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Ocean tracking technologies: observing species at risk

Richard Apostle and Tsafrir Gazit*

* Correspondence:
Gazit.Tsafrir@gmail.com
Sociology and Social Anthropology, Dalhousie University, Halifax, Nova Scotia, Canada

Abstract

The Ocean Tracking Network is a major global project to establish tracking of endangered fish and marine mammal species through acoustic telemetry.
The project has only begun to generate the policy-related outcomes that may be utilized as benchmarks for evaluating the success of the project. We propose that projects like this one make technical advances before scientific ones, and that scientific advances may be quite long term. Further, the development of policy outcomes is shaped by the larger political economies in which the technologies are located; scientists are quite used to "flying under the radar", waiting for more propitious circumstances. There are serious questions regarding which actors are capable of making matters of fact issues of public debate.

Keywords: Endangered species, Animal tracking technology, Acoustic telemetry, Actor-network-theory

Introduction

This paper explores the socio-technical dimensions of a major global project to establish tracking of endangered fish and marine mammal species through acoustic telemetry. The paper details the data collection, data storage, and data accessibility features of this new system, and considers the extent to which this system has, or can, convert "matters of fact" to "matters of concern". We think there is reasonable skepticism that a technology-driven scientific project will really succeed in rising above answering descriptive, as opposed to ethical or theoretical questions.

Theoretical framework

At a general level, the sociological study of science and technology has a number of different theoretical paradigms which inform its investigations. The Ocean Tracking Network (OTN) is examining species which live in the water, and are far less susceptible to direct observation, with technologies which need to be adapted to that fact, and the development of new technologies which are gradually being shaped by species-technology interaction. Thus, a study of OTN technologies lends itself, on all three counts, to actor-network-theory as a preliminary framework (Callon 1986; Latour 2005; Lien and Law 2011). The crucial task, as Latour puts it, is the production of a "sociology of translation". Employing Callon's classic study, Latour states, "[s]callops make the fishermen do things just as nets placed in the ocean lure the scallops into attaching themselves to the nets…" (Latour 2005).

Before considering the specific technologies employed by the OTN, we need to establish a specific framework for examining this technology. Following Bijker (Bijker 2010), we would like to sidestep the ontological questions which are sometimes associated with dominant constructivist approaches to technology. One does not need to address the question of what technology is: the only type of relativism required to proceed is a methodological relativism which attempts to "trace the process 'how to *make* technology'." (emphasis his) (2010:34). In this view, "sociotechnical ensembles" are to be treated as both technical and social, with neither being a priori or "independent of context." (2010:35). This assumption leads fairly directly to the treatment of the technical and the social as symmetric components in a "natureculture" (Callon 1986; Haraway 2003).[1]

And, with regard to context, Harty (Harty 2005) makes the important point that "the grounding of concepts within specific contexts, and a commitment to detailed, qualitative and often ethnographic research" are common aspects of studies in the sociology of technology.[2] Such commitments should lead us to try to overcome the greatest "lure of the virtual" in examining models or simulations of animal behaviour: a tendency to short-change the verification process, either due to lack of experience and/or knowledge, or to pressures to produce quick results (Bailey et al. 2012). At the same time, we do acknowledge that actor-network-theory is a micro-sociology and, like its American and European predecessors, does not really suffice as an approach to the analysis of social structure.[3] In particular, there has been a proclivity for micro-sociologies to employ functionalist formulations when challenged to deal with macro-sociological issues (Latour 2004). In short, actor-network-theory is less a theory than a useful methodology for examining issues, which, at first approach, can utilize the specific assumptions of actor-network-theory.

Methods

Our key question is: how do technologies and science reshape nature? Our investigation of OTN science and technology will be primarily informed by a useful post-industrial variant of actor-network theory, one recently introduced in MAST (7:2). Johnsen and colleagues (2009a and b) postulate the existence of cybernetic organizations, ones which involve heterogeneous connections among fish, humans and technologies which generate closer associations than those which existed in earlier, industrial eras. These cybernetic organizations recognize power relations, albeit ones which are more decentralized than earlier ones, and they retain Haraway's (2003) focus on human centrality in natureculture.[4]

OTN technologies

Data recording and retrieval technology

The technologies employed by the OTN may roughly be classified into: 1) Data recording devices; and 2) Data retrieval devices. These devices may use various recording and transmitting technologies, which may overlap at times.

According to Mills, Flemming and Johnsen (OTN Canada, 2012: 19–21),[5] these tools facilitate visualization, which "is a key twenty-first century research skill that provides insight into complex data sets…by communicating their key aspects…of seeing this complexity in a dynamic and integrated fashion."" Visualization itself only provides descriptive, "first order answers to questions". Nevertheless, visualization helps with the second-order generation of "hypotheses that can then be formally tested with appropriate models" for "designing effective tracking studies, necessary for inference about species interactions, and critical for providing conservation/management advice. (Mills, Flemming and Johnsen, 2012:19)"

Acoustic transmitters

The great majority of the acoustic transmitters employed in the OTN project are supplied by VEMCO, a Canadian firm based in eastern Canada whose staff are mostly locally educated (Dalhousie, community colleges), and live in Halifax. The staff will (and do) travel to work with researchers to make scientific adaptations.

The coded transmitters, or tags, come in a range of sizes, sensor options (temperature and/or pressure for most tags), power outputs and battery lives. There has been considerable development in transmitter types since the beginning of OTN activity (in approximately the summer of 2008). At this point in time, the tag "families" run from V6-180Hz to V16, with the family number coming from the tag's diameter in mm. The tags produce a series of "pings" referred to as a "pulse train" which includes information on both tag identification (ID) and error checking information. The larger diameters are indicative of both more power and more weight. Overall, the system provides millions of unique pinger IDs and tens of thousands of sensor tag IDs. The newest additions to the transmitter collection are the V9AP and V13AP coded transmitters. The transmitters produce acceleration and depth values, where acceleration is measured on three orthogonal axes. In addition there are three continuous transmitters (V9, V13, and V16) which may be employed when one is tracking animals from boats using specific tracking receivers (VR28 and VR100).

Pop-up archival tags (PATS) are particularly useful for following the behaviour and movement of fish which do not spend much time at the surface. The species involved include large pelagics: tuna, sea turtles, sharks and American eel. The tags archive temperature, depth and light-level data, with temporal measures available for each variable. The tags have a buoyant body, are attached via tethers, and have corrodible pins to allow tag release. After the tags float to the surface, summary information is transmitted via the Argos[6] satellite system to investigators.

OTN employs benthic pods manufactured by Satlantic to collect information on major oceanographic parameters, including depth, salinity, temperature, dissolved oxygen and density.

Acoustic receivers

The basic pair of receivers, manufactured by VEMCO, is the VR2W, and the VR2W-180 kHz. The former is designed to detect the earlier VEMCO 69 kHz transmitters, while the latter is intended to pick up the new, miniature 180 kHz tags used for smaller fish, over a wider range of species, in both fresh and salt water milieux. Data upload is facilitated by VEMCO User Environment PC software. Data may be brought to the surface with 30-foot VR2W underwater upload cables which are simultaneously attached to the VR2W and an appropriate computer. Alternatively, there is a flexible new VR4-UWM (Underwater Modem), which can pick up both 69khz and 180 kHz signals over a long period of time (more than 6 years), and interface with a surface modem unit employing VUE software. At the surface, this modem is currently equipped to interact only with the Satlantic Benthic Pod instrument cluster.

The VR100 is a tracking receiver, which can do manual tracking from small boats or laboratory data. In addition, OTN projects have attempted to use the Slocum glider (After Joseph Slocum), with only some success. The glider moves through water much like a sailplane in air, and is driven, not by a propeller, but by variable buoyancy. It has only one moveable part, a propeller, controlled by an onboard computer. It has the potential to travel long distances and times, surfacing on GPS command to transit information to a satellite.[7]

Transceivers

VEMCO has developed a mobile transceiver (VMT) which combines the capacities of a 69 kHz coded transmitter with a 69 kHz receiver for external attachment to larger animals. The transceiver ("bioprobe") can operate at depths up to 1000 m to provide information on inter-species association (e.g., grey seals and cod) and schooling behavior.

More generally, Vemco has developed a peer-to-peer technology, known as "Business Card Tags" to focus on characterizing interactions among animals. These interactions include schooling behavior, encounters with predators, and mating events. At this point, tags must be recovered to retrieve information collected.

Another set of primary data is the information collected manually by the research team as they tag the animals and deploy the receivers. This data includes basic animal measurements, such as weight, gender, approximate age, location of capture and release, and other measurements relevant to the specific species. In a similar fashion, physical measurements are taken when the receivers are deployed. These include: location, depth, temperature, salinity, and pressure.

Data retrieval

Data in OTN is retrieved from the various receivers through a wide variety of means, ranging from pulling the receivers out of the water, linking receivers through cables, or a combination of cables and other receivers, gliders and satellites.

A basic question which must be posed about this new technological array, is whether, or to what extent, this new technology can be viewed as an early replacement for what Holm and Nielsen (2007: 181) call the "'TAC Machine'". While it is true that fish stocks are widely distributed, and largely invisible, humans have been attempting, for close to a century, to count fish accurately. Perhaps the current fisheries management practice of employing Virtual Population Analysis (VPA) to set Total Allowable Catch (TAC), as well as Individual Transferable Quotas (ITQs), in a more privatized context, may be supplemented, or displaced by, an even tighter fit of fish, humans and technology. This would be particularly true if tracking technology, either in the public domain, or the private sector, or both, turns its focus towards commercially valuable species. At this point, the financial costs associated with OTN technology may mean the idea is not feasible, at least in the short run. Nevertheless, the experiment is going global, and may serve these other purposes in the future.

Data management

All Canadian OTN lines data sets, primary and secondary, as well as additional data from external sources,[8] are centrally stored at the OTN data center warehouse located in Dalhousie University. However, for all non-VEMCO, or other specialized equipment, oceanographic data is cleaned, processed and stored in various organization according to the OTN data policy.[9] At this time, the intentions for long-term preservation is to deposit the data at the Ocean Biogeographic Information System (www.iobis.org) and the Global Biodiversity Information Facility (www.gbif.org). This will enable future end usage and public download services via global access portals.

Current data management and documentation

Key to the management of OTN data is the OTN Portal located at Dalhousie. Data collected by the OTN partners is transferred to the portal via regional nodes, which store the data, as it is collected from the receivers. Once at the portal, the data is cleaned and integrated into a format easily recognized by, and accessible to, the OTN research community. To ensure the integrity of the OTN data, standardized data quality procedures were designed and implemented, both at the point of collection and as the data is transferred from the nodes to the portal. To provide secure, permanent data storage, DFO took the role of archiving the OTN data. In doing so, OTN is leveraging DFO 's expertise in the storage and management of large quantities of data.

Although officially there is open public access to OTN data, provisions necessary to protect real-time data that might put animals at risk were implemented (e.g., not revealing the location of valuable, endangered marine species that could face a poaching risk if their locations were known). By doing so, the OTN data center was able to publish basic information about ongoing research projects. This data includes basic scientific information, such as species tagged, general location and time, contact information, and the like. The reasoning behind this procedure was to spread knowledge about existing projects and provide opportunities for cooperation between OTN and external scientists. While all OTN data will eventually be available to any interested parties over the Internet, principal investigators (PIs) might have legitimate reasons to delay (embargo) the public posting of their data until their research is complete, and results have been published. The above provisions were officially aimed at protecting animals at risk; they also served as assurances to the PIs of the protection of their data copyrights beyond the official data release period put in place by the funding agencies.

In the current phase of the project, 6 years after the first data were collected, the questions are, which data are of a long-term value and should be retained, shared, and/or preserved? At what level? And when should they be publicly available? For now, all OTN data are archived at DFO and governed by DFO‘s archiving policy. There is synergy in this decision because the OTN data will pass through DFO to be made available on the IODE (International Oceanographic Data and Information Exchange) and OBIS web sites in the near future.[10]

Data sharing

The OTN data center's main function is to organize and preserve OTN data, and make it available and useable for future use by all parties as free public data. This condition was established by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Canada Foundation for Innovation (CFI), the main funding agencies of OTN.

In keeping with the vision of sharing OTN data on a global scale, the OTN nodes and OTN web portal were built on open source technologies. This ensured that any individuals with access to a standard Internet browser would be able to view and download OTN metadata and full datasets when they are released to the public.

At this time, while the project is still running, trackers metadata are subjected to a 2-year renewable embargo (2 years after tag life expiration).[11] Endangered species, release metadata and tag IDs subjected to a maximum of 10 years renewable embargo. Embargoed data can be obtained by contacting the PI, or the embargo can be shortened at the request of the investigator. In the second phase of OTN scientific work (2013–2017), only a handful of investigators requested an extended embargo. As of early 2016, there is not a single OTN-funded dataset that is publicly available as full records accompanied by supporting documents.[12] This widespread reluctance to share data seriously limits the range of public debate.

OTN technology and data management as networking catalysts

The ultimate OTN vision, as expressed in the initial research proposal, and by many of the PIs involved in the planning phase, was to create a structure that was based on research technology advancements which, through centralized data management, will eventually lead to the creation of new, ground breaking, scientific knowledge. This cross-disciplinary knowledge, will contribute to better marine governance and policy making in general, and in particular, to protecting marine species at risk. The OTN vision, as it was initially designed, and evolved, is by definition a network, which can be divided into: 1) infrastructure and operations; and 2) scientific cooperation (Fig. 1).

Infrastructure and operations

Given types of technology, which require enormous investments in installation, data retrieval, and management, a broad base of cooperation is required. While tagging marine animals can easily be based in each individual research project, the construction of the data retrieval infrastructure requires advance technical skills and major financial sources, things that individual research projects will find hard to provide on their own. Moreover, the creation of a shared infrastructure will not only save time and money, but also create standardization which in a later in the research process will make scientific cooperation much easier. During phase I of OTN (2010–2013), a worldwide network of receivers,

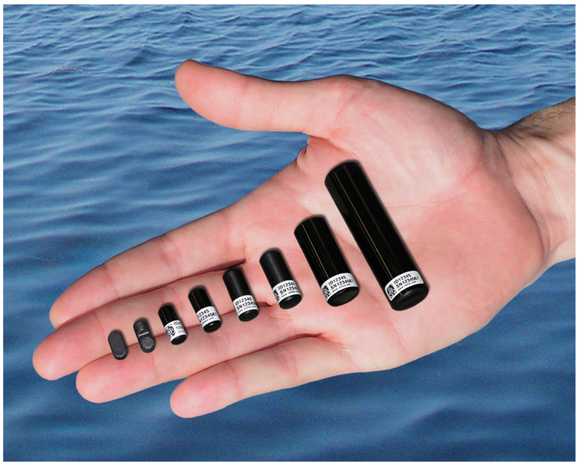

Fig. 1 VEMCO acoustic tags (Source: VEMCO)

known as acoustic curtains, was planned (Apostle 2009). However, only a few curtains were installed on the oceans floor.[13]

Installing these acoustic curtains symbolized the actual beginning of the project and the "go ahead" for the first tagging projects. It was also the point at which the OTN data center became operational. Soon after the acoustic curtains were in place, data started to flow in. This stage of the project was marked by a significant technical cooperation among the various research teams and OTN headquarters. This cooperation has evolved during the first years of the projects, as the data centers provided additional services such as data cleaning, data standardization and, to some extent, data dissemination. However, this cooperation may be characterized as one-sided insofar as OTN headquarters and the data center provide the infrastructure and data services to the PIs. At this point, it is important to distinguish between the technical or operational network and the scientific network. While the operational network, including infrastructure and data management services, were a precondition for the OTN projects, it also had the potential to serve as a platform for a scientific network at various levels (Fig. 2).

Scientific cooperation

While infrastructure and operations cooperation was a primary requirement for the project, one without which nothing could go forward, it also served as the common foundation on which scientific cooperation could grow beyond the individual research projects by themselves. Similar technologies facilitated central data management and data standardization across the various OTN projects and disciplines provide a relatively easy, almost endless set of opportunities for research and scientific cooperation. The potential for a broader and deeper understanding of the marine environment seems to be promising. However, scientific cooperation between projects and across disciplines rarely occurred during the first phase of the OTN project. Most of the research teams focused on their own research projects, with only limited exchange of information in the form of annual presentations[14] and some student exchanges between labs. It seems that the potential for scientific cooperation based on the shared technological foundation and centralized data management and services has yet to occur (Fig. 3).

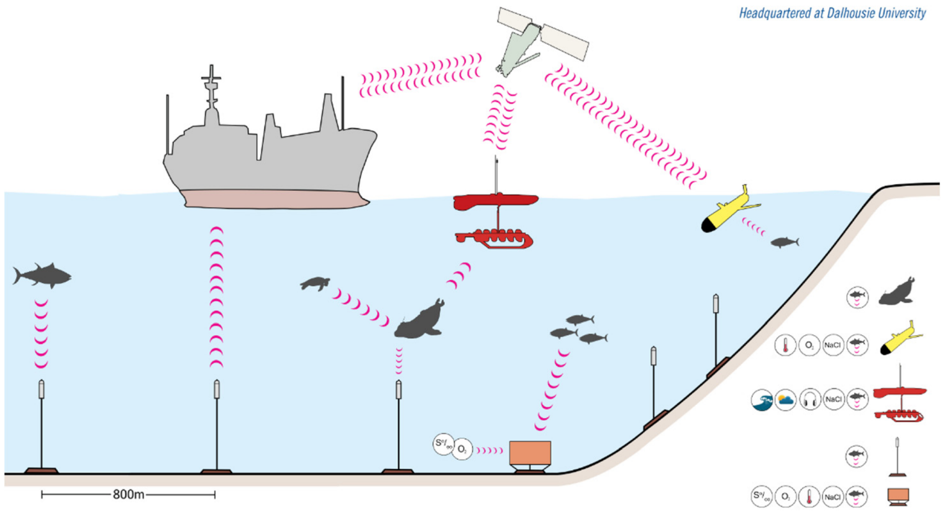

Fig. 2 The different methods of data collection for the Ocean Tracking Network

One of OTN's, and similar tracking projects' outcomes, was the need for more sophisticated tracking and data retrieval. Among these new technologies that developed at VEMCO were the "bio-probes". The introduction of the "bio-probe" technology marked not only a technological advancement, but also another opportunity for scientific cooperation. The use of transceivers attached to large marine animals,[15] which detect other tagged animals that cross their path or are in close proximity, allowed new insights to interspecies interaction, including prey patterns. Some of the observations include grey seal – Atlantic cod, grey seal – Bluefin tuna, and grey seal – porbeagle shark interactions, as well as among American eels and porbeagle sharks.

However, at this point in time, 2 years after the introduction of this technology, there is no major cooperation between the research teams as part of the OTN agenda. Sharing information on cross species interaction remains at the discretion of the PIs, as there is no policy or directive for mandatory data sharing.

Looking at the OTN as a case study on its own reveals many opportunities for scientific cooperation based on the shared technological characteristics. The first level of cooperation is also the very foundation of the entire project, which is the infrastructure of acoustic curtains, data retrieval, and data management, without which the use of these tracking technologies would not be possible. Once this foundation was in place there were supposedly no limits for scientific cooperation. The second level came with the introduction of the new bio-probes technology. This technology serves as another "node" of data transfer and data retrieval, one that require data sharing between the relevant research groups (e.g. grey seal and Bluefin tuna), either directly or through the OTN data center. This potential cooperation may be the data sharing of the detected species (i.e. Bluefin tuna), or both the detected and detecting species (i.e. Bluefin tuna and grey seal). So far, shared OTN technology and data services has failed to launch significant scientific cooperation, either directly between research teams, or indirectly via the data center in the magnitude that was expected from the OTN. Furthermore, the lack of deep, intensive scientific cooperation, limits not only the

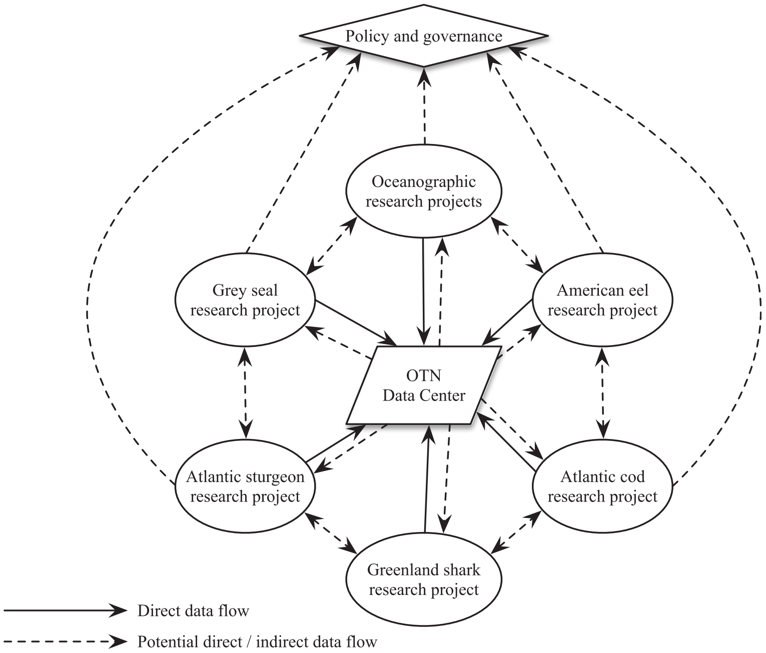

Fig. 3 Ocean Tracking Network opportunities for research and scientific cooperation

creation of new knowledge, but also, and maybe more importantly, the ability to use such knowledge in marine governance and policymaking.

At a more specific level, we should also acknowledge that OTN scientists have been challenged in dealing with a few public controversies that have touched the scientific findings of the project. The best example, which follows on the ANT analysis developed above, as well as Callon's (1986) seminal work, concerns a debate over the relations among grey seals and cod, fisherfolk, scientists, fisheries managers, and federal politicians.

Box 1: A Case Study: Grey Seals and Cod

Following the major Atlantic cod stock collapse in Atlantic Canada in the early 1990s, there have been growing accusations in eastern Nova Scotia, and especially the Gulf of Saint Lawrence, aimed at the grey seal as the main cause preventing an Atlantic cod recovery. This controversy peaked with the 2012 Standing Senate Committee on Fisheries and Oceans recommendation that DFO implement and manage a targeted removal programme for grey seals in the southern Gulf of St. Lawrence to reduce the number of seals (Canada 2012). Many research projects have tried to address this assumption, with no clear answers. The grey seal–cod debate can be characterized by scientific ambiguity, with seemingly contradictory scientific evidence.. Some evidence supports the claim for the grey seal as the main cause of the lack of cod recovery, while other evidence suggests that grey seals have not contributed to the lack of recovery in a significant way (Gazit et al. 2013b). The OTN, and especially the bio-probe program, were presented as probably the most advanced technology available, one that if it did not end the scientific debate, would at the very least clear most of it up. Relying on this OTN technology and the ways it was used raised some criticism about the seal population tagged (mostly on Sable Island, with only few in the cod fisheries-important Gulf of St. Lawrence), and the time of the year they were tagged. It is important to say that the biotelemetry research was accompanied by more traditional research such as fatty acid and stomach analysis which tried to link these elements to foraging patterns. So far, the results cannot clear up the scientific ambiguity, mainly because of the focus on specific methodologies that can supply only so much data, rather than focusing on the full ambit of possible explanations, ranging from ocean conditions and forage patterns to human activity. The main problem is putting the technology as the starting point, as a given, and not as one tool among many. In other words, the technology is used as the engine or the main driving force rather than the scientific question itself. This may lead, as is apparent in this case study, to science that becomes a major barrier for long-term policy.

Following Callon (1986), we may argue that while the OTN is not proposing to deconstruct nature, it does have high ambitions to reconstruct nature by adding another thick layer of knowledge and, to some extent, fill scientific gaps through the use of biotelemetry. By doing so, Callon's four moments of translation come into play: problematization, *interessement*, enrolment, and mobilization. Problematization occurred through a series of what we may call "pre-project" papers presenting the project and its promises, including initial inclusion of fishermen, technology (especially VEMCO) and other stake holders as well as specific species.[16] Similar effort took place with a fruitless effort to engage different actors from the non-academic fishing community in the grey seal research project. However, the level of fisher distrust, based on previous encounters, made that effort impossible. Looking both ways, it seems that both parties, the researchers and the fishermen, have locked themselves into specific roles where the technology serves as the divider between the old and new worlds of data collection (traditional knowledge and science versus the new biotelemetry technology). This has become a bigger problem due to the defined and coordinated roles within OTN. Project compartmentalization of both research activities and data (via the OTN data center) prevented the *interessement*, or interest, necessary for creating the alliances and executing the transition to the next moment of enrolment, which might have enabled cooperation and enhanced policy making. The fourth moment of mobilization is yet to be seen in the grey seal – Atlantic cod case as much as most OTN research projects, perhaps with the exception of the American eel (Engler-Palma et al. 2013). On the macro level, OTN rarely presents any significant analysis. Most projects are "stand alone", with the biotelemetry technology as the common denominator which is pushed forward to the center of the stage as the main actor. That is the case even for the gray seal case study, where biotelemetry is just one among many tools used. OTN scientists, with their new technologies, "sought to become indispensable"; tried to "lock the other actors in the roles that had been proposed for them"; employed strategies "to define and interrelate the roles they had allocated to others"; and very unsuccessfully, tried to ensure that OTN spokespersons spoke publicly about the perceived superiority of the tracking technology to the respective groups that they represent (Callon 1986). Not only was this attempt not a "completed accomplishment", as the full OTN potential is yet to be unlocked; the process will remain open-ended and ambiguous for the foreseeable future.

Examination of the grey seal case on the Canadian eastern seaboard from an actor-network-theory perspective raises basic questions about who the actors are, what specific roles they have, and what joint impact they may have on policy making. Since the 1990s, the public record of the grey seal – cod scientific debate has varied. In all cases, the initiating forces were the fishing communities, motivated by economic incentives, and environmental organizations, primarily driven by moral concerns. By contrast, the divided scientific community has served as a supporting platform for both sides. The much anticipated results from OTN technology failed to provide quick and definitive answers, raising several questions. First, what is the "grace period" for new technologies, or, how long does it take for a new technology to mature and be accepted as trustworthy by the wider scientific community? Second, how can new technologies, and the new types of data they produce, connect to traditional research methodologies? In the case of the grey seal – cod debate, the process is not only slow, but also has had a negative impact on the policy making process by practically neutralizing the scientific component through scientific ambiguity (Gazit et al. 2013b).

Discussion

But, no matter how well designed and executed the data collection and storage is, the basic question to which one must return concerns contributions to new scientific knowledge. Given that the project has a series of predominantly inductive queries it has set out to answer, the overall project remains open to the deductive challenge of "So what?" Was the project motivated by a set of key scientific questions which the research program could answer? One outside observer skeptically suggested "the technology was driving the activities rather than a desire to answer some really important questions".[17] Further, the promise of policy-relevant outcomes for the program does not seem to square with the general lack of policy experience among the natural science investigators. While it is true that some of the natural scientists did make policy contributions, even during the first stage of the research program (Young et al. 2013) the majority of the policy work emerged from joint projects which involved lawyers and social scientists (Journal of International Wildlife Law and Policy, 2013:2–3 and 4). One observer quoted a high-level D.F.O. official as saying, "If you want your work to be of relevance to the government, it's got to be linked to policy. In two ways…if it's work that helps evaluate management strategies or policy alternatives-that's work of relevance to us.[18]"

Further, despite the universalism implicit in modern science and technology, and the broad global aims of OTN at its inception, the road to a global network has been decidedly bumpy. The initial hurdle concerned the sharing of data. Where Canadian natural and social scientists have been encouraged, by funding agencies, among others, to put time constraints on the claims of the original investigators, OTN discovered that, although "we felt that everybody had to share data…most of our partners weren't on that bandwagon…".[19] This tendency was exacerbated by a long time lag between the initial project application and the release of funding which curtailed OTN's capacity to encourage compliance through the distribution of valuable tracking equipment. Two potentially crucial partners received their start-up money years before the Canadians did, and were reticent to share data with a partner which had little to exchange.

The thorny question of data ownership and control is being revisited. Investigators, since the project's inception, have been wary of a legal stipulation that investigators need to transfer data to the central OTN data bank in Halifax after 2 years. The project has now created an international data management committee that seems inclined to create a more decentralized, "regional node" approach for data preservation.

The key issue here concerns fostering international cooperation in data analysis. Academics can be quite obstinate in defending their academic freedoms, but there has been some shift away from nationally-authored publications to more international ones, as the presence of authors from different countries is becoming a way of increasing the legitimacy of scientific claims. Nevertheless, regional nodes may impede access to integrated data sets for wider analysis.

Another major challenge arose from the asymmetry between the approaches of the two major Canadian funding agencies. Whereas the technology agency was prepared to see equipment distributed internationally (with conditions on data-sharing), the science agency was not willing to fund non-national scientists, on the standard, but increasingly debatable, premise that non-nationals should, if they're any good, get funding from their own national agencies.[20] This asymmetry led to inter-agency conflict, and contributed to the substantial funding delays already discussed (Apostle et al. 2013).

Moreover, even within OTN's natural science disciplines, not surprisingly biology and oceanography, there were minor tensions to be negotiated, as each would understandably view their discipline, and perhaps research focus, as most important to the success of the overall project. As one observer put it, "part of it is lack of understanding on the part of the biologists as to the role of the modelling. And probably the modellers … don't appreciate the difficulties with the biology, and all those problems…".

A further cross-cutting tension concerned the distribution of funding across projects located in the three major OTN geographic areas (Pacific, Arctic, Atlantic), and over four different themes. These divisions, in the Canadian federal context, put pressure on any such group to ensure reasonably equitable distribution of funds. However, if the overriding emphasis for the project is research excellence, then perhaps the second round of funding might have been allocated on more meritocratic grounds. But, by and large, this did not happen. As another observer commented, "the Canadian disease of regionalism" frequently trumps meritocratic considerations.

One part of the Canadian scientific endeavour which seems to have been an unalloyed success has been the emphasis on recruiting and training the next generation of Canadian scientists in these areas.[21] The graduate students have put on impressive poster displays and oral presentations at the various OTN gatherings, and seem to be moving through graduate programs very successfully. One observer said, "You know, if you've got the student funded, and they have a good project and a supportive supervisor (and I suspect that's true throughout OTN), then I'd expect they're going to do fine." Another added that the success extends to post-graduate students, as well as research technicians, many of whom do much of the scientific work. More sharply, the observer argued, "They are our leadership for the future, not ——— or ————. When is the last time ——— or ——— wrote a paper? Their only legacy is their students".

Still, this evaluation of OTN scientific accomplishments may be too harsh. First, it takes longer periods of time to generate truly important scientific research. One well-placed commentator said, "If you're doing ground-breaking, fundamental research, the likelihood of a concrete, measurable impact is about 20 to 30 years later." And one has the much longer time associated with the construction of a winning technical and industrial network around VEMCO as an obvious example of appropriate time horizons. Further, the basic topics being studied are not likely to gain much favour with key political figures in Canada. It probably makes good sense, in conjunction with longer time-frames, to "fly beneath the radar" until one can find a more sympathetic audience.

The construction of the VEMCO network is instructive in a number of ways. First, the use of acoustic telemetry in the local area dates to the late 1970s or early 1980s. And the "translations" which made the network or "alliance" successful are connected to the close, but less than obvious, ties among academics and industry in the Halifax oceans networks, which are some of the most developed links in the industrial world. Several key figures in the early stages of OTN growth are academics who did graduate work using acoustic telemetry, both locally and abroad. These figures then migrated into the industrial world to start developing advanced telemetry technology, or worked within OTN itself as "bridges" to the technological world. Some of them also served as connections between the worlds of marine biology and engineering to facilitate the research and development necessary to convert engineering knowledge into useful research tools for the academy.[22] In addition, these connections "helped accelerate the advancement of some things" because the connections led to informed discussions among scientists from diverse fields.

Furthermore, the VEMCO network, as it grew, strengthened its own position by reaching out to individuals and networks around the world (e.g., Australia, South Africa) to both market its own products, and solicit ideas for new developments.[23] They also strengthened their network by providing some scientists was the prospect of identifying "mystery tags", or tags on species of interest, whose origin was not known. This service could only occur where both parties would agree to have their identities revealed. One outside observer who knows VEMCO commented, "They've become the world standard. I mean, nobody makes deep-sea harsh environment acoustic responders better than them…they own the market around the world." In sum, the reach of this technical network was genuinely global before OTN began building a global scientific network.

Thus, in terms of industrial partnerships, the project has been fortunate in having Canadian companies that are world leaders in their field. This has made the acquisition and distribution of technical equipment easier, both logistically and in terms of approval with national evaluators. Still, aside from a few legal stipulations to the contrary, the project is free to source equipment globally when necessary.

The project has overcome some earlier management difficulties with multiple funding sources by moving from bilateral relations between OTN and a given funding source (CFI, NSERC), to a system where all parties are simultaneously involved in management processes and decision-making. This shift stands in marked contrast to two major, earlier oceans-related Canadian projects, where investigators failed to create a genuinely integrated management system.

Conclusions

Given the 5-year existence of the project, it is now possible to identify technical successes and failures. The "Halifax line", running straight out from Halifax itself, has been successful in tracking movement along the south coast of Nova Scotia. By contrast, the "Gibraltar line", which was intended to cross the Strait of Gibraltar, foundered on the economic crisis of 2008. It would have served the needs of many investigators on movement into and out of the Mediterranean, but the economic crisis, which hit southern Europe particularly hard, short-circuited intended cooperation amongst Spain, Portugal and Morocco. One strategy the project developed to circumvent economic constraints, has been to "piggyback" equipment distribution with existing systems, even where they have different purposes. The most successful example here is through cooperation with an Indian Ocean buoy network whose primary purpose is to track tropical weather systems.

In addition, the overall OTN project needs to be located in the larger macro-political context in which it operates. Viewed from the world of science and technology studies (STS), OTN may be described as a theoretical project, as opposed to one which merely describes and documents, and it does not engage in traditional political activism, but does have some ambitions to contribute to political activity. Sismondo (2008) labels this an "engaged program". Put in more abstract terms, "secluded research" (Callon et al. 2011), which encompasses most of OTN work, is confronted with the task of making its way back to the "big world" via successful "translations" which have a policy impact in "hybrid forums" which overcome divisions between specialists and laypersons, as well as citizens and institutional representatives (Callon et al. 2011). Although there are occasional opportunities for this to occur, as with the Fishermen Scientists Research Society (FSRS/www.fsrs.ns.ca),[24] the current project structure suggests that policy implications will most likely be adopted at the middle levels of government bureaucracies.

Thus, while we are coming to a reasonable set of judgments about the initial scientific and technological questions which motivated the project, we have yet to come to any clear understanding of the moral and political dimensions of the project. At an ethical level, we do have a detailed analysis of the sometimes fraught relations between animals and scientists (Young et al. 2013), but we are still left with larger questions of the potential commercialization or privatization of the technology or scientific knowledge the project is producing. While the project commitments discussed above to put new knowledge into the public domain, both the reluctance of individual scientific investigators to move their data into the public domain, and the move to more "regional nodes" may ultimately limit the extent to which the scientific work contributes to matters of concern. At the first level, Canadian scientists, as well as others, have been reluctant to "go public" with their findings on endangered species. The election of a new federal government in Canada is already going some distance to unshackle federal bureaucrats operating in fisheries, or broader environmental, arenas. However, natural scientists are very protective of new data, regardless of political regime, both for their graduate students, and their own publications. Unless the project's governing committees are able to exert considerably more influence than they have to date, open public arenas may not attract those best able to report on findings. The fact that most of the project's funds have largely been allocated also diminishes the leverage of the project's governing committees.

Secondly, the move to "regional nodes" may undermine Canadian or governing committee leverage over the control of scientific information. As OTN technology is diffused around the world, legal bonds become more problematic. OTN is now working with at least three of the four "BRIC" countries, and the rule of law may be somewhat less enforceable than it might in the more advanced systems.

Further, while there have been no indications yet of a move towards commercialization or privatization of OTN scientific knowledge, the very fact that the project began with an option to grow world-class Canadian private enterprises in the technological realm does leave open the question of where the scientific knowledge may finally brought to bear. So far, the only, local, indications are that private fishing enterprises interested in the project will purchase their own equipment to generate knowledge about presently commercial fish stocks, and will do so because they regard the information they create as proprietorial.

At a more explicitly political level, one must acknowledge that the project is operating with public funds, albeit ones which have been meritocratically won from major Canadian and other public agencies. The obligations university-funded researchers have to the general public have normally been restricted to Callon's world of "secluded research". The challenge, and perhaps the commitment, of OTN scientists is to make the transition to Sismondo's "engaged program". While we would hold out relatively little hope for the first line, front line OTN scientists, considerable faith has been placed in the "Highly Qualified Personnel (HYPs)" that the project has assiduously fostered at the graduate level. Some of the first fruits of this new generation of scientists are now emerging, as one of them has taken the lead in solving the thorny problem of how American eels make their way to the Sargasso Sea to spawn (Béguer-Pons, et al., 2015). And this work has provided crucial support for international efforts to see the Sargasso Sea treated as a protected conservation area under the Hamilton Declaration (Sargasso-Sea-Alliance, 2014). Thus, the prospect for transforming matters of fact into "highly complex, historically situated, richly diverse matters of concern" (Latour, 2004: 237), may be as much a question of generational succession as it is of pushing contemporary scientists into unfamiliar domains.

Endnotes

[1] While we accept many of the pragmatic assertions regarding the need to trace associations among human and natural phenomena, we do not, as Bijker suggests, take up the philosophical relativism in some of this work.

[2] Wajcman (2010) reminds us that gender, especially with the digital age, is "embedded in technology itself".

[3] Leonardi and Barley (2010) point out that the major deficiency, at the level of social structure, is an inability to deal with questions of power. Professional associations may, in particular, be influential in shaping the adaptation of new technologies. In a less central way, an individual organization may, at the micro level, control the practices of related organizations. See Blok and Jensen (Blok and Jensen 2011) for a more sympathetic treatment of Latour's approach to social structure and change.

[4] See Apostle (2012) for an appreciation of this work.

[5] OTN Canada Phase 2 NSERC Proposal (Draft). August, 2012. Halifax, N.S. Dalhousie University.

[6] The Argos instrument flies aboard the Polar Orbiting Environmental Satellites (POES) belonging to the National Oceanic and Atmospheric Administration (NOAA) and the European Organization for the Exploitation of Meteorological Satellites (MetOp). The satellites travel a polar orbit at an altitude of 850 km. Nearly 60 stations receive real time data from the satellites and retransmit them to processing centers. The three main receiving stations collect all the messages recorded by the satellites during an orbit, thus providing worldwide cover. These three stations are Wallops Island and Fairbanks in the United States and Svalbard in Norway (http://www.argos-system.org/web/en/67-how-it-works.php.)

[7] The Slocum glider is designed and built by Teledyne Webb Research of Falmouth, Massachusetts, USA.

[8] Several external researchers and organizations deposit various research projects in the OTN data center. These parties include the Department of Fisheries and Oceans (DFO), The Salmon Federation, the National Oceanic and Atmospheric Administration (NOAA), and individual researchers from various academic institutions.

[9] As stated in the OTN data policy: "Oceanographic observations whether or not they are captured on OTN funded equipment, are to be submitted directly (in real time if feasible) to the appropriate International Ocean Exchange (IODE) National Oceanographic Data Centre (NODC). It is there that the oceanographic data will be quality controlled

and submitted into the Global Ocean Observing System (GOOS). All OTN data product where feasible will be based on the oceanographic data being managed by NODCs and GOOS." (OTN 2011).

[10] First datasets are already deposited at IODE and OBIS as part of the development process of the OTN data center.

[11] This by itself is a cause for concern as some of those tags can be "operational" for up to ten years, long after the project is completed. Current improvements in power technologies only increase this concern.

[12] There are few OTN funded limited and redacted datasets, most includes deployment location, detections, and time with no additional data such as depth, salinity, temperature, and other recorded data or any supporting documents for these datasets.

[13] For more details, see Gazit et al. (2013a).

[14] The OTN held an annual symposium from 2010 to 2014. During these events research findings were presented. However, there were no raw data exchanges.

[15] The OTN attached bio-probes to grey seals and white sturgeon.

[16] For example see O'Dor et al. (2009)

[17] From our point of view, the research program passed up a chance, on renewal, to fund an oceanographic modelling exercise which would have joined the science already accomplished to answer one of the great mysteries of (American) eel behavior: how do they make their way to the Sargasso Sea to spawn, and how does this actually occur? Given the recent formation of the Sargasso Sea Alliance, answers to these questions would have been both top-drawer science and very relevant policy work.

[18] One NGO representative explained that OTN activity could be useful, but the fishermen's attitudes can be skeptical. For example, one fisherman argued that, "we need to determine if they're really endangered, or we're not just seeing them for some other reason." Where scientists were concerned with collapse in one particular species, the response was, "Well, no, the fishermen had changed their net sizes they were using so they're not catching a particular year class. That's why they didn't show up in their catch. So is it really endangered? Before we jump the gun and panic, let's make sure that we're determining if it's truly endangered or not."

[19] Surprisingly, this is even true in the United States, where investigators are only required to file a copy of their data with their primary funding agency.

[20] This asymmetry eventually led to the loss of one of the project's main leaders, as his invaluable international network of relevant scientists was considered less important than his continued presence in Canada, with the implied commitment to Canadian science. One doesn't have to examine this funding asymmetry too deeply to predict there would be organizational difficulties. (The Canadian social science agency shares the same national orientation, with similar, but obviously less significant, problems).

[21] Student involvement is a requirement of the project's funding agencies.

[22] Callon (2007) talks about the "co-construction of economy and politics, with a particular focus on the role of the technosciences" in which "economic markets" can be defined as "socio-technical arrangements of *agencements* (STA)".

[23] These individuals or networks might have status as technical or scientific investigators, but one of the things which benefited their work was the existence of "informal networks" amongst them.

[24] Some OTN scientists have attended one FSRS annual meeting.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

The authors are equal contributors to this paper. Both authors read and approved the final manuscript.

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