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Ways of knowing – out-of-sync or incompatible?: framing water quality and farmers' encounters with science in the regulation of non-point source pollution in the Canterbury region of New Zealand

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This paper examines farmers' ways of knowing water quality and their encounters with the science used in policy to address the cumulative effects of agriculture. Drawing on constructivist theories of knowledge and discussions with farmers in two locations of New Zealand's South Island region of Canterbury, the research identifies a significant divergence between farmers' conception of the water quality problem compared to the issue's policy framing. In theory, and increasingly in practice, ways of knowing are assumed merely out-of-sync and their integration or coproduction possible and necessary. This paper poses the question: what if the ways of knowing of farmers and science have become incompatible? The presented research indicates incompatibility that derives from epistemic practices that mobilise different ontologies at different scales. It is shown how the predictive practices of science present what appear to be insurmountable obstacles to integration or coproduction. It is argued that collaborative governance needs to find ways to work with divergent ways of knowing – not for the purpose of integration or coproduction but co-existence.

Keywords: water quality, ways of knowing, coproduction, knowledge practices, problem framing, multiplicity

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1. Introduction

The diminishment of water quality from diffuse losses of nutrients, sediments and pathogens from agriculture is an issue of concern worldwide. With over half New Zealand's land area dedicated to pastoral and arable farming and thousands of kilometres of rivers and streams and associated lakes and aquifers, diffuse pollution from agriculture is a significant issue that farmers are key to addressing. Blackstock et al. (2010) maintain that gaining agreement on what is the water quality problem is fundamental to engaging farmers in changing land management practices to address water quality. They identify gaps in our understanding of the socio-cultural aspects of how farmers "interpret, translate and respond to measures designed to mitigate diffuse pollution" (p. 5632). With significant water management reforms intended to reduce diffuse agricultural pollution gathering pace in New Zealand, the starting point for this research was to identify how farmers frame the water quality problem. From discussions with farmers in two locations of New Zealand's South Island region of Canterbury, the analysis identifies a significant divergence between farmers' conception of the water quality problem when compared to the issue's policy framing. Farmers see it as intermittent, influenced by a range of uncontrollable forces, and scientifically unknowable. Policy frames it as ever-present, quantifiable and a product of farmers not operating at or beyond good management practice. Of course, divergent problem framings and ways of knowing are the norm in contested resource policy and management. In theory, and increasingly in practice, ways of knowing are assumed merely out-of-sync and their integration or coproduction possible and necessary. However, the research findings open the question: what if these ways of knowing have become (or are becoming) so divergent they are incompatible? The research indicates incompatibility that derives from epistemic practices that mobilise different ontologies at different scales. It is shown how the predictive practices of science present what appear to be insurmountable obstacles to integration or coproduction. It is argued that collaborative governance needs to find ways to work with divergent ways of knowing – not for the purpose of integration or coproduction but co-existence.

2. Reconciling divergent ways of knowing and the obstacles

Brugnach and Ingram (2012) use the concept of ambiguity to identify uncertainty between divergent but equally valid problem framings and ways of knowing that inevitably come together in inclusive and integrative natural resource management. They maintain that ambiguity arises from "unrecognized contextual, methodological and substantive differences among knowledge systems" (p. 61). In recognising these elements as unique to knowledge systems, they argue that although knowledge integration cannot be a process of "mere translation" across knowledge systems or the "additive accumulation of facts" (p. 61), co-production can create "new shared knowledge" (p. 61). Therefore, notwithstanding the pitfalls of integration, coproduction is possible. Efforts to integrate or coproduce knowledges draw heavily on boundary concepts, e.g. boundary objects, (Star and Griesemer, 1989) and boundary organisations (Guston, 2001; Cash et al. 2006). A range of useful frameworks and approaches have been proposed to bridge divergences in observation, scale and encounter through integration or coproduction (e.g. Brugnach and Ingram, 2012; Cash et al., 2006; Edelenbos et al., 2011; Giebels et al., 2015; Hoppe and Wesselink, 2014; Lejano and Ingram, 2009; Van der Molen et al., 2015). However, it is important to consider the limits of boundary concepts (e.g. Turnhout, 2009) which became necessary in this research through considering how far the quantitative predictive practices of science that operationalise policy diverge from the epistemic practices of farmers (see also Scott, 1998).

These days, water resource policy and management would grind to a halt without the technological and quantitative capability of predictive modelling to assess potential environmental effects, policy options and potential outcomes. With unprecedented computing power, the way policy-relevant science now knows and communicates nature is increasingly derived from interlinked computer-based models that draw on an array of environmental data systems. The predictive knowledge practices of science are more technically sophisticated yet increasingly black-boxed than ever (Duncan, 2006, 2008; Latour, 1987; Pilkey and Pilkey-Jarvis, 2007; Sarewitz et al. 2000). Arguably, as policy imperatives for prediction and compliance in resource policy and allocation continue, the sophistication and blackboxing can be expected to intensify.

How might knowledge practices such as these influence knowledge integration or coproduction? Important from a constructivist perspective is that epistemologies and ontologies are mutually constitutive – one constructs the other (Jasanoff, 2004; Latour, 1993). Different epistemologies (i.e. how we know) constitute different ontologies (i.e. what we know) (Jasanoff, 2004). Divergent ways of knowing that arise from different yet equally valid and contingent socio-cultural knowledge practices evoke or mobilise different scales of encounter and observation (Ahlborg and Nightingale, 2012; Nadasdy, 1999; Rhoades and Nazarea, 2009; Sillitoe, 2009). Notwithstanding explicit recognition of these issues by Brugnach and Ingram (2012, p. 69) and their expectation that resolution rests with dialogue, deliberation, negotiation and learning to "define a problem then develop knowledge to solve it", this paper questions whether the knowledge practices that mobilise such divergent ontologies at different scales can be meaningfully redeployed in a way that fosters epistemic integrity for both knowledge systems (Nadasdy, 1999; Wynne, 1992, 2014).

The challenges are imbued with politics. Irwin and Wynne (1996, p. 9) argue that assumptions made by scientists and policymakers about what can be predicted and controlled, and a lack of reflexivity on the "unnegotiated social prescriptions" that become embedded in policy-relevant science, alienate publics. When it comes to predictive modelling, the politics that can be obscured from view enters a new realm. For example, in her study of the knowledge practices of the proponents of a major energy infrastructure project in Australia, known as Basslink, Duncan (2006, 2008) shows how a proponent's contingent optimistic assumptions about the past and the future were mobilised and validated into environmental regulations yet unrecognised as such through a cascade of predictive models. Cases such as this support Wynne's call for researchers to turn their gaze from assumed problems with publics, which perpetuates the so-called "public deficit model", to examine how publics encounter science (2014, p. 62).

These insights are used to evaluate how farmers frame the water quality problem. They also provide an analytical lens to examine farmers' encounters with policy-relevant science and question the possibility of the integration or coproduction of knowledges. The next section explains the research methods.

3. Research Methods

To investigate how farmers frame the water quality problem, discussions were held in two sub-regions of the South Island region of Canterbury. The first was the Hurunui-Waiau (HW) where 20 semi-structured interviews were conducted during 2013 with 12 dairy farmers and 8 farmers who owned a mix of sheep/beef/arable farms. Situated across what is known as the Culverden Basin, all farms were irrigated. The latter participants provide dairy support with cows grazing over winter with one farmer providing dairy support by only growing stock feed. With dairy farming recognised as having the greatest impact on water quality, all participants had economic interests at stake with the introduction of regulations to reduce nutrient losses to manage water quality.

Participants were selected from public submissions based on statements about water quality (e.g. recognising its importance but raising questions about how it might be handled) and their long term association with the region. Snowball sampling was also used to access informants across a mix of land uses. Interviews were conducted in farmers' homes and lasted between 45-90 minutes. Interviews were digitally recorded and transcribed. A thematic analysis was undertaken using a deductive and inductive approach. Descriptive codes were informed by theory and research questions while analytical themes were derived inductively from the codes, informed by the author's knowledge of the theory and the water quality policy issues (Cope, 2005).

While this paper focuses on the HW, it also draws on discussions with farmers in another Canterbury sub-region, Selwyn-Waihora (SW). In 2014, a focus group was held to evaluate the legitimacy of Canterbury's collaborative approach to water management (to be discussed). The group included one recreationalist and four farmers. Three farmers had participated in stakeholder workshops run by the regional council to assist in setting water quality limits and were an attempt to coproduce knowledge between scientists and stakeholders (see Duncan, 2013). Through the workshops, SW farmers interacted with scientists and the science used to quantify nutrient losses at the farm and catchment scales (i.e. the models, data and assumptions).

The analysis also draws on empirical resources that included scientific reports, plans, public hearing testimonies and evidence as well as observations from attendance at public meetings and regional plan hearings. Given the numbers of farmers involved, the findings cannot be interpreted as representative of all farmers, but they do provide useful insights into how these farmers located in two locations frame the water quality problem, their knowledge practices and how they compare with the policy framing.

4. Shifts in managing water in New Zealand

Water policy has changed significantly in New Zealand in recent years. Central government has embraced setting water resource limits and sees collaborative governance as the means to this end. In 2011, it introduced a long-awaited National Policy Statement for Freshwater Management (NPSFM). Reissued in 2014 with further provisions to address water quality, its key purpose is "[s]etting enforceable quality and quantity limits" (New Zealand Government, 2014, p. 4). The preamble envisages "managing land use and development activities that affect water so that growth is achieved with a lower environmental footprint" (2014, p. 3).

In the South Island region of Canterbury, where dairy farming has expanded significantly over the past two decades, water management and allocation has been highly contentious. The region's Canterbury Water Management Strategy (CWMS), which also requires setting limits, preceded the NPSFM and has been in place since 2010. The CWMS establishes a collaborative water governance framework with principles, objectives and targets with a vision to "enable present and future generations to gain the greatest social, economic, recreational and cultural benefits from our water resources within an environmentally sustainable framework" (Canterbury Mayoral Forum, 2009, p. 6). The targets are: ecosystem health/biodiversity, natural character of braided rivers, kaitiakitanga (i.e. Maori stewardship), drinking water, recreational and amenity opportunities, water-use efficiency, irrigated land area, energy security and efficiency, regional and national economies and environmental limits (2009, p. 8).

Importantly, its implementation occurred after central government dismissed the elected councillors of the Canterbury Regional Council (CRC) and installed its chosen representatives under the *Environment Canterbury (Temporary Commissioner and Improved Water Management) Act, 2010* (the ECan Act). This controversial move was prompted by stalled irrigation expansion and followed central government's review that found poor performance in processing water consent applications. Under the ECan Act the CWMS has become the driving force behind what is promoted as a new paradigm of collaborative water governance (Memon et al., 2012). It has created ten sub-regions (i.e. zones) with Zone Committees comprising representatives from the CRC, the relevant territorial authority, local Maori and the broader community. Each Zone Committee (ZC) has developed a Zone Implementation Programme (ZIP) which contains objectives and targets to align with those of the CWMS. Both the HW and SW have finalised their ZIPs which have informed the water quality limits and land use rules that are now included in their statutory sub-regional plans. When these ZIPs were written, the respective ZC determined from the available science that there was still some capacity for nutrient assimilation in HW's major rivers while the waterways of SW were over-allocated. Both zones are attempting to address water quality by setting nutrient limits while also seeking to deliver on the key socio-economic goal of substantially expanding irrigated agriculture through large-scale irrigation.

5. Divergent problem framings and ways of knowing

5.1 Policy

In the HW, in addition to an existing 30,000 ha of irrigated land, another 100,000 ha has been identified as irrigable (HWZC, 2011, p. 32). The ZIP (and now the regional plan) requires water quality to be maintained at current levels or improved (HWZC, 2011, pp. 34-36). In the development of the ZIP, the HW ZC's expectation was that nutrient 'headroom' required to allow new irrigation within the *status quo* resource limit, would be created by existing farmers adopting good management practice and over time moving beyond it (HWZC, 2011). It had been maintained by the CRC that to create headroom to significantly expand irrigation a reduction in nutrient losses of between 30-50 per cent would be required from existing farmers within the Culverden Basin (Brown, 2012, clause 34). These claims were informed by a CRC study that modelled potential reductions with the implementation of specific (and potentially high cost) mitigation measures (Brown et al., 2011, Appendix 6; HWZC, 2011, p. 34). However, during the regional plan hearings, assumptions underpinning the modelling (e.g. the area left to be converted from flood to spray irrigation) were drawn into question by farmers (Williamson, 2012). Agricultural industry groups maintained that 17 per cent was a more realistic figure (Dairy NZ and Fonterra Co-operative Ltd, 2012). In testimony this assertion was supported by the CRC report's lead author. To achieve the key aims of the ZIP and implement the regional plan (i.e. address water quality and expand irrigation), existing farmers have been cast as the problem. Efforts to engage them to abide by the rules to adopt good management practice and encourage them to go beyond it has become a priority.

Although limit-setting regimes vary across New Zealand, what is common is a focus on agriculture and outputs based. New Zealand's nutrient cycling model Overseer® operationalises this approach to nutrient regulation (CRC, 2014a). This means nutrient outputs, calculated by Overseer®, rather than nutrient inputs (e.g. fertiliser), are regulated (Duncan 2014). Overseer® can estimate nitrogen losses from the root zone of land and risks of phosphorus loss to generate a farm's average in kilograms per hectare per annum. Initially developed in the 1990s as a decision support tool to help farmers make decisions on how much fertiliser to apply, its more recent use as a regulatory tool has been controversial and consistently challenged in the Courts by the agricultural industry. Its well-known error margin of between 20-30 per cent has been one issue of concern. Shifts in the output numbers (up and down) as the science and data inputs change is another (Duncan, 2014). Nevertheless, Overseer® is now central to limit setting and regional planning across New Zealand. In SW, Overseer® predictions are key inputs to modelling that calculated catchment scale water quality limits and derived farm scale nutrient loss limits that now dictate land use rules and consents to farm (Robson, 2014).

How policy frames the relationship between land, nutrients and water is evident in Overseer®. For example, in Overseer®, where the nutrient budget is summarised, nutrients removed from the farm system are differentiated between products, residues, atmosphere and water. While the category 'to water' is intended to illustrate to the farmer that nutrients are being lost through drainage, these are losses predicted from the root zone. The model cannot calculate what goes to water which is currently not known beyond assumptions about attenuation (Aqualinc Research Ltd, 2015). Nevertheless, it is the 'to water' numbers that are used in policy which means a farm's distance from the river (and what exists underground in between) is constituted as irrelevant.

The CRC's educational materials depict distance using the nitrogen cycle. Arrows show the movement of nitrogen losses from agriculture direct to a nearby waterway through the sub-surface or overland via its various microbial transformations or direct from cow urine patches (see CRC, 2012, pp. 32-33). In these illustrations, the distance between cause and effect is very short and the pathways homogenous and unimpeded. In contrast, the regional plan's Rule 10.1 extends the distance between cause and effect across tens of thousands of hectares. It applies to "any existing land use … that results in a discharge of nitrogen or phosphorus which may enter water" (CRC, 2013, p. 25). This means the rule applies to all agricultural land irrespective of its location, land use, soil type and on-farm land management practices. These science policy moves are necessary to write land use rules that are enforceable and can catch all farmers in one regulatory net.

In contrast to other CWMS sub-regions (including SW), cumulative effects are regulated in the HW by in-stream nutrient concentrations and load limits that trigger land use rules that dictate what can be done on land (CRC, 2013). The nutrient loads are calculated by multiplying a monthly observation of nutrient concentrations by measures of river flow to derive a six-year rolling average. These calculations underpin the statutory rules to enforce the ZC's objective to keep water quality at the *status quo.* This policy framing relies on science's knowledge practices that can standardise, aggregate, quantify and predict nutrient losses from the root zone of land and calculate load at the catchment scale. These practices constitute the water quality problem as ever present by rendering distance and the underground path between land and water as irrelevant. The problem is constituted as quantifiable via a nutrient load limit derived from monthly water quality samples and average flow records at one location that is deemed representative of the river and the land use practices of all farms across the catchment.

5.2 Farmers

5.2.1 Seeing is believing

HW farmers were asked if any problems had been seen in the waterways in their area. It was explained by those with farms near the Hurunui River that while water quality had been a problem in the past, due to the visible effects of the nutrient enriched overflow water from flood irrigation flowing into a tributary of the river, this issue and its effects were no longer a problem with the switch to spray irrigation. When asked if slime had been seen growing in waterways nearby, none had been seen nor was it considered a problem. It was explained that this can happen at times of low flow and high temperatures – if and when it did, it was explained that the slime gets washed away with a fresh or in winter when it rains heavily. Several farmers explained that they had lived on their properties since childhood and the streams running through or near their farms were running clean. The overall perception was that water quality was good and for some, better now than in the past.

5.2.2 Linking land and water

When HW farmers were asked about their farm's contribution to nutrients in the rivers the response was consistent – minimal. Why this was the case diverged substantially. Two dairy support farmers stated they were a long way from the closest river (e.g. one was eight kilometres). They could not see how their contributions could be significant given the distance. They believed the nutrients would get filtered out through the soil over such a long distance. A sheep and beef farmer talked about dilution effects of high rainfall events that would flush nutrients away:

> … we get pugging issues [when a cow herd corralled in a small area churn sodden soil] when it's … really wet like last winter but the winter before we hardly had any mud and ponding of water and …. so, I don't know … it all depends on what comes out of the sky in the winter. But a lot of that's superficial too. If it looks muddy, it looks terrible, everyone jumps up and down but what's actually happening? I don't know if we know enough about it yet because in theory, the river, you know, it's raining, the river's at its highest for that week or whatever, so isn't it going to take it away faster?
>
> (Interview 7, Sheep and Beef Farmer with dairy support)

This farmer had been told by the regional council that phosphorus attaches to sediments that move with runoff from ground pugged by stock during rain. He could see how this could happen, but this information was contextualised by his experience of weather events and how unpredictable and unknowable they can be. He also observed that when it rains conditions change not only on land but also in the river – while nutrients and sediments get washed quickly from land they are flushed away just as quickly down the fast moving high volume river.

Soil type was another reason why contributions were considered minimal. For example, a number of farmers positioned themselves as not on shingle (i.e. highly permeable) soils next to the river. They were alluding to a proposal for a major irrigation scheme that would allow dairy farming to occur alongside the Hurunui River. Rather than where they were located – a long way from the river – they believed dairy farming right next to the river on light permeable soils certainly would, initially at least, result in nutrients getting to water given the short distance and soil type. Depth of top soil was seen as a mediating factor. Farmers spoke about the build-up of organic matter and soil life that utilised fertiliser and cow urine by working it into the soil for growing grass. In this respect farmers positioned themselves as having an active role in utilising nutrients by virtue of their land use (in this case dairy farming) and practices that were encouraging soil activity. A participant who had switched from sheep and beef farming (i.e. without irrigation and the capability to control soil moisture conditions and grass growth) to dairy farming maintained that his land with limited top soil had been transformed into a productive farm that now had a very deep top soil layer. He likened it to a sponge and was confident his farm was using nutrients from cow urine not losing them to water as calculated by Overseer®. He was talking from his long experience of building the soil for production and the worms he sees in the soil.

5.2.3 Encounters with predictive science

Although all farmers were using Overseer® for nutrient budgeting, the notion that nutrient losses can be quantified in a model for policy purposes to determine good or bad farm practice was a mystery:

> it's just the sheer volume of work involved in trying to assemble what's going on in a 7-8 hectare paddock … that would do 400 cows for 7 weeks plus I'm also putting on this amount of straw and am putting on that amount of silage and maybe a wee bit of hay. You put all that in the one area – well where's all the urea and the faeces going from there? Is it staying in the ground or is it getting utilised in the spring-time or is it sitting a metre down, sitting there for a big flush to flush it a bit further down or what? It's something I don't know how on earth they're really going to quantify, is it damage or is it not a problem?
>
> (Interview 5, Arable Farmer).

Farmers were asked about their perspectives on the conclusion from scientists that there was a lag time of around seven years between what was occurring on land reaching the Hurunui River. They were sceptical:

> We think we've got a very good understanding of what happens in the root zone … but what happens between the root zone and waterways? … You've got such a slow path of travel from between this paddock to … the main waterways and that to the coast – there's going to be no quick science to prove anything there … I don't doubt that there are practices that happen in the paddock that impact on water quality … but I think they're probably jumping the gun a little bit making some assumptions that, I don't know, I feel they're very risky some of the assumptions they're making.
>
> (Interview 3, Dairy Farmer)

The notion that nutrient pathways from agricultural land are quantifiable and, thereby, knowable, is seen by this farmer as premature and high risk. He is concerned about the assumptions being made about the land-water connection in the absence of evidence. Invoking gut feel the following farmer is also circumspect about the length of the lag phase proposed by the science:

> we've been told that because it's quite shallow groundwater that it is only taking seven years from the time of an on-farm change for it to reach the rivers but I'm not so sure about that … we're still not convinced on the lag phase – I still have a gut feeling that seven years is probably still a bit short.
>
> (Interview 4, Dairy Farmer)

The length of the lag time influences when nutrient headroom to expand new irrigation is available. Existing farmers maintain that they are prepared to operate at good management practice (i.e. achieve compliance) but no more, which they see as inequitable as they would be subsidising new irrigators. Their assessment of the science is influenced by concerns about getting the numbers wrong which would mean everyone (new and existing irrigators) would have to cut production to deal with an over-allocated river brought about by new irrigation schemes approved on the basis of unrealistic and optimistic assumptions.

5.2.4 Modelling is not science!

Focus group farmers were emphatic that modelling is not science. One farmer stated: "Their so-called science is based on modelling … I'm not a scientist but my whole life revolves around science". He went on to say:

> I'm a consumer so I'm very fussy about what science I'll accept and to me modelling is an information tool for scientists to use, it's not science *per se* … you put in 100 different variables into a model and 95 of those variables are assumptions so you then ask the scientist what's the margin of error here – it could be out by a factor of 10,000 … I don't mind the assertions that the environment is deteriorating or whatever, I don't have a problem with that as long as you can put some concrete evidence in front of me.
>
> (Arable Farmer, focus group participant).

Positioning himself as a consumer of science, he invokes his right to choose and, in that role, criticises scientific practice that relies on modelling that as far as he is concerned is too influenced by assumptions and prone to error to substantiate regulation. Another farmer observed during this discussion that "there's very little real data that's the problem, that was our main objection" (Dairy Farmer, focus group participant).

5.2.4 Comparing time scales

Time scales were important for all farmers. For focus group farmers, having seen the science that supports SW regulations, they made the point that much of the council's monthly or quarterley water quality monitoring started in 1973 but in some locations did not begin until 2000. These farmers' families had been on their farms for over 100 years and deemed council's data as mere snapshots. They spoke of how they grew up seeing dairy shed effluent poured directly into waterways and drains on a daily basis, which was standard practice then but no longer. Hence, it was their view that the claim that water quality in SW is worse now than in the past is based on patchy data and unbelievable assumptions. It can be seen that farmers' ways of knowing are underpinned by direct observation, intuition and their recollections of the past, their soils and the landscape. They are influenced by a range of socio-economic factors, relationships and interests which contextualise how they interpret and contest the science and the modelling.

6. Discussion

The starting point for this research was to examine how farmers framed water quality to help improve engagement through an existing collaborative process. Thinking through the mutually constitutive relationship between how we know (i.e. epistemology) and what we know (i.e. ontology), it was found that farmers' and science policy actors utilise quite different knowledge practices. Farmers draw on direct observation, intuition, their recollections of the past and their interactions with their soils and the landscape. The analysis identified that farmers' epistemic commitments constitute an ontology of the water quality problem as intermittent, influenced by a range of uncontrollable forces, and scientifically unknowable.

Science policy actors encounter the water quality problem through Overseer® and other predictive models that standardise, aggregate and quantify nutrient losses. These knowledge practices constitute an ontology of the water quality problem as ever-present, quantifiable and a product of farmers not operating at or beyond good management practice. These practices operationalise the HW regional plan's Rule 10.1 and give visibility to catchment-scale cumulative effects (with the extrapolation of a simple rendition of the relationship between land and water) and tractability to regulation (via in-stream nutrient load limits derived from monthly measurements of nutrient concentrations at one location on the Hurunui River). In the process, the temporal and spatial heterogeneity of both the bio-physical and socio-cultural landscape are constituted as irrelevant. Importantly, it was these factors that farmers invoked in their understandings of the relationship between land and water.

Undoubtedly, predictive modelling is an indispensable tool for science and policy. Problematically, it appears to defy farmers' ways of knowing. While the findings do not suggest an out-of-hand rejection of science or a lack of regard for the importance of water quality, they do indicate a 'permeable' epistemology whereby farmers critically question scientific claims, in particular those derived from predictive modelling, and after filtering, embrace some but reject others (see Wynne, 1992). It is not suggested that farmers' know-how is 'better' than science – both are contingent (Wynne, 1992). However, farmers' knowledge practices render a heterogenous landscape and times scales that cannot be scripted by the science and the modelling given the policy imperative to set catchment scale limits and write land use rules that can be enforced. Arguably, farmers have vested interests and would be expected to contest the science and the policy framing that has the potential to force change and impose costs. Yet, with a focus on knowledge practices, their politics can be seen alongside the politics of limit setting which, on the one hand, is purporting to address water quality, but on the other is paving the way to significantly expand irrigation and land use intensification – a socio-economic and political endeavour that risks further degradation of water quality. Analysed in relation to one another, it is argued that the profoundly different ways of knowing of farmers and policy-relevant science constitute irreconcilable worlds of observation and encounter and distinctly different conceptions of the water quality problem that are putting integration or coproduction out of reach.

7. Conclusions

Divergent problem framings and ways of knowing in natural resource management, and the barriers they present for integration or coproduction, are well recognised in the environmental science and policy literature. Research has focused on how to overcome the challenges. However, the presented research illustrates how divergent epistemic practices have become. The extent to which these practices mobilise different ontologies at different scales prompted the question: what if these ways of knowing have become (or are becoming) incompatible? This research identified incompatability and the breadth of the chasm getting wider as the indispensible predictive tools of resource policy become more technologically sophisticated, integrated, black-boxed and politically-infused. Notwithstanding the "interpretive flexibility" of boundary objects and their potential to facilitate agreement across social worlds without consensus (Star and Griesemer, 1989; Turnhout, 2009, p. 403), it would appear that the imperative to integrate or coproduce knowledges needs to be tempered by the prospect that we are dealing with epistemologies and ontologies that are (or are becoming) irreconcilable (Turnhout, 2009; Wynne, 1992, 2014).

What do these conclusions mean for collectively deciding and acting? While this is a question that requires further research, the work of Law and Singleton (2015) provides insight. These authors maintain that policy works "on the assumption of ontological singularity" which is inevitably experienced as elusive by policymakers (2015, p. 11). In conceiving that there is no single world, reality or policy, they maintain that "the world is irreducibly multiple and irreducibly distributed between different practices across time and space" and that "forms of knowledge – including policies – and realities – are irretrievably situated" (2015, p. 17). Situatedness and multiplicity align with Star and Griesemer's theorisation of boundary objects (1989). Yet, when 'ontological singularity' is assumed and sought, multiple realities that inevitably exist across heterogenous networks of relations are deemed to be "mistakes" (Law and Singleton (2015, p. 11). The expectation to integrate or coproduce ways of knowing appears to reflect the imperative to capture or create a single world, reality or policy, and to subdue multiplicity that is perceived as cultivating ambiguity and confusion. In contrast, Law and Singleton (2015) encourage working with, rather than closing down, multiplicity. These insights support the argument derived from the research findings that collaborative governance needs to find new pathways to work with divergent ways of knowing, not for the purpose of integration or coproduction but co-existence.

Epilogue: In March, 2014 these findings were presented to the HW ZC. With an expectation to provide advice on how to move forward with engaging farmers, but having found such divergent conceptions of the problem, and in light of constructivist theory, I did not suggest integration or coproduction to resolve it. Instead, I recommended farming communities work out what water quality meant to them (rather than adopting the regional council's scientific framing of the issue) which could involve building narratives that have little to do with the rivers. This was translated by a ZC member as the need to move conversations from "river talk" to "farm talk" (CRC, 2014b, p. 3).

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References:

Ahlborg, H., & Nightingale, A. J. 2012. Mismatch between scales of knowledge in Nepalese forestry: Epistemology, power, and policy implications. *Ecology & Society*, 17(4).

Aqualinc Research Ltd. 2015. Memorandum dated 10 March, 2015 to Hurunui, Waiau, Jed Nutrient Working Group titled Hurunui River nutrient modelling: impact of dryland intensification. http://ecan.govt.nz/publications/Council/memo-hurunui-mainstem-nutrient-modelling-20150310.pdf (accessed 19 March, 2015).

Blackstock, K.L., Ingram, J., Burton, R., Brown, K.M. and Slee, B. 2010. Understanding and influencing behaviour change by farmers to improve water quality. *Science of the Total Environment*, 408, 5631-5638.

Brown, I., Norton, N., Wedderburn, L., Monagham, R., Harris, S., Hayward, S. and Ford, R. 2011. Nutrient Management in Hurunui: a Case Study in Identifying Options and Opportunities. Retrieved 24th June, 2012 http://ecan.govt.nz/publications/Reports/nutrient-management-hurunui-case-study-identifying-options-opportunities-001111.pdf

Brown, I. 2012. Canterbury Regional Council Section 42A Report. Hurunui Waiau Regional Plan hearings submission titled 'Creating nutrient headroom'. Retrieved 25th July, 2014 http://ecan.govt.nz/publications/Plans/hurunui-waiau-plan-014-s42a-report-brown.pdf

Brugnach, M., & Ingram, H. 2012. Ambiguity: the challenge of knowing and deciding together. *Environmental Science & Policy*, 15(1), 60-71.

Canterbury Mayoral Forum, 2009. Canterbury Water Management Strategy. Strategic Framework November 2009. Targets updated July 2010. Canterbury Regional Council; Christchurch. Available from http://ecan.govt.nz/get-involved/canterburywater/Pages/Default.aspx (accessed 11 June 2014)

Cash, David H., Borck, Jonathan C., and Patt, Anthony G. 2006. Countering the Loading-Dock Approach to Linking Science and Decision Making: Comparative Analysis of El Nino/Southern Oscillation (ENSO) Forecasting Systems. *Science, Technology & Human Values* 31 (4): 465-94.

Cope, M. 2005. Coding Qualitative Data in Hay, I. (ed) *Qualitative research methods in human geography*. Oxford University Press: South Melbourne.

CRC (Canterbury Regional Council). 2012. *Wai/Water*, Hurunui Wai Supplement. Retrieved 24th September, 2012 http://ecan.govt.nz/get-involved/canterburywater/key-documents/Pages/cwms.aspx

CRC (Canterbury Regional Council). 2013. Hurunui Waiau River Regional Plan. Retrieved 10th March, 2014 http://ecan.govt.nz/publications/Pages/hwrrp.aspx

CRC (Canterbury Regional Council). 2014a. Matrix of Good Management (MGM) Project website. Retrieved 21 March, 2015.
http://ecan.govt.nz/get-involved/mgmproject/Pages/Default.aspx

CRC (Canterbury Regional Council). 2014b. Minutes of the Ordinary Meeting of the Hurunui Waiau Zone Committee held in Hurunui District Council Chambers on 17 March 2014 at 3 pm. http://ecan.govt.nz/publications/Council//hurunui-meeting-040414.pdf

Dairy NZ and Fonterra Co-operative Ltd. 2012. Opening legal submissions at Proposed Hurunui and Waiau River Regional Plan hearings dated 6 November 2012.

Duncan, R. 2006. The use of predictive modelling in impact assessment: implications for environmental legislation and regulation. *Australian Journal of Public Administration*, 65(1), 75-88.

Duncan, R. 2008. Problematic practice in integrated impact assessment: the role of consultants and predictive computer models in burying uncertainty. *Impact Assessment and Project Appraisal* 26(1), pp. 53-66.

Duncan, R. 2013. Converting community knowledge into catchment nutrient limits: a constructivist analysis of a New Zealand collaborative approach to water management. *Nature and Culture* 8(2): 205-225.

Duncan, R. 2014. Regulating agricultural land use to manage water quality: The challenges for science and policy in enforcing limits on non-point source pollution in New Zealand. *Land Use Policy* 41: 378-387.

Edelenbos, J., van Buuren, A. and van Schie, N. 2011. Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science & Policy*, 14: 675-684.

Giebels, D., van Buuren, A. and Edelnbos, J. 2015. Using knowledge in a complex decision-making process – evidence and principles from the Danish Houting project's ecosystem-based management approach. *Environmental Science & Policy*, 47, pp. 53-67.

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. *Science, Technology, and Human Values*, 399-408.

Hoppe, R., & Wesselink, A. 2014. Comparing the role of boundary organizations in the governance of climate change in three EU member states. *Environmental Science & Policy*, 44, 73-85.

HWZC (Hurunui Waiau Zone Committee). 2011. Hurunui Waiau Zone Implementation Programme, 22nd July, 2011. Retrieved 22nd August, 2011 http://ecan.govt.nz/publications/General/hurunui-waiau-zip.pdf

Jasanoff, Sheila. 2004. Ordering knowledge, ordering society, In: (Ed) Sheila Jasanoff, *States of Knowledge: the Co-production of Science and Social Order*. London, Routledge.

Irwin, A. and Wynne, B. (1996) Introduction In *Misunderstanding Science? The Public Reconstruction of Science and Technology*, Irwin, A. and Wynne, B. (Eds.), Cambridge University Press, Cambridge, pp. 1-17.

Latour, Bruno. 1993. *We Have Never Been Modern*. Translated by Catherine Porter. Cambridge, MA: Harvard University Press.

Law, John and Singleton, Vicky. 2015. ANT, Multiplicity and Policy. http://www.heterogeneities.net/publications/LawSingleton2014ANTMultiplicityPolicy.pdf Published by heterogeneities.net on 21 February 2015. Accessed 14 April, 2015.

Lejano, R. P., & Ingram, H. 2009. Collaborative networks and new ways of knowing. *Environmental Science & Policy*, 12(6), 653-662.

Memon, A., Duncan, R. and Spicer, A. 2012. *The Hurunui Waiau Zone Implementation Programme as a Collaborative Planning Process: A Preliminary Review*. Christchurch, Environment Canterbury Regional Council. Available from http://ecan.govt.nz/publications/Reports/hurunui-waiau-zip-collaborative-planning-process.pdf

Nadasdy, P. 1999. The politics of TEK: power and the “integration” of knowledge. *Arctic Anthropology*, 36(1-2), pp. 1-18.

New Zealand Government. 2014. National Policy Statement for Freshwater Management 2014. Retrieved 1 August, 2014 http://www.mfe.govt.nz/publications/fresh-water/national-policy-statement-freshwater-management-2014

Pilkey, O.H. and Pilkey-Jarvis, L. 2007. *Useless Arithmetic: Why Environmental Scientists Can’t Predict the Future*. Columbia University Press: New York.

Rhoades, R.E. and Nazarea, V. 2009. Forgotten Futures: Scientific Models vs. Local Visions of Land Use Change in *Local Science vs. Global Science: Approaches to Indigenous Knowledge in International Development*. Paul Sillitoe (ed). Berghahn Books: New York.

Robson, M. 2014. Technical report to support water quality and quantity limit setting in Selwyn Waihora catchment. Environment Canterbury: Christchurch. Retrieved 10 August 2014. http://files.ecan.govt.nz/public/lwrp/variation1/tech-report-sw-overview.pdf

Sarewitz, D., Pielke, R.G. and Byerly Jr. R. 2000. *Prediction: Science, Decision Making and the Future of Nature*. Island Press: Washington

Scott, J.C. 1998. *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed*. Yale University Press: New Haven.

Sillitoe, P. 2009. Local Science vs. Global Science: an Overview in *Local Science vs. Global Science: Approaches to Indigenous Knowledge in International Development*, pp. 1-22. Berghahn Books: New York.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, 19(3), 387-420.

Turnhout, E. 2009. The effectivenss of boundary objects: the case of ecological indicators. *Science and Public Policy*, 36(5): 403-412.

Van der Molen, F., van der Windt, H. J., & Swart, J. A. 2015. The interplay between knowledge and governance: Insights from the governance of recreational boating in the Dutch Wadden Sea area, 1981–2014. *Environmental Science & Policy*.

Williamson, N. 2012. Evidence (as Chairman of Amuri Irrigation Company) to Hurunui Waiau Regional Plan Tribunal Hearing dated 12 November 2012.

Wynne, B. 1992. Uncertainty and Environmental Learning: Reconceiving science and policy in the preventive paradigm. *Global Environmental Change*, June, pp. 111-127.

Wynne, B. 2014. Further Disorientation in the Hall of Mirrors in *Public Understanding of Science* 23(1):60-70.