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Actions towards the joint production of knowledge: the risk of salmon aquaculture on American Lobster

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ABSTRACT

Joint production of knowledge (JPK) is said to facilitate proactive mitigation of risks in marine resource management. However, lack of consensus on who should be involved, when it is happening and the exact mechanisms of sharing knowledge has precluded the development of an effective implementation framework. Here, we explore one approach to building a post-normal science, one that both includes local ecological knowledge and bridges scientific silos. We first identify several actions of knowledge production and then provide an Atlantic Canadian case study, drawn from an assessment of the impact of aquaculture on American lobster, to illustrate necessary actions on the road to JPK. Key actions include *theorizing relationships, agreeing on key concepts, specifying*, and *interpreting required data, identifying principles and making evaluations*. We fill a lacuna in the JPK literature by: first, defining knowledge as the result of a set of actions; second, using knowledge generating actions to explore how different knowledge sets come together to contribute to JPK; and third, identifying how knowledge actions can facilitate or inhibit JPK. We conclude that this list of the essential actions of knowledge production is necessary to the successful development of alternative approaches to risk.

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1. Introduction

Improved marine management is said to require well-informed risk analysis and democratic decision-making processes inclusive of both experiential and scientific knowledge, or what Funtowicz and Ravetz (1993, 1994a, 1994b) have termed post-normal science. Chilvers and Kearns (2016) argue that advocates have taken such 'participatory science' in diverse directions in recent years, with some uncritically promoting the 'democractization of science', while others are concerned about the mutually reinforcing power of science and political power. Arguments advocating the value of resource users' ecological knowledge (Corburn 2003; Armitage et al. 2011; Linke and Jentoft 2014) have been somewhat overtaken by a more recent focus on stronger links between 'decision-makers' and scientists (Lemos, Kirchhoff, and Ramprasad 2012; Briley, Brown, and Kalafatis 2015; Cvitanovic et al. 2015b). A confusing terminology has emerged, in which knowledge plays a central role, including: joint production of knowledge (JPK) (Noy, Habersack, and Schaller 2013), co-production of knowledge (CPK) (Jasanoff 2004), knowledge exchange (KE) (Fazey et al. 2012), and more. Space precludes a review of this broad literature here, but it has in common a largely prescriptive approach that fails to address what is meant by knowledge and the exact mechanisms of any collaborative production process.

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As Chilvers and Kearns (2016, 4) note, 'the publics of science and democracy are actively brought into being through matters of concern' and this emergent practice is particularly true around perceptions of risk. While recognizing the breadth and complexity of the participatory science literature, here we focus on scientists who want to actively engage with other forms of knowledge in their assessment of potential environmental risk. To this end, we focus on JPK and report on the collective efforts of a group of fishermen and scientists to develop a research protocol to assess the abundance of ovigerous (egg-bearing) female lobsters (*Homarus americanus*) near Atlantic salmon (*Salmo salar*) finfish aquaculture sites in the coastal waters of Southwest New Brunswick (SWNB), Canada. This project began as part of an ethnographic study of risk (following on Wiber, Wilson, and Young 2012), but gained momentum under Prime Minister Harper's 'war on science' (Turner 2013). Both fishermen and scientists involved in the project shared a concern that political and economic agendas were downplaying environmental risk. But as we worked together, our shared experience helped to illuminate a lacuna in the participatory science literature. In particular, a social science analysis of our collaboration identified five key actions of knowledge production: theorizing relationships, agreeing on key concepts, specifying and interpreting required data, identifying principles, and making evaluations. Herein, we provide examples of each, and then discuss how consideration of these key actions can identify factors that facilitate or inhibit JPK. We conclude that such *enacting* of knowledge can lead to a better path to collaboration that will enhance cooperation both across science silos, and between science and other types of expertise.

2. Theoretical background

2.1. Objects of risk, objects at risk

In fisheries management, risk is defined as 'occurrences beyond our control that may have undesirable consequences' (Lane and Stephenson 1998, 1). They propose a 'decision analysis' process that: (1) establishes bureaucratic objectives and values, (2) undertakes scientific assessment of the level of risk to these objectives, and (3) formulates potential managerial responses. Beck (1992, 1998, 2006, 2007), however, draws attention to the ways in which: 'Risk definition, essentially, is a power game' (2006, 332–333). Following Beck, Boholm (2003, 161) identifies two types of risk, where: 'Objective risk refers to phenomena and causality in the natural world that can have harmful effects', while in subjective risk: 'People understand and judge risk in terms of emic, locally defined, values and concerns'. For Boholm, risk talk links objects of risk (a source of threat) with objects at risk (a potential target of harm) into 'an inherently dynamic relational order of meaningful connections' (2003, 168). When subjective and objective perceptions of these meaningful connections differ, political debate, and conflict follow.

In Canada, the introduction of open net salmon aquaculture into marine nearshore spaces has generated such conflict (Young and Matthews 2011; Loucks, Smith, and Fisher 2014; Grant, Filgueira, and Barrell 2016). Different stakeholders have different perceptions of the risk associated with this introduction. Fishermen were alarmed by large die-offs of lobsters near aquaculture cages and a subsequent investigation that linked this to aquaculture pharmaceuticals. Fish farmers, on the other hand, felt confident that lab tests showed rapid dispersal of pharmaceuticals to nontoxic levels (Carroll et al. 2003; Hargrave 2005). For scientists, a number of unknowns increased uncertainly, including the spatial and temporal distribution of lobster around aquaculture sites, and vulnerabilities during different stages of the lobster life cycle. Our project in SWNB (see Figure 1) began with the assumption that all these differing perceptions of risk and uncertainty could be shared to improve scientific assessment of risk and to serve as a common basis for broader, more proactive prevention.

2.2. Knowledge multiplicities

An inclusive post normal science addresses problems that: hold high risk, are framed in uncertainty, are value laden, and have limited decision time frames. Part of the problem lies in science itself, with scientific methods that sometimes rely on simplified models of natural phenomena that obfuscate risk (Checker 2007). Scientific silos can also lack good cross-communication (Star and Griesemer 1989;

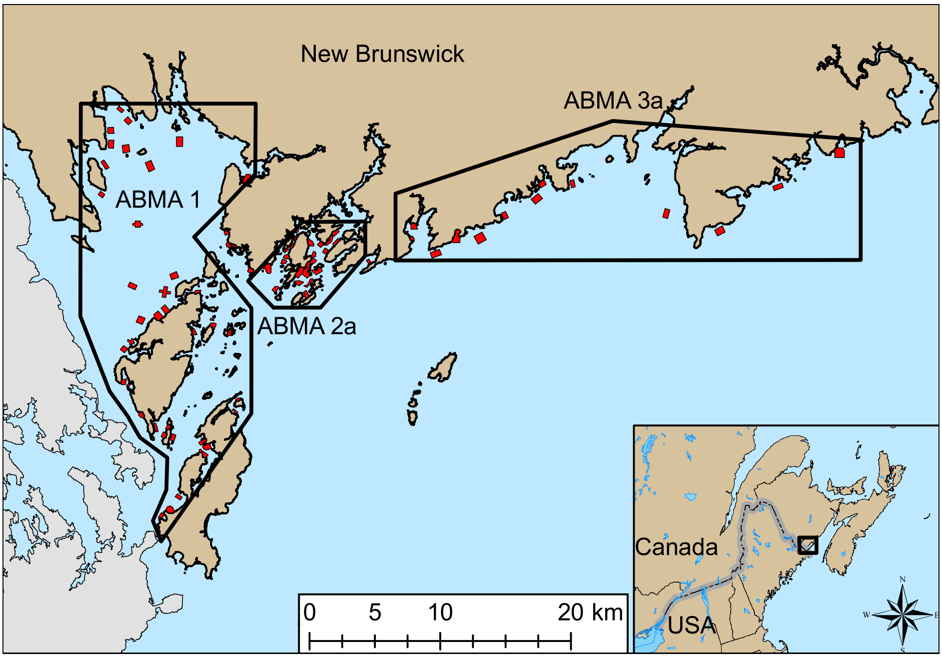

Figure 1. Map of SWNB trap survey area, including aquaculture bay management areas (ABMAs), active aquaculture sites (red polygons), and inactive sites (black polygons). Source: Allain Barnett.

Star 1993, 2002, 2010). The aim then is to improve 'quality assurance' by including knowledge from 'extended peer communities' composed of all relevant stakeholders (Dixon 2016). This opens us up to the 'cultural rationality' of risk (Jasanoff 2003; Fischer 2005) and to experience-based knowledge with 'cognitive authority' (Wynne 1996; Collins and Evans 2002; Fischer 2005).

Wynne (1989) proposes that the value of science increases when such multiple knowledge sets are used in tandem (see also Lyons et al. 2014). Collins and Evans (2002) propose that all participants should be willing and able to learn from each other. Jasanoff (2003) calls for effective institutions inclusive of a wider diversity of knowledge, including participatory, politically conscious forms of science that allow for society to be self-critical, or reflexive, of science and technology practices. As Chilvers and Kearns (2016) note, the participatory ideal has subsequently taken hold in numerous disciplines, including anthropology (Ommer et al. 2012), sociology (Kloppenburg 1991), environmental management (Ballard and Belsky 2010; Raymond et al. 2010), and science and technology studies (Wynne 1992; Irwin and Wynne 1996; Jasanoff 2003; Johnson and McCay 2012).

In marine management, such knowledge inclusivity has been intrinsic to more participatory governance structures, including co-management (Pinkerton 1989) and integrated coastal management (Cicin-Sain and Knecht 1998; Berkes, Colding, and Folke 2000; Wiber et al. 2009; Bigney et al. 2012). However, even with these approaches, problems continue at the level of: knowledge production; translation into decision-making (Finlayson 1994; Irwin 1995; Landstrom et al. 2011; Cvitanovic et al. 2015a, 2015b; Hind 2015; Meadow et al. 2015; Stephenson et al. 2016); and acceptance of knowledge as credible, salient, and legitimate (Cash et al. 2003). Given these knowledge multiplicities, we argue that a fundamental roadblock to JPK is a misunderstanding of the knowledge process itself.

3. The missing piece – what is knowledge?

While a broad literature explores diverse sets of expertise, why such diverse knowledge sets could be useful, and how they could be used for better resource management (Funtowicz and Ravetz 1993;

Irwin 1995; Clark et al. 2001; Collins and Evans 2002, 2007; Cash et al. 2003; Corburn 2003; Carr 2004; Carlberg 2005; Leach, Scoones, and Wynne 2005; Carolan 2006; Johnson and McCay 2012; Hegger and Dieperink 2015), this taxonomic approach fails at the basic level to provide a good understanding of what knowledge is and how it is created. If we want to achieve a more collaborative approach to knowledge, we have to first understand what is meant by knowledge, how that differs from information, and how new knowledge is produced.

Knowledge is 'a multifaceted concept' (Nonaka 1994, 15), and the above literature has distinguished multiple types of knowledge (tacit, experiential, explicit, procedural), but a simple dictionary definition (Funk and Wagnalls 1989) proves more helpful as it describes knowledge *as a process* (see also Latour 1999, 69) that involves several actions: perceiving relations, elaborating concepts, selecting and interpreting data, formulating principles and making evaluations (see Figure 1). Knowledge is thus not a thing held in reserve among different experts, as it is a series of actions in which an individual or individuals must engage, and as Latour (1999, 69) points out, that must be retraceable or 'it ceases to transport truth'. Each of the bubbles in Figure 2 represents complex actions, which cannot be taken in a simple linear fashion. Any attempt at JPK, we argue, must address each of these actions of knowledge. In the case study that follows, we illustrate both the knowledge actions themselves, and how collaboration in these actions affects the success or failure of JPK.

4. JPK case study: the ovigerous female lobster abundance study

4.1. Background to the study

As a multi-species fishery, the inshore sector has long been the economic mainstay of Atlantic Canadian coastal communities (Spanier et al. 2015, 15–16). It relies on boats of less than 13.7 m in length making day trips from homeports. After groundfish stocks declined in the 1980s, lobster (*H. americanus*) became the most commercially valuable species, creating what Steneck et al. (2011) call 'the gilded trap', as fishermen became increasingly reliant on this one species. Environmental, economic and social threats to the lobster fishery range from climate change (Steneck, Wahle, and Sainte-Marie 2013), to gear conflicts and environmental impacts from other marine stakeholders (Wiber and Recchia 2010; Wiber, Wilson, and Young 2012), to volatile market conditions and prices (Barnett and Eakin 2015). When such threats materialize, as after the 2008 financial crises, they affect both the livelihoods of inshore fishermen (Barnett and Eakin 2015) and the economic stability of their communities (Thomas et al. 2014).

The federal department of Fisheries and Oceans (DFO) regulates the inshore lobster fishery and allocates licenses that are spatially restricted to Lobster Fishing Areas (LFA). However, LFAs are increasingly shared with other users of marine resources, including salmonid open-net aquaculture, which in our study area is regulated by the Province of New Brunswick. Aquaculture site licenses are granted within and the cycle of production is regulated through Aquaculture Bay Management Areas (ABMAs). The three-year cycle includes introduction of young fish (smolts) ready for the salt-water phase of their life cycle, a growth period to the adult phase, and a period of fallow after harvest before the cycle begins again. While ABMAs 'only occupy 1.4% of the nearshore SWNB area' (Chang, Coombs, and Page 2014, 8), this area is largely encapsulated within the boundaries of LFA 36 (Wiber, Wilson, and Young 2012). As favorable sites for aquaculture are also lobster nursery grounds (Burridge et al. 2008), conflict between the two industries springs from fishermen's perceptions of threats to commercial fish stocks, competition over space and gear entanglements. This conflict peaked when illegal treatments for sea lice (*Lepeophtheirus salmonis*) killed large numbers of lobsters (CBC Online News 2013), and one aquaculture operator was fined under section 36(3) of the Canadian Fisheries Act (Government of Canada *Fisheries Act,* RSC 1985 m c F-14; R v. Kelly Cove Salmon Ltd 2013 SO).

As both the fishery and aquaculture are important to the economic sustainability of coastal communities, more information was needed on the potential for harmful interactions between them, especially given federal cutbacks on research into environmental impacts and ecotoxicology research. Thus, the executive director of Fundy North Fishermen's Association (FNFA), an anthropologist and a marine biologist formed a team to explore this question. The Ovigerous Female Lobster Abundance Project (hereafter 'the trap survey') was then developed as an iterative collaboration between fishermen and government and academic scientists, both natural and social. This trap survey project provided the opportunity for a JPK case study.

Both the trap survey itself and the project to study it were funded through the Social Sciences and Humanities Research Council of Canada (SSHRC). While the trap survey aimed to measure the current state of lobster abundance, and especially ovigerous females, in proximity to aquaculture sites in SWNB, our JPK study assessed the protocol development, which began in the late summer of 2014, and the first two years of the trap survey ending in October 2015. Here, we draw no conclusions on the trap survey results, but instead focus on the JPK process.

4.2. Project participants

Three project team leaders undertook overall project management. Fishermen (N = 13), ranging in age from their mid-20s into their 80s, were recruited to participate, all with years of fishing experience in the area (see Figure 1). Some owned their own boats and were active captains (N = 6), others were former captains (N = 2), or crewmembers (N = 5). Academic (N = 5) and government participants (N = 2) from both the natural and social sciences (oceanography, marine biology, ecology, anthropology) were recruited based on years of fisheries-related experience in the region. University students undertook sampling on the boats (N = 5 per year over the two years). FNFA office staff (N = 3) held knowledge of DFO science licensing, fishing seasons, bait procurement, and communications with other study area stakeholders. In total, over 30 people were involved and were sources of information in this JPK study. Note that no aquaculture operators were involved in this project, a point to which we will return later.

4.3. Methods

The JPK study included Field Season 1 (3 weeks of sampling) in August 2014 and Field Season 2 (4 weeks of sampling) from mid-July until mid-August 2015. Each field season involved one fishing boat in each of the three ABMAs being sampled.

Three data collection methods were followed (Bernard 2011). First, participant observation was undertaken in meetings and on board the three fishing boats to follow and document interactions between participants and the sharing of experiential and scientific knowledge. During both field seasons, the authors of this paper undertook direct observation (Bernard 2011, 306), one on board each vessel, where we observed deployment and retrieval of traps in each of the three ABMAs. A data collection tool was developed and used as a guide for observing teamwork among fishermen and scientists on the boats (following Bales 1999) and observational data was subsequently discussed among the three observers. Second, 11 open-ended, semi-structured interviews were conducted by one of the authors with at least one representative from each of the participant categories in between the first and second year of sampling. And third, extensive document analysis was undertaken of project correspondence, including emails, field notes, and other materials. Transcripts, minutes and notes were analyzed for 12 project meetings, including maps, nautical charts, graphs, power point presentations, and handouts. The resulting text from interview transcripts, emails, meeting minutes, and project documents were coded for key words and themes relating to topics such as scientific methods, experiential knowledge, relations, concepts, data, principles, evaluations, known and unknowns.

All project data were gathered in keeping with the requirements and approval of the university Research Ethics Board.

5. Results

Given space limitations, we focus here on only two specific pieces of the protocol, the selection of survey methods (trap survey versus transects) and the agreement on potential survey sites in the three

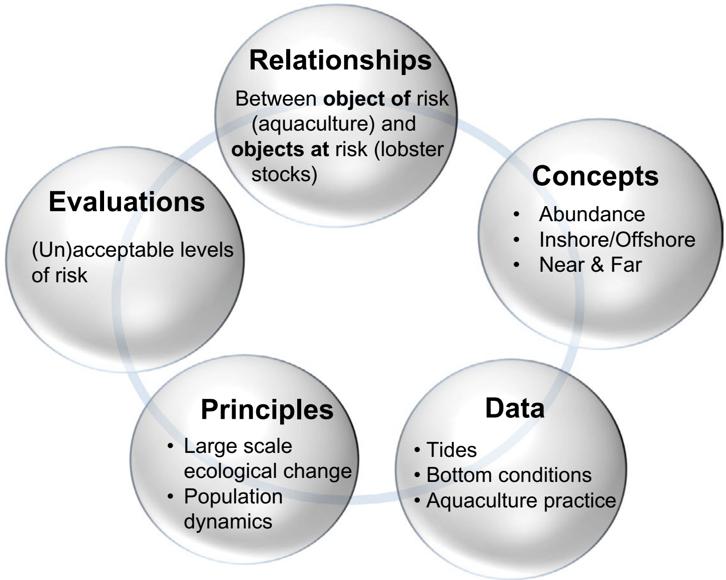

Figure 2. The five knowledge actions with examples from the SWNB Ovigerous Female Lobster Abundance Study.

ABMAs. In all, eight pairs of sites were selected for sampling in the three ABMAs. As we discuss the five actions of knowledge, we use these two protocol decisions to illustrate the complexities involved in each of the bubbles illustrated in Figure 2.

5.1. Relationships: aquaculture as object of risk and lobster as object at risk

Evaluating risk involves investigating the potential relationship between an object of risk and an object at risk (Boholm 2003). In our case, this involved exploring the potential relationship between aquaculture and lobsters; but this in turn required choosing between several possible connections. The lobster lifecycle means that at different stages lobster can be eggs carried by the female, larvae in the water column, juveniles restricted for up to five years to a small nursery area or highly mobile adult lobster. Aquaculture effects could be either 'near field' such as the conditions under aquaculture cages (eutrophication, sulfides, surplus feed, infeed pesticides, net antifoulants, pesticide bath treatments) or 'far field' such as chemical plumes and surface oil slicks. Impact on lobsters could include effects on juvenile growth rates, female egg clutch health, and premature molting. Published laboratory studies, for example, suggest that some sea lice pesticides could lead to premature molting among ovigerous females with subsequent loss of the clutch of eggs (Burridge et al. 2004; Waddy et al. 2007). Fishermen report that egg-bearing lobsters appeared to avoid aquaculture areas undergoing chemical treatments. Based on such information, the original funding application proposed examining the relative abundance of ovigerous female lobsters around active aquaculture pens to assess the potential level of exposure to objects of risk.

In June 2014, a small group of social and natural scientists (N = 5) assembled to discuss how to measure any potential exposure of lobster to threats from aquaculture. One biologist recommended transects with divers to sample lobster abundance directly under aquaculture cages, in order to assess any near field effects. Another biologist, arguing for a trap survey, pointed out that transects had been critiqued in the past and would not give us a broad picture of how exposure could vary across sites and across the three phases of aquaculture production. The oceanographer was then asked how known patterns of ocean currents and tides could help to discriminate between areas with high likelihood of aquaculture impact and contrasting areas with little or no impacts, so that both could be surveyed.

The oceanographer spoke to the difficulties associated with identifying zones of impact:

> [This] is an area of active research. Our models with multiple tides are still being tested – then you get into the bottom situation – then storms, wind, all this modeling takes a long time. We have dye data from a few sites, but not on a scale you would need.

When questioned further about dye tests that he had undertaken in the past, he commented:

> We were instructed to use the dye only in an area where it would not affect aquaculture fish because the dye then was not allowed for human consumption. So, where there was already aquaculture [in 2000], there has been little done, [and] if you look for chemicals without dye tests, good luck! Dispersal isn't steady. Imagine a garden hose spraying your yard; it is pulse stuff. So, that is a state of the art question, what is the profile of exposure? How do I sample you if you are sessile and I know you are exposed in this pulse pattern?

Several unknowns thus affect the relationship between lobster and aquaculture, including the effects of tide, wind, temperature, bottom conditions, and variation in aquaculture site management. After more discussion, one unknown became the focus for assessing a relationship. Outside of fishing season, little is known about female lobster abundance at particular places and times, aside from broad movements inshore in summer and offshore in winter. How then could we assess their relationship with and potential vulnerability to aquaculture? The group agreed that a trap survey that relied on paired sites near to and far from aquaculture would provide the most information on potential ovigerous female vulnerability. For each site in relative proximity to an active aquaculture site, a paired control site unaffected by aquaculture was needed. It was felt that fishermen familiar with these waters would be key to optimum site identification.

5.2. Concepts: inshore/offshore, abundance, near, and far

As Nonaka (1994, 20) suggests, in team work where diverse participants share knowledge, concepts are articulated and developed 'until they emerge in a concrete form'. In July 2014, this process of concept articulation was visible during a meeting of fishermen, natural and social scientists and FNFA staff ($N = 10$) held to identify trap survey sites. The group gathered around maps and nautical charts in order to discuss appropriate locations, but several different mental images or generalized concepts were obviously in play and participants spent some time in arriving at common understanding of key concepts. For example, when discussing the movement of lobster from offshore to inshore, one fisherman asked: 'How far is offshore? What depth of water?' A biologist responded that they had no firm definition for that and what did the fishermen think? Fishermen explained that in practical terms it depended on gear type – off shore fishing required many more fathoms of rope to link traps to buoys. Biologists accepted this distinction and agreed that for the purposes of this project, and for making the concept concrete, lobster arrival 'inshore' would be estimated given the timing of catch using inshore gear.

Another important concept was 'abundance', which was also made concrete using fishermen's experiences. As one scientist put it: 'it is important to get sites that don't give us a false finding. It would be good to know where females were found in abundance before, so that we can assess [vulnerability].' Where were ovigerous females most abundant in the past? One fisherman responded by emphasizing spatial and temporal variation: 'It's complicated! Now lobster are found where they never used to be.' Nevertheless, experience suggested several locations where ovigerous or 'spawn' lobsters were more or less abundant: 'Seal Cove Sound you could get 6 [spawning] lobster a day but when I was fishing the Wolves, I might get 100 spawning lobsters a day.' As the discussion continued, further concepts of 'near to' and 'far from' aquaculture sites were solidified. Much of this discussion was reminiscent of Latour's (1999) discussion of how science turns the field into a laboratory.

In the three ABMAs to be sampled, for example, the lead biologist explained: 'we want stocked sites over three years so that we get all the phases of grow out. We need 3 pairs in each Bay Management Area to have the 9 sites we want'. Fishermen knowledgeable in specific ABMAs were asked to provide prospective test and control sites. Fishermen and scientists agreed that bottom type and tidal range were important concepts to standardize. Each paired site should have the same bottom (mud versus cobble) and the same tidal range ('big tide' and 'good flush' or 'less tide' and 'little flush'). So long, as

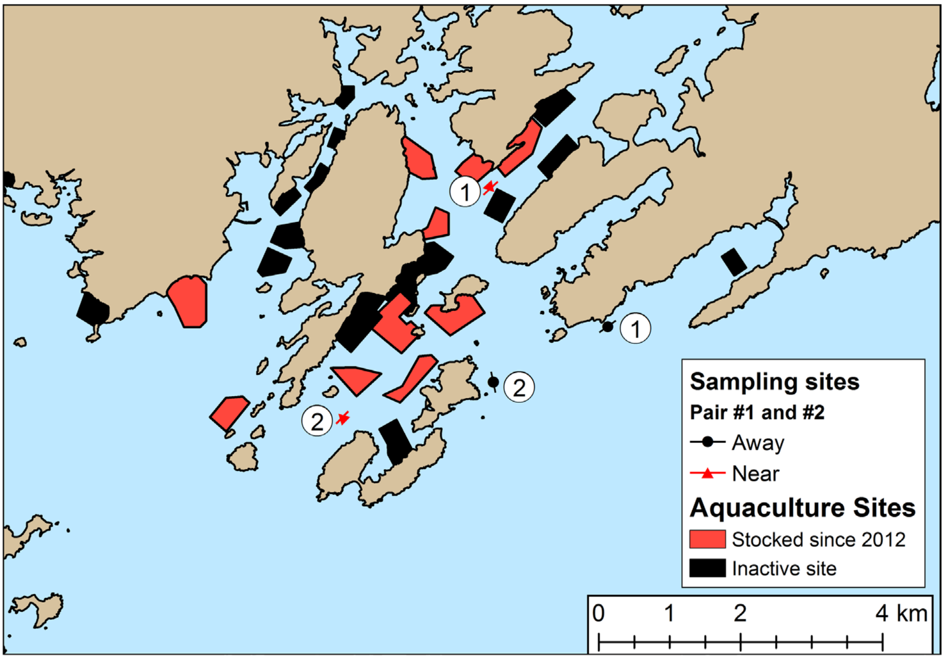

Figure 3. Showing ABMA 2a with the many stocked or empty aquaculture sites, and the two sampling locations with paired near and away locations. Source: Allain Barnett.

bottom type and tidal range was consistent for both test and control site at any one location, trap survey conditions could vary across locations. Finally, three paired sites were selected for two ABMAs, while the third ABMA had too many active and abandoned aquaculture sites to effectively provide control sites and only two paired sites were selected (see Figure 3). Ultimately, biologists accepted fishermen's knowledge on good sample locations and on what trap methods would work in specific locations.

This meeting also raised an issue that was revisited throughout the project, one that highlights the 'relational' nature of participation. While discussing information on tidal ranges, a government biologist raised the possibility of seeking data from aquaculture operators. Fishermen immediately sounded an alarm, citing previous failed attempts to collaborate and the high level of distrust between the two industries. We will return to this contentious question of if and how to include aquaculture participants below.

5.3. Data: aquaculture site activities, pesticide applications

Data or information is 'a flow of messages or meanings which might add to, restructure or change knowledge' (Nonaka 1994, 15). In this case, conclusions about the relationship between aquaculture and lobster depended on: determining information needed to interpret results, getting access to that information; and interpreting that information. For example, one data problem only became obvious as the project moved from protocol development to implementation. Understanding the aquaculture site activity for specific locations where the survey was being conducted was important to drawing conclusions from relative abundance results. Both access to information about aquaculture operations and interpretation of that proved elusive in the trap survey project, since important information was not publicly available. Provincial regulation requires that each ABMA have a period of up to three months when all sites within the ABMA must be in fallow at the same time. The province issues maps for all ABMAs with the specified stocking year for individual sites. The aquaculture industry also provides the province with data on pesticide applications, limited to type of chemical, and number of days of tarp treatments. In tarp treatments, the aquaculture cage is surrounded by tarps, the pesticide applied, and after a time the tarps removed and the pesticide plume allowed to dissipate in the ocean. It was the movement of such pesticide plumes that oceanographers had hoped to track using dye tests. Other data, such as the volume of pesticides used in tarp treatments, or in in-feed pesticides, are considered proprietary information. However, when project participants compared stocking information with data on pesticide treatments, it became obvious that individual sites could be receiving pesticides in a supposed 'fallow' period, and that for various reasons, some sites did not follow provincially designated production cycles. This raised the question of the status (active or inactive) of individual aquaculture sites where trap surveys were being undertaken, a question that the team revisited during numerous meetings.

Fishermen were confident that they could provide data on aquaculture operations, relying on the presence of bird nets and other predator deterrents, feed boat activity, and tarp deployment. The biologists, however, argued that relying on fishermen to provide these data would open the project to critique as the information would not be considered reliable or objective. In the end, the natural scientists relied instead on the data from provincial sources on stocking and from industry on pesticide use, but noted that this 'flow' of information was insufficient to significantly improve our knowledge of the relationship between lobster and aquaculture.

5.4. Principles: scale, population dynamics

For the purposes of the trap survey, relevant principles might best be thought of as any 'established mode of action or operation in natural phenomena' (Funk and Wagnalls 1989, 1072) that might affect the relationship under study. Meeting minutes and boat observations record discussion of several ecological principles, as when biologists speculated about large-scale phenomena such as climate change on the potential distribution of female lobster (see also Steneck, Wahle, and Sainte-Marie 2013). Fishermen, on the other hand, referred to the impact of annual variation in water temperature on timing of lobster migration, and to how females and males arrive inshore at different times. Over time, relevant principles such as: (1) ecosystem change, (2) exposure, life cycle and lobster vulnerability, and (3) sub-lethal impacts of long-term exposure were raised. While salmon in aquaculture sites are a hybrid entity (Latour 1993), and aside from escapements, are constrained by human technology to a relatively small area, lobsters have been found to migrate long distances, and are part of a much larger ecological community (Chou, Paon, and Moffatt 2002). Would aquaculture impacts on lobster in one small area affect wider populations? Lobster landings have been at an all-time high in SWNB, suggesting healthy stocks. But many unknowns surround the impact of warming waters including size at reproductive age, the distribution of lobster across new habitats and potential limitations on population growth. While these influences at variable scales could affect lobster behavior and thus were confounding factors, there was little discussion as to how to improve the protocol to limit their impact.

5.5. Evaluation

Evaluation involves not only establishing that data indicates a relationship (aquaculture as object of risk affects lobsters as objects at risk), but also assessing the impact of that relationship for (un)acceptable consequences on lobster stock health and on the economy of the fisheries. This action of knowledge involves all previous actions, but in JPK may also offer either acceptance of the findings or more conflict. Preliminary results after two years of sampling were unclear. It suggested to some participants that there was less of a relationship than previously assumed, which was comforting to fishermen. On the other hand, the biologists viewed the pattern of relative ovigerous female abundance near to versus far from aquaculture cages in ABMA 2a as 'suggestive'. Final evaluation of results is still ongoing, but suggestive results certainly point to the need for more data.

It is already apparent to participants, however, that data availability and subsequent evaluation of impacts will be influenced by political and industry arguments. Atlantic Canadian provincial governments want more employment opportunities in the region, while federal bureaucrats (especially, under the Harper government) push for a 'social license' for aquaculture in order to increase ocean productivity. Aquaculture proponents have argued that commercial fisheries are collapsing due to overexploitation, and that aquaculture can 'become the next frontier for humankind's food' (Neori et al. 2007, 38). Further, given that lobster populations have undergone a significant growth in the past few decades, any impacts that aquaculture may have on lobsters may be seen as trivial for lobster stocks overall. Members of the inshore fishing industry, on the other hand, argue that their geographically limited access to capture lobster is key to risk assessment, in that aquaculture operations should not compromise local habitats that maintain commercially important species in specific fishing grounds. Given the decline in many commercial species, and the resulting reliance of inshore fishermen on lobster, impacts that may seem acceptable to the aquaculture industry are not acceptable to fishermen.

If JPK is going to bridge objective and subjective perceptions of objects of and objects at risk, then collaborative evaluation of relationships is important. Stirling (2012) argues that objective risk measures are most suitable where our knowledge about the possibilities and likelihoods of an outcome are unproblematic, a rare situation given complex interactions between humans and environment. To adequately address these risks, Stirling (2012) argues that approaches to risk and uncertainty should foster collaboration, learning, and understanding the values and priorities of relevant stakeholders. Our case illustrates how difficult that will be in situations where stakeholders actively distrust each other.

6. Conclusions: JPK in the trap survey

The five actions of knowledge prove key to assessing how participants share respective knowledge sets and integrate them where possible. In this project, marine biology, oceanography, ecology, anthropology, and fishermen's knowledge all contributed to theorizing about the relationship between lobster and aquaculture. The relative abundance of ovigerous females at sites near to and far from aquaculture cages was one measure of a potential relationship, focusing on exposure rates and resulting vulnerability. Concepts refined by the group included: inshore/offshore, abundance, bottom characteristics, and near and far. Data included aquaculture stages of operation at test sites so that trap survey results could be interpreted. However, fishermen's on-the-water observations of aquaculture operations were rejected by natural scientists as potentially biased or incomplete. In terms of principles, there was brief discussion of population dynamics under conditions of large-scale socio-ecological change. And while final evaluation of the trap survey results awaits further trap surveys, ABMA2a, with the most densely clustered aquaculture, did have suggestive patterns of ovigerous lobster avoidance of active aquaculture sites.

This JPK lobster trap survey illustrates the value of incorporating alternative ways of knowing into risk assessment. It also demonstrates how JPK requires more than the will to expand our knowledge sets; it requires thinking creatively about how JPK is to be accomplished. More attention must be focused on knowledge forming actions in order to evaluate whether or not JPK is taking place in any particular case and how this is affecting better understanding of diverse perspectives on risk. In our illustrations, JPK is not a linear process (see Latour 1999, 69). The participants did not start with theorizing relationships, agreeing on concepts, and then moving on to seeking and understanding data, and elaborating principles before making evaluations. All participants came to the table with some preconceptions of relationships, and these were either strengthened or reshaped as the process unfolded. Concepts were shared and revisited, data were often debated and principles only occasionally discussed. All actions of the production of knowledge were ongoing throughout the project, and participants iteratively tacked back and forth between them as new information, experiences and discussions were collectively processed. While final interpretation awaits more data, participants have already begun to shift their understanding and evaluation of potential relationships.

A focus on the five actions of knowledge also helps to understand roadblocks. For example, limited data sources on production stages at sampled aquaculture sites have affected final analysis of potential lobster–aquaculture relationships. Further, the participants have yet to discuss relevant principles that may affect this relationship. In retrospect, holding a specific and focused discussion on such principles may have furthered development of a stronger protocol. Yet our experience shows that integrating fishermen's knowledge from the outset has lent credibility to early survey results. And this raises a further outcome of this study, one that draws in politics and power. Given JPK literature that assumes the benefit of wide stakeholder involvement, we suggest an alternative cost/benefit analysis as to whom to involve as participants. As our trap survey relied on the risk perceptions, expertise, skills, and equipment of fishermen, it proved impossible to invite aquaculture to the table. Doing so would not only have alienated participating fishermen, but would also have cast doubt on the study findings among the fishing community. On the other hand, in the case of any finding of harmful impact, the aquaculture community will likely challenge results as they were not 'at the table'. Perhaps a middle ground in situations of high distrust among stakeholders might involve more and better data provision to a third party such as the government.

The lack of active aquaculture participation cast in sharp relief the actions necessary to the JPK process. These five actions would have undoubtedly been different and more contentious had the project also involved aquaculture participation. Thus, the above case study of the potential relationship between aquaculture as an object of risk and American lobster as an object at risk makes several contributions. It not only fills a lacuna in the literature by defining knowledge as a process involving five knowledge actions, but also identifies how these knowledge actions are necessary for collaborative knowledge construction. Finally, it illustrates several important factors that facilitate or inhibit the JPK, including the importance of giving attention to each of the five actions, and the political practicalities involved in bringing different knowledge sets to the table.

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