organizations have been established throughout Europe and in Australia, Canada, Haiti, Israel, South Africa and the USA. Science shops are usually linked to universities where supervised students engage in research projects as part of their curriculum. Living Knowledge (2017) is a rich source of information about science shops and community based research. Indeed, the EC has played an important role in supporting the growth of the science shop movement by funding such projects as ISSNET (Improving Science Shop Networking) (2017) and TRAMS (Training and Mentoring of Science Shops) (2017). Recent projects funded by the EC have sought to link CS activity to the theme of civil society and to strengthen public engagement in the formulation of research agendas and associated processes.

The preceding discussion enables us now to turn our attention to addressing our guiding question, '*is theory understood by citizens and based on their interests?*' Interrogation of the impetus for CS and how citizens may gain access to it suggests that there are multiple rationales for and versions of CS, and while some are predicated on citizen interests, others are less so inclined.

3.2 Theory and Practice

These are linked because they are the source of research questions that drive the production of knowledge. The traditional scientific approach involves the development of research questions or hypotheses that fill gaps in theory, but it is now accepted that research questions may be based on practice. Hence a question concerning the process of inquiry: *are research questions derived from theory or practice?* This question points to epistemological and methodological issues and how they are addressed.

3.2.1 Community OR

Rosenhead (1986) not only discusses the 'custom' of OR, but also tackles the related issue of 'practice' in reflecting that 'The evolved forms of tools reflect the circumstances of their use' (p.338). Hence, mainstream OR's focus on quantification and modelling effectively down-plays the social and value-laden nature of decision making and renders the basis for decisions 'beyond the comprehension of most people' (p.339). Recognition of this inspired the call for a more transparent OR that supports 'a more lively, complex and elaborate social process of decision-making' (Rosenhead, p.339). Three streams of complementary, sometimes overlapping, activity may be regarded as having emerged in response to this call:

- Problem Structuring Methods (PSMs) (Rosenhead and Mingers, 2001) are a collection of approaches that offer decision support by 'way of representing the situation (that is, a model or models) that will enable participants to clarify their predicament, converge on a potentially actionable mutual problem or issue within it, and agree commitments that will at least partially resolve it' (Mingers and Rosenhead, 2004, p.531). The modelling effort may involve clarification of normative agendas through dialogue, as PSMs are largely founded on interpretivist or social constructivist epistemologies (Jackson, 2006). Well-known examples of PSMs are Soft Systems Methodology (SSM) (Checkland, 1981; Checkland and Poulter, 2006), Strategic Choice

Approach (SCA) (Friend and Hickling, 1987; Friend, 2001), and Strategic Options Development and Analysis (SODA) (Eden and Ackermann, 2001; Ackermann and Eden, 2005). There is now a wealth of case-study reports on the use of PSMs and the potential for learning to be gleaned from the analysis of micro-level practice is widely recognised (Taket and White, 1997; Mingers and Rosenhead, 2004; Rosenhead, 2006, 2009; Shaw, Edwards, and Collier, 2006; White, 2006; Ackermann, 2012; Franco, 2013; Gregory, Atkins, Burdon, and Elliott, 2013; Yearworth and White, 2014; Velez-Castiblanco, Brocklesby, and Midgley, 2016; White, Burger, and Yearworth, 2016).

- Critical Systems Practice (CSP) focuses on the distinction of a broad range of problem contexts and the development of systems based methods appropriate to those contexts. Jackson (1987a, 2004) recognises that 'abandoning the narrow scientism of impoverished OR paves the way for a broader range of methodologies to be brought into play' (2004, p.68) and suggests that the much debated system of systems methodologies (Jackson and Keys, 1984; Jackson, 1987b; Flood and Jackson, 1991) might be put to good use to this end. However, merely having a broad range of systems methodologies to draw on is necessary but not sufficient for good systems practice, as developing a deep appreciation of the underpinning philosophy is also necessary. Reflecting earlier discussions about the commitments of CSP (see for example, Schecter, 1991; Midgley, 1996; Midgley, Munlo, and Brown, 1998), Jackson (2000) encapsulated their essence in three statements: critical awareness, relating to critique of the different systems methodologies, and social awareness of the societal and organizational context; improvement, referring to the achievement of 'something beneficial', reflecting a circumspect aspiration in the light of the postmodernist challenge to the notion of universal liberation; and pluralism, the need to work with multiple paradigms without recourse to some unifying metatheory.
- Systemic Intervention (SI) developed out of CSP and took as its primary concern critical reflection on boundaries. Midgley (2000) defines SI thus: 'Systems thinking pursues the ideal of comprehensiveness, but knows that this is unattainable. However, reflection on the boundaries of knowledge at least enables us to consider options for inclusion and exclusion...If intervention is purposeful action by an agent to create change, then systemic intervention is purposeful action by an agent to create change in relation to reflection on boundaries' (p.129). Drawing on earlier work by Ulrich (1983, 1988a, 1988b, 1993, 1996a, 1996b), Midgley articulates a new approach to SI, explaining key concepts such as boundary critique and marginalization, and his work has been employed in a variety of community-based projects (e.g. Boyd, Brown, and Midgley, 2004; Foote, Baker, Gregor, Hepi, Houston, and Midgley, 2007; Midgley, Ahuriri-Driscoll, Baker, Foote, Hepi, Taimona, Rogers-Koroheke, Gregor, Gregory, Lange, Veth, Winstanley, and Wood, 2007; Córdoba and Midgley, 2008; Midgley and Pinzón, 2013; Barros, Midgley, and Pinzón, 2015).

These three areas of practice have much in common with action research (AR) (Levin, 1994; Midgley, 2000; Mingers and Rosenhead, 2004) and, perhaps not surprisingly, AR has been a focus in

much COR work. Indeed, the Community Operational Research Unit explicitly articulated a working philosophy of AR following the traditions established in Latin America and Scandinavia (Thunhurst, 1992). This work is not without its critics, however, and Johnson and Smilowitz (2012) suggest some of it might be classified as '"capacity-building" rather than applications based on analytic models intended to provide specific policy and operational guidance to decision-makers in a way that extends existing theory and methods' (p.39). While some COR might indeed be classed as capacity building (for example, Boyd, Geerling, Gregory, Midgley, Murray, and Walsh, 2007, are explicit that capacity building was part of their project), it is important not to confuse such interventions with those that are based on the use of models of a qualitative rather than quantitative nature. Even with this clarification, it seems fair to say that, although the ends of COR and CBOR might be aligned, their means are not. So it is perhaps not surprising that, in an otherwise positive review of Johnson's (2012) book, Rosenhead (2013) notes that 'in many cases the models are used only on data collected from a neighborhood; that is, they were not actually used in hot blood to support decision makers in the relevant agencies or organizations' (p.613). Clearly, these comments highlight tensions between COR and CBOR in terms of both custom and practice (also see Midgley, Johnson, and Chichirau, 2017), but perhaps the concerns and approaches of COR do require adjusting for current times, and the emergence of CBOR encourages us to do just this. The needs and skills of citizens and associated groups have moved on since the 1980s, such that the tools of OR (data and models) are familiar to most if not all citizens (Caulkins, Eelman, Ratnatunga, and Schaarsmith, 2008). Indeed, Hindle and Vidgen's (2017) work with the Trussell Trust on mapping food bank data demonstrates that charities can make good use of big data and data visualisation. Hence, 'the OR analyst should not only be concerned with bringing into being knowledge appropriate to the problem under consideration, but also with ensuring that the knowledge is incorporated within the client organization' (Klein, Connell, and Meyer, 2007, p.1536). Such a requirement challenges the OR professional to employ approaches that are: not too complicated, transparent and of their time. The value of such a challenge is that the methods can be handed over (Gregory and Jackson, 1992a,b; Boyd et al, 2007; Gregory and Ronan, 2015), thus bringing about capacity building alongside model building and the use of analytical approaches at the local level in keeping with COR's ideological commitment.

Clearly, both COR and CBOR include a broad range of approaches, some closer to decision makers than others, but all geared to meaningful community improvement-oriented engagements. Recognition of this brings us back again to our guiding question, '*are research questions derived from theory or practice?*' On the basis of the foregoing discussion, we argue that professionals have risen to the challenge of developing the epistemology and methodology of OR so that it better serves citizens' needs, and we answer that research questions are primarily derived from practice.

3.2.2 Citizen Science

While it is recognized that science operates in a diverse range of institutional and disciplinary contexts (Ziman, 1978, 1991), and consequently generalisations should be avoided, the epistemology of much science focuses on the scientist as a detached, laboratory based observer, whereas citizen

knowledge focuses on the embedded, engaged participant (Irwin, 1995). However, when scientists do ‘get out of the lab and remember why they do what they do’ (Stilgoe, 2009, p.41), there is still ‘a sucking-up of "empirical evidence" which is subsequently emptied out at the scientist's desk. From this heap of social "facts," scientific knowledge is created’ (Levin, 1994, p.31). Although it should be recognized that a scientist acting in isolation with a commitment to citizen knowledge may be said to be practising CS, this is more the exception rather than the rule. Citizens are increasingly regarded by scientists as more than a mere source of data or a means to collect data, and are engaged a step further down the research value-chain to evaluate data sets. It would seem that, even in our computer-dominated age, citizens have a valuable contribution to make to science as ‘Our brains can discern patterns in raw data sets that are not picked up by computer algorithms, especially novel patterns or multiple, complex ones’ (Toerpe, 2013). Underlying the popular notion of an enlarged role for citizens in science is the requirement that engagement be dependent on their abiding by certain standards amid concerns about the quality of data collected by amateurs and definitions of good science. Higgins’s presidential address to the British Association for the Advancement of Science Festival of Science in 2004 reflects such concerns in questioning what good science actually means. ‘Do we mean exciting and novel? Careful and thorough? Safe? Probably yes to all these. But what about relevant? Applicable?...I think it is a pity we do not spend more time openly discussing what we mean by “good science”’ (Higgins, 2004, cited in Wilsdon, Wynne, and Stilgoe, 2005, p.50). It is indeed ironic that the protocols developed to ensure standards often act to opposite effect as they are ignorant of, or do not sufficiently value,

> lay knowledges which might enrich decision-making processes...but which are currently excluded due to their supposed “irrationality” and anecdotal nature. From the perspective of a concerned citizen, this does indeed seem insulting, provocative and detrimental to notions of self-identity and citizenship (Irwin, pp.131-2).

Beyond the mainstream, though, there is recognition (Irwin, 1995, pp.166-167) of the need to create new social and knowledge relations which:

- Engage with non-scientific understandings and expertises;
- Appreciate heterogeneity and do not seek to impose consensus;
- Focus on problem situations rather than looking to isolate natural science from social science;
- Acknowledge uncertainty, limitations and the possibility of science practice in everyday life; and
- Are adaptable to institutional and situational change.

Such social and knowledge relations are suggestive of a new approach to doing science, which may be found in the work of Funtowicz and Ravetz (1990, 1993), who propose a ‘post-normal science’ (PNS). In such an approach,

> uncertainty is not banished but is managed, and values are not presupposed but are made explicit. The model for scientific argument is not a formalized deduction but an interactive dialogue. The paradigmatic science is no longer one in which location (in place and time) and process are irrelevant to explanations (Funtowicz and Ravetz, 1993, p.740).

Wesselink and Hoppe (2011) develop our understanding of PNS by defining the elements specific to it as the assessment of: firstly, whether the problem is post-normal in terms of uncertainty, value contestation, high decision stakes and urgency, and secondly, the quality of information based on NUSAP (Numeral, Unit, Spread, Assessment and Pedigree) (2017) and/or extended peer review. Significantly, PNS was recently referred to, not as an approach to science, but 'as a heuristic risk-assessment framework to assist decision-making at the interface between environmental science and public policy' (Grinnell, 2015, p.257).

The method of PNS fits well with key outlets for CS practice, such as science shops. Funtowicz and Ravetz (1993, p.740) characterise PNS as 'issue-driven', and citizens often initiate contact with science shops in the hope of finding research assistance to address their local issues. As there is usually a commitment to developing a true partnership with citizens, and their issues tend not to respect academic silos, most science shops adopt a broad definition of science. In the ensuing engagement, a collective and often multi-disciplinary search for solutions to issues is undertaken with new knowledge being generated, or at least existing knowledge being combined and adapted (Living Knowledge, 2017). Similarly, Bonney's (2009a,b) CS, in which citizens come up with questions or issues and then work with scientists to address them, also fits in well with the new social and knowledge relations.

The above examples of CS may represent opportunities for social learning and could be categorized as 'participatory action research' (Cornwall and Jewkes, 1995; Wilderman, Barron, and Imgrund, 2004; Fernandez-Gimenez, Ballard, and Sturtevant, 2008). However, such examples are perhaps notable because they are exceptions to the dominant modus operandi of science. Once again, we turn our attention to addressing our guiding question, '*are research questions derived from theory or practice?*' Review of the epistemology and methodology of science suggest that there are alternatives to the norm, but the scale and scope of these has yet to be assessed comprehensively, so we are inclined to answer that research questions are derived more from theory than practice.

3.3 Practice and Citizens

These are linked through the notion of improvement or, as Levin had it, empowerment, which is defined as 'the capacity to act both in furthering one's own interest and in enhancing an inquiry process where people can transcend their former position based on their increased knowledge' (Levin, p.32). Hence the question: *are citizens able to act in their own interests?* The question compels us to consider matters of ideology and the politics of the professions.

3.3.1 Community OR

Rosenhead and Thunhurst (1982) align traditional OR with a scientism that ensures 'decisions which might formerly have been considered exercises of power, and hence political, are...presented as if they were not in fact political decisions at all but "scientific" or "rational" ones' (p.119). Just as the underlying ideological commitments of traditional OR can be revealed, so too can those of COR. Indeed, Midgley and Reynolds (2004) assert that 'one of the original motivations for Rosenhead

coining the term “Community OR”, and setting out to build a Community OR movement, was to make OR relevant to his own Marxist politics (partially expressed in Rosenhead, 1986, 1987)’ (p.311). Consequently, a need to be more explicit about the political orientation of COR is recognised. Jackson (1987a, 2004) stakes a claim for ‘a more critical and radical dimension’ by adding two further aims to the four defined by the Steering Group for COR established by the Operational Research Society (Jackson, 1987a, p.50), to:

(e) ‘help redress the resource imbalance that exists under capitalism by assisting those underprivileged in this respect’;

(f) ‘develop decision-aiding and problem-solving methods appropriate to a more democratic and socialist milieu’.

The addition of these aims reflect Habermas’s (1984, 1987) argument that the analysis of power is essential for the understanding of past and present social arrangements, and the suggestion of an emancipatory interest relating to freedom from the constraints imposed by power relations. Such freedom implies citizens taking control of their own destinies through learning supported by participatory democracy, which rather justifies the capacity building orientation to COR referred to in section 3.2.1. Indeed, given the focus of this part of the analysis on citizens acting in their ‘own interests’, it is relevant to consider the implications of COR for the professionals associated with it, for they are citizens too. The ‘differential opportunities for employment and a viable career’ (Rosenhead, 2009, p.S11) between COR and conventional OR are well recognized, but perhaps the intellectual and career risks are not so great, as similar risks exist in other professions ‘without apparently bringing all their colleagues down in penury’ (Rosenhead, 1986, p.337). Thunhurst (1992) highlights the potential benefits resulting from such risks; for example, the dissemination of case accounts of COR practice published in refereed journals, which serve to add to rather than detract from the career prospects of professionals, especially those in academia. Nevertheless, it is not surprising to find that much COR practice consists of student projects and community outreach work (Parry and Mingers, 1991).

The preceding discussion enables us now to turn our attention to addressing our guiding question, ‘*are citizens able to act in their own interests*?’ While much COR practice focuses on citizens’ interests, in the sense of the meaningful engagement of people in communities (Midgley et al, 2017), it is not clear whether such efforts can bring about more fundamental change in society in the service of their interests. Indeed, if fundamental change was really likely, it is possible that this might negatively affect the acceptance of COR within the professions, as many professionals have been successful within the status quo and might therefore want to preserve it. Others, however, might put the interests of the wider citizenry first. Perhaps an equivocal answer is warranted in response to this question.

3.3.2 Citizen Science

Irwin’s book includes several cases that highlight the struggle of citizens to have their concerns taken seriously when science is brought in ‘to defend certain industrial and political practices’ (Irwin,

1995, p.28). He encourages us to be sceptical of the reassurances resulting from investigations when 'science is the servant of power – its investigations claim to open up the possibilities for policy-making but instead serve to reinforce the existing social order' (p.29). Indeed, the politics of the science profession itself act to maintain the status quo. Stewart (cited in Irwin, 1995, p.159) provides an example of this in relation to science shops, and suggests that scientists are reluctant to engage in 'loaded' situations in which they are expected to prove what is already known by citizens. Furthermore, Stilgoe (2009) documents the divide between NGOs and scientists as the latter become increasingly sceptical about the former's instrumentality in using scientists to further their agendas, which may leave them marginalised in their own professional communities. Although the career risks for established scientists are great, the pressure to conform is perhaps strongest for early career scientists who may be 'afraid to say what they think' (Stilgoe, 2009, p.41). Ironically, CS could actually worsen this situation as a research assistant's work could be outsourced to willing amateur scientists, thus making career opportunities increasingly scarce (Riesch and Potter, 2014, pp.117-118).

Not all scientists avoid politics though, and Stilgoe (2009) highlights this in stating that 'All scientists are citizens, but not all scientists are Citizen Scientists. Citizen Scientists are the people who intertwine their work and their citizenship, doing science differently, working with different people, drawing new connections and helping to redefine what it means to be a scientist' (p.11). Recognition of this overlap between science and citizenship forces us to consider the possibility of the politically minded scientist, 'whether born political, acquired an interest in politics or had politics thrust upon them' (Stilgoe, 2009, p.47), who sees CS as a channel to create change through science.

Stilgoe identifies Sulston as a professional scientist and promoter of CS who recognises the ever-increasing body of scientific knowledge and asserts the need for it to be freely available (Sulston and Ferry, 2002). This takes CS into highly political territory, as open access has challenged the established business model of big publishers and should serve to enable citizens to have the same access to scientific information as professionals. Even more controversial than freedom of information, however, is the related issue of patents. Taking a medical example, there is, on the one hand, the argument that medicines are more expensive because of patents which serve to deprive the ill of treatment when resources are scarce; on the other hand, there is the argument that some treatments might not have been brought to market without patents and the investment money they attract (Ossorio, 2015).

It would seem that, while scientists are free to a degree, they are still constrained by power structures and these are related to standards of good science (concerns regarding this have already been referred to in section 3.2.2). The dominance of these structures is revealed in Funtowicz and Ravetz's (1993) comment that 'It has hitherto been a well kept secret that scientific "facts" can be of variable quality' (Funtowicz and Ravetz, 1993, p.740). While their PNS serves to address concerns regarding quality, it too has been subject to criticism of its political underpinnings. Funtowicz and Ravetz (1993) base PNS on engagement with an extended peer community that they anticipate might create 'a possibility for the development of a genuine and effective democratic element in the life of science.' (pp.740-741). Despite such a possibility, Wesselink and Hoppe (2011) decry the naivety of

Funtowicz and Ravetz in assuming that 'the inclusion of extended peer communities ensures dealing with values and stakes' (p.3). By way of remediation, Wesselink and Hoppe suggest PNS professionals refer to Pellizzoni's (2003) and Turnpenny, Lorenzoni, and Jones' (2009) efforts to advance a more politically sophisticated mode of operation.

It is now appropriate for us to turn our attention to addressing our guiding question, '*are citizens able to act in their own interests?*' The foregoing discussion has revealed that, despite a long history of science serving the powerful, challenges are emerging under the banner of CS, and new forms of scientific endeavour rooted in alternative ideologies are being created. But these are sitting alongside other CS practices that are really more about citizens serving mainstream science. So, once again, perhaps an equivocal answer is the best we can provide in response to this question.

3.4 Reflection on the Commonalities and Differences between COR and CS

This section represents a space to pause and reflect on the commonalities and differences between COR and CS that our systematic comparison has revealed. Looking back at the impetus for COR and CS, it appears that both were created in reaction to the neglect of citizens and their interests by the OR and wider scientific professions. Since the creation of COR and CS to rectify this neglect, structures to ensure citizen access to them have been put in place and resourced from professional association and public funds. Engagement with citizens and their interests, though, shifts the source of research questions from theory to practice and also affects the type of question that is deemed worthy of attention. Addressing research questions derived from practice demands new approaches and much effort has gone into this; for example, COR can now draw on a range of approaches represented within the OR literature, including Problem Structuring Methods (Rosenhead and Mingers, 2001), Critical Systems Practice (Jackson, 2000) and Systemic Intervention (Midgley, 2000).

Citizen science appears to have approached this shift from theory to practice in a different way to COR, by encouraging the engagement of citizens with questions that they may have had a role in generating. Consequently, alternative issue-based approaches and logics have been proposed, such as PNS, which are more fundamentally engaging of stakeholders and can be seen to offer the potential for a new method of practising science.

Hence, it would seem that epistemological and methodological developments have taken place that enable both COR and CS to shift the source of research questions from theory to practice. Whether this happens, of course, is largely a matter of ideology and politics. The notion that the professional needs to be politically minded has been long established (Rosenhead, 1986; Midgley and Ochoa Arias, 1999), but such a notion is rather overlooked in mainstream science. Suffice it to say that some COR (e.g. associated with the works of Rosenhead, Jackson, Midgley and Ochoa-Arias) and some CS (e.g. associated with Irwin, Funtowicz and Ravetz) is underpinned by an ideology that challenges traditional power relations and professional structures.

Our systematic comparison of COR and CS has revealed points of commonality and difference that help define each of these areas of practice, but we must now ask, do such distinctions matter?

Well, in some ways ‘no’ and in some ways ‘yes’. Focussing on definitions and professional territories creates divides that sustain current disciplinary arrangements and distract attention from the main issue: the production of knowledge that serves citizens’ interests. That said, clarity of definition is important if it supports awareness of:

- The potential for mission creep. Midgley and Reynolds (2004) recognise this when they state that, ‘most of those who joined the Community OR movement in the late 1980s and early 1990s either disagreed with Rosenhead’s political agenda, or were largely unconcerned about it’ (p.311); and
- Conflicting interpretations of purpose. For example, the crowd-sourced interpretation of CS may be regarded as reinforcing the dominant technocratic ideology that other versions of CS were created to challenge. This plurality of purpose is also evident in COR (Wong and Mingers, 1994).

Thus, while the need for clarity of definition of both COR and CS is recognised, this should serve to reinforce rather than undermine the potential for bringing COR and CS together in constructive alignment. It is appropriate at this point to make explicit how such an alignment might be realized.

4. Aligning COR and CS: Micro, Meso and Macro Level Considerations

In this section, we explore how, and for what purposes, COR and CS might be aligned. While critical of the White Paper on Citizen Science for Europe (SOCIENTIZE, 2014), we do find value in its distinction of the micro, meso and macro levels of practice, which we draw on here to structure our exploration. At the micro level, we focus on a single case of combined COR and CS practice. At the meso level, we discuss how learning might be derived from the evaluation of multiple cases to inform key stakeholders, such as scientific advisors who operate in the policy interface space. Merely identifying the need for evaluation is not sufficient though, and we are required to consider how it might be funded, which causes us to reflect on the macro level issues and belief systems that affect the distribution of resources in networked communities.

4.1 The Micro Level

Environmental management (Midgley and Reynolds, 2001, 2004; Gregory et al, 2013) is an area with a long history of practice that might be said to combine COR and CS, and it is appropriate for us to engage with a case study of practice at this point. To be clear though, the reason for including this case is not to illustrate the use of an approach to addressing an issue that might be categorised as both or either COR and CS (a fuller account of the workshop is given in Atkins and Gregory, 2015; or, for a similar engagement where the models have been more developed, see Videira, Lopes, Antunes, Santos, and Casanova, 2012). Rather, the case is included to promote understanding of what needs to be considered at the micro level of an aligned COR and CS practice.

Our case concerns one of the grand challenges of our age, the achievement of Good Environmental Status in the marine environment. The Marine Strategy Framework Directive (MSFD,

Directive 2008/56/EC) was approved in 2008 by the European Parliament and the European Council to establish a framework for community action in marine environmental policy (European Commission, 2008). The Directive sets out eleven qualitative descriptors of Good Environmental Status in the marine environment and requires member states to achieve it by 2020 (Official Journal of the European Union, 2008). Achieving Good Environmental Status is problematic though, because of the innate complexity of the marine environment and the variety of stakeholders, who obtain an array of benefits from ecosystem services (Atkins, Burdon, Elliott, and Gregory, 2011; Atkins, Gregory, Burdon, and Elliott, 2011), with associated ecological, social, and economic knowledge claims and concerns. Work on ecosystem services challenges the role of scientists in setting the environmental agenda, which distinguishes this area as a prime candidate for a combined COR and CS effort. The workshop that forms our case was part of DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status), a collaborative project funded by the European Union for 4 years (2012-2016) with a total budget of €12 million. The focus of the workshop was on developing understanding of the drivers of, and barriers to, the achievement of Good Environmental Status at the UK's East Inshore and East Offshore Marine Plan Area, as defined by the Marine Management Organisation (2014).

The question of who to involve in a stakeholder-focussed workshop is inextricably linked to that of whose interests the workshop serves, how improvement is to be defined and what action should be taken (Churchman, 1968, 1970, 1971). Stakeholder identification commonly involves a process of brainstorming a list of likely stakeholders and subsequently expanding on this through contacts and referrals until no new stakeholders are suggested (Freeman, 1984, 1994, 1999; Mitchell, Agle, and Wood, 1997). In practice, scheduling events to accommodate different stakeholders is tricky and, as a matter of expediency, it is necessary to identify important stakeholders and schedule the event to fit their diaries. Hence, much stakeholder work is couched in terms that are supportive of current power relations involving classifications around power, legitimacy and urgency (Mitchell et al, 1997). Midgley (2000) reflects on this and suggests that researchers should deal with power explicitly up-front in any such exercise; if this is not done, then the use of power may be hidden to ensure that the interests of the powerful are best served. Ulrich (1996a) and Midgley et al (1998) refer to the process of critically investigating who is and is not regarded as having a legitimate stake as the process of 'boundary critique'. Related to this process is the requirement for systems design to take on the *whole system* (acknowledging that what counts as the 'whole' can be contested) because localized action, based on partial understanding, can lead to unexpected consequences for the wider system (Ulrich, 1988b, credits Churchman with this insight). Of course, to attempt to understand the whole system is an impossible task; what is important, therefore, is to accept the inevitable *lack* of comprehensiveness in our designs, but to make this transparent so all stakeholders can reflect critically on any limitations and their likely implications (Ulrich, 1983, 1988a, 1988b).

In our case, an initial list of stakeholders was identified by members of the DEVOTES research team in response to the trigger question, 'who should have a stake in this issue?' Stakeholders were grouped into four categories: conservation interests/advisory; planning, licensing and management;

marine resource users; and science and academia. Recommendations for widening participation to include other stakeholders were followed up and 24 participants were engaged in the workshop held on 27th November 2014 at the Management Learning Laboratory, Hull University Business School. In the pre-workshop stage, a process of boundary critique attempted to ensure that the 'right' knowledge was brought to bear, although it was recognised that participation alone does not guarantee a broad and inclusive discussion (Arnstein, 1969). To this end, we looked to Taket and White (2000) for practical instruction on facilitation that is tolerant of difference and attuned to what is achievable at the local level. As regards methodology, the works of Eden (1980, 1988, 1992), Eden and Ackermann (1998, 2001) and Shaw, Ackermann, and Eden (2003), which offer simple modelling techniques, were drawn upon with the aim of creating insightful moments for participants 'to see the connections between wholes and parts' (Bryson, Ackermann, Eden, and Finn, 2004, p.298).

As DEVOTES considers three specific descriptors as being particularly important for achieving Good Environmental Status (biological diversity, food webs and non-indigenous species), it was decided that these would provide the focus for three modelling subgroups, each supported by a participant facilitator. The subgroups looked to create cognitive maps of the local case site, which they developed through the elaboration of chains of cause and effect (Maani and Cavana, 2007) that captured the essential nature of the system. Workshop participants used Decision Explorer® software to support the development and analysis of the models.

The engagement of a range of stakeholders in the workshop led to the issue of how to manage different knowledge claims, given that to deny or limit the expression of expertise would be a falsehood akin to believing 'democracy means that "my ignorance is just as good as your knowledge"' (Asimov, 1980). While mindful of Habermas's (1974) theory of dialogue, which says that 'ideal speech' involves everybody having a chance to challenge others on the grounds of truth, morality, sincerity and intelligibility (Gregory and Romm, 2001, 2004), it was recognised that some stakeholders had an understanding of the bigger picture that justified the prioritisation of their concerns over others. Nevertheless, when the bigger picture was prioritised, it was essential to explain the reasons for it in terms of the consequences of a narrow versus a broad view (Ulrich, 1983, argues that explaining the reasons for limitations on discussion is a minimum requirement for respectful, non-manipulative dialogue). Such an approach accords with Bäckstrand's (2003) argument that 'subjugated, local and indigenous knowledge should not necessarily be regarded as better or truer than modern scientific knowledge. In the end, to find the appropriate balance between technical and communicative rationality is a pragmatic and context-dependent judgement' (p.35). Given the need to manage knowledge claims, there was a concern to assess whether participants felt that their voices had been heard in the workshop, so the post-workshop evaluation focussed on matters of communication, consensus and commitment (Rouwette, 2011). See Table 2 for details.

Table 2. Summary Evaluation Results (n=10)

To what extent were the following delivered	Fully	Partially	Not at all	Not sure
(a) An expert view on the current status of the implementation of MSFD	3	6	0	1
(b) An opportunity to engage in a discussion with and better understand different stakeholders viewpoints on Good Environmental Status	6	3	0	1
(c) A better understanding of three key Good Environmental Status descriptors (biological diversity, food webs and non-indigenous species)	3	7	0	0
(d) An introduction to and experience of building and analysing models using Banxia's Decision Explorer® software	6	4	0	0
(e) Understanding of opportunities for and barriers to the achievement of Good Environmental Status	1	7	0	2

The evaluation results and comments from participants during the workshop suggest that further time was required for the analysis of the models for a more complete understanding of Good Environmental Status to be achieved. However, it is important to note that the evaluation did not include consideration of: the perceived 'correctness' of the models, according to the modelling approach adopted; the completeness of the models; and certainty of knowledge upon which the models were based. The last point is particularly pertinent as, during the workshop, a need to capture estimates of the reliability of knowledge was articulated (this need is also recognised in PNS and satisfied through the employment of the NUSAP technique). A concern to ensure the reliability of knowledge on which a model is based nudges us towards the use in combination of different OR approaches (Mingers and Gill, 1997). Indeed, we might have enhanced the model-building effort through the inclusion of Strategic Assumption Surfacing and Testing (SAST) (Mason and Mitroff, 1981) to reveal underlying assumptions and knowledge claims. While SAST does not ensure the ideal of perfect knowledge, it does serve to expose any areas of uncertainty and risk.

Participants developed a set of models during the workshop that represented their first attempts at coming together to share their knowledge of a system of concern using an approach that was new to most of them. As such, emphases were placed on surfacing the diversity of factual claims, opinions and values involved in the situation (Renn, 2008), the co-production of knowledge, and ownership of the models (Videira, Antunes, Santos, and Lopes, 2010) rather than the technical correctness of the process or the models produced. However, privileging such outcomes can become a source of tension if the professionals involved are subject to the drive for publication (Miller, Taylor, Bedeian, 2011; Feeney and Welch, 2014). In the area of CS, it has been found that journal articles, using the wealth of volunteer collected data available, are not as common as expected (Conrad and Hilchey, 2011), but there are several possible reasons for this. First, most publication outlets are not attuned to this form of engagement, and the standards of more mainstream academic journals might lead to the rejection of any papers that do not conform to academic norms. Academics learn the intricacies of specialist terminologies over many years, and the ability to write fluently with these terminologies is a big part of getting published, so non-academics are at a disadvantage. Consequently, for publication to be assured, there may be a need to sanitize or even enhance accounts of, and outputs from, stakeholder-based engagements; for example, even Videira et al (2012), whose work has a heavy focus on participation, states 'The diagrams are presented…depicting as much as possible the way

that participants drew them' (p.608). Why 'as much as possible'? Why not *as was*? The creation of online open access journals dedicated to community-based engagements (for example *Citizen Science Quarterly* and *Citizen Science: Theory and Practice*) may change the publication landscape though, especially if they focus on both 'the story of the content of an OR model and the story of the intervention that generated the model' (Klein et al, 2007, p.1535). Perhaps institutional developments, such as the UK's Research Excellence Framework (REF) exercise, have promoted a move in this direction by including consideration of impact. However, this introduces new issues as it seems to place greater emphasis on work that has national or international rather than local impacts. Also, impact alone is not sufficient for the REF, as publication is also required. Maybe the need for publication to accompany impact represents as much an opportunity as a challenge, although it does imply the need to consider the related and often contentious issue of acknowledgement of diverse contributions, including those from non-academics. Riesch and Potter (2014) recognise that there can be an expectation of 'explicit acknowledgement of the public contribution on the same terms as that of the scientists, through for example co-authorship in scientific publications' (p.117). While this is a worthy ideal to strive for, in practice it may well become an area of active politicking and controversy over who contributed what.

4.2 Meso Level

In the previous section, a case example served to demonstrate what needs to be considered at the micro level of an aligned COR and CS practice. The value of such a case, plus the need to evaluate in order to derive generalisable meso level learning, is recognised in both COR (Midgley and Reynolds, 2004; White, 2006; Midgley et al, 2013; Yearworth and White, 2014) and CS (ETHZurich, 2016). The meso level, though, is beset with conceptual and organizational challenges under present arrangements, as there is a need to combine the essentially observational methods of the natural sciences with knowledge from the social sciences and other sources (Midgley, 2008; Nature, 2016). COR, with its armoury of PSMs and systems approaches, is well placed to provide this level with social insights and to make available support for the design of evaluation, knowledge elicitation and decision-making approaches. Use of such approaches may lead to understanding of the ecological, economic, political and social conditions required for the success of an aligned COR and CS, based on relevant criteria such as citizen emancipation and the use of citizen-generated data and knowledge by decision-makers (Conrad and Hilchy, 2011). In addition, through the definition of relevant criteria of success at this level, incentive structures might be designed at the macro level to stimulate good practice at the micro level. Progress to this end is already evident, with a recent surge of interest in PNS; see for example articles in the *Guardian* (2007), *Nature* (2016) and the special issues of *Science, Technology and Human Values* (2011) and *Futures* (2017). The cause of PNS was further bolstered by Gluckman's (2014) statement that, after five years in the post of New Zealand's Chief Science Adviser, he had 'come to understand that the primary functions and greatest challenges for a science adviser are providing advice not on straightforward scientific matters, but instead on issues that have the hallmarks of what has been called post-normal science'.

The natural territory of scientific advisors, such as Gluckman, is that of the meso level science-policy interface (Heink, Marquard, Heubach, Jax, Kugel, Neßhöver, Neumann, Paulsch, Tilch, Timaeus, and Vandewalle, 2015) and, over the past 20 years, calls for greater interaction between science and policy have provided the impetus for the proliferation of spaces in which that interface can be realized (Heink et al, 2015). Salience, credibility and legitimacy (Cash, Clark, Alcock, Dickson, Eckley, and Jäger, 2002; Cash, Clark, Alcock, Dickson, Eckley, Guston, Jäger, and Mitchell, 2003) have been defined as relevant to the assessment of knowledge within the interface space. However, it is recognised that credibility is often valued over salience and relevance, and that 'actors on different sides of a boundary perceive and value...differently' (Cash et al, 2002, p.1). Such a statement suggests recognition of the need for approaches to structuring issues and dealing with knowledge and value claims; a need which could be met by COR with its armoury of problem structuring methods and systems methodologies designed for just such a purpose (e.g. Ulrich, 1983; Friend and Hickling, 1987; Midgley, 2000). There is also likely to be a need in this meso space for the tools of traditional OR and CBOR in performing policy analysis. As Johnson and Smilowitz (2012) recognise, CBOR may 'complement policy modeling by generating solutions associated with direct and rapid improvements in individual and neighborhood-level outcomes' (p.40). Armed with such information, it is important that professionals put it to good use by influencing the actors and forces that shape decisions and policies at the meso level. But this has traditionally been difficult to do when the distance between COR professionals and policy-makers has been too great for them to have an effect (Caulkins, 2002, makes a similar statement with regard to OR in the US). Activity at the meso level may serve to close the distance between professionals and policy-makers, and the formation of such spaces may be guided by Stone, Maxwell, and Keating (2001), who summarise the actors and networks involved, and by Kingdon (1984), who provides a dynamic model of agenda setting.

Having established awareness of meso level issues and how they may be addressed, it is now necessary to ask who might resource such work. The obvious contenders are NGOs and civil society organizations, but it is recognised that they,

> have puny research resources by comparison with their corporate and state opponents. They seriously lack, and desperately need, the means to aquire reasonably reliable, scientifically validated information on a great variety of highly technical matters. They ought not to have to rely on whatever happens to emerge out of the research system. They need to be able to initiate research projects relevant to their political missions, and have full access to their findings (Ziman, 2007, p.321).

Frickel, Gibbon, Howard, Kempner, Ottinger, and Hess (2010) refer to 'areas of research that are left unfunded, incomplete, or generally ignored' (p.444), which civil society organizations and NGOs nevertheless deem to be worthy of research. They call these areas 'undone science' (p.444). There are three possibilities for other sources of financial support for such work: public research funding; crowdfunding; and pro bono research. However, the emergence of alternative funding mechanisms like crowdfunding should not simply be assumed to be a good thing, and this will be discussed with reference to the next level of analysis.

4.3 Macro Level

A key assumption of this paper is that CS has a preferential position to COR, and this affects the availability of research funding and support. This section will address the macro level and structures that affect research funding and support by considering the distribution of resources and belief systems.

The White Paper on Citizen Science for Europe (SOCIENTIZE, 2014) states that the emergence of more direct and democratic funding mechanisms should be seen as 'a wake up call for policy makers and research funders' (pp.27-28). Gauchat (2015, 2016) also recognizes such a phenomenon in the US, and it is worth asking what is causing these alternative funding mechanisms to emerge. One explanation is that policy makers and research funders are out of touch and simply do not value some citizen-focussed projects sufficiently highly to fund them. An alternative explanation is that the priorities of policy makers and research funders do align with those of citizens, but a shortfall in funds creates the need for alternative funders to supplement established arrangements. There is also a political explanation for the limiting of funding for research. Since WW2, the use of public funds to support research has been justified on the grounds that it creates economic progess. The revelation that wealth is growing faster than economic output (Piketty, 2010, 2013), causing the divide between the rich and poor to increase, makes the use of public funds to support research hard for policy makers to justify to the majority of citizens. It is significant, though, that it is not merely those who are 'just about managing' (HM Treasury, 2016) that are questioning the funding of science. Gauchat (2016) claims that support for science is a matter of 'deeply held cultural dispositions and identities' and suggests that it is a factor in the increasingly sophisticated way in which we project identity and differentiate ourselves from others. Such developments could increase the politicization of funding and, with respect to the US, Gauchat (2016) suggests that '"opposition" to funding coheres on the political right'. In the USA, it appears that the right wing respects authorities and belief systems other than the scientific, such as those associated with religious institutions. A more selective approach to what gets funded would appeal 'to their base of support, alienate strong intellectual adversaries, but not greatly offend the public at large' (Gauchat, 2016).

While the reason for the emergence of alternative sources of research funding may be unclear, it is nevertheless the case that the diversity of belief systems has increased, and this has been to the cost of engagement in scientific inquiry. Recognition of this causes us to argue that there has never been a more opportune time for an aligned COR and CS effort at the macro level, offering analytical support to assist understanding of how beliefs come about and how they are influenced. In highly connected networks, beliefs are reinforced, emotions roused and action incited while, at the same time, critical thinking is suspended and contradictory information denied. Perhaps more concerning still is that 'individuals with shared interests are far more likely to find each other or converge around a source of information online than offline' (Benkler, cited in The Economist, 2016). The internet is a key enabling factor, as unreliable or deliberately incorrect information can be distributed quickly and widely. Indeed, potentially, an outlandish posting on the internet is more likely to attract attention and

rise up the search engine rankings as the latter are based on the number of clicks received rather than the quality of the information provided (Sullivan, 2016; Baraniuk, 2016). Here it is argued that there is a special role for COR and CS in networked communities to:

- Get closer to citizens by using our knowledge about how networks operate. In particular, cybernetics, complexity science and systems theory offer insights into networking. This might shift the focus of COR from its tradition of working with physical communities to working with, and intervention in, online communities, and it might also make COR more relevant to, and afford great opportunities for, engagement with citizens and policy makers.
- Encourage critical engagement and counter incorrect information by offering access to 'practical tools for orienting social problems and overcoming common biases in perceiving social reality. Here, we do not belittle audiences by positing intellectual deficits or elite manipulation, but identity cognitive limitations common to all humans and how they might undermine our collective actions' (Gauchat, 2016).

In framing networked communities in this way, an opportunity is created for COR and CS to help create a more informed and empowered citizenship and a policy process in which 'science insights as well as subjective sources of knowledge are integrated. Additionally, it focuses on enriching the mental models of actors in a policy network by means of multilogic communication' (Geurts and Joldersma, 2001, p.309).

5. Conclusions

One of the aims of this paper was to provide a systematic comparison of COR and CS. Achievement of this aim revealed that there is sufficient commonality between COR and CS to provide the basis for a meaningful alignment and, at the same time, sufficient difference between them for this to be worthwhile. COR's strength in intervention-based approaches, offering access to practical methods for structuring social issues and managing knowledge and value claims, and CS's foci on engaging citizens in the analytical examination of the world, and the assessment of information quality and risk, means that they might come together for mutual learning. The achievement of the paper's second aim, to establish how an alignment of COR and CS might be realised in practice, has led us to argue that there is a need for:

- The evaluation, at the meso level, of micro level cases of combined COR and CS practice that yields theoretical learning, and
- Recognition that there is an important role for COR, in support of CS, at the meso and macro levels in offering analytical support to assist understanding of how belief systems come about and how they can be influenced in networked societies.

These needs are of heightened importance at a time when society's long-granted authority to institutions (for example, the education, science and legal systems) that employ rational inquiry, capable of challenging unevidenced personal belief, is in jeopardy. Recent scandals involving high profile actors in such institutions, and concerns regarding the unequal distribution of resources, have undermined their status; but such circumstances, it may be argued, represent an opportunity for a

much needed alignment of COR and CS. Of course, we are not the first to identify such a need (although previous authors have not focused specifically on COR and CS) and, by way of drawing this paper to a conclusion, it is worth reminding ourselves of Beck's wise words: 'scientific rationality without social rationality remains empty, but social rationality without scientific rationality remains blind' (Beck, 1992, p.30).

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