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

ABSTRACT: This article examines drivers of hybridization of local ecological knowledge (LEK) and scientific knowledge (SK) in small-scale Atlantic salmon (*Salmo salar*) fisheries in western Norway. Using a case study from the Ørsta River, we examine the processes by which knowledge hybridization is performed in local fishing groups as part of wild Atlantic salmon cultivation activities. We find three primary drivers of knowledge hybridization: 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 grown apart 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 local contexts. We discuss whether hatcheries can play an important role adapting and operationalizing large-scale SK and salmon policy to the local environment through hybridization processes. To conclude, we make recommendations about how reframing managerial views on hatcheries as facilitators of knowledge transfer and production may improve the accessibility of SK to local communities and improve the integration of LEK into Norwegian wild salmon management.

SAMMENDRAG: Denne artikkelen belyser årsakene til hybridisering av lokal økologisk kunnskap (LEK) og vitenskapelig kunnskap (SK) i forvaltningen av atlantisk laks i Norge. Med klekkeridrift i Ørstaelva på Vestlandet som utgangspunkt undersøker vi hvordan lokale fiskere og frivillige benytter seg av kunnskapshybridisering i sitt arbeid med å bevare villaksen. Studien finner tre hovedårsaker til denne hybridiseringen: målet om å forbedre lokale kultiverings – og klekkeripraksiser, ønsket om effektivt å tilpasse nasjonale forvaltningsmål til lokale forhold, og ønsket om å styrke LEK som en gyldig og relevant kunnskapsform. Det identifiseres tre utfordringer for hybridisering, og vi analyserer hvordan både drivkrefter og barrierer knytter seg til hvordan LEK og SK før hadde felles mål og forståelsesrammer, men senere skilte lag når SK ble mer kompleks og teknisk. Prosessene som fører til at både LEK og SK oppstår, utvikles og brukes i vern og forvaltning av laks på lokalt plan drøftes. Til slutt diskuteres hvilken rolle klekkerier kan ha i å tilpasse SK og nasjonale mål for lakseforvaltning til lokale forhold gjennom kunnskapshybridisering. Mer transparente ordninger for utveksling og gjensidig nyttiggjøring av lokal økologisk kunnskap og vitenskapelig kunnskap anbefales. Dette vil kunne utgjøre et viktig bidrag i

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018. The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

arbeidet med å oppnå en mer bærekraftig forvaltning av atlantisk laks i Norge hvor sosial og økologisk bærekraft sees i sammenheng.

AUTHORS: Hannah L. Harrison[1]* (ORCID: 0000-0002-1411-4039), Stine Rybråten[2] (ORCID: 0000-0003-2877-3868), Øystein Aas[1 2] (ORCID: 0000-0003-0688-4049)

1. Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management

2. Norwegian Institute for Nature Research (NINA)

* Corresponding author

Address: Hannah Harrison, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway

KEYWORDS: knowledge hybridization; local ecological knowledge; Norway; *Salmo salar*; salmon cultivation

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.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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).

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.

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 has 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, Beveridge, and Mangel 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 (Brook and McLachlan 2005; Agrawal 1995). LEK is broadly referred to as site-specific knowledge of the environment derived from experiences of a particular group of people (Berkes 1999). While often used interchangeably with the terms Indigenous Ecological Knowledge and Traditional Ecological Knowledge (Ellen, Parkes, and Bicker 2000), this article uses LEK as referring to ecological experience-based knowledge, appropriate as the subjects of this study are not indigenous nor is their knowledge derived from an ancient tradition. We use SK to refer to scientific knowledge, commonly described as following a more formal and explicit process of acquisition and transmission, striving for generalizations and replicability in space and time with the aim of impersonal and unbiased results (Degnbol, 2005; Huntington et al., 2004).

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 (Berkes 2012; Berkes 2015; Davis and Ruddle 2010; Ellen, Parkes, and Bicker 2000; Huntington, Suydam, and Rosenberg 2004; Mazzocchi 2006). 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 (Berkes 2015; Brattland 2013; Tengö et al. 2014; Weber et al. 2014; 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

Local salmonid cultivation in Norway represents more than 150 years of tradition (Svåsand et al. 2004), as it does in other countries around the northern hemisphere (Bottom 1997). Essentially, the discovery of 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 aiming at increasing 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 to enable local practitioners to run hatcheries (Berg 1986).

In Norway, national freshwater fisheries authorities were directed to address "applied, practical inquiries" (Berg 1986, p. 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 (Fraser et al. 2011; Garcia de Leaniz et al. 2007; Ryman and Utter 1987). 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, Beveridge, and Mangel 2012). Today, human propagation of salmonids remains a complicated issue for fisheries managers (Lorenzen, Beveridge, and Mangel 2012; Sandström 2010).

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

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 like the county governor 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).

Taken together, these changes represent the phenomenon on which we center this article: 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, remain similar to their original viewpoints where 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 disassociation of these respective viewpoints on hatcheries have caused SK and LEK to represent diverging knowledges, and hatchery practitioners are left in a power struggle to maintain the validity and usefulness of their knowledge.

LEK and knowledge hybridization through a practice-oriented lens

LEK has long been a staple in locally-managed fisheries, derived from and operationalized by experiential, place-based knowledge about fishery environments. Positive working relationships between fishers and management authorities have been identified as fostering effective fisheries

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

management (Hill et al., 2010; Mackinson et al., 2011; Motos & Wilson, 2006). Within a Norwegian context, 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 the importance attached to LEK, nor 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 (Brattland 2013; Thomas and Twyman 2004). 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, 2000, 2011; Lauer and Aswani 2009; Lauer and Matera 2016, Marchand 2010). This processual approach 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 knowledge approach furthermore 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, differences here become related to the actual practices creating the knowledges (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 how all knowledge is dynamic, hybrid, and heterogeneous, this article 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 (local and scientific) or through multi-, inter-, or trans-disciplinary research (Raymond et al. 2010). After Murdoch and Clark (1994) identified a gap in knowledge hybridization studies and called for social science research focusing on ‘hybridity’, several studies have addressed the topic (e.g. Forsyth 1996; Nygren 1999; Thomas and Twyman 2004;

Reid, Williams, and Paine 2011). In these studies, hybrid knowledge refers 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 (Baird 2007; Bohensky and Maru 2011; Davis et al. 2004; Fernandez-Gimenez 2000; Harrison 2013). Raymond et al. (2010), however, defines hybrid knowledge as "knowledge types that have, in some way been integrated," generated through "a social learning process" (ibid: pg. 1769), and as described by Murdoch and Clark (1994), hybridity represents a category of knowledge in which multiple ways of knowing are "inextricably mixed." What processes drive these forms of hybridization of fisher knowledge, however, remain largely unexplored. To that end, this study examines the processes by which 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

This case study was conducted in Norway's western Sunnmøre district in the southernmost part of Møre og Romsdal county. The study focuses primarily on the Ørsta River and hatchery, with supporting information coming from hatcheries in the neighboring villages of Sæbø and Stranda. The Ørsta River is approximately 25km in length, which empties into the Ørsta fjord at the village of Ørsta (pop. ~ 6,800). The river is technically two rivers, the Follestaddalselva and the Åmdalselva, which 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. The river owner organization (Ørstavassdraget Elveeigarlag) is responsible for the management of fishing access and regulation under national salmon river management rules typical to European river ownership schemes. This includes, for instance, renting out fishing access/selling licenses, maintaining banks and shelters and surveillance (Stensland 2010). The study area was chosen after the authors received anecdotal information that the hatchery groups in Sunnmøre were particularly "vocal" about their salmon rearing activities and resistant to changing hatchery regulations. The Ørsta hatchery is run through a voluntary collaboration between the river owners association and the Ørsta hunting and fishing association. The hatchery was originally established to compensate for the loss of salmon spawning and rearing grounds due to river straightening in the 1950s.

Semi-structured interviews were conducted 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

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

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, researchers 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. Participants were recruited using the key informant method ("snowball") (Biernacki and Waldorf 1981) and recruitment saturation was reached when no new individuals were being recommended. In total, 21 individuals participated in recorded interviews typically lasting between 60-90 minutes. All fishers interviewed were male, with typical ages being between 45-75 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 participating translator. Though most informants willingly communicated in English, all interview participants were given the option to make comments in 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 written to elicit perspectives on knowledge production, knowledge sharing, 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 was coded again to analyze the identified themes and elicit insights into specific knowledge-related topics. After

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

more specific codes had been developed, a third round of analysis was conducted using memoing. The most prevalent and thematically relevant codes were used as memo topics to develop theoretical explanations of the data. All coding and preliminary analysis was conducted by the first author. Secondary analysis and results were contributed to and discussed by all authors.

Results - Drivers of Knowledge Hybridization

From our analysis, three primary drivers and three challenges to hybridizing LEK with SK knowledge emerged.

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-acquired 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 burden brought about 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. These beliefs reflect 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 had this experience of working with 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]*

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

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

These comments about reciprocal learning and teaching relationships demonstrate a hybridization of the SK within the general education of younger fishers with the LEK held by older fishers.

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). Now, the new and relatively younger hatchery manager has installed an electronic water flow gauge, adapting to a more accurate measuring system. Still, he double 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 the leadership role of hatchery manager.

Coping with change

Knowledge hybridization allows fishers to cope with policy changes that require them to adopt new methods in their hatchery activities. This phenomenon is evident in the example of broodstock harvest, an annual activity fishers perform in order to obtain reproductive material for the hatchery.

Each year, members of the river owners association and the Ørsta hunting and fishing group work together to harvest salmon broodstock, from which they later strip eggs and milt. Fishers rely upon experience to spot incoming salmon schools within the tidal estuary of the Ørsta River, where they collect broodstock with a small seine net and boat. This activity is labor intensive and requires precise timing in order to seine the fish and transfer them into large plastic holding tanks. The skills and knowledge required to perform the 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 via rod making them less likely to survive captivity. Furthermore, the fish must survive a car journey of approximately 10

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

kilometers 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) [sic throughout]*

The Ørsta area fishers have voiced these concerns to the County Governor who, in turn, has considered this locally-held information and allowed for 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 example demonstrates how fishers are taking new information about broodstock harvesting and adapting their own practices to maximize beneficial outcomes. This is done in combination with advocating for their own knowledge of fish welfare and compromising between SK-based policies and their own LEK-driven practices and needs. Taken together, this example illustrates how fishers are hybridizing their knowledge in order to cope with policy changes that affect their hatchery activities.

Maintaining relevance

As described in the introduction, 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). Within the context of this conflict, knowledge hybridization is also driven by fishers' desire to remain relevant and active within this cultivation 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 an effort to improve 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 (i.e., NINA[2], NTNU[3]), and expressed strong interest in partnering with scientists to study their local and neighboring salmon populations.

One example of the effort to maintain relevance is found in how fishers measure the effectiveness of their stocking activities, a key issue of contention in the hatchery debate. Fishers recognize the need to monitor the results (and by extension, efficacy) of their stocking activities, and have developed a monitoring system based on SK methods and LEK. Each October fishers gather to walk a three kilometer 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. Through this activity they can examine spawning grounds, count redds, and evaluate the condition of the river bed.

It is unclear, however, if fishers' efforts to raise 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 hear the outcomes of research in which they participate, and hope to be able to apply findings toward 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

---

[2] Norwegian Institute for Nature Research, Online: https://www.nina.no/

[3] Norwegian University of Science and Technology, Online: https://www.ntnu.edu/

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

under no obligation to solicit comment 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). The decision as to who should and should not be included in the expert group is made by national-level managers. From our interviews, recruitment to the expert group is based on managerial perceptions of what expertise is necessary and valid in making the decisions at hand.

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. Despite this, 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, rich, and more relevant to local conditions than may be the case of large-scale, more generalized research. As one angler and hatchery operator explained (via interpreter):

[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 water course.

[Translated] "He doesn't entirely trust the scientists because all the rivers are different, and he feels 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 thus view their knowledge more relevant to the 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, fishers commented that they do not believe their knowledge is wanted by management officials. As a leader of a fishing group said:

"We are very seldom asked, but told what to do." (P. Larsen, May 3, 2016)

Another fisher expressed a similar sentiment:

"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 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 said:

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

"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 of 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 that SK which 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 to a national scale, and in incorporating broad, generalized and multi-disciplinary SK into their local hatchery activities.

By the nature of their responsibilities, 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 national managers to manage for the specific needs of each local community. Additionally, there is the sheer logistical challenge of relatively few managers responding to the voices 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, ten, twenty, thirty 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

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018. The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

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 local 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 amongst 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 LEK to be more appropriate in guiding local management decisions. This example demonstrates that the processes of hybridization includes 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, the opportunities that do exist are considered insufficient and ineffective by the fishers in this study. The

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

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 level depend upon fishers to send email, attend public meetings, and submit solicited comments (A. Olsen, Personal communication, April 26, 2016). However, agency staff are few in comparison to the many fishers and fishing groups throughout Norway, and practical limitations apply in their ability to engage stakeholders. Because of these limitations, inadequate opportunities exist 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 this study has 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. The results of this study 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 both relevant, reliable, and valid, LEK is seldom organized in a way that makes the knowledge directly transferable for management purposes (ibid.).

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018. The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

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 knowledges. 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 knowledges 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: within national and international salmon management, can hatcheries 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 argumentations, fishers not only increase their ability to discover weaknesses in scientific recommendations (Bjørkan 2011), but they 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). The results from our study 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, hatcheries may enhance information transmission and facilitate knowledge processes from which important managerial lessons can be learned.

Conclusion

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

Fishers within this 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 (Baird 2007; Gilchrist, Mallory, and Merkel 2005; Mackinson and Nottestad 1998; Mahon et al. 2003).

Overall, the future of salmon hatcheries in Norway, particularly voluntary hatcheries, has yet to be determined. As the use of these 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

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018. The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

hatcheries may be part of a comprehensive salmon conservation strategy that has legitimacy by the riverside as well as in central agency offices.

References

Agrawal, Arun
1995 Dismantling the Divide Between Indigenous and Scientific Knowledge. Development and Change 26(3): 413–439.

Araki, Hitoshi, and Corinne Schmid
2010 Is Hatchery Stocking a Help or Harm?: Evidence, Limitations and Future Directions in Ecological and Genetic Surveys. Aquaculture 308, Supplement 1. Supplement: Genetics in Aquaculture X: S2–S11.

ATLAS.ti
1999. Berlin: Scientific Software Development.

Baird, Ian G.
2007 Local Ecological Knowledge and Small-Scale Freshwater Fisheries Management in the Mekong River in Southern Laos. Fishers' Knowledge in Fisheries Science and Management. Haggan, N., Neis, B. and Baird, IG (Eds). UNESCO, Paris: 247–266.

Berg, M.
1986 Det norske laks- og innlandsfiskets historie. Fiskeetaten 1855-1986. [History of the Development of Norwegian Salmon- and Inland Fisheries. The Fishery Agency 1855-1986]. Oslo: University Press of Norway.

Berkes, Fikret
2012 Sacred Ecology. Routledge.
2015 Coasts for People: Interdisciplinary Approaches to Coastal and Marine Resource Management. Routledge.

Biernacki, Patrick, and Dan Waldorf
1981 Snowball Sampling: Problems and Techniques of Chain Referral Sampling. Sociological Methods & Research 10(2): 141–163.

Bjørkan, Maiken
2011 Fishing for Advice : The Case of the Norwegian Reference Fleet.

Bohensky, Erin L., and Yiheyis Maru
2011 Indigenous Knowledge, Science, and Resilience: What Have We Learned from a Decade of International Literature on "Integration"? Ecology and Society 16(4).

Bottom, Daniel L.
1997 To Till the Water—A History of Ideas in Fisheries Conservation. *In* Pacific Salmon & Their Ecosystems. Deanna J. Stouder, Peter A. Bisson, and Robert J. Naiman, eds. Pp. 569–597. Springer US. http://link.springer.com/chapter/10.1007/978-1-4615-6375-4_31, accessed January 29, 2017.

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

Brannon, Ernest L., Donald F. Amend, Matthew A. Cronin, et al.
2004 The Controversy about Salmon Hatcheries. Fisheries 29(9): 12–31.

Brattland, Camilla
2013 Proving Fishers Right. Effects of the Integration of Experience-Based Knowledge in Ecosystem-Based Management. Acta Borealia 30(1). World: 39–59.

Brook, Ryan, and Stéphane McLachlan
2005 On Using Expert-Based Science to "Test" Local Ecological Knowledge. Ecology and Society 10(2): 3.

Camp, Edward V., Sherry L. Larkin, Robert N. M. Ahrens, and Kai Lorenzen
2017 Trade-Offs between Socioeconomic and Conservation Management Objectives in Stock Enhancement of Marine Recreational Fisheries. Fisheries Research 186(Part 2). Fisheries Enhancement: 446–459.

Charnley, Susan, Courtney Carothers, Terre Satterfield, et al.
2017 Evaluating the Best Available Social Science for Natural Resource Management Decision-Making. Environmental Science & Policy 73: 80–88.

Davis, Anthony, John Mark Hanson, Hadley Watts, and Holli MacPherson
2004 Local Ecological Knowledge and Marine Fisheries Research: The Case of White Hake (Urophycis Tenuis) Predation on Juvenile American Lobster (Homarus Americanus). Canadian Journal of Fisheries and Aquatic Sciences 61(7): 1191–1201.

Davis, Anthony, and Kenneth Ruddle
2010 Constructing Confidence: Rational Skepticism and Systematic Enquiry in Local Ecological Knowledge Research. Ecological Applications 20(3): 880–894.

Degnbol, Poul
2005 Indicators as a Means of Communicating Knowledge. ICES Journal of Marine Science 62(3): 606–611.

Ellen, R. F., Peter Parkes, and Alan Bicker
2000 Indigenous Environmental Knowledge and Its Transformations Critical Anthropological Perspectives.

Environment, Ministry of the
2009 Nature Diversity Act. Lov. Government.no. https://www.regjeringen.no/en/dokumenter/nature-diversity-act/id570549/, accessed December 16, 2016.

Fernandez-Gimenez, Maria E.
2000 The Role of Mongolian Nomadic Pastoralists' Ecological Knowledge in Rangeland Management. Ecological Applications 10(5): 1318–1326.

Forsyth, Timothy

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

1996 Science, Myth and Knowledge: Testing Himalayan Environmental Degradation in Thailand. Geoforum 27(3): 375–392.

Fraser, D. J., L. K. Weir, L. Bernatchez, M. M. Hansen, and E. B. Taylor
2011 Extent and Scale of Local Adaptation in Salmonid Fishes: Review and Meta-Analysis. Heredity 106(3): 404–420.

Garcia de Leaniz, C., I. A. Fleming, S. Einum, et al.
2007 A Critical Review of Adaptive Genetic Variation in Atlantic Salmon: Implications for Conservation. Biological Reviews 82(2): 173–211.

Gilchrist, Grant, Mark Mallory, and Flemming Merkel
2005 Can Local Ecological Knowledge Contribute to Wildlife Management? Case Studies of Migratory Birds. Ecology and Society 10(1).

Grant, W. Stewart, James Jasper, Dorte Bekkevold, and Milo Adkison
2017 Responsible Genetic Approach to Stock Restoration, Sea Ranching and Stock Enhancement of Marine Fishes and Invertebrates. Reviews in Fish Biology and Fisheries: 1–35.

Harrison, Hannah L.
2013 “This Is Who I Am”: Perspectives on Economics, Policy, and Personal Identity and Culture of Cook Inlet and Kenai River Salmon Fisheries. Masters, University of Alaska Fairbanks. Online: http://ine.uaf.edu/media/1247/hharrison-thesis2013.pdf.

Hill, Nicholas A. O., Keith P. Michael, Allen Frazer, and Stefan Leslie
2010 The Utility and Risk of Local Ecological Knowledge in Developing Stakeholder Driven Fisheries Management: The Foveaux Strait Dredge Oyster Fishery, New Zealand. Ocean & Coastal Management 53(11): 659–668.

Hind, Edward J.
2015 A Review of the Past, the Present, and the Future of Fishers’ Knowledge Research: A Challenge to Established Fisheries Science. ICES Journal of Marine Science 72(2): 341–358.

Holm, Petter
2003 Crossing the Border: On the Relationship Between Science and Fishermen’s Knowledge in a Resource Management Context. MAST 2(1): 5–33.

Huntington, Henry P., Robert S. Suydam, and Daniel H. Rosenberg
2004 Traditional Knowledge and Satellite Tracking as Complementary Approaches to Ecological Understanding. Environmental Conservation 31(3): 177–180.

Karlsson, Sten, Bjørn Bjøru, Espen Holthe, Håvard Lo, and Ola Ugedal
2016 Veileder for utsetting av fisk for å ivareta genetisk variasjon og integritet. NINA Rapport, 1269. Norwegian Institute for Nature Research.

Letcher, Benjamin H., and Timothy D. Terrick
2001 Effects of Developmental Stage at Stocking on Growth and Survival of Atlantic Salmon Fry. North American Journal of Fisheries Management 21(1): 102–110.

This is a post-peer-review, pre-copyedit version of an article published in Human Ecology by Harrison, H., Rybråten, S., Aas, Ø. 2018.
The final authenticated version is available online at: http://dx.doi.org/10.1007/s10745-018-0001-3

Lorenzen, Kai, Malcolm C.M. Beveridge, and Marc Mangel
2012 Cultured Fish: Integrative Biology and Management of Domestication and Interactions with Wild Fish. Biological Reviews 87(3): 639–660.

Mackinson, S., D. C. Wilson, P. Galiay, and B. Deas
2011 Engaging Stakeholders in Fisheries and Marine Research. Marine Policy 35(1): 18–24.

Mackinson, Steven, and Leif Nottestad
1998 Points of View: Combining Local and Scientific Knowledge. Reviews in Fish Biology and Fisheries 8(4): 481–490.

Mahon, Robin, Sharon Almerigi, Patrick McConney, Christopher Parker, and Leo Brewster
2003 Participatory Methodology Used for Sea Urchin Co-Management in Barbados. Ocean & Coastal Management 46(1–2): 1–25.

Mazzocchi, Fulvio
2006 Western Science and Traditional Knowledge. EMBO Reports 7(5): 463–466.

McDonald, D G, C L Milligan, W J McFarlane, et al.
1998 Condition and Performance of Juvenile Atlantic Salmon (Salmo Salar): Effects of Rearing Practices on Hatchery Fish and Comparison with Wild Fish. Canadian Journal of Fisheries and Aquatic Sciences 55(5): 1208–1219.

McShane, Thomas O., Paul D. Hirsch, Tran Chi Trung, et al.
2011 Hard Choices: Making Trade-Offs between Biodiversity Conservation and Human Well-Being. Biological Conservation 144(3): 966–972.

Meffe, Gary K.
1992 Techno-Arrogance and Halfway Technologies: Salmon Hatcheries on the Pacific Coast of North America. Conservation Biology 6(3): 350–354.

Motos, Lorenzo, and Douglas Wilson
2006 The Knowledge Base for Fisheries Management. Elsevier Science & Technology.

Murdoch, Jonathan, and Judy Clark
1994 Sustainable Knowledge. Geoforum 25(2): 115–132.

Neis, Barbara, David C Schneider, Lawrence Felt, et al.
1999 Fisheries Assessment: What Can Be Learned from Interviewing Resource Users? Canadian Journal of Fisheries and Aquatic Sciences 56(10): 1949–1963.

North Atlantic Salmon Conservation Organisation
2006 NASCO Guidelines on the Use of Stock Rebuilding Programmes in the Context of the Precautionary Management of Salmon Stocks. Council Report, CNL (04) 55.

Norwegian Environment Agency
2014 Guidelines for Stocking of Anadromous Salmoniods. (In Norwegian: Retningslinjer for Utsetting

Av Anadrom Fisk). Report, M186. Trondheim. Online: http://www.miljodirektoratet.no/Documents/publikasjoner/M186/M186.pdf.

Nygren, Anja
1999 Local Knowledge in the Environment–Development Discourse: From Dichotomies to Situated Knowledges. Critique of Anthropology 19(3): 267–288.

Raymond, Christopher M., Ioan Fazey, Mark S. Reed, et al.
2010 Integrating Local and Scientific Knowledge for Environmental Management. Journal of Environmental Management 91(8): 1766–1777.

Reid, Karen, Kathryn Williams, and Mark Paine
2011 Hybrid Knowledge: Place, Practice, and Knowing in a Volunteer Ecological Restoration Project. Ecology and Society 16(3).

Rosten, Carolyn M.
2017 Interdisciplinary Conservation; Meeting the Challenge for a Better Outcome: Experiences from Sturgeon Conservation. Marine and Freshwater Research 68(9): 1577–1584.

Ryman, N., and F. Utter
1987 Population Genetics and Fishery Management. Seattle: University of Washington Press.

Sandström, Annica
2010 Institutional and Substantial uncertainty—Explaining the Lack of Adaptability in Fish Stocking Policy. Marine Policy 34(6): 1357–1365.

Silvano, Renato A. M., and John Valbo-Jørgensen
2008 Beyond Fishermen's Tales: Contributions of Fishers' Local Ecological Knowledge to Fish Ecology and Fisheries Management. Environment, Development and Sustainability 10(5): 657.

Stensland, Stian
2010 Fishing Rights and Supply of Salmon Angling Tourism in Mid-Norway. Scandinavian Journal of Hospitality and Tourism 10(3): 207–230.

Tengö, Maria, Eduardo S. Brondizio, Thomas Elmqvist, Pernilla Malmer, and Marja Spierenburg
2014 Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. AMBIO 43(5): 579–591.

Thodesen, Jørn, Barbara Grisdale-Helland, Ståle J Helland, and Bjarne Gjerde
1999 Feed Intake, Growth and Feed Utilization of Offspring from Wild and Selected Atlantic Salmon (Salmo Salar). Aquaculture 180(3): 237–246.

Thomas, D. S. G., and C. Twyman
2004 Good or Bad Rangeland? Hybrid Knowledge, Science, and Local Understandings of Vegetation Dynamics in the Kalahari. Land Degradation & Development 15(3): 215–231.

Weber, Edward P., Jill M. Belsky, Denise Lach, and Antony S. Cheng
2014 The Value of Practice-Based Knowledge. Society & Natural Resources 27(10): 1074–1088.