A measure of 'environmental happiness': Infrastructuring environmental risk in oil and gas offshore operations

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Abstract

We know little about the marine environment, particularly in the inhospitable Arctic region. Whereas national authorities often rely on the construction of a solid knowledge base to allow human activity access to new areas, scientists point to the impossibility of building comprehensive knowledge of subsea ecosystems. This paper presents an ethnographic study of a Norwegian oil and gas company's development of a knowledge infrastructure for measuring the long-term trend of the behaviour of the marine environment, i.e. a baseline to be used as a reference to calculate potential risks in a commercially relevant Arctic area. The company's *infrastructuring mechanisms* involve selecting and configuring environmental sensing technologies, and tying them into the fabric of the company's operational analysis routines. We identify and discuss how these mechanisms address and articulate temporal, spatial, and social tensions and how, in so doing, they mould new representations of environmental risk.

Keywords: knowledge infrastructure, infrastructuring, environmental risk

Introduction

November 2013. We are sitting in the office of an IT advisor in the research centre of a Norwegian oil and gas company. The advisor is leading the development of a web portal used by the company to display several real-time environmental parameters measured from a subsea observatory on the seafloor offshore northern Norway. The data indicate the salinity, temperature, chlorophyll level, pressure, and depth of the water. There is also a graph representing the biomass concentration in the water column, which is updated every few minutes, and a video made from pictures over the last two days. These pictures are obtained using a camera placed next to a coral reef. The IT advisor has an Internet browser open on one of his two PC screens and an instant messaging program on the other screen. While explaining something to us, he is suddenly distracted by the blinking of the *messaging program. One of the programmers working on the web portal wants his attention because "the fish is back". The advisor turns to the browser, opens the web portal, and looks at the video frame, where a fish has just appeared in front of the subsea camera. It floats calmly, looking at the camera lens for a while, and finally leaves. The advisor explains that it is not the first time that fish has behaved in that way. An analysis of the acoustic measurements previously indicated that that fish also speaks to the camera:*

> And that's what happens, he gets really angry. So he says "Shshshshsh!" (…) Or maybe he gets annoyed. Maybe he gets used to it. And that's also one of the things. Will we [have an] influence? Will the local fauna get used to the sounds when we do the stuff? (Excerpt from field notes)

A Norwegian research magazine was recently titled "*We know the moon better than the seabed*" (Haugan, 2015). In this paper, we tell a story of infrastructuring a baseline of the seabed. We recount of a project by a Norwegian oil and gas company (NorthOil, a pseudonym) to perform real-time environmental monitoring in the sub-Arctic marine ecosystem off the coast of north Norway (Venus, a pseudonym). Venus is estimated to be rich in petroleum resources but is the only portion of the Norwegian continental shelf (NCS) where oil and gas operations are currently banned. NorthOil's goal is to build an approach to continuously survey several environmental parameters in order to obtain a robust baseline, i.e. a reference long-term trend of the behaviour of the Venus ecosystem. This approach could put NorthOil in a better position to obtain permission to operate in the event of a future opening.

NorthOil's initiative is motivated by the Norwegian government's promotion of a knowledge-based approach for making decisions that can potentially affect the environment (NME, 2009). This technocratic perspective implies monitoring environmental parameters over a long period to obtain a baseline, but it remains uncertain whether it might lead to robust knowledge and thus to input for risk assessment. The situation is complicated by heated political and scientific debates around the uncertainties associated with the environmental impact of oil and gas offshore operations. Scientific institutions have particularly criticised the knowledge-based approach for its shortcomings, arguing that comprehensive risk assessment is ultimately impossible:

> [U]ncertainty cannot fully be quantified when facing ignorance – what we do not know, and even further: what is beyond our conception of what is possible. (Hauge et al., 2014: 87)

Subsea environmental monitoring practices within the oil and gas sector are not new, but they are usually confined to annual or triennial sampling campaigns conducted by external consultants. Datasets are normally sparsely stored in disconnected data silos with data analysis trailing data collection by months or even years. What makes NorthOil's strategies different is that they consist of a combination of tightly interacting remote sensors, desktop systems, risk representations, and work processes. For the newly acquired capacity of NorthOil to have organisational uptake, the strategies draw on existing operational routines, but they must be adapted to a domain that is largely unknown to the oil and gas sector. What becomes apparent, then, is an effort of innovation and experimentation at the fringes between operation-based monitoring and long-term environmental monitoring. At these fringes, our (non-)knowledge of the marine ecosystem is translated into numeric trends that must be understood by an oil and gas audience. We therefore want to enquire into this moment: *How is uncertainty about the marine environment quantified into a baseline of environmental behaviour? How are the emerging tensions addressed in practice?*

Studies into the problem of long-term data collection and curation demonstrated how data are constructed and never result from uncontested processes (Borgman et al., 2012; Ribes & Jackson, 2013; Steinhardt & Jackson, 2014): the very definition of 'data' hides invisible actors and values on technical, practical, and political grounds (Bowker, 2000; Bowker & Star, 1999; Gitelman, 2013). The literature in Science and Technology Studies (STS) has successfully treated cases where data are produced through localised practices – even when they are part of larger arrangements. We present a case where the problem of building a long-term trend of environmental behaviour prior to and during an operational deployment (a baseline) prominently emerges from the interaction between remote distributed measurements and the portfolio of corporate ICT, routines, and values (Edwards, 2010; see also Monteiro et al., 2013). In so doing, we relate to and extend the literature in STS problematizing the co-evolution of knowledge infrastructure and its objects of interest (Bowker & Star, 1999; Ribes & Polk, 2015) and demonstrating that our knowledge of nature is inextricably entangled with the infrastructure that we use to gather data about nature (Bowker, 2000; Edwards, 2010). We specifically investigate how NorthOil is establishing a monitoring infrastructure through three mechanisms: *sensoring*, the bricolage work towards the improvisation and adaptation of acoustic sensors to detect marine biomass; *validating*, the workarounds to ensure that measurements can be trusted and routines can be found to handle them; and *abstracting*, the pragmatic adjustments to make risk representations appropriate to existing routines. These infrastructur*ing* (Karasti et al., 2006; Star & Bowker, 2002) mechanisms showcase the oscillation between local, real-time measurements in Venus and the need for the results to travel to be understandable and significant across and outside the infrastructure over the long term.

Even though NorthOil's effort is directed at knowing nature in an undisturbed environment, it is still embedded in the oil and gas operational context and monitoring tradition. We show how the infrastructuring mechanisms modulate this embeddedness along the time, space, and trust dimensions. '*Shshshshsh!*' is translated through the spatial and temporal framing performed through NorthOil's knowledge infrastructure. This is, however, not enough for the fish's voice to be *heard*. We further contribute by showing that the monitoring infrastructure must also be weaved into a careful work of social infrastructuring (cf. Bowker, 1994), based on techniques to build trust rather than consensus (cf. Barry, 2013). These techniques are a purposeful mix of social networking with directly useful stakeholders, and of open data sharing to create momentum around the new infrastructure. We thus discuss the relation between infrastructuring and environmental risk perception and show that NorthOil's mechanisms construct environmental risk as a public problem in a way that makes business sense in the context where NorthOil operates. We conclude that '*Shshshshsh!*' has a potential to mean different things – or nothing at all – based on the political and economic context of infrastructuring.

Theoretical background

From uncertainty to risk quantification

Social scientists have been interested in the relationship between uncertainty and risk quantification in terms of its political, economic, and social connotations (Beck, 1992; Jasanoff, 1999). Technical routines of quantitative risk assessment always embed socio-political assumptions (Jasanoff, 1999). Consequently, risk is not an external object that can be measured; it is instead a reflection of our (evolving) knowledge (Beck, 1992). We rely on Latour's (2003) interpretation of Beck's concept of 'risk' as a *network* of distributed relations between social, technical, and natural elements. A vivid example is the case of the 'mad cow' disease:

> [Y]ou begin with a T-bone steak on your plate and you end up in the laboratory of a protein specialist showing you the tertiary structure of the now infamous prion (…) But in the mean time you have visited European Commission bureaucracies, the cattle farmers' unions, quite a few hospitals, and participated in a lot of scientific meetings. (Latour, 2003: 36)

In sum, definitions of 'risk' contain an inherent tension between global visibility and local conditions that make it possible and measurable in practice (Latour 2003). Risk is constructed, it emerges through constant negotiations between what can be known, viz., sensed, represented, and valued. Currently, the translation of the uncertainty into the language of risk management has become a constitutive feature of corporate governance, where the underlying idea is that well-governed companies are those that are able to handle risks properly (Power, 2007, p. 7; cf. Jasanoff, 1999):

> Uncertainty is therefore transformed into risk when it becomes an object of management, regardless of the extent of information about probability.

This is certainly the case when we speak of *environmental* risk. However, scholars in the field of marine policy, notably, those from the Norwegian Institute for Marine Research (IMR), have argued against the possibility of actually defining and quantifying environmental risk on an epistemological level (Blanchard et al., 2014; Hauge et al., 2014). Ecosystems are never unambiguously given, but the 'facts' that constitute a baseline of natural behaviour are constructed through categorisation processes and are fed into governance, which is often, in turn, driven by financial reasons (Knol, 2013).

Several studies in marine policy also emphasised the networked nature of environmental risk assessment (Blanchard et al., 2014; Hauge et al., 2014; Knol, 2013). A complex relationship exists between socio-political choices and their environmental consequences. Some authors have stressed the need to investigate this relationship in terms of the uncertainties associated with the side effects of routine operations rather than with major accidents, such as large oil spills (Blanchard et al., 2014). This perspective opens the black box of the connection between the less visible details of quantitative risk assessment procedures and how knowledge emerges: the former can restrict the debate on the issues and uncertainties that are considered relevant when deciding the scope of risk assessment, the methodologies, and the presentation of results (Hauge et al., 2014). Crucially, then, our perception of environmental risk is influenced by risk assessment methodologies:

> All these choices are value-laden because they have the potential to influence perceptions on what is at risk, how high the risk is, and what ought to be done with regard to the issue. (Hauge et al., 2014: 88)

To summarise, the analysis of the process of feeding uncertainty into risk requires a theoretical concept able to account for the networked and long-term dynamic relations between social, technical, and natural elements. We believe that this problem should be addressed as one of knowledge infrastructure.

From knowledge production to knowledge infrastructures

Our knowledge inevitably depends on the apparatus that we use to know the world (Barad, 2003) and co-evolves with it (Bowker, 2000). The data that we collect and that constitute the base of our knowledge are always cooked, never entirely raw: "Raw data is both an oxymoron and a bad idea. On the contrary, data should be cooked with care" (Bowker, 2005: 184). For STS researchers it is important to look "under the data", at the practices to *produce* rather than discover knowledge (Gitelman, 2013), by investigating empirically how techniques for data collection and curation become constitutive of scientific facts (Bowker & Star, 1999; Chang, 2004; Pinch & Bijker, 1984). Ribes and Jackson (2013) describe the non-heroic workarounds of sampling and measuring river water quality while also balancing concerns about the long-term usability and readability of the data for future research. Bowker and Star (1999: 36) illustrate what this perspective entails: "While pregnant cow's urine played a critical role in the discovery and isolation of reproductive hormones, no historian of biology had thought it important to describe the task of obtaining gallons of it on a regular basis". Scientific data curation is often the result of collaborative routines, which strictly depend on the members trusting the value of each other's data because what counts as data to one scientist might be context to another (Borgman et al., 2012). Often different temporal perspectives drive the scientists' daily work practices. Steinhardt and Jackson (2014) focus on the alignment work to bend different temporal perspectives to accommodate the activities of different groups. Observing how rhythms are prioritised gives us an understanding of otherwise invisible relational dynamics. The spatial dimension of data production also deserves attention. In a case from a domain similar to ours, Almklov and Hepsø (2011) describe how mismatching interpretations of petroleum reservoirs are generated by geologists and geophysicists, who are accustomed to examining geological sedimentation in opposite directions, the latter from the top (by reading electric logs) and the former from the bottom (by studying rock layers).

In sum, these studies have shed light on the material enactment of data, front-staging issues of *trust* (Borgman et al., 2012), *time* (Steinhardt & Jackson, 2014), and *space* (Almklov & Hepsø, 2011). They have successfully demonstrated how data construction is part of a larger arrangement of communities and information tools, but data acquisition often has a situated character: e.g., a point in a river stream (Ribes & Jackson, 2013) or a pregnant cow (Bowker & Star, 1999: 36). NorthOil's approach to data construction is peculiar because it is only made possible through an ecology of distributed devices and systems, each with a different origin and genesis, made to interoperate through the constant and not necessarily always successful work of maintenance, upgrades, and adaptation (Edwards et al., 2013; Monteiro et al., 2013). We thus supplement the findings of the literature reviewed above with those that explicitly focus on how the *knowledge infrastructure* matters to fact constructions. Relevant examples originate from heterogeneous fields, such as the petroleum industry (Bowker, 1994; Østerlie et al., 2012), energy provision (Silvast et al., 2013), climate science (Edwards, 2010), medical practice (Jirotka et al., 2005) and research (Ribes & Polk, 2015), and environmental research (Karasti et al., 2006; Karasti et al., 2010). Some of these studies investigate the evolution of infrastructures by observing the work to balance immediate and situated needs with the uncertainties associated with long-term and global constraints (Karasti et al., 2010; Ribes & Finholt, 2009). To embrace the evolving and unstable nature of infrastructures, Star and Bowker (2002) used 'infrastructure' as a transitive verb. Thus, the term *infrastructuring* (Karasti et al., 2006) was introduced to refer to the reflexive strategies of designers and users to make infrastructure flexible to meet tensions and anticipate future problems. Infrastructuring avoids clear-cut categories of system development, use, and maintenance where infrastructure evolution does not quite fit.

Nevertheless, our knowledge still crucially depends on the experience in a local context (Zimmerman, 2008). Edwards (2010) describes the making of a climate science infrastructure as a matter of simultaneously conducting local measurements into planetary climate data networks and processing dirty datasets into consistent and readable representations. Hence, the making of imperfect data models has a fundamental role in constituting reality, rather than describing it. NorthOil's experimentation unfolds along a similar vein. A methodological perspective to tackle the tensions generated by infrastructure evolution involves inverting the infrastructure. *Infrastructural inversion* is similar to a 'pair of glasses' for the actors in the field as well as for the researcher to move the focus from situated instances of technology development towards the continuous articulation work to upgrade and maintain the infrastructure (Bowker, 1994; Bowker & Star, 1999; Edwards, 2010). Inversion is a powerful tool for looking "under the data" and exposing the inner mechanisms of infrastructuring knowledge production. For the actors, inversion is a generative resource to "reinterpret the status quo of infrastructure in light of potentialities, thus paving the way for embedding new tools in particular ways" (Kaltenbrunner, 2014: 19).

In the case of NorthOil, however, old habits and practices die hard. Partly because of a focus on safety, oil and gas operations are fairly conservative and slow to adapt. Against this backdrop, ongoing experimentation to create an environmental risk-monitoring infrastructure creates space and opportunities to explore how environmental risk will be rendered for heterogeneous audiences; on the other hand, it also presents challenges in terms of the appropriation or institutionalisation of tools, practices, and formal procedures.

Case

The NCS and the uncertainties of environmental monitoring

The waters off the coast of Norway are home to the world's largest population of a species of cold-water coral called *Lophelia pertusa* (Fosså et al., 2002). The corals are centres of complex marine ecosystems, where fish and other marine species seek shelter and food (Costello et al., 2005; Figure 1). The waters off the Lofoten and Vesterålen Islands in north Norway (Venus) host some of the

Figure 1. Fish swimming over a coral reef. Photo: MAREANO/Institute of Marine Research, Norway.

world's largest stocks of fish, particularly cod and herring, which migrate there from the Barents Sea to spawn. Their eggs and larvae later drift back towards the Barents Sea following the water currents (Hauge et al., 2014). In addition to the substantial economic interest in the region going back thousands of years, the coastline is scenic and attractive for both tourism and recreation.

Since the discovery of hydrocarbons in the North Sea in 1969, there has been constant controversy between fishery and environmental concerns on the one hand, and oil and gas operations, on the other. Alongside this debate, the oil and gas sector in Norway has developed an intricate network of rigs, platforms, pipelines, vessels, and fibre-optic cables to explore, extract, and produce resources. Currently, 78 oil and natural gas fields are active in Norwegian waters (MPE, 2014), which are home to thousands of wells (Figure 2). The socio-economic significance of the oil and gas sector represents approximately 25% of the GNP (SN, 2014), is the largest export, employs approximately 15% of the non-public workforce, and has accumulated one of the largest governmental investment funds in the world.

The constant hum of controversy surrounding oil and gas operations in Norway is regularly accentuated by particularly antagonistic issues. The present issue of whether to allow oil operations in Venus, which is the richest fishing ground in the country, is a perfect example of such controversy (Blanchard et al., 2014; NME, 2006). The pressure to open the areas relates, among other things, to the estimate that approximately 24% of the world's undiscovered oil and natural gas resources are hidden in the High North, above the Polar Circle (Hasle et al., 2009). Norway is one of the five countries having territorial claims in those areas, which are characterised by harsh weather conditions and environmentally sensitive habitats. Little or sparse knowledge exists about the behaviour of these habitats and on the possible effects of oil and gas activities. The Norwegian Ministry of Climate and Environment has adopted a knowledge-based approach in its decision-making processes. Its aim is to acquire a 'reasonable' baseline for assessing the risks associated with human activity, including fishing, tourism, and oil and gas operations (NME, 2009: Section 8):

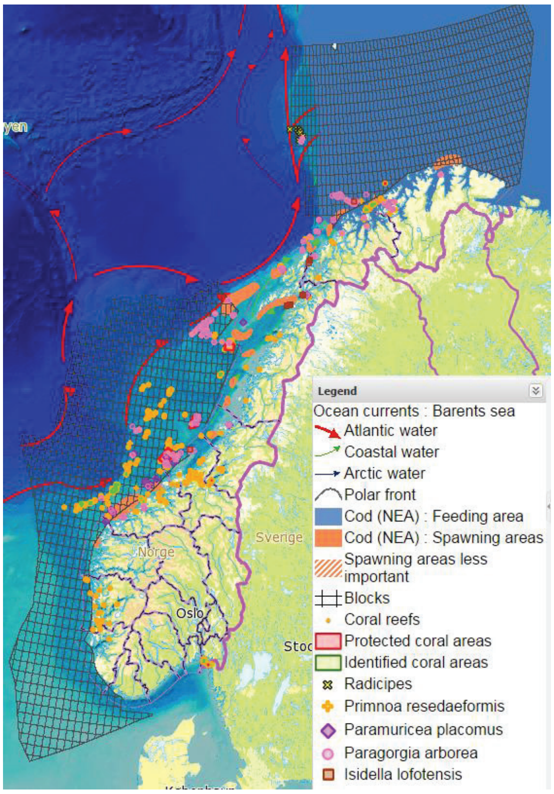

Figure 2. The Norwegian continental shelf, where the operational blocks assigned by the Norwegian government (grid) overlap with the environmental resources. Credit: MAREANO/Institute of Marine Research, Norway.

> Official decisions that affect biological, geological and landscape diversity shall, as far as is reasonable, be based on scientific knowledge of the population status of species, the range and ecological status of habitat types, and the impacts of environmental pressures. The knowledge required shall be in reasonable proportion to the nature of the case and the risk of damage to biological, geological and landscape diversity.

In making a provocative statement to emphasise that there can be no ‘reasonable’ scientific background behind environmental risk assessment calculations, the IMR argued that “between 0 and 100 per cent of a cohort of fish spawn can be lost in an oil spill” (Helgesen & Tunmo, 2009). Oil and gas companies have in turn criticised scientists for exaggerating precautionary considerations in the risk calculation process.

Today, risk mitigation measures are generally used by oil and gas companies operating on the NCS in a reactive manner by following regulations that were set in advance by authorities and politicians (Hasle et al., 2009). However, these regulations are often indefinite and general (Hauge et al., 2014). The Norwegian Directorate for Nature Management argued that the risk models developed for the areas offshore of north Norway are unable to account for local conditions, e.g., narrow fjords, local currents, tides, and wind (Strand, 2014).

Disagreements about the possibility of turning the environment into baseline behaviour are due not only to spatial consideration but also to the observation that the environment does not respond to the same temporal scale of industrial activities. The time scale for offshore drilling engineers is seconds and minutes when responding to sensor-based pressure, torque, temperature and directional measurements. Companies seek an operational window that is as wide as possible while remaining constrained by the slow and formal decision hoops that every new technology must jump through in an oil and gas organisation. However, environmental trends and effects may only become visible over years, decades, or even centuries. The corals have existed on the NCS for at least 9,000 years. Pollution on fish spawning products becomes visible only in the next generation, when cod larvae could die after 3–4 years. Fish generations are the concern of fishermen, who want to have knowledge about the present population and to ensure that there will be fish to catch in the subsequent seasons. When asked about the tension between a real-time approach to risk assessment and long-term natural changes, one NorthOil environmental chemist wondered if it makes sense to frame the environment in human-constructed patterns:

> That’s a potential paradox, of course, but I guess that the easy, the obvious answer is that (…) you need to start to monitor early (…) when you start doing what you could define as a baseline, ’cause then it’s not really a baseline. But then another existential question: Is there such a thing called ecological baseline? Is that possible? Because no environment is constantly… constant over the whole time.

The Venus observatory

NorthOil is the primary oil and gas operator in Norway. Founded in the early 1970s, the company was historically organised around a geographically local operational site. Currently, NorthOil is promoting the development of cross-disciplinary and cross-geographical infrastructures, which are supported by the installation of collaborative work technologies (e.g., SAP and Microsoft SharePoint) and fibre-optic Internet connections that allow for faster communication between offshore sites and onshore control centres.

Given the strategic location of Norway relative to the High North, NorthOil decided to start collecting oceanographic parameters halfway between the more familiar Norwegian Sea and the unwelcoming High North. In collaboration with marine research institutes and technology vendors, NorthOil installed an ocean observatory in the mid-2000s on the seafloor in the Venus area, approximately 20 km off the Lofoten Islands, above the Arctic Circle. The observatory consisted of a metallic semi-conic structure equipped with a few off-the-shelf sensors to detect basic environmental parameters such as sound, pressure, temperature, turbidity, chlorophyll, and floating biomass. A camera and a camera flash were placed on a 2-meter-high satellite crane to take pictures of a coral reef that was selected by project participants.

The project was considered successful and strategically relevant; therefore, it received funding in 2011 from the production and development department of NorthOil. In 2013, the observatory was connected to the shore with a fibre-optic cable. Environmental data began to be fed into a publicly accessible web portal in real time (Figure 3). An environmental advisor from NorthOil summarised how they could use the data to demonstrate their ability to drill safely and increase the operational window as follows:

> We want to look at different types and possible technologies or methods to get this done. (…) If we can argue that we can measure when the biomass comes, either when fish come or go or when the spawning products return, we can stop drilling on time before the products return.

NorthOil was interested in using real-time data to find a correlation between the time of year and the marine biomass concentration (fish, eggs, and larvae). By analysing the trends over several years, a threshold value could be obtained to indicate the beginning and end of the spawning season. Therefore, the operational window could be set outside this interval.

Research method

This paper is the result of a longitudinal ethnographic study conducted within NorthOil. Even in the traditionally open Scandinavian environment, access to an oil and gas organisation is not straightforward for external researchers. The first author was granted a pass to NorthOil's R&D department through one member of our research team who also holds a full-time senior position at NorthOil and has a history of collaboration with the second author.

Beginning in April 2012, the first author spent an average of 2–3 days per week for two years at the field site. She was initially granted a desk at the entrance of the department, where projects related to environmental monitoring were happening. However, sitting next to the entrance is equivalent to having a 'guest' label. Not all information is shared with guests. As the researcher began to take part in some meetings and to follow a few informants to coffee breaks and lunch breaks, the employees became more accustomed to her presence. In November 2012, the head of the section, who initially granted the researcher a badge, also allowed her to use a desk in an open-space office shared with key participants in NorthOil's real-time environmental monitoring programs.

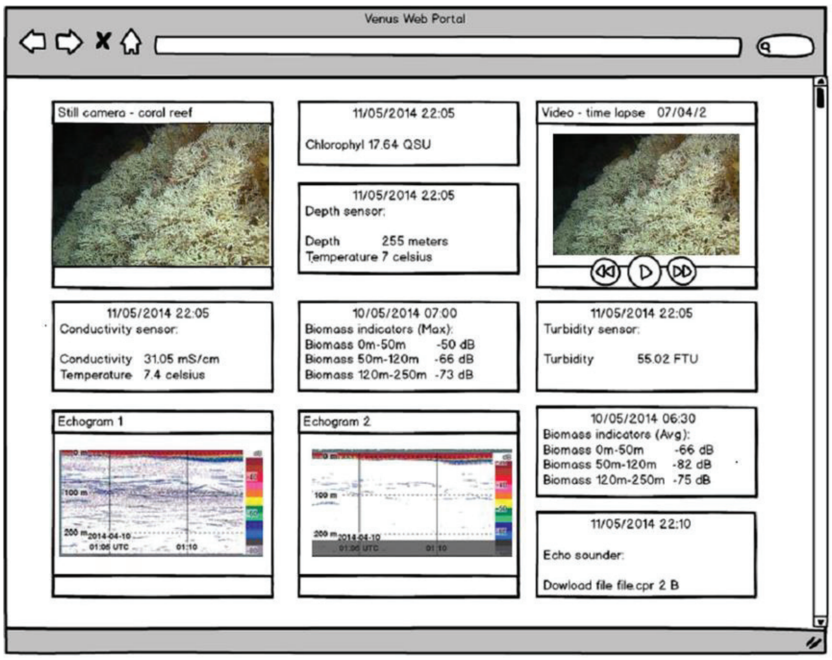

Figure 3. The Venus web portal. 'Biomass indicator' is the environmental value (reproduction by the authors with www.Balsamiq.com). Photos: MAREANO/Institute of Marine Research, Norway.

Along with this physical vicinity, access to information was greatly increased. Corporations today often hire ethnographers to collect qualitative data on the functioning of daily work (Hepsø, 2013). This habit makes the subjects in the field more comfortable with being observed, but it does not guarantee an easier life for external personnel. To blend with informants, the researcher regularly went to the office on days dedicated to fieldwork at approximately 8:30 and left after 16:00, as did other employees. Together with the constantly visible NorthOil badge, this approach allowed the researcher to intermingle with the people who were working in the department. In fact, she was sometimes mistaken for a full-time employee. She was often invited to meetings, workshops, and teleconferences with external partners and technology vendors and with other NorthOil offices located elsewhere in the world. Observations have been continuous (producing hundreds of pages of field notes) and fundamental for identifying internal documentation (reports, presentations, and deliverables) and informants to interview.

Semi-structured interviews (33 in total) were initially conducted with NorthOil representatives and later with representatives from other companies that were collaborating with NorthOil, namely nine environmental advisors from a company active in risk assessment and quality certification and one project manager from a technology vendor company. We travelled a few times by plane to personally interview people located in other Norwegian cities. The second author could also participate in several events and in the interview process. Data collection occurred regularly until April 2014. Henceforth, the first author has only occasionally visited the NorthOil R&D department to conduct short follow-up discussions regarding the themes emerging from the data analysis process.

The data analysis proceeded in parallel with data collection and was aided by a discussion between the two authors and with the members of the research group. In line with an interpretive tradition stemming from the field of Information Systems (Klein & Myers, 1999; Walsham, 1995), we relied on several iterations to make sense of the empirical data. Initially guided by our research question, we searched for practical mechanisms with which to build a baseline of the unknown subsea environment in Venus. The iterative analysis guided our attention to shift from the artefacts (web portals, sensors, and subsea observatories) to the infrastructures that sustain these artefacts across space and time (Edwards et al., 2013; Monteiro et al., 2013). In doing so, we operationalised an infrastructural inversion (Bowker, 1994), which has influenced our data access, collection, and analysis strategies. However, this approach tends to leave its dynamics underspecified, particularly when the investigation of infrastructure is primarily in the hands of a single researcher for a limited number of years. For example, how could we understand the way the effort of building a new knowledge infrastructure is concerned with problems of accessing the sea floor? How could we know about NorthOil's existing routines for handling real-time datasets? Following the suggestions of Ribes (2014) and Beaulieu (2010), we identified key relevant actors in the field and aligned with them because we realised that they sought to answer the same questions that we were. This strategy was facilitated by our increasing familiarity with the actors. As a result, we were sometimes asked for feedback or for help with small tasks in the Venus project (e.g., commenting on a draft document).

Findings: Three infrastructuring strategies

The literature identified a number of concerns associated with the processes of data collection and maintenance, such as data sampling (Ribes & Jackson, 2013), long-term curation (Karasti et al., 2006), and validation and modelling (Edwards, 2010). We identified three similar difficulties encountered by NorthOil: (1) establishing routines to generate measurements of the marine ecosystem; (2) investigating existing standardised mechanisms to validate the trustworthiness of the datasets collected in unmanned locations; and (3) attempting to abstract the datasets into general representations of environmental risk that make sense for the oil and gas professionals. We call the strategies enacted by NorthOil to overtake these difficulties *infrastructuring mechanisms* because, more prominently than other examples in the literature, they are only made possible through the infrastructure as a whole. At the intersection between environmental monitoring and operation-based monitoring, these infrastructuring strategies encompass phases of selection and design, installation, adaptation, and use, and result in an amalgam of institutionalized and new information systems, devices, routines, and locations. As we shall see, these mechanisms encapsulate a range of infrastructural concerns inside the representations of risk for the marine resources.

Sensoring

The monitoring of the subsea environment over the long term – viz. outside daily operations such as drilling and producing – is not a core activity for oil and gas companies. NorthOil and its partners took inspiration from actors with established experience on and in the sea, primarily fishermen and external marine research institutions, including the IMR. The adaptation of their technologies to the Venus project, however, soon gave birth to new situated problems.

The sensors installed on the observatory were rather inexpensive off-the-shelf devices. Particularly significant were the active acoustic devices such as echo sounders. In principle, echo sounders send an acoustic pulse at fixed intervals (shorter than 1 s) and measure the strength of the signal returned when a target is hit within its audible range, which depends on predefined settings and on the speed and direction of the water current. In general, these instruments can be used to determine the size of the targets in the water column, such as fish, fish eggs, larvae, or even zooplankton.

A first challenge for the Venus project was that targets as small as zooplankton or fish larvae and eggs were almost impossible to locate because they are smaller than the wavelength of the echo sounders available to the Venus project. As a consequence, computer models simulating the dispersion of eggs and larvae drifting along with the water currents were integrated to obtain the missing data. A marine biologist from a company collaborating with NorthOil described this challenge:

> One example is that we want to monitor larvae and eggs drifting through the bottom masses; but (…) [w]e know [that the Venus ocean observatory] is not able to monitor that. So what do we do then? (…) The equipment will be better in a few years perhaps, 'cause we know that there are organisms that are vulnerable to oil pollution, much more vulnerable than adult fish, that can swim away from the oil, but [larvae can't].

A second challenge related to the positioning of the acoustic sensors. These instruments are typically installed on fishermen's boats and point downwards.

Placing the acoustic devices on the seafloor means that the new measurements are obtained

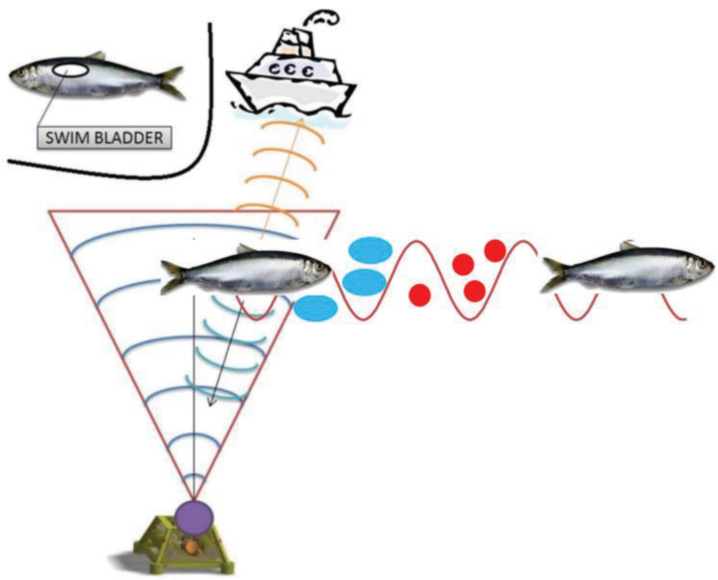

Figure 4. Approximate position of the swim bladder (top left) and exaggerated schematic representation of two directions used to spot fish (from the seafloor or from a boat). The sound waves are often unable to spot targets smaller than their wavelength. Source: authors' drawing.

from the bottom up rather than from the top down (Figure 4). This approach had an unpredicted consequence because the way in which upward-looking data should be interpreted is not obvious. The most audible fish for an acoustic device are those that have a swim bladder, an internal organ located in the dorsal portion of some fish species that not only allows them to control their buoyancy but also to emit and receive sounds. These fish reflect a stronger signal and are thus easier to spot, but the way that the swim bladder reflects the signal depends on the orientation of the acoustic sensor. Given that time series collected by other research institutions or by fishermen have generally been taken from the top down, the Venus data were not directly comparable with the historical datasets available to NorthOil and its partners. An environmental advisor from a partner company involved in NorthOil's project summarises as follows:

> [A]nother problem about the [Venus project] is that the fish experts don't have any experience about having the sensors from the bottom, that goes from the bottom. So they don't know the echo actually from the [underbelly] of the fish.

In sum, the production of a long-term and global picture of the subsea life in Venus was struggling to cook its data and move past very situated issues involving spotting a fish, an egg, or zooplankton. Networking with the existing infrastructure of research institutions and fishermen proved useful to produce – or to *not* produce – some initial measurements that, in their imperfection, began to draw the boundary between what constitutes a baseline of the marine ecosystem and what does not (e.g., small fish without a swim bladder).

Validating

Large-scale industry depends on predictability and quality assurance to run its business. Especially because the sensors were placed at unmanned subsea locations, the Venus datasets had to undergo validation steps. However, how can one quality-assure the environment?

One solution involved rendering the environment in a format that fitted industrial reporting routines. A few NorthOil members close to the Venus project decided to investigate the routines that the company adopts to handle real-time data during an oil and gas company's daily operations, for example, when a new well is drilled. The idea was to borrow insights and to adapt those routines to the environmental domain. As is the case for many oil and gas companies, NorthOil has a dedicated support centre (called here Online Support Centre, or OSC) whose scope is to determine the technical quality of the data gathered by the service companies in charge of the drilling operations on behalf of NorthOil. The drilling of a new well is a delicate phase that must be carefully monitored to prevent accidents that can range from a stuck drill pipe that halts operations for a few days and causes the loss of huge amounts of money to more serious consequences for the surrounding environment. However, knowing if things are going right or wrong is a challenging task when there is a lack of references against which to decide whether a given measurement respects the safety intervals. One OSC engineer stated that some errors can go completely unnoticed, generally due to sensor calibration:

> It could be that the data are shifted for some reason. Let's say that the whole dataset coming in is 5 metres too deep or 5 metres too shallow. We wouldn't be able to notice that (…) and that could be due to a calibration error to the sensor.

The OSC relies on both situated workarounds and standardised approaches to overcome these tricky issues. A typical approach involves trusting the vicinity of the offshore personnel to the measuring points because of their grounded knowledge of the site and the well. The same engineer continued as follows:

> [I]t is up to the data owners out in the asset because they know the formation, know they are supposed to hit this and that layer and so forth; they are fully responsible for the overall and the petro-physical quality of the data. And that requires a human to look at the screens and basically perform that type of checking.

Therefore, local experience of the site is a prerequisite for data validation. The same is true when an error is reported in an incoming dataset. Another OSC member echoed his colleague:

> [W]hen you have typically [Driller A] doing an MWD [measurement while drilling] and you have [Driller B] doing surface in the same rig, they are not doing the same depth references, so they are both wrong or both right. (...) But to really fix this problem, you have to really get closer to the sensors, to the system, and you have to really fix it offshore for every rig that is where you actually are solving it. And you need to monitor it and follow it up.

However, the OSC does not solely rely on the ability of offshore personnel to spot errors. Validation practices are also tied to economic incentives. The centre has developed a complex system of penalty and bonus contracts to either penalise or award service companies based on their capacity to provide trustworthy datasets. It is a flexible system because penalties or bonuses are directly proportional to the money that a service company earns for providing the datasets in each drilled section of a well. This approach is standardised because the OSC applies it to all of its service companies and it stems directly from the contract, regardless of the details of the subsurface sensors. In a nutshell, money is directly linked to the technical quality of the datasets by increasing the bonus (or the penalty) as the drill bit nears the reservoir. This system triggers the development of better measurements from the service companies and indirectly becomes a metric for measuring the datasets delivered.

A review of the existing *validating* strategies taught NorthOil's environmental experts that the situated knowledge of the data collection site should be simultaneously ensured (thus leveraging on the experience developed when *sensoring*) and pragmatically tied to the company's standards and economic parameters.

Abstracting

Even if data are technically sound, predicting the risk associated with oil and gas operations is often difficult. Abstractions are necessary to cook the datasets further into a format that makes the possible risk for the environmental resources detectable and visible to the oil and gas professionals in the control room. We present two NorthOil's solutions to abstract risk representations for static (coral reefs) and moving marine fauna (fish).

The coral risk matrix. At the intersection between the oil and gas business and the environmental domain, NorthOil adopted a coral risk assessment method engineered by a third-party environmental service company to predict the risk to coral reefs. One of the experts who designed the methodology summarised it as follows:

> [W]e can express some kind of a risk to the operation (…). [W]e combined a probability based on the current measurements, and we have established a consequence matrix where we give the different habitats a value. We implemented dispersion modelling into this, and when we combine it to this resource map, of course, we get a risk of conflict between discharges and the resources.

Because corals are static resources, surveyors traditionally identify and label them on a 2D map of the seafloor. The map is subsequently overlain with a prediction of the particle plume that is generated during a planned drilling operation. Each coral structure is then mapped onto a 'coral risk matrix', based on the vicinity of each coral structure to the particle plume (Figure 5). The risk matrix is an adaptation of a general-purpose risk visualisation tool that represents corals as risk objects. The probability for a coral structure to be hit by the discharge plume (likely, large, moderate, or small) is evaluated against the consequences that the discharged particles may have on that structure (i.e., if the coral is healthy, the consequences will be severe; if it is dead, the consequences will be minor). Boundary values are set for each specific case in collaboration between third-party experts and the Norwegian authorities.

The coral risk matrix is finally included in a standard list of attributes describing a coral structure and is used to archive and compare the results of different surveys. Because the coral risk assessment methodology has been adopted by the Norwegian Oil and Gas Association, the risk matrix has become an infrastructural element for operators who seek to locate safe drilling locations on the NCS.

		Consequence			
		Minor	Low	Considerable	Severe
Probability	Likely				
	Large				
	Moderate				
	Small				CR-01

Figure 5. The coral risk matrix (reproduction by the authors).

The environmental value. Assessing the risk associated with moving marine resources is not easy. A typical model for displaying the echo sounder measurements is the chromatogram, in which measurements are plotted over time and coloured in different ways based on the concentration of marine biomass at a given depth. A chromatogram for the area surrounding the Venus station was displayed on the Venus web portal (see Figure 3). In late 2013, a few members of the Venus project travelled to a small town in north Norway to present the Venus web portal to a local community of fishermen. Positive feedback was received. A local newspaper wrote enthusiastically that the portal was becoming "*More popular than the Disney Channel*" (Figure 6). However, the fishermen also noted that the chromatogram was too densely populated for their purposes. In addition, the chromatogram's granularity was deemed excessive by some environmental experts

Figure 6. Newspaper report on the workshop between NorthOil and the fishermen. Title: "More popular than the Disney Channel. Now you can see reality TV from the seafloor outside Bø. On Thursday, the ocean observatory of [NorthOil] and the Marine Research Institute was opened. It can also be useful for local fishermen" (Erlandsen, 2013, faces covered for anonymity).

who were collaborating with NorthOil because the users of the analysed environmental trends want to receive results on a monthly basis; their databases are not ready for such detailed datasets.

To overcome these difficulties, NorthOil and its partners took inspiration from the coral risk matrix. In so doing, they decided to synthesise the water column into a discrete set of values. Each of these values represented a biomass indicator that summarised the biomass concentration in larger chunks of the water column (Figure 3). The biomass indicator was then named an 'environmental value', inheriting an earlier term from the Norwegian Directorate for the Environment[1]. The environmental value is obtained by collapsing a subset of the original sections scanned by the echo sounders into one; measurements are provided at hourly intervals instead of every few seconds. This strategy enhanced not only the visualisation but also the storing of data streams, generating drastically fewer data entries every hour. As presented during a 6-hour project meeting with representatives from NorthOil and its partner companies, the environmental value has been defined by two participants as a

> [N]ewly cooked term… to express environmental happiness!

Upon closer inspection, the environmental value is the evolution of the risk matrix applied to moving marine biomass:

> [W]e want to do [the coral risk assessment] more generic, meaning that it can be used for other environmental resources as well (…) But you can also think of using the same method on the pelagic species like fish and things that swim around and move. (Environmental advisor)

However, adapting the coral risk assessment method to the fish revealed a hidden challenge: fish and marine biomass are continuously moving, meaning that the environmental value means different things at different moments and in different locations. For example, two fish in usually deserted areas represent a high concentration, whereas two fish in an otherwise densely populated location represent a low concentration. To collapse the unpredictability of nature into abstractions that work in an operational setting, the risk categories based on the environmental value must be calibrated with historical data, but such data are currently unavailable to NorthOil. In sum, *abstracting* mechanisms feed back into the *sensoring* and *validating* practices, which, in turn, shape the abstractions of the marine environment.

Infrastructuring the sea into a baseline: Seeking environmental happiness?

The fish quoted in the beginning sounds very annoyed. It repeatedly pops out of its coral shelter to *speak* to the camera. Is it really annoyed, after all? Or is it attracted to the camera? Our research question could be rephrased as follows: *How does 'Shshshshsh!' come to mean something for NorthOil in its long-term efforts to gain permission to operate in Venus?* The infrastructuring mechanisms that we have outlined serve to stage the voice of the fish as part of a measurable and repeatable play in NorthOil's world (cf. Mol, 2002). NorthOil crafts a baseline *despite* limitations in the time-space sampling of data and the profound uncertainties surrounding the possibility of gaining robust knowledge to feed risk assessment practices.

We build upon the literature reviewed above to convey the key message of this paper. First, "raw data should be cooked with care" (Bowker, 2005). The fish's voice is heard – or 'cooked' – through specific sensor configurations (*sensoring*) and processes to assess the incoming data as trustworthy (*validating*) and understandable (*abstracting*). Second, not only one hydrophone, but also an entire knowledge infrastructure is needed to translate the voice of the fish into a trend of the environmental behaviour of that portion of Venus. This process seeks to quantify the little knowledge that we have about a small submarine area into representations of ecosystem behaviour and embed them into the operations of a globally distributed oil and gas company.

NorthOil's case exposes the new infrastructural relations while they are accommodated at the boundary between the existing, operation-based routine monitoring and the new possibilities afforded by a new space such as Venus. The emerging tensions between oil and gas corporate processes and environmental (non-)knowledge cannot be solved because of the incommensurable nature of large-scale industry and the environment; whereas the first is tied to predictable and routinized work processes to ensure its productivity, the latter does not fit well into this type of system. As the environmental chemist quoted above commented, "*no environment is constantly… constant over the whole time*". We observe NorthOil's deployment of trust-building techniques to purposefully manage this unsolvable controversy and to mould the political dimension where the company is operating.

Three dimensions emerge from comparing our findings with those of the literature presented above: space, time, and trust. Our case is novel because NorthOil is simultaneously changing the context and the machinery of data production and curation along these three dimensions through an infrastructural inversion.

Infrastructuring space and time

The purpose of embarking on environmental risk monitoring is to create a 'global' account in the sense that one assesses not only the specific measurements that are actually collected but also the risk of extended regions/areas or habitats (cf. Power, 1999). This purpose thus assumes quantification to allow local measurements to travel and involves grappling with certain tensions that we discuss here (Porter, 1996).

First, a spatial connection exists between the working method and the perspective that we have on certain phenomena (Edwards, 2010). Similar to Almklov and Hepsø (2011), although the drilling process necessarily occurs from the top of the well, the OSC must make sense of the online data stream from the bottom up. The same applies to the acoustic sensors deployed in Venus. Having originally been used on floating vessels, they are now turned upside down and made stationary, residing on the seabed. The data remain the same; however, the altered spatial perspective (from the bottom, not the top) simultaneously renders them different. Reversing these spatial orders also emphasises the material dynamics involved in measurements. Acoustic signals collected at the bottom exhibit different reflections when they encounter a fish's swim bladder. Global knowledge is made possible locally (Latour, 1999). When knowledge infrastructures are designed, this aspect must be carefully taken into account for its political meaning: the material relations between the infrastructure and the outside environment (e.g., sensors/swim bladders), if properly handled, have the potential to shape how risk is perceived outside (e.g., through the environmental value).

NorthOil's infrastructuring mechanisms have a generative potential in how they allow for the purposeful management of the interplay between global access to data and knowledge of the local processes of data acquisition (cf. Zimmerman, 2008). For example, the Venus project participants had to learn how the echo sounders functioned with respect to the swim bladder of some fish in the Venus area. The OSC bonus/penalty contracts must be complemented by the experiences of offshore service companies related to subsea formations. At a first glance, the coral risk matrix represents an outstanding exemplar of the creation of a contextual void. Such a simplified representation is also useful for comparing different environmental surveys in a particular area at different moments. As the world is reduced to inscriptions through measurements and simplifications ("*we give the different habitats a value*"), local knowledge can be amplified ("*we can express some kind of risk to the operation*"). However, under scrutiny, the risk matrix does not exist in a vacuum. It embeds locally acquired expertise to assess what is a healthy coral reef and the experience needed to define a safe distance from a drilling location. However, the strategies for tackling the local/global interface and achieving baseline environmental data might follow different dynamics if we consider other types of risk, such as climate change risks. In that case, risk calculations are primarily (but not entirely) performed at global scales, for example through climate models that are then adapted to the local setting (Edwards, 1999, 2010). In the case of subsea environmental monitoring, the opposite is generally true: representations such as the environmental value, are made 'global' but remain grounded in the historical data gathered at the local site.

Second, NorthOil's efforts are ostensibly about creating a knowledge infrastructure for *real-time* data. What used to be an offline, disconnected, and slow practice in which risk was often assessed in an ex-post manner has suddenly become fast, interconnected, and closely visible. This shift occurs by balancing the years during which the environmental trends become clear and the seconds that the technology uses to measure them. Different conceptions of time must be frozen into different enactments of risk that make sense to the different stakeholders that are involved. However, a variety of incommensurable time scales exists, all of which are imbricated with distinct materiality (Ribes & Finholt, 2009; Steinhardt & Jackson, 2014). The starting point is a system such as the bonus/penalty contract used by the OSC. The formulation of this contract enacts risk as an economic risk for the service company. If we unpack the contract, it is a compromise between the months and years required by formal governance and the seconds with which drilling engineers operate. Similarly, the enforcement of the risk matrix by the Oil and Gas Association led it to acquire an infrastructural quality that intersects the oil and gas and environmental domains. It represents a trade-off between the temporality of risk to the coral reefs (damage might become visible over the course of several decades) and what constitutes risk to operations (being stopped, which is visible in only a few seconds). In extending the matrix, the environmental value was developed by adding one step not only to create real-time monitoring machinery but also to make it dynamic. Because no operations are currently permitted in the Venus region, the environmental value constitutes an indirect measure of risk and computes in a few seconds the historically relative amount of marine fauna that could potentially be affected.

This new real-time/long-term scenario introduces new ways of assessing the risk associated with present or future oil and gas activities. As a consequence, it dramatically shuffles and ultimately reduces the temporal gap between human operations and their possible consequences. In analysing how risk emerges as a phenomenon, we should be specific about the agency of the material elements because, if the feedback loop between an action and its consequences is shortened, the generative role of the combined materiality of nature and technology gives birth to new and unprecedented results.

Trust infrastructuring

We suggest that future STS research could pay more attention to the way infrastructures are "constructed as a public problem in specific imaginative spaces of opportunity and closure" (Schick & Winthereik, 2013: 82; Jirotka et al., 2005). Infrastructures always inscribe a political address in the way technologies are configured to represent specific possibilities of modernity and future (Larkin, 2013). Barker (2005) describes how that happened in Indonesia, where satellite technology was infrastructural to build a sense of national self in the country through the daily work of engineers. NorthOil's strong but contested political-economic position in the Norwegian context led the company to invest in becoming infrastructural to the construction of environmental risk in Venus as a public problem for specific audiences. The infrastructuring mechanisms described above are thus complemented by a subtle but continuous application of techniques of social networking and openness – a combination that is not often registered in the infrastructure literature. Interestingly, these strategies are directed towards building *trust rather than consensus* with the potential stakeholders of NorthOil's infrastructure, including fishermen, research institutions, and the general public (Shapin & Schaffer, 1985; Yearley, 2009). In other words, NorthOil is opening a space of mutual respect about the means for rather than the ends of real-time environmental monitoring. For example, the a priori antagonistic relationship between fisheries, the environment, and petroleum operations has not and most likely will not result in a consensus. Instead of a stand-off awaiting consensus, "[in] the presence of antagonism…decisions often have to be arrived at…in the face of persistent disagreement" (Barry, 2013: 7).

Bowker (1994) highlights the importance of building an onshore 'social infrastructure' that mirrors the technical subsea infrastructure. Let us consider two public risk representations developed within the Venus project: the chromatogram and the environmental value. They are associated with NorthOil's careful work of *social* *infrastructuring* around the specific problem of subsea environmental risk, for which no closure has been reached in public debates. This aspect shows how the relationship between data and data *perception* is inextricably connected to mutual trust (Yearley, 2009: 158). Conveying the message that the Venus web portal – used to display the environmental value and the chromatogram in real time – is better than the Disney Channel lessens the tensions generated by everything related to oil and gas – not only with the fishermen to whom the presentation was addressed but also with the newspaper readers. This message resonates with the definition of environmental value as a "*measure of environmental happiness*". This mechanism also occurs in the context of the more traditional drilling operations, where measurements are often conducted by one or more service companies. Incomprehension happens when the OSC lacks a reference to service company measurements and when "*they are not doing the same depth references, so they are both wrong or both right*". To quote the OSC engineer, "*if you don't trust the data, you don't use the data, and some shit happens*". It is true that "the ability to comprehend data collected by others…is the key to their use" (Zimmerman, 2008: 648), but trusting how third parties perform the work (rather than why) is a necessary condition for trusting the data that they produce (Borgman et al., 2012). What differs in Venus is that measurements are collected in a non-operational area, where no direct oil and gas interests can be claimed. This aspect underlines the second relevant feature of NorthOil's trust infrastructuring mechanisms: openness. The Venus real-time data are shared through a colourful publicly accessible web portal. On the one hand, the absence of operational data and the openness of the portal enforce the genuine impression of the Venus project and shadow its business-related character. On the other hand, given how little we know about the Arctic sea floor, these features are a strategy to enrol collaboration from external research institutions that might not agree with NorthOil's motivations, but crave datasets to develop a better knowledge of the marine ecosystem.

NorthOil's approach to building trust shows that infrastructural inversion has an economic thrust. Some within NorthOil argue that openness is in particular a prerequisite for achieving credibility, including in cases of legal liabilities, with governmental agencies. However, one of our informants noted that the current strategy of openness might be discouraged when/if the uncertainty about the environment is quantified into measurable economic concerns:

> There is not so much profit involved [in environmental data]. For the moment!

Conclusions: The politics of risk

We probably still know the moon better than we know the seabed. We reported on NorthOil's strategies to overcome this status of non-knowledge in the Arctic marine environment and to establish a baseline of the marine ecosystem behaviour to assess operational risk. We followed the data construction process across a knowledge infrastructure-in-the-making and analysed how uncertainty about the marine environment is quantified into a knowledge base by carefully leveraging cross-infrastructure spatial, temporal, and socio-political tensions. Infrastructur*ing* highlights the continuous, interacting, and distributed nature of NorthOil's efforts in an amalgam of design, development, and adaptation work. To support its infrastructuring strategy, NorthOil is investing in building a context of mutual trust, rather than consensus, with external stakeholders. Our case complements the infrastructure literature by showing that infrastructural inversion also consists of tuning strategies of social networking and open data sharing and, as such, has a key role in establishing trust. This observation invites us to reflect on the politically charged character of 'facts,' technologies, and numbers (Barry, 2013; Bowker, 2000). What can we make of the way in which the politics of risk unfold between the oil and gas world and environmental concerns?

First, there are not only profound uncertainties about environmental knowledge as we have described it: there are also ambiguities about what constitutes oil 'operations' and their consequences. The international newspaper The Guardian has initiated a campaign against providing financial support to companies that operate using fossil fuels[2]. The Venus area is presently off limits to oil drilling and production; however, the area is subject to seismic 'surveys.' Seismic surveys are conducted by shooting bursts of seismic sound-waves from long cables trailing vessels that are directed towards the seabed and then reading off the echoes. As environmentalists have noted, these surveys are likely to be harmful to whales and other sea life, although nobody knows to what extent. One marine biologist, quoted in a Norwegian newspaper (Vegstein, 2014), uses hydrophones to listen to the singing of sperm whales in the vicinity of Lofoten. She then detects the seismics from the ongoing "surveying". Through the hydrophones, the seismics sound like "thunder" or "explosions" and cause the whales' singing to subside:

> They tell us Lofoten is sheltered from oil operations. That is political bollocks. This ocean is severely affected. It is only that we cannot hear it [without hydrophones].

Second, it is not clear whether other oil and gas companies are interested in bringing possibilities for online and open environmental monitoring to the attention of the authorities. Traditionally, the operators have taken more of a back seat role. One of our informants told us that other operators were contacted about environmental monitoring initiatives, but they withdrew as they feared that they might be required to pay for and install new technologies. This point hides an important conception of the relation between infrastructure and power. NorthOil has larger competitors in the quest for subsurface resources in the Arctic, with stronger economic and political weight. Investing in similar technological innovation strategies would probably make less sense for them. NorthOil's infrastructuring mechanisms are weaved into the Norwegian context (e.g., the co-presence of a strong fishery infrastructure) and NorthOil's size. For NorthOil and its stakeholders to survive, it is important to sit where a specific future (e.g., real-time environmental monitoring) is being constructed thus where uncertainty is turned into a knowledge base.

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Notes

1 See 'Environmental values in Norwegian marine areas' (http://www.havmiljø.no/) for additional details.

2 See http://www.theguardian.com/environment/series/keep-it-in-the-ground

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