A Knowledge Ecology of Urban Australian Household Water Consumption

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Abstract

Despite urban water providers' commitments to ideas of 'triple bottom line' sustainability, insights from humanities and social science research are still not well articulated into Australian water policy and practice, which remains dominated by a positivist epistemology that tries to 'integrate' multiple knowledges into its singular objective rationality. Arguing that 'integration' suppresses what is most valuable about Social Sciences and Humanities (SSH) contributions, this paper outlines a post-positivist 'knowledge ecology' framework in which scientific and quantitative knowledges are among the diverse ways of knowing valued for helping to understand, represent and change a reality that includes a variety of knowers and standpoints. This framework is used to identify and discuss some key features of the knowledge ecology of Australian urban household water consumption, where interpretive and qualitative research is creating a modest niche and contributing to development of more socially sustainable and culturally intelligent approaches to urban water management.

Introduction: Integration and Epistemological Diversity

It is widely recognised that the complex problems of the 21st century cannot be addressed by the STEM (Science, Technology, Engineering, Mathematics and/or Medicine) disciplines alone and require interdisciplinary approaches or a even a new 'interdiscipline' of "integrative applied research" (Bammer, 2013).

Less readily acknowledged are the difficulties in establishing the respectful knowledge pluralism on which successful collaborative multi-disciplinary efforts depend, though these are hinted at in a recent response to the European Commission's new Horizon 2020 research programme:

> Solving the most pressing societal challenges requires the appropriate inclusion of SSH [Social Sciences and Humanities[2]]. This can only succeed on a basis of mutual intellectual and professional respect and in genuine partnership. Efficient integration will require novel ways of defining research problems, aligned with an appropriate array of interdisciplinary methods and theoretical approaches. (Nowotny *et al*., 2013, 26).

The implications – borne out in experiences of humanities and social science researchers on water – are that this basic condition of respect for social sciences and humanities is often lacking, and that SSH knowledge is too often 'integrated' into a science-centred framework without affecting the definition of problems, the questions asked or methods deployed. The notion of knowledge integration arguably expresses a "positivist perspective that knowledge is cumulative and hence the integration of knowledge is both possible and good" (Sharp *et al*., 2011, 503).

Whilst many biosciences and geosciences have moved from reductionism to a complexity paradigm, discourse on water is normally "dominated by engineers as the discursive elites, united by one overarching paradigm that is based on Newtonian physics and underpinned by Baconian and Descartean philosophy" (Turton and Meissner, 2002, 11). This positivist science tends to produce an epistemological monoculture by validating only knowledge that can fit within its own paradigm: quantitative and supposedly objective data. Epistemological pluralists and interpretive researchers find ourselves most at odds with positivists on issues touching on cultural norms – like 'demand management', itself a positivist concept (Sharp *et al.,* 2011, 504) – for "positivist researchers seek to achieve a 'scientific' ideal of objectively standing outside the policy under investigation, whereas for post-positivists their positionality is one consideration that contributes to the development of their methods and their narrative" (Sharp *et al*., 2011, 502).

Alternatives to a positivist idea of 'integration' include Pohl's (2005) notion of "interrelating interdisciplinary research" advocated by Sharp *et al*. (2011), and the idea of a 'knowledge ecosystem' or 'knowledge ecology', mobilised here to frame a description of relationships among different knowledges in and of metropolitan household water consumption. Sharing concerns with how to more effectively bring different knowledges together, I start with the working definition

[2] 'SSH' in Europe corresponds to HSS (Humanities and Social Sciences), used in some British reports, while in Australia HASS (Humanities, Arts and Social Sciences) is the more usual term.

of a knowledge ecology developed in the "Knowledge Ecologies Workshop" project with Amanda Third, Philippa Collin, and Sky Hugman: "a heterogeneous, dynamic, open-ended system in which diverse knowledge paradigms, disciplines, modalities, specialities and localities find their niches; co-evolve and form adaptive and contingent assemblages; and feed on, compete, collaborate and exchange with one another to consume and produce knowledge resources" (Sofoulis *et al.*, 2012, 10).

Concepts of knowledge ecologies are mainly discussed in an interdisciplinary strand of management theory that applies key ideas from ecosystems science, systems theory, and new media theory to understand and facilitate productive knowledge flows within and outside organisations. The idea also emerges from postdualistic, neomaterialist and systems-oriented approaches that form part of my humanities background (Anderson and Braun, 2008; King, 2012). In contrast to the positivist ideal of a cumulative, objective and unitary knowledge, a knowledge ecology framework presupposes that knowledges (including the 'objective') are partial, plural and situated (Haraway, 1988). The knowledge ecology concept is therefore relevant to debates about new configurations of university knowledge in the information or knowledge economy, especially "mode 2" research (the term by which Gibbons *et al.*, 1994, describe research with extra-academic partners, driven by practical concerns rather than pure curiosity).

This paper is an experiment in taking the metaphor of a knowledge ecology literally and applying an ecosystems analysis framework to the field of household water consumption, as seen from my knowledge niche as an Australian cultural researcher. In describing an ecological system, an ecosystems scientist would first consider the biotic factors – the living components – and the abiotic, or non-living elements, including features like sunlight, climate, and hydro-geography. They would then examine the interactions between the living and non-living elements, and those amongst the different kinds of living entities, including 'food chains' and cooperative or competitive relations across species and orders. Completing the description would be a consideration of the inputs and outputs exchanged across ecosystem boundaries, and evolutionary factors that lead to change in the system components over time (see Table 1, Column 1).

TABLE 1: Knowledge Ecology Matrix

ECOSYSTEM	KNOWLEDGE ECOLOGY	A KNOWLEDGE ECOLOGY OF HOUSEHOLD WATER CONSUMPTION (Urban Australia)
1.Biotic (living) factors	Knowers and actors Knowledge modalities	Quantitative: water experts, economists, market researchers and psychologists. Qualitative: social scientists, cultural researchers, householders.
2. Abiotic (non-living) factors	Policy settings and resources Policy climate, landscape	Science-dominated, neoliberal emphasis on efficiency and customer choice. Jobs, funds, research infrastructure for STEM not HASS.
3. Interaction of biotic with abiotic factors	Knowledge/Power/Resources Dynamic interactions, distributions	HASS - over 50% of Australia's researchers; STEM get 95% of government research funds. STEM experts define questions, scope and collaboration paradigms even for 'social' research.
4. Interaction among biotic factors	Relations between knowers, knowledges, knowledge practices Models of collaboration	'Integration' rather than co-creation: water authorities feed on 'social data' providers who depend on their funding. Dangers: positivist monoculture, culturally unintelligent policy.
5. Inside & outside system boundaries	Boundaries, translation, sources, contributions beyond overt, covert, unacknowledged	Some STEM experts claim to do 'social' research. Home life, 'barbeque conversations'- sources of social intelligence for technical water managers.
6. Evolution	Evolution of new or improved knowledge ecologies	DIY networking of social water researchers. Emergent new generation of engineers with interdisciplinary backgrounds. Systems thinking.

The experiment starts with the analogy between the 'living' ecosystem components and communities of knowers and their knowledges (See Table 1, Column 2). First it will describe the main 'species' of knowers and knowledges, then identify salient features of the research environment, such as the policy climate, research funding priorities, and other enablers of research, such as research networks and institutes. Crucial to a knowledge ecology analysis are questions about interactions of 'biotic' and 'abiotic' factors, that is, how are resources ('abiotic factors') distributed amongst knowers ('biotic factors')? The third step of the description therefore asks: What are the politics of knowledge in a particular context of knowledge practice? The ecosystems terminology of food chains (such as predator/prey relationships, parasitism) can work surprisingly well for looking at interactions among and between communities of knowledge practitioners, though here, the fourth section concentrates on relations between water authorities, social and cultural researchers, and household water users. Analysis of the systems dynamics of how different knowledge communities and knowledge ecologies protect, open or deny the existence of borders to knowledge flows (Section 5), and the identification of sources of innovation and emergent new knowers and knowledges that can prompt evolution (Section 6), complete the knowledge ecology description.

These six sections demonstrate steps in an heuristic method rather than stages of an argument. My overall point is that policymakers, water managers and researchers involved in setting research funding priorities, or co-creating, sharing and distributing knowledge resources, would do well to undertake a comparable analysis of their own knowledge niches, with special attention to knowledge/power relations and epistemological diversity, in order to arrive at a better starting point for harnessing different knowledge contributions to solve urgent common problems. This would contrast with the positivist 'integration' approach where, typically, STEM researchers "get their whole project up and running and funded and … then they say, 'Now, of course we need a bit of social science'" (quotation from interview with a social researcher, in Sofoulis, 2011a, 42-43). To counter the fantasy of seamless knowledge integration, this paper emphasises some of the difficulties and constraints SSH researchers face in the knowledge ecology of household water.

What follows did not begin as a knowledge ecology analysis; rather, the ecosystems template is used to marshal key observations, findings and conclusions from earlier research: interview and diary studies of householders (Sofoulis, 2005; Allon and Sofoulis, 2006; Sofoulis and Williams, 2008; Sofoulis, 2011b) and interviews and document analysis of corporate and government urban water management (Sofoulis *et al.*, 2007; and especially Sofoulis, 2011a; Sofoulis, 2011b), as well as questionnaires and interviews with social and cultural researchers on water (Sofoulis, 2011a, Humphry *et al.,* 2011). Further input comes from participating over the last decade in a number of gatherings of water researchers from technical, scientific, social and cultural areas, some of which I helped organise, including the 2012 conference *Tapping the Turn*, source of other papers in this special issue.

1. Biotic Factors: Species of Knowers and Knowledges

The growing difficulties of managing water provision in a complexly changing world have led urban water authorities to become increasingly concerned with water's social and political dimensions, including making demand management interventions at the household level. Scientists, engineers, water planners and technocrats have been the dominant knowers in the knowledge ecology of metropolitan household water *supply* for over a century. Their expansion into the field of managing residential *demand* was accomplished more by extension of technocratic logic than by building the knowledge base with experts on the politics, sociology and cultures of consumption. Frank Fischer finds that the technocratic approach is undergirded by the "basic positivist principle that mandates a rigorous separation of facts and values", and tends "to see technical solutions as applicable to most social and cultural situations" (Fischer, 2000, 18). By avoiding values and seeking objective, factual and evidence-based accounts, technocrats aim at "moving as many political and social decisions they can to the realm of administrative decision making, where they can be redefined and processed in technical terms" (Fischer, 2000, 18). For example, the complex social, technical/infrastructural, aesthetic and environmental values that shape water consumption practices are reduced to the quantitative measure of household 'demand', which then is to be efficiently 'managed' (Sofoulis, 2005, Allon and Sofoulis, 2006, Sharp *et al*., 2011, 504).

Household water consumption, in the technocratic view, can be reduced by efficient devices (such as low-flow shower heads) and behavioural change (such as turning off the tap when brushing teeth). Behaviour of the human subcomponents is adjustable by information inputs that produce changed attitudes and encourage 'green' consumer choices, according to the 'ABC' (Attitudes-Behaviour-Choice) model favoured by technocrats across the natural resource and climate change sectors (Shove, 2010). Large-scale questionnaire surveys that produce statistically analysable results for comparatively low financial outlay are preferred, though occasionally there are funded small scale case studies of household water consumption using such qualitative methodologies as water diaries and ethnographic methods (see other papers in this issue, and Allon and Sofoulis, 2006; Sofoulis and Williams, 2008; Head, 2008).

A distinctive feature of this knowledge ecology of household water consumption is the imbalance between the kinds of knowers and knowledges most often brought to bear on this topic (water experts, positivist and quantitative social scientists, and psychologists), and the kinds of knowledge practitioners and practices that potentially offer the keenest insights into the meanings and dynamics of change in everyday household water practices (householders, qualitative and interpretive social and cultural researchers, ethnographers and sociologists).

STEM experts remain the dominant varieties of knowers in the knowledge ecology of household water *consumption*, aided by the economists, statisticians, and consultant market researchers, psychologists and demographers who create social and economic data. Volumetric information about household consumption is obtained via the water meter, a device designed to be read by technicians, though as part of the shift from 'the customer' to the 'Resource Man' (Strengers, 2013), new smart meters provide householders more legible details of volumes and uses in near-real time. Vital roles are played by the accountants and programmers who link consumption data to billing.

Much research that purports to address the *social* dimensions of water goes no further than *individual* consumer behaviour, or more precisely, some notional 'average' of statistical aggregations of individual survey responses on socio-economic status variables and behavioural intentions (Sofoulis, 2011b). Social change is expected to happen arithmetically through the incremental accumulation of individual psychological changes, as confidently voiced by one water demand manager: "How do you bring about change in the thinking of a community? By getting a whole lot of individuals to think differently about something." The ABC model subordinates as mere "factors" affecting individual psychology (Shove, 2010, 1275) the historical, infrastructural, cultural, sociotechnical, political, capitalist, social justice, environmental, intergenerational and ethical considerations that qualitative researchers would call on to explain why water is 'demanded' and used in different ways by people of different times, places, wealth and cultural affinity.

The social is meta to the individual and comprises interactions among actors in a field or network of sociality that frames those interactions (for example, kinship networks, formal and informal organisations, faith traditions). Scaling down the social to the individual makes these interactions, and hence the social dimension, disappear, while extrapolating up from the individual forms merely a population, not a society. That is, to focus on the individual psychology of consumption is to target precisely where the social is not. A genuine integration of SSH perspectives might generate for water managers a more "culturally intelligent" (Ang, 2011) picture of consumers and consumption. New research questions and policy directions arise from the recognition that people are not isolated individuals but members of communities who share material ways of life, whose resource consumption practices are in large part based on available infrastructures and collective decisions and conventions rather than individual deliberations and choices. Change strategies could focus less on propagandising 'green' consumers, and instead try starting different conversations, forging new connections, enacting different practices and collectively changing ways of living.

'The household' gets caught in the confusion between individual and societal levels. Market surveys target individuals but water consumption is metered at the level of the *property*, often taken as a proxy for the social unit of the *household*. Some water companies receive detailed property data – a carry-over from when water services were bundled with property rates – and can correlate this with consumption data and rainfall, temperature and storage measures. However, they lack the datum most salient for predicting demand management: the number of inhabitants. 'Average' water consumption figures are approximated by such means as dividing the overall city residential consumption volumes by the estimated total population (or in some cases, number of households) over a certain period, with average litres per capita per day being one measure, as used in Brisbane's *Target 140* [litres] campaign, specifying the desired daily consumption during drought.

This reductionist view pictures the household as a service site and unit of metered consumption, populated by average individuals with average consumption, when it is more like a multicultural assemblage (Sofoulis, 2011b, 802), a mini ecosystem. One engineer involved in sustainability expressed dissatisfaction with this approach: "our database is households, but the people who use water are individuals, and they're in very different spaces in the house"; he cited the water-saving parents compared to "the lazy son who empties the tank" and the daughter who "uses twenty-five thousand towels". As Lahiri-Dutt points out, categorising the household as "the lowest unit of production, consumption and decision-making" denies basic and almost universal social facts that "in most cultures men and women, often supported by children, do different work, have different access to resources and different areas in which they can make decisions and exercise control" (Lahiri-Dutt, 2006, xxx).

The household literally is a multiculture in families with migration heritage, whose different generations of members may have experienced quite different kinds and phases of water provision. Such families hold "practice memories" of life where expectations of infrastructures were different; these memories "represented a source of adaptive capacity on which they could draw" to change practices during drought in suburban Australia (Strengers and Maller, 2012, 6). The picture of the 'average' household is also contested by UK researchers Medd and Shove (2007), who found that households of matched size conforming to 'average' water consumption figures used water quite differently, while Browne, Medd and colleagues (Browne *et al.*, 2012; Pullinger *et al.*, 2013) identified several "clusters" of household water practices – numbers of households across a medium-large scale study who were found to use comparable amounts of water for much the same purposes and with similar rationales.

The largest category of people who know about household water consumption are householders themselves, experts in the social norms and cultural meanings around water use as part of everyday life and domestic routine. This expertise traditionally counts for little compared to that of the water experts, but is valued in post-positivist social and cultural research.

Philosopher and cultural historian of mathematics Ian Hacking found that with the rise of social statistics as a tool of governance, population data was often presented to give the effect of "statistical laws that look like brute irreducible facts", masking how those facts were constructs that "could be noticed only after social phenomena had been enumerated, tabulated and made public" (Hacking, 1990, 3; Sofoulis, 2011b, 98). Such quasi-facts appeal to technocrats as they seem value-free. By ignoring or dismissing as irrelevant any commentary and responses that fall outside a survey's multi-choice options, positivist social researchers preserve their control over the field of data and the inventory of variables over which their statistical methods can be exercised. Post-positivist cultural researchers, by contrast, tend to be more interested how people experience the social (and sociotechnical) world as meaningful, in all its mess, ambivalence and contradiction.

As Fischer (2000, 19) describes the differences, "positivists tend to construct explanatory models that implicitly *impute* assumptions and value judgments to them", whereas interpretive researchers seek to "get *inside* the situation" from the actor's point of view (emphases in original). Research subjects are treated as experts (or at least intelligent participants) in their own cultural and social worlds, capable of generating and expressing meanings that can be directly quoted and do not need statistical aggregations, averaging and predicting of results according to some hypothetical 'social law' in order to be considered valid evidence. A water diary, for example, is a record valued for being person-, place- and time-specific: a case study allowing glimpses inside domestic water culture.

Sharp and her colleagues found it "unattractive" and unworkable to integrate positivist and post-positivist approaches to demand management, but acknowledge both were necessary, since planning would be impossible without tools for assessing future human and environmental needs, while "without post-positivist science to highlight and question the values embedded in those concepts and models we could become frozen in a static set of values with limited ability to revise and reform to suit changing circumstances or understandings" (Sharp *et al*., 2011, 513)

2. Abiotic factors: Research Climate and Resources

Climate, soil type, geomorphology, sunlight, winds, tides, water: these abiotic factors determine what kinds of life may survive or thrive in a particular ecosystem. Equivalents for a knowledge ecosystem include the policy climate that results from shifting and sometimes contradictory international and domestic pressures, as well as research priorities, freedom of knowledge circulation, and basic funding available for different kinds of knowledge production. Australia's water policy climate was shaped by an unfortunate synchronicity in the early 1990s, when principles of triple bottom line sustainability (considering social and environmental costs and benefits along with economic ones) were being taken up by some government departments of natural resources just as the nation was enthusiastically embracing Thatcherite neoliberalism and the associated sell-off, privatisation or corporatisation of what had until then been publicly owned utilities

(Syme and Hatfield-Dodds, 2007). In water policy, concerns about social justice and equity were marginalised in favour of customer choice and technical efficiency (Syme and Hatfield-Dodds, 2007, 18). The result is that most Australian governments and policy makers seem to hold a "double bottom line" view of sustainability (Sofoulis, 2013), preoccupied with the marketisation of water, accepting limits as dictated by 'the science' and environmental protection regulations, and reducing 'social' sustainability to the customer's 'willingness to pay'. Australia's national research priorities reflect this market bias. A decade of struggle by Australian learned academies to expand the priorities beyond STEM topics and introduce a priority related to HASS fields has so far been only partly successful, with the latest iteration sporting a new economics priority instead (Department of Industry, 2013).

Many STEM communities acknowledge that scientific and technological expertise is insufficient to address complex 21st century problems: "Natural sciences should no longer dictate the Earth system research agenda; social sciences will be at least as important in its next phase", declared the editors of *Science* (W.V. Reid *et al*., 2009, 245). So while higher levels of government may hold the "double bottom line", a more holistic understanding of sustainability and its social dimensions prevails amongst scientists and other researchers, amongst environmentalists, in some local governments, and, importantly, in water companies whose professionals actively participate in research and scientific communities. These trends create favourable 'microclimates' and 'niches' receptive to and supportive of SSH research on water.

3. Biotic and Abiotic Interactions: The politics of knowledge resourcing

It is possible for discussions about knowledge integration or the virtues of interdisciplinarity to proceed as though all disciplinary knowledges held equal status, value and potency. Similarly, the idea of a knowledge 'ecosystem' may be used to invoke a diversity of knowledges while overlooking the resource differentials between them. Large disparities between the status and funding of the STEM disciplines compared with SSH are the politely ignored "elephant in the room" in discussions of interdisciplinarity and innovation, according to one Australian report (Spoehr *et al*., 2010, 13; see also Sofoulis 2011a, 41). A 2010 summary of Australian research funding statistics indicated that STEM fields, including health, attract 95% of available government research funds, while over half of Australia's researchers compete for the remaining 5% meted out to HASS fields (ABS, 2010, 12-13; Sofoulis, 2011a, 4 and Appendix B). Ideally, every discipline might be equal, but in funding reality, positivist, data-driven sciences benefit most from this maldistribution of resources. One senior water research manager informed a *Cross-Connections* workshop that of the approximately $400 million spent annually on water research in Australia, he had calculated a mere $5M -$10 million, or around 2%, went to social research.

Data is a knowledge resource equivalent to an ‘abiotic’ element – not quite knowledge but necessary for its existence. Unequal access to household water consumption data is another notable characteristic of this knowledge ecosystem. Water companies accumulate what one insider described as a “scary” amount of data about properties, consumption, and consumer attitudes, but do not employ social or sociotechnical or statistical researchers to interpret this data in non-volumetric terms. Many classify such data, along with the findings of commissioned social research, as “commercial in confidence”, which prevents it circulating in public or amongst social researchers, though water companies circulate it amongst themselves as “grey literature”. Social researchers like Thornton and Reidy (this issue) who want to correlate qualitative evidence of water practices with volumetric data may have to go through many hoops to access the data, or collect tiny bits of it in close cooperation with householders (see Lahiri-Dutt, this issue; Lahiri-Dutt and Harriden, 2008; Harriden, 2013).

These lop-sided distributions of resources mean uneven flows in knowledge and funds amongst the varieties of experts and researchers interested in household water consumption, which in turn affects relationships and interactions between communities of knowers in this ecology. For example, the research funding and organisational resources available to industry and STEM university and government water researchers means they have the funds and facilities to host interdisciplinary gatherings and collaborations, and the power to define the terms under which SSH researchers can participate. A small example is how industry rates charged for peak national water conferences can exceed the annual travel allowance of many humanities academics.

Most water research funding appears to be allocated on the basis of 20th century assumptions that only those in the STEM sector were entitled to it. One way to begin effecting a fairer distribution of resources in this knowledge ecology would be to shift the policy emphasis from the “science base” to the “research base” (British Academy, 2004, 65) and make humanities and social science research projects directly eligible for funding under programs that have to date been limited to scientific and technical proposals where social research is an optional add-on (Sofoulis, 2011a Ch.9, esp. 79).

4. Interaction among biotic factors: Interacting communities of knowers

The relationships among household water users, social and cultural researchers, and water authorities (government agencies and corporatized providers) were touched on in Section 1 (Knowledges and Knowers). A point to add here is that dominant approaches to consumer research and green social marketing are at the ‘extractive’ end of the participatory engagement spectrum (H. Reid *et al*., 2009, 24, Sofoulis, 2011a, 26): consumers are treated as repositories of attitudes and opinions that can be elicited in telephone, on-line or face to face survey questionnaires to produce bundles of data. Many ‘community engagement’ exercises on water services and planning are little better: experts define the problems and consult community representatives, but are not obliged to heed them or involve people in subsequent decision making, let alone acknowledge their influence (for an example, see Sofoulis, 2011a, 43-44). Examples of genuine participation that involve the joint identification of problems, collaborative research and design, and implementation of solutions in co-management arrangements are usually limited to 'pilot' programs.

The concept of knowledge integration implies a master discourse or knowledge base into which other knowledges may be incorporated and assimilated, perhaps to disappear without a trace. This integration model of interdisciplinarity works best among positivist sciences, but is challenged by post-positivist and interpretive knowledges. Epistemologically pluralist concepts like "interrelating disciplinary knowledges" (Pohl, 2005) or "knowledge ecology" (Santos, 2009) insist that knowledges do not have to be amalgamated into a normal science template to make valuable contributions to complex problem-solving. The knowledge ecology approach understands there are not just different fields or subjects of knowledge (such as a positivist paradigm hopes to 'integrate') but many different *kinds* of knowledges, *ways* of knowing, and diverse *perspectives* on any field of knowledge. One organism or species does not an ecosystem make. The proliferation of positivist science and quasi-scientistic reporting styles to the exclusion of SSH insights, cultural intelligence, social wisdom, and other unquantifiable contributions, signifies an unhealthy ecosystem where knowledge monocultures arise through "epistemological fascism" and "epistemicide" (Santos, 2009, 116).

Without such concepts as a knowledge ecology, the differences between STEM projects and HASS research can be under-recognised, as in many examples of water authorities who commission qualitative social research projects but then impose engineering or building project management templates on them, or who insist that only large data sets are valid. Water managers from positivist traditions may lack experience in negotiating different kinds of knowledge and knowers in a social reality where values are inseparable from facts. Resource economists Gentle and Olszac (2007) found the principal obstacles to implementing Australia's National Water Initiative were not imperfect scientific or technical knowledge, but technical water managers' unrealistic and impractical policy objectives and a lack of orientation, knowledge or experience when it came to dealing with "complex economic and social issues and processes", or "community engagement, particularly in situations of conflict and distrust". Likewise, stakeholders and community groups were "inexperience[d] in dealing with conflicts with governments and water planners over science, economic and social impacts, values, information and institutions" (Gentle and Olszac, 2007, 62).

Interactions between social and cultural researchers and the water industry are inevitably constrained, because even water companies that espouse 'triple bottom line' sustainability are reluctant to employ social and cultural research experts, preferring a 'stable' of outsourced social research providers hired and fired on a project-by-project basis. The few social researchers employed full time in STEM water research settings can find themselves in an epistemological (and often a gender) minority, with little power to affect the dominance of positivist and rationalist discourse, and ground down by the constant battle to get human values taken seriously: “I feel like I am self-censoring in daily work where it [insistence on scientific rationalism] still nags away at a daily context” (interviewee quoted in Sofoulis, 2011a, 49)

Water managers unfamiliar with post-positivist paradigms may expect social research reports to be similar to those from engineering consultancies who provide instructions along with results that simply ‘plug in’ to existing operations. One engineer turned policy analyst compared them: “we have detailed reports with clear recommendations of action. Very clear and concise”, whereas “The outcome of social research project is ‘this is this’, ‘could be this’, ‘maybe this’, ‘I recommend doing another research project’”. Social researchers needed to edit more carefully, make more precise recommendations, and “keep it to a language that the water industry is familiar with”. While it is a reasonable expectation that HASS researchers communicate our findings in plain language, avoiding specialist language altogether can also reinforce the idea that social and cultural research, or interpretive methods, are little more than everyday ‘subjective’ or anecdotal knowledge.

‘Translation’ is another alternative to the ‘integration’ model of knowledge relations, as canvassed in a working paper by Sky Hugman that became the basis of Sofoulis *et al*. (2012). Knowledge translation, a concept much elaborated in medicine and nursing, works best when connected to ideas about linkage, exchange and communication, rather than one-way dissemination (Sofoulis *et al*., 2012, 7). Water managers may not know how to apply social and cultural research, while qualitative researchers cannot understand why positivist water managers can’t simply interpret social research findings into their own water management frameworks. Both sides usually lack a category for the labour of knowledge translation or knowledge brokering needed to negotiate radical paradigm differences. Most social water research projects end with the delivery of the final report to the government or industry organisation, after which the research team dissolves; there is normally no budget or workload allocation for translational work. One counter-example was Yarra Valley Water in Victoria, which had employed an experienced cross-sectoral consultant specifically to be “the conduit” to help the corporation work through findings and implications of some qualitative social research into terms that made operational sense (Sofoulis, 2011a, 45).

However, a knowledge ecology perspective reveals limits to translation, for one kind of knowledge is not necessarily translatable, transferable or susceptible to integration with any other kind; nor is there some moral imperative to make it so. Rather, the injunction is to find out what kind of role that knowledge is playing or could play in relation to the other knowledges in the ecosystem, and what kinds of 'conduits' and pathways are available to mediate between the different knowledges and knowers relevant to solving a particular problem.

5. Crossing internal and external boundaries

Drawing an ecosystem boundary is a somewhat arbitrary process, as life systems are multi-scalar and every ecosystem could be a subsystem (or niche) within a larger ecosystem. An ecosystems analysis therefore observes the flow of resources, energy, materials and organisms into and out of the system. By analogy, with a knowledge ecology we might ask: what useful or influential knowledges are imported from *outside* that ecosystem, or exported to other knowledge domains from there? An example of the latter is knowledge from water-saving transferred to energy conservation or climate change adaptation programs. How rigorously or loosely are boundaries between different knowledges (and knowers) *within* the knowledge ecosystem maintained, and which (or whose) boundaries are respected or transgressed?

The water industry's preoccupation with the ABC paradigm and behavioural economics has kept it out of touch with the last half century of cultural studies of consumption. To supply bits of that missing cultural intelligence (Ang, 2011), some water managers turn to their own everyday lives for examples and explanations of aspects of water practices that fall outside of rationalist and marketing paradigms – such as how their wife takes baths according to how full dam storages are, or the pleasure they personally derive from hand-watering the garden. Similarly, in the absence of such sociological concepts as an informal public sphere, meso-level social formations (Sofoulis and Williams, 2008) or the importance of face to face conversations and peer group interactions in facilitating the spread of emotions and practices amongst social networks (Christakis and Fowler, 2009), water managers will refer to "dinner table conversations" or "barbeque conversations" as a way of acknowledging social interactions where people influence each others' ideas and practices, including around the adoption of new technologies, such as rainwater tanks. This access to knowledges of everyday household water practices, and of social network dynamics, provides a vital point of connection between water managers, HASS researchers, and householders.

The question of boundaries *within* a knowledge ecology is a sensitive one for cross-disciplinary collaborations in the water sector. Political philosopher Boaventura de Sousa Santos explains how the epistemological pluralism at the heart of a knowledge ecology requires acknowledging the limits of any particular knowledge system, especially one's own, which is difficult for dominant rationality:

Orthopedic thinking … grounds a kind of knowledge (modern science) that does not know well enough the limits of what it allows one to know of the experience of the world, and even less well the other kinds of knowledge that share with it the epistemological diversity of the world (Santos, 2009, 115).

This arrogance/ignorance is a source of frustration for SSH researchers whose industry partners expect them to merely churn out ‘social data’ for predictive science models, or who critique interpretive studies for lacking a null hypothesis. The insistence that SSH research simulate scientific data is a symptom of failure to appreciate what other kinds of knowledges are being excluded: the “orthopedic” rationalists do not even know what they are missing. What should be respected in “learned ignorance” as a “known unknown” is dismissed in “ignorant ignorance, which is not even aware that it does not know” (Santos, 2009,114, quoting 15th century philosopher theologian Nicholas of Cusa).

Boundaries between areas of knowledge or expertise are not necessarily symmetrical: an unbridgeable chasm between scientific and social expertise to a SSH researcher may be a barely noticeable dip to a STEM expert. It would be a scandal were an architectural historian or a philosopher of engineering to claim the credentials to build an office block or bridge (unless perhaps they were the designer and BBC housing program presenter Kevin McCloud), yet in almost any university water research centre or water utility there are scientists and engineers who claim to do social research, despite lacking formal credentials in theories and methods for studying people, culture and society. The *Cross-Connections* project found ‘do it yourself’ (DIY) social research was common, typically as an end-user survey added on to a scientific or technical study, sometimes with input from professional social researchers (Sofoulis, 2011a, 17). While at one level, DIY interdisciplinarity is a welcome recognition of the value of end-user perspectives, it also denies differences between STEM and SSH knowledges and devalues the latter with the tacit message that doing social research requires no special training.

Humanities and cultural researchers have our own ways of over-stepping ourselves, typically through being weak on methodology, but so strong on interpretation we can make the connections between the smallest sociological factoid – such as what some householder has to say about their washing up practices – and large scale societal and environmental issues of great import! For the pragmatic water managers who want to know how this knowledge will change “what we do on Monday”, more modest and delimited claims about where a particular bit of sociocultural knowledge best applies, and how exactly it might be used, are preferable to grand interpretations and theories.

6. Evolution: Post-positivist engineers

While this paper has emphasised points of unease in relationships between SSH and STEM knowledges around household water, there are factors that facilitate collaboration and help bring about changes in this knowledge ecology. First among these is climate. From the late 1990s to the mid-2000s, a behaviourist, price-focussed, systems engineering approach to managing household water demand applied broadly across Australian water authorities. As the so-called ‘Millennium Drought’ dragged on for up to a decade in some places, household water consumption dropped to a half or as low as a third of normal volumes; the uptake of water tanks and subsidy schemes exceeded economists' predictions, and many water-saving technologies and practices became normal, including reduced toilet flushing and low-water gardening. Water managers gained new respect for the water consciousness and civic mindedness householders were demonstrating, and started to picture water users as intelligent, responsible co-managers of urban water rather than selfish price-driven customers (Sofoulis and Strengers, 2011).

Some 'old school' engineers have become post-positivists who embrace a sustainability paradigm that includes social accountability and acceptance of diverse perspectives – even including the spiritual and aesthetic – as part of planning and decision-making. New generation engineering graduates may have taken units or sub-majors in engineering or environmental management, environmental engineering, or in SSH areas, all of which introduce aspects of human, social and/or biological complexity that were missing from conventional engineering training. Some innovative engineers (notably, Mitchell *et al*., 2013) take a transdisciplinary approach and incorporate socio-cultural-technical considerations at the outset.

Changes afoot in the humanities and social sciences make collaborations with the water sector more likely. Among these are the rise of post-dualist and systems thinking, such as the knowledge ecology idea articulated here, which can facilitate communications with those from the STEM sector. Fields like human and cultural geography and the environmental humanities have emerged as important locales for SSH researchers interested in questions of climate change, resource management, everyday practices and their supporting infrastructures. One concentration is the Australian Centre for Cultural Environmental Research, directed by Laureate Professor Lesley Head at the University of Wollongong; another is the Fresh Water Governance network (Patterson *et al*., 2013). Ongoing impetus to cross-disciplinary and cross-sectoral collaboration comes from universities and governments keen to develop engaged research and show useful applications for public spending on research, so that SSH researchers are encouraged to find partners and funding.

Conclusion

The notion of a knowledge ecosystem readily invokes a diversity of knowledges, knowers and interactions that do not all end in integration, despite the imaginings of those on top of the knowledge food chain. Paying attention to the distribution of resources and facilities adds a political economy dimension to a knowledge ecology analysis, revealing divergent wealth and status across knowledge sectors. These disparities limit interdisciplinary interactions, as some kinds of knowers literally do have more power than others to define the reality and determine what counts as evidence or knowledge and who gets to produce, consume or hide it.

Tendencies towards a positivist knowledge monoculture are countered by a flourishing of social and cultural research and humanities scholarship to produce an epistemologically diverse array of knowledges, supported by a wide variety of agencies besides water providers (see Humphry *et al.,* 2011, 8-35). The water industry is interested in social research, but keeping researchers outside reduces the capacity for their insights to alter the scope of research questions or aid translation between knowledge paradigms.

Among the most fragile elements in this knowledge ecosystem are the links between and amongst social and cultural researchers on water, small minorities within their diverse 'home' disciplines, who interact with much better resourced STEM counterparts without enjoying anything like their supportive infrastructures of professional or academic organisations, shared research facilities and sponsored annual conferences. The connections we forge and maintain, however informally, and the events we manage to stage, however irregularly (like *Tapping the Turn*), can create more secure knowledge niches by manifesting ourselves as communities of knowers who for a few hours or days are not in an epistemological minority.

Adopting a knowledge ecology perspective will not in the short term alter the power/knowledge relations that let STEM experts determine if, when and why SSH research on water is needed and fundable. What it can do, though, is help break down an epistemological monoculture, and change how interpretive, qualitative and site-specific knowledges are valued and respected, and at which stages and in which forums experts on culture and society – including the voices of ordinary people – are to be heard.

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