Norwegian University of Life Sciences
Faculty of Environmental Sciences
and Natural Resource Management

Philosophiae Doctor (PhD)
Thesis2018:76

Cultivating conflict: Perspectives on the human dimensions of voluntary Atlantic salmon (*Salmo salar*) hatcheries in a conservation context

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Ås (2018)

Thesis number 2018:76
ISSN 1894-6402
ISBN 978-82-575-1544-7

PhD Supervisors

Professor Dr. Øystein Aas
Faculty of Environmental Sciences and Natural Resource Management (MINA)
Norwegian University of Life Sciences (NMBU)
P.O. Box 5003
NO-1432 Ås, Norway

Dr. Stine Rybråten
Norwegian Institute for Nature Research (NINA)
Vormstuguvegen 40
NO-2624 Lillehammer, Norway

Professor Dr. Robert Arlinghaus
Department of Biology and Ecology of Fishes
Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB)
Muggelseedam 310
12587 Berlin, Germany

Evaluation Committee

Dr. Juliette Claire Young
Centre for Ecology & Hydrology, NERC
Bush Estate, Penicuik, Midlothian
EH26 0QB, United Kingdom (Scotland)

Dr. Maiken Bjørkan
Nordland Research Institute
P.O.Box 1490
N-8049 Bodø, Norway

Dr. Stian Stensland
Faculty of Environmental Sciences and Natural Resource Management (MINA)
Norwegian University of Life Sciences (NMBU)
P.O. Box 5003
NO-1432 Ås, Norway

Preface

This dissertation is submitted in partial fulfillment of the requirements for the degree of Philosophiae Doctor (PhD) at the Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Norway. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie project IMPRESS (GA No 642893), the Norwegian Miljødirektoratet (Reference No 166S2D396), The German Federal Ministry of Education and Research (BMBF) **"**Green Talents – International Forum for High Potentials in Sustainable Development**"** award (2017 – 2018), and from Oxford Small Travel Grants (2016). The research presented in this dissertation is a sub-product of the IMPRESS (Improved Production Strategies for Endangered Freshwater Species) Initial Training Network (ITN), which is a European training Network of the Marie Sklodowska-Curie Actions funded by the EU Research and Innovation Programme Horizon 2020 for the period 2015-2018.

This dissertation consists of four papers and a synopsis that presents the theoretical background of the research, the aim and the research questions of the project, the research settings and methods, the results, and finally a discussion of the findings, future research possibilities, and implications for managerial applications.

List of Appended Papers

1. Harrison, Hannah L., Stine Rybråten, and Øystein Aas. 2018. "Hatching Knowledge: A Case Study on the Hybridization of Local Ecological Knowledge and Scientific Knowledge in Small-Scale Atlantic Salmon (*Salmo salar*) Cultivation in Norway." *Human Ecology* 46 (4): 449–59.

2. Harrison, Hannah L., Janine Hauer, Jonas Ø. Nielsen, Øystein Aas. 2018. "Disputing nature in the Anthropocene: technology as friend and foe in the struggle to conserve wild Atlantic salmon (*Salmo salar*)." In review: *Ecology and Society*.

3. Harrison, Hannah L., Sophia Kochalski, Robert Arlinghaus, and Øystein Aas. 2018. "'Nature's Little Helpers': A Benefits Approach to Voluntary Cultivation of Hatchery Fish to Support Wild Atlantic Salmon (*Salmo salar*) Populations in Norway, Wales, and Germany." *Fisheries Research* 204 (August): 348–60.

4. Harrison, Hannah L., Sophia Kochalski, Robert Arlinghaus, and Øystein Aas. 2018. "Understanding and managing social conflict over Atlantic salmon (*Salmo salar*) conservation using discourse analysis: the case of termination of voluntary hatcheries in Wales." In review: *People and Nature.*

Acknowledgements

During the course of this PhD programme, I have been the fortunate recipient of help, support, guidance, and wisdom from many outstanding colleagues. First and foremost, I wish to thank my primary supervisor and angler extraordinaire Dr. Øystein Aas of NMBU and the Norwegian Institute for Nature Research (NINA). Your unending support, humor, encouragement, willingness to read whatever I put in front of you, and dedicated support of my PhD journey has been without equal. You are truly the best supervisor I could have ever hoped for. Thank you.

Thank you also my co-supervisors Dr. Stine Rybråten and Dr. Robert Arlinghaus for your thoughtful guidance, writing, and willingness to think through tough research challenges with me. Your advice and wisdom is greatly appreciated. Thank you also to my research colleagues Dr. Sophia Kochalski and Janine Hauer. Your contributions and camaraderie were more important than I can describe. This thesis was a success because of your collaboration and friendship.

I wish to also thank the administration at MINA for their support of my PhD work, as well as the support staff at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin and Humboldt-Universität zu Berlin, Germany, and the Norwegian Institute for Nature Research, Lillehammer, Norway. Thanks also to the PhD community at NMBU, especially the SoDoC board, for your support and willingness to share your experiences amongst our community.

Thank you also to Dr. Finn-Arne Weltzien and Dr. Eirill Ager-Wick with the IMPRESS project, as well as all of the other IMPRESS PIs. Special gratitude to all of my friends and colleagues, the IMPRESS ESRs: Dr. Mitchell Fleming, Dr. Daan Mes, Dr. Elia Ciani, Carlos Espírito Santo, Benjamin Boehm, Christoffer Rozenfeld, Elena Santidrian Yebra-Pimentel, Aurora Campo, Juan German Herranz-Jusdado, Abdul Rasheed Baloch, Sahana Gowda, and Carina Caldeira. These 3+ years spent with you have been some of the most rewarding in my life and career thus far. I look forward to many more future collaborations together. Thank you.

A very special thank you to all of the anglers, scientists, managers, hatchery operators, and everyone else who participated in my case studies. You opened your offices, homes,

heads, and hatcheries to me and shared your wells of wisdom and experience. For that, I cannot thank you enough. I hope this research meets your expectations and has produced something of value to each of you. Thank you.

Finally and most importantly, thank you to my wonderful husband Rob and my family for your unending and unwavering support. You have put up with many years of my graduate school journey and it gives me great joy to now be reaching The End (or, *an* End) together. Thank you for your love, wisdom, and proofreading. Without you, this PhD would have been impossible.

Ås, Norway, 2018

Abstract
The overall goal of this thesis is to offer a more in-depth human dimensions understanding of voluntary Atlantic salmon hatcheries, focusing on the underlying drivers of conflict over hatchery use in a conservation context. To achieve this, the thesis looks at hatcheries through different conservation social science lenses over the course of four papers. In doing so, this thesis represents a much-needed human dimensions approach to conflict revolving around the use of small-scale, voluntarily operated Atlantic salmon hatcheries in Wales, Norway, and Germany. The methods used for data collection and analysis are qualitative and include interviews, document analysis, and participant observation.

Voluntary hatcheries have been in use for over 150 years in Europe, and for much of the twentieth century they were viewed as popular management tools for improving local salmon stock levels for angling and conservation purposes. In the past 30 years, scientific knowledge has emerged showing that these hatcheries and their associated stocking practices may have deleterious effects on wild salmon populations due to behavioural, physiological, and genetic changes that occur to salmon when born and reared in the hatchery environment. This emerging knowledge has reshaped managerial attitudes toward Atlantic salmon stocking for conservation purposes at the international level, and state level stocking policies have changed to reflect those shifting views. In an instance of this, in 2014 both Wales and Norway made changes to their stocking policies that resulted in significant conflict between local-level cultivators and regional and state-level managers. Combining these case studies with a case in Germany (where stocking remains largely unregulated, but also unsupported at the state level), this thesis seeks to understand the underlying causes of conflict surrounding these cases, and shed light on the changing perspectives about cultivation as a conservation practice.

This thesis approaches this central problem from several perspectives. In the first paper, this research investigates how different knowledge forms meet, merge, and are reproduced in hatcheries as a form of hybridized knowledge. In the second paper, the thesis examines how technology affects and defines the human-salmon relationship via definitions and ontologies of nature and "naturalness" employed by managers and local-level cultivators. In the third paper, the thesis investigates what benefits hatcheries may provide aside from the production of fish. This paper identifies and describes what

social, psychological, and conservation benefits hatcheries are producing to the surrounding salmon communities, and reveals how the production of these benefits plays into conflicts over the closure or restriction of hatchery activities. Finally, the fourth paper takes a close look at how conflicting discourses over the role of hatcheries form, change, and move between different planes of communication, and how conflict occurs in stages.

Taken together, the findings of this thesis point to several key reasons why stocking remains popular and contentious between pro- and anti-stocking advocates. First, this thesis demonstrates that hatcheries and stocking have different socio-cultural values to different stakeholder groups, and these disparate values are not sufficiently included in contemporary debates over stocking, particularly within academic and scientific spheres of discussion. For example, hatcheries provide opportunities for local-level stakeholders to integrate and hybridize broad scientific knowledge into their local contexts in order to improve their hatchery and fishery outcomes. It also shows that, like salmon themselves, hatcheries provide a broad range of benefits beyond the production of juvenile salmon. Thus, hatcheries are being valued beyond their mere capacity to produce fish, and are a preferred means of performing conservation in contexts that are not necessarily limited to the genetic, ecological, and biological concerns surrounding salmon cultivation.

This thesis also finds that underlying philosophies toward salmon conservation held by local-level stakeholders and state-level managers differ in their ontologies toward nature and knowledge. While managers and fisheries scientists commonly remain grounded in ecological and biological management priorities such as maintaining genetic biodiversity and naturalness within salmon populations, local-level stakeholders may view conservation priorities somewhat differently.

Similarly, local stakeholders are shown to draw from multiple ways of knowing in order to support their conservation efforts, and they are keen observers of the local environment and salmon population. This research shows that local-level cultivators are keenly aware and interested in improving their scientific knowledge as a means to improve their cultivation practices, and thus are adapting their knowledge sets to

incorporate this information. Hatcheries are thus acting as facilitators for this process of knowledge hybridization, a function not yet incorporated into the hatchery debate.

This thesis shows that the common scientific understanding of the effects of salmon stocking, while important in biological and ecologically-oriented discussions, falls short of addressing all social, cultural, and conservation-oriented issues that are valuable to local-level stakeholders. Inspired by the "conflict transformation" approach, this thesis situates the implications of these findings in an emerging framework that suggests a transformation of the role of voluntary hatcheries from problematic producers of juvenile fish toward a conservation technology embedded in local contexts and capable of producing and facilitating a range of benefits, knowledges, and desirable conservation and social outcomes. More succinctly put, this emerging framework suggests that while voluntary hatcheries are biologically and ecologically problematic, they also simultaneously produce and perform many positive and beneficial socio-cultural aspects that have primary and secondary benefits to the cultivator communities engaged with them and to conservation of the surrounding salmon riverscapes. Instead of acting as the problematic centrum of conservation conflicts, this framework re-positions hatcheries as indicators of dynamic processes that acknowledge, support, and utilize the underlying social aspects of the conflicts identified in this thesis. As such, the thesis highlights strengths over which managers, scientists, and cultivation stakeholders may engage more productively, through focusing work around shared knowledge, a wider understanding of benefits, engagement in conservation and participatory research, and adaptive management.

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"When everything is natural [in the river], you thank God that it works. But as an old [angler] told me, "Why don't we help God a little? He's a busy man. He just can't fix everything. We can give him a hand sometimes."

- E. Arntsen, May 2016, Ørsta, Norway

Forty years of research supports a simple, long-standing, evidence based scientific consensus: if the integrity of wild salmon is a management priority, stocking hatchery fish should be avoided."

- Kyle A. Young, June 2017
(North Atlantic Salmon Conservation Organisation 2017)

SYNOPSIS

1. Introduction

The Atlantic salmon (*Salmo salar*) is a dietary, economic, recreational, and cultural icon amongst fish species and has been a key story of failure and success in European fisheries management over the past several centuries. Atlantic salmon once inhabited a wide range of European fresh water systems, but their populations have declined dramatically (Aas et al., 2011; Parrish et al., 1998) and, in some cases, have been driven to extinction (IUCN, 2018). In what has become a predictable refrain, humans and our societal history of altering habitats and consuming natural resources are largely responsible for the decline of this iconic species.

In response to declining Atlantic salmon populations, management of this species has undergone significant shifts in the past century. In particular, the use of hatcheries and stocking programs as a method for stock enhancement (typically for fisheries purposes) and stock conservation has shifted from being a popular and widely used management tool in both Europe and North America (Aas et al., 2011; Bottom, 1997; Hilborn, 1992; Wolter, 2015) to being criticized due to its negative impacts on wild stocks (Amoroso et al., 2017; Camp et al., 2017). In particular, emerging knowledge in the 1970's and 1980's about stock genetics and the genetic integrity of wild salmon populations has become a central feature of stocking debates within management and the scientific literature (Aas et al., 2011; Verspoor et al., 2008). Though some leading voices within the field of salmon conservation may argue that the stocking debate is over – that stocking is rarely justifiable, and is never a solution to the improvement of pre-existing wild Atlantic salmon stocks (North Atlantic Salmon Conservation Organisation, 2017) – logic would dictate that this cannot be true. The stocking debate remains a contentious issue in European and North American contexts and is still a widely used and popular conservation tool for river owners, angling clubs, and as a state-level disaster mitigation tool (e.g., gene banking, hydro power habitat loss compensation).

To deal with this apparent juxtaposition of claims, this thesis focuses on the stocking debate taking place in the field; or, perhaps more appropriately, on the river bank. Though the call for increased knowledge about Atlantic salmon has been met with much literature focusing on salmon biology, ecology, behavior, and genetics (Aas et al., 2011; Verspoor et al., 2008), the human dimensions aspects of stocking and hatchery[1] programs, and more broadly the

[1] Hatcheries are facilities where eggs are hatched in artificial, protected conditions. For salmon, most hatcheries also include the human-facilitated mixing of eggs and milt and the rearing of alevins to the fry stage or beyond. The rationale behind hatchery use is often case specific, but general motivations for stocking include enhancing natural productivity of a salmon stock for purposes of enhancing angling opportunities, compensating for

integration of social sciences into conservation practice and research, has received unequal attention and thus remains in a nascent stage (Bennett et al., 2017b). The social sciences, within which human dimensions of natural resource management research is embedded, are used to describe and understand "social phenomena, social processes or individual attributes" under study by asking why or how they are occurring (Bennett et al., 2017a, pg. 95). As salmon hatcheries and stocking practices within these case studies are social processes (Harrison et al., 2018a), a social science approach is both appropriate and necessary for understanding the ongoing salmonid stocking debate. Within the context of managerial implications toward the debate, the human dimensions research gap may have wider-reaching implications than are currently recognized, as human dimensions research has been identified as necessary for producing meaningful conservation policies, regulatory outcomes, and action on the ground (Bennett et al., 2017b; Sandbrook et al., 2013).

Some human dimensions research in the field of recreational angling has highlighted the value of stakeholder perspectives, and prioritized more research on social-ecological systems (L. M. Hunt, Sutton, and Arlinghaus 2013) including discussions of hatcheries and stocking (Arlinghaus and Mehner 2005; Len M. Hunt, Gonder, and Haider 2010). However, these debates often takes a managerial or ecological point of view and situates stocking as a problem to be fixed (Arlinghaus, 2006a; Johnson et al., 2009). Taking a social science perspective on the "problem" of stocking allows a critical deconstruction of these views, and creates space to develop more effective and socially acceptable solutions (Toomey, Knight, and Barlow 2017) toward the complex biological, ecological, and social challenges of salmon stocking practices.

Within human dimensions research, in-depth, qualitative studies that capture the perspectives of hatchery stakeholders on multiple scales, and indeed socio-political research in general, are underrepresented in the stocking debate (Young, 2017). Thus, little is empirically known about how and why hatcheries are valued and what underlying perspectives, beliefs, and attitudes drive the hatchery debate forward, particularly from a local-level perspective. This is an important and critical knowledge gap to fill. Without such efforts, the information

damage done to the natural productivity of a stock (e.g., *Gyrodactylus* infestations (see O'Reilly and Doyle, 2007)), commercial aquaculture production, and to provide lasting benefits to salmon populations via a conservation approach (Fleming and Petersson 2001; Aprahamian et al. 2003). Regardless of the hatchery purpose, the fundamental mechanism at work in the hatchery is overcoming life stage bottlenecks to allow a larger percentage of juveniles to achieve adulthood.

fisheries managers have about hatchery stakeholder views will remain incomplete since stakeholder feedback is often offered only in times of emotional or social duress (such as stakeholder meetings, public consultation responses, etc.). Thus, this thesis offers a more detailed and empirical picture of the social aspects of the stocking debate through three case studies. Each approaches a facet of the debate by using different and supplementary theoretical approaches, grounded within data representative of stakeholder views, values, and perspectives.

Over the course of the four articles that comprise this thesis, I approach a central set of questions (Table 1).

Table 1 Overarching research questions of the thesis.

1. Why does stocking remain so popular amongst local-level stakeholders (and some managers) if the preponderance of empirical evidence appears to condemn stocking as an ineffectual conservation tool? 2. From a human dimensions perspective, what social aspects are missing from the stocking debate and how could those issues be better addressed? 3. What social obstacles exist toward improving manager-stakeholder relations around stocking (and thereby mitigating or relieving conflict), and what can be done to overcome them?

In answering these questions, this work focuses on what I term 'voluntary hatcheries', or those hatcheries which are owned and/or operated by local salmon interest groups and are *not* mandatory or obliged by state or regional fisheries policy. These hatcheries and the cultivation methods that preceded them have been historically common in Northern European salmon cultivation (Berg 1986; Aam 2009; Gilbert 1929), but notably are not common-place in contemporary North American cultivation practices. Thus, though the findings of this thesis may have applications beyond these specific cases, this study is focused solely within the European context.

1.1 The goal and structure of this thesis

The overall goal of this thesis is to offer a more in-depth human dimensions understanding of voluntary Atlantic salmon hatcheries, focusing on the underlying drivers of conflict over hatchery use in a conservation context. Within that goal, I hope to increase knowledge about hatchery stakeholder beliefs, attitudes and perspectives toward hatchery and stocking programs aimed at improving wild Atlantic salmon conservation outcomes. More specifically, I aim to present multiple perspectives on hatcheries that illuminate why they are

valued by hatchery practitioners and advocates, the multiple dimensions of knowledge production and utilization in hatcheries, how conflict over hatcheries are (mis)understood between competing stakeholder perspectives, and to offer insights into how such conflicts may be remedied or avoided. Most importantly, it is my hope that the insights from this thesis may offer managers, fisheries scientists, and hatchery stakeholders ways forward in creating more comprehensive approaches toward Atlantic salmon conservation that are inclusive of multiple objectives (i.e., social, ecological, economic) and approaches.

*What this thesis does **not** do*

In addition to explaining the purpose and contributes of this thesis, it is equally important to indicate the limitations of this research and what this body of work does *not* do. First, it is important to reiterate that this work is based within the social sciences, though it contains many aspects and junctures with natural science literature and disciplines. Its purpose is to examine the social aspects of wild Atlantic salmon conservation and cultivation, *not* to debate the natural sciences literature or argue one way or another about whether hatcheries are 'good', 'bad', or something else.

Along those same lines, it is not the intention of this thesis to say, or be used to say, who is right or wrong about hatchery science, hatchery debates, or hatchery use in salmon conservation in general. It is my view that within the stocking debate, research that results in further polarizing views on hatcheries is counterproductive to reaching sustainable conservation outcomes for salmon. Thus, the aim of this thesis is to contribute insights and advice toward strengthening local-level salmon conservation activities and help clarify the human dimensions aspects of the stocking debate.

Four papers constitute the major part of this thesis, and the introduction constitutes a general framework within which the four papers may be better understood and contextualized. Chapter 1 introduces the topic of the thesis, presents the goals and overarching research questions of the study, and gives an overview of the papers contained therein. Chapter 2 presents the project within which the thesis research was embedded, and introduces the case studies used in the thesis research. Chapter 3 gives a contextual background for the research and introduces the central research problem of the thesis. Chapter 4 presents a discussion of the epistemological, theoretical, and conceptual approaches used in the thesis to embed the research findings. It also presents some of the central theoretical approaches used in the appended papers. Chapter 5 presents the methodological underpinnings of the research,

including the details of data collection and analysis. Chapter 6 presents the research findings from the appended papers. Chapter 7 presents a discussion of the findings and the linkages between the individual papers. It also presents their contributions to aspects of human dimensions in conservation social science, a discussion of the research within the context of conflict studies, and presents managerial and stakeholder implications as an emerging framework for cultivation management. It concludes with suggestions for future directions in salmon cultivation study. Chapter 8 closes the thesis with brief concluding remarks.

1.2 The papers

Paper 1: Hatching knowledge: a case study on the hybridization of local ecological knowledge and scientific knowledge in Norwegian small-scale Atlantic salmon (Salmo salar) cultivation

Paper 1 examines hatcheries through the lens of knowledge systems. This article uses the Norwegian case study to examine how local ecological knowledge and scientific knowledge are undergoing hybridization, a process facilitated within voluntary hatcheries and their associated fish rearing practices. This article traces the use of local ecological knowledge and scientific knowledge as once compatible ways of knowing that, when used together, informed fisheries conservation at the local level. Now, these knowledge sets have diverged as scientific knowledge about salmon cultivation has grown increasingly technical and complex. We examine the processes by which these knowledge sets develop, evolve, and are used to facilitate wild salmon conservation practices. We conclude that rather than treating these knowledge sets as separate and (sometimes) equal, managers should take advantage of hatcheries as laboratories in which knowledge may be integrated into local knowledge sets (and, by extension, conservation practices) as well as producers of new knowledge sets that represent the most relevant and useful aspects of both ways of knowing.

Paper 2: Disputing nature in the Anthropocene: technology as friend and foe in the struggle to conserve wild Atlantic salmon (Salmo salar)

Paper 2 examines the role of attitudes and ontologies about nature, naturalness, and the ‘best salmon’ in the context of increasingly complex human-nature entanglements in the Anthropocene. Specifically, this article reveals dynamic shifts over the past two centuries with regard to how hatcheries are used as conservation tools in a Norwegian and Welsh case, and frames the analysis through a lens of shifting conceptualizations of naturalness and human-salmon relationships. Starting at the multinational level and then moving to ground-

level cases, the article shows how naturalness is conceptualized by managers and hatchery stakeholders, and how those perceptions play into definitions of desired outcomes for wild salmon conservation as well as the strategies and technologies implemented to achieve these conservation goals. The findings highlight two paradoxes: first, that hatcheries are no longer perceived as appropriate technologies to increase wild salmon populations and are being withdrawn, limited, or transformed, often resulting in local-level controversy. These changes are, in themselves, highly technical processes involving genomic testing and big data inventories. Second, despite the recognition of ever more complex human-nature entanglements, the practical outcomes for salmon conservation are oriented toward standardized testability and manageability and limiting certain human-salmon interactions. As a result, those techno-social communities organized around hatchery technologies are at risk of being removed or otherwise excluded from their preferred conservation activities.

Paper 3: "Nature's Little Helpers": A benefits approach to voluntary cultivation of hatchery fish to support wild Atlantic salmon (Salmo salar) populations in Norway, Wales, and Germany

Paper 3 examines the perspectives of hatchery stakeholders at multiple levels of governance to understand the non-fish benefits of voluntary hatcheries in case studies in Norway, Wales, and Germany. These benefits are categorized into social, psychological, and conservation benefits following a similar categorization found in outdoor recreational angling literature. The perspectives represented in this article include those of fisheries managers, hatchery operators, angling clubs, and river owners from each case. We compare the benefits found within the three cases and show that some or all of the benefits identified in each case study are non-substitutable, and likely influence local-level resistance to policies that limit or terminate stocking activities from which these benefits derive. The article argues for the improved incorporation of multiple social, psychological, and conservation hatchery benefits into future fisheries management decisions allowing for a more holistic and inclusive approach to hatchery management and reduced stakeholder conflict.

Paper 4: Understanding and managing social conflict over Atlantic salmon (Salmo salar) conservation using discourse analysis: the case of termination of voluntary hatcheries in Wales

Paper 4 dissects the social conflict that surrounds hatchery and stocking programs via a case study where conflict erupted after a 2014 policy decision to terminate all salmonid stocking

across Wales. The article utilizes a critical discourse analysis of interview data, online print media, social media, and policy documents to evaluate the social and conservation effects of this policy change. The study finds that conflict between two identified discourse coalitions was formulated around ecological reasoning about the outcomes of salmon stocking, opposing views on economic efficacy in conservation projects, challenges to governance systems, and personal conflicts between stakeholders. We identified shifting power dynamics that favored anti-stocking discourses, eventually leading to the institutionalization of dominant anti-stocking discourses via a win-lose decision to terminate all stocking in Wales. This article shows how this decision contributed to continued conflict by forcing all stakeholder groups to accept one perspective of stocking, and consequently led to undesired social side effects such as secondary conflicts and alienation of some stakeholder groups. It concludes by advocating for transdisciplinary active management designed for joint learning as a suitable alternative to the "top down," "either-or" consultation process exercised in the case study.

2. The project and cases

The articles in this thesis represent the findings of one sub-program of IMPRESS (Improved Production Strategies for Endangered Freshwater Species)[2]. IMPRESS was a multidisciplinary project that brought together PhD fellows and researchers from across geographic and disciplinary distances to work toward shared fisheries conservation challenges. Specifically, IMPRESS aimed to investigate means by which to better conserve European eel (*Anguilla anguilla*), sturgeons (*Acipenseridae spp*), and Atlantic salmon through innovative cultivation measures. Though many contributors to this project utilized quantitative methods within the frame of the natural sciences, this thesis represents the qualitative approach and contributions to the overall IMPRESS project. In doing so, it opens the door for a discussion about the role of qualitative studies in addressing the human dimensions of conservation problems.

While biology, ecology, and other natural science fields allow society to understand much about endangered fish species and their habitats, over-reliance on these approaches has led to failures to understand complex social problems, leading to the inhibition or failure of science-driven conservation policies (Mascia et al. 2003). While it may seem counterintuitive to some, some of the most relevant factors concerning the making of effective environmental policy come from the social science research, disciplines which have demonstrated strong relevance and applicability to unearthing the social roots of conservation problems (Charnley et al., 2017a). Still, some social dimensions of environmental challenges, such as cultural value and interactions with ecosystems, remain poorly understood (Poe, Norman, and Levin 2014). Thus, it is imperative that projects like IMPRESS, which claimed an innovative distinction toward conservation science, embrace multidisciplinary and multi-methodological approaches toward understanding conservation problems such as those faced by endangered freshwater fish species in Europe.

Critical reflections on the research

The PhD experience has been challenging, yet highly rewarding in both an academic and personal development context. In terms of the research project itself, I have been very pleased with how it has been received by the stakeholders who participated in the data collection. Based on a number of presentations to both academic and stakeholder audiences, it appears

[2] www.impress-itn.eu

that the findings of this work closely reflect perspectives held by both local and managerial level stakeholders – a very rewarding outcome to my personal research ethics and priorities which, amongst empirical concerns, include accurately and closely reflecting the concerns, perspectives, and priorities of those who have a stake in this work. Similarly, I have received feedback from a few fisheries managers outside of these case studies who have expressed interest in utilizing some of the findings from this work in their own management practices. This is also a rewarding outcome, though it is yet to be seen whether their interest carries through to execution, or if the recommendations we made are successful in the field.

Along that same vein, this research falls short of its own recommendations in that none of the papers appended in this thesis actually test the recommendations they make. Further, they fall short of offering real theories of change (Baynham-Herd et al., 2018), and are almost certainly influenced by my (and my co-author's) ethical and rational perspectives toward salmon conservation (ibid). Similarly, the theoretical lenses used and findings made in this research likely reflect our disciplinary silos and training (Baynham-Herd et al., 2018; Margles et al., 2010; Sandbrook et al., 2013), though this effect is likely lessened somewhat by the multi- and transdisciplinary nature of the research team.

The papers contained within this thesis contribute a social sciences dimension to the otherwise biological and genetic contributions from other IMPRESS research sub-programs. Specifically, it offers perspectives from stakeholders involved in the cultivation of threatened fish species, and thereby gives important context, perspective, and insight into how stakeholders – that is, those individual and groups for whom the research from the IMPRESS project should be most relevant – understand, receive, and make use of research derived from projects like IMPRESS. These findings are essential to IMPRESS as without an understanding of stakeholder needs, wants, and wishes for cultivation research, the empirical finding of IMPRESS sub-products, while novel and interesting within the scientific and academic worlds, may be inappropriate, undesirable, misunderstood, and otherwise unusable in real-world contexts. Thus, the work contained within this thesis offers insights that help to bridge that gap.

2.1 Why these case studies?

The case studies used to investigate the research questions in this thesis were selected because they represent a spectrum of unique governance features, hatchery practices, and comparability in terms of how voluntary hatcheries are currently being managed (or not managed) in each location (Figure 1)(Aas et al., 2018).

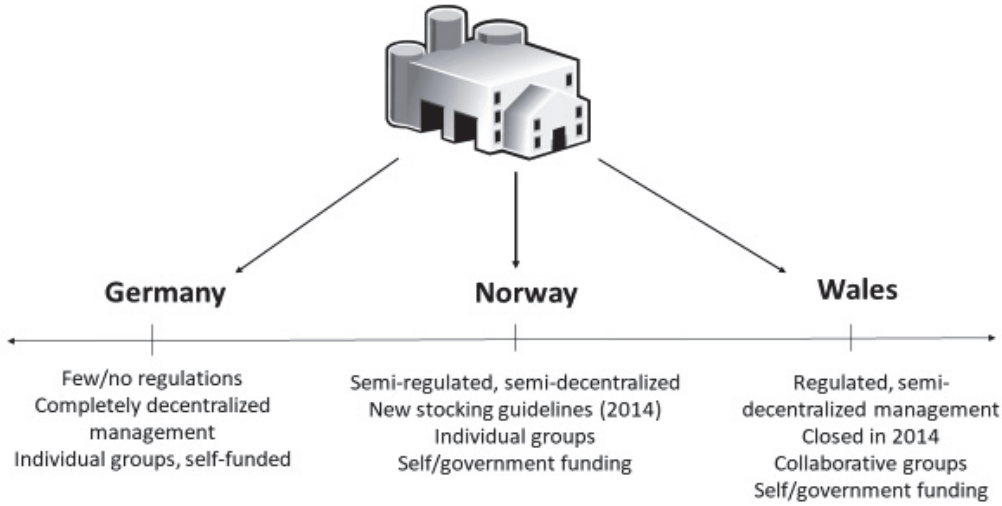

Figure 1 Case studies within this thesis shown on a spectrum of management (decentralized to more centralized management) and from open, growing stocking programs to closed programs.

Prior to the primary fieldwork conducted in 2016, preliminary assessment of each case study revealed conflicts surrounding policy decisions to restrict or eliminate stocking activities in Norway and Wales (respectively). As wild salmon populations still exist in both cases, they offered a good example of how conservation practices of existing stocks interacted with changing attitudes and governance of hatchery use. In order to gain alternative perspectives to those offered in these initial cases, the scope of this work was expanded into areas where salmon hatcheries remain a viable and popular conservation strategy, resulting in a case study in Germany in collaboration with IMPRESS project partners. In Germany stocking has emerged as a preferred (and necessary) approach to restoring extinct salmon populations (Granek et al., 2008), though state level management has taken little formal interest in these efforts, resulting in less intense conflict than in the other cases. This additional case gave a different perspective both in terms of interest in stocking issues from state and regional level managers and of hatchery group attitudes about the value and outcome of cultivation work.

2.1.1 Norway

In Norway, the study area is the community of Ørsta in western Norway's Sunnmøre district.

Specifically, the study focused on the Ørsta River, approximately 25km in length with its estuary in the Ørsta fjord, and its associated salmon hatchery. The river is technically two rivers, the Follestaddalselva and the Åmdalselva, that join approximately three kilometers from the river mouth and are collectively referred to as Ørsta River. The Ørsta River hosts a population of wild Atlantic salmon, the fishing rights for which are privately controlled by river property owners, a typical ownership scheme for most European rivers (Stensland 2012). The river owner organization (Ørstavassdraget Elveeigarlag) is responsible for the management of fishing access and regulation under national salmon river management rules (Stensland 2010), and the Ørsta hunting and fishing association (Ørsta Jeger- og Fiskerforening) owns and is responsible for the management of the Ørsta hatchery.

Stocking of the Ørsta River is an old tradition, started by a local river owner in 1925 with roe brought from the nearby Hellesylt River. The impetus for early stocking efforts is not entirely clear, though it is thought that Ørsta stocking was driven to improve the average size of salmon stocks by introducing large conspecifics from neighboring watersheds. Whatever the reason, the Board of Salmon for Sunnmøre (Sunnmøre Laksestyre), an early salmon governing body, eventually built a small hatchery in 1931 to support local stocking efforts (Aam 2009, pp. 16-18).

Between 1948-1952, three kilometers of the Ørsta River were channelized to ease farmland improvements in a nationwide post-WWII effort to improve Norway's food supplies through more efficient and productive agriculture. These changes to the river channel effectively destroyed salmon habitat within the channeled area (Personal communication, March 6, 2017), making important spawning and rearing grounds no longer available to returning fish. Partly as a response to this loss, the Ørsta hunting and fishing association (Ørsta Jeger- og Fiskerforening), a group founded in 1952 to represent local hunting and fishing interests, began work on a new, more modern hatchery in 1957 to replace the original facility from the 1930s (which had long suffered from poor water quality during spates). The first fish from the new hatchery were stocked into the Ørsta River in 1961 (Aam 2009, pp. 31-32).

Today, the Ørsta hatchery is run through a voluntary collaboration between the river owners association and the Ørsta hunting and fishing association and, with the exception of a period from 1996 – 2000, produces an annual cohort of parr that are stocked into various points on the Ørsta River. Their partnership supports a valuable community of cooperation, environmental stewardship, and conservation activities as well as a healthy angling

community frequented by locals and the occasional visitor from elsewhere in Norway and abroad.

The Ørsta River and its hatchery were selected as a case study for several reasons. First, the region has been anecdotally described by salmon managers and researchers alike as particularly "vocal" about changes to Norway's stocking guidelines made in 2014. The resulting disagreements about how voluntary hatcheries should be managed at the national versus the local level formed a well-suited focal point to study these unique hatcheries and why they form a controversial part of Norway's salmon conservation strategy. Additionally, preliminary interviews with key informants from this Ørsta hatchery indicated that stakeholders in this area were both interested and encouraging of a social science research project that would allow them an opportunity to explain their point of view and the value of hatchery work to the Ørsta salmon community. Additionally, the Sunnmøre area is home to several other hatcheries within driving distance of the Ørsta, therefore allowing us to broaden the scope of our data collection and improve the rigor of the study.

2.1.2 Wales

As the 5th longest river in the United Kingdom, the Wye's ~135 miles flow past and shape a wide variety of people landscapes and commands a huge watershed of over 1500sq miles. The Wye begins in the Cambrian Mountains in Wales and flows through the Wye Valley, a landscape designated as an Area of Outstanding Natural Beauty[3]. As it joins with tributaries and passes through agricultural land, the river becomes significantly larger and more colored with sediments and effluents (particularly after rainfall) until it reaches the sea in the Severn Estuary. The agricultural and residential areas that surround the Wye for much of its length depend on the river as a source of water abstraction and, in some locations, agricultural effluent disposal. Similarly, the river serves many recreational purposes including fishing and, particularly within the last decade, heavy use by watercrafts such as canoes and kayaks. Though its natural beauty and supply of water were important to the many surrounding communities, the Wye is especially famous for its salmon fishing, and in particular the large quantity and size of spring run salmon (often called "springers").

The Lower Wye is a designated salmonid fishery under the Freshwater Fish Directive, and the entire Wye is designated as one of two Special Areas of Conservation[4] (divided above

[3] Areas of Outstanding Natural Beauty are designated by the appropriate natural resource management body (e.g., Natural Resources Wales, Natural England, etc.)

[4] Special Areas of Conservation are designated under the EU Habitat Directive (92/43/EEC)

and below Hay-on-Wye) due to its importance as a wildlife corridor and key breeding area for many important species. Salmon fishing on the Wye is governed by Natural Resources Wales in conjunction with river property owners who, by virtue of owning the river property, maintain the right to lease fishing rights to stretches of river, known as "beats." As the Wye has enjoyed a longstanding reputation for large salmon that return in the spring, salmon fishing has been a popular and notable recreational activity throughout much of the Wye watershed. This regional affiliation with salmon has become embedded with salmon lore stemming from books such as Tale of a Wye Fisherman by H.A. Gilbert (1929) and Wye Salmon and Other Fish by J. Arthur Hutton (1949), as well as in art, statues (such as that of the three leaping salmon in Ross-on-Wye), and local culinary traditions.

However, the Wye salmon's fame has not protected it from the many threats that plague the River Wye; agricultural pollution, acid waters resulting from poor commercial forestry practices, water abstraction, contamination from sheep dips and other chemical byproducts from intensive animal husbandry, overfishing and other problems in the marine environment, and a wide variety of migratory barriers and weirs. These impacts have sent the Wye's salmon populations into a state of serious decline. Measured by reported rod caught fish, historical trends show a steep decline from the peak catch of nearly 8,000 salmon in the late 1960's and mid-1970's to an all-time low of 357 salmon in 2001 (see Paper 4, Table 2). Compensating for this decline has been an issue of much contention as advocacy groups for habitat improvement and continued stocking compete for limited financial resources. As a result, passions for salmon conservation in the Wye catchment run high and, over the past century, have been ignited on more than one occasion due to policy changes to river access, permissible fishing methods, and fishing season length, and, most relevantly to this study, the use of salmon hatcheries as fishery enhancement and conservation tools.

For the purposes of this study, we were especially interested in the Wye in the context of a 2014 decision to close all salmon stocking in Wales (with a few scientific exceptions). In conducting preliminary research on this closure, potential key informants were most visible within the Wye fisheries and politics. When we sought exploratory interviews with those participants we could identify in press and written reports, it became clear that this case presented a vast network of willing research participants. Thus, we selected the Wye as a case study that represented a different position on the scale of policy change, particularly in comparison to Norway where such policy changes are conceived of but not yet implemented,

as well as a relatively similar system of natural resource governance and historical trajectory concerning salmon management.

2.1.3 Germany

As already mentioned, Atlantic salmon once commanded a vast range that included the major rivers of central Europe. Famously, the River Elbe, which flows from the Czech Republic through Germany before emptying into the North Sea at Hamburg, was once home to huge runs of Atlantic salmon. In the past century, however, this has ceased to be the case. Catch records record that the last Atlantic salmon was caught in the Elbe in 1949. This sad occasion marks the Elbe's extinction of wild Atlantic salmon, a trend fueled by demands on water and declines in water quality from central Europe's burgeoning textile industry and increasing propensity for installing hydropower dams and locks to enable commercial shipping up and down the Elbe from the early 1800s. Though German authorities attempted to compensate for this loss by stocking the Elbe and other former salmon rivers, by the mid-twentieth century salmon had effectively been extirpated from German waters.

However, all hope is not lost for Elbe salmon. Anglers and angling clubs scattered throughout Germany are picking up the torch of salmon conservation through a burgeoning hatchery program supported by partnerships with German biologists and Scandinavian egg banks. While the genetically unique Elbe salmon may not be possible to recover, salmon now swim again in the Elbe, though their future remains tenuous at best. This newfound role for hatcheries is exciting for German angling clubs, though the reintroduction of salmon has found little political interest or support thus far. In comparison to the more rigidly governed salmon conservation programs in the United Kingdom and Norway, German salmon hatcheries present an ideal contemporary case study to look at the "beginning" of a hatchery-based approach to salmon conservation, and thus rounds out the developmental spectrum of salmon management in Europe within this thesis.

In this case study, we visited hatcheries and angling clubs on the Stepenitz River, a tributary to the River Elbe. Stocking in this tributary began in 1999, inspired by improved water quality in the River Elbe and by other German salmon stocking programs. Though the hatcheries studied in this case originally began stocking efforts using reproductive material imported from Denmark, Sweden, and Norway, most have begun to work with own returning

salmon since 2013. Our case study focuses on the Fario fly fishing club in Berlin and the hatchery they operate outside of the city. The hatchery is operated in cooperation with Institute for Inland fisheries (scientific monitoring), the Federal State´s fishing association (financing), and local fishing clubs close to the stocked waters (labor for stocking activities), and represents a growing interest in restoring salmon to Germany's rivers.

3. Contextual background

This chapter introduces the context within which the included case studies may be understood by offering an overview of wild Atlantic salmon management from broad international scales down to the local-level. Then, it introduces how hatcheries have been used and abused as part of salmon conservation and enhancement efforts. Finally, this chapter positions the thesis within a theoretical background by giving an overview of the current stocking debate and explaining how this research contributes to this ongoing discussion.

The Atlantic salmon

The Atlantic salmon is distributed along the coasts and sea in the North Atlantic Ocean, and makes its home from the northern reaches of Iceland, Norway, and Russia to Portugal in the Eastern Atlantic to the United States and Canada in the West. Through human help, the Atlantic salmon has also become a resident of the eastern Pacific Ocean through commercial aquaculture in North and South America. Atlantic salmon, like their Pacific cousins, share the taxonomic family of *Salmonidae* and commonly have an anadromous life cycle. However, Atlantic salmon depart from their Pacific counterparts at the genus level (*Salmo*), possessing only two species (*Salmo salar* and *Salmo trutta*, a trout) instead of the multiple *Oncorhynchus* species found in Pacific salmon.

The Atlantic salmon's life cycle is variable from population to population as this species is highly locally adaptable (McCormick et al., 1998). For example, the freshwater stage of Atlantic salmon life may last anywhere between 1-8 years, with the freshwater stage ending with smoltification and a springtime migration to sea. They then spend typically 1-4 years feeding in the North Atlantic Ocean before returning to freshwater to spawn (Thorstad et al., 2011). Though this life history description is generally typical for wild Atlantic salmon, variations to this history are strongly influenced by the environmental conditions experienced by individual fish (Metcalfe, 1998). Perhaps one of the iconic characteristics of Atlantic salmon (and most salmonids in general) is their return to their natal streams to spawn (Quinn, 1984). Between five to ten percent of wild individuals (and higher rates of hatchery-reared individuals) stray and spawn outside their natal stream (Jonsson et al., 2003), a natural mechanism that allows for some mixing of genetically unique subpopulations, thereby avoiding inbreeding.

Once in their spawning sites, females dig redds (nests) and lay eggs which are fertilized by returning adult males or, sometimes, precocious parr who live their whole life cycle in fresh

water (Myers and Hutchings, 1987). Though many adults usually die after spawning, Atlantic salmon are iteroparous, meaning they can survive to spawn multiple times, an important distinction from Pacific salmon. Each stage of the life cycle, from egg to returning adult, experiences high mortality reaching up to 99 percent in some life stages (Thorstad et al., 2011). Though many bottlenecks, predators, and obstacles contribute to the high mortality of salmon throughout their life cycle, perhaps the most effective and dangerous salmon foes are humans. Whether through overfishing, dam building, channelizing waterways, polluting salmon waters, or contributing to the slow warming of in-stream temperatures through climate change mechanisms, human activity has had detrimental effects on wild Atlantic salmon populations by negatively altering their habitats and impeding or preventing different stages of their migratory life history (Forseth et al., 2017; Parrish et al., 1998).

Today, abundance and distribution of Atlantic salmon has reached an all-time low (Hindar et al. 2011), and though most remaining salmon populations are still found in Nordic and British watersheds, populations in the rest of the Atlantic salmon's range are classified as vulnerable, endangered, or critical (WWF, 2001:6). In countries such as Portugal and Spain, populations are threatened by warming stream temperatures and are expected to be extirpated in coming decades (Horreo et al., 2011). By and large, salmon are threatened by riverscape alteration and energy production. Dams (particularly hydropower) (Johnsen et al. 2011), river channelization and other stream blockage or alteration (Thorstad et al. 2011), and a multitude of other environmental pressures such as habitat destruction, pollution (particularly from agriculture), acid rain, invasive species, pressure from escaped farm salmon (Thorstad et al. 2008), and parasites such as salmon lice and *Gyrodactylus salaris* (Harris et al., 2011) have all wreaked havoc on salmon populations, in some cases wiping them out entirely. Similarly, in some instances poor in-stream population monitoring combined with high fishing mortality at sea and high in-stream angling pressures have also reduced salmon populations (Parrish et al., 1998). Though some problems like overfishing are fairly straightforward to address, other problems like changing ocean conditions or unexpected weather patterns remain wicked problems (Jentoft and Chuenpagdee, 2009) and nearly impossible to plan for or address on a year-to-year basis.

In many places, salmon management regimes have instituted protective measures to improve local salmon stocks, such as catch and release, bag limits, and closed seasons (Arlinghaus et al., 2007; Øien et al., 2000). However, these approaches come with potentially problematic trade-offs as anglers have a multitude of responses to different angling conditions and

management incentives (Arlinghaus, 2006b, 2006a). In light of these multiple challenges, the role of hatcheries to (un)successfully address these problems becomes relevant.

3.1 Wild Atlantic salmon management: from international to local scales

Salmon governance systems and their approaches to stocking differ throughout the world. At the international level, salmon governance and policy-making is enacted through major international governing bodies such as The North Atlantic Salmon Conservation Organization (NASCO) and the International Council for Exploration of the Sea Working Group on North Atlantic Salmon (ICES WGNAS). These groups enable and direct research, develop multi-national treaties for their party states, and exert influence over national-level Atlantic salmon management. These multiple organizations reflect a shift in governance of Atlantic salmon from informal localized river or catchment-based governance to national and international scales.

At the national level, salmon management differs from country to country. In the United States and Canada, salmon management tends to be highly centralized where the state controls the right to harvest salmon and salmon populations are managed by state-employed professional biologists. In Europe, salmon management – particularly control over harvest rights and access - is considerably less centralized. State-level managers generally draw advice from and contribute advice to the aforementioned international bodies, but individual states have the final control over how to manage their fisheries in home waters and to whom they delegate managerial responsibilities. In Norway, fishery guidelines are developed by state-level managers, but implementation and enforcement of policies are typically delegated to regional-level managers (e.g., Fylkesmannen, or County Governors). Additionally, local river owners associations often have some degree of control in carrying out managerial obligations (i.e., managing bag limits, season lengths, etc.) (Klima- og miljødepartementet, 2012).

This system of management comes as recognition of the importance of decentralization in natural resource management and inclusion of localized stakeholder groups has grown. This trend has resulted in the delegation of natural resource governance power being transferred back to local institutions in a managerial preference for co-management (Berkes et al., 1991). Both of these shifts are driven by the need for additional scientific and empirical knowledge for the development of better and more refined salmon management tools (Verspoor, Stradmeyer, and Nielsen 2008), as well as a social drive for greater equity in natural resource

management for multiple stakeholder groups. However, the transition from international policy to local application of salmon conservation approaches has proven to be challenging.

3.2 Stocking: a techno-fix or techno-folly approach to salmon conservation?

The decline of salmon stocks combined with angling interests and decentralized management created the right environment for stocking of salmonids to take hold and become commonplace in European salmon management(Aas et al., 2018). For the past 150 years, salmon stocking has been a popular managerial tool for purposes of both stock enhancement and 'conservation' (Berg 1986; Bottom 1997). Ranging from hauling buckets of juvenile fish by hand from watershed to watershed to today's more sophisticated and automatized cultivation techniques, approaches to stocking typically fall under one of several possible categories. Cross et al. (2007, pg. 329) offer the following categorization (in **bold**), which I have adapted with additional terms (in *italics)* that reflect terminology used by practitioners in these case studies:

- Type 1: **Reintroduction** or *replacement* stocking:
  Stocking where populations(s) are extinct and the aim is to re-establish health, self-sustaining populations maintained at carrying capacity.
- Type 2: **Rehabilitation** or *conservation* stocking:
  Stocking where there are existing native populations at levels ranging from very low to just below carrying capacity. The aim is to increase population size.
- Type 3: **Enhancement** stocking:
  The artificial production of fish in excess of the natural production of the host ecosystem. The aim is to increase populations above carrying capacity for the explicit purpose of increasing harvest potential.
- Type 4: **Mitigation** or *compensatory* stocking
  Stocking for mitigation against or compensation for some negatively influencing factor, or the protection/maintenance of biodiversity (genetic and taxonomic).

While there is arguably some degree of overlap in these definitions (for example, Type 2 and Type 4 are not clearly defined in how they are different from one another), Type 2 stocking, particularly when termed 'conservation stocking', has become increasingly controversial. Put simply, this is because some fisheries scientists argue that stocking cannot effectively conserve or rehabilitate an extant native population (Christie et al., 2012; Garcia de Leaniz et al., 2007; North Atlantic Salmon Conservation Organisation, 2017; Verspoor et al., 2008;

Waples, 1999). This position is a reflection of how attitudes and knowledge about stocking have shifted in the last three to four decades, moving from stocking as an important and preferred management tool (Bottom, 1997) to views that stocking is an ineffective approach to improving salmon stocks in the case where wild stocks still exist. More specifically, today's policies at both the international and national levels reflect a growing trend in management to view stocking as, at best, an inefficient use of economic resources (Welcomme, 2008) and, at worst, a potentially harmful practice that could have long-lasting negative impacts on the genetic integrity of wild salmon stocks.

As stocking Types 1, 3 and 4 are often state mandated (e.g., Norway's gene bank program) or take place in closed systems, this thesis does not attempt to address their use. Rather, this research focuses on understanding the underlying values, purposes, and conflict surrounding Type 2 stocking and the hatcheries used to support them, which I call 'voluntary hatcheries' for the purpose of this thesis. In doing so, this thesis expands the discussion of the value of these hatcheries in today's contemporary salmon cultivation management.

3.2.1 An overview of the stocking debate

The conservation of salmon is important to many stakeholders for a variety of reasons. As a result, hatcheries became a unique approach to salmon conservation that was both achievable on small, local scales and gave stakeholders, particularly anglers, opportunities to employ their knowledge sets in a tangible conservation activity (Harrison et al., 2018a). Thus, hatcheries were popular management tools over much of the second half of the nineteenth century and most of the twentieth century (Berg 1986; Bottom 1997; Wolter 2015).

However, scientific knowledge about salmon biology, habitats, genetics, and interactions with the increasingly complex web of human-environmental interactions that characterizes the Anthropocene (Naish et al. 2007; Garcia de Leaniz et al. 2007; Finnegan and Stevens 2008; Grant et al. 2017) has changed contemporary scientific and managerial views on hatcheries (Arlinghaus and Mehner 2005; Sandström 2011). At its essence, fisheries scientists and policy makers have gradually come to agree that stocking may be a cause of declining wild stocks as opposed to the solution to the decline as previously thought (Chilcote 2003). Though the stocking debate extends to recreational fishing in closed systems and other similar contexts, this thesis focuses only on the debate as it applies to migratory wild fish populations and their conservation. In that context, the stocking debate focuses on two main

categories of impact that stocked fish have on wild populations: competition and interbreeding (Verspoor, Stradmeyer, and Nielsen 2008).

Broadly, stocked fish have been found to potentially reduce population survival and growth of wild stocks (Chilcote, Goodson, and Falcy 2011), contribute to challenges faced by wild fish in anthropogenic affected rivers through competition (Buoro, Olden, and Cucherousset 2016; Laikre et al. 2010), and spread disease (Hewlett, Snow, and Britton 2009), amongst other impacts. In terms of interbreeding, stocked fish negatively affect local genetic integrity (and diversity) through population mixing (Laikre et al., 2010) and reduced effective population size, resulting in a reduction of overall fitness and long-term survival of wild stocks (Araki and Schmid, 2010). At the extreme end of the debate, some have concluded that it is very unlikely salmon can be produced in a rearing program without changes to their genetic composition that will negatively affect wild stock fitness (Chilcote 2003). Taken together, these concerns underlie the marked shift in scientific knowledge and criticism toward stocking and the trade-offs between stocking and other social, economic, and conservation concerns (Amoroso et al., 2017; Camp et al., 2017).

However, other arguments have been made in favor of stocking and its ability to produce benefits for fisheries and assist in the restoration of fish populations (Lorenzen 2012). Similarly, there may be little alternative to stocking in places where wild populations are already extinct (Granek et al., 2008) or where wild populations are threatened by lethal diseases and parasites (Forseth et al., 2017). Additionally, anglers, river owners, and the general public have expressed strong preferences for stocking (Arlinghaus and Mehner, 2005; Gray and Charleston, 2011; Kochalski et al., 2018; Stensland, 2010), adding additional pressure to managers already beholden to constituent preferences.

These two sides of the debate – that stocking is inherently "bad" versus "good" under the correct circumstances – have dominated discussions of stocking. Research intended to illuminate the reality of arguments on either side has been largely limited to evaluating the biological, ecological, and genetic effects of hatcheries on wild salmon populations. However, it seems clear that as the debate still continues even with a preponderance of evidence in place, a continued quest for more scientific knowledge is not the panacea for ending the stocking debate. Thus, it is necessary to have a better understanding of the social dynamics that underlie the stocking debate and drive conflict over this contentious conservation issue.

4. Epistemological, theoretical, and conceptual approaches

The social sciences are designed to describe, explain, and occasionally predict the behavior of individual groups, institutions, societies, and their relationships to one another. Within social science as a whole, this thesis is situated within conservation social science, which Bennett et al. (2017) describe as the "diverse traditions of using social science to understand and improve conservation policy, practice and outcomes (Bennett et al., 2017a, pg. 94)." As such, this thesis explores applied questions (Table 1) related to the management of and conflict surrounding voluntary salmon hatcheries as they are used in a conservation context. Tightening the lens even further, this thesis employs a human dimensions frame through which to view the analytical findings of this study. This framing is explored in greater depth in the discussion, but it is noted here so the reader may understand how the thesis is rooted in research designed to understand and, more importantly, *improve* upon conservation outcomes. As such, it is inherently critical in its positioning within conservation social science, and seeks to understand the conservation 'problem' of stocking from on-the-ground as well as policy-maker perspectives.

To that end, the methodological or theoretical approaches employed in this thesis, the ontological and epistemological position of me, the researcher, and these approaches as a foundation for my research questions, are important to explain (Moon and Blackman, 2014).

4.1 Epistemological positioning

Epistemology, put simply, is the manner in which knowledge is generated and validated, and is concerned with how knowledge can be produced, collected, or otherwise generated (Moon and Blackman, 2014). Though many scientists have similar training in conducting research, they may still answer questions about "what counts" as knowledge generation differently (Crotty 1998), thus leading to profound differences in how they interpret research findings. These individual perspectives may be understood as explaining relationships between the subject (in this case, the researcher) and the object (e.g., knowledge, or the object of research and its nature) (Crotty 1998, Moon and Blackman 2014). These perspectives exist on a spectrum which, broadly speaking, range from objectivism to subjectivism. Within this spectrum, this research fits centrally into a constructionist view. Constructionism says that humans construct knowledge and meaning as they interact with and interpret the world around them (Crotty, 1998; Moon and Blackman, 2014). In contrast, objectivist epistemologies (which are not uncommon in fisheries science) consider meaning and an

objective reality to pre-exist, the nature of which may be discovered using appropriate methods (Moon and Blackman, 2014).

The results of my research challenge commonly accepted interpretations of reality concerning hatcheries by illuminating alternative perspectives typically held by local stakeholders, as well as more abstract notions of concepts surrounding hatchery practices such as "nature" and "naturalness." In doing so, the work in this thesis challenges the idea that there is one objective truth that may be discovered, and instead creates space for multiple interpretations of reality to contribute to an overall concept of hatcheries, salmon cultivation, and salmon conservation. Though some research participants and fisheries researchers in these case studies may place themselves into objectivist epistemologies where reality exists independently of human perceptions and may be "discovered" using the right methods (Moon and Blackman, 2014), this thesis questions such views by elucidating the many ways in which these supposedly objective realities may be viewed. This is accomplished by approaching hatcheries as producers of benefits, facilitators of knowledge production, and centers of social conflict, around which many perspectives of reality compete for power.

But, why these epistemological positions? These choices reflect my own thinking as a researcher and past research experiences where subscribing to rigid, objectivist views proved to be a disservice to social science research meant to uncover underlying truths and perspectives of natural resource stakeholders in Cook Inlet, Alaska (Harrison, 2013). I found that asserting the truth or the nature of reality to be only one discoverable position limited the ability of my research to identify and understand multiple perspectives on the same controversial issue (such as salmon cultivation), and to harness the emancipatory and critical potential of social science research on contested issues. Though my personal opinions and positions on some topics related to salmon conservation may fit more into objectivist positions, I intentionally situate this research to resist rigid categorizations of truth, reality, and diverging perspectives.

4.2 Approaches

4.2.1 Grounded Theory

Qualitative research moves beyond the "what" of scientific inquiry, and explores more deeply the "how" and "why" of a research question. To this end, it is not always useful to begin with a hypothesis or take a deductive approach to a data set (Kennedy and Lingard, 2006), as the pre-formed expectations of the researcher may cloud the opportunity for novel findings

present within the data. From the beginning of my research, I was inspired by grounded theory, an approach seeking to generate new theories about research as it exists in the field or on the ground (McGhee et al., 2007). To that end, the research in this thesis employs a grounded theory approach (Glaser et al., 1967) as the basis for approaching the research questions in each article and data collection across the three cases.

Grounded theory, in its essence, is a flexible yet deliberate way of analyzing data. As Glaser said "grounded theory is multivariate. It happens sequentially, subsequently, simultaneously, serendipitously, and scheduled (Glaser, 1998).” There are three required elements in any study utilizing grounded theory: theoretical sensitive coding, theoretical sampling, and comparison between phenomena and contexts (Corbin and Strauss, 1990). This approach to data analysis directs the researcher to use absolutely anything and everything she or he encounters as potential data source or point. Because this process requires the researcher to be interpreting and re-interpreting data as it is collected, researchers themselves can become a source of data as they generate new ideas about the data set from their own thinking (i.e., through self-interview) (Ramalho et. al., 2015). In short, grounded theory opens the door for a researcher to take in practically any source of data as a means of informing their understanding of their subject, as well as increased self-awareness by the researcher (Martin and Turner, 1986; Ralph et al., 2014).

However, this latitude in determining data sources does not give license to collect data without rigorous inspection of the source and content. Rather, this breadth of scope actually places an increased onus on the researcher to verify and inspect sources of data (and, by extension, the data itself) while constructing theories, and constantly compare emerging theories to the original data sources and sets. Additionally, the researcher must be wholly explicit in their approaches and methods and transparent in their analysis and interpretation of data (Corbin and Strauss, 1990). Researchers may attend to this requirement in a variety of ways, including the production of reflexive text that simultaneously allow the reader *and* the researcher to reflect upon the biases, implicit or otherwise, of the researcher and how they inevitably effect the generated theories (Guillemin and Gillam, 2004; Mauthner and Doucet, 2003).

In the case of this thesis and myself as the primary researcher presenting this body of work, reflexivity has been an important aspect of my work. My cultural and economic background from growing up and studying in a salmon society (Alaska) play an important role in how I

identify with both salmon themselves, the salmon landscapes in which this research was conducted, and the research participants. Additionally, my understanding of the salmon world is richer due to my experiences as a salmon fisher(wo)man, conservationist, and researcher, but was also inherently influenced from these experiences prior to developing a deep understanding of each case. Thus, it was an ongoing challenge to prevent my previous assumptions and knowledge of salmon lives and activities from disrupting my ability to understand new information in different salmon contexts. Finally, my gender and age are uncommon within the case studies comprising this research, which meant I sometimes had to gently assert my knowledge and experience before stakeholders were able to take me – and the study - seriously. Though this additional part of the rapport-building process was sometimes frustrating, I was able to adjust by introducing pre-interview phone conversations to introduce myself to interview participants, as well as allowing extra time for informal conversation at the beginning of interviews so participants could assess me and my intentions prior to turning on the tape recorder. Taken together, these issues have required significant reflexive moments in order to assess their influence on my data collection strategies, and eventual interpretation and understanding of data from these cases.

Over time, different branches of grounded theory have evolved representing differences in the ways they assess the validity of different data sources, grounding of analysis in the original data, and prelude data collection with (or without) hypothesis developed or structured questioning (Charmaz, 2014, 2008; Corbin and Strauss, 1990; Glaser, 1978, 1998; Mills et al., 2006; Ramalho et al., 2015; Strauss and Corbin, 1990). In my own research, I have drawn from these different branches to focus on several key concepts I have found inspiring and useful in approaching fisheries conflict research. From Glaser, I admire the effort to position the researcher as a blank slate (Glaser, 1978). By considering "all as data" (ibid), the research setting becomes rich with possible means and methods by which to understand a case. I viewed this open approach research to extend to the analysis stage, where theories can be explored and developed by supplementing lines of thought with additional resources from the case study as needed.

A Straussian approach to grounded theory was also useful in approaching the second and third round of data collection (Wales and Germany, respectively) where knowledge of hatchery conflicts had already been gained by the research team from the Norwegian case (Corbin and Strauss, 1990). As preliminary theories concerning hatchery were already emerging, this approach gave methodological direction in how to hold these theories in the

researcher's minds and pursue them through structured questioning while still maintaining an open, grounded approach to the cases as a whole.

Similarly, drawing from constructivist grounded theory was useful to introduce the use of literature to better situate my understanding of emerging themes and topics (Ramalho et. al., 2015). While in traditional grounded theory this practice would normally come after data collection and analysis, the order of paper development and the writing process meant that later papers could not be truly 'open' in that initial coding of the same data set for earlier manuscripts had already formed impressions and theoretical ideas in my mind. Allowing these emerging concepts to be explored through literature, and interrogating the data through emerging hypotheses and theories, allowed for me to better acknowledge my own positions on the developing theories as well as frame the next stages of coding for these manuscripts (see Ramalho et al., 2015; Thornberg, 2012).

Criticisms and benefits of Grounded Theory

Grounded theory has both strengths and weaknesses that should be well understood by any researcher utilizing this methodology in their work. Because grounded theory is tied so closely to data and real world contexts, perhaps its two greatest strengths are what are known as its close reflection of real-world settings and environments and its usefulness in allowing researchers to find novelty in their subject matter (Charmaz, 2008). Additionally, grounded theory is simple in that it has few constructs or assumptions built in to its use, yet provides some benefits in the confidence a researcher may have in the integrity of their data. For example, because grounded theory draws meaning and develops theory from the information provided by research participants, a researcher may feel reasonably confident that the data is based in the participant's own categories of meaning and understanding (Johnson & Onwuegbuzie, 2004). Similarly, the lack of predetermined theoretical constructs allow the researcher to be versatile, responsive, and adaptive to the needs of the case study or research participants (Johnson & Onwuegbuzie, 2004).

Grounded theory also faces many criticisms. Thomas and James (2006) outline three primary criticisms, saying that grounded theory should not be considered as a theory, *per se,* since what is produced is not theory so much as conceptual or thematic categories. Additionally, they challenge the idea that grounded theory works to use inductive knowledge, and argue that it is practically impossible for researchers to divest themselves of preconceived ideas of their subject matter as was originally prescribed by Glaser and Strauss (1967) (Thomas and

James, 2006). Johnson and Onwuegbuzie (2004) also warn of this same problem, saying that researchers may not be aware of or able to account for the influence of their own idiosyncrasies and biases. Indeed, the label of 'grounded' may give researchers, particularly those who are inexperienced with the approach, a false sense of assurance that the nature of their data and results will have an inherent grounded quality, when in fact this outcome must be constantly reinforced by deliberate action from the researcher throughout a study. I largely agree with these criticisms, but argue that these challenges – if properly acknowledged by the researcher – actually add to the quality and rigor of conflict research as they force the researcher to engage an important question in this field: is conflict actually occurring, or do I perceive conflict based on my own perceptions of the case where actually a different phenomenon is at work? For this reason, rigorous training of qualitative researchers in understanding and dealing with personal biases and limitations is essential to any development of quality research practice – both qualitative and quantitative.

Finally, grounded theory faces the typical challenges of any other qualitative approach. Because theoretical concepts are built upon the data, the resulting theories or hypotheses may not be generalizable to other cases, being too specific to the variables in the case from which they are derived (Johnson and Onwuegbuzie, 2004). Though this specificity is not inherently a negative outcome, it does mean that any theories or hypotheses generated from any one case may be difficult to test through replication study, and thus may not be useful in developing generalizable explanations of phenomena. This underlies the high demands on the validity (or credibility) of this type of research. To address these concerns in this study, I worked closely with qualitative researchers to design the study, collect data, and analyze and interpret the data, thereby producing a system of reliability through this collaboration. While grounded theory has formed my main source of theoretical inspiration, other theoretical approaches have also been important in giving adequate theoretical framing to the findings of my research and the links between them.

4.2.2 Discourse Analysis

Qualitative research approaches have demonstrated value in eliciting underlying knowledge sets, belief systems, and practices that challenge natural resource management and policy (Baird, 2007; Charnley et al., 2017a; Loring et al., 2014; Loring and Harrison, 2013; Neis et al., 1999), particularly in conflict scenarios. Discourse analysis as a qualitative theoretical approach has been harnessed to evaluate nature resource conflicts, particularly with regard to politics and policy evaluations (Campbell, 2002; Delaney et al., 2007; Gelcich et al., 2005;

Whittaker and Mercer, 2004). Within the Welsh case on which the 4th paper in this thesis is focused, environmental events became political issues surrounded by social conflicts. We used discourse analysis to study the underlying mechanisms of social conflict within the Welsh hatchery case, as understanding environmental discourses, their power, and from where and whom they arise is important to understanding environmental conflict (Hajer, 1995).

Discourse analysis draws together many elements and ideas from within the social sciences to incorporate and make sense of how meaning is made through language – written, spoken, or otherwise (Wood and Kroger, 2000). Though discourse itself has many definitions (see example in Whittaker and Mercer, 2004), a fundamental tenant of discourse analysis is that people use language to construct the social world around them, including their own place within it, and therefore language cannot be a "neutral or transparent medium" (Burck, 2005), instead being constitutive of experience rather than representational or reflective (Smith, 2015; Willig, 1999). In this thesis, I use Dryzek's working definition of discourse which we find particularly appropriate to the analysis of conflict (1997, pg. 8):

> "A shared way of apprehending the world. Embedded in language, it enables those who subscribe to it to interpret bits of information and put them together into coherent stories or accounts. Each discourse rests on assumptions, judgements and contentions that provide the basic terms for analysis, debates, agreements and disagreements."

Discourse analysis is divided into three primary categories that focus on the study of social interactions, investigation of selves and sense-making (primarily within psychology), and culture and social relations (Wetherell et al., 2001).

Critical discourse analysis (CDA) begins with social issues and problems and takes a critical approach to the relationships between language and other elements of society and social life (Wetherell et al., 2001; Wodak and Meyer, 2009). In this, CDA has inherent emancipatory characteristics and demands change as a result of analysis. Within conflict research, this characteristic of CDA gives researchers tools by which to examine socially related problems by beginning with the problem itself rather than a typical research question. Through CDA analytical frameworks, such as that laid out by Fairclough (Fairclough, 2001), it is possible for researchers to produce knowledge that can lead to progressive change.

The purpose of applying this theoretical approach was to better grasp the multiple conflicting discourses of the Welsh hatchery case, in order to understand the causes, drivers, and underlying debates of each. Here, we drew from elements of CDA by identifying language, themes, and events within the discourses that encapsulate the main drivers of conflict and power relations between the interviewed individuals and the groups they represent. Importantly, we focused on semiotic elements recurring within the analyzed texts (e.g., interviews, media articles, policy documents, etc.) and how they were used to describe, critique, and shape the salmon hatchery conflict.

4.2.3 STS

Science and technology studies (STS) are, broadly speaking, the study of how scientific research and technological innovation, and by extension the production of science and technology itself, are affected by and affect society, politics, and culture. Importantly, STS consists of a set of theoretical and methodological practices, forming a multidisciplinary area of research. As this thinking underlies Paper 2 and its discussions of socio-technological communities and the human-salmon-technology relationship, I find it useful to include some theoretical background in this introduction.

STS focuses on the role that scientific knowledge and technological innovations play in social, cultural and political change, and how the contents of science reflect their context including the time period, location, and underlying values of their production (Bennett et al., 2017a). Additionally, STS also seeks to understand the co-production of knowledge between society, science, and policy via how these different concepts impact one another (Jasanoff et al., 1998). Situated within critical schools of thought, STS seeks to understand, critique, and improve upon these relationships in order to better facilitate how scientific knowledge can be utilized in social and political change (Clark et al., 2016; Forsyth, 2015; Webster, 2016). Though STS studies are not yet a particularly coherent or well-defined field, approaches within STS such as “technosocial” (Woodhouse and Patton, 2004) are useful in understanding conservation technologies such as hatcheries.

Technologies and their functions may be considered social processes based in social groups or networks and dependent on social relationships (Laegran, 2010). Through this lens, technology and the social landscapes within which it resides become intertwined and co-dependent on one another for stability and progress. Combined with the application of STS studies to emerge as “reconstructivist” and emancipatory in technosocial research (Ardoin,

2006; Meurk, 2014; Woodhouse et al., 2002), this approach of thinking about hatcheries as technosocial centers to salmon conservation fits well into the constructivist positioning of this thesis.

Within the hatchery context, the STS approaches provide a suitable lens through which to view hatcheries as technologies driven simultaneously by scientific and local ecological knowledge. Both ways of knowing, and their emerging hybrids (Harrison et al., 2018b), have the capacity to drive forward and restrict the ways in which hatcheries are utilized by salmon stakeholders. By applying an STS approach to these case studies, we were afforded insight into how different ways of knowing are relevant to technological approaches to salmon conservation across temporal scales. In particular, these findings may provide useful ways to understand why voluntary hatcheries have acted as harbingers of conflict within these cases, and constructively critique the role that scientific knowledge plays within the socioecological context of salmon hatcheries. To put it another way, STS allows us to examine the way conservation science and policy is interacting with conservation outcomes (Bennett et al., 2017a, p. 201; Wyborn, 2015).

5. Methods

Qualitative methods emphasize seeking the "why" and the "how" of human behaviors, a key strength within conservation research where human attitudes, perspectives, and value systems can create unexpected behaviors related to preferences and desires for conservation outcomes. However, in cases where little is empirically known about a phenomenon or the nature of what is known presents competing interpretations of reality, qualitative methods can offer a multitude of approaches to derive meaning from data and possibly illuminate multiple versions of reality. Qualitative methods are also especially well-suited to case studies where a researcher can invest time and energy examining purposive samples in great depth (Stake, 1995).

As such, the studies in this thesis utilize two primary approaches: semi-formal, in-depth interviews and ethnographic methods such as participant observation. These methods were appropriate for answering the "why" and "how" aspects of the research questions as well as eliciting underlying perspectives and insights within each case that would not have been possible to ascertain with more quantitative approaches. As each case study area presented unique logistical, geographic, and linguistic challenges, the fine details of each case are presented in the appended papers. This section instead gives a broad overview of data collection methods and analysis.

5.1 Data collection

Interviews were conducted within relevant stakeholders in each case study. In this thesis, stakeholders are defined as those individuals, groups and organizations that are affected by or have the possibility to affect the salmon restoration policies in the respective case study. To identify stakeholders, we used a combined method of the key informant method ("who should we speak to who is knowledgeable about this topic?") (Marshall, 1996), snowball sampling ("who else do you know?") and interviews questions ("who else do you think is affected by/affecting the hatchery management?") (Reed et al., 2009), and purposive sampling (Palys, 2008) to access those knowledge holders directly engaged with hatchery activities. An initial set of key informants were identified through purposive sampling by utilizing prior research and connections within our research institutions. Stakeholder identification is an iterative process (Reed et al., 2009), so new stakeholders were identified during and throughout the fieldwork as knowledge of stakeholder networks grew and new topics were explored.

Prior to beginning an interview, interview participants were presented with an information and consent form explaining the study, the intended use of data they provided, their rights as study participants, and details about data storage. Prior to recording, consent forms were signed by the interview participant and lead researcher, and copies of the signed form were kept by both the participant and the researcher (see Appendices 3-5).

Interviews were based on a pre-determined set of questions (semi-structured) with flexibility to allow the respondent to guide the direction of the conversation (see Appendixes 1 & 2). Interviews were conducted until thematic saturation was reached (Guest et al., 2006). Post-data collection, interviews were transcribed and coded our for thematic content (Meuser and Nagel, 2009) using qualitative analysis software packages NVivo and Atlas.ti (*ATLAS.ti*, 1999, *NVivo qualitative data analysis Software*, 2012).

Interview guide development

Development of the interview guide was based on the objectives of the PhD project as laid out by both the candidate and the IMPRESS project, as well as on the research questions for each of the proposed articles intended to result from the case studies. Exploratory phone interviews were conducted with key informants (Marshall, 1996) in each case study in order to develop and test potential lines of inquiry prior to formal data collection interviews. The interview guide was designed in collaboration with the research team and discussed to ensure an appropriate and natural order of questions, effectiveness in soliciting the desired information, and an appropriate degree of range in topics relevant to the project objectives. The guide was intentionally designed to be broad and wide-ranging so as to be appropriate for soliciting data on a wide range of topics that could be later explored and used as the foundation for articles. Though the research questions guiding this thesis were at the core of the interview questions, the guide benefited from an itinerant field process where the interview guide was amended during the fieldwork process on a case-by-case basis in order to meet the needs of each interview participant and adapt to new topics introduced to the study. The interview guides used as the foundational guide for data collection in each case study are shown in Appendix 1 and 2.

5.2 Data analysis

In grounded theory, analysis must be conducted using the fundamental principle of constant comparison (Lingard et al., 2008). This directs researchers toward coding of data and comparison between what is known about the data and what is constantly being learned as

analysis progresses. When directed by the research question, this process effectively limits the seemingly vast collection of data and potential interpretations of data from the original data collection process.

In this thesis, the initial coding of transcribed interviews and other documents relevant to each case was open or substantive. Codes were organized around concepts and related or similar concepts and codes were grouped together to form categories and identify patterns and linkages, known as concepts or themes (Strauss and Corbin, 1990). Coding was an itinerant process repeated several times within each data set in order to analyze, group and re-group, and contextualize the data within the growing understanding of the data set (Corbin and Strauss, 1990). For Papers 2 and 4, selective coding, in which additional codes already fitting a central theme from the data are sought, was used to analyze the data with a research topic already in mind from previous coding of the same data sets (Strauss and Corbin, 1990). From these processes, theories were built to help explain the phenomena we observed in the data.

The theory-building phase was performed in conjunction with memoing, described by Glaser as a "core stage" of the methodology (Glaser, 1998). Memos are the process by which the researcher generates ideas and theories based on their findings from the coding process and input from other data sources, and to develop, compare, and refine ideas derived from the data through the constant-comparison process inherent to grounded theory. During this process, I composed memos to describe major code groupings, developing theories, and categories of thought and explanation, thereby introducing my own cognitive processes into the understanding and interpretation of the data through the writing process (Charmaz, 2003).

The last steps in my data analysis process involved sorting the memos with the goal of putting pieces of concepts and theoretical understanding of the data into a more coherent and complete set. This process allowed me to draw from all of my ideas, understanding of the cases, and observations of the data during both fieldwork and the coding process and develop the connections between them into a consistent set of results.

6. Research findings

In this chapter, I discuss the links between the research questions and findings within each of the four papers. Following this, I present a synopsis of how these findings are linked together and form a more comprehensive understanding of voluntary hatcheries and persistent social conflicts that surround their use and management.

6.1 Paper 1: Hatching knowledge: a case study on the hybridization of local ecological knowledge and scientific knowledge in Norwegian small-scale Atlantic salmon (Salmo salar) cultivation

Paper 1 examines the underlying knowledge sets, and the processes from which they are derived, that drive hatchery use in the Norwegian case study. As scientific knowledge is a strong arbiter of hatchery and wild salmon management in each of these case studies, we examined how and which knowledge sets are used in the hatchery setting. This research interest evolved from observations made in the field where managers often assumed that a lack of willingness to accept new policies based on fisheries science (specifically, genetics and the hatchery influence on wild salmon genetic integrity) was based on ignorance or a lack of understanding of empirical knowledge in cultivator communities. These assumptions were contradicted by our observations in the field where cultivators were often highly interested in and well informed of the scientific underpinnings of fisheries management and were eager to implement science-backed advice in their cultivation practices. This paper examined that mismatch in understandings by looking at the processes by which scientific and local ecological knowledge sets are developed, evolve, and are utilized within the hatchery setting.

We found that in this case study, hatcheries are acting as facilitators of knowledge hybridization, or the combining of scientific and local ecological knowledge (LEK) into novel knowledge sets that allow for the integration, operationalization, and evolution of knowledge that supports salmon cultivation in local contexts. We identified three drivers of knowledge hybridization: the need for cultivators to engage in intergenerational knowledge exchange, the need to cope with regulatory changes and new information, and as a means by which to improve the perceived validity of LEK sets. We also identified three challenges to the knowledge hybridization process: (1) inadequate channels by which to share knowledge, particularly LEK moving into traditionally scientific knowledge-driven spheres; (2) questioning of the expertise of knowledge holders who exert influence over salmon management and cultivation policies, leading to lack of trust between cultivation and

managerial groups; (3) challenges of scale, particularly in applying scientific knowledge into local river contexts.

These findings are novel and relevant to the hatchery debate because, as hatcheries are shown in Paper 3 to hold additional and sometimes surprising benefits to cultivators, Paper 1 demonstrates how hatcheries are facilitators of knowledge integration and exchange. This service is valuable to both cultivators and managers who often struggle to have salmon cultivation strategies accepted by local level stakeholder groups. For that reason, we pair the findings of this study with recommendations as to how reframing managerial views of hatcheries – from producers of salmon and environmental concern toward facilitators of knowledge production and transfer – may improve both the dissemination and accessibility of scientific knowledge and messaging as well as the availability and integration of LEK into broader scales of salmon management. Within the context of the overall thesis, this is especially relevant in the question of conflict over hatcheries and means by which better understandings of local and managerial perspectives may be understood and implemented.

6.2 Paper 2: Disputing nature in the Anthropocene: technology as friend and foe in the struggle to conserve wild Atlantic salmon (Salmo salar)

Paper 2 utilizes a science of technology and society approach to give a strong theoretical underpinning to discussion of hatcheries as (in)appropriate conservation technologies. This paper is focused around the research question: how do stakeholder groups within the Norwegian and Welsh cases conceptualize and construct notions of nature and naturalness in the context of salmon hatcheries? From this, we take a closer look at how hatcheries are understood and (dis)allowed as conservation technologies and what impact barriers to those technologies have on the techno-social networks surrounding hatcheries in these cases.

We found that managers and fisheries scientists have significantly different ontological views of nature and naturalness than local-level cultivators in these cases. Managers and fisheries scientists primarily viewed wild salmon and their habitats as best left unimpeded by human activity. In essence, human-influenced was viewed as “unnatural,” and this distinction was extended to hatchery and stocking activities. In their views, naturalness – meaning without humans – was an important arbiter of which activities, and by extension human-salmon relationships, were acceptable and which were not.

Conversely, local-level cultivators tended to have a more mixed view of human-salmon relationships. They typically viewed humans as interrelated with the natural environment, and

hatcheries provided an important bridge to human entanglements with nature rather than an obstacle to pristine salmon environments. Importantly, cultivators argued that in today's increasingly interconnected environments, it is impossible to remove human influence from nature and thus those technologies (e.g., hatcheries and stocking) which bring humans closer to nature and allow them to maintain natural processes should be encouraged rather than eliminated.

In addition to these discrepancies in perspectives, two important paradoxes that may help explain conflict over hatchery use were identified. First, we found that as relationships between humans and salmon become increasingly complex in the age of the Anthropocene, managers are paradoxically seeking means by which to test, define, and limit the definitions of nature and appropriate or "best" fish. In doing so, they must arbitrate over which technologies and, by extension, human engagements with salmon, are acceptable. Secondly, this study found that as scientific definitions of natural shift from qualitatively natural to genetically (and therefore testable) natural, they depend on increasingly complex technologies to 'discover' and define genetic naturalness. This turn toward technologically defined naturalness threatens to exclude those conservation stakeholder groups, such as cultivators, who are unable to access such technologies.

From these insights, we argue that though a focus on biodiversity (genetic or taxonomic) and salmon habitats is an essential aspect of wild salmon management, disallowing some conservation technologies without provisioning adequate replacement opportunities, as well as utilizing science as the only meaningful arbiter of nature and naturalness, fail to account for the importance of techno-societies and their contributions to conservation. These findings are important because they help explain underlying drivers of resistance to change in cultivation policy, particular when those changes disrupt currently-engaged conservation technologies and their surrounding communities.

6.3 Paper 3: "Nature's Little Helpers": A benefits approach to voluntary cultivation of hatchery fish to support wild Atlantic salmon (Salmo salar) populations in Norway, Wales, and Germany

Paper 3 approaches the issue of underlying hatchery value from the perspective of local-level hatchery stakeholders (typically river owners and angling club members involved with hatchery work) and borrows from outdoor recreation frameworks (Driver, 1976) to identify and describe 'non-fish' benefits produced by hatcheries. The impetus for this paper was

derived from observations made in the field where interview participants would frequently describe the many aspects they enjoyed or benefited from through engaging with hatchery work, but that did not specifically involve salmon cultivation work. Thus, the theoretical framing and results of this paper are closely grounded in data from all three case studies.

We found that hatcheries are producing psychological, social, and conservation benefits to those who engage in cultivation work or peripheral hatchery activities (e.g., meetings, river-based conservation work, etc.). Psychological benefits include feelings of contribution by cultivators toward salmon conservation, aspects of personal identity tied to salmon well-being, and cultivation as an important hobby and part of a daily, monthly, and yearly routine (Table 2, Harrison et al., 2018a). Social benefits included social interactions with peers/people of similar interests, networking opportunities, intergenerational knowledge exchange, amongst others (Table 3, Harrison et al., 2018a). Conservation benefits included participation and interest of hatchery groups in non-hatchery related conservation activities (e.g. bank improvement, litter removal, etc.), biodiversity support, improvement of trust and collaboration between cultivation groups and managers, and retention of local ecological knowledge and cultivation skills which were considered to be an important "insurance policy" against ecological damage to local salmon habitats (Table 4, Harrison et al., 2018a).

Importantly, these benefits were found to be produced interdependently, and were coupled and interrelated (Fig. 1, Harrison et al., 2018a). This means that some benefits cannot occur independently of others, and cannot occur independently of the hatchery work. We also found that these benefits were often not replaceable by alternative activities such as angling or other types of conservation work. These findings are important as they help illustrate why managers may face pushback from local-level cultivators when hatchery activities are restricted, terminated, or made much more arduous to engage in. Instead of simply being frustrated by the lack of salmon enhancement (as was commonly assumed by managers in these case studies), cultivators are also frustrated by the removal of these benefits, though they are often unable to specifically express these perspectives.[5]

[5] This can be due to a lack of appropriate feedback mechanisms where cultivators may speak specifically about non-fish benefits to managers, or due to a lack of specific awareness amongst cultivators of the benefits, and thus they are unable to articulate their loss.

6.4 Paper 4: Understanding and managing social conflict over Atlantic salmon (Salmo salar) conservation using discourse analysis: the case of termination of voluntary hatcheries in Wales

Paper 4 examines conflict around using voluntarily-operated hatcheries as a conservation tool within European wild Atlantic salmon populations. The paper focuses on the Welsh case study, specifically because the case presents a classic example of a "before-and-after" management scenario where a salmon management policy had recently changed (2014) and stakeholders were able to express clearly their perspectives on hatcheries and hatchery management from before and after this change.

This paper uses discourse analysis to trace the evolution of the stocking conflict (or debate) across multiple discourse planes. This analysis revealed several important findings. First, discourses were developed and maintained by two major discourse coalitions, the "Recovery" and "Decline" coalition, and evidence of a third coalition oriented around consensus-building, titled the "Middle Ground" coalition, was also present. Second, over the four discourse planes on which analysis was conducted, we found that conflict was produced, reproduced, maintained, or eliminated by moving between planes. The social plane, media plane, social media plane, and policy planes all supported different discourses, and in different ways. This finding demonstrates how some discourses (primarily "Recovery" coalition discourses) were able to be manifested into policy, and some (primarily "Decline" discourses) were rejected by managers and other powerful stakeholder groups. This movement of discourses was supported and often driven by shifting power dynamics between discourse coalitions and discursive events that stimulated or damped the conflict. Third, we identified that conflict in this case occurred in multiple stages, primarily driven by the conflict-enhancing public consultation period initiated by managers.

The discussion of these findings embeds these results in issues of equity and adaptive management strategies as a means of avoiding conflict. It also describes multiple perspectives on hatcheries held within the case as a means of negotiating latent conflict, a notion that is undermined when policy decisions force all parties to accept (or reject) one common version of stocking reality.

These findings are novel because they offer insight into why the River Wye stocking conflict persisted at a relatively high degree of intensity even after the decision to close stocking had been taken. It also identifies how similar conflicts may be driven forward or maintained in

different discourse planes, giving insight as to what planes, or “societal locations,” managers might try to address stakeholders in order to build consensus toward proposed policy decisions.

7. Discussion

The overall goal of this thesis was to offer a more thorough understanding of the human dimensions aspects of voluntary Atlantic salmon hatcheries, with particular focus on the underlying drivers of conflict over the role of hatcheries in a conservation context. In this final chapter, I discusses the theoretical contributions made by this research to conservation social science and natural resource conflict research by showing the relevance of this research to and within these fields. I also highlight practical applications of this research to academic, managerial, and local-level discussions about salmon hatcheries and stocking practices in the conservation context. This chapter also suggests an emerging framework of cultivation that repositions hatcheries as centerpieces of conservation opportunity.

7.1 Linking the papers: salmon cultivation through multiple lenses

These papers are linked together by their contributions toward gaining a better understanding of the human dimensions of salmon cultivation, illuminating previously less explored social aspects of salmon stocking conflicts through complementary conservation social science approaches (Bennett et al., 2017a, 2017b; Hunt et al., 2013). As such, they share a common topic: perspectives on the roles of hatcheries and stocking in wild Atlantic salmon conservation, as well as the social science disciplines from which they mutually draw. All four papers sit in similar epistemological positions in that they are critical of existing power structures and predominant academic (natural sciences based) thinking about salmon cultivation, and their findings open new perspectives by which cultivation and salmon conservation science may be understood. In that, each paper addresses this topic from different but complementary positions within social science (Figure 2) – from classical to applied traditions – thus creating a spectrum of inquiry that addresses different angles of the stocking debate.

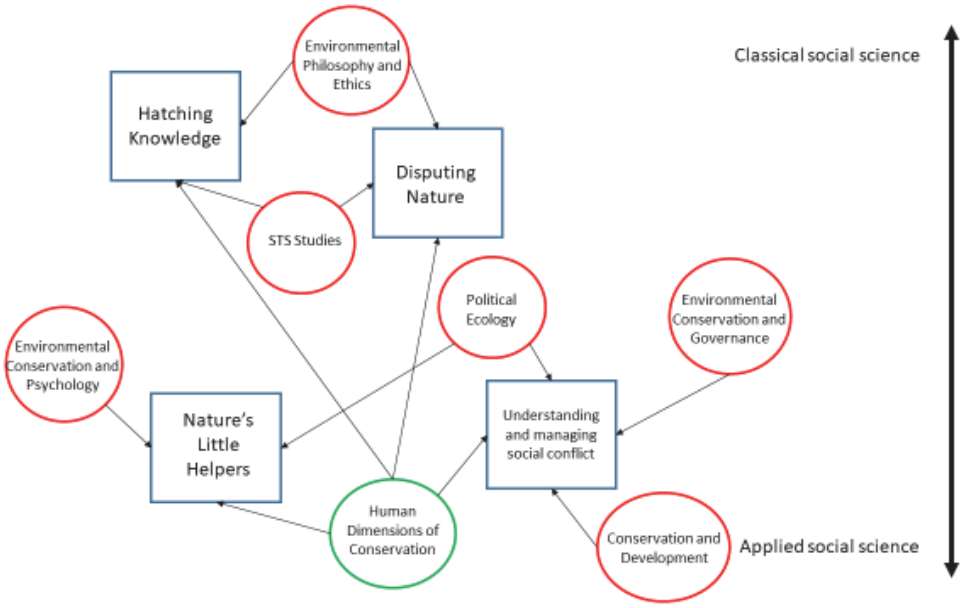

Figure 2 Linking the papers within conservation social science. The four papers of the thesis (blue boxes) are linked together by drawing from shared fields in conservation social science (circles), and by spanning the spectrum of classical to applied social sciences (right). Human dimensions of conservation make the strongest contribution (green circle) to the four papers. Definitions and arrangement of conservation of social science fields from (Bennett et al., 2017a).

Figure 2 shows that human dimensions of conservation (HD) is the common link between the four papers. Human dimensions is multidisciplinary and integrates social science, humanities, natural science fields to improve natural resource management (Bauer et al., 2010) and has been used by others to study the social aspects of natural resource problems and phenomena across multiple scales (Bennett et al., 2010, 2017a; Fleischman et al., 2014; Pietri et al., 2015). For that reason, the spectrum of disciplines and approaches covered by these papers is best described as human dimensions of Atlantic salmon cultivation, because it fits the HD "approach to conservation social science that aims to inform and improve the management of specific natural resources" (Bennett et al., 2017a, pg. 9). The papers within this thesis are also relevant to the HD category because they set out to address managerial information needs highlighted by the overarching questions of this thesis (Table 1). Importantly, they address these needs by offering data-driven approaches toward resolving the managerial and conservation information needs found in the different cases, in relation to the role of hatcheries and stocking in salmon conservation regimes (Figure 3).

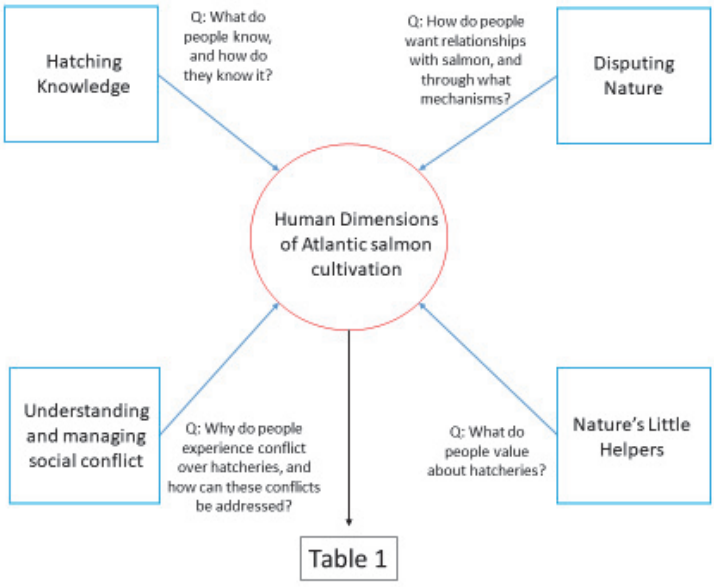

Figure 3 Linking the papers together within a human dimensions frame. This figure shows the links between the papers within the thesis (blue boxes) and the central theme of human dimensions research (red circle) via the different knowledge pieces contributed by each paper (Q) to the overarching research questions of the thesis (Table 1).

Through the HD lens, the management recommendations of this thesis become salient to a field that has been typically dominated by discussions driven by biology, ecology, and economy. The HD approach bridges these disciplines with the social aspects of salmon conservation and hatchery management, thereby making social objectives and aspects of cultivation equally relevant in the discussion of voluntary hatcheries.

7.2 Theoretical ties to conservation social science

Though the papers in this thesis are linked together by their interrelated contributions toward human dimensions of salmon stock research and by the social science disciplines from which they draw, they also contribute individually to the theoretical frameworks they are grounded within.

For instance, Paper 1 highlights the epistemological differences between different stakeholder groups who surround, regulate, and engage with voluntary hatcheries, particular in regard to knowledge generation and utilization (Crotty, 1998; Wyborn, 2015). LEK studies form a broad body of scientific literature, where LEK has been identified as an important aspect of fisheries with a local managerial influence (Harrison et al., 2018b). This article identified

hybridization as a practice by which local cultivators were integrating LEK and SK together to form a novel knowledge that both informed quality cultivation work and was locally contextualized. These findings fit closely to previous research showing knowledge as a practice-oriented phenomenon (Ingold, 2011; Lauer and Aswani, 2009; Lauer and Matera, 2016).

The concept of knowledge hybridization itself is not novel to this study (see examples in Raymond et al., 2010), but its application to bridging LEK and SK divides within fisheries management remains nascent and focused on adapting LEK into larger contexts (Forsyth, 1996; Reid et al., 2011; Thomas and Twyman, 2004). This article contributes to the hybridization literature by focusing on the processes of hybridization at local levels, and drawing attention to the value of hatcheries as facilitators of knowledge hybridization. This finding is particularly relevant to large-scale fisheries (or cultivation) managers who could view hatcheries as *in situ* knowledge laboratories where best available cultivation empirical knowledge might be integrated into local contexts (and vice-versa), an otherwise difficult managerial adaptation (Hind, 2015). This finding also challenges current knowledge paradigms in salmon cultivation management that seek to validate LEK against SK (Agrawal, 1995; Brook and McLachlan, 2005), build knowledge hierarchies (Lauer and Aswani, 2009), and maintain the hegemonic role of SK (Hind, 2015).

Issues of knowledge and how dominant knowledge paradigms interact with policy are closely tied to science and technology studies, a disciplinary link between Paper 1 and Paper 2 (Figure 2). In the same way that Paper 1 challenges dichotomies of LEK and SK, the STS link allows this research to also examine and challenge the interactions between social, political, and ecological values in the hatchery context. More specifically, this article shows how conceptualizations of nature and naturalness are aiding in the drive for particular policy agendas via mutually reinforcing relationships (Jasanoff et al., 1998) between empirical studies about hatchery effectiveness and political and social values and views of nature. This lens offers the opportunity to investigate these relationships and critique the political and social power structures that support them, thereby creating the capacity for this research to support innovative social and policy change around hatchery use (Clark et al., 2016; Webster, 2016). This is an important addition to the stocking debate, which has traditionally been dominated by scientific knowledge sets (Silvano and Valbo-Jørgensen, 2008) and politically powerful discourses.

The literature that approaches fisheries and conservation through an STS lens is relatively small and poorly-defined (but see e.g., Bjørkan, 2011). Still, some authors have made strong links between discussions of hatchery technologies and the human-nature relationship as bounded by dichotomic concepts of 'natural' and 'artificial' (Birnbacher, 2014; Scarce, 2000). The construction and deconstruction of the human role within (or out of) nature is well documented and debated as a philosophical question (Cronon, 1995; Hepburn, 1967; McKibben, 2014; Soper, 1998), and again as a more applied question within natural resource management (Haydon, 1997; Hayes et al., 1987; Kilgore, 1987; Kormondy, 1974; Turner, 1994). Paper 2 uses an STS lens to interrogate the human-nature (or more appropriately, human-salmon) relationship by including the dimension of human technologies as tools by which we interact with nature. In this case, Birnbacher (2014) and Scarce (2000) have laid the groundwork for this discussion by exploring hatcheries as socio-technological systems (see also Dwyer, 2011), and asserting the facilitative role of hatcheries for human-salmon relationships. They also raise the question of the 'good' or 'right' salmon and its relationship to conservation and technology. Paper 2 adds a novel aspect to this STS-based discussion by addressing it in the context of the Anthropocene, wherein 'natural' processes that once occurred independently of human influence are now permanently intertwined in human life and processes. Considering these issues together, scientific knowledge, discourses and ontologies surrounding human-salmon relationships, and which technologies are permitted to facilitate those relationships, remain hegemonic in terms of which evidence is meaningfully considered by managers during decision-making processes (Charnley et al., 2017b; Hind, 2015).

The questions raised in Papers 1 and 2 may also be viewed through an environmental ethics lens, which reveals close linkages between stakeholder views about the human-salmon relationship and disagreements about what knowledges and actions are (in)appropriate for engaging with salmon and salmon environments for conservation purposes (Scarce, 2000). These closely-related perspectives both explain underlying drivers of conflict in these case studies and simultaneously raise the issue of hatcheries and human-salmon relationships as ethical, rather than merely ecological or political, challenges within conservation (see Jamieson, 2008). Thus, these lenses allow us to see the study of voluntary hatcheries not solely as a variety of empirical questions (which, in themselves, may be inadequate for understanding hatchery challenges (Jardins, 2012)), but also as an ethical debate over how humans should engage nature, and technology.

Paper 3 demonstrates how a critical lens can help elucidate ways in which conservation science and policy sometimes (unintentionally) fail to include the needs of human stakeholders (Adams and Hutton, 2007; Neumann, 2004) and, occasionally, the ecosystem itself (Walker, 2005). This article borrows from "classical" outdoor recreation research (Driver, 1976; Manning, 2009) by applying a benefits framework to hatchery use in order to understand what social, psychological, or conservation benefits such activities may produce, an area of research that has been largely unexplored until now (Harrison et al., 2018a). While in the field of outdoor recreation benefits research is often quantitative or mixed-methods, this qualitative approach to the same framework used in a hatchery context adds descriptive depth by identifying and understanding the relationships between co-occurring benefits. Further, this use of the benefits framework expands its well-documented use in recreational fisheries (Driver and Knopf, 1976; Fedler and Ditton, 2001; Holland and Ditton, 1992; Parkkila et al., 2010; Weithmann, 1999) and fisheries conservation work via hatcheries.

Paper 3 identified psychological, social, and conservation benefits occurring as a result of hatchery work, or being facilitated by the hatchery itself. This suggests that the outdoor recreational benefits framework (Manning, 2011) is a good fit for evaluating activities beyond typical recreational activities (e.g., recreational angling). It also demonstrates that within the hatchery debate, common notions of hatchery work as 'replaceable' with other non-hatchery activities are invalid as cultivators seek hatchery-facilitated benefits *in addition* to their regular recreational pursuits. Thus, cessation of hatchery activities (and related stocking programs), toward which managers within these cases have shown a preference, has become more difficult in places where hatcheries (and related stocking work) are a longstanding tradition (Berg, 1986; Bottom, 1997) because cultivators experience loss aversion (Kahneman et al., 1991) when facing stocking policy changes. These are important findings as they help explain the ways in which hatcheries are valuable to cultivators beyond the function of fish production, and offer one frame by which to understand conflict over stocking restriction and termination in these cases.

7.3 Theoretical ties to conflict studies

Conservation conflicts may be framed in many ways (Baynham-Herd et al., 2018) as they become increasingly frequent, intense, and difficult to manage (Young et al., 2010). In this framing, the definition of what a conflict is, and whether or not it is viewed negatively, is important. I prefer LeBaron and Pillay's definition where conflict "is a difference within a

person or between two or more people [or between groups of people] that touches them in a significant way" (LeBaron and Pillay, 2006, pg. 12) because it denotes something important about how conflict is born out of the inner meaning people assign to important aspects of their lives. It also exemplifies an important aspect of how conflict should be understood: as both an inner turmoil rooted in personal values and beliefs (Madden and McQuinn, 2014), as well as a contestation between people to recognize and assert those feelings. The papers within this thesis demonstrate how hatcheries and stocking work touch people in significant ways, and thus the changes in recent years to how people engage in these activities are also significant. This is an essential contribution to stocking and salmon conservation research as many authors have highlighted how conflict research often fails to investigate, recognize, and address the deep-rooted, social or psychological origins of wildlife and natural resource conflicts (Baynham-Herd et al., 2018; Dickman, 2010; Madden and McQuinn, 2014; Redpath et al., 2013; Young et al., 2010).

Conflicts surrounding wildlife management[6] occur in several forms, usually divided by conflicts that occur between humans and wildlife itself, and those that occur between humans *about* wildlife (Dickman, 2010; Redpath et al., 2013; Young et al., 2010). Conflict surrounding the stocking debate in these cases obviously falls into the latter category, and also contains aspects of group in-fighting, conflict between groups with unequal power to enact change, and conflict between groups with equally strong but conflicting interests (Deutsch et al., 2011).

In addition to asking "between whom" is conflict occurring, this study gives novel insight into "what" the stocking debate is about from a social perspective and the current state of conflict in each case. Importantly, the answer to this question is slightly different in each case due, in part, to the spectrum of social, cultural, and governance variables in each case study (Aas et al., 2018 and Figure 1). By using the model of conflict from the Canadian Institute for Conflict Resolution as adapted by Zimmerman (2018), we can compare the current state of conflict in each case study to the recommended versus actually applied solutions (Figure 4).

In Germany, stocking conflicts as found in this study are generally at the border of Stage 1 and Stage 2. As in the other cases, German cultivators have deep social, cultural, and economic investments in their cultivation activities. However, the conflict is based in the desire to be acknowledged and supported in their restorative salmon conservation work.

[6] In this usage, I consider wildlife management to be inclusive of fish and fisheries.

Thus, this conflict currently sits as a dispute where practical solutions such as funding, state sanctioning and support, and more widespread acknowledgement and support from the general angling public are possible. However, if managers and the public continue to ignore, denigrate, or otherwise withhold needed support and acknowledgement from these groups, the conflict could easily move from Stage 1 to Stage 2 and take on aspects of underlying social conflict.

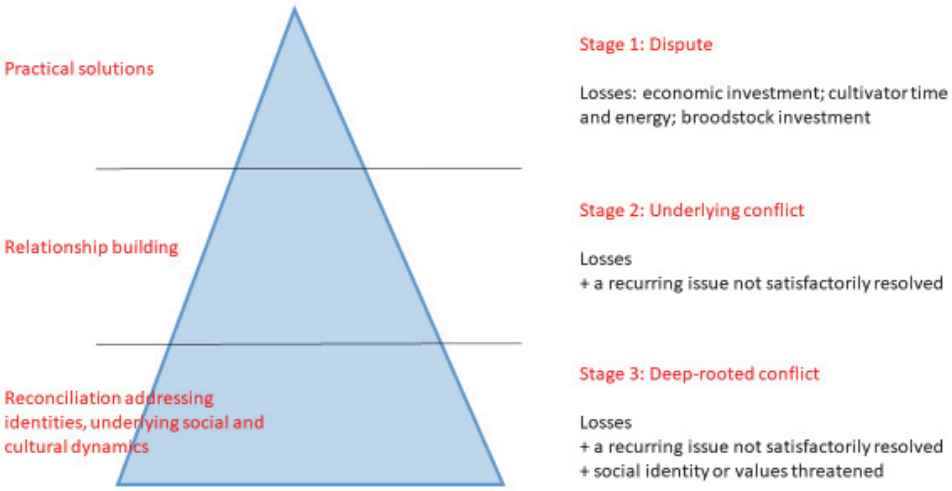

Figure 4 Three levels of hatchery and stocking conflict and resolution approaches. Source: Adapted from Zimmerman (2018) and Madden and McQuinn (2014). Original from: Canadian Institute for Conflict Resolution.

Meanwhile, stocking conflicts in Norway fit more closely to Stage 2 as they demonstrate the same qualities of Stage 1 due to conflict, but also possess strong underlying social conflicts revolving around issues of evidence, scientific versus local ecological knowledge use to inform salmon conservation policy, and the value of hatcheries and cultivation activities to the cultivator community and surrounding salmon landscapes. Importantly, relationships in this case were reported as being damaged by ongoing and recurring conflict. Thus, relationship building is an essential step to improving conflict in this case. As Norwegian cultivators have demonstrated important underlying identities and cultural dynamics related to their cultivation activities, failure to course correct in these cultivation scenarios may result in a deepening of the existing conflict to Stage 3 (Figure 4).

Finally, stocking in Wales has many signs of being in Stage 3 – a deep-rooted conflict (Figure 4). This is largely because of significant differences from the other two cases: (1) the

termination of stocking altogether in Wales and (2) the means by which the policy-making process to terminate stocking was carried out. Additionally, this case shows evidence of deeply-rooted personal, recurring conflicts, and strong social identities and values that were threatened during the closure and likely remain threatened (and thus a source of conflict) today. In this case, practical solutions and relationship building are not enough to address these deep social conflicts. Instead, reconciliation on the problems identified through this study would be necessary to overcome stocking conflicts and related social divisions in a timely manner.

The nature of the conflicts within these case studies also fit well-established themes within conflict literature such as imbalances of power (Raik et al., 2008) as local hatchery groups face off against the international scientific community and state policy makers in making their interests understood, and must adapt their arguments to fit dominating scientific and political discourses. Furthermore, the studies address debates over knowledge and evidence (Araki and Schmid, 2010; Entricott and Wilkinson, 2013) and where policy makers and hatchery advocates disagree about what knowledge and evidence priorities should be taken into account in policy-making. They also attend to the discussion of appropriate or equitable governance processes (Lute and Gore, 2014), an issue of strong contention where hatchery advocates expressed feeling excluded or unwanted in the policy-making process.

These cases also show that the interventions used to attempt to mitigate or address conflicting viewpoints treated hatcheries as structural rather than dynamic conflicts, and thus implemented structural interventions to address concerns about stocking through technical and legal changes (e.g., introducing genetic testing requirements (Norway), terminating stocking (Wales)) (Baynham-Herd et al., 2018; Madden and McQuinn, 2014). This research demonstrates that these hatchery conflicts are actually dynamic conflicts that undergo change and occur in stages (see Paper 4). Similar findings of conflicts as discourses focused around stages of key events exist within related research on natural resources (Ockwell and Rydin, 2006; Whittaker and Mercer, 2004) and fisheries and stocking conflict literature (Butteriss et al., 2001; Hunt and Jones, 2018). My findings support the assertion that the stocking debate and localized conflicts like those exemplified through the case studies are wicked problems (Jentoft and Chuenpagdee, 2009), and thus need localized, adaptive, and stakeholder-driven approaches if sufficient solutions are to be accepted and maintained by all stakeholders (Madden and McQuinn, 2014).

This point actually raises an important question: are hatchery stakeholders in these cases being empowered to participate in leadership roles during decision-making about stocking policy and implementation? Other types of "human(-human)-wildlife" conflict studies have demonstrated the essential importance and effectiveness of including stakeholders as partners in conservation conflicts, such as with elephants (Osborn and Parker, 2003; Zimmerman et al., 2009) or tigers (Karanth and Gopal, 2005). In the case of hatcheries as conservation tools, this research finds little evidence that stakeholders are being considered or treated as equal partners in the salmon policy-making process. In terms of understanding intervention success (or lack thereof) in this study, models such as the Conflict Intervention Triangle (Moore, 2014; Walker and Daniels, 1997) show that the lack of relationship building and centering of hatchery stakeholders as important players in stocking conflict resolution may lead to lopsided attention to the substance (reduced harm from stocking) and process (e.g., policy proposal, public consultation periods) of the stocking debate and related policy.

If we then ask "why have the approaches used in these cases to manage stocking conflict failed?" the Conflict Intervention Triangle offers possible explanations. It is clear that managers in these cases lacked understanding of stakeholders' underlying values and needs through structural solutions to stocking problems, but also ignored or were unsuccessful in relationship building and maintenance. This explains, in part, why the policy-change processes in these cases resulted in conflict escalation instead of resolution, and have weakened relationships between stakeholder groups (which include scientists and managers). Importantly, though managers carry much of the onus to enact relationship building by representing powerful stakeholder groups within public natural resource policy-making, it is difficult to overcome a typical conflict feature of an unwillingness for parties to engage (Redpath et al., 2013). Thus, local-level stakeholders in dyadic conflicts such as those in this study must also be willing to engage in compromise and collaborative work (i.e., Thomas and Kilmann, 2008).

Management approaches to stocking conflicts in these cases also fell short because they failed to address the underlying social conflicts taking place within each case. Examples of these conflicts are visible across this study as elements that are lost or limited due to hatchery restrictions. These include values such as personal identity tied to hatchery conservation work, a deep desire from cultivators to have opportunities to engage in conservation work, the many social and psychological benefits derived from hatchery work (Harrison et al., 2018a), the use of accessible, if controversial, technologies (Waples, 1999), and desires to

participate in fair and inclusive governance processes. This failure to account for social needs and wants are well-documented in other wildlife conflicts too, such as with wolves (Naughton-Treves et al., 2003), elephants (Zimmerman et al., 2009), and commercial fisheries (Harrison, 2013; van Ginkel, 2001). This pattern is reflective of a systemic problem in natural resource conflict research where conflicts are analyzed based on problems that are visible, and fail to capture the underlying social conflicts driving those presented disputes (Madden and McQuinn, 2014). As such, this thesis lays a better foundation to apply ample conflict recognition, mitigation, and resolution approaches from the literature (Baynham-Herd et al., 2018; Fujitani et al., 2017; Madden and McQuinn, 2014; Redpath et al., 2017) to future hatchery and stocking conflictual states.

7.4 Applied contributions to salmon cultivation, conservation, and management

To address the central goals of this thesis and understand the applied contributions of this thesis to the salmonid cultivation debate, this section focuses on how this work fits into the overall stocking debate and how the four papers collectively answer the central questions of the thesis laid out in Table 1.

Q1: Why does stocking remain so popular amongst local-level stakeholders (and some managers) if the preponderance of empirical evidence appears to condemn stocking as an ineffectual conservation tool?

The findings in this thesis point to several key reasons why stocking remains popular and contentious between pro- and anti-stocking advocates. First, this thesis demonstrates that hatcheries and stocking have different socio-cultural value to different stakeholder groups (Ives and Kendal, 2014), and these disparate values are not sufficiently included in contemporary debates over stocking, particularly within academic and scientific spheres of discussion. For example, hatcheries provide opportunities for local-level stakeholders to integrate and hybridize broad scientific knowledge into their local contexts in order to improve their hatchery and fishery outcomes (Harrison et al., 2018b). It also shows that, like salmon themselves (Ignatius and Haapasaari, 2018), hatcheries provide a broad range of benefits beyond the production of juvenile salmon (Harrison et al., 2018a). From this, we can understand that hatcheries are being valued beyond their mere capacity to produce fish, and thus are a preferred means of performing conservation in contexts that are not necessarily limited to the genetic, ecological, and biological concerns surrounding salmon cultivation (Cowx, 1994).

This thesis also finds that underlying philosophies toward salmon conservation held by local-level stakeholders and state-level managers differ in their ontologies toward nature and knowledge (Harrison et al., 2018b). While managers and fisheries scientists commonly remain grounded in ecological and biological management priorities such as maintaining genetic biodiversity and naturalness within salmon populations, local-level stakeholders may view conservation priorities somewhat differently. Importantly, this is not to say that local-level stakeholders fail to understand or disagree with the value of biodiversity in local salmon stocks. Rather, this thesis demonstrates that they view the human relationship with nature in a different way than managers, seeing humans as *part* of the salmon ecosystem rather than adjacent to or apart from it (Scarce, 2000). Within the context of salmon-human environments and a rapidly changing global environment, this distinction between the biological and the social is increasingly complex to make (Lavau, 2011; McKibben, 2014).

Similarly, local stakeholders are shown to draw from multiple ways of knowing in order to support their conservation efforts, and they are keen observers of the local environment and salmon population (Baird, 2007). This research shows that local-level cultivators are keenly aware and interested in improving their scientific knowledge as a means to improve their cultivation practices, and thus are adapting their knowledge sets to incorporate this information (Brattland, 2013; Thomas and Twyman, 2004). Hatcheries are thus acting as facilitators for this process of knowledge hybridization (Harrison et al., 2018b), a function revealed by this research and not yet incorporated into how hatcheries are valued in salmon conservation.

From these insights, we can see that the common scientific understanding of the effects of salmon stocking, while important in biological and ecologically-oriented discussions, falls short in addressing all social, cultural, and conservation-oriented issues that are valuable to local-level stakeholders. Thus, hatchery management and salmon conservation regimes should undergo epistemological adjustment and ask new questions (Figure 6) in order to find more socially sustainable and workable approaches (Ignatius and Haapasaari, 2018) to salmon cultivation.

Q2: From a human dimensions perspective, what social aspects are missing from the stocking debate and how could those issues be better addressed?

The hatchery debate is currently focused around biological and ecological issues of stocking, and classic pro- versus anti-stocking positions have been upheld with evidence from those

scientific fields. However, the conservation social sciences should not be considered an "optional complement" (Bennett et al., 2017a) in the case of stocking, but rather a central focus for conservation decision-making and management of stocking programs. While some fisheries researchers have given attention to the issue of social-cultural objectives in salmon stocking programs (Arlinghaus, 2006a; North Atlantic Salmon Conservation Organisation, 2017; Waples, 1999; Young, 2013), this thesis has shown that there are still some key social-cultural questions missing from the stocking debate.

Perhaps the most relevant issue is the framing of the stocking debate and how social issues and objectives are positioned within that frame. The stocking debate is often framed as a "pro

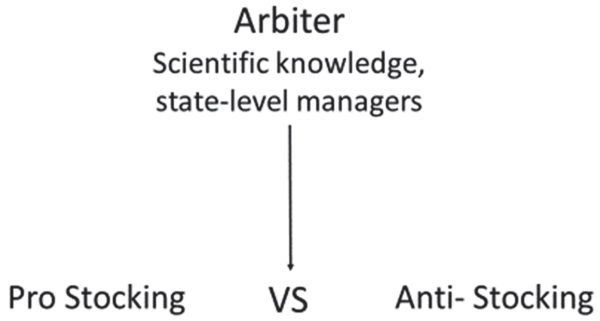

Figure 5 A common framing of the stocking debate.

versus anti-stocking" dichotomy where scientific knowledge is the arbiter of "truth" and reality. This portrayal excludes many interrelated and complex underlying factors for arguing both for and against stocking, leading to less acceptable and more contentious policy outcomes.

Rather than being a dichotomous issue (Figure 5), this thesis demonstrates that the stocking debate is a multi-faceted discussion containing multiple ontologies, value systems, and objectives for salmon cultivation and salmon-human relationship.

These social aspects are closely reflected in the social sciences conservation literature. For example, Bennett et al., argue that the effective evaluation and incorporation of these social, economic, cultural, and governance considerations (Bennett et al., 2017a) will help to produce stocking initiatives (or alter existing ones) that can better address local contexts (Nursey-Bray, 2011) – a highly desired outcome (Harrison et al., 2018b, 2018a). Similarly, such outcomes would be more socially acceptable to multiple stakeholder groups (Bennett et al., 2017b), resulting in more effective and acceptable democratic decision-making and

equitable governance outcomes (Kooiman and Jentoft, 2009), and facilitate better and more desirable ecological and biological stocking outcomes.

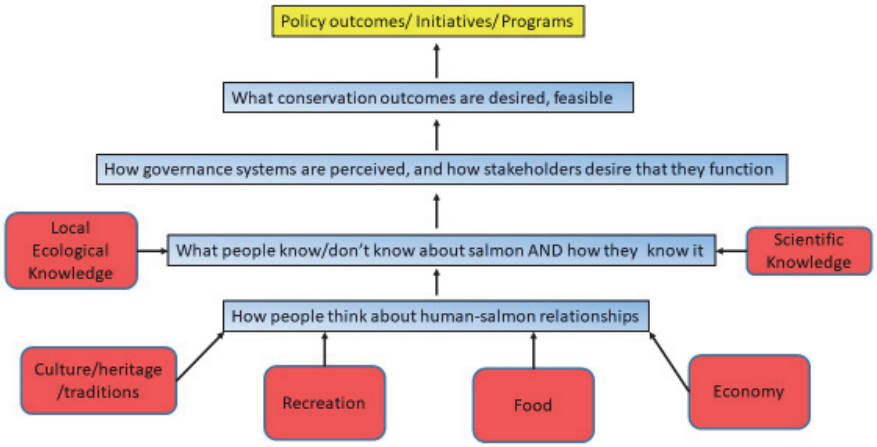

Figure 6 What questions are missing? Four central conservation questions (blue) have been identified as missing from the current pro-versus-anti-stocking debate. They are informed and supported by many underlying values and knowledge systems (red), and link together to form policy (yellow).

Social aspects can then be better incorporated into ecological and biological considerations to identify acceptable tradeoffs and solutions appropriate for both salmon and human environments and needs. The disciplinary lenses that frame this thesis (Figure 2) and questions identified as missing from the current stocking debate (Figure 6) may act as a starting place to gain additional insights for achieving these goals.

Q3: What social obstacles exist toward improving manager-stakeholder relations around stocking (and thereby mitigating or relieving conflict), and what can be done to overcome them?

The findings in this thesis bring to light several social obstacles that inhibit productive manager-local stakeholder relationships, and therefore contribute to prolonged and intensified conflict over stocking. As shown in conflict models (Walker and Daniels, 1997), relationships are a key component to effective conflict management, and the findings of this thesis demonstrate that the state of local stakeholder-manager relationships are an underappreciated and poorly managed aspect of these conflicts. Thus, it is important to identify what obstacles exist to improving these relationships.

To begin, social obstacles exist in terms of how knowledge that supports salmon conservation is produced, shared, valued, and integrated into cultivation policy. Paper 1 shows that

multiple forms of knowledge are being used to support local level cultivation activities. Though these cases demonstrate that managers find LEK to be a potentially useful source of information (Holm, 2003), they also show that managers have inadequate mechanisms by which to solicit and incorporate LEK (Harrison et al., 2018b) and engaging stakeholders effectively is a challenging task (Rosten, 2017). Similarly, local-level cultivators and other salmon stakeholders struggle to elevate their LEK into large-scale-oriented management regimes (Harrison et al., 2018b). From this, it is clear that in places where conflict over which knowledge sets should inform local-level salmon management, more must be done to create better two-way mechanisms for knowledge exchange (Joks and Law, 2017) between upper echelons of salmon management and local-level practitioners, where associate scientific knowledge and local knowledge systems are considered complementary (Mackinson and Nottestad, 1998).

Social obstacles also exist in the way local-level cultivators and mid- to national-level managers perceive naturalness, and what activities, interactions, or facilitating technologies between humans and salmon are permissible. These frameworks of thinking extend into practical considerations about what conservation objectives should be at the forefront of cultivation efforts (Kooiman and Jentoft, 2009), and whether those objectives should include social objectives as well as typically centered biological and ecological concerns (Harrison and Loring, 2014). Thus, the social obstacle at work is not a structural one, but a conceptual one that is inherently difficult to address given its intangible nature. To address this, managers should consider their ontological positions and accepted epistemologies more explicitly, and allow for input and meaningful discussion of conservation approaches that allow for alternative views to be given meaningful consideration.

Another social obstacle common to the conflicts in these cases concerns mismatched expectations (see Davies and White, 2012) as to how evidence informing stocking policy would be considered. In Paper 4, pro-stocking stakeholders expected all evidence, including that produced through LEK or other localized means, to be held and considered equal to scientifically-derived information. Similarly, they expected the consultation process that took place in 2014 to be objective, and for a decision to be made *after* the collection and consideration of all opinions and evidence. As Paper 4 describes, these expectations were not met, leading to increased conflict and animosity between pro-stocking interests and anti-stocking and managerial groups. This points toward an important lesson that has been identified by other researchers: the co-production of knowledge and inclusive *processes* that

build consensus amongst stakeholders rather than forcing binary decisions are essential (even if time-consuming) (Arlinghaus, 2006a; Fujitani et al., 2017; Granek et al., 2008; Walker and Daniels, 1997). Fishery models for this type of integration have already been discussed using regional advisory councils (Linke et al., 2011), a system for which the basic organizational elements in these cases already exist.

Finally, as has been done in the field of outdoor recreation (Driver, 1976), closer examination should be given to "for whom" and "for what purposes" hatcheries are being managed. It could be that the benefits derived from voluntary hatcheries could be maintained by transitioning the purpose of these facilities from controversial, localized conservation approaches toward facilitating the production and transfer of local knowledge sets (Harrison et al., 2018b), participation of angling and river owner groups in conservation activities (Harrison et al., 2018a), and other purposes that do not require the direct production of large quantities of fish for stocking, a major concern within the stocking debate (Araki and Schmid, 2010; Young, 2013). Most essentially, managers must pay greater attention to replacing, supplementing, or otherwise providing the activities facilitated by or associated with hatcheries, particularly with the focus on maintaining skill-set appropriate opportunities for current or former cultivators to continue participation in conservation work (Harrison et al., 2018a).

7.5 Implications for managers: an emerging framework of hatchery use

The effort invested in understanding the unique social conflict elements of conservation problems, such as those in the case studies of this thesis, is required on a case-by-case basis in order to get local buy-in to attempt and maintain solutions (DeCARO and Stokes, 2008; Zimmerman, 2018). Thus, it is important not to try to derive 'ready-made' solutions from these cases to apply to other settings that may have similar structural conservation problems, but possess unique social, cultural, and psychological dynamics (Zimmerman, 2018).

Despite this, the findings of this thesis are valuable unto their own right, and offer an opportunity to re-frame the voluntary hatchery and stocking debate. Following Madden and McQuinn's suggestion for a re-orientation of understanding approaches to conservation conflict (Madden and McQuinn, 2014), I take inspiration from the conflict transformation (CT) approach (Lederach, 2015; Miall, 2004) to suggest an emerging framework for managing cultivation conflicts. The CT approach is useful as it "conceptualizes immediate problems as opportunities to understand and positively change causal relationship, decision-

making processes, and systems shaping conflicts" (Madden and McQuinn, 2014, pg. 100), and focuses on the dynamics of conflict and attempts to transform negative feedback cycles (e.g., relationships) into positive ones by advocating for long-term, humanizing engagement between conflicting parties (Lederach, 2015; Madden and McQuinn, 2014). As such, my proposed framework lays the groundwork to attend to the ecological and biological problems of stocking while simultaneously addressing the social elements underlying the use of voluntary hatcheries as conservation tools.

At the surface level, the stocking debate focuses on whether hatcheries are or are not effective tools for conservation, with arguments primarily focused on improving population levels of wild, self-sustaining salmon. However, this thesis has demonstrated that significant social conflict covering a range of issues continues to drive the hatchery debate, and has impeded managerial efforts to enact policies to remediate the surface-level disputes. Amongst the underlying social conflicts are three key issues that offer an opportunity to re-orient how the stocking debate, in as far as it concerns voluntary hatcheries, operates:

1. Managerial shortcomings in understanding and acknowledging how stocking projects are perceived as conservation tools and voluntary hatcheries as conservation technologies, therefore managing them as an anti-conservation tools and inappropriate technologies;
2. Managerial challenges in recognizing the complex technosocial community evolved around hatchery use, how these technologies link cultivators to nature and salmon in important ways, and how those connections are subsequently lost when these technologies and their associated communities are eliminated;
3. Lack of identification and understanding of the capacity of hatcheries and cultivator activities facilitated by hatcheries to produce important capacity, benefits and knowledge sets which then support salmon conservation more broadly.

By addressing these core issues, this framework seeks to transform the role of voluntary hatcheries from problematic producers of juvenile fish into conservation technologies embedded in local contexts and capable of producing and facilitating a range of benefits, knowledges, and desirable conservation and social outcomes (Figure 7). More succinctly put, this framework suggests that while voluntary hatcheries are biologically and ecologically problematic, they also simultaneously produce and perform many positive and beneficial social-cultural aspects that have primary and secondary benefits to the cultivator communities

engaged with them and conservation of the surrounding salmon riverscapes. This re-orientation of perspective also allows hatchery conflicts, such as those described in these case studies, to be transformed from a focus on fact-based disputes (Stage 1, Figure 4) that miss the underlying causes of the conflict to a focus on resolutions of underlying conflicts and, in particularly extreme cases, reconciliation of deeply-rooted conflicts (Stage 2 and Stage 3, Figure 4).

Figure 7 shows three feedback loops that center around voluntary hatcheries and three stakeholder groups: governance institutions, scientific institutions, and cultivator groups. Instead of acting as the problematic center of conservation conflicts, this example re-positions hatcheries as indicators of dynamic processes that acknowledge, support, and utilize the underlying social aspects of the conflicts identified in this thesis. As such, the three key issues described above are highlighted as strengths over which managers, scientists, and cultivation stakeholders may engage more productively. Specifically, conflict transformation in this framework could center around:

1. *Knowledge*

This example acknowledges that hatcheries actively facilitate the production, transfer, and hybridization of knowledge sets that are important to both high-quality salmon cultivation as well as conservation activities surrounding hatchery use. As such, managers would take advantage of these facilities by considering them and the communities engaged in cultivation work as repositories of valuable scientifically-informed LEK and skill sets. Such qualities are inherently useful in addressing locally-situated problems or sudden natural phenomena that threaten salmon populations and environments (Harrison et al., 2018a). Similarly, fisheries researchers could treat voluntary hatcheries as local-level laboratories where knowledge hybridization processes may be utilized to speed the integration of current scientific knowledge into on-the-ground salmon conservation practices.

2. *Benefits*

Voluntary hatcheries are producing or facilitating the production of psychological, social, and conservation benefits for cultivators, the most predominate of which is the opportunity to use existing skill and knowledge sets to participate in conservation. Managers should be encouraged to acknowledge and account for the value of these outputs when considering the value of hatchery and stocking programs. To do so, managers should open policy-change

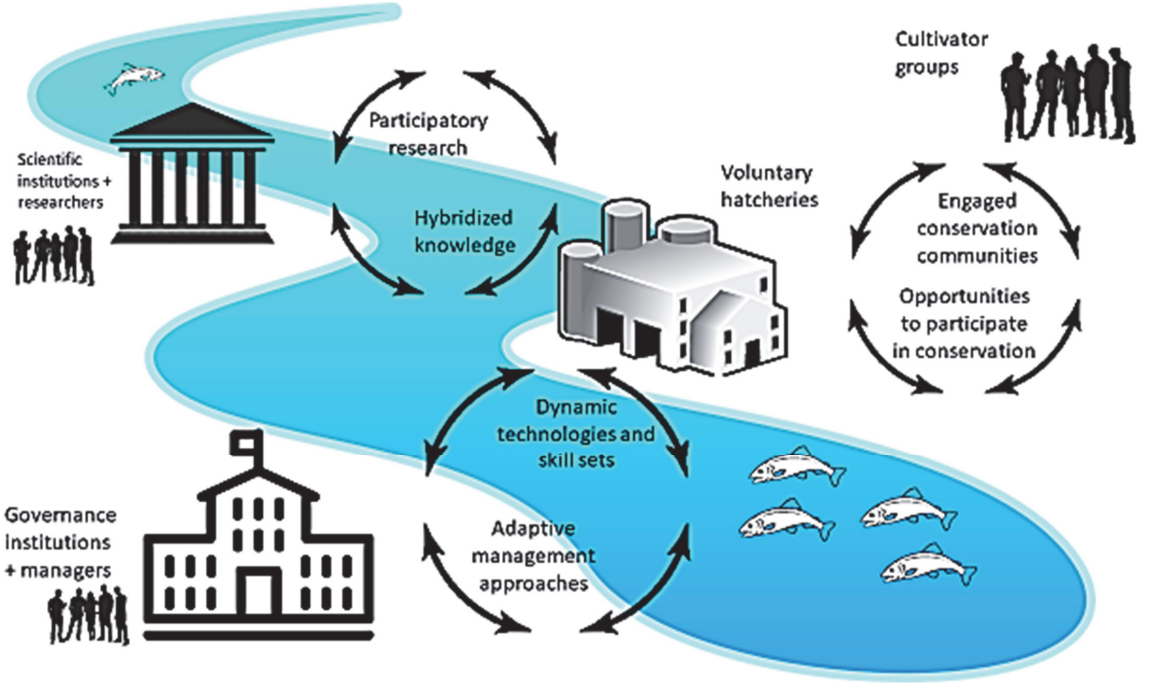

Figure 7 An example of a conflict transformation approach to voluntary hatcheries. Hatcheries are re-oriented as the center of dynamic positive feedback loops between research institutes, governance systems, and cultivator groups.

conversations to be inclusive of these valuable benefits and explore in tandem with cultivators ways by which stocking practices may be improved, stocking may be supplemented by other less damaging practices, or other approaches which may maintain the provision of these benefits while reducing harm. Similarly, cultivators could consider how these benefits may be maintained while doing the least harm to wild salmon populations via unsound stocking practices.

3. *Engagement in conservation*

Across all three cases, an underlying reason for cultivator persistence in pursuing cultivation work is a desire to participate in salmon conservation using their pre-existing skill and knowledge sets, a desire rarely (and sometimes snidely, see Young et al., 2010, pg. 20) acknowledged in the hatchery debate. Rather than viewing hatcheries solely as a problem unto themselves, managers might reframe their evaluation and instead view hatcheries as indicative of two things: (1) an engaged community of salmon-interested individuals and groups prepared to invest time, energy, and resources into salmon conservation, and (2) an indicator of a lack of alternative means, or technologies, by which these interested parties are able to engage in salmon conservation (i.e., habitat restoration or improvement projects).

Hatcheries are time consuming, expensive, and increasingly viewed as inappropriate and "unnatural" conservation technologies. This study showed that cultivators often engage in other non-hatchery conservation activities when and as they are able, thus indicating that hatcheries are not necessarily used because they are a "first choice" activity. However, non-hatchery conservation activities are also shown to be expensive and legally arduous (or sometimes impossible) to undertake on a voluntary basis (e.g., permitting requirements, expensive contractor fees for in-river work, etc.), are dominated by conservation NGOs exclusive of angling interests, are considered the domain of professionalized managers rather than amateur conservationists (i.e., electrofishing to conduct stream surveys), or simply are outside the skill and knowledge sets present within current cultivation communities.

Understanding this, managers should consider hatcheries as indicators of gaps within the current conservation landscape, indicating environmental regulatory frameworks which are insufficient in engaging lay salmon conservation interests as well as the potential for uneven social or organization power structures that have resulted in some parties being excluded from salmon conservation work. Taken together, managers may also see these indicators as markers of potential social conflict surrounding salmon conservation, and proactively seek

means by which to engage cultivation stakeholder groups in solving conservation access issues.

4. *Participatory research and adaptive management*

Using the framing of hatcheries as social indicators laid out above, managers could consider more actively engaging the knowledge and experience of local-level stakeholders by pursuing participatory adaptive management approaches (Fujitani et al., 2017) that hold equally valuable multiple means of knowledge production and utilization (Crotty, 1998). Voluntary hatcheries could be viewed as local laboratories for hybridization of relevant advancements in cultivation and conservation science into local environments (and vice-versa), thus easing the burden on regulators to convince local-level cultivators of policy validity. Similarly, voluntary hatcheries act as locales in which long-term research on salmon conservation topics may be co-produced through participatory means between local cultivators and non-local researchers. These approaches give attention to the underlying social aspects that drive hatchery and stocking conflicts and could help develop better rapports of trust and beneficial exchange between local cultivators and mid-high level managers. This development could have particular relevance to improved policy-making processes as it could create space and opportunities to communicate stakeholder expectations of governance and enact decision-making and input-seeking processes that fully engage, utilize, and equitably represent stakeholder perspectives.

Taken together, this framework is a new and somewhat dramatic shift from conventional thinking about voluntary hatcheries that places hatcheries at the center of community-driven, place-based salmon conservation solutions rather than positioning hatcheries as the central problem. Interestingly, it also raises the question of the value of conflict itself. Should systems of management and stakeholder involvement be designed to try to eliminate or avoid conflict? Through this framework, I argue that they should not. The feedback loops presented in Figure 7 are all likely to contain conflict. Indeed, conflict is a normal and important part of natural resource management that comes and goes (Lederach, 2015; Madden and McQuinn, 2014) as new issues and power dynamics rise and fall. Importantly, it inspires creativity and the evolution of solutions to new problems and challenges in social-ecological systems (Lederach, 2015). Thus, conflict is not an aspect of conservation that should be avoided as it is indicative of those issues which conservationists hold most significant.

7.5.1 Local-level cultivators

Within this proposed emerging framework of voluntary hatcheries there are equally important considerations from which local-level stakeholders may benefit.

Local-level stakeholders should not feel obligated to enter the stocking debate entirely through scientific arguments; still, these groups must ground themselves in recent research on the hazardous effects of stocking on wild salmon stocks. Put simply, cultivators must acknowledge the building scientific agreement that hatcheries and stocking have negative effects on existing wild stocks. In these cases, cultivators sometimes argued that the scientific research on stocking was not conducted on their specific local circumstances, and thereby was not conclusive on the effects of stocking in *their* river. While they may be factually correct about a lack of local research, they commit the reverse foul as managers by demanding the same local applicability of their LEK from scientific knowledge and studies, which are inherently intentioned toward broad-scale and generalizable findings. Thus, local-level cultivators would benefit from a more nuanced understanding and appreciation of the benefits and limits of LEK and scientific knowledge, and make better use of incorporating both knowledge sets together toward local cultivation practices (Harrison et al., 2018b).

As with managers, local-level cultivators also must critically examine the objectives of local stocking operations. For what purpose are they stocking, and are the methods and strategies they use in hatchery and stocking activities appropriate to achieving those purposes? Perhaps most critically, are those purposes appropriate to the salmon stock and environment in question? These are essential questions that, in the histories and traditions of stocking found in these cases, are sometimes left unasked even as the local salmon stock and environment undergo constant change. These questions have been asked in the literature (Araki and Schmid, 2010; North Atlantic Salmon Conservation Organisation, 2017; Waples, 1999), and just as managers must be able to ask these critical questions without the threat of a hatchery or stocking program shutdown, cultivators must be willing to hear and think critically about these questions in order to achieve their own stated goals: improved cultivation and salmon conservation practices.

7.6 Future research directions

The studies in this thesis have set forth recommendations for the stakeholders within these cases, particularly managers and fisheries scientists, aimed at better understanding and incorporating multiple viewpoints, value sets, and objectives into the management of wild Atlantic salmon conservation and cultivation. However, future research aimed at finding

techniques to actually solicit understanding and achieve integration of stakeholders – inclusive of knowledge, preferences, needs, and values – into management is needed. This need has also been identified by other authors who argue that the challenge of analyzing stakeholder values and integrating them into the policy process is challenging (Granek et al., 2008), and thus requires the development of novel scientific approaches (Ignatius and Haapasaari, 2018; Sharp and Lach, 2003). This effort should go one step further beyond the goal of novel *scientific* approaches, to also focus on what I term *social-scientific* approaches.

The "how" as well as the "what" in terms of future research directions is important to describe here, as this thesis has shown that even a plethora of research on a species, if not diversified and thoughtful in its nature and design, may fail to bring us closer to meaningful conservation solutions. To that end, I consider social-scientific approaches to prioritize real-world problem-solving methods over the development of empirical frameworks, to hold biosocial ways of knowing and learning equal to those based solely in the natural sciences (Setchell et al., 2017), and to prioritize the use and maintenance of social capital in conducting conservation research (Pretty and Smith, 2004). In this, participatory adaptive management should be further studied in the hatchery context, as successful adaptive management techniques may allow both scientists and local-level stakeholders to gain from the problem-solving process. Examples in the recreational fishing literature (Fujitani et al., 2017) and other contexts such as forestry and agriculture (Roling and Wagemakers, 2000; Smith et al., 2007; Stringer et al., 2006) already exist from which to model cultivation-oriented models.

The identification of the emerging framework of voluntary hatcheries presented in this thesis is just that: emerging, and in need of further testing and verification. It could be that the findings made across the case studies within this thesis are unique and not applicable to similar hatchery types under other regulatory frameworks or in other locales. Thus, further research is needed to verify the validity of this framework and test whether it can be applicable in real-world management in conflict settings.

Finally, my experience in IMPRESS has demonstrated that while multidisciplinary projects are excellent education tools for PhD candidates, they do not offer a strong platform by which multiple disciplines may approach the same research questions. Thus, truly transdisciplinary research should be the goal for future salmon cultivation-oriented projects where questions

that transcend typical social or natural science barriers (Fox et al., 2006) may be asked and answered by integrated, collaborative student teams.

8. Conclusion

This research helps to explain the differing perspectives on the value of stocking as a conservation tool, a gap that previously existed and was exacerbated by the "pro- versus anti-stocking" framing commonly applied to the stocking debate (Figure 5). In particular, the case study approach of this thesis makes use of critical social science analysis (Bennett et al., 2017a) by deconstructing pre-existing assumptions and knowledge about voluntary hatcheries and offering new insights, suggestions, and questions toward overcoming this dichotomous conflict surrounding hatchery and stocking programs in these cases.

This thesis has demonstrated that there are multiple, interconnected ways in which voluntary hatcheries are valued and used to pursue salmon conservation goals. The findings of this study taken together construct a socio-cultural frame by which to understand hatcheries and how they are important to local-level cultivators. By that same token, these findings also illuminate why policy changes focused on limiting or terminating hatchery use (and associated stocking programs) have been met with such controversy and resistance.

Even with these steps forward in understanding hatcheries as social as well as biological tools within the salmon conservation tool belt, this thesis is most appropriately viewed as a step toward an integrated biosocial approach to hatchery use. The emerging framework of hatcheries described in the implications section could, with further testing and development, form an innovative approach to hatchery management that looks forward toward what hatchery, and salmon, and stakeholders can and should be in the age of the Anthropocene. Will the salmon management paradigms and techniques used in the past be appropriate for the political, societal, and scientific conservation objectives of the future? This thesis already suggests that they may not, but how these approaches should or even can shift to meet the needs of the future remains unknown.

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APPENDICES

Appendix 1: Interview Guide, Norway

Introduction Questions – Purpose: to relax participant, build report, set tone of interview, provide demographic information to researcher.

1. What is your role in the agency?
2. What is the primary goal/mission of your agency?
3. What sorts of tasks/programs do you work in/on? [examples]
4. How long have you worked here?
5. Who do you work with/what groups do you primarily interact with in your official capacity?
   Do you feel that your input matters in decision making?
   What's the quality of your/your group's relationship with the primary environmental agency?
6. How does your agency (if they do) include the stakeholders in management decisions?
   a. Is there criticism or dissent? How does your agency respond to criticism from stakeholders?
7. Who is the most powerful/influential decision maker in the current salmon management system?
8. How have things changed over time in regard to management of salmon?

Management and Conflict (Regulatory questions)

Explaining the issue – 2014 regulatory change concerning rules around hatchery operation and stocking.

1. What do you think about stocking as a practice in general?
2. Why do you think people disagree about these changes?
   If necessary discuss opposition to changes from people in Møre og Romsdal area, etc.
3. What do you think the 'other' groups thinks?
4. Are the people in Møre og Romsdal/Sunnmøre more vocal about these changes than in other areas of Norway? Why or why not?

Knowledge

Purpose – To determine what information and ways of knowing people base their decisions and opinions on within the context of hatcheries and stocking as a conservation tool.

1. What do you know about the changes made in 1994 and 2014?
   a. Why were they made?
   b. Have you read the literature involved?
   What the interviewee knows about the rule changes, why they were made, etc.?
2. Who do you go to/who do you consider knowledgeable about local fishing and management issues? And about salmon in general?

3. Where do you get your information from?
4. How have you learned about this fishery? (schooling, experience, etc.)
5. In your opinion, do you have a way to share what you know with managers/decision makers?
6. Do you support the new 2014 guidelines? Why or why not?
    a. Why do you think these changes were made? Based on what information/process?

Ecosystem Services

1. Why is it important to preserve salmon in Norway? In the Sunnmøre region?
   For interests of your organization? For which other people is it important and why?
   - economics, food, next generation, culture/tradition, recreation, "just being there", education
2. Explain: Try to understand how people interacting with salmon "see" the fish, do you feel comfortable with that?

- Salmon important for you personally/ care about salmon in and beside the job?
- Interaction with salmon outside of the position in the organization?
- How well do you think you know salmon?
- Think that salmon is good for the rivers?
- Personally worried about salmon stocks?
- Want salmon to be happy/ not suffer?
- Like to catch salmon/ fishing in general?
- Like to eat salmon/ tastes good?
- Like to observe salmon in the wild or in hatcheries?
- As a fish: friendly/ intelligent/ beautiful/ clean/ dangerous/ interesting

3. How are salmon doing in Norway? [evaluating current state of salmon]
4. Are current conservation actions [stocking] necessary to the future existence of salmon?
5. What would happen if salmon stocks decreased?
6. Is there anything that could replace the role that salmon plays?

Final questions

1. Who else should we talk to?
2. Age
3. Level of education

Appendix 2: Interview Guide, Wales and Germany

Introduction Questions – Purpose: to relax participant, build report, set tone of interview, provide demographic information to researcher.

1. What is your role in the group/organization?
2. What is the primary goal/mission of your group/organization?
3. What sorts of tasks/programs do you work in/on? [examples]
4. How long have you worked here?
5. Who do you work with/what groups do you primarily interact with in your official capacity?
6. Do you feel that your input matters in decision making?
   - What's the quality of your/your group's relationship with the primary environmental agency?
7. Who is the most powerful/influential decision maker in the current salmon management system?
   How have things changed over time in regard to management of salmon? What do you think is working or not working?

Management and Conflict (Regulatory questions)

1. What do you think about stocking as a practice in general?
   a. If positive to hatcheries/stocking, what do you like about hatcheries?
   b. Can you share some experiences you've had doing hatchery work? (if applicable)
   c. Tell us about how (your local) hatchery is operated, and who participates.
2. Why do you think people disagree about stocking/hatcheries?
3. (If not already indicated) Do you think hatcheries work?
   a. Follow up: It appears hatcheries are having a positive effect on stock levels in [Country]? What do you think of this?
4. To your knowledge, what types of hatchery and/or stocking activities take place in [Country]?
   a. Do you think these activities ever conflict with other conservation projects? Hydropower, etc.?
5. What do you think the 'other' groups thinks?
   a. (If applicable) Why you think these groups disagree with each other?

Interaction with Decision Makers

Purpose – To determine what information and ways of knowing people base their decisions and opinions on within the context of hatcheries and stocking as a conservation tool.

1. Who do you go to/who do you consider knowledgeable about local fishing and management issues? And about salmon in general?

2. How have you learned about this fishery? (schooling, experience, etc.)
3. In your opinion, do you have a way to share what you know with managers/decision makers?

Ecosystem Services

1. Why is it important to preserve salmon in [Country]?
   For interests of your organization? For which other people is it important and why?
   - economics, food, next generation, culture/tradition, recreation, "just being there", education
2. Explain: Try to understand how people interacting with salmon "see" the fish, do you feel comfortable with that?

- Salmon important for you personally/ care about salmon in and beside the job?
- Interaction with salmon outside of the position in the organization?
- How well do you think you know salmon?
- Think that salmon is good for the rivers
- Personally worried about salmon stocks?
- Want salmon to be happy/ not suffer?
- Like to catch salmon/ fishing in general
- Like to eat salmon/ tastes good
- Like to observe salmon in the wild or in hatcheries
- As a fish: friendly/ intelligent/ beautiful/ clean/ dangerous/ interesting

3. How are salmon doing in [Country]? [evaluating current state of salmon]
4. Are current conservation actions [stocking] necessary to the future existence of salmon?
5. What would happen if salmon stocks decreased?
6. Is there anything that could replace the role that salmon plays?

Final questions

1. Who else should we talk to?
2. Age
3. Level of education

Appendix 3: Information letter and consent form, Norway

Request for participation in research project

Invitasjon til å delta i forskningsprosjekt

"Understanding conflict between user groups concerning the role of hatcheries as a conservation strategy for wild Atlantic salmon in Norway."

Undersøkelse av konflikter omkring klekkeridrift og utsettinger som del av norsk lakseforvaltning og bevaring av ville laksebestander

Background and Purpose
This research is being conducted in as part of a doctorate degree from the Norwegian University of Life Sciences. This work will investigate an ongoing conflict over salmon management and conservation between user groups in the Møre og Romsdal area. In this county, there is disagreement as to how hatcheries and salmon stocking should be used as a conservation technique to help improve salmon numbers and environmental quality in local rivers. The goal of this project is to uncover these root causes and analyze them to determine if there is some consensus or middle ground that could be reached to help minimize the conflict and maximize efforts for conserving salmon.

Bakgrunn og formål
Dette forskningsprosjektet er en del av et Phd prosjekt ved NMBU. Arbeidet vil se på konflikter og ulike syn på klekkerivirksomhet og utsettinger av lakseunger som del av norsk villaksforvaltning, og studere dette i Møre og Romsdal. I dette fylket har endrede forskrifter og retningslinjer fra sentrale miljømyndigheter medført begrensninger i kultiveringsvirksomheten og ulike grupper er uenige om hvilken rolle kultivering har for vern og utvikling av de ville laksebestandene. Målet med prosjektet er å studere de underliggende årsakene til konfliktene, og blant annet søke å finne fram til løsninger eller kompromisser som alle parter aksepterer, for å redusere konfliktene og samle kreftene om å ivareta villaksen.

What does participation in the project imply?
Participating in this study implies that you have had the purposes and goals of this research explained to you, either in English or Norwegian, and you fully understand that your participation is entirely voluntary. You also acknowledge that any information you provide, including your opinions, thoughts, and experiences, may be used anonymously in peer-reviewed publications in the future. Exceptions to this are described below.

Hva innebærer det å delta i prosjektet?
Hvis du velger å delta, har du krav på å få forklart hva prosjektet handler om, enten på norsk eller engelsk, og at deltagelsen er fullt og helt frivillig. Du godtar også at den informasjonen og de synspunkter, meninger og erfaringer du formidler til forskerne i prosjektet, kan bli brukt i anonymisert form som del av forskningspublikasjoner i årene som kommer. Unntak er beskrevet nedenfor.

What will happen to the information about you?
All personal data will be treated confidentially. Only researchers involved in this project and

their supervisory team will have access to data collected during this project, including but not limited to audio, written materials, photographs, etc. Any identifying information used in this study will be anonymized prior to publication and in its entirety when the project has concluded, prior to storage. During the course of the study, all information will be regarded as confidential and kept secured.

Information about participants will not be used in a way that is identifying to the participant unless explicit, written permission is granted by the participant.

The project is scheduled for completion by August 2018. All data will have been made anonymous by this time and will be stored on the NMBU servers as according to Norwegian data storage regulations. At that time, no data will be attributable to an individual.

Hva skjer med informasjon om deg?
Alle personlige data vil behandles konfidensielt. Kun forskere i prosjektet vil ha adgang til data, for eksempel lydfiler, nedskrevne referater og fotografier. Informasjon som kan bidra til å identifisere deg skal anonymiseres før det brukes i offentliggjorte forskningspublikasjoner (rapporter, artikler mv.). Videre, når prosjektet er fullført og dataene evt skal lagres wil alt som kan brukes til å identifisere informantene bli slettet og anonymisert. Under gjennomføringen av prosjektet vil alle data anses som konfidensielle og lagres på en sikker måte.

Materiale vil aldri brukes på en måte som kan medføre identifikasjon uten at det er innhentet skriftlig samtykke.

Prosjektet skal vare fram til august 2018. Da skal alt materiale anonymiseres før det lagres i tråd med de reglene som gjelder for offentlig finansierte forskningsprosjekt i NMBUs arkiver. Det lagrede materialet vil være anonymisert.

Voluntary participation
It is voluntary to participate in the project, and you can at any time choose to withdraw your consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous or deleted, according to your wishes. Information you have provided up until that point will not be used in any future publications.

If you have any questions about your participation in this study, please contact Chief Investigator Hannah Harrison at hharrison.green@gmail.com or by phone at +47 45445385.

The study has been notified to the Data Protection Official for Research, Norwegian Social Science Data Services.

Frivillig deltagelse
Det er frivillig å delta, og du kan trekke deg fra videre deltagelse når som helst uten å oppgi grunn. Hvis du bestemmer deg for å trekke deg, vil alle data og opplysninger du har gitt enten slettes eller bli anonymisert, avhengig av hva du foretrekker. Dine bidrag fram til da vil ikke brukes i framtidige publikasjoner fra prosjektet.

Hvis du har spørsmål om din deltagelse, ta kontakt med ansvarlig forsker Hannah Harrison, mobil + 47 45445385.

Prosjektet er meldt til Norsk Samfunnsvitenskapelige Datatjeneste.

Consent for participation in the study

I have received information about the project and am willing to participate as a consenting adult of my own free will, understanding how information I provide may be used.

(Signed by participant, date)

Samtykke til å delta i forskningsprosjektet

Jeg har mottatt informasjon om forskningsprosjektet og er villig til å delta som en voksen, myndig person som forstår hvordan informasjonen jeg gir vil bli brukt.

(Signert av deltager, sted, dato, navn)

Appendix 4: Information letter and consent form, Wales

Request for participation in research project

"Understanding conflict between user groups concerning the role of hatcheries as a conservation strategy for wild Atlantic salmon in Wales."

Background and Purpose
This research is being conducted in as part of a doctorate degree from the Norwegian University of Life Sciences. This work will investigate an ongoing conflict over salmon management and conservation between user groups in the River Wye area. In this watershed, there is disagreement as to how hatcheries and salmon stocking should be used as a conservation technique to help improve salmon numbers and environmental quality in local rivers. The goal of this project is to uncover these root causes and analyze them to determine if there is some consensus or middle ground that could be reached to help minimize the conflict and maximize efforts for conserving salmon.

What does participation in the project imply?
Participating in this study implies that you have had the purposes and goals of this research explained to you, either in English or in Welsh, and you fully understand that your participation is entirely voluntary. You also acknowledge that any information you provide, including your opinions, thoughts, and experiences, may be used anonymously in peer-reviewed publications in the future. Exceptions to this are described below.

What will happen to the information about you?
All personal data will be treated confidentially. Only researchers involved in this project and their supervisory team will have access to data collected during this project, including but not limited to audio, written materials, photographs, etc. Any identifying information used in this study will be anonymized prior to publication and in its entirety when the project has concluded, prior to storage. During the course of the study, all information will be regarded as confidential and kept secured.

Information about participants will not be used in a way that is identifying to the participant unless explicit, written permission is granted by the participant.

The project is scheduled for completion by August 2018. All data will have been made anonymous by this time and will be stored on the NMBU servers as according to Norwegian data storage regulations. At that time, no data will be attributable to an individual.

Voluntary participation
It is voluntary to participate in the project, and you can at any time choose to withdraw your

consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous or deleted, according to your wishes. Information you have provided up until that point will not be used in any future publications.

If you have any questions about your participation in this study, please contact Chief Investigator Hannah Harrison at hharrison.green@gmail.com or by phone at +47 45445385.

The study has been notified to the Data Protection Official for Research, Norwegian Social Science Data Services.

Consent for participation in the study

I have received information about the project and am willing to participate as a consenting adult of my own free will, understanding how information I provide may be used.

(Signed by participant, date)

Appendix 5: Information letter and consent form, Germany

Einwilligungserklärung zur Teilnahme an dem Forschungsvorhaben

"Menschen, Flüsse, Wanderfische: Chancen und Herausforderungen"

Hintergrund
Diese Studie wird durchgeführt vom **Leibniz-Institut für Gewässerökologie und Binnenfischerei (IGB)**, Berlin. Der Leitspruch des IGB ist „Forschen für die Zukunft unserer Gewässer". Unsere Vision ist das Verständnis aller grundlegenden Prozesse in Gewässern und deren Lebensgemeinschaften. Unser Forschungswissen soll die Gesellschaft und Entscheidungsträger in die Lage versetzen, den globalen Umweltveränderungen zu begegnen und wasserbasierte Ressourcen und Ökosysteme zum Wohl von Mensch und Natur zu bewirtschaften und zu erhalten. Weitere Informationen erhalten Sie unter: http://www.igb-berlin.de/

Das Projekt wird durchgeführt im Rahmen des **EU Projektes IMPRESS**. IMPRESS ist ein innovatives Trainingsnetzwerk (ITN) der Marie Sklodowska-Curie-Aktionen, die vom EU-Forschungs- und Innovationsprogramm Horizon 2020 gefördert werden. Das Projekt vereint Experten aus verschiedenen Fachgebieten von der Molekularbiologie bis zu den Sozialwissenschaften und läuft von Januar 2015 bis Dezember 2018. Die Hauptziele von IMPRESS sind die Entwicklung innovativer Produktionsstrategien für die Wiedereinführung, Erhaltung und Bewirtschaftung gefährdeter Wanderfischarten (Atlantischer Lachs, Europäischer Aal, Störe) und die Ausbildung einer neuen Generation von Forschern mit multidisziplinären Fähigkeiten, die im Bereich der Fischereibiologie benötigt werden. Weitere Informationen erhalten Sie unter: http://www.impress-itn.eu/

Studienziel
Das Studienziel ist zu untersuchen, wo von einer gesellschaftlichen und politischen Perspektive her die Chancen und Herausforderungen für den Erhalt und die Wiedereinführung von gefährdeten Wanderfischarten liegen. Im Einzelnen sollen dafür die Wahrnehmung von Fischbesatz, der Beitrag von staatlich und privat (Angelvereine) getragenen Initiativen und Konflikte mit anderen Wassernutzungsarten untersucht werden. Dafür werden Interviews mit verschiedenen Akteuren und Gruppen durchgeführt, die in Deutschland für den Erhalt und die Wiederansiedlung von Wanderfischarten relevant sind. Die Ergebnisse werden mit ähnlichen Daten aus Norwegen und Wales, die im Jahr 2016 erhoben wurden, verglichen.

Was bedeutet die Teilnahme am Projekt?
Die Teilnahme an dieser Studie impliziert, dass Sie die Ziele dieser Forschung verstehen, und dass Ihre Teilnahme freiwillig ist. Sie erkennen auch an, dass alle Informationen, die Sie zur Verfügung stellen, einschließlich Ihrer Meinungen, Gedanken und Erfahrungen, anonym in der Zukunft in wissenschaftlichen Veröffentlichungen verwendet werden können.

Was passiert mit Ihren Informationen?
Das IGB als Forschungsinstitut befolgt alle Grundlagen des deutschen Datenschutzgesetzes sowie die Regeln der guten wissenschaftlichen Praxis der Deutschen Forschungsgemeinschaft. Alle Informationen und personenbezogenen Daten werden

vertraulich behandelt. Nur Forscher, die an diesem Projekt beteiligt sind, haben Zugang zu den Daten, die während dieses Projekts gesammelt wurden, einschließlich, aber nicht beschränkt auf Audio, schriftliche Materialien, Fotografien usw. Alle Daten, die in dieser Studie erhoben werden und eine Person als Studienteilnehmer identifizieren können, werden zu Ablauf des Projektes in 2018 anonymisiert und nach den deutschen Datensicherungsvorschriften gespeichert. Ab diesem Zeitpunkt wird es nicht mehr möglich sein, die Informationen und Daten einer Person zuzurechnen.

Freiwillige Teilnahme
Es ist freiwillig, an dieser Studie teilzunehmen, und Sie können jederzeit Ihre Einwilligung ohne Angabe von Gründen zurückzuziehen. Wenn Sie sich dazu entschließen, werden alle Ihre personenbezogenen Daten nach Ihren Wünschen anonymisiert oder gelöscht. Informationen, die Sie bis zu diesem Zeitpunkt bereitgestellt haben, werden nicht in zukünftigen Veröffentlichungen verwendet.

Wenn Sie Fragen zu Ihrer Teilnahme an dieser Studie haben, wenden Sie sich bitte an Sophia Kochalski unter kochalski@igb-berlin.de oder telefonisch unter +49 151 68 52 87 00

Bestätigungen durch den Studienteilnehmer
Ich erkläre mich hiermit freiwillig zur Teilnahme an der geplanten Untersuchung bereit. Ich bestätige, dass ich durch Frau Sophia Kochalski, wissenschaftliche Mitarbeiterin am IGB, mündlich aufgeklärt wurde. Ich habe alle schriftliche Information gelesen, ich fühle mich ausreichend informiert und habe verstanden, worum es geht. Mir wurde ausreichend Gelegenheit gegeben, Fragen zu stellen, die alle für mich ausreichend beantwortet wurden. Ich hatte genügend Zeit, mich zur Studienteilnahme zu entscheiden. Ich habe eine Kopie der Information und dieser unterschriebenen Einwilligungserklärung erhalten.

Datum Studienteilnehmer/in (Name gedruckt) Unterschrift

Datum Verantwortliche/r Forscher/in (Name gedruckt)
Unterschrift

Paper I

Human Ecology (2018) 46:449–459
https://doi.org/10.1007/s10745-018-0001-3

Hatching Knowledge: A Case Study on the Hybridization of Local Ecological Knowledge and Scientific Knowledge in Small-Scale Atlantic Salmon (*Salmo salar*) Cultivation in Norway

Hannah L. Harrison[1] · Stine Rybråten[2] · Øystein Aas[1,2]

Published online: 23 May 2018

Abstract
We investigate drivers of hybridization of local ecological knowledge (LEK) and scientific knowledge (SK) in small-scale Atlantic salmon (*Salmo salar*) fisheries in western Norway through a case study from the Ørsta River. We find three primary drivers of knowledge hybridization in local fishing groups as part of wild Atlantic salmon cultivation activities: facilitating intergenerational knowledge exchange, coping with regulatory change, and improving the perceived validity of local knowledge sets. We also identify three challenges to knowledge hybridization, and discuss how both drivers and challenges relate to once complementary SK and LEK sets that have diverged as SK has become more technical and complex. We examine the processes by which LEK and SK develop, evolve, and are used to facilitate wild salmon conservation in these fisheries and discuss the role hatcheries can play adapting and utilizing large-scale SK and salmon policy to the local environment through hybridization processes. We conclude with recommendations as to how reframing managerial views on hatcheries as facilitators of knowledge production and transfer may improve both the accessibility of SK to local communities and the integration of LEK into Norwegian wild salmon management.

Keywords Knowledge hybridization · Local ecological knowledge · Scientific knowledge · Norway · *Salmo salar* · Salmon cultivation

Introduction

Over the past 100 years, cultivation practices for wild Atlantic salmon (*Salmo salar*) and Pacific salmon (*Oncorhyncus*) have undergone significant changes. As studies of salmonids have developed into a well-established science (Motos and Wilson 2006), fisheries management and conservation practices have changed to reflect a more specialized and professionalized approach to salmonid management (Hind 2015), translating into a shift away from cultivation-as-conservation (Lorenzen *et al.* 2012). In Norway and elsewhere, this change has led to a debate over whose expertise counts and what knowledge types and traditions should inform salmon management and conservation. In particular, the divergence of local ecological knowledge (LEK) systems from scientific knowledge (SK) systems presents challenges to managers and local practitioners alike as to what knowledge should inform salmon cultivation management.

Local ecological knowledge has commonly been compared with, or found to contradict, scientific knowledge (Agrawal 1995; Brook and McLachlan 2005). LEK is broadly referred to as site-specific knowledge of the environment derived from experiences of a particular group of people (Berkes 2012). While often used interchangeably with the terms Indigenous Ecological Knowledge and Traditional Ecological Knowledge (Ellen *et al.* 2000), we here use LEK to refer to ecological experience-based knowledge since the subjects of this study are not indigenous nor is their knowledge derived from an ancient tradition. We use SK to refer to a more formal and explicit process of knowledge acquisition and transmission, striving for generalizations and replicability in space and time with the aim of achieving impersonal and unbiased results (Huntington *et al.* 2004; Degnbol 2005).

✉ Hannah L. Harrison
hannah.lee.harrison@nmbu.no

[1] Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences (NMBU), P.O. Box 5003, NO-1432 Ås, Norway

[2] Norwegian Institute for Nature Research (NINA), Vormstuguvegen 40, NO-2624 Lillehammer, Norway

Multiple studies point to significant differences between LEK and SK in terms of knowledge acquisition, forms of knowledge transmission, and degree of particularization, generalization, and verification of the knowledge involved (Ellen *et al.* 2000; Huntington *et al.* 2004; Mazzocchi 2006; Davis and Ruddle 2010; Berkes 2012, 2015). In recent decades, however, a growing recognition of complementarities in these knowledge sets has developed. Within academic circles as well as political initiatives, there is increasing acknowledgement of LEK as a credible and valid source of knowledge of ecological processes, and as valuable in contemporary natural resource management and decision-making (Brattland 2013; Tengö *et al.* 2014; Weber *et al.* 2014; Berkes 2015; Hind 2015). The multiple ways of categorizing 'knowledge' in studies advocating knowledge integration still leave room for confusion and divergent interpretations when it comes to the meaning of LEK and other knowledge terms, as well as their applicability in environmental management (Raymond *et al.* 2010).

Knowledge in Salmonid Management and Conservation: the Case of Salmonid Hatcheries

The artificial breeding and rearing of salmonids and subsequent stocking into natural watersheds was a starting point for science-based, modern fisheries management in most countries draining to the North Atlantic as well as the North Pacific oceans (Bottom 1997). This knowledge, coupled with clear policy objectives to increase yield and provide economic benefits, established a solid platform for cooperation between scientists and managers at the national or regional level and local practitioners, often with the aim of enabling local practitioners to manage hatcheries (Berg 1986).

In Norway, national freshwater fisheries authorities were directed to address "applied, practical inquiries" (Berg 1986: 80). In addition to a focus on hatcheries, fish ladder construction and tagging experiments were typical activities for managers and applied fisheries scientists until the 1970s (ibid.). New scientific knowledge emerging during the 1970s – 1980s indicated that salmonids have genetically distinct populations due to their homing behavior, leading to local adaptation to specific catchments (Ryman and Utter 1987; Garcia de Leaniz *et al.* 2007; Fraser *et al.* 2011). Knowledge on how salmon biodiversity can be threatened by the introduction of conspecifics from non-native origins led to regulations and guidelines recommending reduced stocking and transfer of salmonids (North Atlantic Salmon Conservation Organisation 2006). Despite these changes, stocking of salmon in natural watersheds continues to varying degrees, ranging from supplementation of natural stocks to reintroduction of extinct native populations (Lorenzen *et al.* 2012). Today, human propagation of salmonids remains a complicated issue for fisheries managers (Lorenzen *et al.* 2012; Sandström 2010).

The Norwegian Environment Agency (Miljødirektoratet), Norway's fish and wildlife management authority, is the primary agent for the aggregation, dissemination, and utilization of scientific knowledge for wild Atlantic salmon management, and for establishing regulations for cultivation hatcheries and issuing permissions to operate. The updated "Guidelines for stocking of anadromous salmonids" from 2014 (Norwegian Environment Agency 2014) provides directions for the cultivation and stocking of salmon in Norway. This is in line with the decentralized nature of Norwegian salmon management policy aimed at empowering regional officials such as county governors to implement broad policies at local scales, and local river owner organizations to manage and implement local-level decisions.

The guidelines (ibid.) put emphasis on avoiding stocking cultivated salmon when natural recruitment is sufficient, and prioritize habitat restoration over cultivation. If cultivation is approved, there are strict rules for the use of local, wild broodstock, which include genetic testing and broodstock collection protocols (ibid.). Optimizing genetic diversity of the broodstock (e.g., avoiding using few males), and avoiding domination of cultivated fish over the naturally recruited component through careful computation of so-called effective population size are key responsible cultivation objectives (Grant *et al.* 2017). The 2014 guidelines also prioritize stocking individuals at the earliest life stage possible (e.g., fertilized eggs over smolts) to minimize any selective impacts of the hatchery environment (Karlsson et al. 2016).

The focus of our research presented here is how small-scale, voluntarily operated salmon hatcheries are managed, and the knowledge sets that inform that management. After a long period of coherence between SK and LEK resulting in an unequivocally positive judgment of hatcheries, the last several decades have seen the evolution of SK toward a much more critical view on hatcheries and their role within conservation. LEK holders, meanwhile, maintain their original viewpoints that hatcheries can play an important role in allowing local salmon practitioners to engage in conservation and adapt large-scale SK and salmon policy to the local environment. The divergence of these respective viewpoints on hatcheries has left hatchery practitioners in a power struggle to maintain the validity and usefulness of their knowledge.

A Practice-Oriented Perspective on LEK and Knowledge Hybridization

LEK has long been a staple in locally managed fisheries, derived from and used through experiential, place-based knowledge about fishery environments. Positive working relationships between fishers and management authorities have been identified as fostering effective fisheries management (Motos and Wilson 2006; Hill *et al.* 2010; Mackinson *et al.* 2011). In Norway, the obligation of resource management authorities to

also emphasize LEK in otherwise scientifically-informed management is explicitly expressed in the Nature Diversity Act of 2009 (Section 8, Ministry of the Environment 2009). While describing LEK as a knowledge source supplementary to SK, the act does not include further details describing what weight LEK should be given in management considerations. The act is an example of the growing recognition of local people holding relevant knowledge to environmental management. Yet, specific guidelines and established practices for LEK inclusion in policy remain lacking. In part as a coping mechanism to address inclusion barriers, fishers are adapting their knowledge sets through both institutional and less formal processes (Thomas and Twyman 2004; Brattland 2013). As the knowledge that drives policy-making is fundamental to how natural resources are managed, understanding the factors that drive such knowledge adaptation processes (and what challenges may impede them) becomes important.

Recently, studies within the field of knowledge in general, and LEK in particular, have promoted a practice-oriented approach to knowledge (e.g., Ingold 2011; Lauer and Aswani 2009; Lauer and Matera 2016) that conceptualizes knowledge as dynamic and situated practices that cannot be contextually separated. From this perspective, knowledge is never fully stable and durable but "the ever-emergent product of a complex process" (Ingold 2011: 159). This approach further provides a theoretical basis for bridging the divide between LEK and SK, and thus abandons culturally specific hierarchies of knowledge, as both knowledge forms are conceptualized as practices (Lauer and Aswani 2009). Rather than relating differences between LEK and SK to comprehensiveness or validity, they are related to actual practices (ibid.). With the increasing distance between salmon knowledge produced through experience-based and scientific practices, active processes of inclusion or exclusion of "the other" knowledge also relates to issues of power. Inspired by the practice-oriented approach, acknowledging all knowledge as dynamic, hybrid, and heterogeneous, we pays particular attention to processes of explicit hybridization of LEK and SK for the purpose of developing more efficient, relevant, and locally adapted salmon hatchery practices.

Within environmental management literature, hybrid knowledge is often described as the new insights that evolve from integrating different knowledge types or through multi-, inter-, or trans-disciplinary research (Raymond *et al.* 2010). Following Murdoch and Clark's (1994) call for social science research focusing on knowledge 'hybridity,' several studies have addressed the topic (e.g., Forsyth 1996; Nygren 1999; Thomas and Twyman 2004; Reid *et al.* 2011). These researchers use the term 'hybrid knowledge' to refer to adapting local examples of knowledge to larger contexts through the mechanism of scientific knowledge. Most knowledge hybridization studies are focused on collection and integration of LEK into the existing science-based natural resource management frames, indicating a singular direction of knowledge flow (Fernandez-Gimenez 2000; Davis *et al.* 2004; Baird 2007; Bohensky and Maru 2011; Harrison 2013). Raymond *et al.* (2010), however, define hybrid knowledge as "knowledge types that have, in some way been integrated," generated through "a social learning process" (ibid: 1769), and as described by Murdoch and Clark (1994), 'hybridity' represents a category of knowledge in which multiple ways of knowing are "inextricably mixed." The processes that drive these forms of hybridization of fisher knowledge, however, remain largely unexplored. To that end, our research examines how LEK and SK are hybridized in the context of small-scale salmon hatcheries, and identifies and describes the drivers of knowledge hybridization in local fishers and hatchery groups.

Study Area and Methods

Our case study was conducted in Norway's western Sunnmøre district in the southernmost part of Møre og Romsdal county. We focus primarily on the Ørsta River and hatchery, with supporting information from hatcheries in the neighboring villages of Sæbø and Stranda. The Ørsta River is approximately 25 km in length and empties into the Ørsta fjord at the village of Ørsta (pop. ~ 6800). The Ørsta River, technically two rivers, the Follestaddalselva and the Åmdalselva, which join approximately 3 km from the river mouth, hosts a population of wild Atlantic salmon, the fishing rights for which are privately controlled by river property owners. The river owner organization (Ørstavassdraget Elveeigarlag) is responsible for the management of fishing access and regulation following national salmon-river management rules typical of European river ownership schemes. This includes, for instance, renting out fishing access/selling licenses, maintaining banks and shelters and surveillance (Stensland 2010). We chose the study area after we received anecdotal information that the hatchery groups in Sunnmøre were particularly "vocal" about their salmon rearing activities and resistant to changing hatchery regulations. Originally established to compensate for the loss of salmon spawning and rearing grounds due to river straightening in the 1950s, the Ørsta hatchery is run through a voluntary collaboration of the river owners association and the Ørsta hunting and fishing association.

We conducted semi-structured interviews in April and May of 2016 in the Ørsta region primarily within hatchery settings to solicit perspectives on LEK and SK use in salmon conservation in the hatchery context. As individual experiences vary (Neis *et al.* 1999), recruitment of interview participants was designed to capture a wide variety of individuals involved with voluntary hatchery work or regulation. Interviews were conducted with hatchery managers, both current and retired ($N = 2$), board members and chairpersons of the local hunting and fishing club and river owners association ($N = 6$), and

anglers involved in hatchery activities on a regular basis ($N = 3$). Additional interviews were conducted with neighboring hatchery operators ($N = 4$). We also sought interviews with county and national level fisheries managers within the Norwegian Environment Agency and County Governor (N = 4), and scientists working within fisheries ecology, biology, and genetics at predominant Norwegian research institutions such as the Norwegian Institute for Nature Research (NINA) and the Norwegian University of Science and Technology (NTNU) (N = 2). Additionally, we conducted substantial participatory observation during hatchery and fishing-related activities.

Recruitment was focused on informants identified by peers to be knowledgeable about the fishery and salmon cultivation recruited using the key informant method ("snowball") (Biernacki and Waldorf 1981) and recruitment saturation was reached when no new individuals were recommended. In total, 21 individuals participated in recorded interviews typically lasting between 60 and 90 min. All fishers interviewed were male, typically between 45 and 75 years old.

Interviews were conducted in English (the native/preferred language of the interviewers) except in some cases where translation from Norwegian to English was provided through a translator. Though most informants willingly communicated in English, all interview participants were given the option to use their native language if they preferred. Any non-English comments were later translated and included in interview transcriptions.

Interviews were guided by a written set of discussion prompts. As the interviews included multiple research topics beyond those in this article, the interview guide was designed to elicit perspectives on knowledge production, knowledge sharing, the evolution of knowledge over time, mechanisms of knowledge hybridization, and applications of knowledge (SK and LEK) within a hatchery context. Questions were open-ended and intended to engage interview participants to share additional information and stories. Thematic saturation was achieved when either all members of a stakeholder group had been interviewed, or when no new information was being produced.

Analysis of interviews and ethnographic field notes was an iterative process conducted using Atlas.ti version 7 (ATLAS.ti 1999), a qualitative analysis software. Interviews were first open coded for emerging themes through repeated reading and categorizing of data. Following this, the data were coded again to analyze the identified themes and elicit insights into specific knowledge-related topics. After more specific codes had been developed, a third round of analysis was conducted using memos. The most prevalent and thematically relevant codes were used as memo topics to develop theoretical explanations of the data. All coding and preliminary analysis were conducted by the first author. Secondary analysis and results were contributed to and discussed by all authors.

Results - Drivers of Knowledge Hybridization

Three primary drivers and three challenges to hybridizing LEK with SK knowledge emerged from our analysis:

Intergenerational Knowledge Exchange

Knowledge hybridization in fisher groups occurs through intergenerational knowledge exchange enhanced by the transition of responsibility and leadership from older fishers to younger generations. Intergenerational transitions of hatchery operations are slowly taking place as younger fishers with a contemporary science education take on operational responsibilities. Through shared practices, older generations are hybridizing their LEK with incoming SK, and younger generations are developing or learning LEK as an addition to their more generalized school scientific knowledge.

The transition of hatchery operations responsibility is considered essential, especially by the oldest members of the fishing groups who consider the additional paperwork required by the new stocking guidelines as something for "younger men." They also believe that new technologies to improve the quality of the cultivated fish are a positive change, even if challenging to learn and adopt. This reflects deeply held attitudes within fisher groups that they should try to produce salmon of the best possibly quality, typically described in terms of quantity, fitness, size, and similarity to a "wild type" salmon.

Younger fishers also reflect positively on the learning experience of intergenerational hatchery work. One of the youngest group members described working with older fishers, illustrating a hybridization of the SK within the general education of younger fishers with the LEK held by older fishers:

> Sometimes I learn something from them and the next day they are asking me something and I [teach] something to them. Most of the older [men] are very kind. They also appreciate [that] the younger generation are coming up and see what they are doing and learning by what they have done, these last centuries. It's quite interesting. (E. Johansen, May 10, 2016)[1] [sic throughout]

Another example of hybridization takes place within particular hatchery operations. For example, the flow rate of the hatchery's incoming water was for many years determined by the sound of water moving through the pipes, a technique developed by the oldest hatchery manager over a half century of listening (T. Mortensen, Personal Communication, May 6, 2016). The new and relatively younger hatchery manager has now installed an electronic water flow gauge providing a more

[1] All names attributed to quotes have been fictionalized to preserve anonymity of research participants.

accurate measuring system. He nevertheless checks the gauge readings, counting seconds on his watch while water fills a pre-measured hand-held container. Through these adaptations, the new hatchery manager is hybridizing LEK with more technical SK techniques in an effort to improve the quality of hatchery operations as he adapts to his role of hatchery manager.

Coping with Change

Knowledge hybridization allows fishers to cope with policy changes requiring adoption of new methods in their hatchery activities. This is evident in the broodstock harvest, an annual activity to obtain reproductive material for the hatchery.

Each year, members of the river owners association and the Ørsta hunting and fishing group together harvest salmon broodstock from which they later strip eggs and milt. Fishers rely upon experience to spot incoming salmon schools within the tidal river estuary, where they collect broodstock with a small seine net from a boat. This requires precise timing to seine the fish and transfer them into large plastic holding tanks. The skills and knowledge required to perform the labor-intensive broodstock harvest are derived from many years of practice, and refined through interactions with researchers and experts within the aquaculture industry.

The location of the broodstock harvest has been controversial in recent years due to changes in regulations from the County Governor. According to the 2014 stocking guidelines, broodstock must originate from the watershed/river to be stocked (Norwegian Environment Agency 2014). Within this scope, Ørsta's County Governor has directed that broodstock must be collected from the same location where stocking takes place. This interpretation requires that broodstock be harvested by rod in the upper Follestaddal River, the branch most affected by straightening. Fishers say these requirements place undue stress on the fish, which fight to the point of exhaustion when caught with a rod, making them less likely to survive captivity. Furthermore, the fish must survive a car journey of approximately 10 km from the river to the tanks. Here, the fish reside until DNA testing is complete and the genetic material can be harvested if deemed suitable for hatchery use (as required by the stocking guidelines).

Fishers agree that it would take many skilled fishermen fishing in Follestaddalen for several days to catch enough broodstock to supply the hatchery, a challenging task for a voluntary force. Their primarily concern, however, is that the new harvest location threatens the welfare of the broodstock:

> Yeah, I think it's better for the fish to take it with a net… because then the fish are healthy and it's not tired, and it's not so stressed that they die [as when] we have to go up in the river and fish it and then transport it in 10km in a truck, and put it in our [tanks]. If we can use the net… and then put it right in the pool, we don't have to touch it with our hands…And then you also have a smaller risk that the fish can be affected, get sick. I think the best ways to take it [is] all the way down by the fjord. And use nets and gloves… instead of using a rod and a lure or something. The fish is much more healthier when you do it that way. (E. Johansen, May 10, 2016)

The Ørsta area fishers have voiced these concerns to the County Governor who, in light of this local information has allowed an adjustment to the requirements. A year-to-year agreement about broodstock harvest location accounts for real-time environmental conditions, fish return, and other seasonal changes that are relevant to the operation of the Ørsta hatchery. Simultaneously, fishers have experimented with harvesting broodstock in the Follestaddalen area and are continuously trying to improve the quality of rod-caught broodstock by reducing fish stress during harvest and improving transportation conditions.

This development illustrates how fishers are taking new information about broodstock harvesting and adapting their own practices to maximize beneficial outcomes through both advocating for their own knowledge of fish welfare and compromising between SK-based policies and their own LEK-driven practices and needs, i.e., hybridizing their knowledge in order to cope with policy changes.

Maintaining Relevance

As noted earlier, the use of hatcheries as a conservation tool for wild Atlantic salmon is contentious, characterized by an ongoing debate over the value and efficacy of stocking programs (Brannon *et al*. 2004; Araki and Schmid 2010). Consequently, knowledge hybridization is also driven by fishers' desire to remain relevant and active within this debate.

Fishers recognize that hatchery management policies are founded upon scientific knowledge. In response, they have sought to improve their own SK expertise and develop SK-type practices in order to enhance the legitimacy of their voice in the hatchery debate. For example, fishers have learned new techniques that allow them to participate in DNA sample collection and preservation, and to perform factorial cross breeding. Similarly, fishers reported reading scientific articles and reports produced by Norway's premier fisheries research institutions (NINA,[2] NTNU[3]), and expressed strong interest in partnering with scientists to study their local and neighboring salmon populations.

[2] Norwegian Institute for Nature Research, Online: https://www.nina.no/
[3] Norwegian University of Science and Technology, Online: https://www.ntnu.edu/

For example, fishers recognize the need to monitor the results (and by extension, efficacy) of their stocking activities, a key issue of contention in the hatchery debate, and have developed a monitoring system based on SK methods and LEK. Each October fishers walk a 3 km stretch of the Follestaddalen River above the straightened section where, using waterproof cameras, they film below the surface to count adult spawners and groups of juveniles and evaluate the condition of the river-bed.

It is unclear, however, if fishers' efforts to produce fit salmon and monitor the effectiveness of the hatchery are improving the legitimacy of their hatchery activities in the eyes of fisheries managers. Though fishers desire to participate in scientific studies, they also expressed frustration with participating in research and then never hearing from researchers again. Notably, they desire to learn the outcomes of research in which they participate, and hope to be able to apply findings towards improving their own hatchery and stocking efforts.

Challenges to Knowledge Hybridization

Along with the drivers of knowledge hybridization are several challenges that impede, de-incentivize, or dissuade fishers from incorporating SK into their own LEK:

Inadequate Channels and Perceptions of Validity

The Norwegian Environment Agency includes local stakeholder perspectives in policy changes by holding public comment or consultation periods. Though some activities by the agency require a public comment period, the 2014 stocking guideline changes did not. While the Norwegian Environment Agency was under no obligation to solicit comments for this case, it recognized the value of local input from those groups operating voluntary hatcheries, and managers chose to provide a 90-day window for public comment:

> Some of those [consultation] processes are mandatory for us. If we make a new provision or something we have to have a public hearing of at least three months hearing period. For guidelines it's more [that] we can, and we usually do that, but it's not mandatory by law. We could develop guidelines without a public hearing necessarily, because it's not legislation. But usually we do [have the public comment period]. (A. Lund, April 26, 2016)

Even with the opportunity for LEK holders to participate in the public comment process, the advice and knowledge used for the agency's eventual drafting of the stocking guidelines (Karlsson *et al.* 2016) emerged primarily from an expert advisory group (A. Lund, Personal Communication, April 25, 2016). National-level managers are responsible for the decision as to who should or should not be included in the expert group. From our interview data it appears that recruitment to the expert group is based on managerial perceptions of what expertise is necessary and valid in making the decisions in question.

For example, the expert advisory group did include two individuals – a hydropower stocking expert from a major Norwegian electricity company[4] and a stocking expert representative from the national veterinary institute – whose expertise managers described as "practical" knowledge (A. Lund, Personal Communication, April 25, 2016). While these ways of knowing are not, in themselves, representative of LEK, they demonstrate an interest at the national level to include the "on the ground, practical" perspective on hatchery and stocking operations. Nonetheless, no voluntary hatchery experts were included in the expert group.

From this, it is evident that managers and fishers view the validity and value of LEK differently. Fishers strongly believe that their experiences and years of accumulated knowledge are valuable and more relevant to local conditions than may be the case for large-scale, more generalized research. As one angler and hatchery operator explained (via interpreter):

> [I] don't entirely trust the scientists because all the rivers are different, and [I] feel that they do not have the specifics as such from [our river]. So when a new requirement shows up, it's not necessarily the best for our river. (B. Thorkild, May 10, 2016)

When it comes to local specifics, fishers view their knowledge more relevant to actual conditions, based within everyday observations of "what is actually happening" and inclusive of SK-based information.

Expertise and Trust

Comments about the important nature of trust between local fishers and outside groups, particularly fisheries managers and fisheries scientists, arose frequently during interviews. In particular, fishers find the knowledge sources informing fisheries management decisions highly relevant to the amount of trust they later place in those decisions. In terms of their own LEK,

[4] In Norway, hydropower installations that impede or otherwise damage migratory routes or spawning and rearing habitat for fish are, in most cases, legally obligated to perform compensatory stocking to the affected waters.

fishers reported that they do not believe that management officials want their knowledge, as the following comments illustrate:

> We are very seldom asked, but told what to do. (P. Larsen, May 3, 2016)
> I find it somewhat hard for these officials to understand the value of the local knowledge. Sometimes it kind of feels like they feel they know it better, learn it out of a book or whatnot. And I'm sure that is valuable of course, but local knowledge is very important. (R. Pedersen, May 12, 2016)

This latter comment represents a common fisher perception of a hierarchy of access and power associated with access, where opportunity to contribute meaningful information and perspectives to policy-making processes is most available to those stakeholder groups whose knowledge is most similar to the knowledge base already in play. The majority of Ørsta fishers believe that fisheries scientists and managers currently hold that position. One university researcher described this perception as, in part, a communication problem. Commenting on the historical transition from positive to negative managerial views on stocking, he noted:

> Of course, scientists, managers, we are not always very good at addressing public– especially when it comes to new principles and so on. In these areas what we are saying is… that your father, your grandfather, even your [great] grandfather was wrong. In the 1920s we had plenty of hatcheries. So we are actually going into a generation and saying that what you did was wrong, you know. Especially when you come to rural areas, it's a hard message to get. (O. Muslat, April 25, 2016)

This comment illuminates the challenges of communicating change in SK to stakeholders, especially when that knowledge comes with requirements to change practices that may contradict past communications. It also hints at the way hatchery-related LEK and SK once related to one another and cohered around mutual understandings and objectives, but now maintain disparate positions in the hatchery debate.

Challenges of Scale

Both fishers and fisheries managers face challenges of scale when it comes to the relevance of knowledge sets and application of policies. As fishers emphasize the importance of LEK, and the SK that they may integrate into their LEK, their knowledge practices are experiential and place-based, producing knowledge and perspectives most applicable to their local environment. This creates challenges in making their LEK-derived observations and concerns relevant on a national scale, and in incorporating broad, generalized, and multidisciplinary SK into their local hatchery activities.

National and county level managers are tasked with creating policies and regulations that are applicable at broad temporal and spatial scales. Therefore, it is inherently difficult for them to manage for the specific needs of each local community. Additionally, there is the sheer logistical challenge of relatively few managers responding to the input of many individual stakeholders across more than 400 salmon-bearing rivers in Norway.

Currently, the somewhat decentralized nature of Norwegian salmon management policy aims to empower local stakeholders and delegate decisions to local river owner organizations, thereby providing opportunities for regulatory adaption to local conditions. As one manager pointed out:

> If you go back in history sort of, 10, 20, 30 years, [there] was much less involvement of the general public or stakeholders in all sides of fisheries management. Everything was decided by a very few people. The whole salmon management has developed from a very centralized sort of management to more and more local management. Where river owners have got a much bigger possibility of influencing the management and actually deciding how their river is managed in every sense, you know, from fishing regulations to stocking. (R. Haussman, April 26, 2016)

Still, locals are challenged to fit the needs of their specific conditions into nationally (or internationally)-oriented policies and regulatory frameworks and, conversely, apply broad-scale SK to localized conditions.

Discussion

Three primary drivers of knowledge hybridization were identified in the Ørsta River hatchery case: facilitating intergenerational knowledge exchange, coping with regulatory change, and improving the functionality and validity of local ecological knowledge. Conversely, several challenges that impeded or prevented hybridization also emerged: perceptions of validity, inadequate channels for knowledge sharing, challenges of power and trust, and challenges of scale. Fishers are hybridizing their knowledge out of the necessity to both improve the quality of hatchery fish and actively participate in the debate over voluntary hatcheries as conservation tools.

Intergenerational knowledge exchange fosters the development and sharing of LEK while integrating the increasingly in-depth formal education of younger generations of fishers.

The prevalence of intergenerational and peer-to-peer knowledge sharing processes within this case indicates its importance in maintaining group coherence. This knowledge exchange within the fisheries' groups also includes integration of SK, at varying degrees, depending on the issues at hand. Fishers desire to remain both practically and socially relevant in their work and in how they are perceived by managers and the public. In practical terms, fishers are interested in producing high quality hatchery-reared fish, and make deliberate trade-offs in cost, effort, and other variables in order to achieve this goal (McShane *et al.* 2011; Camp *et al*. 2017).

For example, the decision about how long to keep fish in the hatchery before stocking them into the Ørsta River is informed by combined LEK and SK of water temperature effects on developing fish embryos, environmental events typical to the Ørsta River, and the condition of ideal stocking locations. It is also informed by SK of the impacts on physiological and behavioral fitness of the salmon from the hatchery environment (McDonald *et al.* 1998), the effects of feeding juveniles with aquaculture-grade food (Thodesen *et al.* 1999), and the potential survival advantages of stocking larger, stronger juveniles (Letcher and Terrick 2001). Combined with intergenerational (re)production of knowledge, hybridizing LEK with SK allows fishers to make more informed trade-offs in their stocking practices.

Fishers are actively concerned with public perceptions of voluntary hatcheries (see also Meffe 1992) and seek to remain relevant and engaged in salmon conservation debates. They want to be taken seriously by county and national-level decision makers, and so have adapted their advocacy and communication styles to fit the predominant scientific arguments about stocking. For example, broodstock selection and harvest location have been major points of contention, and fishers have shaped their arguments to be concerned with best practices in maintaining genetic diversity among broodstock and their welfare during harvest.

Simultaneously, fishers also leverage their LEK to counter-argue issues where SK and their own LEK contradict one another or are otherwise incompatible. For example, SK-informed rules about broodstock harvest location and the desired genetic composition of the Ørsta River salmon population are rebutted with arguments that these rules do not adequately reflect the conditions or meet the needs of the local river environment. In this case, fishers argue that their LEK is more appropriate in guiding local management decisions. This example demonstrates that the processes of hybridization include not only the production of new knowledge, but also the selection of knowledge considered most useful to the knowledge holder within particular contexts and for particular purposes.

As compared to fishers, our study did not find substantial evidence that fisheries managers are hybridizing their knowledge (bringing LEK into SK). This is likely due to many of the same challenges that limit knowledge hybridization for fishers. But while hybridization itself may not be taking place amongst managers, there is evidence that LEK is viewed, if not well-utilized, as a potentially valuable source of information and input (Holm 2003). Managers demonstrated attempts to be inclusive of stakeholder knowledge when designing policy, such as in the case of the non-mandatory public comment period in the 2014 stocking guideline development. From interviews with managers, we know that engaging with dissatisfied stakeholders is time-consuming as well as expensive, and so managers are motivated to try to satisfy stakeholder groups when creating new policy. This approach is driven in part by practical considerations given that stakeholders are unlikely to voluntarily comply with rules that do not reflect their own perceptions (Degnbol 2005).

However, effectively engaging stakeholders is challenging (Rosten 2017), particularly for purposes of including LEK perspectives. In Norway, formal channels for such inclusion are limited and the opportunities that do exist are considered insufficient and ineffective by the fishers in this study. The public comment period, along with occasional visits to stakeholder areas and topic-driven meetings, represent the extent of institutionalized inclusion of local stakeholder perspectives into policy-making processes. Aside from this, fisheries managers at the county and national levels depend upon fishers to communicate through email, attendance at public meetings, and submission of solicited comments (A. Olsen, Personal communication, April 26, 2016). However, there are few agency staff in comparison to the many fishers and fishing groups throughout Norway, and there are practical limitations to their ability to engage stakeholders leading to inadequate opportunities for local fishers to meaningfully include their LEK in Norwegian salmon management. Together with the hegemonic role of SK within the current knowledge-based salmon management (Hind 2015), these insufficient opportunities create an inherent hierarchy between LEK and SK holders and their respective power to contribute to (salmon) cultivation regulations.

It is, however, important to keep in mind that attention to LEK inclusion in salmon management is still relatively new in Norway and thus processes of inclusion are still developing. Some recent Norwegian projects such as The Norwegian Reference Fleet (Bjørkan 2011) hold promise in offering fisheries information from a broad range of knowledge sources. Meanwhile, knowledge hybridization functions as a coping mechanism among hatchery operators, where improving their literacy in SK serves as a strategy to gain validity and an access point for LEK contributions to salmon management.

From a broader perspective, the process of knowledge hybridization also acts as a reversal of the disassociation of SK from LEK as complementary knowledge systems (Mackinson and Nottestad 1998). While our study is focused on identifying and describing the drivers and challenges to knowledge

hybridization, it also underscores the power dynamics involved when different knowledge sets are considered contradictory rather than complementary, and illustrates processes by which these power dynamics are maintained. Our results show that both LEK and SK are useful and necessary for fishers to perform conservation via hatcheries, yet the 2014 policy changes reflect the prioritization and institutional power of SK over LEK. The formalized scientific institutions that produce and empower SK, combined with positivistic traditions in fisheries science (Hind 2015), place a high premium on "best available science" (Charnley *et al*. 2017) when crafting policy. The processes through which LEK is produced, however, do not follow correspondingly systematic, formalizing methodologies as applied in the production of SK (Bjørkan 2011). Consequently, LEK does not fit the frame of formal, authorized knowledge upon which salmon management is founded and further separates LEK from knowledge with which salmon managers are familiar. While potentially relevant, reliable, and valid, LEK is seldom organized in a way that makes the knowledge directly transferable for management purposes (ibid.).

It is not surprising that though some authors have argued for the value of LEK and its relevance to SK-dominated salmon management (Forsyth 1996; Silvano and Valbo-Jørgensen 2008), in the current hatchery context LEK is clearly viewed as a secondary means by which salmon management should be informed. The drivers of hybridization identified in this study demonstrate how those whose knowledge is in a position of lesser power use hybridization as a means of reclaiming and reasserting the value of their knowledge. In this way, they reclaim their credibility as knowledge holders. Looking forward, the processes of hybridization may offer new ways to integrate fishers' knowledge into other knowledge cultures, an effort within knowledge disciplines that has yet to be fully successful (Hind 2015). In doing so, the partial knowledge of hatcheries currently produced by both LEK and SK may be made more complete and useful to local practitioners and broad scale managers. Local hatcheries thus appear to be an important bridge between LEK practices and the highly desired improvements to cultivation made possible through SK processes.

Understood through a practice-oriented approach to knowledge, hatcheries are facilitators of the reproduction of knowledge, where both LEK and SK are acknowledged and included. This finding leads to a new question as to whether, within national and international salmon management, hatcheries can play a role in improving local conservation measures rather than being viewed as a cause of conservation harm to wild salmon stocks. We argue that this new view is possible if hatcheries are considered facilities for localized salmon knowledge production where insights gained from experience-based as well as scientific practices are integrated for the purpose of developing more effective and locally appropriate salmon hatchery practices. Furthermore, through growing insights into scientific methods and argumentation, fishers not only increase their ability to discover weaknesses in scientific recommendations (Bjørkan 2011), but may also develop new ways of gathering and presenting their experience-based knowledge, thereby making it more accessible to managers. Simultaneously, managers would need to develop new ways for recognizing and acknowledging insights gained from other processes beyond the scientific (Joks and Law 2016). Our results show positive tendencies when it comes to a managerial recognition of the value of local stakeholder involvement. By further developing hatcheries as a social learning arena for knowledge reproduction with a more lateral approach to LEK and SK, they may enhance information transmission and facilitate knowledge processes from which important managerial lessons can be learned.

Conclusion

Fishers interviewed in our case study possess a rich variety of LEK that enables them to enact conservation activities for salmon in the Ørsta River, especially in the context of their voluntarily-operated hatchery. Fisher knowledge sets are built upon lived experiences and a robust network of knowledge sharing within and between local fishing groups, across generations. These fishers are operating within a formal management system primarily based upon SK and developed through empirical and scientific inquiry within Norwegian and international scientific and regulatory institutions. While SK and LEK once represented complementary knowledge in the context of salmon cultivation, in recent decades they have evolved in disparate directions. For multiple reasons, local fishers use hatcheries as facilitators of knowledge hybridization and knowledge production processes as they struggle at the interface and uneven power dynamics of LEK and SK.

This study identifies three drivers of knowledge hybridization within fisher groups in the Ørsta hatchery: to facilitate intergenerational knowledge exchange, to cope with changing hatchery regulations, and to maintain social and practical relevance and improve fishers' role as essential knowledge holders within Norwegian salmon management. Three challenges to hybridization are also identified, indicating that while hybridization may be an effective tool for knowledge integration and hatchery operation in some aspects, it is not a replacement for the integration of multiple knowledge systems into a management framework.

Fisheries management systems that better integrate multiple knowledge systems may result in policies, regulations, and scientific understandings of salmon conservation that are more reflective of and adaptable to the local level, thereby reducing conflict over the adoption process. Similarly, understanding the means by which LEK are being used to solve local

problems could better inform managers as to how broad policies may be made more adaptable to local contexts. We recommend that hatcheries be reframed as management tools for information transmission and facilitators of knowledge reproduction, where both LEK and SK are acknowledged and included. Examples of LEK-integrated fisheries management systems abound in fisheries literature and could be adapted to a Norwegian model (Mackinson and Nottestad 1998; Mahon *et al.* 2003; Gilchrist *et al.* 2005; Baird 2007).

As the use of salmon hatcheries in Norway, particularly voluntary hatcheries, becomes more contentious, research into the drivers of conflict and the role that knowledge sets play should be pursued. Just as importantly, the knowledge used to inform perspectives and research will have a significant influence over the degree to which hatcheries may be part of a comprehensive salmon conservation strategy that has local as well as national and possibly international legitimacy.

Acknowledgements The authors wish to thank Sophia Kochalski for her participation in fieldwork and data collection, and Suzanne Haines for proofreading services and corrections to the manuscript. Thanks also to N.O. Brekke for his translation services and proofreading, and to NINA staff for their transcription and translation help. The authors also thank the Norwegian Environmental Agency, the County Governor's office, and the fishers of Sunnmøre who made this study possible.

Funding This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie project IMPRESS (GA No 642893) and from the Norwegian Miljødirektoratet (Reference No 16S2D396).

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors beyond that which is described in the text. All data collected and used in this study was collected in accordance with the Norwegian Centre for Research Data Authority standard via project #47203.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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Paper II

Title: Disputing nature in the Anthropocene: technology as friend and foe in the struggle to conserve wild Atlantic salmon *(Salmo salar)*

Authors: Hannah L. Harrison[1], Janine Hauer[2], Jonas Ø. Nielsen[2], Øystein Aas[1 3]

1. Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Nature Management (MINA), Universitetstunet 3, 1430 Ås, Norway

2. Humboldt-Universität zu Berlin, IRI THESys and The Department of Geography, Unter den Linden 6, D-10099 Berlin, Germany

3. Norwegian Institute for Nature Research (NINA), Vormstuguvegen 40, NO-2624 Lillehammer, Norway

Abstract:

The ‘Anthropocene’, simply put, is characterized by the recognition that ‘natural’ processes are inextricably entwined with human influence. Against this backdrop, managing ‘natural’ resources needs to be fundamentally rethought as balancing human-nature entanglements continues to challenges policy makers and conservation managers obligated toward politically and scientifically feasible measures. A closer look at wild Atlantic salmon management in Europe reveals dynamic shifts over the past two centuries, particularly with regard to how hatcheries are used as conservation tools. In this paper, we use case studies on Norwegian and Welsh wild salmon cultivation practices to trace these shifts in conservation and management practices. We frame our analysis through a lens of shifting conceptualizations of naturalness and human-salmon relationships. Starting at the multinational level and then moving to ground-level cases, we show how naturalness is conceptualized by managers and hatchery stakeholders, and how those perceptions play into definitions of desired outcomes for wild salmon conservation as well as the strategies and technologies implemented to achieve these conservation goals. We highlight two paradoxes that are illuminated by the disputes and shifting perceptions surrounding salmon hatcheries. First, we show that hatcheries are no longer perceived as appropriate tools to increase wild salmon populations. Rather, hatchery technologies are being withdrawn, limited, or transformed, often resulting in local-level controversy. Paradoxically, these changes are, in themselves highly technical processes involving genomic testing and big data inventories. Second, despite the recognition of ever more complex human-nature entanglements, the practical outcomes for salmon conservation are oriented towards standardized testability and manageability and limiting certain human-salmon interactions, and while some technologies are instrumental, others are disregarded. As a result, those techno-social communities organized around hatchery technologies are at risk of being removed or otherwise excluded from their preferred conservation activities.

Introduction - The disputed nature of hatchery salmon

Atlantic salmon (*Salmo salar*) hatcheries were originally multi-purpose tools intended to re-enact or repair existing salmon habitat and spawning grounds after (usually) anthropogenic events, and improve upon the perceived inefficiencies of nature by offering fishers an opportunity to pursue greater numbers of prey (Bottom 1997). Hatcheries thus represent a technological approach to approximating and, in some cases, improving upon wild and natural salmon habitats to compensate for human-caused damage (Cronon 1995). Combined with an angler preference for stocking (Arlinghaus and Mehner 2005; Stensland 2012), these dual purposes made hatcheries a popular management tool in Europe and North American during the 19th and 20th centuries (Berg 1986; Wolter 2015; Bottom 1997).

However, in the last three decades, debates of what a 'good' salmon is, and how that quality should be defined in conservation, have changed. Whereas hatcheries have previously been viewed as adequate tools to compensate for destructive human impacts on salmon environments, today they are increasingly considered producers of an unnatural salmon: a non-wild or "hatchery-type" fish (North Atlantic Salmon Conservation Organisation 2017). Previously, it was sufficient for hatchery-produced fish to be qualitatively wild; to look, taste and behave like a wild salmon (Scarce 2000). Now, a growing body of research suggests that when stocked into naturally recruiting populations, hatchery-reared fish can produce undesirable outcomes for wild stocks such as disease transmission (Hewlett, Snow, and Britton 2009), negative competitive interactions with wild progeny and reduction of effective wild population size (Chilcote, Goodson, and Falcy 2011), and negative impacts on the genetic integrity and diversity of local genetic populations and subpopulations (Laikre et al. 2010). This improved scientific understanding of salmon cultivation has turned the tide of scientific and, more recently, managerial opinion toward requiring genetically 'natural' instead of qualitative 'natural' salmon, a change that has been met with opposition in some local salmon cultivation communities.

This paper introduces two cases and sketches the historical development of hatcheries in Wales and Norway with regard to how human-nature relationships were conceptualized and facilitated over time. We ask: how do stakeholder groups conceptualize naturalness and construct naturalness in the context of salmon hatcheries? Based on these understandings, how are hatchery technologies being understood and (dis)allowed as tools within salmon conservation, and do these technological thresholds of evaluating salmon 'naturalness' impact the inclusion of salmon conservation stakeholders in these cases? Finally, we grapple with the

effect of changing understandings of naturalness and how they are used to arbitrate appropriate conservation technologies for the techno-social communities in these cases.

The term 'natural' and its derivatives (i.e., naturalness, etc.) are popularly used across disciplines to describe desirable natural resource management objectives (Scarce 2000; Haydon 1997), often alluding to a state of nature free of human impacts, influence, or presence (Hendee, Stankey, and Lucas 1978). Though subject to manifold definitions, the shifts we trace in this study concern how relationships between humans and, in this case, salmon, are considered and permitted. Whereas human intervention in salmon lives via hatcheries has long been a politically and managerially prioritized and popular means of compensating for destructive human impacts on salmon habitats, it has increasingly, among certain stakeholders, become a threat to the composition of nature itself. Improved scientific understandings of salmon biology, physiology, ecology, and genetics have created new boundaries for acceptable salmon genotypes and phenotypes, the definition of which are heavily science and technology dependent and represent ideals of wildness situated within "conservationist culture" and manifested by technology (Milton 2000).

Recent guidelines from the intergovernmental North Atlantic Salmon Conservation Organization (NASCO) reflect that managers of salmon stocking projects and scientists view genetic and ecological 'naturalness' as a top management priority (North Atlantic Salmon Conservation Organisation 2017). NASCO is an intergovernmental organization based on a shared treaty with direct influence over its member states' salmon management policies. Its objectives are to "conserve, restore, enhance and rationally manage Atlantic salmon through international cooperation taking account of the best available scientific information".[1] Here, concepts of 'naturalness' are linked closely with scientific knowledge about salmon genetics, ecology, and reproduction, and are paired with discussions about which technologies are appropriate for enacting salmon conservation toward 'wild' salmon genotypes. As these perceptions are intermingled with a growing scientific consensus on the potential harms of stocking, policy makers and managers at the local, national, and international level have turned away from hatcheries due to concerns that they produce salmon with reduced genetic and behavioral fitness than wild conspecifics. In practice, this shift has resulted in stricter stocking guidelines, and in some cases the introduction of controversial restrictions and closures of existing stocking projects (Harrison et al. 2018; Harrison, Rybråten, and Aas 2018). Our analysis will show how the definitions of wild, natural, or 'good' ('right') salmon are situated across stakeholder groups, and how their contrasting positions may influence

[1] From NASCO website ("About NASCO"); www.nasco.int/about.html

disagreement about the use of salmon hatcheries in conservation. Secondly, our analysis sheds light on the specific roles that technology performs in salmon conservation and management and highlights how technology is seen as both cause and solution for challenges to wild salmon conservation.

We embed our analysis of these shifts in the broader discussions of the Anthropocene. The Anthropocene is characterized by the recognition that 'natural' processes – that once occurred independently from human influences – are inextricably entwined with human life. Against this backdrop, managing natural resources should include nuanced consideration of human-nature entanglements and, as in these cases, the entwining of conservation technologies with pre-existing social-ecological systems (Ban et al. 2013; Berkes, Colding, and Folke 2008). Effectively managing human-nature entanglements poses a challenge to policy makers and conservation managers who must balance the prioritization of biodiversity and ecosystem management with stakeholder needs and economic and social constraints. In doing so, we look at how these challenges are being dealt with through more testable and definable means of evaluating nature, and how these means of nature definition rely upon increasingly complex technologies.

We examine the tension occurring within both cases between the shared recognition of complex human-nature entanglements in salmon management and the practical need to implement measures of governing conservation goals. In these, we are interested in understanding how hatchery technologies and their associated techno-social systems are dealt within in the complex salmon systems. We conclude by identifying the multiple ways in which human-salmon entanglements are thought of and managed in both cases, particularly through the assessment and institutionalization of appropriate and inappropriate salmon conservation technologies. We argue that though managing and reducing complexity are necessary in salmon conservation, a careful consideration of situated approaches and ontological positioning on concepts such as nature and naturalness are incorporated into advising on natural resource management issues.

Methods

This study draws on fieldwork conducted among and within salmon cultivation settings in April, May, and June of 2016 in Sunnmøre, Norway and the Wye Valley, Wales.[2] The main methods used during fieldwork were semi-structured interviews with fisheries managers,

[2] The study is part of a larger research program on small-scale salmon hatcheries (See Harrison et al. 2018a and 2018b).

fisheries scientists from predominant Norwegian and Welsh research institutes (NINA[3], NTNU[4], NRW[5]), river owners, angling society members and club leaders, hatchery operators and volunteers, and casual anglers unassociated with clubs or hatchery operations. The first author also engaged in participant observation to gain important insights into the practices and personal experiences of hatchery operators, anglers, and managers. Participant observation was conducted in hatcheries (Norway only) and river monitoring/observation work. Site visits ('go-alongs') (Kusenbach 2003) were also made to closed hatcheries (Wales only), important angling locations, or other sites of salmon conservation interest. These visits were conducted in order to gain a broad picture of the salmonscapes in these cases and to inform the researchers of the nature of locations or activities described in interviews, as well as to build rapport with interview participants and allow space for casual, informal conversations about research topics (Evans and Jones 2011).

Interview participants were identified using the key informant method (Marshall 1996) as well as through purposive sampling (Palys 2008) in an effort to interview those knowledge holders directly engaged with hatchery activities. In total, interviews with 45 individuals were conducted across both cases. All interviews were conducted in English and either with individuals or in small groups if desired by the interviewee. Interviews typically lasted between 60 – 180 minutes and were recorded and later transcribed. Questions were intentionally opened-ended and interview participants were encouraged to share relevant information and stories to allow the introduction of topics not previously anticipated by the data collection team.

As Norwegian interview participants gave the interview using English as a second language, we did not take literally terms like "nature", "naturalness", "wild" and like terminology unless specified by the interview participant. Rather, we analyzed statements referencing a desired state of salmon characteristics, paying close attention to the context of comments. Thus, conceptualizations of nature emerged from the interview data as descriptions, which we then analytically term and categorize as discussions of nature and naturalness. We compared interview findings to a similar textual analysis on guiding policy documents and stocking guidelines from international and national-level publications.

The relevant policy documents that frame the work of the hatchery operators and inform the broader debates amongst stakeholders were analyzed. Specifically, we analyzed

[3] Norwegian Institute for Nature Research
[4] Norwegian University of Science and Technology
[5] Natural Resources Wales

the 2017 Report of a Theme-based Special Session entitled "Understanding the risks and benefits of hatchery and stocking activities to wild Atlantic salmon populations" (North Atlantic Salmon Conservation Organisation 2017), which was written as part of a NASCO Theme-based Special Sessions on stocking. This document was selected to form an internationally-scoped view of how scientific and managerial communities now view salmon hatcheries and stocking practices in Norway and Wales because it frames and informs all hatchery-related rules and regulations in both cases top- down. This report was analyzed through a naturalness lens by attending to how language surrounding naturalness conceptualizations was used (e.g., "wild", "natural", "artificial", etc.) by the report authors (some of whom are also managers within these cases), and the lines of argument created in each report to support or reject stocking practices or offer guidance toward 'naturalizing' hatchery practices.

All data were analyzed using qualitative data analysis software packages Atlas.Ti (*ATLAS.Ti* (version 7.5.10) 1999; Paulus and Lester 2016) and NVivo (*NVivo Qualitative Data Analysis Software* (version 10) 2012). Data was first analyzed by the 1st author using a thematic coding approach. Once an initial set of themes was identified within the topic area, several more rounds of itinerant coding were conducted to refine the coding scheme and draft memos on the emerging themes. The findings of this process were discussed between the 1st and 2nd authors, further refined through additional questioning of the data, then discussed again within the entire author team to check the inductive reasoning behind code and theme identification and rationale behind the explanations arising from the analysis.

Case backgrounds

River Wye, Wales

Since the early 1900's, a series of hatcheries and stocking projects have been established. Aside from early compensatory stocking projects, hatcheries on the Wye have been built as a means of supporting the existing fishery during periods of low returns and to conserve remaining wild populations by overcoming reproductive and early life-stage bottlenecks to salmon survival within the relative safety of the hatchery.

Salmon form a central piece of the River Wye's character (Hurley 2008; Gilbert 1929), and management and conservation of this species has frequently been a topic of debate. Efforts to improve and conserve wild salmon runs in the Wye have been attempted over the past several centuries via anti-poaching campaigns, harvest regulations, cultivation efforts, and most recently catchment-scale habitat improvement efforts. Of these efforts,

hatcheries have been a particularly contentious aspect of the salmon conservation debate since the 1990s.

Wye salmon hatcheries were initially instituted as a compensation measure for dams, indicating beliefs that the right science and technologies could compensate, at least in part, for human damage to the environment (Haydon 1997; Lamont 1990). This trend is reflective of attitudes of "techno-arrogance" (Meffe 1992) or the belief that innovative technologies can overcome environmental damage. Thus, the introduction of hatcheries on the Wye marks a point where hatcheries fit into paradigms of nature as an aid to repair (or improve upon) naturalness disrupted by human interventions. Importantly, hatcheries in this period are aimed at achieving qualitative naturalness. That is, they produce salmon that look and behave similarly to wild fish (Scarce 2000). With the limited scientific understanding of salmon physiology and ecology of the day, hatchery-produced fish were viewed as a more 'natural' outcome than the reduction or absence of fish entirely.

In 2012 a new approach to salmon cultivation was initiated by a collaboration of river owners and anglers: semi-natural rearing ponds (SNR). This initiative was a response to growing pressure to conduct hatchery and stocking projects in more standardized and scientifically sound ways, particularly with respect to the threat of genetic introgression of 'hatchery-type' fish on wild fish populations (Laikre et al. 2010). This shift marks a distinct shift in understanding of what a desirable Wye salmon should be, and how it should be produced. The SNR pond initiative was matched with an agreement between pond supporters and Environmental Agency Wales (EAW, Natural Resource Wales' (NRW) predecessor) to conduct a 10-year study on the hatchery/pond raised fish in order to properly assess the effectiveness of such a stocking effort.

At the same time as the SNR project was getting underway, an evaluation of stocking in Wales was found contraindicative to the main statutory and principal requirements that govern the UK's salmon resources, notably the Habitats Directive (92/43/EEC 1992), Precautionary Principle (A. Jordan and O'Riordan 1995), the Ecosystems Approach ("COP 5 Decision V/6" 1995) as well as guidelines set by NASCO's Williamsburg Resolution (NASCO 2007). After a hotly contested public consultation period, NRW ended all stocking in Wales in 2014 (with the exception of some research-based projects). In 2015, the last remaining SNR pond salmon were released into the Wye, thus inconclusively ending the associated study.

Ørsta River, Norway

In 1931 when the first Ørsta hatchery was built along a forested stretch of the Åmdalselva (Aam 2009), it joined a long practice of local salmonid hatcheries along the Norwegian coast (Svåsand et al. 2004). It was first constructed as an enhancement measure during a wave of hatchery-building in the Sunnmøre region. At the time, salmonid hatcheries were used to improve fishing and harvesting opportunities, a scheme that was strongly supported by the state-level salmon management organization of the time (Statens Fiskeetat) (Aam 2009; Berg 1986). The original Ørsta hatchery used Ørsta River water to hatch and raise salmon parr, a deliberate choice intended to recreate their natural condition (i.e., river water) within the artificially safe rearing habitat of the hatchery. This design choice reflects thinking at the time that prioritized maintaining the 'natural' conditions of the river as a way of improving the quality of hatchery-reared fish.

This hatchery was used on-and-off throughout the 30's and 40's, interrupted by WWII and poor fishing years when insufficient broodstock could be captured to stock the hatchery with fertilized eggs. In the 1950s, the fishing community began to stabilize again and the local hunting and fish club was established, a group who restarted cultivating in 1953-54. Throughout Norway, a new wave of fish cultivation began as part of the effort to rebuild Norwegian food security (Aam 2009). As part of this effort, the Ørsta River was straightened and the existing Ørsta hatchery transitioned from a salmon stock enhancement tool to a compensatory tool.

In the 1960's, a new hatchery was built to compensate for the sediment and debris-filled water that inundated the hatchery during floods and led to fish kills. This hatchery is still in use today and produces an annual crop of salmon and brown trout, which are stocked within the Ørsta River watershed. In 2014, a new set of guidelines was released (Norwegian Environment Agency 2014) based on recommendations concerning salmon stock enhancement produced by NASCO (North Atlantic Salmon Conservation Organisation 2006) that initiated a review of stocking practices and regulations in Norway. Amongst other demands, the new guidelines required all broodstock used in voluntary hatcheries to be genetically tested to exclude escaped farmed fish and their descendants from being used as reproductive material donors in order to avoid introgression of domestic conspecifics on wild stock genetic diversity. This change in stocking guidelines reflections an institutionalized shift in attitudes toward which salmon are and are not appropriate for wild stocks, as well as offers clues as to how hatchery technologies and their operators are being directed to conduct conservation by setting definable limits around what constitutes a 'natural' or 'wild' fish.

Results

Nature in Salmon Policy

The study, regulation, and management of Atlantic salmon begins at the international level where major international organizations contribute toward developing policies, guidelines, and recommendations for wild salmon management based on best scientific advice[6]. Thus, we began our analysis at this level so as to build a contextual background in which to understand and compare local-level stakeholder perspective.

NASCO is a key organization to which individual countries with interest in wild salmon conservation have become party, agreeing to contribute toward and abide by the recommendations released by NASCO. With regard to Atlantic salmon stocking, the Williamsburg Resolution is a key resolution that directs NASCO member states to minimize the impacts of stocked fishes on wild fish populations (NASCO 2007) with particular attention to the negative impacts of stocking on genetic integrity of wild stocks (pg. 16 – 17).

As part of the ongoing work directed by the Williamsburg Resolution, the 2017 Report of a Theme-based Special Session entitled "Understanding the risks and benefits of hatchery and stocking activities to wild Atlantic salmon populations" (2017) was written as part of a NASCO Theme-based Special Sessions on stocking intended to report on best practices and facilitate knowledge exchange related to the risks and benefits of hatchery and stocking activities to wild Atlantic salmon populations (North Atlantic Salmon Conservation Organisation 2017, pg. 2). The report consists of several individual reports authored by wild salmon managers, scientists and hatchery regulators, including managers from Norway and Wales. These expert's viewpoints and evaluations offer a unique summary of the different positions towards the use and challenges of hatcheries as conservation tools. As such, the reports allows us insights into how these managers conceptualize the relationships between nature, salmon, and hatchery technologies and, subsequently, enshrine those views into wild salmon management policy. Several sections within the report argues for defining appropriate or natural salmon, and thus the desirable salmon, through genetic considerations. More specifically, the report focuses on issues of genetic integrity and associated behavioral and physiological traits of salmon born and/or reared in hatcheries. The report contributors point out that the relaxation of natural selection or unintentional selection by humans constitute the biggest culprits of denaturalizing salmon genetics in the hatchery:

[6] NASCO, ICES, etc.

> "Selection of mates for crossing in hatcheries generally cannot take account of the natural spawning destination of fish. The artificial crossing decisions result in crosses highly unlikely to have occurred naturally. This over-rides natural mate selection processes, placing at risk factors that preserve and protect genetic variability and adaptations and natural disease resistance" (pg. 66).

Taken as a whole, the report marks a condensed shift towards genetically-coded criteria for defining the appropriate, or natural, salmon in wild Atlantic salmon management. In our analysis we identified three important themes within the report, (1) how natural processes are prioritized in salmon lives, (2) how humans should or should not be involved in salmon lives, and (3) how these ideas are couched in notions of appropriate technologies to facilitate human-salmon relationships.

Taking an example of the first theme, the word 'naturally' in the above quotation is clearly used to delineate between those pairings facilitated by humans, and those pairings that would have occurred without human intervention. The underlying argument is that humans have only partial knowledge of the process by which salmon, when left unfettered by humans, make their own mating choices (Watters 2005; Foote 1988; Landry et al. 2001) and thus humans cannot accurately imitate this process. This means that hatcheries cannot accurately reproduce the genetic diversity that occurs in wild salmon populations, thus "placing at risk factors that preserve and protect genetic variability and adaptations and natural disease resistance" (North Atlantic Salmon Conservation Organisation 2017, pg 66). From the Norwegian section of the report:

> "[t]o preserve the original population and its genetic variability, measures to remove limits on natural production (like habitat restoration) must be prioritized" (pg. 80).

Genetic variability that occurs without human influence appears as the desirable outcome of salmon reproduction, but active restoration of existing habitat in order to expand production is acceptable. Preferably, the salmon itself is not to be touched by conservation methods, but rather its environment is to be targeted. Contextualizing this within changing attitudes toward hatcheries, the second theme of the report, regarding human-salmon relationships, emerges. It appears that habitat improvement efforts are still acceptable at the quantitative level – where salmon hatchery outcomes used to be acceptable – whereas the salmon themselves must be genetically natural, a far more challenging outcome to secure.

Thus, we can see that habitat improvement work appears to assume less overall risk than hatcheries to the salmon population at hand.

Regarding the third theme, the report conceptualizes naturalness to describe natural selection within the report, or how and what variables kill salmon in their juvenile stages (i.e., life stage bottlenecks). In this respect, hatcheries may be considered useful technologies used to widen life stage bottlenecks during the salmon's juvenile period. The underlying goal of this being that more salmon reaching adulthood to spawn than occurs without technological intervention, subsequently producing a larger breeding population that can eventually reproduce this process without the hatchery is a clear objective of hatcheries. However, the report argues that the value of natural selection on salmon populations is paramount to the quality of those salmon which may eventually reproduce, thus indicating that how salmon live and die, rather than simply *if* they live or die, is an important element to determining their quality and appropriateness to the natural salmon landscape in addition to supporting biological arguments of the role of natural selection in ensuring fish fitness.

This discussion of fitness in the report, and in the wider salmon hatchery community, thus clearly touches on how ideas of nature are tied into ideas of wildness. In the report, discussions about natural selection and reproduction are limited to the confines of the hatchery. However, in both Norway and Wales many other human technologies impact the survival, behavior, and eventual reproduction (i.e., agricultural runoff, migratory barriers, catch and release recreational fisheries, impacts from commercial salmon aquaculture etc.) of juvenile and adult wild Atlantic salmon. Yet, environments outside of the hatchery are frequently termed "natural"; "natural streams", the "natural environment" or "natural rearing conditions" by the report and our interview participants. Though 'natural' is a term not well defined in the report, the primary reason for stocking in these two cases is precisely because the stream is paradoxically *not* entirely natural, having undergone human disturbance.

Human impacts within the salmon environment (apart from the hatchery), while important parts of the overall salmon conservation discussion, seldom came up within discussions about how, why, or whether to use cultivation technologies to produce salmon. The exception is actually to justify stocking, where report author Young describes environments so damaged that wild salmon populations have ceased to exist and thus cannot be harmed by the introgression of hatchery-type salmon (North Atlantic Salmon Conservation Organisation 2017). Similarly, we also read that improving existing salmon habitat is (and should be) prioritized, inherently calling for human (artificial) interventions to improve functional ecosystems. These types of artificiality are acceptable within the report's

conceptualizations of naturalness, indicating that some types of human interventions in salmon environments are acceptable while others are not. Thus, we understand that the mechanisms for deciding upon appropriate interventions are based on prioritizing biodiversity and functional salmon environments. While an ecologically and scientifically sound approach to conservation, this prioritization tacitly implies that other priorities, such as social demands on salmon environments, are less justifiable reasons for human intervention in salmon lives.

Salmonscapes on the Ground: Wales

We now transition our analysis to examining how conceptualizations of nature take place at the ground-level, and within the context of the broad, international-level policies analyzed in the previous section. Interpretations of naturalness from Welsh managers were embedded the relevant salmon management statutes (see case background). Importantly, these statutes prioritize biodiversity and special protection for Atlantic salmon and its habitat in the River Wye. Concerned by the threat to biodiversity presented by hatchery-reared fish to wild stocks, managers view genetic naturalness as a priority issue by applying the precautionary principle (distinct from the precautionary approach) which disallows any activities that may risk the genetic integrity and biodiversity of Welsh salmon stocks. As managers did not find sufficient new evidence during the publication consultation period to demonstrate a lack of harm (or acceptable level of risk), their 2014 decision to terminate stocking in Wales was presented in interviews as a straightforward and obvious step mandated by statutory duty:

> "We have statutory duties for maintaining, improving and developing fisheries for freshwater fish, migratory fish, and the eel. So, we have a duty to protect the fish stocks themselves as components of the environment and in many cases as features of designated sites." (P. Simmons[7], June 16, 2016).

These duties are derived from regulations such as the Habitats Directive, for which the main aim is to:

> "Promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species listed on the Annexes to the Directive at a favourable conservation status, introducing robust protection for those habitats and species of European importance. In applying these measures Member States are required to take account of economic, social and cultural

[7] All names have been changed to protect the anonymity of interview participants.

requirements, as well as regional and local characteristics." (2000/60/EC 2000)

This is particularly relevant to the River Wye, which has been designated as a Special Area of Conservation (SAC) for the presence of Atlantic salmon in addition to several other high-value species and topographical features of the watershed. However, the description of the Atlantic salmon as a key species for conservation (92/43/EEC 1992, Annex II) remarks only upon the qualities of the salmon and the unique population of multi-sea winter fish that occur in the Wye. The description does not say specifically *why* the River Wye salmon are valuable, nor in what context that value should be measured (i.e., cultural, economic, etc.). Thus, the way in which salmon are valued and therefore must be maintained is left up to interpretation from the Habitats Directive line "Member States are required to take account of economic, social and cultural requirements, as well as regional and local characteristics" (92/43/EEC 1992).

As in the NASCO report, Wye managers utilize an interpretation of naturalness which categorizes human interventions into those which are acceptable (i.e., habitat improvement) and those which are not (i.e., hatcheries). How the practical categorization of activities are made is not explicitly clear, but it appears to depend on ecological and biological assessments on changes to the environment that can be concretely determined as a result of the conservation activity (i.e., improved water pH, addition of gravel for spawning areas, etc.). Especially within the context of NASCO's guidance, this is a logical response on the part of managers, as specific managerial goals are more realistic and achievable standards to which managers may set their sights. However, this position tacitly interpreted human intervention in the salmon reproductive and rearing processes as "unnatural", and therefore damaging to the desired wild/natural salmon archetype. The Welsh decision to end stocking effectively removes humans from juvenile salmon life stages, therefore implying that salmon lives are more natural when set apart from human interaction or influence.

However, these strict interpretations of naturalness and nature were not shared by everyone in the case. Many stakeholders perceived the natural riverine environment to be something from a past age on the Wye, and that human influence remains inextricably a part of the River Wye landscape and, therefore, salmon. A Welsh fish biologist exemplified this conflict by saying:

> "I think we all agree that [habitat] going to be important, but I think sometimes the guys who are just pro-habitat and nothing else […] feel that we can turn back the clock

> like 350 years and put everything back the way it was, and that's never ever going to happen. You'll never get rid of man-made impacts. It'll never be perfect. You can reduce them for sure but you can never get rid of them. It'll never go back to what it was." (J. Daesh, June 16, 2016)

This comment indicates that not only are the characteristics that define naturalness in question, but also which time period represents the ideal natural salmon state and environment. This interpretation also disallowed for alternative conceptualizations of naturalness and human-salmon interventions that support human-salmon interactions aside from habitat improvement efforts.

In addition, there was little acknowledgement from managers about the ontological viewpoints of fisheries science and scientists, and whether these knowledge producers had alternative or underlying agendas (i.e., values, priorities) when contributing their knowledge into management policy. Within angling, river owner, and even scientific communities, however, people challenged the concept that science produces infallible knowledge free of ontological biases. For example, one scientist criticized underlying, perhaps unacknowledged, motivations within the scientific community:

> "I think that sometimes people believe [science is] not fallible. Well I think it is. I think recently genetics has been used against hatcheries pretty much every time you see it explained in the literature. And I think it hasn't been helpful. I personally think there has been a kind of an academic agenda amongst many geneticists to make a name for themselves. To be the first one to prove that hatchery fish definitely don't contribute better than wild." [sic throughout] (J. Daesh, June 16, 2016)

These findings indicate that achieving a type of naturalness, while desirable to most managers and fisheries scientists, may not actually achieve the objectives of many stakeholders. Thus, the dominate conceptualizations of naturalness used on the Wye are not necessarily appropriate or accepted by all parties. For example, one stakeholder's comment about the value of interacting with salmon in a "natural" way, even if the salmon themselves are not "wild-natural" salmon:

> "I don't think it really matters if that salmon doesn't have an adipose fin or it does if you see it jumping up on the weir. And maybe that's the way we have to have a

balance in nature, not just pretend that everything can be the same that it was 300 years ago." (J. Thompson, June 16, 2016)

Salmonscapes on the Ground: Norway

In Norway, managerial views of nature were quite similar as reported in Wales, unsurprising as the managerial agencies in both countries draw from the same international guidelines and regulatory frameworks of NASCO and ICES. As much of the salmon habitat in the Ørsta River case remains relatively intact, managers promoted the utilization of available habitat as much as possible, though some human interventions, such as installing fish ladders, were considered acceptable (perhaps reflecting an overarching objective of the anthropogenic, rather than the salmonid, benefits of having 'natural' salmon). As in Wales, the arbitrator of naturalness was the reproductive process of salmon and improving rearing habitat. Naturalness, in the case of reproduction, was described as an activity free of human interventions. For example:

> "We [are] extending the natural habitat. That's something we do in order to increasing [sic] the number of fish that you can harvest, and have a bigger fishery. But then again, it's supposed to function by itself, you know. It's natural production." (A. Lund, April 25, 2016)

Norwegian managers also conceptualized the natural world as complex, complicated, and difficult to appropriately intervene in without causing incidental damage. They also separated humans from nature by describing processes within the natural world as processes which occur over non-human life scales (e.g., thousands of years), and must operate unimpeded by humans if they are to function correctly. For example:

> "We think there is a job to do to make them [anglers] understand that the nature is very complicated, and it's so much to take care of. It's invisible, invisible behavior systems taking care of the thousands of years selection, evolution, and so on." (L. Larsen, May 11, 2016)

From this, we can see that managers view the Ørsta system as being nearly sufficient to provide all aspects required for salmon to thrive. Combined with views that human intervention in this otherwise effective natural system of salmon rearing is too complex to achieve without the risk of damage, it is unsurprising that managers in this case approach

naturalness by removing human interventions, and thus humans, from the system. In effect, to do nothing – to eliminate active salmon cultivation – is viewed as a more sustainable approach than enacting risky cultivation schemes. As described by one manager:

> "A very important key word: sustainable. Sustainable management of a river. Maybe the sustainable management of a river is [to] "do nothing". The river ecosystem is well-equipped for meeting all the needs of the different species. Here is our argument. There is suitable, original, naturally [sic] conditions for natural production. Thus, hatcheries are not necessary." [sic throughout] (L. Larsen, May 11, 2016)

One further aspect illuminated by this statement is the complexity not only of the natural system, but also of the social ecological systems in which salmon are embedded. Here the manager highlights the notion of sustainability, a complex term imbued with social, economic, and ecological meaning. Thus, the managers argument to "do nothing" and withdraw human technologies from nature attempts reducing and managing both anthropogenic and ecological complexities, an apparent paradox in the current Anthropocene where there intermingling of human and environmental systems is growing ever more complex.

Naturalness was also closely intertwined with ideals of wildness, which together construct the notion of the "best fish". Characterized as a fish that can survive its life cycle without human interventions, this categorization of "best" fish juxtaposes hatchery-produced fish as being deprived of the opportunity to evolve and struggle without human intervention (though, as before, apparently only in the context of reproduction and natural selection of juveniles). As described by one manager:

> "The finest and most precise nature product is a fish spawning for themselves in the rivers. And where Charles Darwin are working with them. And the smolts is a product of a tough freshwater period. It's the best fish." [sic throughout] (L. Haugen, May 11, 2016)

In addition to humans being removed from salmon reproduction, it is also clear that human objectives and interests in the fishery are also invalidated if they conflict with natural events. For example, spring flooding in the Ørsta River occasionally rips up the streambed gravel and destroys redds, particularly within the straightened section. This issue is of great concern to anglers and reinforces their beliefs that the hatchery is allowing them to

compensate for natural events made abnormally destructive by the straightness of the river; in essence, the hatchery achieves naturalness damaged by human interventions while simultaneously allowed anglers to achieve another important objective: angling opportunities. However, managers view the flooding as part of natural disasters in which hatcheries are artificial intrusions:

> "An often heard thought is every spring there is a spring spate [flood]. The flow is so big [that] it turn[s] around all the gravel and the living conditions in the rivers. [But] here [for] ten thousand years, it has been a spring spate every year. This is the way the nature is. So, these are [the] natural machinery. We have to accept nature's conditions. They are never fixed." [sic throughout] (L. Larsen, May 11, 2016)

This comment reflected the manager's view that interfering with natural processes to achieve human objectives, or even perhaps to compensate for past damage, is not an acceptable reason for intervention. This argument reinforces the view that removing humans from the salmon lifecycle remains a preferable managerial approach. However, it did not account for large-scale influence, such as the effects of climate change and other systemic, overarching changes occurring on a planetary scale with local impacts on salmon habitats, feed, and behavior.

Local anglers took a more pragmatic approach to preserving naturalness in their salmon rivers. From their perspective, naturalness and the idea of the wild salmon were desirable and, to some degree, still preferred in the peopled landscape around the Ørsta River. However, they viewed the attempt to achieve genetic naturalness as just one of many possible targets that could be achieved in salmon conservation. For example, they were greatly concerned with the marine environment being impacted by a whole host of unnatural challenges affecting migrating salmon (e.g., competition with escaped farmed salmon, dense biomass of sea lice, lack of prey for the migration smolt in the estuary and coastal habitats), but little attention being paid to these problems. As one angler explained:

> "They are afraid of the answer. Afraid to admit that the problem is in the ocean. And in the fjords." (P. Magnus, May 3, 2016).

With these concerns in mind, anglers found it counterintuitive to refuse technologies that may help balance the impacts of these human impacts at sea and expect that the rivers will remain natural.

Discussion: Defining Nature with New Technologies

This study shows that managers and scientists in these cases hold different and, at times, competing conceptualizations of nature and naturalness than those stakeholders engaged in hatchery work. Managers in both cases prioritize habitat improvement approaches over hatcheries to pursue salmon conservation work, citing the removal of human intervention from salmon reproductive and rearing processes as a way of reducing risk to the genetic integrity of wild salmon stocks. These arguments are underscored by international level stocking guidance produced by NASCO, which asserts a clear preference for minimizing hatchery technologies in a conservation context. These views are challenged by hatchery advocates who see the shift toward limiting, transforming, or removing humans from salmon lives as ignoring the many other problems that negatively affect adult salmon (e.g., pollution, angling pressures, etc.) and prioritizing naturalness over the pragmatic realities of the river environments in this study. Whereas the fisheries scientists and most managers interviewed in both case studies view hatcheries as inappropriate technologies and subsequently have taken managerial steps to transform or limit the use of these facilities, angling and river owner stakeholders view hatchery technologies as a link between humans and the 'natural' salmon. These disparate views underlie conflict that surrounds both case studies in determining the role and appropriateness of hatchery technologies in wild salmon conservation.

We find that the 'nature' of salmon invoked by the political debates and policy documents raises two paradoxes. First, as relationships between humans and salmon becoming increasing complex and multimodal, managers are paradoxically seeking increasingly testable, defined, and limited means by which to define nature and 'best fish', resulting in the removal or limitation of human interventions (i.e., hatcheries) in salmon environments. This is clearly illustrated in the fieldwork where managers in both Norway and Wales conceptualized naturalness as that which occurs in the absence of human intervention or manipulation thus setting humans and human action as opposite or otherwise apart from what is natural (Hepburn 1967).

Hatchery advocates, meanwhile, take a more constructed view of nature and comingle salmon and humans together. This view that includes humanity as part of nature has been shared by others (W. R. Jordan 1992; Kormondy 1974; Rassler 1994; Turner 1994) and can be considered a "nature-skeptical" position (Soper 1995) where the usefulness or possibility of separating natural from unnatural is questioned (Haydon 1997). Both cases were embedded in heavily peopled landscapes with long histories of human interactions with salmon via

different technologies in which the hatchery has become an established means of performing human-salmon interactions. Thus, the line between humans as a part of nature and humans as alien to salmon lives and environments is blurred by the interactions within the hatchery.

The issue of technologies leads to the second paradox identified in this study: the managerial and scientific preference for a natural salmon has shifted from being qualitatively to genetically naturally, a state that requires major technological efforts to be 'discovered' in the first place. Thus, nature is technologically defined and requiring of technological intervention in salmon lives, even as some technologies are assessed as inappropriate means of facilitating human-salmon interactions. This selection of what is and is not an appropriate technology is a key aspect of contention within these cases. Technologies, such as hatcheries, are embedded in technological systems that include people and organizations, known as socio-technological systems (Dwyer 2011). Technologies in these cases may be understood as a form of technological power (Lamont 1990) by allowing some groups to choose which technologies – and by extension, the relationships they facilitate– are allowed and which are not. In that instance, the co-mingling of scientific, natural, and wildness conceptualizations have become the arbiters of determining appropriate technologies for salmon conservation and positions science as the only possible solution to all social and environmental problems (Haydon 1997). Many have critiqued this notion that technology can provide such limitless solutions, calling such notions the "fallacy of environmental control" (Relph 2015, pg. 152-154). By including and excluding certain technologies to achieve desired versions of nature, managers risk excluding their related social systems (people, organizations) as well.

Overcoming the hatchery paradox

In both cases, perceptions of nature were coupled with changing perceptions of the appropriateness of hatchery technologies in salmon conservation. In particular, the development of improved scientific knowledge strengthened managerial obligations to move away from the previously acceptable qualitatively natural salmon toward genetically 'natural' salmon (Scarce 2000). This is unsurprising as conservation norms surrounding nature and naturalness fit well into the methodology of the natural sciences (Birnbacher 2014), and because of the inherent complexity of managing a socially and economically important species in a changing environment. This dependence on scientific knowledge and technology to determine the naturalness or wildness in salmon was not well-acknowledged by our study participants. This is important as it indicates a transition not only in how the scientific and conservationist communities view human-salmon relationships, but also in how the

relationships themselves should be defined, measured, and controlled. In essence, technology, and how it is used to facilitate human-salmon relationships, becomes both friend and foe, necessary yet inappropriate.

Humans have been impacting the landscape in these cases for thousands of years, thus obscuring where the natural state ends and the 'unnatural' state of human impacted nature begins (McKibben 2014). Within the ecosystem management framework, naturalness is generally defined as the pre-industrial state within Europe (Hayes, Riskind, and Pace 1987; Kilgore 1987). However, in the case of European salmon management, human influences dating from before industrialization have erased any definable concept of true naturalness (McKibben 2014), a view pointed out by pro-hatchery interview participants. Thus, in principle there are no clear indicators as to where, or when, definitions about the state of naturalness in salmon or their environments can be made. Managers and salmon conservation interests are thus forced to construct demarcations of acceptable naturalness and, by extension, human-salmon relationships in order to contend with increasingly complex managerial obligations.

Lavau (2011) points out that it is a resource and time intensive task for managers to establish and maintain boundaries between what species or environments are natural or wild, and therefore permissible, and those that are not (Lavau 2011). This follows a nature-endorsing view, where nature cannot practically be considered all-inclusive without becoming overwhelming (Wright 1992) and thus what is natural and unnatural must be divided along the lines of human action. From this, we argue that the empirical views of naturalness described in this study are constructed to be testable and achievable, and maintained as conceptualizations of nature where humans and salmon are distinct and separate. Humanism separates humanity from nature via a "cultural estrangement" (Ehrenfeld 1978) where humanity acts as an outside observer of nature and centers human-environmental relationships on human needs and values. This fits closely to the mandates of wild salmon managers, and thus their job is simplified if naturalness can be made "testable" and objectively achievable for managers. Thus, we can look at arguments about the genetic impacts of hatchery-rearing on salmon in both cases to understand how highly technological approaches have been used to make naturalness a testable ideal. In both processes, only salmon who are determined to be sufficiently free of human influence are considered to be appropriate for the production of future generations of wild salmon.

Concluding Thoughts: Naturalness, for all?

The findings and arguments in this study concerning conceptualizations of naturalness are not offered in condemnation of NASCO or country manager's adherence to biodiversity prioritization in salmon conservation policies. We understand that these priorities are based on what is considered best for the longevity and sustainability of threatened wild salmon stocks in both cases. Indeed, our objective in presenting these cases is to illuminate a middle perspective toward naturalness and 'best salmon' that may help explain the contentious nature of stocking debates. As stated in the Habitats Directive, the way in which salmon are valued or maintained must "take account of economic, social and cultural requirements, as well as regional and local characteristics" (92/43/EEC 1992). As such, we suggest that the conceptualizations of nature that, when operationalized, have resulted in the rejection of hatchery technologies be understood as contingently taking place in a techno-social sphere not shared by all stakeholder groups, thus resulting in conflict and frustration within both cases.

Though we agree that a focus on biodiversity and habitats is unquestionably an important priority for the longevity of wild salmon populations in both of these cases, we question whether disallowing some technologies wholesale without adequate replacement opportunities and using science as the only meaningful arbiter of what naturalness or wildness are (particularly when they can be known only through complex technologies) ultimately fail to account for how salmon are valued and maintained in local techno-societies. Similarly, we question whether naturalness *should* always be the ultimate goal, or whether more diversified strategies such as Sweden's river and fishery zoning system (Havs- och vattenmyndighetens 2015) might offer more appropriate solutions to localized challenge. As such, we argue that rather than moving toward stricter interpretations of nature as a means of reducing managerial complexity, conceptualizations of naturalness should remain disputable and human-salmon relationships and the technologies that support them should remain a priority in salmon management schemes.

Finally, this study demonstrates that both producers and implementers of empirical scientific knowledge in these cases hold specific, but often hidden ontologies related to naturalness and human-salmon interactions. The results suggest that managers and scientists are often unaware or unreflective of their ontological positions or beliefs, and thus are unable to account for or question the impact of personal values and social norms on natural resource management decisions or research (see Moon and Blackman 2014). This lack of consideration has led to mismatched perceptions between stakeholders groups in both cases concerning how wild Atlantic salmon should be conserved and which technologies are appropriate in meeting

conservation goals. Therefore, decision-makers should reflect more carefully on the ontological "baggage" they bring to their research and regulatory positions, particularly when interpreting scientific data and implementing management decisions.

These two cases offer a lens by which to understand the divergence between increasingly complex and technology-driven salmon management that seeks to achieve specific scientific, social, and economic objectives, and the needs, objectives, and conceptualizations of local-level stakeholders and their human-salmon relationships. We identified how managers in both cases hold certain conceptualizations and manifestations of naturalness that allow them to achieve challenging and occasionally competing managerial goals by reducing complexity of these social ecological systems, and how the process of defining nature and entangled "natural salmon" have become reliant on highly complex technologies. In this, relative simple hatchery technologies and our more intuitive (or qualitative) relationships with salmon with been replaced with advanced genetic technologies that assert, define, and maintain a new definition of naturalness and human-salmon relationships (Scarce 2000; Birnbacher 2014). This shift within hatchery management has invalidated voluntary hatcheries as appropriate technologies, and in doing so has perhaps unintentionally begun to invalidate those stakeholders who are part of hatchery techno-social systems.

Within the Anthropocene, it is likely that change and the infiltration of human-driven artificiality will only become increasingly evident within salmon environments. As humans become inextricably mixed with nature via our technologies and influences, perhaps instead of attempting to identify specific definitions of a natural salmon we should instead consider what habitats, characteristics, and interactions with humans and their institutions will be necessary for salmon to thrive in human-salmon environments in the future. To do so, managers and practitioners must not forget the valuable critiques that caution again one-size-fits-all solutions to natural resource problems (Campbell et al. 2006), and their collective plea for situated solutions that keep open degrees of freedom to incorporate local circumstances (Fujitani et al. 2017; Armitage 2005). To prevent these oversights, the fundamental ontologies managers and stakeholders adopt to support their salmon cultivation goals must be better understood, explicitly recognized, and then expanded to include and value multiple biological, ecological, and social objectives (Harrison et al. 2018).

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Paper III

Fisheries Research 204 (2018) 348–360

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

"Nature's Little Helpers": A benefits approach to voluntary cultivation of hatchery fish to support wild Atlantic salmon (*Salmo salar*) populations in Norway, Wales, and Germany

Hannah L. Harrison[a,*], Sophia Kochalski[b], Robert Arlinghaus[b,d], Øystein Aas[a,c]

[a] Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management (MINA), Universitetstunet 3, 1430, Ås, Norway
[b] Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 310, 12587, Berlin, Germany
[c] Norwegian Institute for Nature Research (NINA), Vormstuguvegen 40, NO-2624, Lillehammer, Norway
[d] Division of Integrative Fisheries Management, Faculty of Life Sciences and Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys) Humboldt-Universität zu Berlin, Unter den Linden 6, 10099, Berlin, Germany

ARTICLE INFO

Handled by George A. Rose.

Keywords:
Salmonids
Salmonidae
Hatcheries
Conflict
Recreational benefits
Community resource management

ABSTRACT

Voluntary hatcheries, or hatcheries operated privately by local anglers and fishery owners, are a historical part of salmonid conservation and enhancement efforts in Europe. However, these types of hatcheries have faced increasing scrutiny over the last several decades because of the potential negative ecological impacts created by stocking salmon into wild (albeit declining) populations. We hypothesized that hatchery programs provide value to communities well beyond the possible conservation contribution to local salmon. Utilizing a qualitative ethnographic approach, we identified and classified a range of benefits produced by voluntary salmon hatcheries within three case studies in Norway, Wales, and Germany. Across all cases, voluntary hatcheries facilitated or provided diverse social, psychological, and conservation benefits to individuals and groups of cultivators, as well as to the river environment. Voluntary hatcheries can be considered as a visible means of environmental stewardship and are perceived by many operators as an important means for mitigating human obstacles to wild salmon conservation. Based on the multiple benefits that voluntary hatcheries create for the people engaged in hatchery activities, we lay out alternative views that add to the traditionally black-and-white, pro or anti-hatchery perspectives. Improved incorporation of multiple social-psychological hatchery benefits into future fisheries management decisions, outreach, and communication will provide a more holistic approach to sustainable hatchery management, reduce stakeholder conflict, foster civil engagement in salmon conservation, and enhance environmental stewardship.

1. Introduction

Stocking is a much used and abused management tool in fisheries management and conservation world-wide (Cowx, 1994). Stocking objectives range from improving fishing opportunities to purely conservation-oriented stocking activities designed to protect and enhance small or declining populations (Arlinghaus et al., 2016; Lorenzen et al., 2012). Though stocking of salmonids (*Salmonidae*) has historically been a widespread, popular management initiative among many stakeholder groups to improve ("cultivate") wild stocks (Berg, 1986; Bottom, 1997; Wolter, 2015), improvements in scientific understanding of potential negative impacts of cultivation on wild salmonid populations (Bolstad et al., 2017; Glover et al., 2017) have challenged the scientific and managerial opinion in relation to stocking (Arlinghaus et al., 2015; Lorenzen et al., 2012; Sandström, 2011). Stocking can produce significant benefits to fisheries and help restore and conserve fish populations (Lorenzen et al., 2012). Although a range of contextual factors affect the outlook of stocking programs, in many situations alternative tools to stocking may prove superior in protecting and enhancing threatened fish stocks (Arlinghaus et al., 2016). However, stocking where hatchery fish are released into naturally recruiting populations can produce significant conservation concerns. Stocking has been documented to spread disease (Hewlett et al., 2009), affect local genetic integrity through population mixing (Laikre et al., 2010), reduce population growth of wild stocks (Chilcote et al., 2011), and contribute to the challenges faced by the wild stock component in anthropogenically altered rivers (Buoro et al., 2016; Laikre et al., 2010; Lorenzen et al., 2012).

* Corresponding author at: Norwegian University of Life Sciences, MINA, P.O. Box 5003, NO-1432, Ås, Norway.
E-mail addresses: hannah.lee.harrison@nmbu.no (H.L. Harrison), kochalski@igb-berlin.de (S. Kochalski), arlinghaus@ibg-berlin.de (R. Arlinghaus), oystein.aas@nina.no (Ø. Aas).

https://doi.org/10.1016/j.fishres.2018.02.022
Received 24 September 2017; Received in revised form 22 February 2018; Accepted 23 February 2018

Over the past 30–40 years, science has become increasingly critical toward stocking in light of unavoidable trade-offs between yield increase, cost, and potential negative impacts on wild stocks (Amoroso et al., 2017; Camp et al., 2017). As a result, in places where wild salmon populations still exist, stocking programs are increasingly being restricted (e.g., Norway) or ended (e.g., Wales) in a managerial preference to strengthen wild stocks through habitat restoration initiatives. Meanwhile, in places where salmon have gone extinct (e.g., Germany) or where populations have greatly declined (e.g., France), there is little alternative to stocking when trying to re-establish self-sustaining stocks in the wild (Granek et al., 2008). The same is true for rivers where the local salmon population has been significantly affected by parasite infection or environmental destruction (Forseth et al., 2017). In Germany, for instance, despite decades of salmon stocking no single self-sustaining salmon stock is known to the authors, suggesting that habitat limitations continue to constrain re-establishment of a stock.

Stocking governance systems differ throughout the world. In some countries such as the USA and Canada, stocking is typically conducted by state-run hatcheries. Conversely, in much of Europe fishing rights are private and tied to land ownership; here stocking decision-making is often conducted by local-level clubs and associations or by land owners (henceforth "cultivators") (Fujitani et al., 2017; Riepe et al., 2017; Stensland, 2010). In the European context, it has been commonly observed that private actors organize voluntary hatcheries designed to support, protect, and restore wild stocks of iconic, high-demand species such as Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) (Arlinghaus et al., 2015; Daedlow et al., 2011; Fujitani et al., 2017), and that these initiatives remain popular amongst cultivator groups (Riepe et al., 2017). This study focuses on what we term "voluntary hatcheries", or hatcheries operated by local angling or river owner groups for the purpose of conserving local wild Atlantic salmon stocks through stocking either in stock rebuilding or stock enhancement contexts.

Hatcheries and associated stocking programs raise three primary concerns: 1) the physiology, behavior, and overall fitness of hatchery-reared fish and how they differ from wild conspecifics (Blanchet et al., 2008; Fleming and Petersson, 2001; Jonsson and Jonsson, 2006; Swain and Riddell, 1990); 2) the effect of stocked fish on wild stock genetics through inbreeding and disease and parasite transmission (Garcia de Leaniz et al., 2007; Verspoor, 1988); and 3) a preference among many stakeholders (i.e., anglers, river owners, and local managers) for hatcheries, sometimes used as a substitute for the lack of opportunity for large-scale river rehabilitation (Arlinghaus et al., 2015; Dabrowska et al., 2014; Stensland, 2012). Salmon cultivation opponents argue that hatcheries provide a false "easy fix" to more insidious problems affecting salmon stocks, effectively detracting funding and interest from long-term conservation work (Waples, 1999). From an economic standpoint, hatchery and stocking critics also argue that stocked salmon have generally low return rates in comparison to wild cohorts (Milot et al., 2013; Romakkaniemi, 2008; Saltveit, 2006) while requiring high annual investments. Stocking advocates, meanwhile, argue that stocking programs may accelerate a population's recovery when used in tandem with habitat improvement work, and that stocking can create additive effects to increase catch in some situations (Amoroso et al., 2017). Similarly, in cases where a population verges on extinction, there is arguably no alternative to stocking due to lack of a wild stock that could produce sustainable recruits (Arlinghaus et al., 2015).

Many organizations and stakeholders are involved in the stocking controversy at multiple scales of organization, including local stakeholders, regional and state agencies, and scientific and international organizations (Sandström, 2010,2011). International policies are often bluntly critical of salmonid stocking; for example, the intergovernmental North Atlantic Salmon Conservation Organization's (NASCO) Williamsburg Resolution "is designed to minimise impacts of aquaculture, introductions, transfers and transgenics on the wild stocks" (North Atlantic Salmon Conservation Organisation, 2006). In doing so, the resolution provides guidelines to stocking, which give direct attention to the negative impact of stocking on the genetic integrity of wild stocks (North Atlantic Salmon Conservation Organisation, 2006, pg. 16–17). These and other conservation guidelines (e.g., UN Convention on Conservation of Biological Diversity North Atlantic Salmon Conservation Organisation, 2017) direct national-level fisheries managers and policy makers to develop more restrictive guidelines for country-specific stocking programs (Sandström, 2011). Meanwhile, local-level hatchery supporters try to engage in the debate by citing hatchery-supportive literature and arguments, questioning the credibility of work that showcases negative impacts of stocking, and often referencing the specific circumstances of local hatchery and stocking projects (or related problems such as escapees from aquaculture) (Brannon et al., 2004; Siemens et al., 2008). Somewhat in the middle, Waples (1999) argues that hatcheries are neither inherently good nor inherently bad, and "neither of these positions leads to productive dialogue, nor is either supported by a thoughtful consideration of the issue" (pg. 13). Yet, managers are often compelled to rely upon "best available science" (Charnley et al., 2017) in designing cultivation policies. Such science typically is ecology and biology-oriented, omitting the human dimensions (Arlinghaus et al., 2017; Ditton, 2004). This is unfortunate, as human dimensions are usually of prime importance in fisheries management success (Arlinghaus, 2006). Attention (from both managers and local stakeholders) focusing on the non-human dimensions of fisheries management (Ditton, 2004) runs the risk of ignoring important causes and drivers of conflict (Arlinghaus, 2005; Arlinghaus et al., 2017, p. 201), in cases of voluntary hatcheries and stocking in general (Riepe et al., 2017; van Poorten et al., 2011).

While the debate over hatcheries focuses primarily on the effectiveness and risks of stocking, alternative roles and benefits of stocking and hatcheries, such as the psychological and educational benefits of being involved in conservation, remain largely unexamined. In this context, voluntary cultivation of salmonids shares many similarities with outdoor recreation. Such activities are self-chosen, voluntary, and based on the individual's investment of resources such as free time, money, and knowledge/skills. A large body of literature in outdoor recreation in general, and recreational fishing in particular, has underscored that participants engaging in angling activities reap multiple types of benefits (Driver and Knopf, 1976; Fedler and Ditton, 1994; Holland and Ditton, 1992; Parkkila et al., 2010; Weithmann, 1999). These benefits enable people to meet their needs, pursue their goals, and increase their quality of life; in other words, to increase their well-being (Britton and Coulthard, 2013; Pretty et al., 2007).

The psychological, physiological, social, and economic benefits that accrue on the level of the individual also interact across scales leading to effects on society on a larger scale (social/cultural, economic, and ecological) (Driver, 2009; Manning, 1999; Parkkila et al., 2010). For example, engaging in cultivation can foster the subjective/cognitive and relational well-being of the individual while also achieving instrumental conservation benefits (by increasing or conserving salmon stocks) that benefit communities or entire human-ecological systems (Voyer et al., 2017). If participants in voluntary cultivation of salmon derive multiple benefits from the activity, the resulting individual and societal benefits potentially exceed the costs of fish cultivation and its assumed physical contribution to salmon conservation.

We posit that voluntary hatcheries produce multiple benefits at both individual and group levels that exceed the "narrow" focus on the biological contribution of hatcheries to wild salmon populations. By drawing on the multiple benefits framework from outdoor recreation research (Driver, 2009; Manning, 1999), the objective of this study is to identify and assess the full range of benefits produced by voluntary hatcheries. We then use this assessment to understand the influence of these multiple benefits on salmon management, conservation, and conflict.

2. Methods

In this study, an ethnographic approach allowed access to observe and experience the cultivator-hatchery relationship and associated benefits, including personal issues of value, relationships, and meaning assigned by individuals to their hatchery activities. Ethnography is a well-established approach to study fisheries, particularly in the small-scale fisheries literature (Carothers, 2010; Fabinyi et al., 2015; Harrison, 2013; Harrison and Loring, 2014; Loring et al., 2014). Using typical ethnographic methods such as interviewing and participant observation, the research team examined the multiple functions of hatcheries as producers of psychological, social, and conservation benefits for fishing groups and individuals within three case studies.

Data was collected through in-depth, semi-structured interviews with 15–25 individuals per country representing both voluntary hatchery groups and salmon managers in Norway, Wales, and Germany. All interview participants were identified through the key informant method (Marshall, 1996). Case studies were selected to represent a variety of hatchery programs with respect to longevity of stocking program, governance system, and current state of stocking in the area. Fisheries management in these three case studies is typical to European privately-owned recreational fisheries (Arlinghaus, 2006). Details concerning the spatial, governance, and stakeholder characteristics of each case are described in Table 1.

As part of the data collection protocol, the research team also engaged in participant observation in a variety of hatchery and fishing-related activities in Norway and Wales, spending between two to three weeks in both locations. Participant observation activities (e.g. angling, observing river conditions with anglers, conducting regular stock maintenance, and moving fish into new tanks prior to stocking) took place in a variety of locations that allowed the researchers to gain important insights into hatchery and salmon-related activities. These insights functioned as a necessary basis to, and were explored further through, the interview process.

In Norway, data collection was conducted in April and May of 2016 in Sunnmøre district, with the primary focus on the voluntary hatchery used to stock the Ørsta River. In Wales, data collection was conducted in June of 2016 within the River Wye catchment area primarily between the Builth Wells and Monmouth areas. In Germany, fieldwork was conducted between March and June of 2017 in the tributaries of the River Weser and the River Elbe, with a focus on one hatchery on the River Elbe.

Interviews typically lasted between 60 and 120 minutes and were recorded and transcribed in full. In Norway and Wales, most interviews were conducted in English, and those who preferred a non-English language were provided with a translator during the interview. Alternatively, interview participants were encouraged to express detailed comments in their native language and provide only a short summary in English. The detailed native language descriptions were then later formally translated to English and included in the transcribed interview texts. In Germany, most interviews were conducted in German, and later transcribed and translated into English. Interviews were semi-structured in nature and guided by a written set of questions and discussion prompts. The interview guide was written to elicit perspectives on several topics, including knowledge production, hatchery practices and organization, drivers for hatchery and stocking practices, benefits and consequences of hatchery work and stocking, local history of stocking, social networks within hatchery groups, causes and drivers of conflict surrounding the use of voluntary hatcheries, fisher habits and demographic information. Questions were open-ended, intended to encourage interview participants to share information and stories they found most relevant in illustrating their perspectives.

Analysis of interviews and ethnographic field notes was an iterative process conducted using Atlas.ti version 7 (*ATLAS.ti*, 1999), a qualitative analysis software. The data was first open coded for emerging themes through repeated reading and categorizing of data using software tools (Charmaz, 2014). In this context, codes are a word or phrase that are chosen to capture the essence of the concepts emerging from the text. Through the coding, concepts are being categorized and the researcher may begin to group together like concepts or ideas (Corbin and Strauss, 1990). The data was then coded a second time to explore previously identified themes and elicit insights into specific topics. A third round of analysis was conducted by writing analytic memos using the most prevalent and thematically relevant codes as memo topics. Coding and memoing are an important part of a grounded analysis of data that allows concepts to emerge and theories to develop through consistent and repeated presence in the data (Corbin and Strauss, 1990), thereby forcing the researcher to remain grounded within the text and check all developing theories against evidence from the data. Text from the memoing analysis and significant code names formed the basis of the data analysis in this article.

The data sets for each country were transcribed and coded in the sequence in which they were collected, beginning with data from the Norwegian case, then Wales, then Germany. In this, the authors were immersed several times in each interview, beginning with conducting the interview, then transcribing the interview through hours of intense listening and re-writing, then through the analysis process. Time between the original interview and the first transcriptions (2–3 months) was intentionally inserted to give the authors a fresh view of each interview before data analysis. The first author coded the Norwegian and Welsh interviews, and themes were discussed amongst the authors afterwards. The German interviews were divided and coded separately by the first and second author, and codes were then compared and discussed afterward to compare the results of each researcher's analysis. Though category labels naturally varied between individual researchers, this comparison revealed overall agreement on identification of the major concepts presented in this article. This agreement provided researchers relative certainty in the validity and rigor of their approach to data categorization and interpretation.

3. Results

We identified a range of psychological (Table 2), social (Table 3), and conservation benefits (Table 4) mentioned by interviewees as derived from their participation in hatchery and salmon stocking activities. Throughout the text, alphanumeric references relate the text to descriptions in the benefit tables ("P" refers to psychological benefits, Table 2; "S" refers to social benefits, Table 3; "C" refers to conservation benefits, Table 4). All benefits presented here were identified across all three case studies unless otherwise described.

3.1. Psychological benefits

3.1.1. Achievement, contribution, and satisfaction

Cultivators reported strong feelings of personal satisfaction resulting from their cultivation activities. Cultivators find great value in caring for and contributing to the well-being of salmon (P2), especially when releasing salmon into the wild. This satisfaction derives from two subsidiary feelings that are closely linked: achievement and contribution.

In terms of achievement, cultivators enjoy overcoming the challenges of raising a sensitive and at-risk species and, in Germany, of completing the "impossible" task of bringing back an extinct species (P4). Closely linked with this is the cultivators' perceived ability to learn new skills, adapt cultivation practices to the local environment, and successfully raise otherwise vulnerable juveniles (P3). Doing hatchery work and participating in salmon stocking is obviously deeply satisfying to cultivators and creates positive feelings of self-esteem and achievement.

In terms of contribution, cultivators feel they have a responsibility as anglers to contribute to the well-being of salmon (P4). Many cultivators enjoy being part of something "bigger than themselves", as

Table 1
Detailed descriptions of case study areas and features.

	Hatchery locations and river details	Hatchery history	Hatchery operated/stocking done by:	Hatcheries regulated by:	Guiding legal frameworks or policies affecting hatchery and stocking management (state level)	Current status of voluntary hatcheries and stocking
Norway	Ørsta River; ~25 km long; designated National Salmon River	Original hatchery was built in the late 1950′s to compensate for channelization of three kilometers of the Ørsta River; current hatchery built in 1970′s	Ørsta river owners association and Ørsta Hunting and Fishing Association (joint collaboration); average age range of cultivators: 60–80 years old.	Norwegian Environment Agency (Miljødirektoratet) makes overarching regulations; regulations interpreted, implemented, and enforced by County Governor (Fylkesmannen)	"Guidelines for stocking of Anadromous salmonids" released in 2014; guidelines focus on controlling genetic integrity of stocks	Active – annual rearing and stocking
Wales	River Wye and some tributaries; ~250 km long; forms partial border between England and Wales; designated Special Area of Conservation	Glasbury hatchery: 1974; Green Bottom Hatchery: 1995–2001; Painscastle hatchery: 2002–2008; Natural Resources Wales Cynrig hatchery (Cynrig Fish Culture Unit) 2009 on; Semi-natural rearing ponds were started in 2012 in conjunction with Natural Resources Wales hatchery	Various groups over the years; Wye Salmon Fishery Owners Association; Wye and Usk Foundation; Natural Resources Wales; Welsh Water Authority, Central Electricity Generating Board; average age range of cultivators: 50–80 years old; average age of managers and conservation groups: 40–65 years old.	Natural Resources Wales; historically hatcheries were managed by predecessor public bodies including Environment Agency Wales, National Rivers Authority, and Welsh Water Authority.	European Union's Habitats Directive (92/43/EEC); Salmon & Freshwater Fisheries Act 1975; Live Fish Movement Regulations.	Closed in 2014; last parr released from semi-natural rearing ponds in 2015; Cynrig, the only remaining hatchery operated by Natural Resources Wales maintained as research facility.
Germany	River Stepenitz, ~84 km long tributary to the River Elbe; designated Special Area of Conservation, designated nature reserve within Germany's Federal Nature Conservation Act and one of three project water bodies for the reintroduction of Atlantic salmon in the Federal State of Brandenburg	Stocking in the tributaries started in 1999 inspired by improved water quality in the River Elbe and by other German salmon stocking programs. Hatchery has worked with own returning salmon since 2013	Fario fly fishing club in Berlin; most members 40–60 years old; hatchery operated in cooperation with Institute of Inland Fisheries Potsdam-Sacrow (IfB) (scientific monitoring) and the FederalState's fishing association (financing)	Federal State's law	European Union's Habitats Directive (92/43/EEC); Veterinary regulations for the hatchery; Fishing laws for catching of broodstock	Active – annual rearing and stocking

Table 2
Psychological benefits derived from voluntary hatchery activities.

Benefits derived from cultivation work	Norway	Wales	Germany	Example activity/quote
P1: Personal Identity	Cultivators associate personal and cultural identities (i.e., "being Norwegian") with salmon and salmon-related activities; work within the hatchery allows a tangible relationship with salmon, strengthening the relationship between anglers/river owners and salmon as a part of personal identity;		Norwegian and Welsh cultivators and anglers identify as "salmon people", but not the Germans; all cases value volunteering and to "look beyond the end of my nose".	*"Everyone has a relation to salmon because salmon, that's Norway. Atlantic salmon, that's Norway. Every Norwegian [has] a relation to salmon I think. Yes. "* [sic throughout]
P2: Empathy/caring for salmon	Cultivators enjoy witnessing and facilitating the salmon life cycle and caring for juvenile fish; meaningful when done with family members; opportunity for parents to teach skills to children;	Cultivators in all cases enjoyed witnessing and facilitating the salmon life cycle, particularly during captive stages in semi-natural rearing ponds	Same as other cases, additionally they enjoy tangible interactions with salmon; opportunity to "close" the currently incomplete life cycle	*"We love these fish and we want the fish to be in the river. We are very happy when we see a fish coming back to the river, and we can help the river to reproduce."*
P3: Learning or fascination	Facilitated by the hatchery setting, cultivators have opportunity to closely interact with a species that provides fascination and awe; cultivators have learned new skill sets to cultivate high quality fish, and in most cases are interested to continue learning and improving their cultivation skills			Example: cultivators have learned electro-fishing and other skills to improve their cultivation practices
P4: Feeling of contribution (sense of purpose/achievement/ self-esteem/life satisfaction)	Cultivators feel a responsibility to care for nature and perceive the decline of salmon as something they should work to resolve; hatcheries provide opportunities to do this using existing skill sets;	Cultivators feel responsibility as river owners and as anglers to actively maintain the stock, but lack opportunities to do so; loss of hatchery activities is a loss of opportunity to participate in the well-being of salmon	Cultivators feel they contribute to bringing salmon back to Germany; they believe if they did not do this work, the salmon stock would decline and disappear; they enjoy the achievable challenge of rearing salmon; they agree that conservation work improves the reputation of anglers in Germany	*"I think people get a lot of different things from [hatchery work]. Some of them I'm sure feel they want to give something back."*
P5: Nature ethic/spiritual	Cultivators develop and reinforce feelings of respect, wonder, awe, and experiences of humility and connectedness to salmon through hatchery activities; some relate spiritually to "helping God" by rearing fish	Cultivators experience wonder and awe while caring for juvenile salmon; cultivation activities are linked closely to the wellbeing of the riverine environment, providing a sense of connectedness	Strong perception that what is good for salmon is good for all animals; belief that it is inherently good to have salmon living in the rivers, even if not fishable	*"When everything is natural, you thank God that it works. But as an old [angler] told me, "why don't we help God a little? He's a busy man. He just can't fix everything. We can give him a hand sometimes."*
P6: Hobby (incorporates relaxation, getting away, physical activity, stress reduction)	Middle and late-aged cultivators regard having a meaningful, active hobby as an important part of later life; they derive relaxation and connection to others through hatchery activities	Cultivators enjoy engaging in conservation activities that support their hobbies; thus, hatchery work has become an enjoyable hobby as well	Cultivation is tied to fly fishing as a hobby and to a laborious activity; anglers enjoy and look forward to many of the activities associated with the hatchery;	*"It's become a hobby. And a big interest. Yeah, 'cause it's not so fun to have a [hatchery]. It's a lot of work. Many, many hundred [hours] a year. So it's not [just] for fun. But I think it's for fun. [A man] gets away from his life for some time."*
P7: Routine	Hatchery work forms an important part of the daily/weekly/seasonal routine for those involved in hatchery activities	Time spent at hatchery and semi-natural rearing ponds provides an opportunity to escape from normal routine	Cultivators look forward to hatchery work at the end of each fishing season; the fishing and cultivation "seasons" complement each other in an annual cycle of fish-related work;	Example: cultivators look forward to visiting and caring for the growing salmon each day or each week, as well as attending regular meetings held at the hatchery

Table 3
Social benefits derived from voluntary hatchery activities.

Benefits derived from cultivation work	Norway	Wales	Germany	Example activity/quote
S1: Inter-generational local ecological knowledge transfer via teaching/ experience (includes activities specifically with family members)	Cultivators value the opportunity to pass salmon and cultivation knowledge to younger generations; conservation work is important recruitment strategy to bring young people into angling and cultivation work	Cultivators possess rich knowledge of river conditions, ecological history, and salmon; hatchery groups regularly visited schools, hosted courses teaching salmon ecology, biology, angling skills;	Have in-depth knowledge of local riverine environments; pass knowledge on to younger or new anglers; learn from salmon hatcheries of the same type in other river systems and countries and share knowledge between groups;	*"Sometimes I learn something from them and the next day they are asking me something and I [teach] something to them. Most of the olders are very kind. They also appreciate the younger generation are coming up and see what they are doing and learning by what they have done, these last centuries. It's quite interesting."* [sic throughout]
S2: Social interaction with peers/people with similar interests	Enjoy social interactions with peers organized around hatchery activities and using the hatchery as a meeting place; social interactions are important to quality of life and supporting conservation work;	Opportunities to interact with peers through hatchery activities are important to late-aged men; Social networks support organization of conservation work	Cultivators enjoy spending time with other people of similar values and interests; many anglers join club to participate in conservation activities;	*"But the sense of community and everything else that they develop with those little hatcheries… okay, it's mainly older guys and stuff like that, but it's like a social club. And some of these are quite poor communities so that is really an incredible benefit to that place."*
S3: Opportunities to network with people outside of normal social groups	–	Cultivators enjoy meeting people with similar interests from outside their regular social groups; networking allows information and cultivation technique exchange between geographic areas	Hatcheries facilitate opportunities for cultivators to meet people from different backgrounds and livelihoods with shared interest in cultivating salmon; cultivators enjoy finding "community" amongst other anglers	Example: anglers come from long distances, take time away from work to participate in hatchery tasks; anglers meet others who share common interests; interaction facilitates building of angler and conservation networks
S4: Historical/heritage Value	Fishers perceive salmon cultivation as an important part of Norwegian history, culture; they are inspired by past abundance to cultivate for the future	Salmon are an important part or angling legacy, reputation; river would be "less" without the presence of salmon; inspired/ motivated by past abundance of stocks	Cultivators are inspired by salmon stocks of the past feel loss and desire to restore salmon as legacy for children and as part of national legacy	Example: many hatcheries have historical photos that show the height of the fishery; cultivators link their present-day activities to a tradition of cultivation work
S5: Community identity	Cultivators identify as part of an angling, river owner, and cultivation community;	Community identity was previously supported by hatchery activities; absence has fractured club and personal relationships	Cultivators perform outreach activities to raise awareness about heritage value of salmon; they encourage "ownership" by locals of reintroduced salmon	Example: cultivators wish to bring their surrounding communities into contact with the hatchery through outreach activities

Table 4
Conservation benefits derived from voluntary hatchery activities.

Benefits derived from cultivation work	Norway	Wales	Germany	Example activities
C1: Participation and interest in conservation activities	Hatcheries facilitate interest in conservation activities; cultivators act as lobbyists for health of the river system and habitat improvement in addition to stocking; cultivators act as sentries to problems in the river, especially escaped farmed salmon	Prior to closure, cultivators formed a cross-section of other interest groups who organized and enacted conservation work; hatcheries offer low barriers to entry to participate in salmon conservation	Cultivators perceive habitat improvement measure as essential and complementary to hatcheries; they lobby for habitat improvement on multiple scales, and do habitat improvement activities; hatcheries incentivize better stock monitoring; cultivators are first to identify and act on environmental threats	Example activities: bank clearing and maintenance; invasive species monitoring and removal; litter cleanup; habitat improvement projects; flushing out sediment buildups; creating new spawning habitats
C2: Builds trust and likelihood of collaboration between cultivation groups and managers/policy makers	Hatcheries regulations facilitate regular communication between cultivators and managers; all stakeholder groups value open lines of communication about hatchery management and stocking; this discourse has fostered a willingness to collaborate on non-hatchery conservation initiatives	Termination of the stocking efficacy study created a breach of trust between cultivators and management authorities; cultivators report little trust for fisheries policy makers and managers, view the management process as politicized, unwelcoming to angler perspectives	Cultivators have tenuous relationships with local, regional governments based on managerial interest in cultivation projects; cultivators want more interest at the state level (and downward) to do studies on stocking outcomes; hatchery work creates political interest and gives starting point and incentive to politicians, managers to address river conditions	Example: cultivators have better working relationships with managers who support hatchery activities, allow cultivators to adapt regulations to local conditions; cultivators participate in policy consultations and want to work with managers to achieve conservation goals
C3: Facilitates partnerships to support conservation work (i.e. fundraising; invasive species control; conservation science)	Cultivators have relationships with local aquaculture companies to communicate about escaped farmed fish, and build relationships that support hatchery expenses; cultivators rear brown trout for hydropower compensatory stocking; cultivators want to develop scientific partnerships to further salmon research	In the absence of the hatcheries, new groups have formed to advocate for strategic use of hatcheries, predator control, shared use of the river, scientific studies on salmon, etc.; conflict over the termination of stocking led to dissolution of some long-standing groups	Cultivators develop partnerships with other angling associations and scientific institutions, domestic and international, to support monitoring, stocking, and hatchery operations; they have strong interest in science and believe cooperation between angling groups and scientists is essential for the hatcheries to succeed in the long run, both in terms of the labor and financing involved and the support for hatcheries in general	Example (Norway): cultivators work with a local aquaculture facility to monitor and remove any escaped farmed fish, and receive advice and some material support in operating the hatchery
C4: Biodiversity support	The hatchery provides a location for compensatory brown trout rearing (for hydropower facility); cultivators see salmon as keystone species; believe what is good for salmon is generally good for the river ecosystem	Remaining hatchery is used as research and biodiversity enhancement facility by government agencies; anglers express concern about other species in the river seeing similar decline as salmon	Salmon viewed as flagship species – its conservation greatly benefits other species; hatcheries used for sea trout and brown trout; cultivators consider hatcheries as potential conservation tools for other species	Example activities: hatcheries can be used to produce threatened species (e.g. freshwater pearl mussel, white-clawed crayfish) in the same facility as salmon, potentially with symbiotic benefits
C5: Risk reduction by retaining knowledge/skill ("insurance policy")	Cultivators strongly believe hatcheries provide an "insurance policy" against environmental or anthropogenic disaster; hatcheries provide a repository of cultivator skill and knowledge acquired through years of learning by doing, cooperation with other groups, and formal education	Cultivators and managers believe that hatcheries provide an "insurance policy" against environmental or anthropogenic disaster; cultivator groups hold a repository of skill and knowledge for local salmon cultivation, but without opportunities to practice and transmit knowledge, may lose these qualities	Hatcheries are now developing self-sustaining and locally adapted stocks, acting as inventory to a growing population; they are occasionally viewed as insurance policy for environmental disaster and act as repositories for knowledge cooperation with other groups and formal education;	Example (Norway): gene banks are used to store the genetic material for salmon runs threatened by disease (e.g. *gyrodactylus*); cultivators view voluntary hatcheries as institutions, for storing knowledge and skill (and potentially genetic material) in the same manner as the nationally operated gene bank program

described by one Norwegian cultivator:

> *"When everything is natural, you thank God that it works. But as an old [angler] told me, 'Why don't we help God a little? He's a busy man. He just can't fix everything. We can give him a hand sometimes."' (Participant #20, Norway)*

In Norway and Wales, hatchery projects have few, if any, clearly defined or quantifiable stocking goals beyond 'improved' stocks and the upper limits of allowable stocked material. Instead, most cultivators desire to restore salmon stocks to their "glory days", while others aimed at maintaining current salmon populations as well as achieving benefits for other aquatic species and the ecosystem. Similarly, conservation project timelines are a critical issue, as some cultivators anticipate the restoration of salmon stocks will likely come too far in the future for them to personally enjoy it. While many see the "journey as the reward", others concluded that hatchery work was necessary to speed up the process of salmon restoration. Notably, cultivators in Germany tended to have defined stocking goals with specific timelines or other metrics, but these goals varied amongst individual cultivators within the same hatchery project.

For many cultivators, hatchery work supports a nature ethic based around care for and interaction with nature (P5) and a philosophy of responsibility to engage in work that will benefit the natural world. Many cultivators consider the hatchery to be a symbol of this ethic, and the cultivation work an act of ethical fulfillment. Nearly all cultivators indicated strongly that their motivation to do cultivation work is primarily to give back to nature and a belief that conservation work is a good thing to do, both for people and for salmon. As exemplified by the chairman of one German angling club:

> *"We wanted to do more than a normal angling club. To put it this way, we wanted to give something back [to] nature. As a user of nature, one takes from nature, destroys nature, and that was a bit the original idea, to give something back to nature." (Participant #5, Germany)*

3.1.2. Hobby and leisure time

In all three cases, cultivators desire to do conservation work that matches both their personal interests (i.e., salmon and angling) and utilizes pre-existing skills and knowledge sets. In all cases, hatchery work is perceived as meaningful and highly enjoyable, and many cultivators categorized their hatchery work as an important "hobby" or leisure activity (P6). Dependent on the time of the year, some of the cultivators spend a significant amount of time (often 1 + hours per day) in the hatchery doing cultivation-related work. Interestingly, many cultivators also spent unstructured free time in the hatchery when no work was required (P6), a behavior related to fascination, awe, and desire to interact frequently with salmon (P3). Another reason for frequent hatchery visits is the social factor, as many groups host regular social meetings in the hatchery (P2). As explained by a Norwegian cultivator:

> *"I think that's the most important thing and why people are willing to do it. It's social. We meet often every Friday in the hatchery and have a chat and spending time [sic]… we have a house by the river here. It's very nice. Sit there and watching the fish in the summer… so it's, of course, social. That's a really important [thing] when you're going to use so much of the free time." (Participant #4, Norway)*

Hatcheries also fulfill an annual cycle of salmon activity for cultivators (P7). For approximately half the year, cultivators fill their free time with angling. When the angling season ends, cultivators fill time once spent angling with hatchery work. For many, this transition from angling to cultivation also achieves a transition from extraction from the salmon resource to contribution. The satisfaction achieved by this pairing of activities relates strongly to the nature ethics held by cultivators (P5), as well as their desire to see a sustainable salmon resource (P4).

3.1.3. Personal identity

The personal identity of cultivators is strongly linked to and supported by their involvement in hatchery work (P1). Cultivators experience feelings of independence and self-determination while doing fish cultivation as the work grants an ability to act in a semi-independent manner alongside like-minded people. Some cultivators even said they would be "lost" without the hatchery as part of their weekly routine. Being a volunteer, a salmon person, capable craftsmen in charge of the hatchery operations, or a respected member of the club's board forms an important part of cultivator's positive self-perception. In some cases, cultivators related not only personal identities to their relationships with salmon cultivation, but also their national identities. As one fisher described:

> *"Everyone has a relation to salmon because salmon, that's Norway. Atlantic salmon, that's Norway… every Norwegian [has] a relation to salmon I think. Yes. I remember when I was a small boy, once in a while a small piece of salmon [to eat]. It was heaven." (Participant #11, Norway)*

3.2. Social benefits

3.2.1. Facilitation of social relationships

Hatcheries are important social outlets, particularly for middle to late-aged, male anglers (S2). Hatcheries provide cultivators with ways to enjoy time with peers who have similar interests through activities they find mutually meaningful and fulfilling. Similarly, the value of volunteerism and engaging in community stewardship through hatchery activities was perceived as important by many interviewees. Based on these shared values, some hatchery groups have developed a strong feeling of community (S5). Said one Norwegian cultivator:

> *"So a hatchery is [a] very positive way of having [a] good environment locally. All people interest[ed] in the river, they meet, they have a little cigarette and talk about the river. They agree tomorrow, we do this. Yeah, so it's important. It's a club feeling." [sic throughout] (Participant #5, Norway)*

The social aspect is also important to younger cultivators, who enjoy spending time with and learning from the older members of the hatchery community (S1). Time spent with multiple generations of anglers is an important prerequisite for the transfer of knowledge, valued tradition to the oldest members of hatchery groups. Intergenerational activities also support the recruitment of new individuals into fishing and cultivation activities. Cultivators argue that hatcheries provide opportunities for young people to take part in traditional (or heritage) activities related to an iconic species, since some hatchery practices span over 50 years (S4). In all three case studies, cultivators are inspired by historical cultivation activities and expressed the desire to maintain or restore historic salmon populations for the benefit of future generations.

3.2.2. Networking

Hatcheries act as facilitators of social network development by bringing together individuals who might otherwise not interact through activities such as broodstock collection, stocking, and fin clipping, all of which demand significant labor. Leaders of some angling groups reported that work done in hatcheries helps spread awareness and support for other activities, such as teaching fishing skills to children and adults, visits to or by schools to hatcheries to teach conservation and ecosystem sciences, or activities such as litter cleanups and riverbank maintenance – all activities that additionally provide direct conservation benefits in addition to social value. Cultivators enjoy meeting new people from outside their regular social networks and making social connections related to angling and other recreational activities. As one German cultivator described:

"What is typical for our club is that many people got to know each other well. The club consists of very different groups of people, so let's say from the lawyer to the craftsman, and somehow everybody has this common topic that connects them, and there are no barriers, no barriers at all." [sic throughout] (Participant #6, Germany)

Opportunities to cultivate also build trust and working relationships between cultivation groups (and, by extension, anglers and river owners) and fisheries scientists and management officials (C2). Cultivators in all cases expressed concerns about a lack of support for hatcheries from fisheries managers and policy makers. In cases where managers, policy makers, or scientists included hatcheries in conservation schemes, however, cultivators responded with increased trust and interest in cooperation (C3). In Germany, cultivators wished for more support from the government and see the possibility of raising public interest in rivers through hatcheries. In Norway, cultivators and managers expressed that though they may disagree about the use of voluntary hatcheries in salmon conservation, successful salmon management requires working together to find common ground and mutually support worthwhile conservation efforts. A Welsh biologist echoed these sentiments:

"*I've seen a lot of my fisheries management colleagues hated by anglers, [and] who hate the anglers with a similar passion, and yet we've always had a fantastic relationship with them. I mean, okay, partly that's because they see hatcheries as a great thing because they're putting fish in the wild. But it's partly because we recognize the value of giving these guys some ownership of some part of the river. Of something that they can take care of themselves, have pride in, learn from and… have a passion for the other things about the environment. Conservation, that's really important." (Participant #15, Wales)*

3.3. Conservation benefits

3.3.1. Facilitation of conservation work

Voluntary hatcheries provide opportunities for cultivators to participate in conservation activities due to a low barrier-to-entry compared to that of habitat improvement projects, which can be expensive and require overcoming substantial legal requirements (C1). Participation in hatchery and stocking activities also contributed to cultivator's interest, support, and engagement in other types of conservation work otherwise unrelated to stocking. For example, Welsh volunteers organize litter cleanups and teach school children about ecosystem science and salmon fishing as part of their seasonal conservation work.

Cultivators participate in a variety of conservation activities as a direct result of interest, skills, or social networks developed through involvement with the hatchery. Across cases, these activities include the creation and improvement of spawning habitats and the removal of barriers for migration. For example, cultivators in Norway evaluate stocking efforts through annual autumn assessments. Similarly, cultivators in Norway and Wales reported catching and removing escaped farmed salmon while conducting broodstock collection. In some German rivers, cultivators also reported catching an increasing number of farmed salmon in the past five to ten years, and are working to inhibit their reproduction.

Hatchery activities have led cultivators to develop relationships with scientific, conservation, and (in some cases) aquaculture interests to generate financial, intellectual, and material support for hatchery work. For instance, cultivators are deeply interested in scientific research surrounding conservation and restoration techniques for salmon stocks. In all cases, cultivators discussed their efforts to incorporate best management practices into their hatchery operations, and expressed interest in participating in scientific studies focused on their local fish populations. Cultivators also exhibited long-term efforts to learn cultivation techniques recommended by scientific literature and develop working relationships with researchers.

3.3.2. Biodiversity and mitigating future disaster

Cultivators believe voluntary hatcheries provide support to biodiversity initiatives and scientific research on wild Atlantic salmon (C4). In both Norway and Germany, voluntary hatcheries raise brown or sea trout alongside salmon, while in Wales the remaining hatchery (now used only for research purposes) is used to grow indigenous, critically endangered species (e.g., freshwater pearl mussel (*Margaritifera margaritifera*)). Cultivators point out that the skill and knowledge used to grow salmon in voluntary hatcheries could also be used to support restoration or conservation work for other species, an added conservation benefit especially in rural areas where no other such facilities exist. In Germany, cultivators have adopted the biodiversity mindset into their long-term hatchery goals with some groups using hatcheries to cultivate other threatened fish species.

Cultivators and some fisheries managers view hatcheries as repositories of cultivation skill and knowledge, held collectively within the cultivators themselves and supported, developed, and transferred through their social interactions. As one fisheries manager said when describing the remaining cultivation facility on the River Wye:

"The other point is retaining capacity and competence. The husbandry of salmonids would be an important skill competence… so we're maintaining that [hatchery] [for] rearing of salmon for investigation purposes. And we believe that retaining that capacity and competence is important." (Participant # 17, Wales)

This knowledge and skill base, along with the physical capacity of the hatchery itself, act as an "insurance policy" that could mitigate against future ecological or anthropogenic disaster within the targeted salmon stock or river ecosystem (C5). In Norway, for instance, cultivators fear that incidences of escaped farmed salmon will only increase as the commercial aquaculture industry grows, and voluntary hatcheries will play an important role in magnifying wild stock genetics in the midst of farmed interlopers. Similarly, disease outbreaks are considered to be a serious threat to vulnerable salmon stocks and voluntary hatcheries-turned-gene banks could be used to mitigate the consequences.

4. Discussion

This study revealed a rich bundle of benefits produced by voluntary hatcheries that exceed their biological contributions to wild salmon conservation and fisheries. In our three cases, voluntary hatcheries provided or facilitated many of the psychological (Table 2), social (Table 3), and conservation (Table 4) benefit domains described within the outdoor recreation research literature (Freudenberg and Arlinghaus, 2009; Haas et al., 1980; Manning, 1999), with notable parallels to non-catch benefits produced by recreational angling opportunities (Arlinghaus and Mehner, 2004; Ditton, 2004; Fedler and Ditton, 1994; Manfredo et al., 1996; Weithmann, 1999). All three benefit domains were identified across all cases, though specific benefits within each domain were produced through different mechanisms and to varying degrees between cases, and not all benefits arose in every case. For example, all three cases had strong representation of social benefits (Table 3), but in Norway the benefit of *networking opportunities* (S3, Table 3) did not emerge as strongly as in the Welsh and German cases. This is likely caused by the small river size and relative isolation of each cultivation group in the Norwegian case, resulting in minimal opportunities to build social networks.

Across all three cases, the most significant benefit produced by voluntary hatcheries was as a means of participating in salmon conservation. While cultivators' interest in conservation through stocking fits in line with the history of stocking (Bate, 2001; Cowx et al., 2010; Granek et al., 2008), the use of hatcheries in enacting environmental stewardship runs counter to common perceptions that angler-driven stocking efforts are motivated primarily to improve catch opportunities through a technological fix ("techno-arrogance" (Meffe, 1992).

Enhancing opportunities for angling was either not relevant (such as in Germany), or took a seemingly secondary role in motivating hatchery work. Survey research among German fishery managers in angling clubs revealed that helping to conserve threatened species is a major motivator and driver of local management actions, including stocking (Arlinghaus et al., 2015; Riepe et al., 2017).

Another key benefit facilitated by voluntary hatcheries was engaging cultivators to support non-hatchery-related management and conservation by generating the networks, resources, and the human capital necessary to engage in small or large-scale conservation activities, such as stock monitoring, removal of escaped farmed salmon, and habitat improvement (Granek et al., 2008). Importantly, these examples of participation in conservation are distinct from work done by state hatchery programs (common to Norway and formerly to Wales, and to salmonid stocking in North America), as state programs do not typically offer opportunities for the lay public to take part in hatchery work (von Lindern and Mosler, 2014).

4.1. Examining hatchery-related benefits through frameworks for understanding benefits of outdoor recreation

Our findings suggest that the outdoor recreation framework (Manning, 1999) is suitable as a means to identify most of the benefits associated with voluntary hatcheries, though, some challenges have arisen in categorizing and describing benefits. For instance, the *routine* (P7) benefit is typically described in the literature as the opportunity to escape from daily routine by engaging in a recreational activity (Manning, 1999). While this definition remained true in the German and Welsh case, Norwegian cultivators described their hatchery activities as an important part of their normal routine as opposed to escape, and described being "lost" if their hatchery were closed and their hatchery routine interrupted. This example demonstrates that the definitions of some categories must be flexible to remain relevant in the hatchery context.

Most importantly, the way hatchery benefits were elicited through the ethnographic approach showed the way benefits were coupled and interrelated, demonstrating interdependency between benefit domains required for the production of each individual benefit (Fig. 1). For example, *routine* (P7) occurred as a function of the social nature of hatchery work as well as the fulfilling nature of participating in conservation. In another example, *networking opportunities* between cultivators (S3) provided satisfaction at the individual psychological level while simultaneously tied to shared conservation interests in cultivator groups. Social and psychological benefits shared significant overlap (S1, S2, P6), as did psychological and conservation benefits (P5, P4, C5), and to a lesser degree, social and conservation benefits (C2, C3). These overlaps not only present challenges in categorizing benefits, but importantly reflect the realities found in our case studies: psychological, social, and conservation benefits are interdependent upon one another, and each domain facilitates or enhances the production of the others. If one of the domains is threatened (e.g. if hatchery work as the catalyst for group activities is eliminated), the other benefit domains are also reduced.

The provision or secession of psychological and social benefits through hatcheries should be of interest to fisheries managers because they affect the cultivators' well-being, a strong contributor to behavior of humans in general (Hunt, 2005). Well-being is a multi-dimensional concept defined as "a state… where human needs are met, where one can act meaningfully to pursue one's goals and where one enjoys a satisfactory quality of life" (McGregor, 2008). Recreational outdoor activities can, for example, contribute to people's subjective well-being by increasing their self-esteem and improving their mood (Pretty et al., 2007). As with the benefits categories, relational and social well-being are closely interlinked and interdependent (Coulthard et al., 2011). In the present study, voluntary hatchery work was a way of both being with others (social benefits) and pursuing meaningful goals (psychological benefits), both contributing to individual and social well-being.

Hatcheries also produced specific conservation benefits (Table 4) and supported conservation as a secondary outcome of the production of psychological and social benefits. These interdependencies raise some interesting questions about the nature and substitutability of voluntary hatchery work, particularly to the relevance of "recreational" as

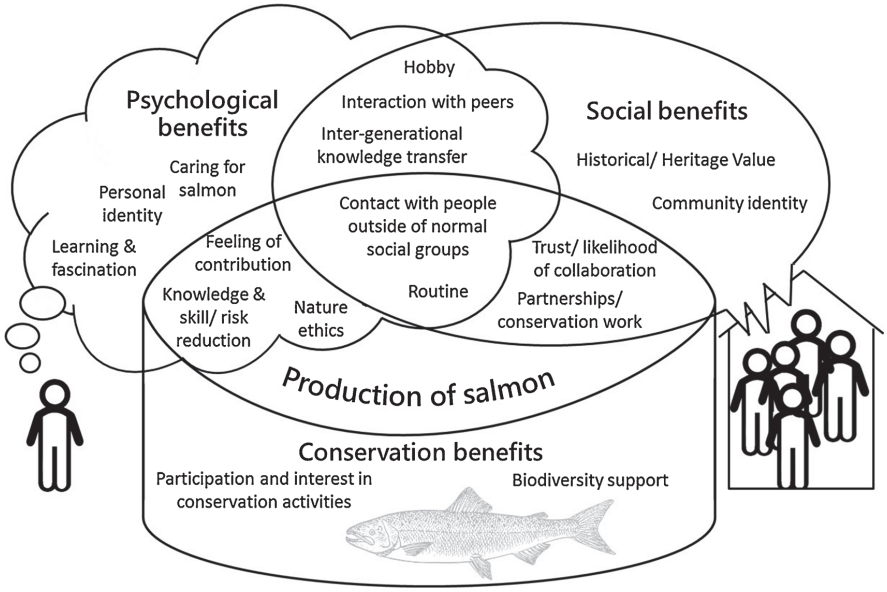

Fig. 1. Illustration of the interconnected and overlapping nature of psychological, social, and conservation benefits produced by voluntary hatcheries. Some benefits are interdependent on multiple functions and interactions occurring within hatcheries, and could not occur without the co-production of multiple benefit domains at once.

a descriptor of voluntary hatchery activities. For example, is voluntary cultivation simply another broad form of outdoor recreation focused on fish and fishing? Or, does this work belong in a category of activity more akin to traditional non-government organization conservation work, such as habitat improvement, monitoring, or activism?

These questions are relevant as voices critical of voluntary hatcheries often suggest that benefits gained from hatcheries could be substituted with a different recreational activity or a more "appropriate" conservation activity. From our study, we know that cultivators seek hatchery activities *in addition* to their regular recreation activities (e.g., angling), suggesting that cultivation work fulfills different needs or provides different or supplementary benefits than those already obtained elsewhere. Additionally, the primary benefit of "access to conservation opportunities" described above is not a benefit typically identified as part of the outdoor recreation framework in general or angling specifically, and therefore is not truly "recreational" in nature.

From this, we conclude that voluntary hatchery work, while providing many of the same benefits as typical recreation activities, is not typically sought after as a recreational pursuit and therefore should not be categorized as a recreational activity *per se*. Rather, engagement in voluntary hatcheries can be constructed as providing opportunity to achieve a higher good; to give something back to nature and help salmon recover or maintain in the face of environmental (or perhaps political) adversity, perhaps best termed as environmental stewardship.

4.2. Understanding the drivers that keep hatcheries open

Taking these findings into account, it is unlikely that voluntary hatcheries are immediately substitutable solely through other activities such as habitat improvement. In addition to the reasons stated above, preference for hatcheries over other types of conservation activities may be a result of historical path dependencies, political visibility of stocking, or strong social norms by the angler constituency (van Poorten et al., 2011; Riepe et al., 2017). For example, all cases had a long lasting tradition of hatcheries where stocking has been a key management and conservation tool for a long period of time (Berg, 1986; Bottom, 1997; Wolter, 2015), likely transferring hatchery practices into habit. Once this transformation occurs, cessation or substitution of the activity is exceedingly difficult due to loss aversion (Kahneman and Tversky, 1984) in light of the multiple benefits created by hatcheries.

The cultivators in our investigated cases had few, if any, alternative means of pursuing their conservation drive due to substantial legal and economic structural constraints in pursuing habitat work. This is another reason why voluntary hatcheries have become the primary outlet for conservation work by local stakeholders and anglers (Arlinghaus et al., 2015). Anglers "stubborn" allegiance to hatcheries for conservation reflects these constraints, as well as the other benefits they derive from participating in hatchery-based conservation. Importantly, habitat improvement is different from stocking; it demands intensive networking with other social-ecological systems and decision-makers and often suffers from low implementation rates and high costs (Aprahamian et al., 2003; Bilsby et al., 1998). By moving from hatcheries to habitat work, cultivators lose some sovereignty through collaborating with agencies, agricultural sectors, hydropower, water management and other actors. Thus, the transactions costs of habitat management are high, and the way such activities tie into empowerment and abilities of individual anglers to make decisions is substantially different from that of stocking. It is thus unlikely that habitat management activities can easily substitute the benefits derived from voluntary hatcheries from a sociocultural perspective.

Finally, in cases where voluntary hatchery status is under debate, valuation of multiple benefits helps to explain conflict-oriented behavior from both cultivators and managers. From this study, it is clear that the focus on efficacy and cost-effectiveness by some scientists and managers is divergent from the multiple focuses of local cultivators. Thus, groups are valuing and prioritizing the benefits produced by voluntary hatcheries differently. This point is essential as contemporary debates about hatcheries and stocking have focused on efficacy of hatcheries to help conserve wild stocks as compared to economic and opportunity costs, and most scientific discussions relate to the actual contribution (or damage) hatcheries can do to wild salmonid stocks and their environment. This is not the framing local cultivators have about their hatcheries. Consequently, many scientists and managers effectively ignore the many other psychological, social, and conservation benefits produced by voluntary hatcheries which matter to stakeholders.

Assumptions that the drivers for continued local hatchery work on salmon are related primarily to increased opportunities to catch fish are refuted by this study (particularly in the Welsh and Norwegian cases). The same is true for assumptions that the lack of engagement in alternatives to stocking is the result of the inability of cultivators to understand and adapt to new scientific knowledge. Further efforts to manage voluntary hatcheries solely from this framing will likely exacerbate existing conflicts between conservationists, fisheries managers, and local cultivation groups. Moreover, in countries where Atlantic salmon are extinct there is little alternative to engaging in stocking − an activity that must be supplemented by (or perhaps should supplement) large scale habitat restoration. If public managers of rivers and fisheries need or want to restrict or terminate hatchery programs (or hold discussions about such initiatives), our study suggests they must be aware of the multiple meanings cultivators attach to hatcheries and the specific contextual setting in which hatcheries are operated (e.g., extinct wild stocks). Manager and communicators would be well-advised to accept the underlying psychological forces and be cautious in their communications and decision-making if they are to maintain a constructive dialogue.

4.3. Holistic strategies for managing voluntary hatcheries

A key message of this article is the importance of hatcheries to hatchery practitioners, and how they and society gain many important benefits from hatcheries apart from the production of salmon. To that end, management of voluntary hatcheries should be cognizant of and ideally facilitate different types of benefits. While legitimate concerns about hatcheries should not be ignored (Cowx, 1994; Grant et al., 2017; Waples, 1999), managers could shift the focus and purpose of voluntary hatcheries toward a more holistic approach (Lorenzen et al., 2010) by adding non-biological benefits to stocking and hatchery objectives. This shift will require all stakeholders to reach a shared understanding of the goals and objectives underlying hatchery programs, consider trade-offs to achieve multiple outcomes (McShane et al., 2011), and recognize the merits of all stakeholders' arguments and values (Harrison and Loring, 2014; Loring et al., 2014; Redpath et al., 2013). This change in perspective would achieve a broader scope of purpose for hatcheries and avoid alienating stakeholder groups that pursue conservation activities, but who also derive social and psychological benefits from hatchery work.

Until now, cultivators have been incentivized to argue the case in support of hatcheries from a stock-based perspective, engaging in a power dynamic that situates research-based knowledge superior to other knowledge types (Ingram, 2008). However, research on the efficacy of voluntary hatcheries is often insufficient (Cowx et al., 2010), allowing the hatchery debate to continue without sufficient information. Rather than relying upon reactive commentary on top-down proposed policy changes, we recommend a transdisciplinary management approach (Chapin et al., 2010; Cowx et al., 2010; Fujitani et al., 2017) which will achieve four important outcomes: (i) explicit consideration of non-conservation benefits, (ii) jointly-produced knowledge that brings better information into hatchery management and effectively corrects misconceptions held by anglers, cultivators or managers about the achievements of stocking programs (Arlinghaus,

2006; Cowx, 1999); (iii) increase buy-in of non-scientists into research outcomes; (iv) help in conflict resolution.

5. Conclusion

Our study provides new perspectives and information for considering voluntary hatcheries as salmon conservation tools. Voluntary hatcheries provide diverse and bundled psychological, social, and conservation benefits to both cultivators and salmon stocks. These benefits have strong parallels to benefits derived from recreational angling and outdoor recreation, but are likely not replaceable by angling or other already-present recreational activities in these case studies. Decision makers could take advantage of these many benefits by creating better-defined goals and objectives for hatchery and/or stocking projects in harmony and close collaboration with hatchery operators, pursuing joint studies and co-production of knowledge about stocking impacts and outcomes, and better fostering civil engagement toward salmon conservation with anglers and other stakeholders. In this context, managers and policy makers should recognize the many non-conservation benefits that hatcheries provide when implementing outreach and communication strategies to avoid defensive and conflicting situations.

Hatchery groups have the same basic goals of most river and fishery managers − to generate means to help salmon maintain or recover their populations. It will be beneficial to build on this common interest and jointly work toward addressing the overarching reasons for why wild salmon stocks often decline. By contrast, taking an exclusive biological perspective and being overly critical of hatchery efforts promises to create enduring tension with those for whom hatcheries provide the means to generate meaningful civil engagement for salmon conservation. We recommend greater opportunity should be made of cultivator's willingness to participate in a wider set of conservation measures beyond stocking and provide the political and social resources to address the reasons of salmon decline.

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie project IMPRESS [GA No. 642893]. The first author also received funding from the Oxford Small Travel Grant [2016]. No funding agencies had any role in the study design, execution, or reporting of results.

Conflict of interest

The authors declare that they have no conflicts of interest.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors beyond that which is described in the text. All data collected and used in this study was collected in accordance with the Norwegian Centre for Research Data Authority standard via project #47203.

Contributors

All authors listed have participated substantially in the manuscript's development. Hannah Harrison (HH), Øystein Aas (ØA), and Robert Arlinghaus (RA) designed the study; HH and Sophia Kochalski (SK) collected the data; HH and SK performed the analysis; HH, SK, RA and ØA interpreted the data and wrote and edited the manuscript and its revision. All authors approve the final version.

Acknowledgements

The authors wish to thank all those who graciously gave their participation, knowledge, and time to this study. Thanks also to N.O. Brekke for his translation services, and to NINA staff for their transcription and translation help. Special thanks to the two reviewers and editors of this article who gave helpful critiques and comments to the text.

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Paper IV

Title: Understanding and managing social conflict over Atlantic salmon (*Salmo salar*) conservation using discourse analysis: the case of termination of voluntary hatcheries in Wales

Authors: Hannah L. Harrison[1], Sophia Kochalski[2], Robert Arlinghaus[2 4], Øystein Aas[1 3]

1. Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management (MINA), Universitetstunet 3, 1430 Ås, Norway
2. Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 310, 12587 Berlin, Germany
3. Norwegian Institute for Nature Research (NINA), Vormstuguvegen 40, NO-2624 Lillehammer, Norway
4. Division of Integrative Fisheries Management, Faculty of Life Sciences and Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys) Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

Abstract: Stakeholders with shared interests in fish conservation often disagree about which conservation measures are appropriate, leading to conflicts with long-lasting, disruptive effects on their cooperative relationships. Using the 2014 termination of Welsh Atlantic salmon (*Salmo salar*) stocking as a case, a critical discourse analysis of interview data, online print media, social media, and policy documents was conducted to analyze mechanisms of conflict and evaluate the social effects of this policy change. We report five key findings: (1) we found that the stocking debate was shaped by two discourse coalitions ("Decline" and "Recovery"), promoting either pro- or anti-hatchery arguments, and an emerging third coalition promoting compromise and inclusive conservation practices. (2) We identified four discourse planes on which discourses were reproduced: the social plane, media plane, social media plane, and policy plane. On the social plane, conflict between the discourse coalitions was formulated around ecological reasoning about the outcomes of salmon stocking. The media and social media planes illustrated how these discourses have changed over time and move from plane to plane. The policy plane showed which discourses were considered valid by different groups in supporting their arguments for or against the 2014 stocking closure. (3) Our analysis identified shifting power dynamics supported by discourses that were successfully reproduced across discourse planes. The Recovery coalition was successful in pairing their anti-stocking discourses with prevailing scientific discourses about stocking risks, eventually leading to the institutionalization of anti-stocking discourses via a win-lose decision to terminate all stocking in Wales. (4) We identified multiple stages of conflict within this case, moving from a manifest-yet-negotiated conflict that was intensified by the decision-making process. We found that the policy change forced all stakeholder groups to acquiesce to one perspective of stocking, and consequently to undesired social side effects such as secondary conflicts and alienation of some stakeholder groups. (5) We conclude that transdisciplinary active management designed for joint learning about stocking trade-offs may be a suitable alternative to the "top down", "either-or" consultation process exercised in this case study that mainly fostered sustained stakeholder conflicts rather than leading to joint production of knowledge and understanding.

Introduction

Stocking of fish has historically been a popular management measure with the intention of enhancing fishing opportunities, compensating for degraded environments, replacing missing reproduction sites, and supporting vulnerable populations (Arlinghaus et al., 2015; Berg, 1986; Cowx, 1994; Hilborn and Eggers, 2000; Lorenzen et al., 2013). In many species supported by stocking, wild captured fish are artificially bred and offspring reared for part of their life cycle in hatcheries before being released back into the wild. Atlantic salmon (*Salmo salar*), a culturally and economically important migratory fish species in North Atlantic regions (Aas et al., 2018; Ignatius and Haapasaari, 2018), have been stocked for well over a century to support dwindling wild populations in North America and European countries, such as Norway, Germany, Sweden, Ireland, UK and Denmark (Berg, 1986; Parrish et al., 1998). In France and Germany where salmon extinction has occurred due to river channelization and fragmentation, stocking is today performed to re-introduce the species (Granek et al., 2008; Monnerjahn, 2011; Prouzet, 1990; Wolter, 2015). Beyond ecological reasons, stocking can also enhance the satisfaction and benefits that fishers and other users derive from aquatic systems (Holmlund and Hammer, 1999; Ignatius and Haapasaari, 2018; van Poorten et al., 2011). The same is true for hatchery work, which has been shown to provide multiple psychological and social benefits to cultivators (Harrison et al., 2018b).

Progress in the scientific understanding of genetics and population dynamics has raised concerns about the potential negative impacts of stocking on wild fish populations. The main concern is that hatchery fish, particularly when released in high numbers into wild populations under pressure, can outcompete or outnumber their wild conspecifics (Blanchet et al., 2008; Jonsson and Jonsson, 2006; Swain and Riddell, 1990) and thereby through cross-breeding may affect the genetic integrity of wild populations (Garcia de Leaniz et al., 2007; Laikre et al., 2010). Such effects could narrow the genetic diversity amongst wild populations (Araki and Schmid, 2010; Garcia de Leaniz et al., 2007; Naish et al., 2007), while producing fish that could be maladapted to the natural environment in the long term (Araki et al., 2007; Henderson and Letcher, 2003). For Atlantic salmon, the accumulating evidence that stocking may have adverse effects on wild populations and genetic biodiversity has led to recent changes in stocking guidelines and practices in Europe over the past decades and an emphasis on habitat restoration to rebuild declining wild stocks (North Atlantic Salmon Conservation Organisation, 2017; Norwegian Environment Agency, 2014). Concerns about hatchery practices have also been raised towards voluntary initiatives by local angling clubs and river

owner associations (Harrison et al., 2018b, 2018c), which coexist in Europe with larger state-driven initiatives but are not mandated by law and are often informally run (Berg, 1986).

The interplay between social and ecological risk and benefits makes stocking a contentious issue (Hunt and Jones, 2018), particularly because some research has pointed toward stocking as an effective measure depending on stocking objectives and circumstances (Amoroso et al., 2017; Arlinghaus et al., 2016; Camp et al., 2014; Lorenzen, 2014; Lorenzen et al., 2013). When policy changes restrict fish stocking and hatchery use, people can experience loss aversion (Kahneman et al., 1991) or a decrease in their overall satisfaction with a fishery (Dorow and Arlinghaus, 2012; Riepe et al., 2017; van Poorten et al., 2011). These psychological effects can foster conflictive behaviors (Harrison et al., 2018b, 2018c; Harrison and Loring, 2014) such as resistance toward policy changes and a breakdown of stakeholder trust in fisheries governance systems. While it is necessary for different groups to exchange views and eventually adjust practices to reflect improved scientific knowledge on management of natural resources and wildlife (Fujitani et al., 2017), prolonged and "violent" conflict over stocking-related issues can undermine conservation goals (Harrison and Loring, 2014; Loring et al., 2014; Pomeroy et al., 2007), and have other undesired social and ecological outcomes (McGinnis and Ostrom, 2014; Pomeroy et al., 2007). For example, salmon cultivators often establish collaborations with the public sector and local actor groups (Sayles and Baggio, 2017), and engage in other conservation activities beyond stocking (Harrison et al., 2018b). Conflict over cultivation – the human-facilitated crossing of salmon reproductive material and rearing in artificial environments - to support wild stocks may then disrupt these collaborative relationships and alienate cultivators from participating in future conservation work, potentially losing important promoters for change in the local environment (Granek et al., 2008). This is why the accessibility of conflict resolution mechanisms is seen as one of the preconditions for the sustainability of social-ecological systems (Ostrom, 1990).

To prevent, mitigate, or resolve conflicts surrounding stocking and fisheries management in general, it is necessary to understand a conflict's underlying mechanisms. Given that conflicts in fisheries often persist and develop over years, we posit that it is not only necessary to look at structural and material causes for conflict (Arlinghaus, 2005; Charles, 1992; Harrison and Loring, 2014; Pomeroy et al., 2007; Redpath et al., 2013), but to view conflicts as processes and take into consideration the development of conflict over time (Bennett et al., 2001; Harrison and Loring, 2014). Our interest was to understand a stocking-related conflict as a process by using a case study on the 2014 termination of Atlantic salmon

stocking in Wales. Despite a policy review, consideration of the relevant scientific literature, and a public consultation process, the policy shift and the process by which it was made has drawn significant criticism from hatchery supporters and contributed to conflict between pro- and anti-hatchery factions (Harrison et al., 2018b). The aims of this study were to describe the stocking debate before, during and after the consultation process and to analyze mechanisms of conflict in this case. We used critical discourse analysis (CDA) (Fairclough and Wodak, 1997) because it views discourse as the linguistic manifestation of social reality, thus giving us the opportunity to access social processes through spoken words and written text. In using this approach, we extended the example of others (Butteriss et al., 2001; Whittaker & Mercer, 2004) to look at the discourse at four different societal arenas, called discourse planes: the societal, media, social media and policy planes. By describing and analyzing a real-world example of the stocking debate, we aimed at understanding underlying social aspects to the debate with the goal of drawing conclusions for more sustainable management of wild salmon populations that considers social and ecological outcomes of cultivation work.

Case background: Salmon stocking on the River Wye

The River Wye salmon fisheries have been important to the region since the medieval period (Hurley, 2008). Fishing rights belong to owners of property adjacent to or including the river, an ownership scheme common to European riverine fisheries (Arlinghaus, 2006; Daedlow et al., 2011).

Following the peripatetic cycle of salmon fisheries and anthropogenic events on the Wye, efforts to improve and conserve wild salmon runs in the Wye have been undertaken throughout the 19^{th,} 20th, and 21st centuries. Because of logistical and environmental challenges to in-river stock monitoring, current stock assessments on the Wye are made from egg-deposition modeling and rod catch surveys of adults, and electrofishing surveys for juvenile abundance estimates (M. Guys, Personal communication, September 10, 2018). These surveys show trends in Wye salmon stocks similar to trends in wild Atlantic salmon populations in other European countries: a relative abundance of salmon from the mid-1960's until the late 1980's, followed by a sharp decline in the early 1990's that precipitated into the comparably low abundance found today (Figure 1). Current fishing regulations on the River Wye limit salmon angling to catch and release only, and fishing licenses are purchased through private river owners, angling clubs, or other local organizations who lease fishing permissions.

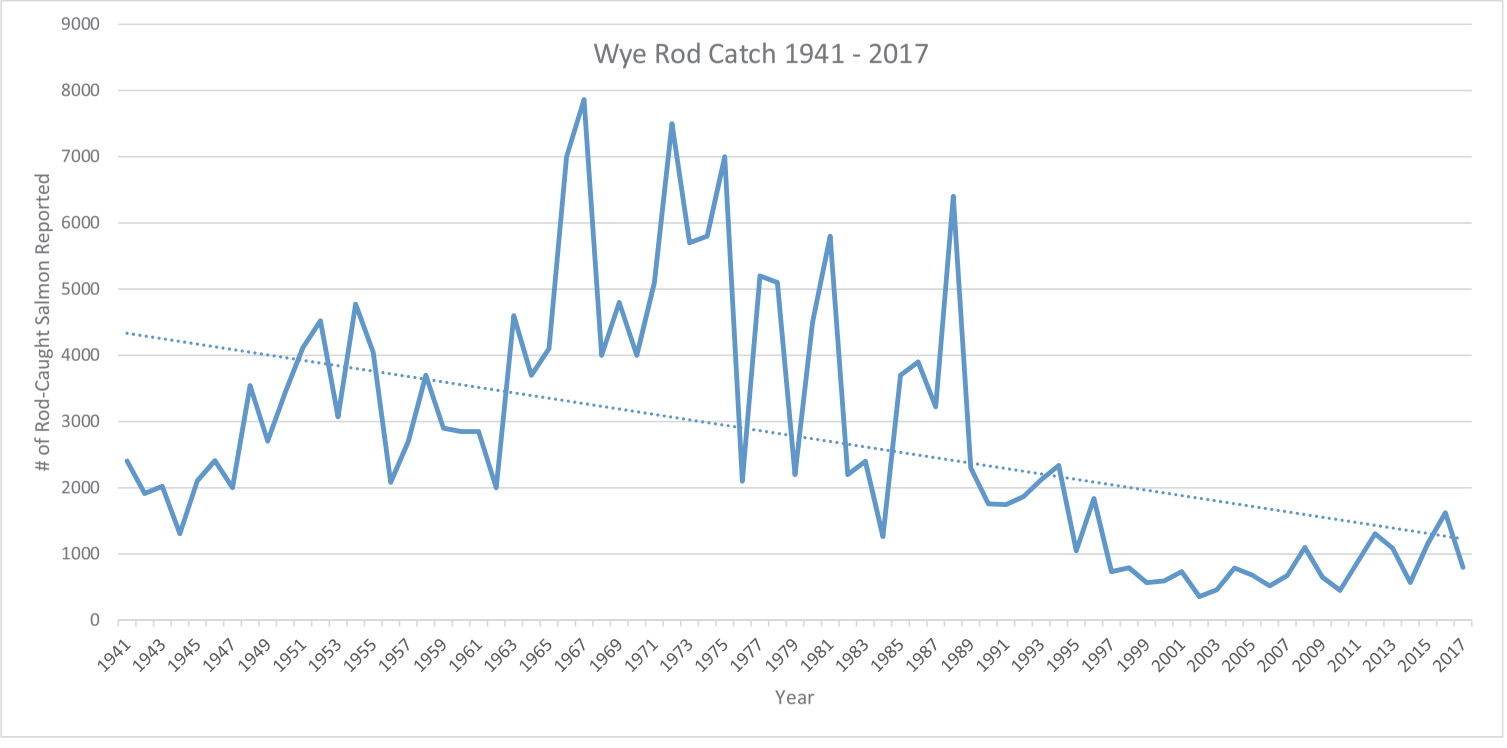

Figure 1 Wye Rod Catch from 1941 – 2017 with trend line, showing an overall decrease in number of reported rod-caught salmon.

Data sources for Figure 1:
1941 to 1965 Wye River Board, Fisheries Dept, Annual reports.
1966 to 1973 Wye River Authority, Fisheries Dept, Annual Reports
1974 to 1976 Welsh National Water Development Authority, Wye Rivers Division, Fisheries Dept, Annual Reports
1977 to 1983 Welsh Water Authority, Wye Division, Fisheries Dept, Annual Reports
1984 to 1988 Welsh Water, Wye Area Fisheries & Conservation Dept, Annual Reports
1989 to 1993 National Rivers Authority, Welsh Region, Wye District Annual Reports
1996 to 2012 Environment Agency, Welsh Region, Area Annual Reports
2013 to 2017 Natural Resources Wales, Annual Salmonid and Freshwater Fisheries Statistics

Hatcheries and salmon stocking were implemented on the River Wye in the early 20th century in response to damming of the Elan Valley to improve the water supply to nearby metropolitan areas (Mansergh, 1901). Since then, a series of hatcheries and stocking projects operated by both the state as well as conservation organizations have been used to stock the River Wye with juvenile salmon. The most recent incarnation of stocking efforts began in 2011 with the introduction of a semi-natural rearing (SNR) pond initiative intended to rear a more wild-type salmon with potentially improved behavioral and physiological adaptations to survival in the Wye. The SNR pond project recapture study was intended to run for 10 years, where all rod-caught salmon from the River Wye and its tributaries were to be inspected for an indicative clipped adipose fin.

The River Wye is a transnational river that makes up part of the border between eastern Wales and southwestern England. Prior to 2013, the river and its fisheries were managed in cooperation between Environmental Agency Wales (EAW) and Environmental Agency England (EA). However, in 2013 EAW was merged with the Countryside Council for Wales and the Forestry Commission Wales into the consolidated and broader-reaching agency Natural Resources Wales (NRW) (*Asiantaeth yr Amgylchedd Cymru*). The resulting managerial structure separated the duties of NRW and EAE to their respective sides of the national border.

In Wales, NRW is responsible for a broad remit of governance. Specifically with regard to their management of salmon fisheries, NRW commits "to protect, through best-practice scientific management and the ecosystem approach, the sustainability and productivity of wild salmon and sea trout stocks in Wales" (Gough, 2017). In this, NRW defines an ecosystem approach as an "approach in which populations of fish are managed in a holistic way as a component of the environment, and not solely for the support of recreational or commercial fisheries" (Natural Resources Wales, 2014a. pg. 9). NRW salmon managers also balance other competing regulatory obligations such as overarching frameworks such as the European Union's Habitats and Water Directives (92/43/EEC, 1992; 2000/60/EC, 2000) and the Salmon and Freshwater Fisheries Act 1975, as well as considerations such as encouraging the sale of fishing licenses that fund resource management initiatives.

The 2013 agency restructuring prompted a re-evaluation of many projects and their compliance with multiple requirements and multiple agencies. The review resulted in a proposed policy to terminate all stocking projects in Wales, inclusive of third-party commercial hatchery and stocking operations. After a contested public consultation process, the eventual decision was to terminate all stocking in Wales in 2014 (with the exception of

some research-based projects). In 2015, the last remaining SNR pond-reared salmon were released into the Wye.

Methods

Theoretical approach

We applied critical discourse analysis (CDA) (Fairclough and Wodak, 1997) by identifying language, themes, and events that together composed discourses about the policy decision to terminate stocking. Importantly, CDA is not interested in the linguistic elements of the source texts, but rather in what elements are recurring within the text and how power, society and culture are shaped by and shape the discourse (Fairclough and Wodak, 1997). By analyzing the component strands of those discourses, the main drivers of conflict and power relations between the discourse coalitions were revealed (Fairclough, 2001; Jäger and Maier, 2009).

We followed the steps to discourse analysis proposed by Fairclough (1989, 1992): compilation of the data corpus, transcription of recorded information (where applicable), and selection of relevant text section that were related to conflicts over hatcheries and stocking. For each text sample, we analyzed the text (themes, structures, patterns, language, events), the immediate textual context (e.g., how are people interpreting the situation? How does the text relate to the other discourse fragments in the text?), and the relationship to the context and the overall discourse (e.g., do people agree or disagree? What contextual factors influence this discourse? Does the discourse contribute to a social power struggle?). For concrete work with the text, we followed the coding and categorization procedures developed for and applied in grounded theory such as open coding, development of concepts and then categorization of concepts to form theories (Corbin and Strauss, 1990; Strauss and Corbin, 1990).

Data collection

The analysis was based on the categorization of discourses in four planes: the social (interview data), media (news articles), policy (documents relating to NRW's hatchery consultation in 2014), and social media planes (postings in forums and social media platforms). Discourse planes are societal locations where discourses about a specific topic are taking place (Jäger and Maier, 2009). Different discourse planes "influence each other and relate to each other" (Jäger and Maier, 2009, pg. 48) so studying them conjointly offers a better opportunity to better to represent social complexity and understand complex social processes than studying a single discourse plane.

For the social plane, in-depth, semi-structured interviews and site visits were conducted with 26 individuals in locations selected by interview participants during two weeks in June 2016. Participants were identified using the key informant method (Marshall, 1996) as well as through purposive sampling to equally include all relevant stakeholder groups (representatives of angling clubs and conservation organizations, river owners, retired

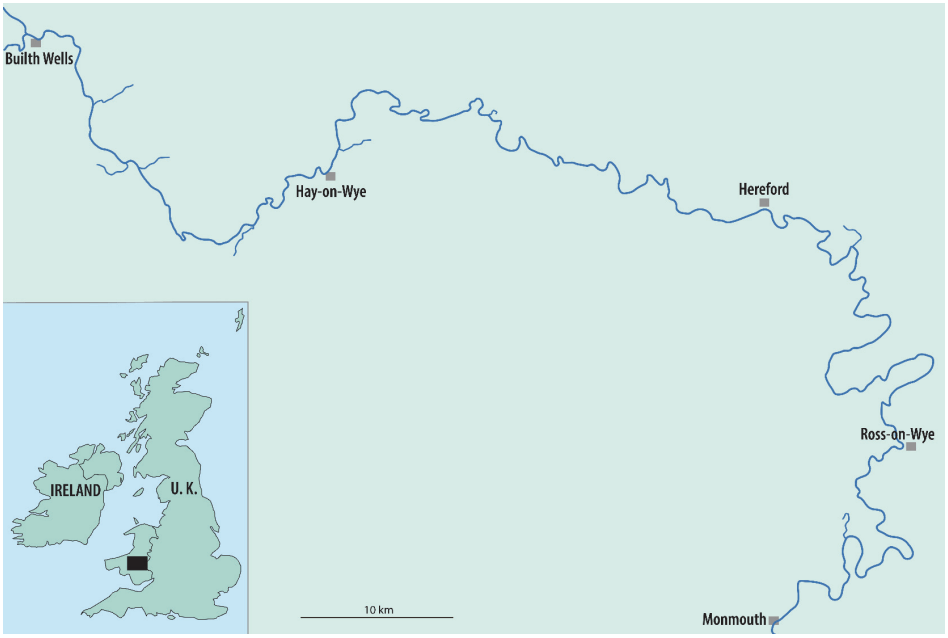

Figure 2 Map of the study area. River Wye and catchment area between Builth Wells and Monmouth.

and current salmon fishery managers, biologists and salmon cultivators, individual anglers, and ghillies). Researchers traveled to meet interview participants throughout the Wye catchment area between the Builth Wells and Monmouth areas (Figure 2). Researchers also engaged in participatory observation activities, allowing them to gain insights about the River Wye salmonscape, salmon rearing practices, and the social experiences of interview participants. Interviews were conducted with individuals and small groups, typically lasted between 60 – 180 minutes, were recorded with the approval of the participant, and later transcribed. The interviews were semi-structured with open-ended questions and interview participants were encouraged to share relevant information and stories (Corbin and Morse, 2003; Witzel and Reiter, 2012).

The analysis of the media plane was based on 23 online newspaper articles from outlets such as the BBC (*N* = 9) and The Guardian (*N* = 1), the Hereford Times (N = 2), the Independent (N = 3), and a selection of smaller news outlets (N = 8) spanning the time period from 1995-2017 (see Appendix 1). Articles were selected based on keyword searches (i.e. River Wye salmon, salmon stocking, stocking, Wye salmon fisheries, etc.) using internet search engines and searches on news websites who matched keyword searches. For analyzing the policy plane, all official responses (N= 26, representing 112 individuals) to the 2014 public consultation regarding the change of policy to close stocking and hatchery projects in Wales were collected and analyzed, as well as documents and reports produced by NRW and other government agencies as related to the policy change (e.g., evidence assessment, consultation response summary). For the social media plane, comments and postings from online forums and from social media (Facebook pages of angling groups and clubs) were collected and analyzed in the same manner as the media plane.

Data analysis

Each document was first read in its entirety and evaluated for recurring arguments, events, and discourses as well as the context in which they took place. Coding of these findings was done using qualitative data analysis software packages Atlas.Ti (Paulus and Lester, 2016) and NVivo (*NVivo qualitative data analysis Software*, 2012). Codes were organized around concepts; related or similar concepts and codes were grouped together to form categories and identify patterns and linkages (Strauss and Corbin 1990).

Coding was primarily conducted by the first author. To evaluate the robustness of the analysis, the second author coded parts of the text corpus from the social, policy and media plane separately. Comparing the emerging codes and themes between the coders revealed a high degree of agreement between the two coders. All codes and themes, especially those not initially agreed upon by both coders, were discussed between the coders and other authors to further corroborate the validity of the coder's findings.

The process of coding, grouping and categorizing made it possible to identify and disentangle discrete discourses strands which eventually could be attributed to opposite points of view (i.e. pro or anti-hatchery). Based on these opposing lines of argument, the social groups or individuals repeating and promoting them were categorized inductively into discourse coalitions. Members of a discourse coalition share particular terms, concepts and ways of thinking of and representing social and physical processes, but the members of a

discourse coalition do not need to have a formal relationship and discourse coalitions are not forms of conscious coalitions to promote specific agendas (Hajer, 1995).

Finally, we re-constructed the narrative of each discourse coalition by examining how those discourses were produced in, supported by, changed within, or were intermittently present or absent across the discourse planes. We identified primary discourse strands within each plane and discourses that occurred together and focused on a common topic (Jäger and Maier, 2009). We verified each discourse strand by comparing each of them against the same features of the other discourse planes. Through this process, we were able to identify whether discourses were specific to one plane or shared across the case and which discourses were consistently produced in the different planes by which discourse coalition.

To build an integrated understanding of the stocking debate on the Wye, we present our analysis in three parts. In part I, we identify and examine discourses about the stocking debate, focusing specifically on discourses on the state of the Wye salmon stocks and what actions should be taken to address problems. Here, the results focus on discourses elicited from the social plane via interviews. The social plane is formed through ongoing conversations prior to and during the time of the study, and thus was the most appropriate platform by which to gain detailed and in-depth descriptions and understandings of the major discourses within this case. These discourses were then supported by evidence found in the media plane, and later were consolidated and reproduced in the policy plane. We also established a timeline of discourse development by comparing discourse from the media plane (which take place over known time periods) to discourses described in the social plane. Thus, we could verify how discourses had changed over time even with the limitation of collecting social plane discourses in one discrete data collection period (spring 2016) after the stocking termination event had already occurred. In part II, we examine discourses specifically about the 2014 consultation process ahead of Natural Resource Wales' decision to terminate stocking throughout Wales. These discourses arose from the policy plane, which is composed of consultation responses and other public documents related to the consultation process. This discourse plane also offered documented evidence of themes described by the discourse coalitions in the social plane and media plane. In part III, we look at the aftermath of the policy decision. As our fieldwork took place in 2016, we examined how the binary choice to end stocking shaped subsequent discourses and evaluated whether this policy change exacerbated or relieved the hatchery debate. Here, the social plane was important for providing current impressions of past events, and the media and social media planes

supported, challenged, or expanded on those social plane impressions by providing additional information.

Results

Part I: the stocking debate

Discussions about salmon and stocking of salmon in the River Wye were shaped by two major discourse coalitions that we call the Recovery and the Decline Coalition. These coalitions were discernable across all discourse planes and were characterized by charismatic leaders within each discourse coalition who, to varying degrees, influenced the evolution of their coalition's discourses. Longstanding personal conflicts between these leaders emerged strongly within discourses from both coalitions. The Recovery Coalition portrayed the River Wye salmon stocks as in a state of incremental recovery which was credited primarily to habitat and water quality improvement. The group included a breadth of attitudes about hatcheries and salmon stocking, ranging from rigidly "anti-hatchery" to questioning the cost-benefit balance of funding hatchery work. The decision to end all stocking activities in Wales in 2014 was generally supported. Member of this coalition included some fisheries managers, members of Wye angling groups and individual anglers, and leaders of environmental NGOs which work within the Wye watershed but are not necessarily focused on salmon issues. The Decline Coalition took positions explicitly in response to claims of the Recovery Coalition. They portrayed the River Wye salmon stocks as in a state of continuous decline or as failing to fully recover and were generally dissatisfied with the decision to end all stocking in 2014. This coalition was comprised of individuals and groups primarily made up of private and club anglers, river owners, some fisheries managers, and some NGO salmon groups.

Specific to stocking, the debate between the Recovery and Decline Coalition revolved around ecological benefits, risks, and cost-effectiveness, discourse strands raised primary in interviews (social plane) but also echoed in the media and policy planes. With regard to the benefits of stocking, the members of the Recovery coalition stated in interviews that they believed hatchery projects had not and, if not for the ban, would not offer any improvement to Wye salmon stocks. They credited any increase in the stock levels to barrier removal, habitat improvement, and bringing agriculture and forestry industries within the Wye's catchment into better compliance with river and water quality protection guidelines. Consequently, the conservation group member leading the salmon habitat restoration and improvement efforts was credited as the "savior" of the river (A. Bishop, June 13, 2016).

While habitat remediation was described as "treating the disease" of salmon stock decline, stocking was seen as only addressing the "symptoms" (S. Miles, June 20, 2016).

The interviewed Decline Coalition members unanimously agreed that the ecological recovery of the Wye was essential for salmon stocks, but believed that guidelines and regulations were interpreted in such a way that conservation work outside of habitat restoration was precluded. They argued that "habitat improvements are only one tool in the box" (Consultation response #11, pg. 3) and that stocking was a necessary addendum. As one fisheries manager exemplified:

> "What I find quite interesting is that quite often, people think it's either-or. You've got to do all the habitat, or you just got to forget the habitat and put loads of hatchery fish in. For me, it's never been that—why should the two be mutually exclusive?" (H. Smith, June 15, 2016).

Specifically, the Decline Coalition credited hatcheries as preventing stock collapse during years of low abundance and also pointed toward a lack of evidence indicating that habitat improvement was the sole effective effort on the river. They believed that the decision to end stocking had worsened future outcomes for Wye salmon, particularly in the event of an environmental catastrophe. That years of stocking had not achieved a full recovery of the salmon stock levels was attributed by the Decline Coalition to imperfect technologies, insufficient funding of research and monitoring of hatchery results, and politicized management rather than stocking as a principally faulty approach to conservation.

The debate about the effectiveness of stocking was enabled by a lack of precise monitoring of Wye salmon stocks. All coalitions were highly interested in obtaining accurate population data, as well as information about the return rate of stocked fish. The semi-natural rearing ponds initiated in 2011 were of strong interest for the Decline Coalition as a means of performing a recapture study to assess stocked return rates, as well as implementing more "wild-type" conditions to improve behavioral and conservational outcomes of stocked fish.

For the members of the Recovery Coalition, fish reared semi-naturally were still perceived to be inferior to wild stocks and the recapture study was a way to consolidate their arguments against stocking. For them, the project would have either shown that the hatchery produced fish that return as adults for spawning, meaning then that stocking had the potential to damage the genetic integrity of wild stocks; or it would have confirmed that stocking did not "work", meaning hatcheries were a waste of energy and financial resources.

According to the analysis of the media plane, this outright rejection of stocking was a result of a creeping polarization of the stocking debate. From 1996 until as late as 2010-2011, stocking and habitat improvement were portrayed in the media as complementary measures toward restoring Wye salmon stocks ("Thousands of salmon released into Severn", The Forest Review, October 20, 2010, (Appendix 1)). However, the voices represented in the media changed in the early 2000s with the efforts of the conservation group conducting habitat restoration work on the Wye being gradually more recognized.

Becoming more dominant in the media discourse was linked to the conservation group's ability to obtain grants for their work. Finances were treated by both discourse coalitions as a zero-sum game where increased funding for one measure takes away resources from another one. When weighing up stocking and habitat improvement, the Recovery Coalition argued that habitat initiatives, while expensive, were a "capital investment" (S. Miles, June 21, 2016) that could attract significant matching funds from external institutions (i.e., the EU) and thus eventually be self-sustaining. Hatcheries, they argued, required ongoing annual infusions of capital with comparably little return on investment. The Decline Coalition responded by pointing out that some hatchery initiatives were privately funded, arguing for the economic autonomy of individuals and private organizations in choosing to fund stocking programs. For example:

> "Enhancement stocking on all Welsh rivers (not being supplied by EA/NRW) is funded by Anglers, Angling Clubs, Associations and Federations who feel the need to at least try and maintain their river runs of Salmon and Sea Trout, as EA/NRW's remit "to maintain and improve" has failed so badly." [sic throughout] (Consultation response #12)

While not explicitly stated by the coalition members, our analysis suggests that the disagreement about stocking was deeply rooted in people's perceptions of the status of the salmon stocks and their goals for the future of the River Wye. This becomes most clear when taking into account the history of the River Wye. The Recovery Coalition considered 2016 stock levels to be indicative of a 'successful' (if slow) recovery of Wye salmon stocks, referencing the positive trend in rod catches from the 1990s onward (Figure 3). In contrast, the Decline Coalition, which included many of the oldest anglers (age 65 -75) interviewed for this study, refuted the Recovery Coalition's assessment of Wye salmon recovery, as many coalition members remembered stock levels from the 1970's when stocks and catch rates

were booming (Figure 1). Taking this long view, stock levels in 2016 were only an improvement in comparison to 2002 levels when total Wye rod catches were at historic lows. Some members of the Decline Coalition recognized these different temporal scales and expressed concern that the younger generation would accept the present stock levels as 'the new normal'.

With regard to the future, the two coalitions followed different conservation objectives. The Recovery Coalition sought to return the river to a more 'natural' state and viewed stocking as humans interfering with natural processes, whereas the Decline Coalition maintained that the River Wye catchment was a peopled landscape in which naturalness included some degree of human activity, and contested the notion that a policy change toward 'naturalness' would overcome many centuries of human influence. These different lines of argumentation sparked a "what comes first" debate: should habitat be improved and then seeded with stocked fish (if necessary)? Or should stocking continue until the habitat supported a sustainable population? As one consultation response asserted:

> "With the levels of salmon so low in many of our Welsh rivers it would be madness to remove this option [stocking]. Only once rivers reach a certain [stock] level can stocking be safely stopped." (Consultation #8).

The Recovery Coalition was also willing to accept a lower, if natural, level of salmon stocks. Members of the Decline Coalition supported stocking in the hope of higher stock levels and faster conservation success. Higher stock levels were seen as desirable to accommodate social, recreational and economic objectives, and faster conservation success was often valued by interviewees of advanced age who would be unlikely to live long enough to see a full stock recovery.

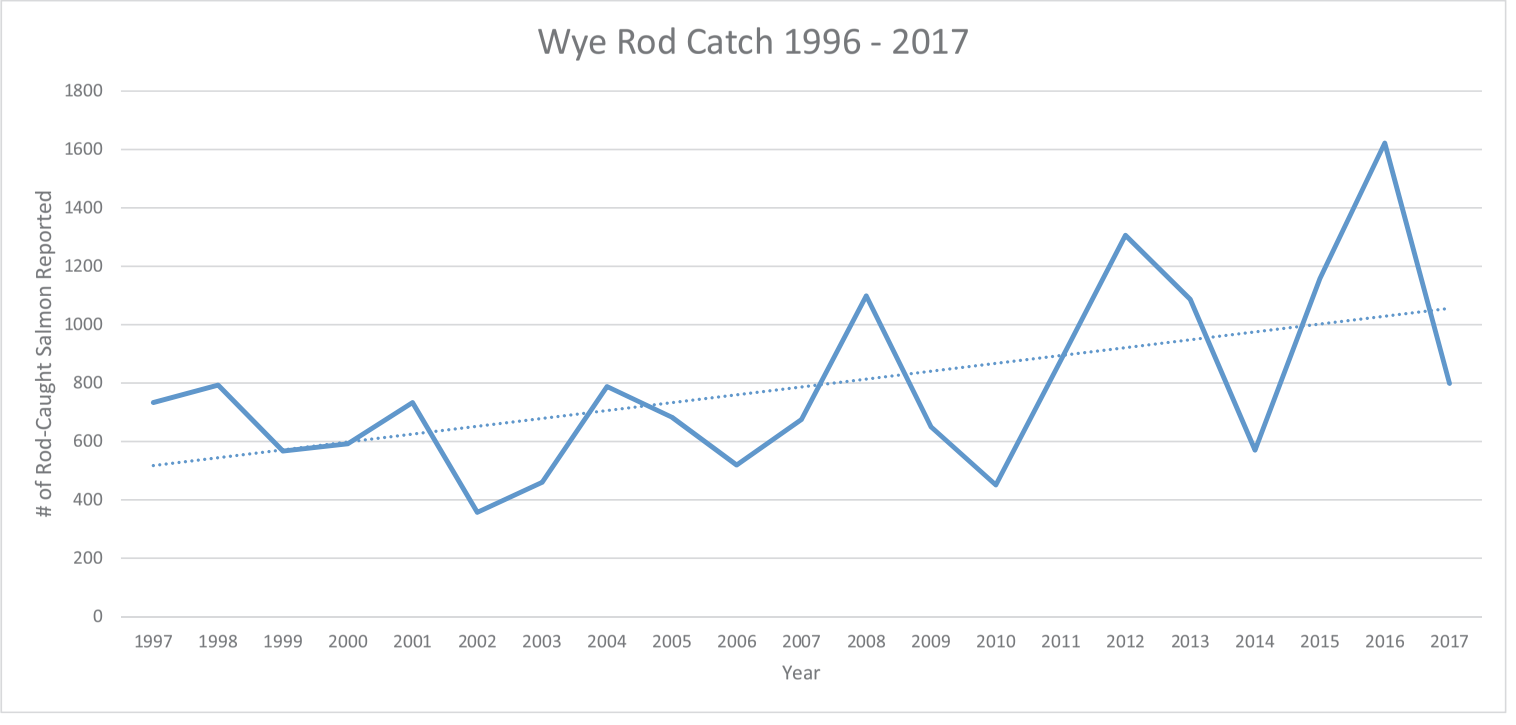

Figure 3: Wye Rod Catch from 1996 – 2017 with trend line, showing a graduate increase in overall reported rod-caught salmon.

Data sources for Figure 3:
1996 to 2012 Environment Agency, Welsh Region, Area Annual Reports
2013 to 2017 Natural Resources Wales, Annual Salmonid and Freshwater Fisheries Statistics

Part II: The public consultation process

The public consultation process occurred from March – May of 2014 during which NRW solicited comments from the public about the proposed policy change to terminate all stocking programs in Wales (Proposal document reference). This consultation process was not mandatory by law, but as a NRW official explained:

> "We wanted to talk to people. We wanted to hear views, we wanted to explain what we were doing and why we were doing it and what it would mean and what we were going to do instead. We wanted to do all of these things, and the most obvious mechanism was through this consultation process." (P. Simmons, June 17, 2016).

Within the policy plane's consultation responses, discourses were similar to those from interviews and media articles, focusing on the social, economic, and ecological costs and benefits of stocking programs on the Wye, and the scientific debate about whether hatcheries improve wild salmon stocks or cause damage. However, new discourses emerged from the consultation responses: the issue of evidence and NRW's interpretation of evidence, issues of fairness concerning how policy consultation responses were solicited, and how these issues might affect the mutual trust and future collaboration between groups.

The issue of evidence, and what information should constitute evidence about the effects of stocking, was discussed frequently in the policy plane. Evidence from other rivers outside Wales was considered simultaneously appropriate and inappropriate, depending on whether it was being used to support or refute the writer's argument. While the Recovery Coalition drew on scientific studies and international salmon management guidelines (i.e. from the North Atlantic Salmon Conservation Organization) to support the 2014 hatchery closures, the Decline Coalition referenced scientific arguments as well as social and psychological arguments for salmon cultivation.

NRW's summary and analysis of the consultation responses (Natural Resources Wales, 2014b) stated that "there has been no new evidence brought to our attention that might amend the conclusions set out in our initial review" (NRM & Salmon Stocking Report, pg.3), though our analysis found that many consultation responses from the Decline Coalition cited a number of authors, policies, and studies that they believed to support their case. Nonetheless, NRW did not consider that evidence sufficiently compelling to warrant further consideration.

This disagreement about information validity created mistrust for NRW's ability to manage Wye salmon stocks. In explicit and implicit statements, stakeholders questioned

NRW's prioritization of conservation initiatives to benefit salmon, and ability to fairly evaluate evidence from all stakeholder groups and interests. Several anglers referred back to this issue in interviews, for example:

> "There's about a half a dozen of us that felt sort of, angry I suppose, in the way that the decision had been taken and we felt that the decision to shut the hatcheries had been made and then they had to come out with the evidence as to why they made the decision and the evidence they produced was very, very weak. Extremely weak… We sort of felt we'd been steam rolled really." (T. Clemmons, June 18, 2016)

The suspicions within the Decline Coalition that the policy decision to close hatcheries was made prior to the consultation process was fueled by a design of the consultation call itself which was perceived as biased. The consultation questionnaire was written so that an inherent dichotomy between habitat improvement and stocking was established. Multiple responses to the consultation from both coalitions criticized this framing of the issue, suggesting that options inclusive of both outcomes are possible. For example:

> "We do not believe that habitat improvement and mitigation stocking are mutually exclusive. We do believe they can, and should, operate alongside each other until such time as there is substantial evidence to do otherwise." (Public consultation response #13, NRW)

Though in interviews NRW officials rejected the accusations that the call was biased and that the decision was already taken beforehand, the notion of such biases alone undermined the integrity of the consultation and diminished stakeholders' willingness to collaborate with the authorities in the future:

> "The Environment Agency [NRW] was well on its way to establish a meaningful "working relationship" with many of its stakeholders including many of the angling fraternity, this proposal will potentially put that hard won progress back considerably." (Public consultation response #21, NRW).

This challenge was acknowledged by the managers:

> "I think we've learned-- we always learn. The consultation exercise itself, the mechanics of it, could have been better. We are hoping that we've learned from that and are making a better job of talking to, listening to, and explaining issues which will affect future decisions. So, it's important we learn from this." [sic throughout] (P. Gibson, June 16, 2016)

Managers pointed out that they were also bound in their decisions by higher principles such as the Precautionary Principle (United Nations, 2002), which grants:

> "Authorities to take preventive action when there is a risk of severe and irreversible damage to human beings; action is required even in the absence of certainty about the damage and without having to wait for full scientific proof of the cause-effect relationship; when there is disagreement on the need to take action, the burden of providing the proof is reversed and placed on those who contend that the activity has or will have no impact" (United Nations, 2002).

Part III: The Aftermath

The decision to close all non-research stocking in Wales was made as a binary choice: leave hatcheries open or close them. Discontent over the consultation added a second level of conflict on top of the original conflict. People who did not achieve their preferred outcomes were discontent, but they were also dissatisfied by the process itself, e.g. that some evidence was not taken into consideration. This mismatch of expectations between what NRW was required to consider and how those who submitted consultation responses believed their input would be considered, a common theme within the social plane, illuminates why this conflict persisted during our fieldwork in 2016 when stocking had already been closed for two years.

The 2014 stocking closure also prematurely ended the semi-natural rearing ponds project, another point of frustration arising in the social and policy planes from Decline Coalition members who believed that the findings from the project could have provided conclusive information toward ending the Wye stocking debate. Without ongoing stocking, it became impossible to meaningfully evaluate the effectiveness of stocking and demonstrate one way or another the actual impacts of stocking on the Wye.

In this situation, social media filled this gap by allowing a somewhat subversive space to express critical opinions to the decision. This is perhaps an indicator that those who felt unheard in mainstream media discourses turned to cyberspace and social media platforms.

Unlike in other planes where Recovery Coalition discourses were becoming dominant, the social media plane was dominated by Decline Coalition discourses.

This re-emergence of evolved discourses often surprised those who were not privy to their evolution in social media, and sometimes re-ignited old conflicts. For example, a fishing syndicate's Facebook page reaction after a 2017 pollution event reflected that grievances about the prohibition on stocking were still present:

> "Is it a coincidence this is happening now[?] It is illegal to operate salmon/trout hatcheries in Wales. Is it fate or is it just destiny that the easiest way to kill off salmon is to let the farmers do [pollution] while we are impotent to do anything about it and the powers that be twiddle their fingers and refuse us the right to restock?" (Facebook post, April 17, 2017)

This comment from the media plane indicates that the decision to end stocking in Wales may have achieved certain policy goals but was not effective in ending conflict over hatchery use. Rather, the public consultation process and policy decision to end stocking may have entrenched already polarized discourse coalitions further.

The polarization and subsequent fractioning between the existing discourse coalitions had another, possibly beneficial, outcome: the emergence of a Middle Ground Coalition. This group had begun to emerge before and during the 2014 policy change process and the policy change created space for their discourses to gain attention within the Wye watershed. This coalition elevated concepts of compromise in order to create room for all parties at the salmon management table. It included fringe members of both the Recovery and Decline coalitions who believed that the River Wye was probably recovering ecologically, but simultaneously acknowledged that there were great social divides that must be bridged in order for the Wye to recover in all aspects – socially, ecologically, and economically. Crucially, it appears that although small in numbers, the members of the Middle Ground Coalition had the potential to achieve outcomes that leaders from the other coalitions could not. For example, a leader from the Recovery Coalition posted online:

> "As a group, we Wye anglers and owners, guides, ghillies, associations, trusts and seem to be committed to punching as far below our weight as we can. We have problems agreeing in many areas; we seldom agree to disagree and this is a gift to those who would have the river used for other things. So my plea for 2018 is to ask

> everyone to value the benefit of a more united front. Can we agree to disagree on some of the dividing areas and put right some of the bad things that affect is all and reclaim the lost ground?" [sic throughout] (January 2, 2018, flyfishingforums [flyfishing.co.uk])

To which a Decline Coalition member replied to the original author:

> "Biggest load of cr*p I have ever heard. Anyone who has had dealings with this man is unlikely to want to do so again in my opinion. Time the elephant left the room ASAP." [sic throughout] (January 4, 2018, Facebook)

Yet, the same sentiments were expressed in the social plane by a Middle Ground Coalition member who was reported as very well respected and admired by other interview participants:

> "Ultimately you try to get together a group of individuals who can work together, rather than spend three hours arguing. My fundamental sort of aim whenever I'm involved [with] the Wye is simply the good of the river, and the good of the salmon. And I don't really care whose side you're on or what your agenda is. The only thing I look at is I try to improve the salmon runs, and 'do you care about the river?' Providing those are your aims then I'm happy to try to work with you." [sic throughout] (D. Adams, June 23, 2018)

This discord indicates a power shift from polarized coalition leaders to centrist members of the emerging Middle Ground Coalition.

Discussion

Sustainable fisheries management is constantly challenged by conflict over contentious issues. In this study, we analyzed the stocking debate in the River Wye in Wales over time and across different discourse planes, including a policy consultation in 2014 that resulted in the termination of all non-scientific stocking of Atlantic salmon. The conflict can be summarized by its three basic elements: 1) stocking and other contentious issues over which conflictive behavior emerged, 2) two opposing discourse coalitions with different values, worldviews and interests, and 3) societal arenas – discourse planes - where the coalitions "met" at different times to debate the contentious issues.

The conflict took place between two Discourse Coalitions who, put simply, possessed and argued from the position of different worldviews about most facets contained within the stocking debate. Importantly, these differences were complex and nuanced and did not fall neatly into a commonly-heard oversimplification of the stocking debate: that stocking is wholly "good" or "bad". Rather, stakeholders in this case disagreed not only on the effectiveness of stocking as a salmon conservation and enhancement practice, but also on many underlying aspects related to fisheries management and on the policy consultation itself. For example, the two coalitions viewed the state of River Wye salmon fisheries differently due to different baselines for comparison, known in the literature as shifting baselines syndrome (Pauly, 1995). The Coalitions also valued evidence about the effects of habitat restoration and stocking differently because of divergent valuations of local and scientific knowledge (Harrison et al., 2018c). The Coalitions also had different goals for Wye salmon, either wanting to sustainably use or conserve the resource as 'natural' (Harrison et al., 2018a) or, because older anglers exhibited different rates of environmental discounting (Hellweg et al., 2003), achieve robust salmon stocks faster via stocking. These values and beliefs were so entangled with the topic of stocking that it is impossible to say whether stocking was to some degree a proxy for other conflictive issues or solely because stakeholders cared deeply about stocking (Arlinghaus and Mehner, 2005; von Lindern and Mosler, 2014), and feared the loss (Kahneman et al., 1991) of benefits they derive from cultivation work (Harrison et al., 2018b). These results show that different values and worldviews fueled the stocking debate in this case.

Why, then, were these differences in worldview and valuation of salmon environments difficult to see? One reason is likely found in how the many sub-topics of the stocking conflict existed, evolved, and were shared through discourse planes. The CDA approach enabled us to trace these individual discourse strands and understand these dynamics. Though each plane allowed for different types of discourses to develop based on characteristics of the plane (e.g. private vs public, formal vs informal), discourses appeared across and moved between planes in response to events, indicating a tacit, ongoing negotiation wherein discourses move, evolve, are maintained, or are forgotten if not reproduced (Figure 4).

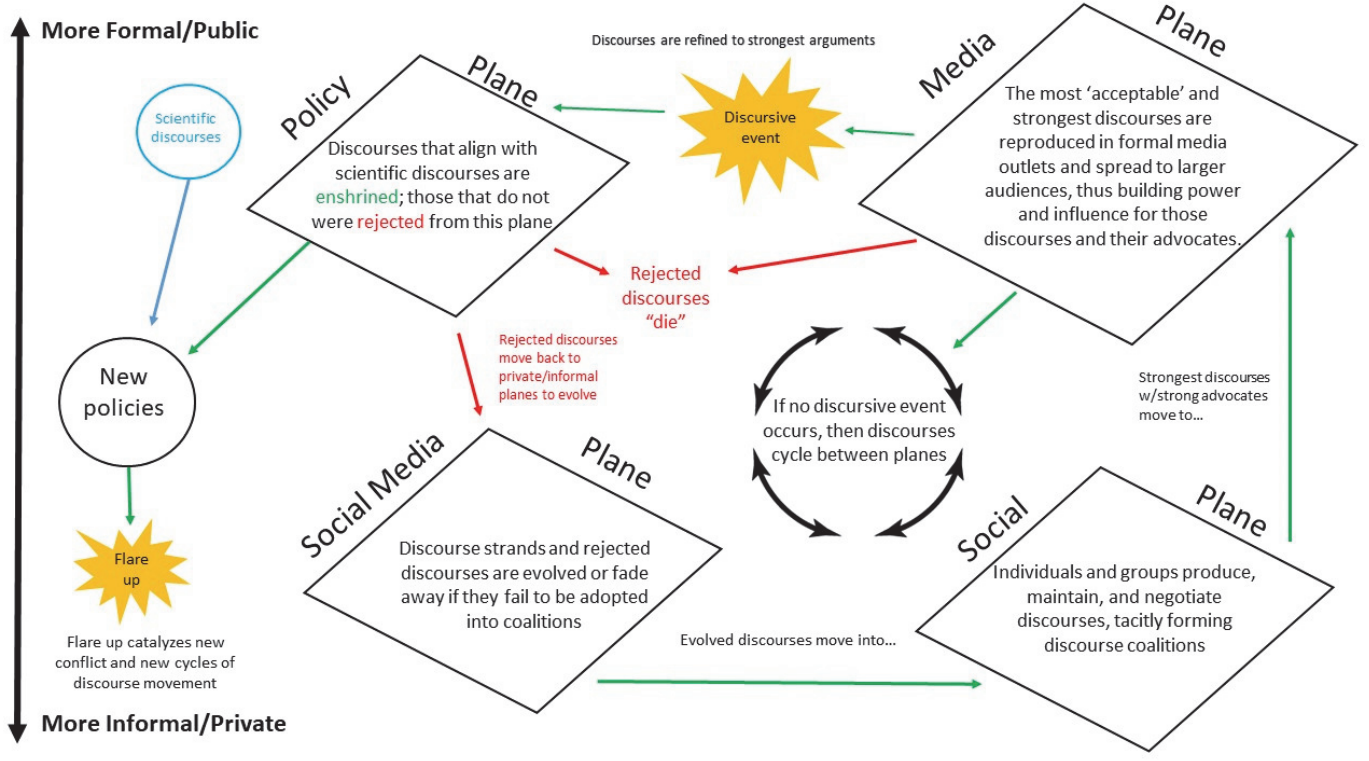

Figure 4 Discourse Plane Dynamics. Figure shows how discourses move between discourse planes the interactions taking place between them.

This is an important finding as it illuminates why some discourses persisted even while they were otherwise unpopular in the public eye. For example, the anonymity of social media perpetuated discourses that might otherwise be ignored in the social plane, policy plane, or attributed media within the media plane. Thus, this plane allowed ideas and theories about the state of Wye salmon to evolve, later re-emerging into social and media planes when a suitable discursive event, or "flare up" took place, such as the 2014 policy change debate (Figure 2). This process also explains how certain discourses gained dominance and eventually were enshrined in policy. For example, the decision to end stocking was influenced by the Recovery Coalition successfully linking its pro-habitat improvement discourse to scientific uncertainty about the effects of stocking and economic efficiency debates, discourses already embedded within managerial and scientific thinking.

As noted above, stakeholders had different agendas and conflicting values (Rittel and Webber, 1973) and coalitions struggled to define and agree upon the problems behind stocking in part due to the transitory and itinerant nature of some conflict discourse strands. One reason for this disagreement stems from a lack of definitive information and scientific consensus about the nature of stocking. While a great body of research demonstrates the potential harms of stocking into extant salmonid populations, other research discusses the potential benefits of stocking (Amoroso et al., 2017; Lorenzen et al., 2013; Sandström, 2011). From these characteristics, it is reasonable to assess salmon and hatchery governance in this case as a "wicked problem", meaning that it is inherently complex, varied and dynamic (Jentoft and Chuenpagdee, 2009; Rittel and Webber, 1973), and difficult to manage using traditional policy approaches.

Understanding conflict in stages

Despite its complexity, looking at the stocking debate, the public consultation process, and the aftermath as three stages of conflict can explain why the conflict is persistent today even after the policy decision in 2014 has passed. Before the policy decision, stocking was already perceived as a conflictive issue by the actors and the conflict was observable from the outside, i.e. the River Wye was at the stage of "manifest conflict". From classic conflict theory (Glasl, 1982; Pondy, 1967) we would expect a previous phase of latent conflict when people were not yet aware of their differences. However, we were not able to reconstruct the discourses far back enough in time to unveil this stage and gray literature suggests that harvesting, stocking and protecting salmon have been contentious issues in the River Wye for as long as there have been salmon interests (Gilbert, 1929). During the stage when the

conflict was manifest, evidence from the media, social and policy planes indicated that the hatchery debate waxed and waned in intensity based on discursive events such as policy changes and significant shifts in stock health or size. The analysis of the media plane suggests that during the 2000s, there was a polarization between the groups, suggesting that the conflict was on its way to escalation (Glasl, 1982). However, projects like the semi-natural rearing ponds and habitat improvement grants offered ways by which groups could disagree, yet still pursue their own salmon conservation goals, albeit linked to different expectations (i.e., proof of failure/ proof of success for stocking or habitat improvement measures).

Importantly, the 2014 policy change was not the government's reaction to an escalating conflict. Instead, the reorganization of Welsh resource management agencies acted as an external disturbance to a manifest, but negotiated, conflict. Thus, the River Wye salmon fishery could be seen as an example of social-ecological regime shift (Capon et al., 2015) where low salmon stocks and changing power dynamics enabled a policy change during a window of opportunity for change (Holling and Gunderson, 2002) with potentially long-lasting ecological and social consequences. As this change occurred in neither an empty, a-political or a-social atmosphere (Holland, 2002; Kooiman and Jentoft, 2009), an immediate social consequence was the emergence of a secondary conflict over the policy decision, more specifically the consultation process leading to the decision itself. This secondary conflict can be explained by three main factors:

(1) The consultation response call framed stocking and hatcheries as a binary choice to support or reject these techniques, and suggested that hatcheries were about ecological effectiveness only. However, the analysis of the social and the media plane showed that stocking and habitat restoration measures had not always been seen as opposites in the River Wye context, and stocking was discursively entangled with many different issues. Thus, the consultation forced a wide array of opinions and concerns to a narrow band of ecologically-oriented issues. The consultation process was meant to represent different opinions and evidence, but it simultaneously reproduced and strengthened positions on these issues rather than seeking compromises or fostering a discussion that encompassed all aspects of the stocking debate. This outcome indicates that fisheries managers must be aware of the dialectic nature of participatory processes and that their actions and decisions create, reproduce and suppress discourses.

(2) Prior to 2014, the ongoing debates between different groups formed a contentious but relatively stable regime state in which multiple ecological realities and understandings of stocking could co-exist. Though the issue of hatcheries and stocking was contentious, the

potential for future win-win outcomes (McShane et al., 2011) (real or imagined) existed. The 2014 decision eliminated this possibility and restricted the opportunity for discussions about stocking by forcing all stakeholders to accept one version of reality, effectively creating winners and losers amongst stakeholder groups (Cinner et al., 2014).

(3) Members of the Decline Coalition had difficulty accepting the decision to end stocking. In this case, hatchery advocates expected the public consultation to be a democratic and participatory process where all discourses concerning stocking would be heard and held in consideration equally. The actual consultation process did not fulfil these expectations, and thus was perceived as a violation of the established rules of the game. As shared and trusted procedural rules are one of the foundations enabling stakeholders to operate and negotiate within a safe space (Maguire and Lind, 2003), this perceived violation intensified conflict during and after the consultation process, a point NRW officials recognized as important to learn from and improve. Thus from a normative and an instrumental point of view, participatory processes need to adhere to principles of good governance (Costanza et al., 1998; Sissenwine and Mace, 2003) and to be fair and transparent.

The last stage of the stocking conflict, the aftermath, is characterized by the departure from stocking. Based on uncertainty about the actual strength of Wye salmon stocks and about the effectiveness of salmon stocking (Sandström, 2010), stocking was ended in adherence with the Precautionary Principle (Jordan and O'Riordan, 1995). While the long-term ecological consequences of (not) stocking the Wye are still unknown, we observed social consequences where the 2014 policy decision acted as a crucible for the previously manifest conflict. As a result, power dynamics between discourse coalitions have shifted and the Middle Ground Coalition has emerged as an influential actor group. Additionally, stocking was prohibited and so the debate over stocking became fruitless, a debate over a now-obsolete activity. As a result, people retreated to the anonymity of the social media plane to express pro-stocking views. However, the decision did not address the underlying latent issues such as opposing worldviews and values, making it possible that new conflicts will emerge in the future if they are maintained through discourses in the interim.

The decision also has resulted in unexpected costs in the form of loss of potential capital for habitat improvement projects from Decline Coalition members, social capital amongst salmon interests groups (Harrison et al., 2018b), and goodwill and trust from Decline Coalition members toward other stakeholder groups (particularly managers). The case confirms that acting solely on ecological principles can threaten other valuable assets to conservation, such as local capacity to act and social cost-effectiveness (Recuerda, 2008).

The danger of failing to address social objectives is likened to ignoring a broken leg on a three-legged stool: environmental and economic objectives will fail to bring about sustainability if not supported by satisfied social objectives (Fabinyi et al., 2014).

Ways forward

In River Wye salmon fisheries, the issue of evidence emerged as a dominant theme in the policy and social planes. There was great interest from all parties for an improved knowledge base, but continuous ecological monitoring and studies can be difficult to fund (Walters, 2007) and are logistically difficult to enact on the River Wye (P. Gibson, June 18, 2016). If such projects were funded, their outcomes could still be interpreted differently, a common feature of fisheries management under uncertainty about the state of the resource and the robustness of scientific assessments (Fulton et al., 2010; Hutchings et al., 1997). Recognizing the existence and validity of different answers, along with clear objectives and explicit, shared goals, is a prerequisite for finding shared ways forward (Harrison et al., 2018b; Redpath et al., 2013).

As this case demonstrates, participatory processes in management, such as the consultation call and response, are not necessarily effective. In the Wye case, managers chose a public consultation process which did not allow for two-way negotiation or exchange of information (Rowe and Frewer, 2005). Within the wicked problem context, the consultative approach was not able (or appropriate) to relieve conflict between the discourse coalitions who were already accustomed to and engaged in an ongoing negotiated debate. Rather, collaborative decision-making strategies in which decision-makers seek to engage all stakeholders in finding mutually acceptable solutions would likely have been more effective (Roberts, 2000). Such strategies include joint fact finding (Gray et al., 2008) and adaptive experimentation where different stakeholder groups, including scientists and managers, work together to obtain evidence that is mutually accepted (Fujitani et al., 2017). In the Wye, such an approach was started through the primarily privately-funded stocking experiment using semi-natural rearing ponds but came to a premature end. Looking back, it would have been prudent to initiate this type of project and, importantly, carry it through with respect to the established social contract between the participating parties and time required to collect rigorous scientific data on salmon.

Similarly, the emergence of the consensus-oriented Middle Ground coalition reflects action organized around the shared interests of its stakeholders. River Wye managers could take advantage of this coalition by allowing them to lead affected stakeholders into active

planning and policy-making participants. However, as with participatory adaptive management (Fujitani et al., 2017), collaborative management are time and energy consuming processes (Rittel and Webber, 1973), and the Middle Ground coalition may be effective insofar as they can address social conflicts, but not entrenched environmental or climatic challenges. Thus, pursuing interventions to perceived problems on a place-based, catchment-wide scale, rather than outright solutions to very localized problems, is a shift necessary in salmon management thinking (see Gayeski et al., 2018).

This inherently requires that managers are working within national or international management frameworks that allow them to make these priorities, which we have demonstrated is a limiting factor within the Welsh case. We posit that had the Welsh managers been working within a regulatory framework that allowed them to postpone or avoid the binary choice to leave open or terminate stocking programs, alternative approaches that achieved multiple and shared objectives may have been possible. Thus, collaborative strategies that allow competing stakeholder groups to work toward shared realities and achieve multiple objectives (Harrison et al., 2018b) could be a productive way forward in avoiding future conflicts.

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Appendix 1 – Media Plane Analysis Sources

1. NRW staff survey aims to 'get under skin' of negativity
   November 16, 2017
   http://www.bbc.com/news/uk-wales-42012809

2. To: George Eustice MP, Mister of State at DEFRA, Lesley Griffiths AM – Cabinet Secretary for Environment and Rural affairs and The First Minister of Wales, Carwyn Jones (Petition). Give Welsh Fishing Clubs and Salmon and Seatrout a Chance Campaign by Reuben Woodford
   November 2017
   https://you.38degrees.org.uk/petitions/give-welsh-fishing-clubs-and-salmon-and-seatrout-a-chance?source=facebook-share-email-button&time=1510729717

3. River Wye salmon catch hits 20-year high
   3 July 2016
   http://www.bbc.com/news/uk-wales-south-east-wales-36686081

4. Bumper spring for salmon fishing in Wye
   30 June, 2015
   http://www.herefordtimes.com/news/13362032.Bumper_spring_for_salmon_fishing_in_Wye/

5. Wye enjoys best spring salmon in two decades
   June, 2015
   http://flyfishing-and-flytying.co.uk/news/view/wye_enjoys_best_spring_salmon_in_two_decades/

6. Salmon stocking for Welsh rivers to stop from 2015
   3 October 2014 – Day after decision to close hatcheries
   http://www.bbc.com/news/uk-wales-29475698

7. Corwen salmon hatchery closure to be decided by Natural Resources Wales
   2 October 2014 – day of vote to close hatcheries
   http://www.dailypost.co.uk/news/north-wales-news/battle-save-welsh-salmon-stocks-7873009

8. Welsh salmon stocking under threat
   April 11, 2014 – Article by Hatchery International, a pro-hatchery group
   https://www.hatcheryinternational.com/news/welsh-salmon-stocking-under-threat-1642

9. North Wales: Fears for salmon numbers as hatcheries set to close
   6 March, 2014
   http://www.dailypost.co.uk/news/north-wales-news/north-wales-fears-salmon-numbers-6781314

10. Three salmon hatcheries in north and mid Wales under threat
4 March 2014
http://www.bbc.com/news/uk-wales-26437099

11. Fish legal calls for action to restore wild fisheries after closure of hatcheries in Wales
2014 – 2015 (actual date unknown)
http://www.fishlegal.net/page.asp?section=1050#

12. Salmon numbers rise in river Wye tributaries Lugg and Arrow
30 October 2013
http://www.bbc.com/news/uk-wales-mid-wales-24738260

13. Rivers Wye and Usk salmon catches increase
November 25, 2012
http://www.bbc.com/news/uk-wales-20486105

14. Wye monster salmon return
Friday 30 March, 2012
http://www.bbc.co.uk/blogs/wales/entries/59febd81-288d-3e48-b154-e060c9ef30c7

15. Salmon numbers leap to reverse two decades of decline in UK rivers
26 June, 2011
https://www.theguardian.com/environment/2011/jun/26/salmon-numbers-leap

16. Fisheries Minister Richard Benyon supports River Wye's move
5 March, 2011
http://www.herefordtimes.com/news/features/farming/8884694.Fisheries_Minister_supports_River_Wye___s_move

17. Thousands of salmon released into Severn
20 October, 2010
http://www.theforestreview.co.uk/article.cfm?id=403&headline=Thousands%20of%20salmon%20released%20into%20Severn&sectionIs=news&searchyear=2010

18. Stockings put UK Rivers in Top Form
June 17, 2009
https://www.anglingtimes.co.uk/fishing-news/2009/stockings-put-uk-rivers-in-top-form

19. River salmon given protection
August 28, 2003
http://news.bbc.co.uk/2/hi/uk_news/wales/mid_/3185447.stm

20. Salmon increase in the Wye
29 May, 2003
http://news.bbc.co.uk/2/hi/uk_news/wales/2947188.stm

21. Country and garden: Floodwaters bring hope of a revival in salmon stocks
14 November, 1998
http://www.independent.co.uk/arts-entertainment/country-garden-floodwaters-bring-hope-of-a-revival-in-salmon-stocks-1184799.html

22. Plot is hatched to save Wye's salmon
28 April, 1996
http://www.independent.co.uk/news/plot-is-hatched-to-save-wyes-salmon-1307351.html

23. The Poacher's story
15 September, 1995
http://www.independent.co.uk/travel/poaching-salmons-not-thieving-rustling-sheep-is-thieving-you-cant-put-them-on-the-same-scale-1601285.html

Social Media Sources

1. Fishing Thread
January 23, 2014
http://www.fishingthread.com/forum/hatcheries-closing-in-wales/4954-abercynrig-hatchery-to-close-will-all-welsh-hatcheries-close-all-stocking-stop

2. Wye Salmon Association Forum
November 20, 2017
http://www.wyesalmon.com/community/salmon-stocking/fin-clips/#post-64

3. Fishing thread – River Wye – Wye Results
April 2013
http://www.fishingthread.com/forum/welsh-rivers/river-wye/107-wye-results-2013/page18

4. Facebook – Wyebank and Courtfield Spring Salmon Syndicate
https://www.facebook.com/wyebanksyndicate/

5. Facebook - Wye Salmon Association
https://www.facebook.com/WyeSalmonAssociation/

6. Facebook – The Wye and Usk Foundation
https://www.facebook.com/wyeusk/

ISBN: 978-82-575-1544-7
ISSN: 1894-6402

Division of Integrative Fisheries Management
Faculty of Life Sciences and Integrative Research Institute
on Transformations of Human-Environment Systems
Humboldt-Universität zu Berlin
Unter den Linden 6
DE-10099 Berlin, Germany
www.iri-thesys.org

Department of Biology and Ecology of Fishes
Leibniz-Institute of Freshwater Ecology and Inland Fisheries
Müggelseedamm 310
DE-12587 Berlin, Germany
www.igb-berlin.de/en

Vormstuguvegen 40
NO-2624 Lillehammer, Norway
www.nina.no

Norwegian University
of Life Sciences

Postboks 5003
NO-1432 Ås, Norway
+47 67 23 00 00
www.nmbu.no

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