The Importance of Scale Complexities in Fisheries Research

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Diverse fishing boats off the Conche harbour. Credit: Evan Andrews

Abstract

Complex issues of scale are fundamental to all our understanding: they so much underpin it that they often pass unnoticed, and we fail to realize that the situations we are examining may be operating at mismatching *geographical, temporal, technological and/or intellectual scales*. It is only by being aware of these different scales that we will be able to recognize when one or more of them are in play and may possibly conflict. The paper examines these scales and their possible mismatches in turn and indicates their importance for fisheries management at all scales (including local small scales) in fisheries management in Canada and globally.

Introduction

Complex issues of scale are fundamental to all our understanding: they so much underpin it that they often pass unnoticed, and we fail to realize that the situations we are examining may be operating at mismatching *geographical, temporal, technological and/or intellectual scales*. It is only by being aware of these different scales that we will be able to recognize when one or more of them are in play and may possibly conflict. Only then can we interrogate fisheries management adequately, recognizing at which scale(s) we should be examining that. Scale, in this sense, is a graduated range of units of value, forming a standard system for measuring or grading something. The ranges involved can be considerable. *Geographically* the lens can vary from the atmospheric and global (which brings in climate change (Miller et al. 2010; IPCC 2021) to the local. *Temporally* scales can vary from millennia, or decadal to timespans of a day or less. *Technology* is also scalar in the sense that we deal with a large range of vessel and gear sizes, for example, which have different implications for management. Even academic disciplines are scalar in that the *intellectual* scale at which scholars work may range from the disciplinary or even sub-disciplinary through multidisciplinary or interdisciplinary to transdisciplinary (Perry & Ommer 2003). Scales can also intersect: business, for example, operates in long and short-term cycles (Kondratieff 1935), while functioning at various geographical scales. The point is that it is important to recognize whatever potentially important scale factors are involved in the issue we are studying (see e.g., Perry & Sumaila 2007) and pay attention to how they interact. Clarifying this will then let us know how widely our work covers the matter at hand and hence what we may have not included, or not thought about, that may also need to be considered by us, or pointed to for consideration by other scholars.

Small-scale, social-ecological, and community-based fisheries research comprises studies of communities of fishers *and* their interdependent communities of fish — an important concept that is still inadequately recognized (Berkes in Ommer et al. 2011). In more recent years such studies have been addressing issues of scale, and this has brought to light the narrow basis of fisheries policy and its application in fisheries management globally, nationally and locally. It has illustrated the kinds of mismatches in the scholarship that lie behind policy and management matters and often arise from inadequate consideration of scale. It is a pity because the problem has hindered the pursuit of fruitful ways forward that could result in more appropriate prosecution of fisheries at all levels, including Canadian small-scale fisheries. Let us examine the ones I have selected, in turn.

1. Scholarly approaches: The intellectual scale of what we do

Fisheries scholarship in the past has suffered from too little interdisciplinary work despite the complexities involved in fisheries, a problem that has still not been widely understood and applied. It is hard to teach student scientists, given the way most academic institutions are currently organized, and also the organization of the funding sources available to them and their professors (Andrews et al 2018; Ommer 2018). This is unfortunate since discipline-based studies provide a necessary, but not sufficient, foundation for understanding all fisheries, not just small-scale fisheries and coastal communities. Initial disciplinary bridges in and between government and the universities have always been there: most government scientists were university trained. But for most of the problems in fisheries, this is not adequate: they need to understand society, and hence the social sciences, if marine governance is to be responsive to the dilemmas it faces. This is increasingly being recognized, as in ICES/PICES and the US Integrated Ecosystem Assessments, but more integration is needed.

Interdisciplinary bridges have been built, but have mostly been between economists and marine biologists, probably because the quantitative approaches, economic models and methodologies of both fields are compatible. However, good as they were and are, such models do not and cannot take into account the complexities of human behaviour (Beverton & Holt 1957; Parsons 1996), nor do they demonstrate adequate awareness of the marine environment. The thinking behind such modelling is, at its simplest, that the number of fish next year can be calculated from the number of fish that occurred this current year, the assumption being that the natural environment varies randomly and thus can be ignored over longer time scales. This means scientists must apply their findings to larger-than-local spatial and temporal scales, but the consequent lack of awareness of local environments renders such models deficient, given the importance of small local scales where so many nurseries for fish occur. That can be remedied by the kind of interdisciplinary small-scale analysis that uncovers local human knowledge of the marine environment as well as the motivations of inshore fishing families, even though not all of them will necessarily always see things the same way!

In the university research community, interdisciplinary research involving social and natural scientists began to be developed in the 1990s, although the same cannot yet be said for many government science research programs. The first in which I was involved came about after the collapse of the northern cod (Ommer 2002), a social-ecological disaster that rendered the cod stocks of the northwest Atlantic commercially extinct and threw over 30,000 people out of work overnight.The resultant crisis created a research funding opportunity for those who could work across the great divides between health, natural science and social science/humanities, in a Canadian government funding program 'the Green Plan'. In 1993, a team of thirty researchers from these three rubrics came together to carry out 'eco-research' (a name we adopted) to explore the social-ecological ramifications of the collapse. We worked at various scales including community-level analysis, with marine scientists, sociologists and ecologists all involved in field research, including fishers' local knowledge, which was not generally accepted at that time. We understood that working with local fishers tells us about the complex dynamics that exist between communities of fish and communities of fishers and about the relationship between these. It makes us aware of how artificial is the divide between people and nature. I am aware that to say humans are part of nature is to challenge received wisdom, and it is precisely that kind of thinking that has kept the social and natural sciences apart for a long time. Humans depend in an absolute sense on the environment in which we are embedded, although urban society in particular forgets that, protected as it is by the web of trade and technology that surrounds urban life.

2. Geographical scale

As world fisheries have fallen more and more into disarray, it has become increasingly clear that working with human problems in the social sciences and humanities, and with the fish population problems in the marine sciences, in separate solitudes is proving increasingly dysfunctional. Newer work is involving social scientists, humanists and natural scientists coming together in teams with communities and industry leaders.However, this remains highly unusual, not least because of the institutional impediments involved that inhibit this kind of good work. There are exceptions, including Integrated Ecosystems Assessments, US MidAtlantic Fishery management, and the work of the Canadian Fisheries Research Network. Such work is often detailed and painstaking, but it is essential and rewarding.

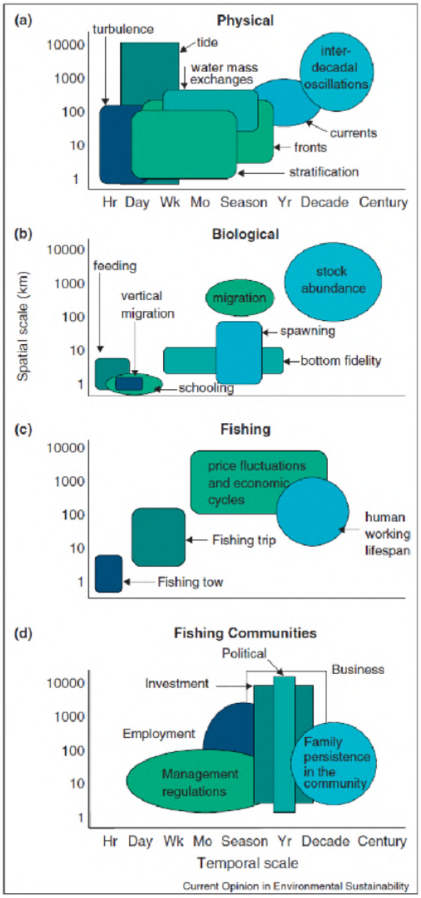

Figure. 1 Space/time-scale diagram of the four different perspectives involved in understanding fish and fisheries from the natural sciences: (a) physical; (b) biological and from the social sciences; (c) fishing; (d) fishing communities (in Perry and Ommer 2003)[40]

Figure 1 shows four different space/time-scale perspectives involved in understanding fish and fisheries. Obviously, the data in which the fishing business community were interested would have been those data and analyses that would be of financial benefit to them, since businesses are mostly

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concentrated in the deep-sea fisheries that are important for employment. These operate at very different geographical, technological and political scales and are carried out for very different purposes. Some of the human activities in Figure 1 may conflict and they certainly require different levels of environmental detail. The local information that small-scale independent fish harvesters possess is probably the most finely-grained and may go back a long way in time. Figure 1, then, shows something of the scales at which the physical, biological, fishing and fishing communities operate, and how these can and often do intersect. Scale complexities are endemic to the fishery.

The beginnings of getting at such environmental and human complexities, in the context of fisheries, began with the work of Berkes and others (Berkes et al. 1998), who created the concept of *social-ecological analysis* that set us on the path to researching and understanding human-marine ecosystem reciprocal interactions. In an important 2011 paper for a global audience on the concept, Berkes noted that "*the delineation between social and ecological systems is artificial and arbitrar*y" and that "*restoring unity*" in managing marine fisheries is necessary and is achieved through reconnecting "*natural science, social science, and humanities perspectives*," reconciling "*the various disciplines*" as part of the process (Berkes in Ommer et al. 2011, p. 9). He then discussed the implications of that and appropriate methodologies. As an approach, social-ecological analysis is now being used more, but has not yet met with wholesale adoption. It is a good way of understanding the interdependency of people and the marine ecosystem (Ommer 2007; Ommer et al. 2012; Stephenson et al. 2018) at a variety of geographical and temporal scales.Social-ecological systems are, of course, hugely complex and central to the evolving state of global fisheries; by definition, they require interdisciplinary approaches and environmental awareness.

When dealing with scale issues in social-ecological systems, it is important to consider lay and expert knowledge because it is imperative that we think about the *purpose* for which such knowledge has been created. The matter is one of motivation (goal), and involves both geographical and intellectual scale. Fishers are *harvesters*. Their knowledge is about where, when and how to catch fish. That means knowing a great deal about the fish themselves, and their behaviour within a local and thoroughly understood ecosystem. There are three groups to be thought about here: small-scale fishers, academic scientists and government scientists.

Small-scale fishers know about fish and fishing assemblages – but only about the ones with which they are or have been engaged. In Trinity Bay, NL, for example, their taxonomy for codfish (*Gadus Morhua*) in the 1990s distinguished between 'herring fish' that came in the spring following the herring, and cod that came later. They talked about 'mother fish', larger older and more fecund female cod that they thought settled out in deeper water: some thought they should be protected because of their importance to the stock. Local taxonomies speak to local ecosystem dynamics. They also speak to behavioural and other complexities in a way that standard stock assessment concepts like 'biomass' do not. Because fishers classify fish according to local harvesting information built up over generations, they are aware of micro-level variability and trends that are often invisible in stock assessment data. These kinds of knowledge can be aggregated by researchers across spatial and temporal scales: taking the data from interviews with fishers from different bays, through headlands, to offshore, and from several generations, for example, it is possible to assemble information that is often unavailable, or only partly available, in stock assessment data. Local fishers' knowledge encompasses effort as well as catch information (including changes in efficiency), along with spatial and temporal distribution of effort, and information on fish migrations. That means it can be used to track trends in efficiency, which is crucial for the interpretation of catch per unit of effort data and relevant to understanding trends in abundance. Harvesters, as well as processors and others in the industry, also know a great deal about markets and value chains, including past data, and this can provide insights on discarding practices – i.e., fishing mortality that often does not make it into landings statistics.

Local fishers' collective insights may be *similar* to those from stock assessment science — in which case they provide independent verification; where they *differ*, they provide the basis for careful analysis of both sets of information in order to move understanding forward. This is perhaps particularly important for under-studied and relatively low abundance species that can be depleted through bycatch fisheries and targeted fisheries. As shown in research on the northern cod collapse, effort after that has tended to shift to these other species in the context of resource decline (Neis et al. 1999). The wisdom of local fishers can point to information that government scientists using trawling samples cannot get far enough inshore to observe and monitor: as in distribution and trends in eelgrass bed abundance, where local knowledge has led to an appreciation of its value as critical nursery areas for fish and shellfish. In like manner, the traditional knowledge of First Nations on the Pacific coast has given us information on, for example, seamounts or cold-water sponges, about which Indigenous fishers and even some non-Indigenous commercial fishers have long been aware.

Our second group under consideration is marine scientists who have been academically trained. They are classifiers of a different kind – their task is to *understand the species as a whole* and in all its physical and related behavioural complexity, and then describe that 'to science' although that is changing a little now as scientists become more acquainted with the importance of writing more broadly, as in the recent IPCC report shows. They deal, therefore, with the species writ large - they are generalists where fishers are particularists.

The third group, government scientists, are a kind of half-way house between the other two, because they work with the specialist scientific language of classification, but then apply that descriptive and classificatory knowledge to issues of harvest *management* in order to make recommendations to policy-makers about management regulations. Strictly speaking, they should actually be a bridge between the other two groups. But, sadly, the local fishers are typically ignored, although they could be working on generating inshore management regulations, the lack of which is an ongoing problem. The frame of their work is actually much wider – perhaps covering several ecosystems or a whole coastline and *that scale pertains to more than deep-sea fisheries.* Beyond that, they may work with other nations to deal with blue water ocean-roaming fisheries. I am not going to get into the additional complexities of that, except to note that the larger NAFO zones, for example, are a problem because they influence the scale at which data are aggregated and quotas set. Here we are dealing with what is essentially a *technological scale* difference, a category I consider later.

It makes sense for all scientists involved in fisheries research, management and policy to listen to the language of harvesters at all scales because it will contain information of use to harvesters and hence also to harvest managers, as well as academic scientists interested in species behaviours and evolutionary distinctions between sub-species. When, as is all too often the case, government science works with only economists, they are not only missing out the local picture, but they create *policy scale* mismatches because they miss out this first part of their mandate. At the local scale, problems are obvious to those living with them. But at larger scales, such problems are less obvious, so policymakers often ignore them. Hence misunderstandings arise in both directions: government science assigns incorrect motivations to communities. This mismatch intensifies existing lack of trust in and respect for small-scale communities since this science has not acknowledged and dealt with the various scales involved, particularly that at which local fishers operate. The obverse of that coin is the distrust fishers have for government scientists and policy-makers. I will address this later, when I consider technological scale.

Figure 2 shows the over-simplicity of the current management model when compared to the kind of complexity we have been discussing. The Figure 2 (from Ommer et al. 2012) offers some explanation for how complex the web of interests in fish and fisheries actually is, and the right side of the figure is, to me, an explanation of why managers try to keep it simple: it is just too complicated! It is, of course, an 'ideal type' and is probably unachievable at least in the foreseeable future, but there is no good reason why thinking that is somewhat more complex than the left side of the Figure 2 could not be taking place within fisheries management. If such complexities were treated seriously, it would let us deal openly with the different scales that are involved in both the human and the interdependent natural world subsystems, and do so without involving the artificial divide between humans and nature. The challenge will be significant, but it urgently needs to be tackled if we are to bring small-scale fisheries and their interdependent fishing communities to the attention of management and policy making, in Canada and internationally, and demonstrate that the global and the local are deeply connected.

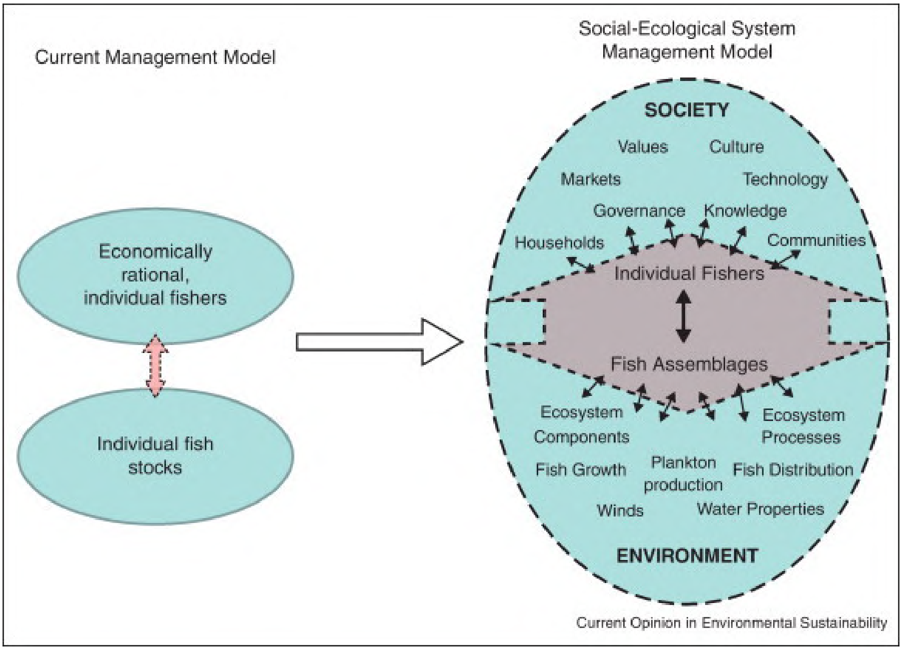

Figure 2. Two fisheries management models (in Ommer et al. 2012)

3. Temporal scale

A third scale problem is that of temporal scale mismatches, such as that manifested by the 'shifting base line syndrome' that Daniel Pauly (1995) has pointed to and that we showed in Coasts Under Stress (Ommer et al 2007; Schijns et al. 2021, especially their Figure 1, depicted below as Figure 3).

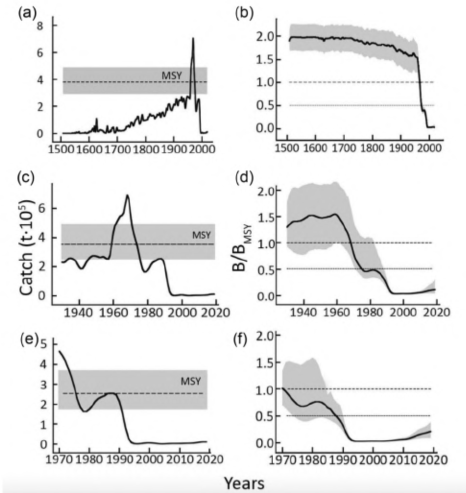

Figure 3. Catch and estimated biomass of Northern cod (Gadus morhua) off Eastern Canada from 1508 to 2019 (A, B), with emphasis on 1930 to 2019 (C, D) and 1970 to 2019 (E, F). The catch and relative biomass level compatible with Maximum Sustainable Yield are shown (dotted lines), along with the 95% confidence intervals (in Schijns et al. 2021)

Figure 3 shows what happens when starting analysis of trends at an artificially selected time, perhaps based on convenience, perhaps on ease of attaining records. The end result is a timeline which purports to show a trend that may be misleading and not consistent over a longer time span. Work that we did in partnership with Tony Pitcher and *The Sea Around Us* project showed the problem on the scale of the whole west coast fishery over time — going back to archaeological time.

Figures 4 and 5 shows the problem and its attendant ills - known as 'fishing down the food web'. These are for the Hecate Strait and for Newfoundland. I do not intend to belabour this point but, as well as showing the problem of shifting baselines and fishing down the food web over time, our work also showed that it was important to recognise not just present, but also past motivations, and states of knowledge 'way back when,' including what data existed and how well they fitted the analysis for which they were being employed. In this respect, the work done by Nancy Turner and her First Nations colleagues has underlined the temporal dimension in their thinking. Indigenous thinking about fisheries is rooted in the concept of stewardship - an essentially multi-generational temporal scale of thinking about the environment, including the oceans that is historically and culturally informed.

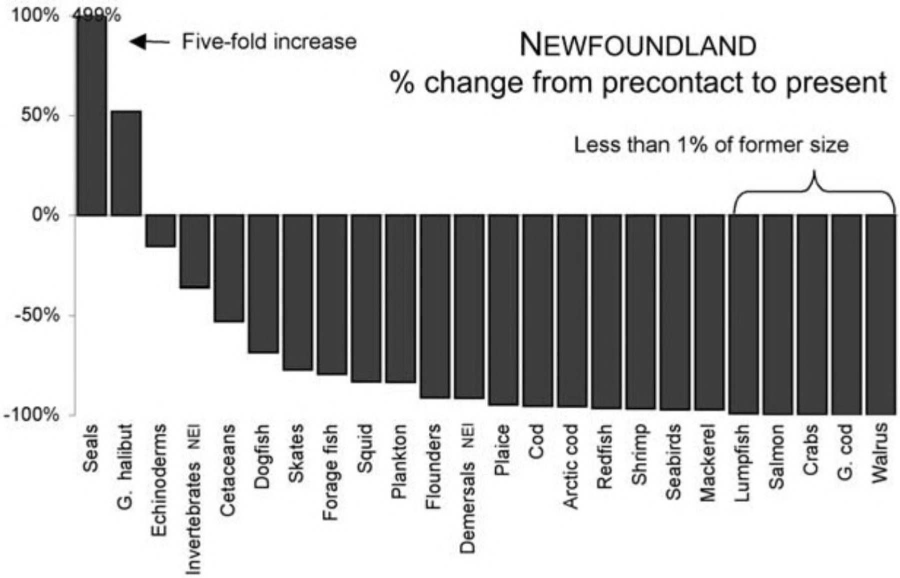

Figure 4. Percentage change in biomasses of selected ecosystem groups from pre-contact to present for Newfoundland, as based on whole-ecosystem simulation models (in Ommer and Team 2007)

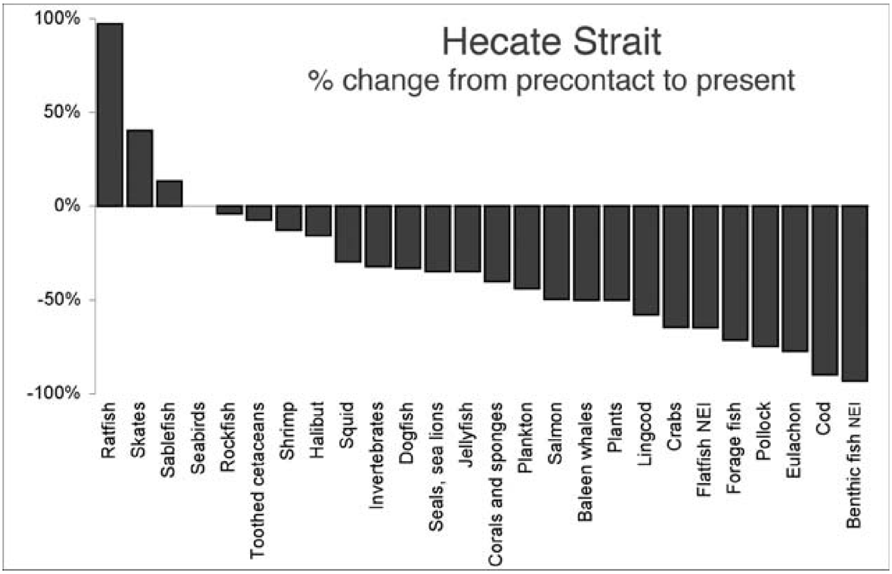

Figure. 5 Percentage change in biomasses of selected function groups from pre-contact to the present for norther British Columbia, as calculated using whole-ecosystem simulation models (in Ommer and Team 2007)

4. And now I get to Technological scale

Interaction between the inshore and the offshore happens in small-scale fisheries management as well, but the interactions are complex and not always obvious. A serious problem in terms of technological scale was evidenced by the 1995 Kirby Report of on the Atlantic Groundfish Fishery (Kirby 1995). The Report thought the inshore fishery was over-subsidized since it was not taking all its quotas. Inshore fishers, however, complained bitterly that they could not catch their quotas because deep sea trawlers had already left insufficient fish for inshore fishers to catch.

Deep sea fishery vessels individually generate significant fishing effort when compared to smaller (midshore) vessels or small (inshore) vessels where the effort is significantly less. The implications for management of these different amounts of effort are that technological scale must be mirrored in marine fisheries management. Said otherwise fishery managers should not be thinking in terms of 'too many fishers chasing too few fish' but in terms of 'too many large-technology trawlers chasing too few fish'.

The collapse of the groundfish fishery in the NW Atlantic, and the shift to (and subsequent declining trend of) shrimp, lobster and crab in that area, show how these interactions work together. The shift to new fisheries in new places has led to increased production costs and new occupational health risks for humans. This is coupled to stock recovery failures, and they in turn have led to fishing down the trophic levels. That then creates new fisheries in still poorly understood 'under-utilized' species, which creates greater scientific uncertainty. It produces fewer fishers using the same or greater fishing effort, because managers need to remember that *technology is the key variable here*, not the number of workers. It is that confusion in thinking that leads to communities declining, and fishers being driven to outmigrate. The end result is residual communities facing continued human and biological risks and becoming increasingly mired in social inequality and poverty. It is not a pretty picture, but it is an accurate portrayal of what happens when scientific analysis starts at the large scale and works down from there, blurring the details of lived reality, which can only be found using bottom-up analyses. One also needs to remember that human experience impacts the natural world: that is, what people can end up doing to the marine ecosystems upon which they depend is a responsibility for all of us.

Conclusion

In conclusion then, unless we understand not only *what* we do, and *how* we do it, but also *why* we do it, there is little hope that things will change. It is only when one understands the root motivations for human actions that one uncovers the place from where to start instituting change. Put another way, when a policy-maker understands that by imposing *this* regulation on *these* communities, the communities will be forced to respond in *this* way, which in turn will have *this* impact on the ecosystem – then policy-thinking will finally have the data from which to make wiser decisions, regulations which will work with people to bring about healthy communities of fish and of fishers.

In future research, as Figure 2 shows, we are increasingly going to need to think of those complicated *nested social-ecological webs,* composed of human institutions and natural marine environments, that cross scales. This is going to be hugely important, since:

Multiscale analysis, including fractal concepts, is needed to characterize phenomena that are smeared across a range of scales by the interaction of fast with slow processes. The interaction of fast with slow rates often plays out as the interaction of local with large-scale processes (Schneider 2009).

We also always need to remember the wider geographical and political worlds in which small-scale community studies are necessarily embedded. Although structural rigidity within various human bureaucracies may be preventing reorganization, change is essential if we are not going to face species extinction. It is that academic structural rigidity that prevents emerging scholars from undertaking the interdisciplinary work they know is needed (Miller et al. 2010; Kelly et al. 2019; Andrews et al. 2020), and equally prevents academics from pursuing interdisciplinarity, because institutions do not recognize or facilitate it, reward it or get it funded often enough, which is my personal experience. Another is the apparent impossibility of getting the nations to agree to a fishing access strategy that produces equity for many, rather than profit for a few. That's a problem of vested interests: political, economic, national, and international. There is now a strong likelihood that the danger in which our global fish stocks find themselves is very much the result of this kind of institutional rigidity. It is unfortunate that many valuable data are not pooled and put to better use. More generally, I fear that there is too little connection between various forms of knowledge and too little awareness of past work that is about mistakes made and lessons learned, and there is far too little international comparison and learning. It has to happen better and more often if we are to shift the direction of global, and even national, policies and management away from single-minded concentration on deep-sea fisheries and large corporate fleets. Vested interests remain considerable and powerful, and they can and do influence fisheries policy, often not for the good of the fish or the fishers.

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