesis would not have been possible without support and help from many other people. First of all, I would like to thank my three supervisors, Jon Helge Vølstad, Jeppe Kolding and Odd-Børre Humborstad. All of you gave me an extraordinary freedom to plan and conduct my work, but always supported me whenever I needed help or advice – be it academic or personal. I am also grateful to Marie Hauge, whom I actually consider my fourth "popular-science" supervisor. You always supported me in writing and editing popular science publications and in communicating the message of my findings not only scientifically correctly but also interestingly and understandably for everyone.

The part of my PhD work, which I admittedly enjoyed the most, was spending time in the field. However, this part was also one of the most challenging, both physically and psychologically. Without the exceptional support and help of Harald Næss, Marc Simon Weltersbach, Alf Ring Kleiven, Harry Strehlow, Martin Wiech, Enrique Blanco and many others, this would not have been possible – thank you very much for making this part of my PhD such a memorable experience! In this context, I would also like to thank the teams at "Sjøtun Brygge" and "Lauklines Kystferie", and all other angling tourism businesses involved, for their practical support during the field work.

Another amazing and inspiring highlight during my PhD was a four-month stay at the Institute of Marine and Antarctic Studies in Hobart, TAS, Australia. I am not only grateful to the Institute of Marine Research (IMR) and the University of Bergen (UiB), for financing this stay, but also to all the people who made this stay possible and such a valuable experience. Special thanks to Jeremy Lyle, Robert French, Amos Mapleston, Sean Tracey, Sarah-Jane Pyke and Justin Bell.

Being affiliated to two institutions can be challenging as it is physically impossible to be at both places at the same time. However, I always had the feeling that I was part of both the Fishery Dynamics Research Group at IMR and the Fisheries Ecology and Aquaculture Research Group at UiB. Thanks to all my colleagues and office mates for making me feel "at home" in both groups, and for all the fruitful and interesting

discussions we had. I am also grateful to colleagues from other institutions for taking special interest in my work and providing invaluable feedback throughout the course of my PhD. A special thanks to Trude Borch and Claus Reedtz Sparrevohn.

I would also like to thank my friends who, apart from listening to all my PhD blathering, provided a social outlet and gave me the possibility to do things other than working for this PhD, like *recreational* fishing for example.

To my parents: Vielen Dank für Eure Unterstützung!!! Ohne Euch hätte ich es sicher nicht bis hierher geschafft! Ich werde Euch für immer dafür dankbar sein.

Last, but definitely not least, I would like to thank my greatest supporter Tessa Bargmann. Thank you for always being there for me, for your selfless support, for your understanding when the whole apartment smelled of fish, and your patience when I delayed my household duties until tomorrow because I had to finish writing – Ich gelobe Besserung!

Beach time in Northern Norway after a successful field trip. From left to right: Marc Simon Weltersbach, myself and Harald Næss (Photo: Marc Simon Weltersbach)

Abstract

The role of recreational fisheries in the exploitation pressure on fish resources is increasingly recognized. This has led to the introduction of new harvest regulations for several European marine recreational fisheries. Such regulations have been shown to increase the practice of regulatory catch-and-release (C&R). Additionally, anglers have been shown to practice voluntary C&R due to various personal motivations. Access-point surveys in two study areas in Northern and Southern Norway found that marine angling tourists release more than 60% of their catch for several species due to regulatory and voluntary C&R. For Atlantic cod (*Gadus morhua*) alone, this corresponds to more than one million individuals released annually by angling tourists in Norway. A review of published, unpublished and grey literature on C&R for nine European marine recreational fisheries found that C&R is a common practice in many European countries. Among the studied European marine species caught by recreational anglers, the highest absolute release numbers were found for Atlantic cod. Impacts of C&R on Atlantic cod under "best practice" conditions, and the effects of different capture depths on barotrauma symptoms and post-release mortality of cod were investigated in a telemetry study and a containment study, respectively. The telemetry study showed that some cod show behavioral alterations after C&R, but can recover quickly if they are caught in shallow waters (<20 m) and properly handled before release. The containment study showed that even though cod develop several barotrauma symptoms depending on capture depth, short-term mortality due to barotrauma is negligible (assuming minimal predation) if cod submerge quickly and are otherwise not substantially injured. Based on these results and other studies, a framework for the development of best practice C&R guidelines for cod is presented. To ensure that the study findings are understood and adopted by fisheries managers and anglers, efficient communication is essential, which requires a combination of several communication channels, including scientific publications, the media and information flyers. Even though emergent animal welfare concerns could not be resolved, a better understanding of C&R impacts on cod through this thesis will hopefully contribute to improving recreational fishing practices, which subsequently may minimize sublethal C&R effects and lead to decreased post-release mortality of cod in the future.

List of publications

Paper I

Ferter, K., Borch, T., Kolding, J., and Vølstad, J.H. (2013). "Angler behaviour and implications for management - catch-and-release among marine angling tourists in Norway." Fisheries Management and Ecology **20**(2-3): 137-147.

Paper II

Ferter, K., Weltersbach, M.S., Strehlow, H.V., Vølstad, J.H., Alós, J., Arlinghaus, R., Armstrong, M., Dorow, M., de Graaf, M., van der Hammen, T., Hyder, K., Levrel, H., Paulrud, A., Radtke, K., Rocklin, D., Sparrevohn, C.R., and Veiga, P. (2013). "Unexpectedly high catch-and-release rates in European marine recreational fisheries: implications for science and management." ICES Journal of Marine Science **70**(7): 1319-1329.

Paper III

Ferter, K., Hartmann, K., Kleiven, A.R., Moland, E., and Olsen, E.M. (2015). "Catch-and-release of Atlantic cod (*Gadus morhua*): post-release behaviour of acoustically pretagged fish in a natural marine environment." Canadian Journal of Fisheries and Aquatic Sciences **72**(2): 252-261.

Paper IV

Ferter, K., Weltersbach, M.S., Humborstad, O.-B., Fjelldal, P.G., Sambraus, F., Strehlow, H.V., and Vølstad, J.H. (in review). "Dive to survive: effects of capture depth on barotrauma and post-release survival of Atlantic cod (*Gadus morhua*) in recreational fisheries." (*Manuscript accepted with minor revision in the ICES Journal of Marine Science*)

Paper V

Dedual, M., Sague Pla, O., Arlinghaus, R., Clarke, A., **Ferter, K.**, Geertz Hansen, P., Gerdeaux, D., Hames, F., Kennelly, S.J., Kleiven, A.R., Meraner, A., and Ueberschär, B. (2013). "Communication between scientists, fishery managers and recreational fishers: lessons learned from a comparative analysis of international case studies." Fisheries Management and Ecology **20**(2-3): 234-246.

Contents

1. Introduction

For a long time, the potential role of recreational fishing in the exploitation of fish stocks was neglected (Cooke and Cowx 2004). During the past decades, however, substantial biological impacts and important socio-economic benefits of recreational fisheries have been documented in several countries (McPhee et al. 2002, Coleman et al. 2004, Arlinghaus and Cooke 2005, Lewin et al. 2006, Arlinghaus and Cooke 2009, Gray and Jordan 2010, Brownscombe et al. 2014a). For some species, the annual harvest by recreational anglers has been shown to be as high or even exceed commercial landings in some countries (Dorow and Arlinghaus 2011, Herfaut et al. 2013). The FAO (2012, p. 2) defines recreational fishing as "fishing of aquatic animals that do not constitute the individual's primary resource to meet nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets". Even though recreational fishers use a range of fishing gears (e.g. angling gears, spears, long lines, and gill nets) depending on local traditions and regulations (Pawson et al. 2008), the main focus of this doctoral thesis is on angling gear as a fishing method.

To preserve sustainable exploitation, harvest regulations, e.g. minimum landing sizes and bag limits, closed seasons, species protections and/or closed areas have been implemented for many recreational fisheries. While these regulations limit the harvest, i.e. the landed catch, they do not necessarily limit what is caught (Coggins et al. 2007). Thus, anglers often release some part of their catch due to such regulations (Harper et al. 2000). This practice is known as regulatory catch-and-release (C&R) (**Figure 1**). C&R is defined as "the process of capturing fish by using hook and line, mostly assisted by rods and reels, and then releasing live fish back to the waters where they were captured, presumably to survive unharmed" (Arlinghaus et al. 2007a, p. 77). Apart from regulatory C&R,

Figure 1: Catch-and-release is practiced due to management regulations and voluntary decisions with the assumption that the released fish will survive. Photo: Martin Wiech

anglers may also practice voluntary C&R, i.e. when an angler releases a fish which would have been legal to keep. When all fish are released (due to voluntary C&R, regulatory C&R, or both), the term total C&R is used (Arlinghaus et al. 2007a). Historically, C&R was practiced by anglers targeting Atlantic salmon (*Salmo salar*) in freshwater in the UK (Policansky 2002), but nowadays both regulatory and voluntary C&R have become increasingly common in many freshwater and saltwater recreational fisheries around the world (Pierce et al. 1995, Bartholomew and Bohnsack 2005, Northeast Fisheries Science Center (NEFSC) 2013, Brownscombe et al. 2014a).

The underlying principle of C&R is that the released fish have a high survival potential and do not experience any substantial sublethal impacts. Post-release mortality varies between species and fisheries, and is influenced by a range of factors including, but not limited to, anatomical hooking location, fighting time, water temperature, capture depth and air exposure duration (for reviews see Muoneke and Childress 1994, Bartholomew and Bohnsack 2005, Cooke and Wilde 2007, Hühn and Arlinghaus 2011). Several studies of freshwater and marine species have shown that anatomical hooking locations leading to bleedings and substantial injuries are among the main factors leading to post-release mortality (Bartholomew and Bohnsack 2005, Hühn and Arlinghaus 2011). Even if the released fish survive, they can still experience sublethal impacts (Wilson et al. 2014). Examples of such impacts are increased levels of stress hormones in the blood (Cooke et al. 2013) and deviations from normal behaviour (e.g. a resting period or hyperactivity after the release; Thorstad et al. 2004, Baktoft et al. 2013), which can for example lead to a failure of reproductive success (Suski et al. 2003) and increase the risk of post-release predation (Cooke and Philipp 2004, Brownscombe et al. 2014b, Raby et al. 2014).

The common practice of C&R has led to several public debates and ethical discussions (Aas et al. 2002a, 2002b, Salmi and Ratamäki 2011, Arlinghaus et al. 2012). Even within the angling community emerging conflicts due to voluntary C&R have been reported (Arlinghaus 2007). One of the main criticisms of C&R is that anglers catch a fish and subsequently release it just for the personal satisfaction of catching it (Arlinghaus 2008). This concerns the practice of voluntary C&R in particular. In contrast, regulatory C&R is mandated by law and, according to Cooke

and Sneddon (2007), should thus be accepted by everyone as long as recreational angling in itself is accepted.

To mitigate the negative impacts of C&R, scientists, managers and angling organizations have developed best practice C&R guidelines that can be used by anglers. To improve post-release survival chances and minimize sublethal impacts, anglers are generally encouraged to minimize fighting time, avoid fishing in very high water temperatures, use hooks that minimize hooking injuries, avoid long air exposure, and avoid fishing during spawning season (Cooke and Suski 2005). Apart from these general guidelines, species-specific guidelines have also been developed, e.g. for species that are known to develop barotrauma. Barotrauma occurs when a fish is rapidly hauled up from deep water and the swimbladder expands due to rapid pressure reduction (Hannah et al. 2008a). Typical barotrauma symptoms are swimbladder ruptures, exophthalmia (eye protrusion), swollen coelomic cavities, and stomach and gut eversions (Rummer and Bennett 2005, Hannah et al. 2008b). To mitigate barotrauma symptoms different procedures, such as venting (i.e. using a needle to release excess gas; Keniry et al. 1996, Roach et al. 2011) and recompression using release weights (Butcher et al. 2012) have been suggested as possible treatment methods. The efficiency of venting to increase survival has been debated (Wilde 2009), and although it can be beneficial for some species (Collins et al. 1999, Alós 2008), it has no or negative effects for others (Brown et al. 2010).

A sustainable development of recreational fisheries can only be ensured, if the management of a fishery is effective, and all aspects that may have an impact on fish stocks are considered (Post et al. 2002, Lewin et al. 2006, Post and Parkinson 2012). Thus, it is important to not only estimate the landings of anglers in a particular fishery, but also release proportions from C&R practices and their associated post-release mortalities (Kerns et al. 2012). Moreover, to evaluate the efficiency of harvest regulations and justify their use, it is important to understand which impact regulatory C&R has on the released fish (Coggins et al. 2007, Johnston et al. 2014). In addition, to improve C&R practices, irrespective of the underlying motivation, and to reduce undesired bycatch, it is important to develop and implement best practice guidelines, which requires a successful communication between scientists, managers and recreational anglers (Cooke and Wilde 2007, Pelletier et al. 2007).

2. Study background and objectives

Recreational fishing is a popular outdoor activity in Norway. According to a recent survey by Statistics Norway (SSB 2014), approximately 43% of the Norwegian population went fishing (freshwater and saltwater fishing, and all gears combined) at least once during 2014. In addition, Norway is a popular destination for marine angling tourists (Borch 2004). The marine angling tourism industry has undergone rapid development during the last two decades (**Figure 2**), and has led to several conflicts of interest, particularly with the commercial fishing industry (Borch 2009, Solstrand 2014). One important marine target species that has often been the focus of these conflicts is Atlantic cod (*Gadus morhua,* hereinafter cod). The coastal cod stock, which is genetically distinct from the Northeast Arctic cod stock (Sarvas and Fevolden 2005), is found close to the Norwegian coastline and inside the fjords (Stransky et al. 2008). In contrast to the Northeast Arctic stock, which is currently at a historical high, the coastal cod stock has experienced a significant decline during the last decades. In fact, the International Council for the Exploration of the Sea (ICES) recommended a harvest moratorium of coastal cod in the Norwegian Sea from 2004. Since 2011 the advice has been to follow a rebuilding plan allowing some harvest (ICES 2014).

Figure 2: The Norwegian marine angling tourism industry has expanded rapidly during the last years, providing lodging and rental boats for its guests. Photo: Keno Ferter

Until 2006, the only regulations for foreign marine angling tourists (i.e. those without permanent residency in Norway) were that they were allowed to use hand-held tackle only and that the sale of catches was prohibited. However, in 2006 a 15 kg export limit was introduced, which restricted the export of self-caught marine fish species to 15 kg filet (or other fish products) and one whole trophy fish per person (Fiskeridirektoratet 2015a). In 2010, minimum landing sizes for several marine fish species were made effective for both marine angling tourists and domestic resident recreational fishers (Fiskeridirektoratet 2015b). Bag limits and minimum landing sizes of fish have been shown or suggested to increase the practice of regulatory C&R

for regulated species in other recreational fisheries (Pickett et al. 1995, Harper et al. 2000, Alós et al. 2009). This could be in conflict with Norway´s discard ban. However, even though all captured fish in Norway have to be landed as a general rule, fish which are protected or under the minimum landing size and which can be expected to survive have to be released by law. Except for in the Skagerrak, fish that could be harvested legally are also allowed to be released if they can be expected to survive (Forskrift om utøvelse av fisket i sjøen 2013).

Although a range of studies have attempted to estimate the harvest by the Norwegian marine recreational fishery (including the marine angling tourism) (e.g. Hallenstvedt and Wulff 2001, 2002, Cap Gemini Ernst&Young 2003, Hallenstvedt and Wulff 2004, Jacobsen 2005, Vølstad et al. 2011), the estimates by Vølstad et al. (2011) are the only ones that are based on probability-based sampling and thus include measures of uncertainty. Vølstad et al. (2011) estimated that marine angling tourists staying in organized angling tourism businesses (defined as enterprises "renting out rooms and boats for recreational fishing at sea and with facilities for gutting and freezing catches", Vølstad et al. 2011, p. 1786) harvested 3,335 t (relative standard error, RSE = 17%) in 2009, of which 1,613 t (RSE = 22%) were cod (**Figure 3**). For comparison, the estimated commercial harvest of coastal cod was 24,800 t in 2009 (ICES 2014). Studies to estimate catches by marine recreational fishers have also been initiated in several other European countries. In fact, since 2009, the European Council requires that all European member states collect recreational catch data (i.e. harvest and release amounts) for species that are included in the European Union Data Collection Framework (DCF) under the Common Fisheries Policy (CEC 2008, 2009). The relevant DCF species include cod, European eel (*Anguilla anguilla*), Atlantic salmon, European sea bass (*Dicentrarchus labrax*) and Atlantic bluefin tuna (*Thunnus thynnus*).

Figure 3: Cod is the most important target species for marine angling tourists in Norway. Photo: Keno Ferter

Despite the implementation of the 15 kg export limit with its high potential to increase C&R, the amounts of fish released by marine angling tourists in Norway were not quantified before 2010. A master thesis by Ferter (2011) indicated that C&R is commonly practiced by marine angling tourists in Norway, both due to voluntary decisions and harvest regulations. As that thesis was only based on one sampling season and a limited number of angler interviews, confirmation of these findings through an extension of the study was necessary. Similarly to Norway, many marine recreational fisheries in Europe are regulated by harvest regulations leading to an increased potential for regulatory C&R practice. In addition, it was highly likely that marine recreational anglers in Europe also practice voluntary C&R to some degree. While some published studies (e.g. Sparrevohn and Storr-Paulsen 2012, Strehlow et al. 2012) had shown that C&R is common in some European countries, a general overview of C&R practices in European marine recreational fisheries was not available when this doctoral study was planned.

Through the course of this doctoral study, cod was found to be one of the most popular marine target species with substantial release proportions in many Northern European recreational fisheries. Thus, it was necessary to extend previous studies for this species to increase the understanding of C&R impacts on cod. A previous containment study by Weltersbach and Strehlow (2013) that investigated post-release mortality of cod in the recreational Baltic Sea charter boat fishery showed that bleeding and holding water temperature were the only significant factors leading to post-release mortality. For bleeding cod, the odds of dying were almost 5 times higher than for non-bleeding cod. Similarly, Milliken et al. (1999, 2009) and Pálsson et al. (2003) showed that hook-caught cod that had substantial hooking injuries (**Figure 4**) had a higher post-release mortality than uninjured cod. Even though cod with minor hooking injuries were shown to have high survival rates in these studies, sublethal effects of C&R and post-release

Figure 4: Cod with substantial hooking injuries or heavy bleedings have high post-release mortalities. Photo: Marc Simon Weltersbach

behaviour of surviving cod in a natural setting were not investigated. However, knowledge of such C&R effects is important, e.g. to evaluate the susceptibility to post-release predation (Raby et al. 2014) and to allow the evaluation of C&R of cod from an animal welfare perspective (Cooke and Sneddon 2007).

As cod have a closed (physoclistous) swimbladder, they develop barotrauma when hauled up rapidly from deeper water (Midling et al. 2012, Humborstad and Mangor-Jensen 2013). Barotrauma has been shown to increase post-release mortalities in some species (e.g. Collins et al. 1999, St John and Syers 2005, Alós 2008). The study by Weltersbach and Strehlow (2013) was limited to water depths shallower than 20 m. Milliken et al. (1999, 2009) and Pálsson et al. (2003) covered greater capture depths, but the main study focus was on commercial fishing gears (longline and automatic jigging machine), while rod-and-line caught fish served as control groups. Thus, an investigation of the effects of different capture depths on barotrauma symptoms and post-release mortality of rod-and-line caught cod was lacking.

The results of this thesis, in combination with the findings from other post-release mortality studies on cod (Milliken et al. 2009, Weltersbach and Strehlow 2013, Mandelman et al. 2014), contribute to the identification of critical factors that have an impact on the post-release mortality of cod. In addition, the findings assist in evaluating the efficiency of existing harvest regulations for cod and in developing best-practice C&R guidelines. Successful communication of these findings to fisheries managers is essential so that the efficiency of harvest regulations can be evaluated, and that appropriate best-practice C&R guidelines can be developed and implemented. Moreover, recreational anglers need to be able to understand the study findings and guidelines so that they can adjust their fishing methods and handling practices to reduce negative impacts of C&R on cod. As communication between scientists, fisheries managers and recreational anglers can be challenging, it was important to identify the main potential obstacles for successful communication, and how these can be overcome.

Given the increased importance and impacts of recreational fisheries, and thereby the need for a better understanding of marine C&R practice in Norway and

other European countries, the potential negative impacts of C&R, and the need for mitigation measures, the primary objectives of this thesis were:

1. To estimate C&R proportions by marine angling tourists staying in organized angling tourism businesses in Norway, and to identify the motivations for C&R.

2. To summarize existing data on C&R (extents and underlying motivations) for European marine recreational fisheries.

3. To investigate the post-release behaviour of cod in their natural environment under best practice C&R conditions.

4. To investigate the effects of different capture depths (range 0 - 90 m) on barotrauma symptoms and post-release mortality of rod-and-line caught cod.

5. To prepare a framework for the future development of best-practice C&R guidelines for cod to mitigate negative C&R impacts.

6. To identify means of successful communication of the study findings and guidelines to fisheries managers and recreational anglers.

Objective 1 was addressed in **paper I** by interviewing marine angling tourists in two study areas in Northern and Southern Norway (access-point surveys). Objective 2 was focused on in **paper II** by summarizing existing data (published, unpublished and grey literature) on C&R for nine European marine recreational fisheries (Denmark, England, France, Germany, Netherlands, Norway, Poland, Portugal and Sweden). Objective 3 was investigated in **paper III** by examining the post-release behaviour of cod in their natural environment using acoustic telemetry. Objective 4 was addressed in **paper IV** by investigating the effects of different capture depths (range 0 - 90 m) on barotrauma symptoms and post-release mortality of rod-and-line caught cod using a field containment study and a supplementary radiology study in the laboratory. Based on the results of **papers III** and **IV**, and other studies on C&R impacts on cod, objective 5 was addressed. Objective 6 was investigated in **paper V** by reviewing 11 case studies concerning communication between fisheries managers, scientists and recreational fishers, and presenting how the main obstacles for successful communication can be overcome.

3. Abstracts of papers I-V

Paper I: The role of recreational fisheries in the competition for marine resources is increasingly recognised. Their contribution in stock dynamics needs to be accounted for in assessments and management. Management regulations should be based on scientific advice on human and biological dimensions to be effective in reaching their goals. A survey among marine angling tourists staying in fishing camps in two study areas in Norway was conducted to study catch-and-release (C&R) behaviour. Although C&R has been assumed to be low in many marine recreational fisheries, this survey showed that for some species, more than 60% of the catch was released. As C&R may be associated with post-release mortalities, the current management system could be inefficient towards its aim of reducing fishing mortality. It was concluded that it is necessary to quantify release mortalities, to consider C&R behaviour in future management decisions, and to minimise the potential negative impacts of C&R through handling guidelines.

Paper II: While catch-and-release (C&R) is a well-known practice in several European freshwater recreational fisheries, studies on the magnitude and impact of this practice in European marine recreational fisheries are limited. To provide an overview of the practice and magnitude of C&R among marine recreational anglers in Europe, the existing knowledge of C&R and its potential associated release mortality was collected and summarized. The present study revealed that in several European countries over half of the total recreational catch is released by marine anglers. High release proportions of 60% were found for Atlantic cod (*Gadus morhua*), European sea bass (*Dicentrarchus labrax*), pollack (*Pollachius pollachius*), and sea trout (*Salmo trutta*) in at least one of the studied European countries. In the case of the German recreational Baltic Sea cod fishery, release proportions varied considerably between years, presumably tracking a strong year class of undersized fish. Reasons for release varied between countries and species, and included legal restrictions (e.g. minimum landing sizes and daily bag limits) and voluntary C&R. Considering the magnitude of C&R practice among European marine recreational anglers, post-release mortalities of released fish may need to be accounted for in estimated fishing mortalities. However, as the survival rates of European marine species are mostly

unknown, there is a need to conduct post-release survival studies and to identify factors affecting post-release survival. Such studies could also assist in developing species-specific, best-practice guidelines to minimize the impacts of C&R on released marine fish in Europe.

Paper III: Studying the sublethal effects of catch-and-release (C&R) is challenging, as there are several potential sources of bias. For example, if behavioural alterations immediately after the release event are to be studied, separation of tagging effects from actual C&R effects is required, which is a challenge in the wild, particularly in marine environments. To investigate the effects of C&R on Atlantic cod (*Gadus morhua*) in their natural environment, 80 cod were caught in fyke nets, fitted with acoustic transmitters, and released. After recovery from tagging and handling for at least 14 days, nine individuals were recaptured and released at least once during experimental angling, following best release practice. All cod survived the C&R event and did not show any large-scale behavioural changes (i.e., changes in diel vertical migrations). However, analysis of small-scale vertical movements showed that three individuals underwent short-term alterations (e.g. reduced or increased swimming activity). This study showed that pretagging fish with acoustic transmitters before experimental angling is an option when investigating fish behaviour immediately after the release event in marine environments. Moreover, release guidelines for cod should be developed, as cod can recover quickly if caught in shallow waters (<20 m) and properly handled and released.

Paper IV: Atlantic cod (*Gadus morhua*) caught in recreational fisheries are commonly released, often with symptoms of barotrauma after rapid decompression. Mouth-hooked, non-bleeding cod kept in a surface cage showed mortalities ≥40% when angled from >50 m depth, most likely because of thermal stress in warm surface water. In a follow-up study, 97.8% of similarly selected cod managed to dive following immediate release, while 2.2% were floaters. No mortality was observed for divers and recompressed floaters kept in cages which were lowered to capture depth for 72 h. The occurrences of swimbladder ruptures, swollen coelomic cavities, venous gas embolisms, and gas release around the anus were significantly influenced

by capture depth (range 0-90 m). A supplementary radiology study showed inflated swimbladders in 87% of the cod after 72 h, and most barotrauma symptoms had disappeared after one month. This study encourages investigation of survival potential of physoclistous species when high mortalities are assumed but undocumented. When a thermocline is present, matching natural post-release and containment environment is essential in the experimental setup, as failure to do so may affect survival estimates. Assuming minimal predation, short-term mortality of cod experiencing barotrauma is negligible if cod submerge quickly and are otherwise not substantially injured. However, sublethal and long-term impacts remain to be studied. To ensure that cod have enough energy to submerge, anglers are encouraged to avoid fighting the fish to exhaustion, and to minimize handling before the release.

Paper V: The management of recreational fisheries benefits from good collaboration between scientists, managers and recreational fishers. However, the level of collaboration largely depends on the levels of effective communication among the different stakeholders. This paper presents the views of scientists, managers and fishers concerning the quality of communication in eleven case studies of recreational fisheries. Case studies were synthesised and common reasons why communication did not always flow as intended were identified. The prevalent barriers to good communication, and therefore collaboration included a lack of rigorous scientific information transfer from scientists to fishers and managers, a fear from fishers that management actions will limit fishing opportunities, pre-existing antagonism between commercial and recreational fisheries, and fishers' suspicion of science. Overcoming these issues is paramount to improve collaboration and participatory processes that help lead to robust, well-accepted management actions.

4. Results and Discussion

4.1 Extent and motivations for C&R

The access-point surveys in two study areas during 2010 and 2011 showed that marine angling tourists released substantial amounts of their catch (**paper I**). Release percentages between 48 % and 82 % (in terms of numbers) were estimated for cod, saithe (*Pollachius virens;* **Figure 5**), haddock (*Melanogrammus aeglefinus*), tusk (*Brosme brosme*) and ling (*Molva molva*) in the northern study area (Nordland and Troms). Similar to the northern study area where 66% of the captured cod were released, 62% of the captured cod were released in the southern study area (Hordaland). For the other species, release percentages were significantly lower in the southern study area than in the northern study area. Compared to release percentages for cod in other marine recreational fisheries in Europe, the ones by marine angling tourists in Norway are amongst the highest (**paper II**). The only fishery, for which a higher cod release percentage was estimated, was the English marine recreational shore fishery (70 %). However, this estimate was based on preliminary data from an online survey and thus was likely biased upwards. This is because avid and more specialized anglers (which potentially have higher release rates (Aas and Kaltenborn 1995)) are more passionate and likely to participate in online surveys (Oh and Ditton 2006, Graefe et al. 2011).

Figure 5: Saithe is a usual bycatch when fishing for cod and is commonly released. Photo: Keno Ferter

For other European marine recreational fisheries, the release percentages for cod ranged from 1 % (Poland) to 61 % (Denmark). In terms of numbers, these percentages correspond to several million released cod in Europe annually. **Paper II** shows that C&R is also practiced for other marine species in Europe, and that release rates varied substantially between countries as is the case for cod. For example, release percentages for European sea bass varied from 19 % (Portugal) to 77 % (England). Again, these percentages correspond to several million released European

sea bass by recreational anglers in Europe per year. On condition that **paper II** covered the majority of marine C&R practice for DCF species, pollack (*Pollachius pollachius*) and sea trout (*Salmo trutta*) in Europe, cod has the highest absolute release amounts in term of numbers among the studied marine species in Europe, followed by European sea bass. Taking cod releases by recreational anglers in other parts of the North Atlantic into account (Northeast Fisheries Science Center (NEFSC) 2013, Brownscombe et al. 2014a), cod is one of the most important marine species in the North Atlantic, North Sea and Baltic Sea in terms of absolute recreational release numbers.

Interestingly, the variation in release proportions for cod between European countries coincided with the C&R practice by nationality in the Norwegian marine angling tourism study. In general, there was a tendency that Eastern European marine angling tourists had lower release percentages, while Western European and Scandinavian angling tourists released a higher percentage of their catch (**paper I**). Similarly, the release percentage for cod was only 1% in Poland, while the release percentages for cod were at least 24% in the other European countries (**paper II)**. These variations between nationalities can be partly explained by different cultural backgrounds and angler culture (i.e. degree of consumptive orientation) (Aas et al. 2002a, Arlinghaus et al. 2007a).

For cod, saithe and ling the main reason as to why angling tourists in the northern study area in Norway released their catch was because the fish were too small. In fact, this was the main reason for all species in the southern study area. For haddock in the northern study area, the main reason was the practice of total C&R, while the main reason for releasing tusk in the northern study area was that the anglers did not like to eat it. Only a few anglers specifically named the minimum landing size as a release reason, implying that most anglers were either not aware of the minimum size regulations or had their own personal minimum landing sizes which could exceed the legal minimum landing size (**paper I**). In contrast, 96% of the anglers in the German recreational Baltic Sea fishery reported that they released cod because they were under the legal minimum landing size (**paper II**).

There are several potential reasons for the different underlying motivations for cod release in Europe. One reason could be the generally larger size of fish and higher catch rates that an angler can expect in Norway compared to the size of fish and catch rates in the Baltic Sea (**Figure 6**). Thus, marine angling tourists in Norway may be more likely to release cod that are over the legal minimum size than anglers in the Baltic Sea. In a similar vein, Sullivan (2002) found that anglers targeting walleye (*Stizostedion vitreum*) were more likely to follow minimum landing size regulations when catch rates were high. Moreover, marine angling tourists in Norway are legally obliged to comply with the 15 kg export limit, which is why they have to harvest more selectively. If all the catch over the minimum landing size was landed, the 15 kg limit would in many cases be easily exceeded, particularly in Northern Norway (Solstrand 2015). In fact, some of the marine angling tourists in Norway named too many fish as a release reason. For the German Baltic Sea, no such bag limit for cod exists, so anglers can keep all cod over the minimum landing size (**paper II**). With increasing development of the angling industry, and increasing angler specialization and environmental conservation focus, one can also expect an increase in voluntary C&R practice as specialized anglers mainly focus on the experience itself and are generally less consumptive oriented (Bryan 1977, Aas and Kaltenborn 1995, Oh and Ditton 2006) which makes them more likely to release fish (Chipman and Helfrich 1988).

Figure 6: Chances of catching large cod like this 17 kg specimen are very high in Northern Norway compared to most other regions of Europe. Photo: Keno Ferter

4.2 Biological impacts of C&R and mitigation measures

The telemetry study (**paper III**) showed that cod do not alter their large-scale behaviour (e.g. diel vertical migrations) after C&R, if the fish are caught in depths <20 m, are not substantially injured and are released quickly after the catch. However, short term small-scale effects are possible, as three of nine cod in the study altered their vertical swimming behaviour after C&R. Two cod showed decreased

vertical swimming activity, while one cod exhibited an increased vertical swimming activity. These cod returned to normal, pre-capture behaviour within 10 to 15 hours after the C&R event. There are several other species, for which altered swimming behaviour as a consequence of C&R has been documented. For example, Baktoft et al. (2013) and Klefoth et al. (2008) documented short-term decreased swimming activity in European pike (*Esox lucius*) after C&R. For bonefish (*Albula* spp.) that were angled to exhaustion, a similar alteration in behaviour has been observed (Cooke and Philipp 2004). Furthermore, Brownscombe et al. (2014b) showed that refuge seeking of Great barracuda (*Sphyraena barracuda*) was increasingly impaired with increasing exposure to fishing-related stressors like exhaustion and air exposure. Thorstad et al. (2004) and Gurshin and Szedlmayer (2004) documented short-term hyperactivity in large cichlids (*Serranochromis robustus* and *Oreochromis andersonii*) and Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*), respectively, as a consequence of C&R.

While most of the above mentioned behavioural alterations were short-lasting, the recovery period can be longer if the fish experience additional impacts, e.g. barotrauma when brought up from deeper water. For example, Nichol and Chilton (2006) showed that Pacific cod (*Gadus macrocephalus*), which was rapidly decompressed, returned to shallower water after an initial escape dive. These fish returned to water depths where they were neutrally buoyant to refill their swimbladders, and descended only gradually over the next days (recuperation period). This behaviour has also been observed for cod after rapid decompression (van der Kooij et al. 2007). Apart from behavioural changes after C&R, a range of barotrauma symptoms have been described for cod after rapid decompression (e.g. Midling et al. 2012, Humborstad and Mangor-Jensen 2013), which have been suggested to increase post-release mortality of cod (Pálsson et al. 2003). **Paper IV** found that cod caught with angling gear show different barotrauma symptoms depending on the capture depth. Capture depth had a significant impact on the occurrence of swimbladder ruptures, swollen coelomic cavities, gas release around the anus and venous gas embolisms. Gut eversion through the anus was also common but not significantly influenced by capture depth. Other external barotrauma symptoms observed, though much less frequent, were exophthalmia, stomach

eversions and subcutaneous gas bubbles. Even though one should expect high post-release mortalities with such barotrauma symptoms, no short-term mortality was observed when the cod (without substantial hooking injuries) were allowed to descend to five meter depth immediately after capture, and subsequently submerged to capture depth in cages (within one to 75 min after capture; mean 32 min) simulating the cod`s natural descent. Similarly, post-release survival of cod with no or minor injuries caught between 44.5 and 83 m was high in a study by Mandelman et al. (2014) when the fish were released immediately after capture. In contrast to other gadoid species, like ling and tusk, some barotrauma symptoms appeared less extreme in cod, most likely due to the excess gas release mechanism from small ruptures around the anus (**Figure 7**; see **paper IV** for details), which may be one explanation for the high post-release survival. Also cod that did not manage to descend on their own (i.e. floaters, 2.2 %) survived after being recompressed, indicating that recompression using release weights (Butcher et al. 2012) could be an option for cod. However, due to the low number of floaters in the study more research on this is necessary, as the percentage of floaters may be higher in other seasons of the year. In contrast, mortalities of over 40 % were observed when cod were kept in a surface cage after being captured at depths greater than 50 m (**paper IV**). This difference in mortality estimates can most likely be explained by an exacerbation of barotrauma symptoms in combination with thermal stress due to an extended exposure to warm surface water. Weltersbach and Strehlow (2013) observed higher post-release mortality of cod during summer when the fish were kept in warm water (mean temperature in June: 15.6°C). Likewise, Milliken et al. (2009) documented higher mortality of longline and angling gear caught cod, when surface temperatures were higher (>9°C), even though the fish were kept in cages submerged to capture depth. This finding by Milliken et al. (2009) is not in line with the findings in **paper IV** where no mortality was observed for cod kept in cages submerged to

Figure 7: Cod release excess gas around the anus after swimbladder rupture due to rapid decompression. Photo: Keno Ferter

capture depth, even though the temperature difference between the lowest capture depth and the surface was over 6°C in the present study. The difference in mortality estimates could be explained by different sampling protocols, because the cod in the study by Milliken et al. (2009) were kept in an on-board holding tank before they were submerged to capture depth. Keeping the cod in on-board holding tanks or at the surface for a prolonged time after the rapid decompression most likely exacerbates barotrauma issues, as for example blood flow could be blocked due to gas embolisms which may explain an increase in post-release mortality (**paper IV**).

Based on the results of **paper III** and **IV** and other post-release mortality studies on cod (e.g. Milliken et al. 2009, Weltersbach and Strehlow 2013, Mandelman et al. 2014), the following framework for the development of best practice C&R guidelines for cod was prepared:

1. Cod with heavy bleedings experience higher post-release mortality than cod without bleedings.

2. Cod which are deep-hooked or foul-hooked in the belly experience higher post-release mortality than lip-hooked cod.

3. Long exposure to warm surface water (relative to temperature at capture depth) increases the likelihood for post-release mortality of cod.

4. Cod without major hooking damage that are caught <20 m return to pre-capture behaviour within 10 to 15 hours when de-hooked carefully and released quickly.

5. Cod without major hooking damage that are caught >20 m experience symptoms of barotrauma but can survive if they descend successfully. Long-term and sublethal effects of barotrauma remain to be studied.

6. The survival of floaters may be increased by recompression but further research is necessary.

4.3 Communication of study findings

The framework for the development of best practice C&R guidelines presented in section 4.2 can be used by fisheries managers to develop best practice C&R

guidelines. These guidelines could contribute to increasing survival chances of cod after C&R, decrease sublethal C&R impacts, and can motivate anglers to follow harvest regulations as released cod can have high survival under the presented circumstances. However, this can only be achieved if the findings in this thesis are successfully disseminated and understood by fisheries managers, anglers, and other stakeholders (Cooke and Wilde 2007, Pelletier et al. 2007), which requires a successful communication process between all stakeholders (e.g. Hasler et al. 2011). **Paper V** indentified the main barriers to successful communication between scientists, anglers, and fisheries managers and presented possible solutions to overcome these. The most common obstacles were the lack of scientific background of anglers and fisheries managers, fear by anglers that the introduction of new management measures could limit angling opportunities, language barriers, and a general suspicion of science by anglers. Suggested solutions for scientists to overcome these barriers included, amongst others, mingling with anglers, organization of information meetings (see also Sullivan 2003), use of non-technical language that can be understood by anglers and fisheries managers, involvement of anglers in research projects, and the use of media to communicate scientific findings. Attracting the attention of the media can be a problem in particular, as it can be difficult to convince them that recreational fisheries news that is based on scientific findings will attract a large readership and is worth publishing (**paper V**).

Ten years ago, the communication flow between scientists, managers and anglers in Norway was still limited. For example, Borch (2009) argued that the introduction of the 15 kg export limit for marine angling tourists in Norway in 2006 was the result of stakeholder pressure from commercial fishermen rather than based on scientific advice. The export limit led to unforeseen consequences like a drop in holiday bookings (Nilssen 2006), and an increased release practice through high grading (Ferter 2011, Solstrand 2014). Moreover, conflicts between commercial fishermen and the marine angling tourism industry (Gjøsæter and Sunnanå 2005) were boosted by media articles blaming tourists for the decline in coastal fish stocks (Borch 2009).

In recent years, however, several improvements concerning the collaboration and communication between scientists, anglers and fisheries managers have been

made in Norway. For example, Vølstad et al. (2011) actively involved marine angling tourism businesses and angling tourists in their project, and stakeholders were informed via a project homepage (www.imr.no/turistfiske) and annual project status updates. Moreover, scientists were invited by the Ministry of Fisheries and Coastal Affairs to give their scientific advice to a working group which was established in 2010 to develop further management measures. In a later meeting organized by the Ministry of Trade, Industry and Fisheries (former Ministry of Fisheries and Coastal Affairs) in 2014, scientists were invited to give further scientific advice (including the findings of this thesis) on the future management of the marine angling tourism industry. Furthermore, the Norwegian Hunting and Fishing Association has been organizing the "Oslofjord conference" since 2014, serving as a platform for anglers, fisheries managers and scientists to communicate and exchange current knowledge on several aspects concerning recreational fisheries in Norway, including C&R practice. Meetings like these contribute to an increased scientific understanding by managers and anglers, and give anglers the opportunity to directly interact and discuss their interests with mangers and scientists which can decrease the fear that the introduction of new management measures could limit angling opportunities and increase angler satisfaction (Beardmore et al. 2014). Moreover, these meetings offer important communication channels for scientists to explain the potential impacts of C&R and for managers to communicate mitigation measures, i.e. best practice C&R guidelines.

Using the media as a communication channel in Norway has also proven to be useful, although some challenges remain. Several approaches were tried during the last years to communicate the findings in this thesis. One of these approaches was to publish press releases in collaboration with a communication officer (Marie Hauge, Institute of Marine Research) once a new scientific article had been published. Apart from presenting the main findings in non-technical language, these press releases contained interview-like quotes which pointed out the strengths and limitations of the study. In parallel with the publication of the press releases, the communication officer took contact with journalists in high impact media, e.g. television or radio, to inform them about the upcoming press release. This approach was applied for **paper I and II.** The main advantage was that the news was taken up by high impact media and communicated via television and radio. The press releases were adopted by

newspapers as they were written in simple, journalistic language. Thus, the strengths and limitations of the study were often included also in the newspaper articles. The risk, however, was that the title got changed, passages were removed or added, or the text was rewritten which changed the initial message of the press release. Another approach was to make contact with a newspaper or news website and ask them to publish an unmodified, self-composed article which was written in collaboration with a communication officer. This was done for **paper II** and **III**. The main advantage of this approach was that the study findings were communicated unmodified through the chosen media channel including the strengths and limitations of the study. However, the impact of this approach seemed to be somewhat lower than for the first approach as the readership was mainly limited to the chosen communication channel. A third approach was used in collaboration with one of the largest newspapers in Norway (Bergens Tidende) in the form of a blog for researchers (innsikt.bt.no). On this blog, some of the findings in this thesis were communicated through short, self-written blog entries (**paper I**, **II** and **III**) on a regular basis. These entries were linked to the main homepage of Bergens Tidende to attract readers. The main advantage of this approach was that it offered a direct link between the researcher and the readers as comments to the entry were possible. Moreover, like in the case of the second approach, the study findings were communicated by the researcher, however, the impact was generally restricted to the readers of Bergens Tidende.

4.4 Perception of C&R in relation to animal welfare

Considering fish welfare in the context of C&R may not be immediately apparent for most anglers and fisheries managers (Balon 2000, Cooke and Sneddon 2007). However, Cooke and Sneddon (2007) argue that its consideration is not only valuable for the individual fish but also for fish populations and fisheries. Fish welfare is a multifaceted, elusive concept and has been reviewed extensively in the light of recreational fisheries and C&R practice in several publications representing different perspectives (e.g. De Leeuw 1996, Huntingford et al. 2006, Arlinghaus et al. 2007b, Arlinghaus 2008, Arlinghaus et al. 2009, FAO 2012). Thus, the aim of this section is not to provide a comprehensive review of fish welfare in relation to C&R, but rather to present how the findings of this thesis were perceived by stakeholders in Norway,

and how future work could be directed to provide an informed basis to evaluate and improve fish welfare. There are several definitions of welfare, however, "there is a general agreement that welfare applies to well-being and that it assumes an animal is in optimum condition" (Cooke and Sneddon 2007, p. 177). For example, this "optimum condition" can be measured by the physiological status of the fish or by deviations from its natural behaviour as done in **paper III** (Cooke and Sneddon 2007). Arlinghaus et al. (2009, p. 2448) present two different approaches to fish welfare represented by the pragmatic, function-based approach and suffering-centred, feelings-based approach, where the former "asks whether and how strongly recreational fishing compromises the health and fitness of individual fishes and what can be done to avoid or mitigate such effects" while the latter "focuses on suffering and pain in fishes and is usually morally prescriptive". Depending on the chosen approach and cultural background, different perspectives on recreational fishing in general, and C&R practice in particular, are common (Cooke and Sneddon 2007, Arlinghaus et al. 2009). This has led to several ethical discussions and public debates, particularly in Europe (Aas et al. 2002a, 2002b).

Media outreach and communications of findings in this thesis (**paper I**, **II** and **III**) led to public debates and ethical discussions on several occasions. Usually, the readers of news items or blog entries shared their perspectives either through the comment field under the article or by responding with another article. While some of these reactions were rather short, others were more extensive. Some of these reactions were more inclined towards the pragmatic approach while others were more in line with the suffering-centred approach. An example of the pragmatic inclination is given in comment #1, while the suffering-centred tendency is exemplified in comment #2:

Comment #1

> *"[...] In my opinion, the release of small fish goes without saying, both for species which are regulated by minimum landing sizes (cod 40 cm etc.) and other fish which I think are too small to be eaten. Incidental bycatch is also okay to release, like for example pollack and saithe if you are fishing for sea trout. [...] I think that it is unnecessary to fish for example for salmon just to release it again. We either leave the salmon alone so that they can spawn, or we catch them to eat them. [...]" (Jonny Eriksen, entry 26.02.2015, "Disqus comment" to innsikt.bt.no/vi-er-alle-fang-og-slipp-fiskere [accessed 09.04.2015], translated from Norwegian by Keno Ferter)*

Comment #2

> *"Fish are included in the Animal Welfare Act, and the main criticism against C&R is actually based on the animal`s welfare. Is it acceptable that fish suffer for recreation? Business-oriented organisations have tried (and unfortunately partially succeeded) to turn this into a question of survival (supporting anthropogenic interests):"C&R is without value if the fish do not survive." [quote from the original news item] Mortality is a terrible measure of animal welfare: the fact that fish survive does not mean that they do not suffer. It is acknowledged that "the tagging procedure can be stressful for the fish, which is why they were given two weeks to recover" [quote from the original news item], but the altered behaviour after C&R is not discussed in relation to animal welfare. "Animal welfare" is not even an issue in the publication! However, the conclusion is that "cod tolerates C&R." [quote from the original news item][...]" (Anton Krag, entry 9.01.2015, "Disqus comment" to http://forskning.no/fisk-fiskehelse/2015/01/torsk-taler-bli-sluppet-ut-igjen [accessed 09.04.2015], translated from Norwegian by Keno Ferter)*

Both of these examples (and several other received comments) raised ethical concerns in relation to C&R practice. This was expected considering the traditional catch-and-harvest culture in Norway (Aas et al. 2002b). However, while the first commentator seems to accept C&R under some circumstances, the second generally questions the practice of C&R because of the suffering of the fish. The second commentator also criticises that animal welfare was not part of **paper III**, implying that he does not accept behaviour alone as a sufficient indicator of animal welfare, and that potential suffering should be considered. In fact, pain perception in fish is a hotly debated issue. While for example Braithwaite (2010) presented evidence that fish experience pain, this was challenged in a recent review by Rose et al. (2014), who concluded that it is questionable that fish perceive pain consciously, as is usually the case with humans and other mammals. A critical review of pain perception in fish is outside the scope of this thesis, however it is acknowledged that more work in this area is needed as this will assist in the discussion of C&R and recreational fishing in relation to fish welfare. The question of pain and potential suffering is particularly important in the light of **paper IV**. While the results in that paper documented that cod have high post-release survival potential even though they experienced barotrauma, the question arises how much discomfort or pain the fish experience as a consequence of rapid decompression. Measuring physiological stress parameters, e.g.

cortisol levels, in future studies could assist in answering this question (reviewed by Cooke et al. 2013). Arlinghaus et al. (2009) concluded that the pragmatic approach should be preferred, as it is based on objectively measurable parameters rather than moral considerations, opens for a constructive discussion concerning C&R, and aims at improving fish welfare based on scientific findings and recommendations. Given the fact that C&R will be practiced as long as recreational fishing is allowed and regulated by harvest measures, this argumentation is also reasonable in the light of C&R practice for cod.

4.5 Conclusion and future perspectives

This thesis shows that C&R is common in European marine recreational fisheries and is driven by harvest regulations as well as voluntary angler decisions. As long as harvest regulations like protected species, minimum landing sizes and bag limits exist, a certain proportion of the catch will be released (assuming regulation compliance). Moreover, voluntary C&R practice has been documented for cod and other European marine species, and can be expected to increase over the years in line with increasing specialization and environmental conservation focus of anglers. Overall, cod and European sea bass have the highest release amounts in Europe, but locally release percentages can also be high for other species, e.g. sea trout in Denmark and saithe in the Northern Norwegian angling tourism fishery. Since little is known about the impacts of C&R on most other European marine species besides cod, it is important that future post-release mortality studies are also focused on species like European sea bass, sea trout and saithe (**Figure 8**). The results of this thesis, in combination with other published studies, contribute towards a scientific basis to evaluate current harvest regulations and estimates of recreational fishing mortality for cod in different recreational fisheries. In essence, post-release mortality of cod will be high if the fish are bleeding due to hooking injuries, are substantially

Figure 8: Future studies should also address C&R impacts on other European marine species like saithe, for example. Photo: Keno Ferter

injured, and/or when they are exposed to warm water for an extended period of time. When cod are caught shallower than 20 m, are released quickly, and are otherwise not substantially injured, then survival chances are high and behavioural alterations are limited. When cod are caught in water depths greater than 20 m, the majority of cod will show symptoms of barotrauma. If these fish are released quickly, are otherwise not substantially injured, and manage to descend, then survival chances are high. Therefore, cod that can be expected to survive based on these findings are allowed to be released despite the general discard ban in Norway. In addition, under the presented circumstances, current harvest regulations like minimum landing sizes and bag limits can be efficient tools to decrease fishing mortality for cod. However, depending on fishery-specific angling practices, post-release mortalities can be high if many of the released fish are bleeding or substantially injured which may have to be accounted for in recreational fishing mortality estimates. Thus, it is important to indentify the lure types used in different recreational fisheries, and investigate and quantify what kind of injuries can be expected for these specific lure types. Moreover, as behavioural alterations are possible there may be an increased risk of post-release predation in some cases. Therefore, future studies should investigate post-release predation of cod for different fisheries as predator presence and densities vary between ecosystems. The effects of extensive fighting time have not been investigated for cod, but should be addressed in future studies as exhausted fish may be more likely to experience C&R impacts. To ensure successful communication of the findings in this thesis, a combination of several communication channels is necessary. This includes, but is not limited to, dissemination via scientific publications, stakeholder meetings, different media channels and information flyers which can be handed out to anglers. As emerging fish welfare issues could not be resolved, more research effort should be directed towards this aspect, e.g. by measuring several additional indicators of welfare including, but not limited to, physiological stress responses of fish after C&R. Angler education on how to release fish and avoid unwanted bycatch is of outmost importance as this will not only ensure decreased post-release mortalities but also minimize sublethal impacts on the released fish. Therefore, fisheries managers are encouraged to develop best practice C&R guidelines based on the framework presented in this thesis.

5. References

Aas, Ø. and B. Kaltenborn (1995). "Consumptive orientation of anglers in Engerdal, Norway." Environmental Management **19**(5): 751-761.

Aas, Ø., C. E. Thailing and R. B. Ditton (2002a). Controversy over catch-and-release recreational fishing in Europe. *In: Recreational Fisheries: Ecological, Economic and Social Evaluation*. T. J. Pitcher and C. E. Hollingworth (eds.). Oxford, UK, Blackwell Science**:** 95-106.

Aas, Ø., C. E. Thailing and R. B. Ditton (2002b). "The discourse about catch and release in recreational fishing in Europe: implications for North America." American Fisheries Society Symposium **30**: 201-204.

Alós, J. (2008). "Influence of anatomical hooking depth, capture depth, and venting on mortality of painted comber (*Serranus scriba*) released by recreational anglers." ICES Journal of Marine Science **65**: 1620-1625.

Alós, J., M. Palmer and A. M. Grau (2009). "Mortality of *Diplodus annularis* and *Lithognathus mormyrus* released by recreational anglers: implications for recreational fisheries management." Fisheries Management and Ecology **16**(4): 298-305.

Arlinghaus, R. (2007). "Voluntary catch and release can generate conflict within the recreational angling community: a qualitative case study of specialised carp, *Cyprinus carpio*, angling in Germany." Fisheries Management and Ecology **14**(2): 161-171.

Arlinghaus, R. (2008). The challenge of ethical angling: the case of C&R and its relation to fish welfare. *In: Global Challenges in Recreational Fisheries*. Ø. Aas (ed.). Oxford, UK, Blackwell Publishing**:** 223–236.

Arlinghaus, R. and S. J. Cooke (2005). "Global impact of recreational fisheries." Science **307**(5715): 1561-1562.

Arlinghaus, R. and S. J. Cooke (2009). Recreational fisheries: socioeconomic importance, conservation issues and management challenges. *In: Recreational hunting, conservation and rural livelihoods: science and practice*. B. Dickson, J. Hutton and W. M. Adams (eds.). Oxford, UK, Wiley-Blackwell**:** 39-58.

Arlinghaus, R., S. J. Cooke, J. Lyman, D. Policansky, A. Schwab, C. Suski, S. G. Sutton and E. B. Thorstad (2007a). "Understanding the complexity of catch-and-release in recreational fishing: An integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives." Reviews in Fisheries Science **15**(1-2): 75-167.

Arlinghaus, R., S. J. Cooke, A. Schwab and I. G. Cowx (2007b). "Fish welfare: a challenge to the feelings-based approach, with implications for recreational fishing." Fish and Fisheries **8**(1): 57-71.

Arlinghaus, R., A. Schwab, S. Cooke and I. Cowx (2009). "Contrasting pragmatic and suffering-centred approaches to fish welfare in recreational angling." Journal of Fish Biology **75**(10): 2448-2463.

Arlinghaus, R., A. Schwab, C. Riepe and T. Teel (2012). "A primer on anti-angling philosophy and its relevance for recreational fisheries in urbanized societies." Fisheries **37**(4): 153-164.

Baktoft, H., K. Aarestrup, S. Berg, M. Boel, L. Jacobsen, A. Koed, M. W. Pedersen, J. C. Svendsen and C. Skov (2013). "Effects of angling and manual handling on pike behaviour investigated by high-resolution positional telemetry." Fisheries Management and Ecology **20**(6): 518-525.

Balon, E. (2000). "Defending fishes against recreational fishing: an old problem to be solved in the new millennium." Environmental Biology of Fishes **57**(1): 1-8.

Bartholomew, A. and J. Bohnsack (2005). "A review of catch-and-release angling mortality with implications for no-take reserves." Reviews in Fish Biology and Fisheries **15**(1): 129-154.

Beardmore, B., L. M. Hunt, W. Haider, M. Dorow and R. Arlinghaus (2014). "Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers." Canadian Journal of Fisheries and Aquatic Sciences **72**(4): 500-513.

Borch, T. (2004). "Sustainable management of marine fishing tourism. Some lessons from Norway." Tourism in Marine Environments **1**(1): 49-57.

Borch, T. (2009). "Contested coastal commercialization: Marine fishing tourism in Norway." Maritime Studies **8**(1): 33-51.

Braithwaite, V. (2010). *Do fish feel pain?*, Oxford University Press: 256 pp.

Brown, I., W. Sumpton, M. McLennan, D. Mayer, M. Campbell, J. Kirkwood, A. Butcher, I. Halliday, A. Mapleston, D. Welch, G. A. Begg and B. Sawynok (2010). "An improved technique for estimating short-term survival of released line-caught fish, and an application comparing barotrauma-relief methods in red emperor (*Lutjanus sebae* Cuvier 1816)." Journal of Experimental Marine Biology and Ecology **385**(1–2): 1-7.

Brownscombe, J. W., S. D. Bower, W. Bowden, L. Nowell, J. D. Midwood, N. Johnson and S. J. Cooke (2014a). "Canadian recreational fisheries: 35 years of social, biological, and economic dynamics from a national survey." Fisheries **39**(6): 251-260.

Brownscombe, J. W., L. Nowell, E. Samson, A. J. Danylchuk and S. J. Cooke (2014b). "Fishing-related stressors inhibit refuge-seeking behavior in released subadult Great Barracuda." Transactions of the American Fisheries Society **143**(3): 613-617.

Bryan, H. (1977). "Leisure value systems and recreational specialization: the case of trout fishermen." Journal of Leisure Research **9**(3): 174-187.

Butcher, P. A., M. K. Broadhurst, K. C. Hall, B. R. Cullis and S. R. Raidal (2012). "Assessing barotrauma among angled snapper (*Pagrus auratus*) and the utility of release methods." Fisheries Research **127–128**(0): 49-55.

Cap Gemini Ernst&Young (2003) *Vurdering av Turistfiske som Inntektskilde i Norge - Hvilke Inntekter Gir Turistfiske Sammenlignet med Yrkesfiske?* Report. Trondheim: 20 pp. (in Norwegian)

CEC (2008). "Commission Decision of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy (2008/949/EC)."

CEC (2009). "Commission Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy, amending Regulations (EC) No 847/96, (EC) No 2371/2002, (EC) No 811/2004, (EC) No 768/2005, (EC) No 2115/2005, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007, (EC) No 676/2007, (EC) No 1098/2007, (EC) No 1300/2008, (EC) No 1342/2008 and repealing Regulations (EEC) No 2847/93, (EC) No 1627/94 and (EC) No 1966/2006."

Chipman, B. D. and L. A. Helfrich (1988). "Recreational specializations and motivations of Virginia river anglers." North American Journal of Fisheries Management **8**(4): 390-398.

Coggins, L. G., M. J. Catalano, M. S. Allen, W. E. Pine and C. J. Walters (2007). "Effects of cryptic mortality and the hidden costs of using length limits in fishery management." Fish and Fisheries **8**(3): 196-210.

Coleman, F. C., W. F. Figueira, J. S. Ueland and L. B. Crowder (2004). "The impact of United States recreational fisheries on marine fish populations." Science **305**(5692): 1958-1960.

Collins, M. R., J. C. McGovern, G. R. Sedberry, H. S. Meister and R. Pardieck (1999). "Swim bladder deflation in Black Sea bass and Vermilion Snapper: potential for increasing postrelease survival." North American Journal of Fisheries Management **19**(3): 828-832.

Cooke, S. and I. Cowx (2004). "The role of recreational fishing in global fish crises." BioScience **54**(9): 857-859.

Cooke, S. and C. Suski (2005). "Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources?" Biodiversity and Conservation **14**(5): 1195-1209.

Cooke, S. J., M. R. Donaldson, C. M. O'Connor, G. D. Raby, R. Arlinghaus, A. J. Danylchuk, K. C. Hanson, S. G. Hinch, T. D. Clark, D. A. Patterson and C. D. Suski (2013). "The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation and relevance to stakeholders." Fisheries Management and Ecology **20**(2-3): 268-287.

Cooke, S. J. and D. P. Philipp (2004). "Behavior and mortality of caught-and-released bonefish (*Albula* spp.) in Bahamian waters with implications for a sustainable recreational fishery." Biological Conservation **118**(5): 599-607.

Cooke, S. J. and L. U. Sneddon (2007). "Animal welfare perspectives on recreational angling." Applied Animal Behaviour Science **104**(3-4): 176-198.

Cooke, S. J. and G. R. Wilde (2007). The fate of fish released by recreational anglers. *In: By-catch Reduction in the World's Fisheries*. S. J. Kenelly (ed.). Dordrecht, the Netherlands, Spinger**:** 181-234.

De Leeuw, A. D. (1996). "Contemplating the interests of fish: the angler`s challenge." Environmental Ethics **18**(4): 373-390.

Dorow, M. and R. Arlinghaus (2011). A telephone-diary-mail approach to survey recreational fisheries on large geographic scales, with a note on annual landings estimates by anglers in northern Germany *In: The angler in the environment: social, economic, biological and ethical dimensions*. T. D. Beard, R. Arlinghaus and S. G. Sutton (eds.). Bethesda, Maryland, American Fisheries Society**:** 319-344.

FAO (2012). *Recreational fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 13*. Rome, FAO: 176 pp.

Ferter, K. (2011). *Marine angling tourism in Norway: The interactions between behavior, management and catch*. Master Thesis, University of Bergen: 88 pp.

Fiskeridirektoratet. (2015a). "Export quota." Retrieved 18.03.2015, from http://www.fiskeridir.no/english/recreational-fishing/export-quota.

Fiskeridirektoratet. (2015b). "Minimum sizes for salt water fish." Retrieved 18.03.2015, from http://www.fiskeridir.no/english/recreational-fishing/minimum-sizes.

Forskrift om utøvelse av fisket i sjøen. (2013). "§ 48 Forbud mot utkast." Retrieved 18.03.2015, from http://lovdata.no/forskrift/2004-12-22-1878/§48.

Gjøsæter, J. and K. Sunnanå (2005). Turistfiske utenfor kvoter og reguleringer. *In: Kyst og Havbruk 2005*. Bergen, Institute of Marine Research**:** 67-68. (in Norwegian)

Graefe, A., A. Mowen, E. Covelli and N. Trauntvein (2011). "Recreation participation and conservation attitudes: differences between mail and online respondents in a mixed-mode survey." Human Dimensions of Wildlife: An International Journal **16**(3): 183-199.

Gray, S. A. and R. Jordan (2010). "Ecosystem-based angling: Incorporating recreational anglers into ecosystem-based management." Human Dimensions of Wildlife: An International Journal **15**(4): 233-246.

Gurshin, C. and S. Szedlmayer (2004). "Short-term survival and movements of Atlantic sharpnose sharks captured by hook-and-line in the north-east Gulf of Mexico." Journal of Fish Biology **65**(4): 973-986.

Hallenstvedt, A. and I. Wulff (2001) *Fisk Som Agn – Utenlandsk Turistfiske i Norge*. Rapport fra et fellesprosjekt Norges Fiskarlag og Norges Turistråd. Tromsø, Norwegian High School for Fisheries, University of Tromsø: 65 pp. (in Norwegian)

Hallenstvedt, A. and I. Wulff (2002) *Turistfiske som inntektskilde*. Norges Turistråd. Tromsø, Norwegian High School for Fisheries, University of Tromsø: 44 pp. (in Norwegian)

Hallenstvedt, A. and I. Wulff (2004) *Fritidsfiske i Sjøen 2003*. Rapport fra et prosjekt støttet av Fiskeri- og Havbruksnæringens Forskningsfond / Norges Forskningsråd. Tromsø, Norwegian High School for Fisheries, University of Tromsø: 66 pp. (in Norwegian)

Hannah, R. W., S. J. Parker and K. M. Matteson (2008b). "Escaping the surface: the effect of capture depth on submergence success of surface-released Pacific rockfish." North American Journal of Fisheries Management **28**(3): 694-700.

Hannah, R. W., P. S. Rankin, A. N. Penny and S. J. Parker (2008a). "Physical model of the development of external signs of barotrauma in Pacific rockfish." Aquatic Biology **3**: 291-296.

Harper, D. E., J. A. Bohnsack and B. R. Lockwood (2000). "Recreational fisheries in Biscayne National Park, Florida, 1976-1991." Marine Fisheries Review **62**(1): 8-26.

Hasler, C. T., A. H. Colotelo, T. Rapp, E. Jamieson, K. Bellehumeur, R. Arlinghaus and S. J. Cooke (2011). "Opinions of fisheries researchers, managers, and anglers towards recreational fishing issues: an exploratory analysis for North America." American Fisheries Society Symposium **75**: 51-74.

Herfaut, J., H. Levrel, O. Thébaud and G. Véron (2013). "The nationwide assessment of marine recreational fishing: a French example." Ocean & Coastal Management **78**: 121-131.

Hühn, D. and R. Arlinghaus (2011). "Determinants of hooking mortality in freshwater recreational fisheries: a quantitative meta-analysis." American Fisheries Society Symposium **75**: 141-170.

Humborstad, O.-B. and A. Mangor-Jensen (2013). "Buoyancy adjustment after swimbladder puncture in cod Gadus morhua: an experimental study on the effect of rapid decompression in capture-based aquaculture." Marine Biology Research **9**(4): 383-393.

Huntingford, F. A., C. Adams, V. Braithwaite, S. Kadri, T. Pottinger, P. Sandøe and J. Turnbull (2006). "Current issues in fish welfare." Journal of Fish Biology **68**(2): 332-372.

ICES (2014) *Report of the Arctic Fisheries Working Group (AFWG)*. ICES CM 2014/ACOM:05. Lisbon, Portugal: 667 pp.

Jacobsen, J. K. S. (2005) *Utenlandske Bilturisters Fiske i Saltvann i Norge*. Report. Oslo, Institute of Transport Economics: 15 pp. (in Norwegian)

Johnston, F. D., B. Beardmore, R. Arlinghaus and V. Trenkel (2014). "Optimal management of recreational fisheries in the presence of hooking mortality and noncompliance—predictions from a bioeconomic model incorporating a mechanistic model of angler behavior." Canadian Journal of Fisheries and Aquatic Sciences **72**(1): 37-53.

Keniry, M. J., W. A. Brofka, W. H. Horns and J. E. Marsden (1996). "Effects of decompression and puncturing the gas bladder on survival of tagged Yellow Perch." North American Journal of Fisheries Management **16**(1): 201-206.

Kerns, J. A., M. S. Allen and J. E. Harris (2012). "Importance of assessing population-level impact of catch-and-release mortality." Fisheries **37**(11): 502-503.

Klefoth, T., A. Kobler and R. Arlinghaus (2008). "The impact of catch-and-release angling on short-term behaviour and habitat choice of northern pike (*Esox lucius*)." Hydrobiologia **601**(1): 99-110.

Lewin, W.-C., R. Arlinghaus and T. Mehner (2006). "Documented and potential biological impacts of recreational fishing: insights for management and conservation." Reviews in Fisheries Science **14**: 305–367.

Mandelman, J., C. Capizzano, W. Hoffman, M. Dean, D. Zemeckis, M. Stettner and J. Sulikowski (2014) *Elucidating post-release mortality and "best capture and handling" methods in sublegal Atlantic cod discarded in Gulf of Maine recreational hook-and-line fisheries*. Technical report. National Marine Fisheries Service, Office of Sustainable Fisheries, Bycatch Reduction Engineering Program (BREP), NOAA Fisheries: 43-51.

McPhee, D. P., D. Leadbitter and G. A. Skilleter (2002). "Swallowing the bait: is recreational fishing in Australia ecologically sustainable?" Pacific Conservation Biology **8**: 40-51.

Midling, K. Ø., C. Koren, O.-B. Humborstad and B.-S. Sæther (2012). "Swimbladder healing in Atlantic cod (*Gadus morhua*), after decompression and rupture in capture-based aquaculture." Marine Biology Research **8**(4): 373-379.

Milliken, H. O., H. A. Carr, M. Farrington and E. Lent (1999). "Survival of Atlantic cod (*Gadus morhua*) in the Northwest Atlantic longline fishery." Marine Technology Society Journal **33**(2): 19-24.

Milliken, H. O., M. Farrington, T. Rudolph and M. Sanderson (2009). "Survival of discarded sublegal Atlantic cod in the Northwest Atlantic demersal longline fishery." North American Journal of Fisheries Management **29**(4): 985-995.

Muoneke, M. I. and W. M. Childress (1994). "Hooking mortality: a review for recreational fisheries." Reviews in Fisheries Science **2**: 123-156.

Nichol, D. and E. Chilton (2006). "Recuperation and behaviour of Pacific cod after barotrauma." ICES Journal of Marine Science **63**(1): 83-94.

Nilssen, G. (2006) *Kartlegging av evt. næringsmessige konsekvenser av innført utførselskvote på 15 kilo fisk / fiskefilet*. Tromsø, Reiselivsrådgiver Gunnar Nilssen: 17 pp. (in Norwegian)

Northeast Fisheries Science Center (NEFSC) (2013) *55th Northeast Regional Stock Assessment Workshop (55th SAW) Assessment Report*. Northeast Fisheries Science Center Reference Document 13-11. Woods Hole, MA: 845 pp.

Oh, C. O. and R. B. Ditton (2006). "Using recreation specialization to understand multi-attribute management preferences." Leisure Sciences **28**(4): 369-384.

Pálsson, Ó. K., H. A. Einarsson and H. Björnsson (2003). "Survival experiments of undersized cod in a hand-line fishery at Iceland." Fisheries Research **61**(1): 73-86.

Pawson, M. G., H. Glenn and G. Padda (2008). "The definition of marine recreational fishing in Europe." Marine Policy **32**(3): 339-350.

Pelletier, C., K. Hanson and S. Cooke (2007). "Do catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices?" Environmental Management **39**(6): 760-773.

Pickett, G. D., D. R. Eaton, S. Cunningham, M. R. Dunn, S. D. Potten and D. Whitmarsh (1995) *An appraisal of the UK bass fishery and its management. Laboratory Leaflet 75*. Lowestoft: 47 pp.

Pierce, R. B., C. M. Tomcko and D. H. Schupp (1995). "Exploitation of Northern Pike in seven small north-central Minnesota lakes." North American Journal of Fisheries Management **15**(3): 601-609.

Policansky, D. (2002). Catch-and-release recreational fishing: a historical perspective. *In: Recreational Fisheries: Ecological, Economic, and Social Evaluation.* T. J. Pitcher and C. E. Hollingworth (eds.). Oxford, UK, Blackwell Publishing**:** 202–236.

Post, J. R. and Eric A. Parkinson (2012). "Temporal and spatial patterns of angler effort across lake districts and policy options to sustain recreational fisheries." Canadian Journal of Fisheries and Aquatic Sciences **69**(2): 321-329.

Post, J. R., M. Sullivan, S. Cox, N. P. Lester, C. J. Walters, E. A. Parkinson, A. J. Paul, L. Jackson and B. J. Shuter (2002). "Canada's recreational fisheries: The invisible collapse?" Fisheries **27**(1): 6-17.

Raby, G. D., J. R. Packer, A. J. Danylchuk and S. J. Cooke (2014). "The understudied and underappreciated role of predation in the mortality of fish released from fishing gears." Fish and Fisheries **15**(3): 489-505.

Roach, J., K. Hall and M. Broadhurst (2011). "Effects of barotrauma and mitigation methods on released Australian bass *Macquaria novemaculeata*." Journal of Fish Biology **79**(5): 1130-1145.

Rose, J., R. Arlinghaus, S. Cooke, B. Diggles, W. Sawynok, E. Stevens and C. Wynne (2014). "Can fish really feel pain?" Fish and Fisheries **15**(1): 97-133.

Rummer, J. L. and W. A. Bennett (2005). "Physiological effects of swim bladder overexpansion and catastrophic decompression on Red Snapper." Transactions of the American Fisheries Society **134**(6): 1457-1470.

Salmi, P. and O. Ratamäki (2011). "Fishing culture, animal policy, and new governance: a case study of voluntary catch-and-release fishing in Finland." American Fisheries Society Symposium **75**: 235-249.

Sarvas, T. and S. Fevolden (2005). "Pantophysin (Pan I) locus divergence between inshore v. offshore and northern v. southern populations of Atlantic cod in the north-east Atlantic." Journal of Fish Biology **67**(2): 444-469.

Solstrand, M.-V. (2014). *Marine tourism fisheries - Challenges of governance and governability. Northern Norway as a case study*. Doctoral thesis. University of Tromsø: 109 pp.

Solstrand, M.-V. (2015). "Institutional challenges for effective governance of consumptive wildlife tourism: case studies of marine angling tourism in Iceland and Norway." Maritime Studies **14**(4).

Sparrevohn, C. R. and M. Storr-Paulsen (2012). "Using interview-based recall surveys to estimate cod *Gadus morhua* and eel *Anguilla anguilla* harvest in Danish recreational fishing." ICES Journal of Marine Science **69**(2): 323-330.

SSB. (2014). "Sports and outdoor activities, survey on living conditions, 2014." Retrieved 18.03.2015, from https://ssb.no/en/kultur-og-fritid/statistikker/fritid/hvert-3-aar/2014-12-18.

St John, J. and C. J. Syers (2005). "Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson 1845) following catch and release: The influence of capture depth, venting and hook type." Fisheries Research **76**(1): 106-116.

Stransky, C., H. Baumann, S. E. Fevolden, A. Harbitz, H. Høie, K. H. Nedreaas, A.-B. Salberg and T. H. Skarstein (2008). "Separation of Norwegian coastal cod and Northeast Arctic cod by outer otolith shape analysis." Fisheries Research **90**(1-3): 26-35.

Strehlow, H. V., N. Schultz, C. Zimmermann and C. Hammer (2012). "Cod catches taken by the German recreational fishery in the western Baltic Sea, 2005–2010: implications for stock assessment and management." ICES Journal of Marine Science **69**(10): 1769-1780.

Sullivan, M. G. (2002). "Illegal angling harvest of walleyes protected by length limits in Alberta." North American Journal of Fisheries Management **22**(3): 1053-1063.

Sullivan, M. G. (2003). "Active management of walleye fisheries in Alberta: dilemmas of managing recovering fisheries." North American Journal of Fisheries Management **23**(4): 1343-1358.

Suski, C., J. Svec, J. Ludden, F. Phelan and D. Philipp (2003). "The effect of catch-and-release angling on the parental care behavior of male smallmouth bass." Transactions of the American Fisheries Society **132**(2): 210-218.

Thorstad, E. B., C. J. Hay, T. F. Næsje, B. Chanda and F. Økland (2004). "Effects of catch-and-release angling on large cichlids in the subtropical Zambezi River." Fisheries Research **69**(1): 141-144.

van der Kooij, J., D. Righton, E. Strand, K. Michalsen, V. Thorsteinsson, H. Svedäng, F. C. Neat and S. Neuenfeldt (2007). "Life under pressure: insights from electronic data-storage tags into cod swimbladder function." ICES Journal of Marine Science **64**(7): 1293-1301.

Vølstad, J. H., K. Korsbrekke, K. Nedreaas, M. Nilsen, G. N. Nilsson, M. Pennington, S. Subbey and R. Wienerroither (2011). "Probability-based surveying using self-sampling to estimate catch and effort in Norway's coastal tourist fishery." ICES Journal of Marine Science **68**: 1785-1791.

Weltersbach, M. S. and H. V. Strehlow (2013). "Dead or alive – estimating post-release mortality of Atlantic cod in the recreational fishery." ICES Journal of Marine Science **70**: 864-872.

Wilde, G. R. (2009). "Does venting promote survival of released fish?" Fisheries **34**(1): 20-28.

Wilson, S. M., G. D. Raby, N. J. Burnett, S. G. Hinch and S. J. Cooke (2014). "Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals." Biological Conservation **171**: 61-72.