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Teresa R. Johnson

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Fishermen, Scientists, and Boundary Spanners: Cooperative Research in the U.S. Illex Squid Fishery

TERESA R. JOHNSON
School of Marine Sciences, University of Maine, Orono, Maine, USA

This article presents a cooperative fisheries research effort aimed to improve the science and management of the U.S. Illex squid fishery. This collaboration between government scientists, the squid industry, and a consultant scientist produced new biological information about squid and improved the assessment of this species. This case illustrates the challenges and possibilities of involving nonscientific citizens in scientific research for policymaking. The involvement of the lead government assessment scientist for Illex squid was critical to the utility of the data collected. In this case, the integration of fishermen’s contributory expertise in science occurred through the work of key boundary spanners with interactional expertise. Here this included a consultant scientist and key fishermen who were able to communicate with government scientists and the industry. The collaboration also provided some fishermen with interactional expertise related to doing science such that they were able to communicate their contributory expertise to scientists.

Keywords: boundary spanners, collaboration, cooperative research, expertise, fisheries management, fisheries science, local knowledge, social studies of science, squid

Many scholars call for greater integration of local knowledge in the science policy process, particularly in the area of natural resource management. This is part of the growing “participatory paradigm” that views citizens as having a meaningful role to play in the production and use of knowledge (Irwin 1995; Fischer 2000). Scholars use the terms civic, citizen, and community science to describe such approaches (Irwin 1995; Backstrand 2003; Carr 2004). Although there are many cases where citizens are involved in identifying research priorities, collecting data, or interpreting research results for policymaking, they are typically not active participants in all phases of scientific research. This article examines a unique case of public participation in science where nonscientific experts collaborate “from start to finish” in scientific research. It presents a cooperative fisheries research effort between the squid industry and the Northeast Fishery Science Center (NEFSC).
aimed to improve the science used to manage the Illex illecebrosus squid fishery in the northeastern United States.

Most public participation studies in science policy focus on ordinary citizens’ involvement, but some citizens possess specialized knowledge. Collins and Evans (2002) define this “experience-based” knowledge as special technical expertise that is not recognized by certification. Collins and Evans (2002) abandon the oxymoron “lay expertise” and identify three types of expertise: (1) no expertise, (2) interactional expertise, and (3) contributory expertise. “No expertise” means that individuals do not have any knowledge or experience to contribute to science. Those with “contributory expertise” are experts who have knowledge and experience to contribute to science. Collins and Evans (2002) identify three types of expertise: (1) no expertise, (2) interactional expertise, and (3) contributory expertise. “No expertise” means that individuals do not have any knowledge or experience to contribute to science. Those with “contributory expertise” are experts who have knowledge and experience to contribute to science. Carolan (2006) further distinguishes between “abstract/generalizable” and “local/practical” contributory expertise. One can refer to these generally as “research-based knowledge” (RBK) and “experience-based knowledge” (EBK). “Interactional expertise” refers to individuals with enough knowledge or experience to understand the science and interact with contributory experts. Most important are those individuals who are able to interact with the both kinds of contributory experts. Interactional expertise is difficult to obtain; few are able to gain interactional expertise without contributory expertise (Collins and Evans 2002).

The value of fishermen’s knowledge and its potential contributions to fisheries science and management are well documented (e.g., Haggan, Neis, and Baird 2007; Neis and Felt 2001). Fishermen have “local/practical” contributory expertise related to the when, where, and how to fish, including the spatial and temporal locations of fish and fishing technology. Different fishermen are likely to have different levels of expertise regarding a particular subject due their diverse experiences. A fixed-gear lobster fisherman may have no expertise related to mobile bottom trawl fishing gear for finfish. However, some fixed gear lobster fishermen may gain interactional expertise about the finfish or mobile fishing gear through communications with other fishermen or from their experience in a similar fishery. This categorization is also relevant to scientists: a stock assessment scientist with contributory expertise concerning cod may have no expertise related to gear technology research but interactional expertise to contribute to the haddock stock assessment. In general, fishermen tend to lack “abstract/generalizable” contributory expertise related to doing science, while scientists lack “local/practical” contributory expertise related to catching fish.

Cooperative fisheries research refers to fishermen and scientists engaged together in scientific research (NRC 2004; Johnson and van Densen 2007). One aim of cooperative research is to integrate scientists’ research-based knowledge (RBK) and fishermen’s experience-based knowledge (EBK). In fisheries, this integration is difficult due to the qualitative, tacit, and anecdotal nature of EBK and the “mandated science” (Salter 1988) aspects of the science policy process that privileges only the “best scientific information available” (NRC 2004b; Wilson and Degnbol 2002). In addition, a history of distrust and miscommunication between fishermen and scientists hinders knowledge sharing (Dobbs 2000; Finlayson 1994). Cooperative research is expected to also improve the quality of science and increase the legitimacy and credibility of the policymaking process (NRC 2004). However, few published studies have examined the social dimensions of cooperative fisheries research (NRC 2004), and thus, whether this “buy-in” and scientific improvement actually have happened, or how they might happen, remains unclear.

This case study is based on ethnographic research conducted from May 2003 to August 2006 that examined the role of fishermen’s knowledge in the science policy
process. Specifically, I draw from 14 semistructured and informal interviews with squid fishermen, scientists, and managers, as well as informal discussions and direct observation at management and stock assessment meetings. My observations included two formal stock assessment meetings (NEFSC 2004; 2006), one assessment working group meeting, and four management council meetings. I also reviewed key documents and publications (Hendrickson and Holmes 2004; Hendrickson and Hart 2006; Hendrickson 2004; Powell et al. 2003; Powel, King, and Bonnier 2005; Powell, Mann, and Banta 2003). Transcribed interviews, field notes, and documents were entered into a database (QSR 2002) for qualitative analysis through coding for emergent patterns concerning the meaning of expertise and its role in cooperative research.

This article focuses on the following themes that emerged in the analysis: the fate of the collaboration, the role of fishermen and EBK, and the role of scientists and RBK. First, in order to assess stakeholders’ meaning of success, informants were asked to reflect on the outcome of the effort and whether they felt the project was successful. These responses and other instances where the project was evaluated, for example, at meetings and in documents, were coded under the theme “fate of the collaboration.” In addition, informants were asked to reflect on the cooperative research process and what each participant brought to the effort. These responses and other instances that alluded to individual or group contributions were coded under the themes “role of fishermen and EBK” and “role of scientists and RBK,” as appropriate. The results of this analysis are presented following the case-study description.

This case offers insight into the challenges and possibilities of involving citizens with EBK in the production of knowledge used for natural resource management. It further illustrates that interactional expertise can facilitate the incorporation of fishermen’s EBK in fisheries management. The integration of fishermen’s contributory expertise in science occurs in cooperative research through the work of key boundary spanners with interactional expertise. Here this included a consultant scientist and key fishermen who were able to communicate with government scientists and the industry. The collaboration provided some fishermen with interactional expertise related to doing science such that they are able to communicate their contributory expertise to scientists.

Case Study: Real-Time Data Collection in the Illex Squid Fishery

Background and Rationale for Real-Time Data Collection

The northeastern U.S. Illex squid (Illex illecebrosus) fishery is a large-vessel offshore fishery comprised of about 70 vessels, of which 15–20 fish regularly. Participation in the fishery varies annually according to market demand and abundance. This fishery is managed by the Mid-Atlantic Fishery Management Council (MAFMC), under provisions of the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan (MAFMC 2008). Management measures for Illex squid include limited entry, annual quota specifications, and trip limits when 95% of the annual quota is reached. Management with annual quotas requires knowledge of how much resource is available for harvest in a given year. However, since the Illex squid lives only 1 year and the abundance indices are highly variable, it is difficult for managers to know the status of the squid population prior to the fishing season. Since 2000, the quota or “total allowable catch” has been set at 24,000 metric tons (see Figure 1), mainly because no new information has been available.
Landings and annual quota or “total allowable catch” are summarized in Figure 1. In 1998, U.S. exclusive economic zone (EEZ) landings (23,568 mt) reached their highest levels since 1977 and fishermen exceeded the annual quota for the first time. U.S. landings subsequently declined, reaching their lowest level in 2002. In 2004, U.S. landings reached their highest level on record (25,059 mt), which again resulted in the closure of the fishery when the quota was exceeded.

According to key stakeholders, a significant management issue related to the Illex squid fishery is the need to allow the fishery to adapt to the variably available abundance of the species and avoid unnecessary fishery closures and/or the unintentional overharvest of the resource. Ideally, stakeholders believe that resource abundance should be assessed annually and landings should be monitored in real time to ensure an appropriate level of harvest.

The variability of abundance is related to the life history of Illex. This species is highly migratory, inhabiting offshore continental shelf and slope waters in the western Atlantic from Florida to Labrador (NEFSC 2006). Individuals from as far north as Newfoundland undergo a lengthy spawning migration in the fall to warmer waters south of Cape Hatteras (Hendrickson and Holmes 2004). Juveniles move onto the continental shelf in late spring and summer, where they feed and grow (Hendrickson and Holmes 2004). Illex squid grow rapidly (NEFSC 2006), and recent advances in aging of squid indicate that they live for only 1 year (Hendrickson 2004). Illex squid are semelparous and females spawn and die within several days of mating; therefore, natural mortality increases with age for the age range where spawning occurs, and fishing mortality and spawning mortality occur simultaneously (NEFSC 2006). An understanding of the stock structure is complicated by the overlap of seasonal cohorts (NEFSC 2006).

The species’ life history and poor data availability make it difficult to conduct a reliable population assessment (NEFSC 2006). Indices of abundance from bottom trawl surveys are highly variable and incomplete, as the Northeast Fishery Science Center (NEFSC) bottom trawl surveys do not cover the entire habitat range of this species (NEFSC 2006). It is unknown whether the survey indices measure relative abundance or availability to the survey gear (NEFSC 2003). Since Illex squid are highly migratory, an unknown fraction of the stock may reside offshore and outside of the area exploited by the fishery or sampled during the government science center’s bottom trawl surveys at any given time. Also, distribution of this species is

Figure 1. 1998–2006 U.S. Illex squid landings and total allowable catch (quota). Data source: Mid-Atlantic Fishery Management Council (2008).
strongly influenced by oceanographic factors and U.S. fisheries data are temporally and spatially coarse, and age and growth information is lacking for the U.S. stock component (NEFSC 2003).

Fishery-dependent data, typically from dealer landings reports and fishermen’s logbooks/vessel trip reports, are critical to the stock assessment process, as they are used to assess fishery removals and effort (Hilborn and Walters 1992; NRC 1998). However, many scientists question the veracity of industry reported data in mandatory vessel trip reports. There are many incentives for fishermen to misreport how much and especially where they catch (NRC 2000). Many fishermen fear data will be used against them through area closures, gear restrictions, trip limits, and so forth. The information reported is also reported on a temporally coarse basis (i.e., trip by trip rather than tow by tow). Hard-copy logbooks filled out by the industry must be keypunched into computers and then audited for errors, creating a time lag that hinders stock assessment and management. In many cases, several tows are made during a trip but only a summary of the entire trip is reported. The reporting of only one location when fishing occurred in multiple areas and the use of large statistical reporting blocks mean that data are spatially coarse. Thus, there has been significant interest in improving the collection of fishery-dependent information, especially at a finer spatial and temporal resolution. The 1996 Stock Assessment Review Committee (SARC) noted the potential of real-time management to preserve spawning stock biomass and to maximize yields in this species (NEFSC 1999). Since then, cooperative efforts between government scientists (NEFSC), the squid industry, and Rutgers University have been underway to implement real-time data collection in this fishery (NEFSC 2003; 2006).

**Description of the Cooperative Research Effort**

Real-time data collection in the _Illex_ squid fishery was initiated after a crisis: the August 1998 closure of the fishery. Fishermen and managers had two major concerns: (1) the science driving the stock assessment that set the quota too low that year and (2) the management process that closed the fishery despite information suggesting that this was not necessary. The industry responded by organizing and putting their own money forward to address these concerns. Organized through the National Fisheries Institute Science Monitoring Committee, the squid boats and processors set up a system to raise money from squid landings to pay for research. This included hiring a scientist from Rutgers University as a consultant to help them plan and conduct research needed for real-time management.

At the same time, the NEFSC was also looking to improve its assessment of _Illex_ squid. The lead biologist started working collaboratively with the squid industry in 1997, starting with visits to the processors and observations of squid fishing practices. After a period of building rapport, fishermen began to provide valuable biological data (i.e., length and weight information). In particular, the lead scientist began to work closely with a squid captain and MAFMC council member. This captain was the first squid fisherman to take the scientist fishing and allow the collection of requisite data. The lead scientist collected tow-based information and observed the captain’s fishing activity (how he set the net, where he fished, which direction he towed, what the bycatch was, etc.). Prior to that time the scientist lacked tow-based data unless an observer had been on a squid vessel. It is notable that the captain allowed the collection of this data, as most fishermen are hesitant about having
observers on their boats due to long-standing concerns that data may be used against them in the development of fishing regulations.

The lead Illex squid assessment scientist led a real-time management feasibility study from June to September 1999. The industry hired scientists from Rutgers University to coordinate the data collection. Twelve vessel captains agreed to keep detailed records of their squid catches and provide them to the scientists. Other captains volunteered to participate, but ended up not fishing during 1999 due to unpredictable availability of squid. This pilot study involved the collection of tow-based fisheries data on hard-copy logbook forms, including tow location, where the net went in and where it came out, length of tow, total number of pounds caught, discards, water temperature, and depth towed. Data represented a total of 71 trips and 1,146 tows. Squid captains also packed up subsamples of the catch, which processors weighed and measured for the study. Processors also provided weight and length information they collected for marketing purposes during pack-out from 1995 to 1998. Processor staff provided dorsal mantle length and body weight measurements for 14,450 squid. In 2002, the NEFSC introduced electronic reporting of the fisheries data (Hendrickson et al. 2003).

In May 2000, the lead government scientist collaborated with the squid industry and Rutgers University consultant to conduct an Illex squid pilot survey. Using commercial gear, two chartered freezer trawlers sampled from May 19 to May 29 from Georges Bank to Cape Hatteras. The National Oceanic and Atmospheric Administration Fisheries Marine Fisheries Initiative program and the squid fishing industry provided funding for the project. Eighty random stations were sampled at depths of 60–200 fathoms. Scientists collected information on species catch weight, gear mensuration, vessel speed and location, water temperature, and depth. They also collected biological data, such as weight, length, and sexual maturing, from more than a thousand individual squid. Sensors mounted on the gear measured how wide the net opened during each tow, which, combined with information about trawl speed, provided the area of the bottom and volume of water sampled. The resulting information could be useful to scientists to estimate the abundance of squid. Industry members identified the time of the year and general areas and times of the day best to sample squid. This was the only survey that the collaboration conducted, but it proved very useful. It provided valuable biological information about Illex squid that was incorporated into the stock assessment in 2003 and 2005, as discussed later.

Since its inception in 1999, there has been a significant decline in participation in this collaborative effort, as shown in Figure 2. In 1999, 63% of the active Illex squid fleet participated in the program. In 2000 this declined by almost half to 36%. In 2001, participation increased again (67%), only to drop by about half again in 2002 (33%). By 2003, only 7% of the Illex fleet participated in the program. Participation increased after 2003 to 19% in 2006 (Figure 2). The annual declines in participation were due to lower catch rates that limited participation of a number of vessels (Powell, King, and Bonner 2005). Lower participation rates from 2004 to 2005 are related to a greater number of participants in the fishery (Figure 2). Other informants suggested that the decline was due to fishermen’s concerns that data would be used to estimate stock size and that this might result in future quota reductions. More significantly, the initial decline was due in part to mistrust that arose after the government implemented gear-restricted areas to protect another species, scup (Stenotomus chrysops) (Powell et al. 2004; Powell, King, and Bonner 2005). These
seasonally closed areas affected the *Loligo* squid (*Loligo pealeii*) fishery, which included many of the same fishermen who fish for *Illex*. Similarly, informants also suggested that the failure of NMFS to waive the hardcopy logbook requirements as promised eroded trust and reduced participation. Although some fishermen remain skeptical and distrustful of future management implications of this research, some fishermen value the effort and recognize the benefits this data can provide, as evidenced by the continued participation in the effort by several vessels and interest in a future survey.

**Results**

This section reports on three key themes from the analysis: fate of the collaboration, role of scientists and their RBK, and role of fishermen and their EBK. Given stakeholders’ perceptions of “success” that emerged from the analysis, this section provides examples that support why this cooperative effort can be considered an example of success and then reports on the role of the scientists and fishermen, and their knowledge and skills, in the effort.

**Fate of the Collaboration**

Key informants related to the *Illex* squid case study defined success as “impacting science or management.” Scientists tended to emphasize the contributions to the science, such as publications and use in assessment, while industry members highlighted contributions to management and stock assessment. As discussed later in this article, compared to other cooperative research efforts initiated in this region in the last 10 years (Johnson 2007), this project is one of the most successful in terms of the utility of the information produced.

If measured in terms of its contributions toward to improving stock assessment, this program can be considered exceptionally successful. In 2003, most of the May 2000 survey was incorporated directly into the assessment (NEFSC 2003). As part of the 2003 assessment, a new in-season assessment model was developed that estimates weekly fishing mortality rates and stock size and, unlike the previous model,
incorporates recruitment and spawning and nonspawning estimates of natural mortality (Hendrickson and Hart 2006). The model and results from that model were considered preliminary, requiring more rigorous testing (NEFSC 2003). Nevertheless, the stock assessment report included special comments indicating that the Illex cooperative research projects “have resulted in improvements in the data available for the current assessment… and should continue” (NEFSC 2003, 41). In 2005, the Illex squid assessment built upon the data collected from this ongoing collaboration. The peer review committee chair reported, “[A] cooperative research programme for 2003 and 2004 was completed and the results incorporated in the modelling analyses; a pre-season survey with commercial vessels was completed in 2000 and the results utilized in the analyses presented” (Payne 2006, 18).

However, progress with the new stock assessment modeling effort lags due to a lack of data. The peer review committee chair noted that “although significant progress has been made towards developing such an improved assessment, the uncertainty generated by the current data limitation precludes its immediate use as a provider of management-usable values of F and stock biomass” (Payne 2006, 17). In particular, the chair noted that more and better data are needed to calculate seasonal growth rates and maturity. In addition, more participation in the program is needed, as discussed earlier. There was interest in gathering some of the necessary data from the Mid-Atlantic Supplemental Finfish Survey, another notable industry–science cooperative research effort (King and Powell 2007), although the future of this survey is uncertain.

In addition to the benefits regarding stock assessment, informants stated that this cooperative effort also generated long-lasting scientific knowledge about the species. One scientist explained: “We got a lot of good biological information, so it was, we think, very successful.” In particular, data from the May 2000 survey enabled Hendrickson (2004) to characterize growth, maturity, and age structure of the Illex population. Prior to this study, spawning areas had not been identified because few juveniles and mature females had ever been landed and the neutrally buoyant, gelatinous egg balloons had never been found in nature. The May 2000 survey with industry boats provided the first evidence to indicate that Illex squid spawning actually occurs on the continental shelf in U.S. waters (Hendrickson 2004). Also, the study was the first time the animal was aged; prior to this study, statolith-based age analyses were lacking for squid from the U.S. shelf and for the population prior to the start of the fishing season (Hendrickson 2004).

Participants also point to this project as a success because real-time management in this fishery is becoming a reality, albeit slowly. One fisherman explained how he worked closely with the scientists on Illex, and that “they did a great job making something out of nothing.” Ideally, real-time fishery management would combine a survey of abundance at the start of the fishing year with in-season catch monitoring. This would “better equip managers and the industry in identifying optimal harvest goals and adjusting harvest strategy when necessary” (MAFMC 2007, xvi). Further, this would avoid unnecessarily shutting down the fishery when the estimated quota was achieved but more squid could have been sustainably harvested, as happened in 1998 and 2004. This would necessitate additional participation in real-time data collection to monitor the fishery in-season, so fishery managers are considering mandatory real-time reporting (MAFMC 2007). As an example of the industry’s commitment, one industry representative reported, “Industry has talked about funding a pre-season survey and providing boats, gear, and expertise.”
Yet if measured in terms of the level of participation, or overcoming distrust and improving relationships, this case could be considered a failed attempt at collaboration. However, it is important to keep in mind the sustained participation and future commitment of some fishermen. Moreover, the fact that some fishermen were involved in data interpretation, as discussed later, is significant. In most cooperative research efforts, fishermen are not involved in this aspect of research (Johnson and van Densen 2007). And most informants agreed that the decline in participation was due to logistical and trust issues in another fishery, and not because the project itself was unproductive or without merit.

**Role of Scientists**

The actions of the government lead assessment scientist in this effort were critical to the utility of the data produced. She initiated early discussions with the industry that led to the development of the effort. By asking questions and taking the time to learn about the fishery, through observation at sea, she was able to build trust with the industry. As we see in most cooperative efforts, trust and communication are critical factors for success (Johnson and van Densen 2007; Hartley and Robertson 2006). The government scientist also provided her expertise regarding what kinds of data were needed to improve the assessment and how to best collect those data. Her involvement from the beginning facilitated the use of the data in the assessment and efforts to create real-time management. Thus, a factor influencing the utility of cooperative research is the inclusion of those who are most likely to use the data, in this case the lead stock assessment scientist. The models used to generate assessments require specific data and collection techniques. If scientists are not included in the project, data generated in collaborations may not be incorporated into science or management. At the same time, this case also illustrates how difficult collaboration is between industry and government scientists. The trust that the government scientist generated was diminished due to her perceived affiliation with a management decision that negatively affected the industry. Government scientists appear to have a much more difficult time initiating and sustaining collaborations with the industry because of their affiliation with the regulatory process. Open communication and frequent interaction are therefore critical for industry collaboration with federal scientists.

Another key to this effort’s outcome was the involvement of the nongovernmental scientist, or industry consultant. The “consultant scientist” helped foster trust, legitimacy, and buy-in to the program because he provided the industry with a voice in the process. The consultant scientist provided a mechanism for communication between the government scientist and the industry. This is important for overcoming the aforementioned trust issues the industry has with government scientists, which typically deter collaboration. A government scientist summarized the critical role of the consultant scientist:

[He] did help facilitate participation and that’s where a consultant that’s paid by the industry can assist, is to get to explain scientific information to lay persons and explain how it would go into the management process. Because let’s face it the industry doesn’t trust the government, we’re like Big Brother. . . . So I think that’s where cooperative research can really be helped is with the industry person facilitating dissemination of scientific information to laypersons and the training of the industry.
Many industry consultant scientists are “boundary spanners” (Johnson 2007). They recognize the value of fishermen and their knowledge and are able to communicate scientific information with nonscientists. As important, they are able to communicate the industry’s concerns to other scientists. These individuals have interactional expertise (Collins and Evans 2002). This is due in part to language proficiency; they know the scientific terminology that is often unfamiliar to fishermen. These boundary spanners can emphasize aspects of fishermen’s behavior that other scientists who do not interact with the industry may not be aware of or recognize as important. They can point to a place for fishermen’s knowledge in science. In addition, these scientists are not associated with the regulatory process, so they tend to have better working relationships with the industry compared to government scientists. However, the effectiveness of these scientists as boundary spanners is diminished when they are perceived as politically motivated, such as when they appear either too involved in the policymaking process or too confrontational (or lenient) toward government scientists. In those cases, they are not able to utilize their interactional expertise to communicate with the government scientists on behalf of the industry. This underscores again the importance of trust in these collaborations.

**Roles of Fishermen and Their Knowledge**

Fishermen and their knowledge were critical to producing useful information in this effort. Fishermen contributed their knowledge related to fishing gear and operations and the spatial and temporal locations of squid (i.e., their contributory expertise). As noted, one site where fishermen’s knowledge was essential to the project was the May 2000 *Illex* survey, as it used fishermen’s ecological knowledge related to the temporal and spatial distribution of squid and to their technical knowledge of gear operations. The design of the 2000 *Illex* survey was random, so fishermen did not pick the tow locations, but they did operate their gear and vessels in a way that was more efficient at catching squid than the government resource survey. Hendrickson (2004, 264) indicated that the use of commercial vessels in this fishery “offered the advantage of improved catchability in conjunction with a standardized, random sampling design.” In the effort, fishermen’s knowledge ultimately was filtered though a scientific assessment model and aggregated with other fishermen’s knowledge (i.e., it was translated into scientific knowledge) but nonetheless significantly improved the quality of the data collected.

A surprising place to see fishermen contributing their knowledge is in the stock assessment process, which is usually thought of as one venue where data from cooperative effort are analyzed solely by certified scientific experts. In most efforts, fishermen are not involved in the interpretation or analysis of data (Johnson and van Densen 2007). Fishermen were observed providing insight at a working group meeting for the 2005 *Illex* assessment, providing scientists with an improved understanding (or explanation) of fleet dynamics and industry behavior. They brought to the discussion their observations of the spatial and temporal distribution of the resource, suggesting that one year was unique because it was characterized by a longer duration of squid abundance throughout the whole area. One *Illex* fisherman also attended and provided insight at the peer review of the assessment. The captain informed scientists of valuable information (i.e., that squid were smaller this year or did not grow), which he knew based on his fishing experience and he felt could be confirmed by 2005 data, which were not yet available to the scientists. This kind of knowledge that the
industry can provide is important in verifying and explaining the data collected by scientists. The chair of the stock assessment review committee (Payne 2006, 7) indicated that fishermen gave "valued input into the assessment and discussion" and that it "is crucial that stakeholder input in particular be sought at reviews of this nature, because scientists worldwide ignore such opinion at their peril!"

Some fishermen are also boundary spanners. For example, the first captain who took the government scientist out to sea communicated often and openly with scientists. As a fishery manager, he is also exceptionally well informed about the complex issues of management and science, and how they interact to impact the fishery. As a participant in the fishery, he was aware of the impacts that traditional quota management and early closures had on the industry, so he saw the benefits of the industry participating in this program. Therefore, this fisherman brought to this collaboration his "local/practical" contributory expertise regarding the squid fishery and his interactional expertise related to fisheries science. This fisherman acquired this interactional expertise through interactions with scientists, including other cooperative research efforts. He is not alone, as he is joined by other fishermen who are similarly positioned to interact between industry and science as a result of their interactions with scientists in cooperative research. Johnson (2007) found these fishermen with interactional expertise to be critical to the success of this and other industry-science collaborations.

Thus, fishermen and their knowledge were critical in this cooperative effort "from start to finish." They raised concerns about the annual quota specification process (i.e., identified a problem), they assisted in the design of the program, they collected the data (i.e., reporting their catch/effort information and providing biological samples), and they offered insight into the interpretation of the data (e.g., at working-group and peer-review meetings).

Fishermen remain important to the future of this effort because use of the data in stock assessment and potentially in real-time management requires that the majority of the fleet participate. As of now, the program is fully voluntary and tends toward a public goods collective action dilemma, where the efforts of a few can benefit the many, and the many have little incentive to try (Olson 1965). Those who do participate are contributing valuable information that is needed to improve the assessment and management of this fishery. Improving participation beyond this group requires rebuilding trust and improving communication between the government agency and the industry.

Conclusion

Cooperative research allows for the integration of scientists’ and fishermen’s knowledge, or boundary spanning. Unlike most forms of participatory science, the fishermen in this case study were engaged in both the collection and analysis of scientific data "from start to finish." To be sure, fishermen’s knowledge is translated into scientific knowledge, so the science/nonscience boundary remains, but there is nevertheless exchange across it, which is far better than the outright dismissal of fishermen’s knowledge that typically occurs when legal mandates privilege only scientific knowledge.

Indeed, fishermen are contributory experts; they hold "local/practical" contributory expertise (Carolan 2006) related to when, where, and how to catch fish, including fish location and fishing technology. However, they most often lack
“abstract/generalizable” contributory expertise (Carolan 2006) that scientists possess. By engaging with scientists in cooperative research, fishermen develop a better understanding of science, including scientific data collection and procedures and how data are used in assessments and management. That is, they gain interactional expertise (Collins and Evans 2002) related to the scientific process, which includes not just an understanding of the data and how it is used in the assessments, but more importantly how to communicate in the process. In many ways, fishermen gain an understanding of the language and practices of a different knowledge culture. To be sure, fishermen would not be expected to conduct stock assessments, so they cannot be said to have acquired “abstract/generalizable” contributory expertise. But they now have interactional expertise with which they can communicate their “local/practical” contributory expertise to scientists.

A key finding in this research is the critical role of the boundary spanners, particularly the nongovernment, consultant scientists. In this case, the consultant scientist utilized interactional expertise to facilitate the collaboration between the government scientists and the industry. Also important is the boundary-spanning role of fishermen with interactional expertise who are able to contribute their “local/practical” contributory expertise to the science policy process. Several key fishermen in this effort brought their interactional expertise gained from previous cooperative research efforts and their involvement in fisheries management, while others gained it from interacting with scientists in this effort.

The boundary spanning seen in cooperative research is expected to reduce conflicts between fishermen and scientists and thus create “buy-in” to science-based management. However, additional research is necessary to better assess the long-term effects of cooperative research on fishermen’s perceptions and attitudes about fisheries science and management. As seen in this case, extraneous events can quickly erode trust and impede collaboration despite results of considerable value, which highlights a critical, albeit difficult, role of boundary spanners: conflict mediation. The benefits of collaboration, including the sharing of expertise and boundary spanning, are by no means guaranteed. Not all fishermen who participated in cooperative research gained interactional expertise or became boundary spanners. Not all industry consultants, regardless of their contributory expertise, will have the capacity to be boundary spanners. The ability to communicate and translate between fishermen and scientists is a set of skills that not all industry consultants are likely to have, but perhaps should. This research raises important questions regarding how these boundary spanners emerge, function, and retain their authority within their social group.

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