ICES Journal of
Marine Science

ICES Journal of Marine Science (2019), 76(2), 370–383. doi:10.1093/icesjms/fsy187

Food for Thought

Taking stock of fisheries science through oral history: voices from NOAA's Fishery Science Centers

Julia Olson[1] and Patricia Pinto da Silva[2*]

[1]*Integrated Statistics, 16 Sumner Street, Woods Hole, MA 02543, USA*
[2]*Social Sciences Branch, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543, USA*

[*]*Corresponding author: tel: + 1 508 495 2000; fax: + 1 508 548 2649; e-mail: patricia.pinto.da.silva@noaa.gov.*

Olson, J. and Pinto da Silva, P. Taking stock of fisheries science through oral history: voices from NOAA's Fishery Science Centers. – ICES Journal of Marine Science, 76: 370–383.

Received 25 July 2018; revised 17 October 2018; accepted 7 November 2018; advance access publication 15 December 2018.

The application of historical perspectives and the documentation of long-term change in and views about the ocean is increasingly sought to frame and contextualize current issues facing marine science and policy. One of the important methods for informing such an historical perspective is through the use of oral histories, long used by social scientists for insight into local knowledge, lived history, and their meaning to participants. In this article, we seek to demonstrate the relevance of oral histories for understanding the changing institutional setting and research focus of marine science in the United States, and the unique platform it offers for introspective reflection on where marine sciences are today, where they have been, and where they might like to go. We discuss the influence of institutional changes on research topics, the impact of regional differences on the sciences, the increasing emphasis on mathematics and modelling, and new directions incorporating ecosystems, human communities, and public involvement. Finally, we conclude with consideration of the value of oral histories and other qualitative methods for elucidating experiences of and perspectives on the past.

Keywords: environmental history, history of marine science, oral history.

Introduction

Historical perspectives have become increasingly recognized in marine science and policy applications, helping to frame current issues by documenting longer-term, historical change in the ocean. Such perspectives serve to link social and ecological systems as they change over time, help put shifting baselines into perspective, and provide contextual information for data poor fisheries (Ames *et al.*, 2000; Thurstan *et al.*, 2015; Engelhard *et al.*, 2016). Although such approaches have been characterized by a variety of data sources and methods, from fossil records to logbooks (Lotze *et al.*, 2011) to cookbooks (Levin and Dufault, 2010), prominent among them is the use of oral histories (Thurstan *et al.*, 2016), long used by fisheries social scientists to document local knowledge, lived history, and their meaning to participants (Thompson *et al.*, 1983).

In this article, we seek to demonstrate the relevance of oral histories for understanding the changing institutional setting of marine science in the United States, and concomitant changes in research focus, for the unique platform it offers for introspective reflection on where marine sciences are today, where they have been, and where they might like to go. As the fisheries biologist Tim Smith has written, the development of fisheries science was buffeted by political and economic pressures that continue to influence the field without historical perspective. Indeed, scientists are left to reinvent the wheel, "periodically rediscovering" factors such as "importance of ecological interactions" as well as "ever shifting scapegoats" without a "clear research program" that is contextualized, comprehensive, and historically informed (Smith, 1994, pp. 2–3). As the marine historian Helen Rozwadowski has written, a historical perspective helps to "sort out politics from biology, the values of mathematical modeling and prediction from the value of environmental monitoring, and capitalism from the red herring of scientific uncertainty. The larger point is that, because the uses of the ocean were, and remain, numerous and intensive, it is incumbent on historians of science to engage with the production of knowledge that enables exploitation, both intentional and unintentional, of the sea" (2014, p. 337). In short, understanding the context of and changes in the production of scientific knowledge about the marine environment helps us to better understand our changing relationships to and ideas about the ocean, and those who interact with it.

In the recent literature about fishing communities and livelihoods, oral histories have been used, for example, to document the social impacts of fishery regulations (Colburn and Clay, 2012), understand the social networks involved in changing fisheries over time (Package-Ward and Himes-Cornell, 2014), and record community history and knowledge (Abbott-Jamieson 2007). More generally, social scientists have argued that local knowledge and cultural memory are deeply connected to conservation issues, "serv[ing] as repositories of alternative choices that keep cultural and biological diversity flourishing" in the face of homogenizing forces (Nazarea, 2006, p. 318). In part, this is due to the inherently social and cultural nature of remembering and interpreting the past (Thomson, 2007). As the oral historian Alessandro Portelli has written, "memory is not a passive depository of facts, but an active process of creation of meanings" (1991, p. 52). And oral histories that particularly centre on communities, including communities of scientists, allow one to look at the changes in those shared understandings: "to explore how and why individual and collective memories interact and to uncover what tacit knowledge underpins the community and is understood but frequently unacknowledged by members" (Nyhan and Flinn, 2016, p. 29).

The turn to a historicized understanding of the marine environment is intrinsically interdisciplinary, crossing natural and social sciences, and demanding new methods and perspectives (Máñez and Poulsen, 2016). While environmental history has begun to historicize both the ocean and the marine sciences, oral histories provide a unique perspective into how "who we are" matters to the way that science is done, in what we choose to study, how we understand it, and what we tend to ignore. As Doel notes in his review of oral history projects with scientific communities, their value can be particularly found as sources about networks of relationships, awareness of "the traditionally invisible members of scientific communities: women, minorities, engineers, and technicians", insight into "largely unexplored dimensions of scientific activity" such as life outside the laboratory, "the role of tacit knowledge in science", "community traditions and communication patterns difficult to discern in standard forms of evidence" and the "dynamics of research institutions" (2003, pp. 359–362). In what follows, we first describe oral histories that were conducted with a cross-section of marine scientists in the National Oceanic and Atmospheric Administration (NOAA), particularly in the National Marine Fisheries Service (NMFS), the federal regulatory agency responsible for managing fisheries in the Exclusive Economic Zone (EEZ) of the United States. These oral histories were collected as part of a larger effort to document the lived experiences of a wide variety of people who use, study, or rely on a changing ocean. We explain the methods used to subsequently analyse the histories and introduce the prominent themes and issues encountered, including the impacts from institutional transitions; regional differences in scientific focus; the turn to mathematical modelling; and the current crossroads at which marine sciences stand, the shift to ecosystem-based approaches in which a more expansive notion of the environment, one that more prominently includes humans, is at issue. We then discuss these themes in more detail, using these oral histories to explicate the interplay between society and science, and the changing role of science and scientists in the context of calls for greater transparency, participation, and relevance.

Methods

In 2007, with funding support from NOAA's Preserve America Grant Initiative (PAIG), the Voices from the Fisheries Oral History Database was created in order to identify, archive, and disseminate recordings and transcriptions of oral histories related to commercial fisheries in the United States. Since the creation of the database, over 1200 oral histories from more than 55 different individual collections have been archived with the Voices project, including histories produced by NOAA scientists as well as external researchers and non-profit organizations. The vast majority of interviews housed in the Voices from the Fisheries database have been conducted with fishermen, processing workers, and others directly involved in the harvesting and processing of fisheries resources in the United States and its territories.

In 2016, the Voices project Principal Investigator (co-author Patricia Pinto da Silva) led an oral history project directed at capturing the experiences and perspectives of scientists employed or previously employed primarily at NOAA's regional Fishery Science Centers. The project was exploratory with the objective to capture institutional knowledge and insight into how fisheries science might have changed since the implementation of national legislation affecting fisheries management (described in more detail in the discussion section) and how NMFS labs have changed over time as workspaces, with the goal of documenting such perspectives as archival sources of information according to recommended practices among oral historians (see http://www.oralhistory.org/about/principles-and-practices/).

The project initially focused on the Northeast Fisheries Science Center, but was expanded to other regions after additional funding became available. Given this opportunistic approach, approximately half of the interviews are from the Northeast with the remaining drawn from other regions (with the notable exclusion of the Alaska Fisheries Science Center and the Southwest Fisheries Science Center due to time constraints). NOAA social scientists from the Northeast, Southeast, Pacific Islands, and Northwest Fisheries Science Centers and headquarters offices worked with the project PI and local staff to identify potential interviewees who were recently retired or nearing retirement age, or otherwise perceived by those regional project partners as high priority according to their own historical trajectories. Effort was directed at interviewing those scientists who played a key role in advancing the sciences in or the institutional development of the agency, including some of the early female scientists in the organization; thus the group of scientists interviewed was a purposive, non-random sample of scientists who had a particularly privileged insight into topics deemed of historic interest by a team of social scientists, and key informants based in offices across the NMFS.

Approximately 115 individuals were contacted for interviews; of these, 10 individuals opted out (including two women) and an additional 15 did not respond despite multiple contact attempts by e-mail. Of the interviewees, 70 (or 77.8%) were male and 20 (22.2%) were female. Although a gender balance was sought, this was not possible given that the majority of fisheries scientists were male, especially among those having reached or nearing retirement age. Age was provided in just over half ($n = 46$) of the interviews, with ages ranging from 49 to 93 years old at the time of the interview. Twelve interviewees gave a date of birth in the 1920s and 1930s, 18 a date of birth in the 1940s, 13 gave a date of birth in the 1950s, and 3 in the 1960s. Of the interviewees who did not give a birthdate, using information provided about education and career trajectories, 31 were still working and in their 50s and 60s, while the remaining 13 were retired and of at least retirement age. All interviewees were asked to provide details about their educational background and to describe the work they were involved with during their NOAA careers; upon this basis 75 of the interviewees (83.3%) can be categorized as natural scientists; 7 (7.8%) were social scientists, 3 (3.3%) were involved in gear and engineering design, while the remaining 5 (5.6%) were in other positions, such as administrative and legal ones.

Interviews were conducted by senior oral history practitioners working in each region and familiar with fisheries science and management. Their backgrounds included environmental history and cultural anthropology. In some cases there was more than one oral historian working in a region due to the necessity to obligate funds and complete the project in a short timeframe, particularly in the Northeast Region where most interviewees were located. But all interviewers were provided with a common interview guide and participated in initial project calls to coordinate interview activities and establish project goals and protocol. A training packet which further detailed topical areas to explore during an interview was also developed and distributed to interviewers by the then Voices from the Fisheries Project Manager and oral historian Josh Wrigley.

Oral histories share much in common with other qualitative interviewing techniques that involve dialogue and conversation between interviewee and interviewer; one key difference is that oral histories are generally recorded, transcribed, summarized, and publicly archived with the explicit aim of being available for other researchers (Ritchie 2003). Yet the practice of oral history has been considerably influenced by as well as contributed to developments in other qualitative social sciences that have wrestled with questions of subjectivity, objectivity, and reflexivity in the production of knowledge (Perks and Thomson, 1998). In short, oral historians have begun to see the memory and narrative inherent to oral histories, as well as the very interview relationship itself, as strengths rather than weaknesses, for the unique insight they offer into the meanings of the past, as well as "the relationships between past and present, between memory and personal identity, and between individual and collective memory" (Thomson, 2007, p. 54).

Given that retiring scientists were the primarily targeted age range, eliciting their experience with and perspectives on the significant institutional transformations in the agency that occurred during their career was especially sought. Thus questions ranged from understanding the body of work that an individual was involved in and the context of that work, exploring both the particular arc of the individual's career but also their perspectives on general changes in the marine sciences as well. Moreover, questions were not limited to scientific work alone but also concerned childhood, educational choices, and so on, providing insight into the broader context of these scientists' lives. Interviews were semi-structured and questions were open-ended, so that the direction and flow of the interview followed the interests of the interviewee and the dialogue created with the interviewer. For example, questions about technological changes in the practice of science were asked in most interviews, as technologies are the means through which people engage with and understand the environment. We expected discussion of the changes brought by computing revolutions but did not anticipate the degree to which biology vs. mathematics and modelling would animate those discussions. And while not all the same questions were asked of all interviewees, key questions on career trajectories and experience, scholarly work, and connections to fisheries management are shared between the interviews.

Interviews were recorded, transcribed, and made available to the public via the Voices from the Fisheries oral history database website (www.voices.nmfs.noaa.gov), with explicit written permission from the interviewees. Although none of the oral histories used or databased in this project are anonymous, we have followed common practice in qualitative social analysis by not identifying interviewees by name and instead have utilized the written transcriptions' numbering system to identify interviewees, and the page number to identify the location of interview excerpts.

The transcriptions were coded and analysed for this study using MAXQDA, a software program designed for qualitative and mixed methods analysis of textual data. Prominent themes were identified and analysed for patterns and divergences among the different interviewees, an inductive method of analysis common with qualitative data. It involves first a careful reading of the data, in this case all 90 oral histories, preliminary compilation of emerging themes, comparison across cases for patterns and divergences, and an iterative process of coding and recoding the data. Coding necessarily involves the judgement of the analyst and a reflexive recognition of how the questions asked and the very interview context can affect the answers given. But because the oral histories were conducted by a team of social scientists, preliminary coding was also informed by team meetings involving personnel from a variety of disciplines who discussed emerging themes. And although the themes highlighted in this study do not exhaust the full universe of possibilities, they were chosen for the frequency of their appearance in the oral histories and their centrality to questions of historical change in the practices of marine science in NOAA. In what follows, we first detail the themes and their frequency across the different interviewees and then present them more fully in the discussion section, particularly with respect to the changing institutional and research setting of marine sciences in the United States.

Results

The primary coded themes that emerged from the preliminary analysis are shown in Table 1. As discussed in the previous section, these do not exhaust the full set of possible themes in the oral histories but rather reflect the initial research question focusing on historical change in the agency. Figure 1 also shows the co-occurrence of codes across the oral histories, giving an initial indication of the relationships between the different themes.

The themes we discuss below explicate in greater detail the predominant co-occurrence in these oral histories of changes in the focus of research, methodological and technological changes, the increasing presence of mathematical and modelling approaches in fisheries and marine science, and the turn to more collaborative and interdisciplinary research. Since the interview excerpts were coded only when they were surrounded by additional explanatory text, the numbers in the table and figure do not represent a full accounting of the number of times a theme appeared in the histories. Moreover, the entanglement of different themes in the conversational nature of oral histories makes a strict accounting of themes difficult and potentially misleading. Rather than quantify the different responses, we have endeavoured to show how oral histories are always deeply personal reflections on lived experiences, relying on quotes from the interviewees to draw out these themes and choosing those quotes that best illustrated particular points or self-reflexive interpretations.

Discussion: themes from interviews

Charting the transition to NOAA and the Magnuson Act

With the focus of the project on historical change in NOAA, one of the subjects touched on most frequently in the interviews were the institutional transitions and transformations of the Agency. Given the age profile of many of the interviewees, the most significant transformations occurred in the late 1970s, entailing first the creation of NOAA and then the passage of the Fishery Conservation and Management Act of 1976 (later known as the Magnuson-Stevens Act), which extended the EEZ to 200 miles and enacted the structure of fisheries management that would govern the extended jurisdiction. Both resulted in a nationalization of resources that changed the political nexus from Cold War to domestic politics, and a shift in emphasis from more basic or exploratory science to stock assessment efforts that directly interfaced with management needs. [While NOAA Fisheries, or the NMFS, has only been in existence since 1970, the precursors of the agency were first formed in the late nineteenth century. The first governmental institution entrusted with the study of marine fisheries in the United States was the US Commission of Fish and Fisheries in Woods Hole, Massachusetts, created in 1871 by the US Congress. Its mission, under the leadership of Spencer Fullerton Baird, was to understand and rectify declining fisheries in New England. In 1903, the commission was renamed the Bureau of Fisheries and placed under the auspices of the US Department of Commerce and Labor, later transferred to the Department of Interior in 1939. In 1956, it became the Bureau of Commercial Fisheries (BCF) under the Fish and Wildlife Service, and finally it was in 1970 that President Nixon created NOAA, placing it under the Department of Commerce, and turning the BCF into NMFS (Hobart, 1996).]

Historical studies on the development of marine sciences have described in detail the importance of geopolitical, military, and economic influences. The historian Naomi Oreskes described how, "Well into the twentieth century, much scientific work in the ocean was opportunistic, as scientists (or their proxies) worked from ships that sailed for commercial or military reasons, creating some well-studied oceanic pathways (such as the Atlantic

Table 1. Primary coded themes.

Coded themes	Number of oral histories with at least one coded segment
Diversity	20
Organization change	7
Public-agency/scientific responsibility	51
Politics in science	37
Freedom and desire to do science	22
Policy	30
Budget and red tape	38
Differences between places and regional focus	30
Collaboration and interdisciplinary work	50
Fishermen research	35
Industry work	19
Public involvement, action	24
Mentoring/leadership	23
Changing research focus	73
Fishery development	13
Changing methods, data, and assumptions	30
Changing technology	60
Field vs. laboratory, bio vs. math/model	39

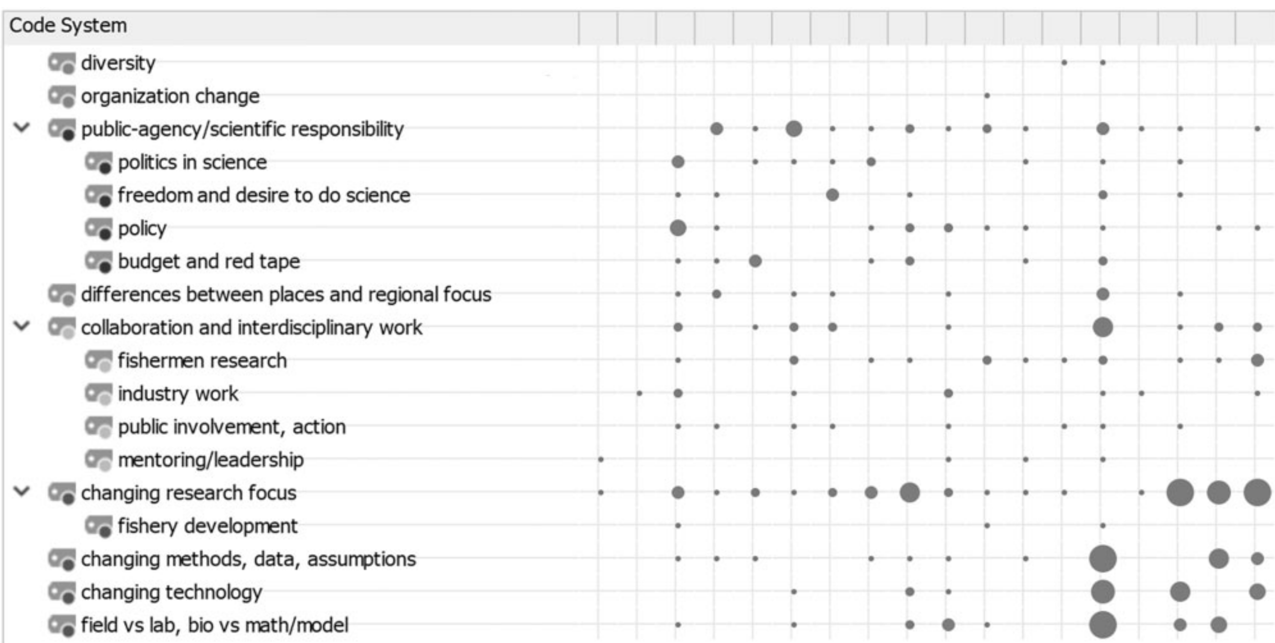

Figure 1. Co-occurrence of coded themes.

Gulf Stream) but leaving large swaths of territory virtually untouched" (2014, p. 381).

Likewise Rozwadowski noted that "virtually all fisheries scientists have, from the late nineteenth century until very recently, been committed to the idea that marine resources should be intensively exploited" (2004, p. 60). The post WWII years were no exception, emphasizing fisheries marketing and promotion, resource exploration, and gear design. As one scientist recalled, before "it was all fisheries exploration, fisheries development. Very strong fisheries lobby. You had in Congress, folks who were very much commerce oriented for the fisheries" (6481: 14). But such interests played out in the geopolitical context of the Cold War. As the historian Matt McKenzie writes, "fisheries resources emerged as a primary tool for reconstruction and an important component in Cold War politics. Desperate for protein of almost any sort, nations from around the world sent fishing fleets to the northwest Atlantic in vast numbers" (2012: 301).

Indeed, numerous scientists recounted working on international research cruises and surveys with a variety of different nations during the height of the Cold War, ostensibly for research purposes but with political motivations ever present (e.g. 6493: 14). As one scientist involved in such work noted, "Then you had the Soviets, Poles, East Germans—the Eastern Bloc. It was always very hard to get the Eastern Bloc to kind of get away from following the party line. Always had this feeling that their objectives were always to ensure that their countries would have maximum access to as much fish as possible" (5854: 24, 25).

As another scientist explained, "if you look at the early 1960s [...] the general focus of most of the fisheries was to increase exploitation. We were going to feed the world. And we were still urging, you know, people to go into different fisheries and find ways that people could catch them. We were just beginning, and again because in the Northeast we were ahead of everybody because of the forcing pressure of the foreign fleets, to look at, looking at things from a population dynamics standpoint and beginning to look at, so, beginning to think, look in terms of regulation" (5871: 6).

Likewise, another scientist recalled "when you saw the size of the, particularly the Russian fleets on Georges Bank, it was like a city out on Georges Bank. Vessels all over the place, and that figure I think, those numbers got the attention of those of us living on this side of the Atlantic, Northwest Atlantic, and that, I think made it obvious that whoa, we've got a problem. Even though we didn't understand a lot of the things controlling the natural reproduction. The fact that a multi-year species could decline so much in such a short time was like a real warning, warning bell" (6422: 10).

Foreign fishing, an interest in Americanizing resources, and other Cold War politics fed into arguments both for and against extending US jurisdiction to 200 miles. While the 1945 Truman Proclamation had already declared ownership of resources in the continental shelf, military interests feared extended territorial control could curtail US military activities in international waters (Galdorisi and Kaufman, 2002). Indeed, Finley and Oreskes (2013) have argued that the strategic interests in the United States that were concerned with freedom of the seas and extending political influence in the high seas were responsible for enshrining the fisheries policy of MSY [Maximum Sustainable Yield] into diplomatic policies and international agreements long before its scientific dimensions had been fully explored. As they write, "Scientists answered the questions that they were asked, but many other questions—including whether this was the right framework to begin with—remained unasked. As ecologist Henry Regier has written, it was science relevant to harvesting a 'relatively undifferentiated mass,' which is exactly how MSY viewed fish" (Finley and Oreskes, 2013, p. 248).

Among the fisheries biologists interviewed, opinion about the EEZ extension was mixed, involving conceptions of the fisheries and the application of fisheries science. One involved scientist recalled that "the whole idea of surveys and some of these studies I have already described was to buttress the arguments for the expanding or establishing the 200 mile limits so we'd have more control over our coastal resources. And our lab and staffs were pressed into service for all kinds of documentation to provide the government for information that they needed for their negotiations" (6422: 8).

This involved detailing "what the resource could stand in each region, how much could be taken and how much was overfished [...] we felt it was a big economic benefit to extend our jurisdiction to protect our resources from foreign influence. Because at that time there were many foreign vessels, whether they be Russian, German, Japanese, fishing our waters and we were not able to control them through the international commissions. ICNAF [International Commission for the Northwest Atlantic Fisheries] was one of these, and it was sort of a silly game that they were playing; they would agree but they would, you couldn't enforce anything" (6429: 5).

Others pointed to the domestic fishing industry, especially in the Northeast: "The debate [over extended jurisdiction ...] was very intense in 1975, 1976 [...] the polarization between the industry and the Center was in part because the industry, you know, felt all the problems were foreigners [...] and the Agency's position was, no, not all the problems are foreigners, actually, you know, we actually have good controls and that sort of stuff" (6489: 9).

This scientist felt "this was a really exciting time because [...] it was during the era when ICNAF was in full, you know, full glory. And actually making some progress in managing the fisheries after, after a decade of gross overfishing by what we referred to as the distant water fleets [...] ICNAF had come into its own and was actually making good progress managing the fisheries and, and really had invented most, a lot of what's now modern fisheries management" (6489: 8).

ICNAF, he continued, was the place for "the really exciting science [...] the science battleground for regulating fisheries" (6489: 10).

Indeed, the move from the ICNAF to domestic control through the regional council system was described as one scientist as "inept" (6839: 11). In part this was because of what some identified as growing pains in the early council system: "back then, I think, there was a lot of laxness in place and it became clear very quickly that there was not too much interest in really regulating. I mean, I couldn't even begin to tell you all of what went on in those first few years. It was probably mostly getting used to the system [...] they really weren't interested in our assessments because they figured they weren't needed. It was kind of a disappointing time for those of us who'd been heavily involved in ICNAF" (5854: 27).

He continued, echoing the loss of excitement others also expressed, "We were now on the council system which none of us really cared for, to be quite honest, from a scientific point of view. No stimulation, nobody—we were only talking to ourselves" (5854: 31).

But this lack of involvement of science in the council system was to change as the emphasis quickly shifted to funding stock assessment that would inform management needs. For the new stock assessment scientists, there was a need to "determine how much of the resources were out there and what sort of productivity they had so therefore you could convert that into allowable quotas [. . .] that was sort of a paradigm shift, I thought, within the agency, in terms of the role. Because prior to that a lot of the science that was going on wasn't all that much different than what people did in academics; individual projects, less focused on management" (6016: 5).

As another scientist recalled, "Before we got into the Magnuson Act the science was basically what you would call marine biology. We did things to find out what was going on, trying to ask 'why' questions, but we were basically marine biologists, or ecologists, if you will. And it was really a fun thing because it was doing research and publishing [. . .] the whole emphasis was just a question of what's in the oceans, how does it work, how it doesn't work. When the Magnuson Act came in it started to change in a number of ways. One, prior to that, probably the [Regional Office] had one or two attorneys. Now I don't know how many they have, maybe they have twenty or thirty [. . .] The centers then changed to studies of population dynamics, more mathematicians, statisticians, stock analysis, and that was the main change" (6429: 9).

The Magnuson Act required the creation of management plans for the now domestic resources, which led to a more regulatory stance in the agency: "prior to our new statutory authority under the Magnuson Act in 1976, we were mostly a scientific organization. The outcome of our work was important, but it never had the consequences on people or the impacts on people from a regulatory standpoint. So, the nature of the science and how it was used changed significantly and so it was under-invested, I think, for many years and so this new regulatory role that we had required more precise data, more timely data, more accurate assessments, and different kinds of modeling then was okay during the sort of the wet foot biologist days of the organization where we were exploring new fisheries and trying out new ideas. It was just a different environment prior to this new statutory responsibility. We became from a science organization to a science-based regulatory organization"(6425: 6).

The new emphases meant that "you were then now able to fine tune the total management, you get into much more complex schemes rather than, for example, a simple overall quota, you'd now get, in some cases, down to individual quotas, some cases group quotas, you know, assignments of catch by gear, type, all of these things to try to deal with the socioeconomic impacts that you didn't do before then, that were brought in by the Magnuson Act" (5871: 7).

Such new orientations that began to grapple more with the social, economic, and ecological entanglements of fisheries entailed for some scientists an uncomfortable blurring of science and policy: the move from BCF to the Department of Commerce was seen as "incongruous" at first (6418: 9). As one scientist explained, "in the beginning we were mostly a fish biology oriented laboratory and towards the end we were definitely more number crunching. Coming up with the assessments, using different methodology to find out how many fish were out there. And we became more regulatory. Which is what I always thought the [Regional Office] was more regulatory. We did the pure science, they did the regulations. But somehow the last few years that got blurred and so we were affected more by different timelines and responsibilities that we didn't have in the beginning. The social science group didn't exist when I first came. The marine mammal group didn't exist when I first was at the lab" (5904: 23, 24).

Others felt more strongly that "there's a disturbing number of people that are policy people, even at the Science Center where, you know, I could see them being up at the RO [regional office] or Headquarters, but we got policy people now that, I don't know if some of them have even touched a fish, and they're making decisions about the science without really listening to the scientists anymore. You know, there are decisions that are made from a policy perspective" (6407: 31).

Such boundary work (Gieryn, 1983) in the marine biological setting involved differentiating what counted, literally, as science, as an early anthropologist in the agency recalled: "There was still, especially among the natural scientists, a little bit of concern that, you know, what do you really do, is this really science—I mean, the economists, they have models and equations, but are you just like, collecting anecdotes, or what are you doing? How is this science?" (5880: 5)

For others though, the move away from engaging less in fundamental ecological science and to a more regulatory orientation was a move away from a more holistic vision that more integrally included social sciences: "there are many ways in which the breadth of the science that we were doing when I first came here in terms of fundamental ecology and other aspects have been diminished [. . .] everybody begins to think that well, it's the mathematics that rules instead of understanding the biology and the ecology and the sociology and the economics" (7130: 15).

Earlier approaches hearkened to more ecosystemic approaches now finding favour again: "most of my personal research was there [in Woods Hole, beginning in the early 1960s] and I focused on population dynamics, stock assessment, and particularly looking at multispecies fisheries management and a lot of things that everybody put aside after extended jurisdiction so we looked at the, what today would have been called ecosystem approach to fisheries" (5871: 5).

Changes in emphasis and workload led to "more isolation [. . .] of the stock assessment people" and "less connectivity" and "cross pollination" with ecosystem based fisheries management than had been the case previously (6489: 28, 29). But these particular changes were not experienced evenly throughout the agency. We turn next to regional differences in these institutional changes before returning specifically to the move toward more ecosystemic models of fishing within NOAA.

The sciences: charting regional differences

As described earlier, NOAA Fisheries is comprised of six regions, each with a primary fishery science centre, as well as numerous field stations and laboratories. With expansion after the Magnuson Act also came a desire for a more national organization. As one scientist explained "you had groups of people that tended to operate independently and particularly with the advent of the Magnuson Stevens Act, one of the overall goals, I thought, was to try to get the centres to act more organized in terms of the same sorts of goals in order to meet the overall NOAA National Marine Fisheries Service objectives" (6016: 6).

One scientist recalled the vision of the chief planner behind the transition to NOAA of uniting the individual science centres to a more cohesive and systematic organization, employing aerospace technicians and logic diagrams to chart organizational change (6929: 11). Numerous scientists from smaller research posts also recounted the efforts to consolidate and close smaller labs (e.g. 5904: 7). But a scientist located at headquarters explained how he struggled "to get a coalition together of a common thought of how we could do things together that would gain some of the efficiencies or gain some of the best practices form one region or the other. You'd be surprised how isolated— within one organization—how isolated a region is or a center is from another one. What's going good in one region was just not known to these other places" (6425: 8).

As another put it, "I think we as an agency get a little hampered on our ability to think nationally because we're mostly really regionally oriented people" (6443: 12).

For example, the changes and pressures described in the previous section came later for satellite labs like Sandy Hook, which had tended to focus on basic research into fish habitat and other ecological concerns. "We've been very much, at least in the early years when I first got here [in mid-1990s], working very much in the estuaries, and then the very near shore ocean [...] In recent years, we've pushed hard to move our operations more off shore, into the shelf ocean [...] We were generating a lot of interesting information, but it wasn't directly tying into the management in terms of single species management and the stock assessment. And so this has come up in the last several years, that we need to be moving in that direction much more. So, that's been a big change, and that's been as a result of Magnuson-Stevens, because that's what we're mandated to do, what this agency is mandated to do. As the funding has become more directed, less in terms of looking at ecology and more in terms of looking at single species like that, we've had to sort of change our perspective" (6424: 6, 7).

Another scientist explained that "[Magnuson-Stevens] had a big factor in where Woods Hole and the Center as a whole went with their research. Those special line items, you know, those earmarks essentially disappeared and what we were doing as researchers here, what we had been doing was the kind of stuff that other people, university people, other branches within NOAA were supposed to be handling. It was shocking to me that that really wasn't part of what Northeast Fisheries Science Center was supposed to do anymore" (6455: 6, 7).

As another succinctly put it, "when you're in the satellite labs like Orono or like Sandy Hook, you kind of feel like you're out of it, because everything is Woods Hole-centric, and I think the other guys at Sandy Hook would tell you the same thing. You kind of feel like you're second class citizens. We get the crumbs so to speak" (6884: 14; also 5961: 6).

Although highly localized studies have arguably been critical to the development of ecological sciences (Billick and Price, 2010), Magnuson and later tightened funding issues then forced scientists, such as those at Sandy Hook, to demonstrate their direct relevance to management. "There really wasn't as much pressure to deliver the products which were going to feed directly and quickly into management. Not as much then, from the fisheries perspective. And I guess that's sort of code for, there wasn't nearly as much pressure then to deliver data and findings which would improve, or support, traditional stock assessments. I mean, that's really, so there was a transition. There was, and the reason there was a transition is because the funding got, every year it got worse" (6448: 7).

But he continued that "in some ways the nature of the data has not changed a whole lot. But the application has [...] we have to start to make that link to management to get the kind of support from with, from within our agency anymore" (6448: 28).

The need for a government science agency to demonstrate relevance to society may not be surprising; not only do such concerns about privileging management advice over basic science echo similar concerns that Helen Rozwadowski (2004) found in her history of ICES, but they more broadly reflect changes that historians and sociologists have identified as Mode 2 or post-normal science (see Dankel *et al.*, 2016 for a fisheries discussion). But it is the boundaries of what is considered to be relevant that are at issue here, especially in the broadening context of Ecosystem-Based Management (EBM). As another scientist at Sandy Hook recalled, "back then we did what I call more basic research. It was fisheries related, but we weren't driven by the needs of the management councils cause the management councils were just getting started, and it was really, I would say, a much more enjoyable time, because you'd just do good science? We looked at fish food habits because, well, we ought to do that. It wasn't because the management council wanted to know something. It wasn't because they were mandated to look at ecosystems based management issues. It was the logical thing to do and it was good science" (6884: 5).

He continued "probably with the '76 change, things became much more offshore driven and people that work in estuaries who are sort of forgotten [...But] there's an intimate connection between the estuaries and the offshore environment and I think again, as we start to look at a little bit more holistically, the systems, maybe that stuff will come to fruition" (6884: 15, 16).

Scientists who had first been affiliated with the BCF also recalled the transition to NMFS involved a distinctly new relationship with the fishing industry, a transition that was intensified only a few years later with the passage of the Magnuson Act. The transition was particularly acute for those laboratories whose original mission was particularly focused on industry development. The Galveston Lab in Texas was, for example, especially oriented to shrimp exploration and aquaculture (Zimmerman 2010). "Early '70s. The federal government was getting out of trying to assist the fishing industry so they weren't felt like we were being bought by the industry itself. And so we, we changed that form of research and gear research developed into, which eventually got into the turtle excluder device to protect animals and not so much to help the fishermen but to protect the resource" (6429: 4, 5).

Likewise, scientists in the main laboratory in Hawaii worked in close cooperation with the local fishing industry, such as the tuna and bait fisheries, and focused on fish research, development, and exploration (6122: 9). As one of the early scientists recalled, "at the time it was absolutely unique as a place in the world where there were live tunas in captivity that could be used for research. And so that was a huge focus of the Honolulu laboratory [...] it was because of the Aku fleet, the boats that would come in and bring the fish to, to the cannery right there by Kewalo Basin where we had our laboratory, that we could get the live fish. So it was a synergy, a symbiosis of the Aku fishery and that laboratory" (6122: 11).

For Hawaii, which received statehood in 1959, the emphasis on exploration continued for some years after it did in other areas: "things on the East Coast, took a while to migrate the West Coast and Hawaii. We were involved in fishery development long after people on the East Coast were beginning to deal with allocation issues" (6465: 14). Even in the aftermath of the Magnuson Act, "although fishery management plans were developed there really still wasn't any management per se. The plans were just set up to monitor the fisheries. It wasn't seen as there being any particular need to control them. But there was an interest, and the Magnuson Act provided an interest in getting foreign fishing out of the U.S. EEZ [Exclusive Economic Zone]. And so some of the earliest studies were to understand the dynamics between distant water foreign fishing, which occurred inside the EEZ in those days, back in the '70s, and the local fish, fish abundance" (6122: 13).

Other studies sought to explore new fisheries to develop in the Northwest Islands of Hawaii and the Western Pacific (6128: 7; 6453: 6, 7; 6457: 5) "this was in the late '70s the early '80s and really the focus was to promote increase utilization of marine resources in the archipelago systems and in the open ocean system. I mean, it was in the '75 that the Magnuson-Stevens Act was passed and they had areas within 200 miles that were excluding foreign fishing and so this was an opportunity to develop the U.S. resources [...] now it's people want to protect the ecosystems, and– and if in some sense it seems like, you know, the pendulum has swung so far that the idea of having sustainable fisheries in the U.S. is under threat" (6457: 5, 6).

Exploring tensions in the field, in the models, and with EBM

Other consistent themes arising in the oral histories included issues such as public agency and scientific responsibility, politics in science and the question of objectivity, collaboration and interdisciplinary work, and differences in scientific approaches from the field to the laboratory to the model. Across ages and disciplines, interviewees described the technological advances in computing power that have enabled the development of extraordinarily complex modelling that can handle large amounts of data, as well necessitated increasing attention to more complex data management needs. Readily available statistical packages have expanded the ease with which scientists can probe their data, making analysis "more thorough [...] more rigorous [...] more reliable" (6468: 8, 9). They have also changed the nature of fisheries science and scientists.

One scientist noted that his mentor recruited mathematicians and physicists "because he thought that's where the future was [...] and he was right, I mean, basically the future in biology to deal with fisheries or other environmental issues was with mathematics and biological models" (6489: 5). He continued later in the interview that the "threat" of mathematics to biology has "become an increasing problem because of this isolation of the people doing the math from the people collecting data and involved in fisheries [...] But it's not the mathematics. Mathematics to me is just thinking, you know, logical thinking that you can precisely articulate in some way, which is, which is always to be desired. But, but just logically thinking about some operational aspect of how we come up with a number that satisfies a legal framework or a policy framework rather than how we actually understand the truth, or how the system works, that, I think, is the threat" (6489: 35, 36).

As another scientist said, "if you can't write it down in the mathematical terms, then you don't really understand what is going on. It's very difficult to use the data if you can't translate it to numbers that someone can understand and use [...] We need people who can say how far down is it? And why is it down. Where are the numbers? What does it look like if we were God, how could we fix it?" (6839: 22).

But perhaps surprising, given the dominance and ubiquity of mathematics in fisheries science and stock assessment, were the frequently expressed reservations about the scale of this turn (see also Kingsland, 1995). As one ecologist noted, scientists not trained in the new techniques get "left behind, but I think on the flip side, um, I think they kept their broad perspective and didn't get led down these narrow channels of trying to resolve a specific parameter of the mathematical models. So I think there's still a lot of value of not being a mathematical modeler or a statistician" (5928: 9).

Another lamented "Nowadays, you have very fancy models, in fact everything is a model these days. You almost don't need reality anymore because you can just go to model something and come up with some statistical solution. The day of the biologist is perhaps numbered" (6884: 12). While Smith (1994) has detailed the century-long synthesis of mathematics and biology in the development of marine population dynamics, and the need for greater awareness of how short-term needs have impacted long-term understandings, scientists interviewed had a profound appreciation for the impact of such organizational changes. The change in hiring primarily modellers, for example, meant to one scientist that "a lot of people aren't really biologists, and don't really, I mean this may even not be entirely true, but so there's more emphasis on the mechanics of producing an assessment rather than a deep interest in the biology and the biological mechanisms that go into effecting the populations" (6475: 18). Another reiterated the impact from a loss of in-house knowledge: "the mathematics shouldn't take precedence over the fundamental scientific understanding. I think that's a real problem because there are whole segments of the Center that have gone away entirely since I've been here that I think to our great detriment" (7130: 15).

For some, the necessary corrective was a change in practice: "modeling and statistics is a two edged sword. You can be led to believe things that are false, because you're looking too much at the computer. So, my feeling is we need to continue with this with our field programs, because that's the way to ground truth those models. Otherwise you can go way off and not know it [...] the modeling and the field sampling go hand in hand, it's not one replacing the other" (6424: 10).

Others noted the pressures from "feeding the machine" of stock assessments (6432: 12): "there's a greater separation between the scientists involved in the fishery management process and the rest of the Science Center that's doing research because the people involved in the stock assessments are doing them full time. And they weren't before. They, because they're not working as closely with the people doing ecological research or whatever, they're less likely to incorporate it into their stock assessments and the ecological research is less likely to be relevant because they're not talking to anybody" (6489: 28).

But an ecologist felt that "many of [our staff] will tell you that they feel frustrated that when they've approached, that when we've approached our stock assessment folks, that they're not taken seriously" (6448: 15). He continued that "sometimes the models are also a little bit of a, of a distraction" (6448: 28).

In the philosophy of science literature, debates about models have largely centred on the representational and ontological nature of models, their realism or antirealism, and the extent to which models are tools or explanatory (Frigg and Hartmann 2018). For example, one biologist made the distinction between: "my work we didn't do much with models; that was the population guys. I basically kind of dealt with, you know, the real data. We'd sample the fish and how many there were and the sizes and everything, and from that, project the size of the spawning population. We really didn't model it, it was a statistical estimation of what the spawning stock size was. And then all the environmental factors that, you know, would enter into why this year was a good year, why last year was a bad year, that sort of stuff. We didn't do any forward projecting and that's what models are usually are for" (6477: 15).

But the conflicting attitudes held by scientists about the nature of modelling point more especially to different modes of scientific practice. They also, as Joan Fujimura has noted for systems biologists, involve debates about holism and reductionism, "fighting words' in the history of biology" (2011: 67), in which metaphors of top-down controls and bottom-up complexities affect both the questions asked and the answers given. As one stock assessment scientist explained, "all models are wrong, some are useful. It's always an issue of trying to make the model good enough to provide advice but don't get lost in the weeds [...] We are recognizing that we've gotten a little too trapped into keeping it too small and that we need to be finding better ways to be linking to more of the broader influences" (6443: 10).

But a habitat ecologist argued that it is precisely the details discovered from wading in the weeds that are explanatory: "there are changes in the environment, in the habitats from year to year, storm, change in wind direction which you can't anticipate, and which have great effects on the animals, on recruitment, where the animals are going to recruit, and how important their recruitment is in terms of numbers of juveniles. And you can't, the model isn't helpful, of any use. There's too many changes out in the wild going on which a model could never anticipate" (6887: 23).

Another scientist now involved more directly in management lamented their complexity and, ultimately, their believability: "you really don't know to what extent, if you turn this knob over here, the result will be different and if you move this lever, how will the model and results change? There's just no way to fathom that because there are almost like an infinite number of combinations that you can use to tweak a model." He continued, arguing that one should not "pretend that the model is actually going to give you a representation of what's actually going to happen so that you can plug the information in here and out comes the result and that's the way it is in reality" (6909: 22).

Such differences of opinion are particularly pronounced in discussions surrounding the modelling of ecosystems and their application in fisheries management. A key scientist involved in formulating NOAA's move to EBM explained that the objections were generally no longer about what EBM is or why to do it, but rather how to do it (6432: 7). The danger that he saw was "being very precise but inaccurate and missing a major driver just because we're not thinking about modeling it" so instead a series of scenario planning is envisioned: "here's the range of what's impossible, can't ecologically get there. Here's the range of scenarios or alternatives that would be really bad, would make you violate the law. And here's a range of scenarios that are okay, pick amongst those [...] it's not as precise as we might be used to, but that kind of broader level bounding the problem, scoping it out, is where we're headed with this" (6432: 11, 12).

Such a different stance to management would mean, in the words of a stock assessment scientist, "an explicit recognition that we can't, we don't have the ability to control the system as well as we would like and have the flexibility to...sort of pick and choose the winners" (6471: 24).

But there were starkly different opinions as to the current capacity to deliver ecosystem models or apply such principles to management. Numerous interviewees felt that lack of data was a current limitation. "My personal opinion is that it's sort of a long ways to go, I think, before we get to the point where the data that we have, the resolution of the data we have is enough that you can do that" (6484: 21). Another scientist expanded that "In order to get the cumulative removals that might occur over a particular time period, you have to multiply those stomach rate contents consumption rates by the number of predators... so that exercise then it really just massively expands the problem of single stock assessment because now the herring assessment depends on estimating the quantities of... monkfish, of dogfish, of cod, of haddock" (6471: 23).

Similarly, one explained, "it's unlikely, certainly within my lifetime, that you're going to end up with large-scale ecosystem models that you actually use for management that helps you come to a decision about TACs, or Total Allowable Catches [...] if you have five, five species, uh, interaction with five species that the interaction rate, all the different kinds of parameters you have to have because it becomes a matrix then, and the dimension goes up, you're just not going to get that kind of data, that level of things."

In his view, ecosystem based management "isn't necessarily trying to predict what's going to happen but rather to be able to detect changes as quickly as possible so that you can respond to those changes. And so, you know, to me that's a lot of what the fisheries assessment science and world is coming to, or has been for a long time, is how do you detect something as quickly as possible, how do you respond to it" (6016: 11, 12), with the end result still focused primarily on fishing effort, "putting in buffers so that instead of taking maximum sustainable yield you're taking some percentage less than that" (6016: 13).

Another scientist, however, pointedly disagreed. One argued that "you've got to come to grips with, okay, what does MSY mean in an ecosystem? It doesn't, it doesn't mean a bunch of individual MSY estimates for individual stocks which we can rebuild them all to at once. And scientists have been saying that for fifty years, probably. But the law and the policies, largely ignore that" (6489: 34).

Another scientist argued that the "ecosystem point of view is looking at long-term productivity changes, so if we see that productivity is increased here or decreasing we should adjust our catch accordingly [...] Now with global warming, coral reef decline and things, and theory in fisheries, if you have overfishing, the solution is you cut back on your fishing mortality, your fishing effort. Or you, if you have any other impact that affects productivity do the same, the answer's the same, you still have to cut back fishery fishing mortality" (5863: 10).

He continued that "fisheries tends to focus on yield now. They tend to overdo it. The idea of an ecosystem point of view is that we're focusing on the persistence and the productivity of the ecosystem [...] in traditional fishery, I call, it's like we fix it when it's broken. And you may be sued if you don't prove it's broken [...]

Ecosystem point of view is more like airplane maintenance. You know, you don't fly unless everything's working" (5863: 13).

And others disagreed that complete data was necessary. A scientist from Hawaii said "there's often this kind of myth and there has often been this resistance towards ecosystem-based management [...that] you have to know everything about everything before you can do anything. We like to actually see it completely differently. You still have to know, I mean you only have as much information as you have [...] you can restructure how you're gathering information for the same amount of money to take any good consistent information, like, I mean right now we're required to do stock assessments of all species. We're not able to do that, we don't have the resources to do that as I mentioned. We instead are focusing all of our resource on doing stock assessments, and not effectively enough again for these very diverse coral reef systems or near-shore systems. We could do that differently by doing it through ecosystem indicators for the same amount of resource" (5866: 13).

A scientist in the Northeast concurred, arguing for a "more holistic point of view" that focused on "constraints on the overall production of an ecosystem [...] that sets limits to how much the overall catch can be" (7130: 6). This means "You're not necessarily having to account for interactions between cod and silver hake or whatever, but it's built into the outcome of the numbers that you're measuring over time [... but] the big impediment is still this belief that it's too complicated to do, which brings us back to what I was talking about before about not falling into the trap of saying we're going to have to have these immensely complicated models that we have to populate with parameters, but instead to take advantage of emergent properties of ecosystems that are more stable and predictable and then your task is to make sure that that stability and resilience is maintained. If you do that, then you can, the rest in one sense can take care of itself" (7130: 7, 13).

Indeed, another scientist argued that what was lacking was not more data, but more focused analyses. "We have a hell of a lot of data on by-catch. We haven't done much, we, we've done a little research on, a little gear research to reduce by-catch but we haven't done really very much to analyze how important it is in terms of population dynamics, overfishing, all those sort of things. It's just a lot more data. We have a lot more surveys that are responding to specific issues of setting quotas and so on, but, um, historically this region was pioneering in implementing surveys from the perspective of ecosystem surveys and that stuff has been reduced. Scientists spend much less time, or have much less time, to actually think about dealing with, you know, long-term scientific problems, or even, even improving their models to be more complete and comprehensive (6489: 27).

Yet another said, somewhat differently, tha "we shouldn't diminish [...] the more reductionist approaches that are really necessary in science; you want to integrate them [...] I'm finding a lot of the ecosystem sort of, uh, cadre, you know, doesn't always recognize the importance of some of those various... detailed sort of physiological experiments that might be done in a small corner of somebody's laboratory" (6448: 27).

This debate, as Fujimura has argued, involves far more fundamental questions: "The principles used by systems biologists frame which biological realities are created. If engineering and command-control principles continue to dominate systems biology models of living organisms, what will they produce? [...] Can scientists use mechanistic models to think about nature and simultaneously keep in mind that these mechanistic models are only one slice into understanding complexity? Or does mechanism limit our abilities to see and account for complexities?" (2011: 79).

Reconciling localized understandings with broader modelling is intensified by efforts to bring people more squarely into ecosystemic understanding at the same time that it has raised other issues as well, such as evaluating trade-offs and accepting a wider appreciation of involvement, to which we turn to next.

Incorporating people

The question of how to prioritize different factors becomes particularly pressing when the ecosystem is expanded to include social considerations: "There's nothing that I know of out in the literature that really provides clear guidance as to what is the most important factor and how do you balance all these parts? The big picture? Ecological, economic, cultural [...] what are the needs and how do you evaluate all of these individual needs specific to those categories?" (6909: 35).

With respect to the trade-offs necessitated from such changes as climatic shifts in fish distributions, "that's a big chunk of the ecosystem approach that people don't want to deal with. Again, it's not science-bound. So I think, I think that there's a huge part of the ecosystem problem that's not science limited and is gone about as far as the science side can go given what people need to start to address the problems" (6489: 33).

For an economist, however, such trade-offs are precisely at issue in social scientific understandings: "do you not fish those species and that means there's more for the predator species which you may be fishing on so you can fish more? What's the tradeoff there? How much more fish will you get? How much do you have to give up? These start becoming economic issues and so I think there's a growing opportunity as we move towards an ecosystem-based fisheries management approach to utilize economics and decision-making at those levels. The integrated ecosystem assessments go beyond fishing to other uses of the marine environment such as offshore oil and gas and wind farms and things like that. Again, what are you gaining in terms of having these facilities and what are you giving up? Framing that in an economic setting is going to be really important" (5944: 21, 22).

But others saw economics issues less about trade-offs than about survival. As an ecologist explained, "you have to understand not just the effects of the ocean on the distribution of the animals and the dynamics of the fleet, but you have to understand the effects of global economics on fish prices and the incentive to fish in the first place. So, it gets very complicated and it's a wicked problem. It's not a deterministic system that you can come out with one solution and that's it. It's a process of sort of mining what's happening right now and coming up with the best solution in an environment where there's very little trust" (5947: 9, 10).

He continued that "We're near carrying capacity for the planet and we have to figure out how to harvest resources in a way that we don't crash the planet. So, that's our job. Economics and ecology are inextricably the same thing. Human beings or animals are inextricable parts of the ecosystem" (5947: 10).

Yet another scientist involved in ecosystem management was concerned about learning to make "the trade-off for protein" between "iconic species" and those less familiar in order to feed a growing world population. But while he admitted that "how many of the iconic species we can maintain is... dependent on how committed we are to sustainable fisheries based on the modelling" he continued that "now people talk about ecosystems and they talk about model projections and climate change on an everyday basis. So the public is tuned in and so are most politicians, not all, so to answer your question am I optimistic, I certainly am" (6929: 16). Indeed in an evaluation of the successes and promises of Large Marine Ecosystem management efforts across the globe, his optimistic assessments, he said, were based on the fact that such experiments have used "a bottom up approach rather than top down" (6929: 14).

But greater involvement also encompasses more than stakeholder participation. Ecosystem based management, by its very nature, represents an expansion in scope of both fisheries management and fisheries science. While the previous section suggested that the institutional change from the BCF to NOAA increasingly blurred the boundaries between science and policy, EBM has arguably blurred boundaries further, especially between once separate knowledge domains. This is especially true for the inclusion of the social sciences into EBM in a more integral fashion. As a social scientist explained, "initially we had to argue to put humans in the ecosystem [...] We literally had to argue to pull that off" (6465: 14). But as another social scientist noted, "more and more in recent years—especially as Magnuson Act has added more and more pieces about ecosystem-based management—we've started to try to figure out how we can do joint work with the biologists and the oceanographers [...] We're creating some kind of multi-disciplinary groups and we seem to be—I wouldn't say we're up and running exactly the way we would want it to be, but I think we're making a lot of inroads in that area" (5880: 11).

The role of the social sciences and understanding the place of humans in the ecosystem has gone hand in hand with recognition of integral societal interactions. As an ecosystems scientist admitted, "we've tended to manage fisheries in isolation from all of the other ocean uses, and coastal uses that need to be managed. You know, so often, you know, agriculture or things particularly for the near shore system, there's lots of things that are going on land that sometimes have a greater influence on say coral reefs, or coral reef fisheries, or near shore fisheries, than fisheries alone, and yet we're managing those things independently of each other [...] so it's trying to reach what is the best societal benefits across all of these sectors and make being able to maintain ecological wellbeing, so that those are sustainable services that, you know, and then kind of taking all of those sectors, you know, into the management decisions concurrently "(5866: 12).

Another agreed that integrated ecosystem assessments must "be interdisciplinary and you have to address the multiple objectives. It can't just be not only one fish or a bunch of fisheries, but you have to look at jobs, you have to look at well-being of resources and communities and human aspects. The economics are part of it, but the sociology is a part of it. It was really intriguing to see that interdisciplinary approach [...] wrestling with how do we make this operational so that you can use it to make decisions" (6432: 11).

Indeed, as another scientist explained, "we're living in a world where we have extreme events happening now all the time related to climate change, invasive species, habitat loss. All these things are affecting fish. So without an ecosystem approach becoming central we are just not going to be able to manage effectively. Likewise I think the incorporation of people into our thinking has been critical because the cliché is that we don't manage the ecosystem, we manage the people. If we don't understand why people do what they do and the effect of either the environmental changes or management changes on people, then we will fail" (5942: 8).

For a number of scientists, achieving a more grounded knowledge, and more socially aware management, necessitated working more or better with members of the fishing community, though understandings of this differed. An ecologist remarked "I really like working with the fishermen because they're real; they're out there, they see. I come from a natural history field biologist background. So the closer I am [...] to the fishermen, the more grounded I feel. Uh, and I feel many of the managers need more of that grounding, too. I've always said that anybody who goes into this field, uh, with the idea of working for a management agency, Fish and Wildlife or NMFS, needs to spend some time in the field, actually handling the whatever critter it is that they're interested in [...] Otherwise you'll sit at your computer and apply your Leslie Matrices and have no idea whether you're really accomplishing anything" (5936: 8).

Another concurred: "nothing's a better habitat ecologist that your main predator, and fishermen are great habitat ecologists in understanding how the liquid works" (5947: 7). He continued, explaining that utilizing the knowledge of fishermen allows for scaling up the knowledge of a solitary scientist: "[fishermen are] the intuition I've got on the estuary. Because it's scaled up, it's now become relevant to ocean management. So, the ecology becomes relevant to ocean management because the technology allows us to do it at the scale of the ecosystem [...] the problem these days is you have tremendous computing power, big data streams and you think you can sort of use data mining techniques to figure stuff out. Well, you actually can't ask the right questions in the first place unless you have a real intuition for what's going on, right. And one way to get that intuition at the scale of the ecosystem is to work with fishermen and actually talk to them, and talk to them about what they think is going on in the system and then trying together to work out modeling approaches that allow you to capture it in a formal way that you can then bring to bear in scientific assessment" (5947: 9).

Those with positive experiences with the fishing industry cited interactive exchanges based on building up long-term personal relations, actively listening to observations, and exchanging ideas. [Many scientists mentioned specific examples where the observations of fishermen on the water, as well as formal cooperative research programs, led to new insights and understandings about life history and habitat ecology, including such examples as monkfish prey relationships (6475: 15), bycatch avoidance (5928: 10), scallop recruitment (6887: 13, 14), scallop management (6471: 19, 20), aquaculture practices (6500: 9), and spawning seasonality (6441: 12). Negative experiences with collaborative research were infrequently mentioned, yet those who did noted a lack of training or miscommunicated expectations (6839: 23) and the difficulty of overcoming antagonistic relations in fisheries under stress (6451: 12).] Others noted more generally that responsible science demanded such acknowledgements: "[fishermen have] a lot of legitimate questions as well as a right to challenge these types of conclusions. So you do have a responsibility as a scientist to sort of take the time to work with them in a variety of ways, and show them [...how we] make these conclusions but... you know, also recognize that... along the way... some decision were made [...] that have [... consequences]" (6471: 27).

Others described working knowledge and know-how that transformed fishery research processes. For example, one scientist described a turnaround in relationship with the clam industry in the Northeast United States, culminating in a fisherman redesigning the dredge used in research: "it was actually a really beautiful thing. And to be honest with you, the industry paid to build it because they were interested in the science [...] you start out with an industry that is at loggerheads with the government [...] coming around to a situation where we're working very closely together, where they're asking, they're asking very legitimate questions about, you know, what do you need and is this a shortcoming of, but not just, uh, not just criticizing, you know, sort of standing shoulder to shoulder and saying, okay, we're going to help you find a solution to this" (5874: 17).

He went on to describe changes in making the stock assessment process more inclusive, to get: "greater engagement from the folks who are really impacted by the assessment, whether they be recreational or commercial fishermen, or, or, um, you know, environmental organizations [...] the demand for science is just increasing, increasing, increasing; and the demand for, um, meaningful involvement is also increasing" (5874: 17, 18).

Working with fishermen was also valued by some scientists for generating mutual understanding and better relationships with the industry. As one scientist described, "what happened is that [the fishermen] become more aware, more sensitive to how difficult it is and what the quality of the data are, and they understand the uncertainty then in terms of the science advice that you provide and why that uncertainty is there" (6031: 7).

Another noted that collaborative research was undertaken "to try to be a little bit more transparent with our work and involve the fishermen, and get a little more of a personal rapport between fishing community and the research scientists so that we understand each other's views more than we have in the recent past. I think if you go back early when Spencer Baird and the boys were there, back in the beginning of the Fish Commission and stuff, there was a better, more open relationship with the fishing community because we did rely on them to get information" (6884: 16, 17). Indeed, it was precisely that lack of cooperation and collaboration in the face of declining stocks, and in particular the disappearance of outreach in the Northeast through port-based dock agents, that one scientist decried "over the years, an erosion of the quality information for many of the stocks, not all of them, but for many of them and here in New England ... we just don't have the information we used to have" (6909: 13). A lack of outreach was criticized by other scientists, who noted "I look at students now, and I remember myself when I was going into this [...] I had no clue as to what was being done [...] I feel it's almost like a mission that we can show people we're doing something really positive here and something that really needs to be done" (6468: 10). A climate scientist observed that "one of our other major challenges, is how do we share information with affected communities, hear from them on what they're seeing, and then have that spark a discussion about what's at risk? What might be affected? And then what steps might we take to prepare?" (6420: 24). Another scientist lamented, "[ocean acidification is] one we could start doing something about but we're not. That's a bit depressing to see that. I think we're pretty good studying it, we're pretty good understanding it but the societal change that causes us to alright, we got to stop screwing this up, I don't know where that is" (6416: 16).

At issue in these observations is a sense of relevance and connecting science to outcome, but also an expansion of the realm of the production of science itself. Some have found an expansion in capability from the use of volunteer groups and citizen science (6416: 8), while others praised a new commitment in the agency to partnering with collaborating organization that share a similar mission (6497: 22). A salmon scientist in particular noted that the need to remove the thousands of salmon-blocking culverts in the Northwest United States. "would be a huge collective thing. But each...each one is just a little bit. But that's why it's important to have local groups that are interested [...] that requires again broad based public support and interest [...] Both the little things collectively and the big things can be important (6039: 10).

As a scientist involved in monk seal recovery explained, "[science] can't be just about understanding [...] you've got to take action [...] if you look at the seal program that we have right now [...] they are all people-focused. They are all looking at how they deal with the community. Prior, it was all science in the sense that, that it was about the animals, what they're eating, where they're going, and then what the population level was. So it's a different type of science [...] it's more than just the outreach, it's basically trying to understand, you know, why people are actually thinking the way they do" (6453: 30).

Conclusion

Oral histories offer tremendous detail, context, and richness into people's lives. They also allow for the possibility of exploratory research, where goals are not predefined and participants play active roles in determining what type of information emerges from the engagement. Through careful analysis, these histories can be examined for their commonalities and differences allowing new knowledge and ways of seeing to emerge. Such qualitative research that is exploratory rather than systematic can generate data rich in detail but not strictly comparable in a numeric sense as topics were conversationally entangled with other topics in highly personal ways. The strength of such methods, i.e. the insight into values, motives, and understandings, is thus also its weakness, i.e. the difficulty of assessing representativeness when answers are not easily separate or countable. We have striven to show how the insights from qualitative approaches are better realized through showing the variety and breadth of interviewee excerpts than a strict accounting of themes per se. Using interview excerpts to show the patterning of themes highlights the commonalities and differences in experiences and perspectives that contribute to a deeper appreciation of lived history.

In the oral histories collected and analysed here, NOAA scientists describe and reflect on the tremendous paradigm shifts in both the Agency and in marine sciences generally. This collection of oral histories has also pointed to some of the current dilemmas and concerns with which the marine sciences are faced, at a junction in which the sciences are pushed to become increasingly inclusive and diverse. As others engaged in the history of science have shown, different scientific values, such as between modelling or mathematical approaches and more traditional "wet foot biologist" approaches, are more than just a reflection of a predilection to abstraction or an appreciation of the purity of mathematics. They inform the very questions that get asked and the ways that science is practiced, and indeed used (see also Hamblin, 2014).

But these histories have also reflected on the profound impacts that the organizations and institutions in which we practice have on our work. Scientists recounted the changes wrought by a political nexus that changed from one dominated by Cold War politics to one focused inwardly on domestic concerns and marked by regional differences, beginning with the historical moment in which EEZ waters were established, fishery resources nationalized, and fisheries science increasingly focused on management needs. Distinctions between abstraction and reality, prediction and understanding, continue to animate the disquiet felt by some in the increasing dominance of mathematics and modelling in fisheries science. The move from basic science to regulatory demands, in particular to stock assessment and population dynamic models, was moreover seen as both a curtailment of scientific freedom but also as a step toward fulfilment of scientific responsibility to the needs of society. Such concerns find expression in the current concern with extending fisheries science to incorporate ecosystemic understandings that include the needs and concerns of the public and collaborative involvement to a far greater extent that in the past. The increasing recognition of linked social and ecological systems and societal influences on research practices has led scholars to argue that marine scientists must learn to integrate and communicate their specialized knowledge into broader and more generalized contexts (Markus *et al.*, 2018) and require "enhanced awareness and communication" about the different roles that researchers engage in the policy process (Dankel *et al.*, 2016). Historical reflection, especially through the tradition of oral history and its stress on social meaning, is vital to both of these.

Acknowledgements

Oral history as a methodology is impossible without having subjects willing to take the time to be interviewed. We are so grateful to each of the individuals that contributed to the Voices from the Science Centers Oral History Collection for their knowledge, experience, insights, curiosity, reflections, and expertise. Their contributions have helped to ensure the documentation of important changes in the agency and in the marine sciences from those who had lived through them first hand, which was the primary impetus for the collection of these oral histories. Almost 100 interviews were conducted between May 2017 and October 2017 by an incredible team of oral historians from around the United States including: Maggie Allen, Bonnie McCay, Fred Calabreta, Michael Chiarappa, Ed Glazier, Madeleine Hall-Arber, Suzanna Mic, and Josh Wrigley. Regional team leads were critical in working with their regions to identify interview candidates and serving as liaisons between interviewers and those interviewed as part of this collection. These individuals include: Patricia Clay, Justin Hospital, Matthew McPherson, and Suzanne Russell. We would also like to thank Laura Orleans, Jessica Bailey, and their team from the New Bedford Fishermen's Heritage Center for their timely and quality transcriptions. A special thanks to Josh Wrigley, then Project Manager for the Voices from the Fisheries project (www.voices.nmfs.noaa.gov), for his help in training and coordinating the work of the oral historians and his attention to detail in reviewing, finalizing and uploaded the final collection. We are also appreciative of the timely pre-publication reviews conducted by Eric Thunberg and Jon Hare from NOAA-Fisheries Northeast Fisheries Science Center and the valuable comments from the journal's reviewers. Finally, we thank Eric Thunberg and Rita Curtis for continuing to support and value the creation, archiving, and use of oral histories in the realm of marine social sciences.

References

Abbott-Jamieson, S. 2007. Using oral history techniques in a NOAA Fisheries Service (NMFS) education and outreach project: preserving local fisheries knowledge. Linking generations, and improving environmental literacy. Annals of Anthropological Practice, 28: 135–147.

Ames, E. P., Watson, S., and Wilson, J. 2000. Rethinking overfishing: insights from oral histories of retired groundfishermen. *In* Finding Our Sea Legs, pp. 153–164. Ed. by B. Neis, and L. Felt. Institute of Social and Economic Research, St. Johns, Newfoundland.

Billick, I., and Price, M. V. (Eds). 2010. The Ecology of Place: Contributions of Place-Based Research to Ecological Understanding. University of Chicago Press, Chicago.

Colburn, L. L., and Clay, P. M. 2012. The role of oral histories in the conduct of fisheries social impact assessments in Northeast US. Journal of Ecological Anthropology, 15: 74–80.

Dankel, D. J., Stange, K., and Nielsen, K. N. 2016. What hat are you wearing? On the multiple roles of fishery scientists in the ICES community. ICES Journal of Marine Science, 73: 209–216.

Doel, R. E. 2003. Oral history of American science: a forty-year review. History of Science, 41: 349–378.

Engelhard, G. H., Thurstan, R. H., MacKenzie, B. R., Alleway, H. K., Bannister, R. C. A., Cardinale, M., Clarke, M. W., *et al.* 2016. ICES meets marine historical ecology: placing the history of fish and fisheries in current policy context. ICES Journal of Marine Science, 73: 1386–1403.

Finley, C., and Oreskes, N. 2013. Maximum sustained yield: a policy disguised as science. ICES Journal of Marine Science, 70: 245–250.

Frigg, R., and Hartmann, S. 2018. Models in science. *In* The Stanford Encyclopedia of Philosophy. Ed. by E. N. Zalta, https://plato.stanford.edu/entries/models-science/ (last accessed 30 November 2018).

Fujimura, J. H. 2011. Technobiological imaginaries: how do systems biologists know nature? *In* Knowing Nature: Conversations at the Intersection of Political Ecology and Science Studies, pp. 65–80. Ed. by M. J. Goldman, P. Nadasdy, and M. D. Turner. Duke University Press, Durham.

Galdorisi, G. V., and Kaufman, A. G. 2002. Military activities in the Exclusive Economic Zone: preventing uncertainty and defusing conflict. California Western International Law Journal, 32: 253–302.

Gieryn, T. F. 1983. Boundary-work and the demarcation of science from non-science: strains and interests in professional ideologies of scientists. American Sociological Review, 48: 781–795.

Hamblin, J. D. 2014. Seeing the oceans in the shadow of Bergen values. Isis, 105: 352–363.

Hobart, W. L. 1996. Baird's legacy: the history and accomplishments of NOAA's National Marine Fisheries Service, 1871–1996. NOAA Technical Memorandum NMFS-F/SPO-18.

Kingsland, S. E. 1995. Modeling Nature: Episodes in the History of Population Ecology, 2nd edn. University of Chicago Press, Chicago.

Levin, P. S., and Dufault, A. 2010. Eating up the food web. Fish and Fisheries, 11: 307–312.

Lotze, H. K., Erlandson, J. M., Hardt, M. J., Norris, R. D., Roy, K., Smith, T. D., and Whitcraft, C. R. 2011. Uncovering the ocean's past. *In* Shifting Baselines: The Past and the Future of Ocean Fisheries, pp. 137–161. Ed. by C. Jackson, K. E. Alexander, and E. Sala. Island Press, Washington, DC.

Máñez, K. S., and Poulsen, B. 2016. Of seascapes and people: multiple perspectives on oceans past. *In* Perspectives on Oceans past: A Handbook of Marine Environmental History, pp. 1–10. Ed. by K. S., Máñez, and B., Poulsen Springer Nature, Dordrecht.

Markus, T., Hillebrand, H., Hornidge, A.-K., Krause, G., and Schlüter, A. 2018. Disciplinary diversity in marine sciences: the urgent case for an integration of research. ICES Journal of Marine Science, 75: 502–509.

McKenzie, M. 2012. 'The widening gyre': rethinking the Northwest Atlantic fisheries collapse, 1850–2000. *In* A History of the North Atlantic Fisheries, Volume II: The Modern Period, pp. 293–305. Ed. by D. Heidbrink, and I. Starkey. Deutsche Shiffartsmuseum, Bremerhaven, Germany.

Nazarea, V. D. 2006. Local knowledge and memory in biodiversity conservation. Annual Review of Anthropology, 35: 317–335.

Nyhan, J., and Flinn, A. 2016. Computation and the Humanities: Towards an Oral History of Digital Humanities. Springer International Publishing, Cham, Switzerland.

Oreskes, N. 2014. Scaling up our vision. Isis, 105: 379–391.

Package-Ward, C., and Himes-Cornell, A. 2014. Utilizing oral histories to understand the social networks of Oregon fishermen in Alaska. Human Organization, 73: 277–288.

Perks, R., and Thomson, A. (Eds). 1998. The Oral History Reader. Routledge, London.

Portelli, A. 1991. What makes oral history different. *In* The Death of Luigi Trastulli and Other Stories: Form and Meaning in Oral History, pp. 54–60. State University of New York Press, Albany.

Ritchie, D. A. 2003. Doing Oral History: A Practical Guide, 2nd edn. Oxford University Press, Oxford.

Rozwadowski, H. 2004. Science, the sea, and marine resource management: researching the International Council for the Exploration of the Sea. The Public Historian, 26: 41–64.

Rozwadowski, H. M. 2014. Knowing the ocean: a role for the history of science. Isis, 105: 335–337.

Smith, T. 1994. Scaling Fisheries: The Science of Measuring the Effects of Fishing, 1855–1955. Cambridge University Press, Cambridge.

Thompson, P., Wailey, T., and Lummis, T. 1983. Living the Fishing. Routledge & Kegan Paul, London.

Thomson, A. 2007. Four paradigm transformations in oral history. The Oral History Review, 34: 49–70.

Thurstan, R. H., Buckley, S. M., and Pandolfi, J. M. 2016. Oral histories: informing natural resource management using perceptions of the past. *In* Perspectives on Oceans past: A Handbook of Marine Environmental History, pp. 155–173. Ed. by K. S. Máñez, and B. Poulsen. Springer Nature, Dordrecht.

Thurstan, R. H., McClenachan, l., Crowder, L. B., Drew, J. A., Kittinger, J. N., Levin, P. S., Roberts, C. M., *et al.* 2015. Filling historical data gaps to foster solutions in marine conservation. Ocean & Coastal Management, 115: 31–40.

Zimmerman, R. J. 2010. A history of the NMFS Laboratory at Galveston. Gulf of Mexico Science, 28: 82–96.

Handling editor: Bo Poulsen