The Infrastructures of Knowing

Emma Cardwell[a], Solveig Joks[b] and John Law[c]

[a] Lancaster Environment Centre,
Lancaster University, Lancaster LA1 4YQ, UK
(e.j.cardwell@lancaster.ac.uk)

[b] Sámi Allaskuvla (Sámi University of Applied Sciences),
Hánnoluohkká 45, NO-9520 Guovdageaidnu, Norway
(Solveig.Joks@samiskhs.no)

[c] Department of Sociology, The Open University,
Walton Hall, Milton Keynes, MK7 6AA, UK,
(John.law@open.ac.uk)

Infrastructures in STS

STS tells us that scientific knowledges grow out of messy laboratory, classroom and fieldwork practices that are shaped by and in turn shape power and context. Its many historical and ethnographic case studies reveal the sheer heterogeneity of what goes into and helps sustain science practices. These include: *materials* (laboratory consumables, technical equipment, specialist software, IT systems, genetically modified creatures, and the fabric of laboratories); trained *people* (scientists, technicians, maintenance, and admin staff); and *documents*, (lab notebooks, data inputs, visualisations, reports, academic papers, grant applications, and patents.) All these run through and help to form the *organisations*, *economic* arrangements, *academic conventions*, *legal frameworks*, and systems of *education* that get taken into and help to shape science practices. This combination of the material-and-social is what we mean when we talk about *infrastructures,* and it is the topic of this entry. So, in the way we use this term, infrastructures extend far beyond obvious inputs like electricity or water. They include everything, material and otherwise, that goes into the practices of knowing.

So, what is an infrastructure in this way of thinking? Here are some common STS suggestions (Slota and Bowker, 2017; Joks et al., 2020).

1. They are *inputs that support and afford* practices.
2. They are *material*, *practical*, and *embedded in practices*.
3. They are *heterogeneous* because, as we have just noted, they are widely different in kind.
4. They mostly work *unnoticed in the background* (becoming visible only when they fail).
5. They are *relations* that have been *'packaged up'* or '*black boxed*.' When they work properly, they seem simple, but when they fail it becomes clear that they are complex weaves created through (and within) many interlocking practices.
6. This packaging-relation dynamic goes on *ad infinitum*, so *infrastructures contain other infrastructures* all the way down. (An example: English language competence is an 'infrastructure' needed to read this encyclopaedia, which in turn depends on an infrastructural education system. Other relevant infrastructures here include the economic and material arrangements for producing and distributing books.)
7. Infrastructures *shape* ways of knowing because it is easiest to know by including and using existing infrastructures. Going against the grain is difficult and may lead to marginalisation and conflict.
8. This means that widespread ways of knowing, their practices, and their infrastructures tend to *marginalise* alternatives. Indeed, after 500 years of European colonialism, Western scientific knowledges can be understood as constitutively colonial, because the infrastructures that shape their conditions of possibility include land theft, imperialism, slavery, and linguistic exclusion, all of which contributed significantly to the power of Western knowledge claims. This history makes a difference, even in relations that are not explicitly understood as colonial. For instance, the infrastructures of scientific publishing mean that Chinese scientists often adopt the language and conventions of dominant Anglophone science, thereby creating a feedback loop that further incentivises publishing in English (Law and Mol, 2020).
9. But ways of knowing and their infrastructures are contingent and could be *different*. And this in turn reveals both that…
10. they are *political*, and that *alternatives*, better or worse, might be imagined and brought into play.

Many have explored how knowledges are shaped and tend to marginalise alternative ways of knowing. This is implied, for instance, in Kuhn's notion of paradigm, and more recent work

has explored how this is also a key function of colonialism. For Linda Tuhiwai Smith (2012) the methods that underpin social science empower some knowledges, and objectify others, denying indigenous groups agency in knowledge creation. Svario Krätli and his colleagues (2015) show how methodological infrastructures in ecology sustain equilibrium modelling and marginalise non-equilibrium alternatives more appropriate to pastoral ways of living (see also Benjaminsen et al. (2015)). Kim Tallbear (2013) explores how the biological essentialism of DNA science undermines First Nations' understandings of kinship. Anthony Hatch (2014) discusses how the narrow medical focus of 'metabolic syndrome' forecloses broader discussion of the role of inequality and oppression in poor health. Mario Blaser (2010) explores the asymmetries between indigenous Yshiro ways of understanding the environment in Paraguay, and those of Western development agencies. Peter Cole (2002) vividly demonstrates how conventions of academic writing limit not only what can be said, but also *how* things may be expressed; while Amâde M'Charek and her colleagues (2020) show how techniques of forensic science reproduce racial categories even as the notion of 'race' is denied. These authors are very different, but they all show how ways of knowing become infrastructurally powerful and marginalise alternatives.

In the second section below, we explore the infrastructures of knowing by drawing on two seemingly similar cases of marine conservation. Starting with Michel Callon's classic account of the failure to domesticate scallops in Saint Brieuc Bay in France, we move to a more recent and successful attempt to do this in Scotland. We explore how powerful economic, technical, scientific, and political infrastructures shaped each, but also how these were assembled in different ways to generate very different outcomes. Our argument is that infrastructures are not all-powerful, and that if they are artfully drawn on and arranged, alternative ways of knowing are possible.

In our third section, we discuss the deeply embedded infrastructures of coloniality, both because these are important, but also because they underscore the importance of metaphysics in those infrastructures. Here we work by touching on two 'Northern' case studies to allow comparison with the conservation cases presented in section 2. We start with a colonial conflict in north Norway where economic, technical, scientific, and political infrastructures are destroying indigenous Sámi ways of knowing salmon. We discuss how scientific knowledge of salmon draws on and reproduces a dominant scientific realism to divide nature from culture in environmental science and management and show how such metaphysical

infrastructures (taken-for-granted assumptions about the character of reality) become visible in contested colonial contexts. Then we move to Newfoundland and describe a bold attempt to problematise this realism by scientists who are practising a novel marine biology that juxtaposes dominant scientific understandings of nature with indigenous relations to the world. This shows that space can be made for other metaphysics and their realities if careful attention is paid to the knowing practices that reproduce such infrastructures of knowledge.

In the fourth section, we briefly summarise the argument by contrasting the overdetermined notion of *social structure* with the possibilities opened up by a focus on *infrastructures*. The latter are powerful, but in principle they are also potentially malleable, and this is particularly important in a colonial context.

Reshaping Economic, Political, Scientific and Technical Infrastructures

The Scallops and the Fishers of Saint Brieuc Bay

STS tells us that scientific findings are created in practices. Michel Callon (1999) described how three biologists tried to answer what seemed like a simple question: do the larvae of *Pecten maximus* (a scallop species) anchor to solid surfaces? This research was socially shaped because the aim was to increase the breeding rate of economically valuable scallops. But Callon also argued that this effort did not simply reflect existing social agendas but also reshaped the social world. His point was that the social and natural are inextricably woven together, and that to practise science is to *rework both*. The experiment was about weaving a new infrastructure in which scallop larvae would anchor, grow, and became commercially valuable, so transforming them from largely unknown entities at risk of overfishing into tractable, predictable and fishable beasts. For this to work new webs of relations were needed. Scallop larvae had to anchor themselves to newly invented collectors; predator starfish had to be kept off; ocean currents needed to be controlled to stop the larvae washing away; and local fishers needed to be kept away too. But none of this was easy. Did the scallops attach to the collectors? Sometimes they did, often they didn't. The reasons for this were unclear, but a whole bevy of actors (currents, parasites, depth, water temperature, and others unknown) were identified as potentially complicit. Even so, there was some success, and for a while this new web held together. Until, one night, fishers invaded the protected area, fished out the scallops, and broke the collectors. The scientists had wrongly assumed the fishers would respect attempts to breed scallops, since this would lead to more scallops, and

therefore larger profits in the end. But the web of relations making up the new infrastructure that was needed to create scientific knowledge (that the larvae of *Pecten maximus* anchor to solid surfaces) failed.

This story illustrates the *heterogeneity* of the infrastructural elements that we mentioned above. It shows that properly working infrastructures are not visible until they go wrong. It shows that infrastructures are complex *webs of relations* that have to be woven together, simplified and packaged up to create 'reality' (the new 'scientific fact' that scallop larvae anchor). It also shows that going against the grain of dominant infrastructures (for instance those of short-term economic pressures) can make building alternative infrastructures difficult.

But were the infrastructural conditions of Callon's scientists contingent? Were they *political,* in the sense that they might have been different? It would be easy to argue that all-powerful 'market forces' led to failure, and there was nothing the scientists could do about a social structure as big and monolithic as 'capitalism'. This isn't completely wrong (capitalism, or market forces, were obviously at work.) But STS tells us that framing the argument as an example of the power of 'social structure' leaves out a crucial step. It fatalistically excludes the possibility that the fishers *might* have acted differently if the scientists had gone about their research in another way. So, here's the STS lesson: yes, actors operate within powerful contexts; yes, they are shaped by these. But they also *work on* those contexts, and they may (re)shape these and even change them in return. And this opening of possibilities is why attention to *infrastructures* is so important in STS. Thinking of infrastructures, rather than structures, suggests that though conditions of possibility are more or less durable, they are also mutable, because they are woven together in creative practices. The infrastructure of 'capitalism' meant short-term profits were central in Saint Brieuc Bay. But things might have been different. So, thinking with 'infrastructures' resists structural determinism. These shape what happens and makes some things easier and others more difficult but how they are woven in practice is important too. With this in mind, we turn to a second story about scallops, fishers, and scientists.

The Scallops and the Fishers of Lamlash Bay

Thirty years on from the Saint Brieuc Bay failure five British scientists started to worry about the disappearing scallops of Lamlash Bay, on the Scottish island of Arran. The two cases

have much in common. The economic value of scallops, uncertainties around their reproduction, desire for conservation, threat of stock collapse, and scientific uncertainty frame both. But in the Lamlash experiment, the study involved creating a 'marine protected area' (MPA). And it was ultimately successful because it created the scientific fact that there were more juvenile scallops inside the Lamlash MPA than outside. But how did the scientists weave existing infrastructures together to achieve this result? How did they reshape 'market forces' so fishers were enrolled into and respected their experimental infrastructure?

The answer lies in an awful lot of hard work, over many years (Stewart et al., 2020). Here's the context. Until 1984, it was illegal to dredge for scallops within three nautical miles of the UK coastline. When this law changed, Arran islander and diver Howard Wood watched the growing destruction of the local seabed with horror. In 1989, his friend Don MacNeish returned from a diving trip to New Zealand where he had seen MPAs with rich and undisturbed seabeds. The two friends concluded that similar protection was needed in Scotland, and in 1995 the Community of Arran Seabed Trust (COAST) was born. This was the beginning of a two-decade, bottom-up effort to protect Lamlash Bay. Importantly, the initiative was supported by the Arran islanders who had first-hand experience of the post 1984 decline and collapse of local fisheries. Also important was the fact that no locals were profiting because the scallop dredgers came from outside. At one point, islanders illegally dropped wrecked cars into the bay to try to destroy the dredging equipment. But overall, the islanders were powerless.

Getting the MPA established was difficult, and local support wasn't enough. COAST needed to mobilise scientists and *scientific evidence* to prove to policymakers that an MPA would increase scallop numbers. And, although the destruction of the seabed was apparent to the divers, the Lamlash Bay scallops weren't so easy to weave into the infrastructure of 'scientific facts' either. (A 2015 paper said there were more juvenile scallops in the MPA, but this wasn't true for adult scallops). And, though this wasn't a priority for COAST, it also needed to weave the politics and the science into *economic arguments* by showing that an MPA would be cost-effective by increasing scallop numbers. Finally, it needed sympathetic *legal* experts to persuade the UK to recognise the sea as a public good, so that government would have a legal duty to recognise the islanders' right to have a say in its management.

In the end, all this worked and a new infrastructure of knowing was brought into being. Islanders, divers, fishers, interested outsiders, scallops and the scientific community were adapted and woven together to create conservation knowledge. Sub-sea observations (requiring technical diving equipment) were collated and turned into scientific evidence. Academic papers were submitted and published. Maps, legal opinions, economic justifications, policy prospectuses and reports were created and circulated. Such conventional forms of paperwork moved alongside – were a part of – the cultivation of local, Scottish, British, and European political connections. A number of powerful infrastructures (the law, science, conservation policy) were brought together to support and enable the new infrastructures of knowing in Lamlash bay.

This is a success story. It includes European conservation directives, economic lobbies and interests, the legal system, and scientific conventions about proof and publication. But in a slow and difficult process that spanned decades, these infrastructural bits and pieces were drawn on, reworked, and woven together to generate a new infrastructural configuration. Lamlash Bay scallops that had been decimated by 'market forces' were protected and started to breed in large numbers again. Infrastructures of conservation were strengthened, while infrastructures of economy were weakened and reshaped. But why was this so unlike Saint Brieuc Bay?

Since infrastructures are inextricably woven together, there can be no single 'structural' explanation. Perhaps the world was more open to 'ecological' arguments than it was forty years earlier, thanks to the multiplication of successful MPAs. The Arran effort was a bottom-up project, not one imposed by outsiders, and locals weren't the people doing the fishing. International commitments to conservation leveraged the islanders' arguments for protection to the Scottish government. It was a slow, organic, and large-scale process that was more expansive and durable than the scientist-led study in St Brieuc Bay. With much sustained effort, new ways of knowing, new ways of fishing, and the new infrastructures needed to render these real were nurtured into being. But sustained effort is not always enough.

Metaphysics and the Coloniality of Knowing

Economic, technical, scientific, and political infrastructures afford ways of knowing, but don't completely determine these. But as we have said above, some infrastructures are more

powerful and entrenched than others. In the next section, we introduce an indigenous struggle in which science and other state-sponsored ways of knowing have squeezed local ways of knowing to the point of extinction and explore what this implies for infrastructures.

Salmon in Deatnu

Called *Deatnu* by the Sámi indigenous people of northern Fennoscandia, this is a huge river that runs north from subarctic Norway and Finland to the Barents Sea. Deatnu has been a central source of livelihood and communication for Sámi since prehistory. And Sámi people have always fished for salmon (Atlantic salmon, *Salmo salar*) with Seine nets, drift nets, weirs, and rods from boats. These ways of catching salmon are woven together with place-based and relational knowledge of salmon, of the river and its flow and currents, of the weather, of the time of year and the seasons, and how people and animals and what outsiders might think of as inanimate forces interact, and interact properly, together. They come, too, with practical and observational skills, with a large specialist vocabulary, and a strong ethical sense of what is right and wrong. About, for instance when it is appropriate to fish (fishing for sustenance takes precedence over recreational fishing); about what salmon like (the answer is, peace and quiet); about the importance of respect (salmon may choose to give themselves to those who fish them, or may not); about fate and the uncertainties of the world (which is filled with powerful morally-sensible entities); and about the need for modesty (you do not count or boast about your catch). This, in short, is a world of traditional (or local) ecological knowledge (TEK). And it has worked sustainably for at least a millennium (Law and Joks, 2017).

But now everything has changed. The British aristocracy came to fish the river for sport 150 years ago, and by the end of the 20th century outsider tourist fishing had become a profitable mass phenomenon. The result? The relationship between the Sámi and the river changed to adapt to these incomers, who also had implicit state support. And, perhaps unsurprisingly, salmon numbers were falling. Why? This is in dispute. Sámi people point to tourist overfishing, constant activity on the river (salmon need peace), lack of protection when the salmon are preparing to spawn, and the role of (conservation-protected) predators. But fisheries science, backed by state policymakers, draws different conclusions. The fish population modellers agree there is too much fishing overall but argue Sámi fishing with nets and weirs is particularly damaging. The consequence of this 'fact'? A draconian squeeze on those Sámi practices. Fishing in traditional ways with nets and weirs has been outlawed, and

the knowledge and experience embedded in these practices are no longer being transmitted to young people. Sámi fishing, an important aspect of Sámi culture, is being strangled because the infrastructures that sustain its practices and ways of knowing have been made illegal.

Despite sustained protests, the set of infrastructures embedded in scientific fish-stock modelling, in policy, and in the Nordic states has completely displaced the alternative infrastructures embedded in and carried by Sámi fishing practices. And there is little sign that this is about to change.

In the scallop cases we showed how some ways of knowing are much easier to craft than others because they weave together relatively standard infrastructures in more or less standard ways, while going against the grain of dominant infrastructures can be difficult. But these cases also showed that in principle it is possible to summon up alternative infrastructures, or weave these together in novel ways, and therefore reshape them. This is what happened in Lamlash Bay. But nothing like this is happening for Sámi ecological knowledge of Deatnu salmon. Science, technology, politics, economics and the law are all working against this way of knowing and the infrastructural practices in which is carried. All these come together to produce, and are in turn strengthened by, their role in the infrastructures of coloniality. And since Scandinavian states have a monopoly over the legal use of force, we need to further add discipline and violence to this infrastructural list.

But there is something else going on too. In principle in Norway Sámi local knowledge is legally recognised alongside scientific fish population modelling. Indeed, it is supposed to feed into policy, because Norway recognises the cultural and environmental rights of Sámi as an indigenous people. But in practice this barely happens because Sámi ways of knowing salmon are disqualified on epistemological grounds. They aren't 'scientific' because they are said to be: 'experience-based' rather than model- or hypothesis-derived; intuitive, oral and visual rather than systematic; subjective, not objective; and qualitative rather than quantitative (Joks et al., 2020). It is treated, therefore, as a way of knowing that carries little or no weight beyond the Sámi community because it doesn't look for universal underlying causal mechanisms to explain phenomena in the world (like the fall in salmon numbers). Instead, it assumes that events unfold as an effect of (hopefully respectful) relations between lively and ethically sensible human and non-human beings. Sámi ways of thinking, then, are unacceptable because they don't *distinguish very strongly between nature and culture*. And

they don't share the philosophically realist and colonial assumption that the natural world is shaped by universal causes.

We have seen that STS describes the (often colonial) infrastructures of science, technology, politics, policy, economics, and the law. In addition, however, this case also shows that those infrastructures are *epistemological* and *metaphysical*. And since these weave together in ways that reinforce one another (for instance, only biologists are authorised to talk about fish-facts to policymakers) reshaping them becomes almost impossible. As Bruno Latour (1993) observed, 'modernity' insists on this nature-culture divide, but it also needs to fudge this, because science is not only messy, but also non-binary in practice. But how to think about this realist metaphysical infrastructural division that sustains colonialism and the coloniality of knowing? Is this a 'structure' too foundational and powerful to change? Once again, the STS focus on practice suggests otherwise.

Newfoundland, and an Anti-Colonial Laboratory

Max Liboiron directs The Civic Laboratory for Environmental Action Research (CLEAR). This is a laboratory in Newfoundland and Labrador in Canada whose members explore marine pollution in ways that respond to and seek to respect both biology and how indigenous people make sense of and live with the sea and its creatures (Liboiron, 2021). Their projects, findings, and practices therefore seek to make both biological and indigenous sense. On one hand, then, if this is to work indigenous communities need to take on board a version of biology. On the other, that biology has also needs to be vastly reshaped. How so?

First, it no longer seeks to uncover universal causal laws about nature and pollution. It doesn't trade in strong nature/culture binaries. Instead, lab members' questions attend to contexted relations about food sovereignty, causal and otherwise. Is it safe for this First Nation to eat this fish in this place at this time of year in Newfoundland? This is the kind of question that makes sense in CLEAR. Second, it therefore refuses large parts of the colonial epistemic and metaphysical infrastructures included in most marine biology. What happens is no longer taken to be a product of universal causal mechanisms that are therefore indifferent to place. Yes, CLEAR members publish scientific papers. But the universalism of colonial realism that we saw being imposed in Deatnu disappears along with the division between nature and culture. Instead, its scientists attend to the specificities of relations between

morally-sensible human and non-human actors experienced and lived in indigenous communities. Finally, they explore what this might mean in practice.

So, what infrastructures might be taken into, or developed, in such a laboratory? This is a continuing matter for experiment (CLEAR, 2021). However, such infrastructures currently include: creating animal respect guidelines; adopting community peer review; discussing and integrating indigenous understandings of the world; producing open source equipment that can be easily used by people without standard scientific training; problematising usually 'black boxed' methodologies in science such as statistical testing; and finding collaborative ways for conducting lab meetings.

The work of CLEAR demonstrates the possibility of alternative ways of knowing. It shows that, difficult though this may be, it is possible to resist the epistemic rigidity and the hard realism that goes with a strong distinction between nature and culture in colonising science. And instead, that it is possible to craft alternative, contextually-sensitive metaphysical, epistemological, and practical infrastructures. And that a good way of doing this is to attend to the practices and values that guide how relations are forged (humility, equity, respect.) A small specialist and STS-inspired marine pollution laboratory thus shows that it is possible to remake the relations embedded in science, and so to challenge the patterns of infrastructural coloniality.

Conclusion

STS describes how knowing practices work by including, drawing on, and reproducing heterogeneous material and immaterial infrastructures. Typically taken for granted, these both shape knowing and are (re)crafted in those practices. Knowing differently is hard work – sometimes near enough impossible – because it takes time and effort to remake infrastructures in novel ways. Helen Verran's (2001; 2002) accounts of overlaps between colonial and indigenous ways of knowing and being (and their metaphysics) explore some of these difficulties, because relative infrastructural conservatism is easier, even for innovators. However, STS work also suggests that that social, economic, academic, legal and material infrastructures can potentially be remade differently, and that even the hard realist epistemic and metaphysical infrastructures of coloniality can sometimes be undone by attending to practices. The CLEAR laboratory case we have just described illustrates one way in which this might be done. And work by Marisol de la Cadena (2015) shows how knowing and

power have together been shifting in indigenous-state struggles in Peru and Ecuador. For such is the significance of infrastructures. They are not social structures, and while they shape possibilities, they do not determine these. Instead, they are resources. How to draw on and use them is not fixed. Alternative ways of knowing are possible.

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