A transdisciplinary approach to modelling complex social-ecological problems in coastal ecosystems

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Abstract

Complex systems are notoriously difficult to model (i.e. rigorously describe). Social systems are complex; ecological systems are complex; understanding social-ecological systems involves cross-discipline complexity. However, knowing why people choose to use resources – and how – is vital to managing them sustainably: funded by the 'Ecosystems Services for Poverty Alleviation' programme[2], the project *Whole Decision Network Analysis for Coastal Ecosystems* (WD-NACE) is using 'structured subjectivity' to help describe 'messy' social-ecological networks regarding decision taking surrounding coastal production systems in Kenya (wild fisheries) and Bangladesh (shrimp aquaculture). Based on empirical knowledge of local stakeholder and experts, we have mapped their conceptions of the social and ecological networks associated with the social-ecosystems in each area. Now – working with local stakeholders and computer modellers – we have used modelling software to 'code' the behaviour of actors into both an agent-based model and an overarching multiple-entity description of the system. This helps to conceptually link the local specific to vertical scale (levels) of decisions making from governments through to stakeholders and vice-versa. Our modelling approach helps us develop tools to capture and conceptualise whole ecosystem dynamics and processes in each case. This bi-modelling approach – and associated data gathering approaches and analysis methods – is an important first step to celebrate the 'messiness' and subjectivity inherent within social systems. This makes the modelling process more dense, but the idea of structuring subjectivity has been used successfully to allow us to try and understand the system from both top-down and bottom-up: that is as 'a system' and also as the constituent stakeholders therein understand it. The implications for – as well as the need for – joint modeller/domain expert understanding is discussed.

Introduction

The agent-based models (ABMs) routinely used by ecologists and biologists to mimic swarming of animals, or to determine the decision processes insects use when moving nests, appear incredibly accurate. Yet ABMs designed to support important policy decisions amongst humans appear to face multiple obstacles in terms of their ability to generate a similar level of accurate representation. One key reason for this apparent performance differential across disciplines is that biological and ecological modellers model a minimum number of aspects, while social modellers include many factors. This problem can also be found encapsulated in the KISS ('keep it simple, stupid') or KIDS (keep it descriptive) debate (Edmonds & Moss 2005). While computer simulation modellers argue for KISS, the KIDS approach has a major part to play in making

2 see http://www.espa.ac.uk/

better, more policy-relevant models of human action – and the descriptive representation of aspects is important. Further, there may be a fundamental difference in what each is trying to do: in general, it is defensible to say that animal-behaviour modellers are trying to simulate (that is mimic) the behaviour of their subjects so as to understand its patterns while modelling done to inform policy has a more complex purpose, which involves and includes that of the modellers and that of the end-users, often the policy makers, policy advisors, or other decision takers. That said, the initial problem is to do with the way the modelling is conceived, and the latter is to do with the way the models themselves (or scenarios produced with them) are used: this paper is primarily concerned with the former problem.

One way of addressing the inclusion of detail necessary for social system understanding is to use multiple models – and associated data gathering approaches and data storage and analysis methods – which celebrate the 'messiness' and subjectivity inherent within social systems. This makes understanding the modelling process more difficult. The idea of 'structured subjectivity' has been used successfully with methods such as community network mapping and the ReAL-D (Resources, Actor Linkages, Decisions) framework in the *Whole Decision Network Analysis of Complex Ecosystems* project[3]. These methods are designed to provide outputs that can be more readily modelled but reflect people's conceptions of the system. Outputs of such structured-subjective approaches can include statistical understanding of actor relationships, network maps of actors, and/or cartoons of 'domain models' of the social milieu as well as other outputs but they must be handled as social science data, not 'objective' facts. They are how people conceive the system, and the models produced with such data are conceptual models.

This paper describes our work developing a 'model' (i.e. a formalised understanding: in practise a suite of modelling approaches) of the link between poverty alleviation and ecosystem services within the context of a wider conceptual framework that links (social) knowledge networks and (institutional) decision-making structures. We identify modelling challenges in relation to dealing with different epistemological backgrounds, the integration of different stakeholder worldviews and knowledge(s), and other bottlenecks in the formalisation process. The model is described and discussed in relation to an example case in coastal ecosystems (south Kenya coast) from which initial ideas and understandings were derived. Then, we discuss how effective and defensible tests of validity of the model can be constructed.

The empirical approach we will discuss is using rigorous 'bottom-up' (participatory) agent-based modelling within an overarching framework provided by the highly structured CoSMoS approach (Complex Systems Modelling and Simulation, see Andrews at al 2010 and Polack et al 2010). This latter approach encourages us not to move directly from the 'domain' (a.k.a. real world) direct to simulation but to create a domain model first that is agreed upon between the modeller and the domain experts. Figure 1 shows all the stages of the CoSMoS approach and how they are linked. In this project we were really only performing the domain modelling exercise using CoSMoS. However; superimposed on the CoSMoS diagram are three ellipses: the domain is the preserve of domain experts, those who know about the reality of ecosystem services and poverty.

3 see http://weadapt.org/knowledge-base/adaptation-decision-making/whole-decision-network-analysis-for-coastal-ecosystems

On the right hand side is the technical modelling and this is the preserve of the computer science modellers. In the middle (dotted ellipse) is an area of explicit transdisciplinarity where domain expert(s) and programmer must engage.

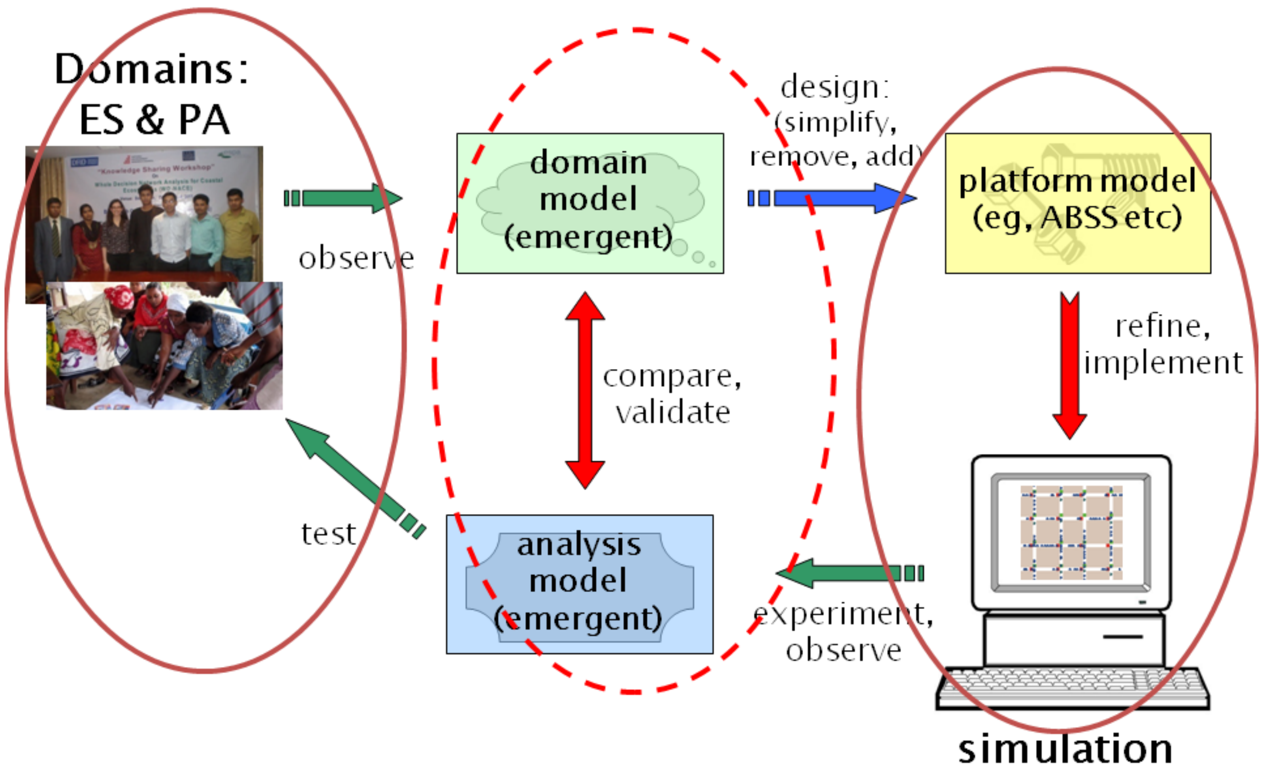

Fig.1: How it 'should' have been done in theory: the CoSMoS approach diagram

Modellers want the domain model to adopt a KISS approach, but we are experimenting with it embodying a ***structured*** KIDS approach, still allowing KISS to be applied in the computer modelling and simulation stages (RHS Fig.1) as and where necessary. The implications for – as well as the need for – a modeller/social science understanding of approaches is discussed, as is the practical and conceptual difficulty in 'layering' the models and the need for a transdisciplinary understanding of how to validate the linking of ABMs and also ABMs with mathematical models which looks to be increasingly necessary if we are to successfully simulate social realities.

Background, including the Setting of the Problem(s)

Since more than ten years colleagues have been identifying ‘a need for a systems approach. This approach can identify inter-linkages and flow of information and decision making processes’ (Rahman, Mallick, Haque & Nishat 2002:28). In natural sciences and in economics it is common to use models inspired by systems thinking and it is equally common, in fact 'normal', to (by virtue of their formality) attribute to these models more scientific merit than their descriptive counterparts. The problem for us is how to represent ‘soft’ (shorthand for ‘social’ – i.e. not ‘hard’ sciences) elements: this is by no means a unique problem to us. Studies including ‘soft’ elements are usually carried out without the use of formalised or mathematical models (see Coulthard, Johnson & McGregor, 2011) where researchers plump instead for a social conceptualisation or else by the use of quasi-economic proxies, see for example Barron et al 2008. This latter report includes institutional and human ‘social’ capital as a soft component, and they attribute economic benefits to the soft elements of the system. The ‘problem’ with these approaches is that, as Coulthard, Johnson and McGregor themselves point out, ‘the quality of life or subjective wellbeing element of the framework is only one dimension of what needs to be understood’. We are trying to build on these approaches and to understand the relationship between these soft elements and natural and physical elements.

This process of modelling soft elements can actually be described very simply:

> ‘the first step, therefore, is to analyze people's value orientations and the way in which they interpret sustainability problems i.e. their beliefs. The next step is to translate the resulting worldviews into model-based narratives, i.e. scenarios. The qualitative and quantitative outcomes are then investigated in terms of associated risks and opportunities and robustness of policy options’ (de Vries & Peterson, 2009: 1006).

In terms of formal modelling, the translation step is one in which actors' worldviews are codified and, in doing so, many assumptions are made explicit. This presents an opportunity to clarify stakeholders' perceptions within a co-construction process with the stakeholders themselves. The following step, scenario building, offers another point of integration of modelling effort with stakeholder priorities. Recent research shows the value of the design of 'what-if' scenarios in collaboration with resource managers when used in the exploration of more context-specific models (Anselme et al, 2010).

However, scenario-building also introduces the second potential problem: the question of whether these assumptions informing scenarios may be shared or not. In other words, whether it is possible (and in fact desirable) to reach ‘shared understandings’ among the informants. From a modelling point of view this would be desirable because it has the advantage of simplifying a model. On the other hand what we are trying to avoid is the dominance of modelling by dominant worldviews when there are other equally relevant insights. Agent-based modelling is perhaps unique in the way it introduces heterogeneity of social actors so that it is relatively easy to incorporate actors' different goals, perceptions and decision processes. It also makes extensive use of modular construction, which makes it feasible that certain aspects of the model could be activated/deactivated or substituted to account even for widely differing interpretations. Seen in this light, there is also the need to avoid that idea that researchers are presenting a given simulation model as a 'solution' to understand a resource issue. It would be much more in line with participatory processes to introduce several different shades of a simulation model to show different possibilities and to allow as much co-construction as possible in the scenario-building activities. The process of modelling soft and hard elements *together* is more problematic, hence our approach was to nest the ABM within a structured framework approach.

Our initial plan within WD-NACE was to use an ABM of the system as ‘an alternative approach that models social life as interactions among adaptive agents who influence each other in response to the influence they receive’ (Macy & Willer, 2002: 143). These influences which actors receive come from both other actors within the system and from other ‘physical’ elements within the system, such as ecosystem services. The important thing to remember within an ABM is that we are modelling the ‘aggregation of local actions’ (ibid: 144) and this approach is ‘most appropriate for studying processes that lack central coordination, including the emergence of organizations that, once established, impose order from the top down’ (ibid: 148). They are particularly useful for helping us to understand patterns ‘such as the diffusion of information, emergence of norms, coordination of conventions, or participation in collective action’ (ibid: 148). Thus, simple linear transmission of information can be understood, as can feedback loops where adoption of actions by some actors can have a positive (or negative) influence on others to adopt that same action.

Although we can produce the relevant primary data for our case study areas – in effect produce a (social) network map and associated data and then produce an ABM based on these social data and also physical data about the natural ecosystem, one problem of our approach is that of validation; that is the internal validation of the theory or ‘conceptual model’ of the *whole* system. In particular the formal (that is mathematical / modelling) validation procedures for ABMs may not work because our models, based on actors’ ‘different understandings of the system’ (Özemi & Özemi, 2004:57), require instead a ‘qualitative validation’ ‘in terms of a “reality check”’ (ibid: 59) with the actors who have informed our model and other significant stakeholders within the system. Similarly, social simulation introduces the idea of ‘cross-validation’ (Edmonds and Moss, 2005) which details a qualitative and quantitative component to comparison with empirical data at the micro- and macro- scales respectively. Thus we needed another model of the whole system to allow us to understand how our ABM fitted in.

The room for error – which makes validation so important for us – lies is the fact that we are trying to 'bolt together' data and inputs from different epistemic backgrounds. There are three broad approaches to doing this as noted by Dr. Jonathan Beecham of CEFAS at a visit to the York Centre for Complex Systems Analysis (YCCSA) in 2011:

- the first is the 'Frankenstein' approach – bolting models together;
- the second is to create a (new) framework to work across the scales;
- the third option is to use less quantitative joins either by human links ('soft' or 'weak') <u>or</u> by using Bayesian approaches.

The issue with the latter is that these tend to be ad-hoc joins; the middle option tends to require huge amounts of 'new' data and input; this threw us back initially on the first option of bolting models together. But the process of 'translation' between models – even when two models are describing the same domain – can be a vast operation. The task herein is to describe the units of one model and map these onto the units of the other. If the relevant spatial, temporal, and social actor units are compatible then this is OK, if they are not compatible then a translation service is required. One problem that remains, Beecham told us, is that even if you have one model that is well calibrated, and you seek to 'bolt it to' another model which is equally well calibrated, when you link them together you still need to re-calibrate the 'new' model.

Another issue, particularly for us, is that in some conceptual models elements such as power and influence; social and institutional capital; and wellbeing; are emergent properties while in others they may be inputs. We wanted the WD-NACE 'model' to be an explanatory model of the complex relationship between poverty alleviation and ecosystem services: thus an over simplistic or too linear model which sees ecosystems services as inputs and poverty alleviation as an output would never be compelling or satisfactory. Apparent linearity might be assumed in Comin, Kumar and Sirven (2009) which 'delves into the links between livelihoods and capabilities, providing and encompassing framework for suggesting solutions for poverty reduction' (ibid:447). What Comin, Kumar and Siverin give us is an excellent set of indicators which can be used to understand the relationship between 'the twin goals of environmental conservation and poverty reduction' (ibid:459). They further affirm however, that 'there does not exist only a simple cause and effect relationship between both' (i.e. between poverty alleviation and conservation of ecosystems services). Thus, complex modelling is required to provide decision takers and policy advisors with multi-scale, multi-sector models to support decisions with respect to poverty alleviation and ecosystem services decisions. As is frequently pointed now out (see Kemp-Benedict, Bharwani & Fischer, 2010) any mathematical or computer model that looks only at the behaviour of actors in one sector (be it economic sphere, political sphere, or whatever) will miss critical dynamic processes in other sector activities and we need to try and get around that. They note, however, that 'The range of possible behaviors [*sic., et seq*.] is not infinite—human agency is bounded by physical constraints, social norms, family behaviors, and physiological endowments. However, the range can be large and the interactions of these elements, complex' (ibid: 3). Thus, while the task is not impossible it is difficult and time consuming. They do conclude, however,

> ‘that ‘matching methods’ can be used to link social-scientific models with models from the physical sciences. The goal with such matching methods is that the social scientist can use the methods that are most congenial to him, while the physical scientist can use the techniques that she finds most familiar’ (ibid: 5).

So how do we find these matching methods – and can matching methods linking ‘hard’ and ‘soft’ elements be similar in any way to the approach as described by Beecham above to link two ‘hard’ models? The necessity of such an approach seems, to us, to lie in the fact that traditional social science approaches (i.e. using soft systems) will not provide – or cannot sufficiently include – a dynamic ecological aspect.

Using a soft systems approach only, Powell and Osbeck can describe a narrative of the implementation process growing out of a policy environment intended to promote the rehabilitation of mangrove ecosystems which includes a description of ‘significant power imbalances in the system, not only between stakeholders, but also between the discourses of conservation and production’ (2010: 260). They are clear, however, that ‘Soft systems analysis critiques the human activity system (in this case the actors, rules, power structures and norms) that governs the resource use and interaction within the mangrove system’ (ibid: 262). Thus a soft systems methodology (after Checkland) on its own cannot produce an all-encompassing model. Powell and Osbeck’s/ Checkland’s SSM can provide a ‘rich picture of the complex institutional setting’ which may, it is hypothesizes, only confound and confuse the process of matching as described above by Kemp-Benedict, Bharwani and Fischer. This is reinforced by Larsen, Acebes and Belen who note that ‘the system’ in the SSM approach is in reality ‘The system of interest bounded by change related issues identified by the clients’ (2010: 9) thus we are in reality thrown back towards a more cognitive approach.

We decided upon using used a 4th approach to Beecham’s three. Most similar to his 2nd approach in theoretical standing but much like his 3rd in practice: that is to create the separate model of the whole system’s framework. Further, though, WD-NACE looks to include the whole-decision making arena, not just the local. Brock, Cornwall and Gaventa noted that ‘making sense of contemporary poverty policy requires a closer exploration of the dynamics within and beyond the arenas in which policies are made and shaped’ (2001: iii). They note that this includes looking back through time to understand why things are the way they are, but in the WD-NACE approach it also includes looking up through policy space to understand how external forces impact upon local reality: that is the whole decision making sphere. We have explored the use of UML (unified modelling language) diagrams to describe this whole system and this allows us to start to think about how to link up the scales.

But the UML descriptions are models of how people think the system is: i.e. they are the structured subjective views of the domain experts. By accessing their understandings we have accessed a window onto their cognitive (or mental) maps of the world. The cognitive map is that which guides the individual in transforming their norms and values into actions. de Vries and Peterson say that 'The archetypical cognitive maps usually are approximate and simplified versions of scientific insights – and are called metamodels, "stylized facts," or simply correlations' (2009: 1011) and, like 'our' metamodels (cf the UML diagrams, see figures 3, 4 & 5) , it is probably best to assume that they are incomplete and imperfect. de Vries and Peterson conclude that

> 'The combination of value orientations and cognitive maps which make up worldviews in this scheme provides the basis for the construction of scenarios, that is, model-based narratives ... [to] support strategic decision-making, as well as heuristic exploration in complex sustainability related macro-problems' (2009: 1017).

Thus, we are thrown back again at looking at what people think, what they know (and what they think they know), rather than 'hard' facts. Further, as also argued by Fioretti and Visser, the complexity is in the thought processes of the actor and the 'explicit recognition of the cognitive nature of complexity fits well with the use of the word 'complex' in common parlance' (2004: 13). Some of the problems of trying to do this include that the 'actors' have cognition above that of simple 'programmable' characteristics. Thus, it might be argued (e.g. Fioretti & Visser, 2004) that one way – maybe the only way – to understand the inherent complexity within the system (or feedback loops between linked systems) is to concentrate on the cognitive effort expended by actors within the system. Thus, we start 'from observing and modelling the way decision-makers represent problems in their mind' (Fioretti & Visser: 13). We do this to some extent by using what Özemi and Özemi call the 'cognitive mapping approach'. They remind us that 'modeling ecological or environmental problems is a challenge when humans are involved' and further note that:

> 'A useful modelling tool for analyzing such problems would bring together the knowledge of many different experts from different disciplines, to be able to compare their perceptions and to simulate different policy options, allowing for discussion and insight into the advantages and disadvantages of possible decisions,' (2004: 44)

and continue that 'the modeling method should be able to incorporate public opinions about ... higher level variables of concern to the public' (ibid: 43 & 44). These 'higher level variables' are, in our case, wellbeing / poverty alleviation and the factors or elements within the system which influence these variables such as social capacity and social and political power and influence. It seems that the physical or natural side of the system is less problematic as it appears more amenable to some form of quantitative analysis. One reason why we think that we are well placed to do it this way is through the equally strong input from the social as well as the natural sciences within WD-NACE. In our project 'social scientists have been invited to play a big role in investigating, laying out and evaluating these societal aspects' (Yearley 2011: 17). Our team includes ecologists natural scientists, and a modeller – but also anthropologists, social-scientists and political-economists.

The first task in achieving a sufficient understanding of the social or ‘soft’ part of the system was thus to describe the way the decision takers perceive the problem in their minds. This allows a rationalised understanding of what the decision taker knows, and what gaps there are in her or his knowledge (i.e. ‘known unknowns’), and, thus, where the complexity lies within the system from the perspective of the decision taker. Accordingly, what we can include in this approach is the perception – in the mind of the actor – of any power issues and need for social capacity building.

Thus, for us, the issue of how the question is framed becomes vital. We must accept that we are a medium of communication in the process and recognise that ‘[...] frames provide audiences with cognitive shortcuts or heuristics for efficiently processing new information, especially for issues that audience members are not very familiar with’ (Scheufele, 2006 in Hellsten, Dawson and Leydesdorff, 2010 :592). This reiterated our perceived need for *structured* subjectivity rather than using methods which allow subjects to determine their own framework.

On the experience of ‘bottom up’ modelling (using the ABM)

A group of French researchers who developed the Companion Modelling (ComMod[4]) approach (Bousquet et al. 1999; Bousquet and LePage, 2004) have, in the past 15 years developed a range of activities to support the use of models in natural resource management and in addressing social-ecological interactions in particular. Michel Étienne and colleagues developed the ARDI methodology for the co-construction of conceptual models (Étienne 2006, Étienne et al. 2007). Such models represent visually multiple viewpoints and can be employed as mediating, discursive objects that promote collective learning processes. Further, they can be used to formulate role-playing games and/or agent-based models. Their design depends upon the research question identified – and if it is stakeholder-driven research it often depends upon the 'overarching negotiated development question' (Étienne et al. 2011). We have partially based our methodology upon ARDI; we have also developed ways to understand how actors access different types of resources, how this influences their decision-making, what have been the important decision-points in the past and what are the power relations that shape control over, access to and use of coastal resources. We have adapted additional methods such as social network mapping[5] to elicit information about central and influential actors as observed by the participants themselves.

4 see also see also http://www.commod.org

5 e.g. see www.netmap.wordpress.com

Our approach that we have been piloting in workshops in Kenya and Bangladesh is the use of 'structured subjectivity' data gathering methods (Q-sorts, social network mapping, and so on) to rapidly inform research into social relations. We call our data gathering methodology ReAL-D because within it we are concerned not just with one aspect of the social but with a multiplicity of Resources, Actor Linkages, and Decisions. Further, within the data gathering process we divide wealth (capital) into four capitals: Social, Economic, Information, and Natural. Any given actor can have wealth in any one or more of these capitals. Of course capitals can be exchanges for other capitals.

Thus the agents (actors) within our ABM are informed (given characteristics) that reflect those of real actors in the field. Because our actors are so defined, they are more recognisable to end-users. Rather than collecting detailed qualitative information, the activity allows different homogeneous 'focus' groups of stakeholders to broadly characterise their networks, the types of interaction they perceive and the actors they consider to be 'influential'. Our project is focused on using networks in the design stage, i.e. to build an ABM based on real social network map data. By bringing these two approaches together (structured subjectivity data gathering and agent-based modelling) it is possible to generate agent-based modelled scenarios based on actors' own hypotheses. The objective is to explore the influence of different types of networks on typical simulation performance measures (rather than on network measures) by analysing simulation runs and comparing the different model-generated scenarios. The model is a dynamic process and end-users can engage with the model, running brief simulations using different inputs to test scenarios generated. The scenarios generated by an ABM typically look like the following:

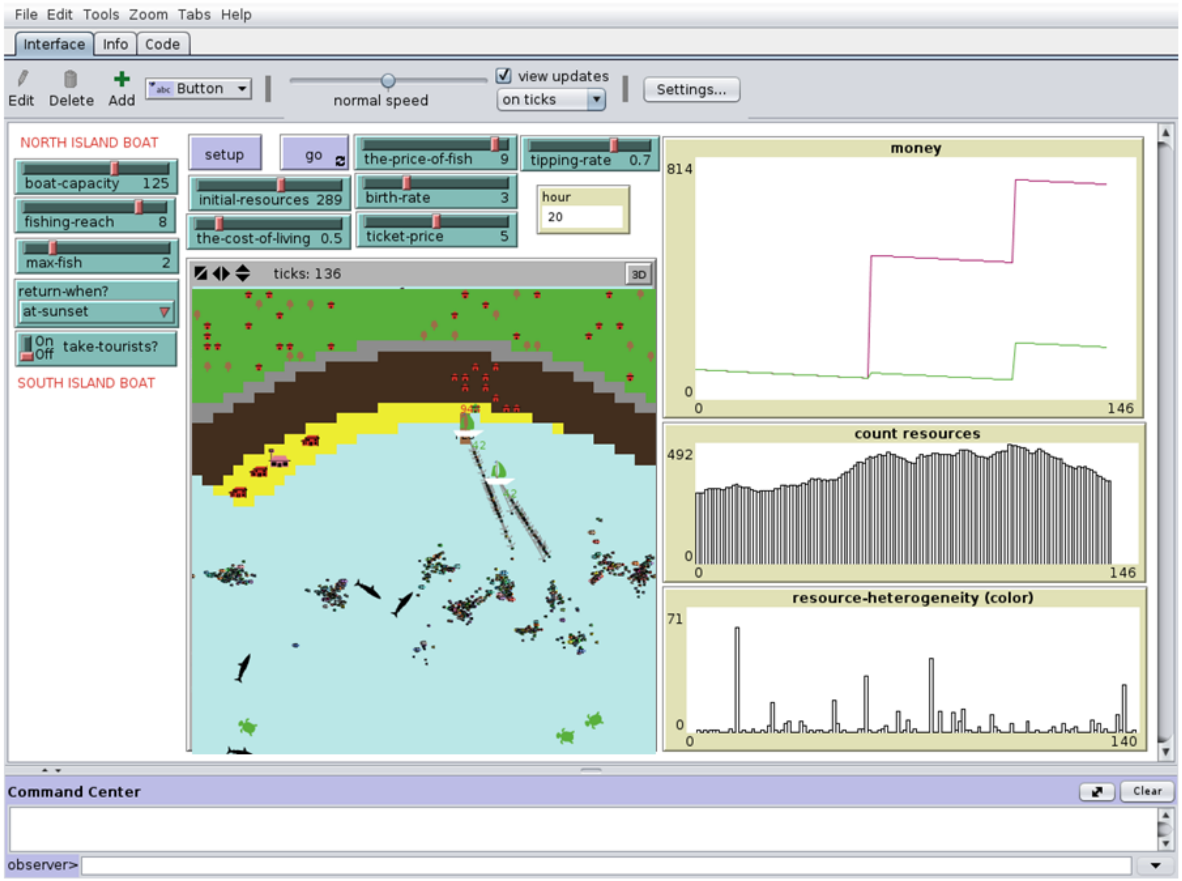

Figure 2: a screen shot of the Network for Computational Modeling for SocioEcological Science (CoMSES Net) model for fisheries: thanks to Howard Noble of Oxford University who provided this

On experience of 'top-down' modelling (UML approach)

At the other end of the spectrum (or scale of model) is our UML model of the whole system – or as close to the whole system as we can get from the actors we have involved (the same actors who informed the ABM). The UML diagrams (a single class diagram – see figure 4; a series of state diagrams for each of the classes of concern – see figure 5 for one example; and a series of activity diagrams for important processes – see figure 6 for an example) were produced by a computer scientist working with a software engineer and various domain experts as apposite.

The purpose of the UML diagram is twofold: firstly, it provides a real-world-based notation of the system which is a useful heuristic device. It has proved useful to communicate the system to stakeholders from different disciplinary backgrounds but it is also useful to describe the system – and its processes – to modellers who are not themselves domain experts. It does so in a formal notation which, like the ReAL-D (or ARDI) approach in the previous section introduces a structure which would otherwise be lacking. Thus, it starts to provide a framework within which we may start to think about how to link different models and models of different part of the system and to do so in a structured, systemic way rather than using ad-hoc soft linkages.

Taking our inspiration from the CoSMoS project's experience in successfully linking complex systems modellers and software engineers with domain scientists in bio-medicine and robotics, we employed UML (through circumstance rather than by design) to represent the 'domain model'. CoSMoS provides us with a series of rigorous steps: York researchers have used the 'CoSMoS approach' to successfully model complex systems in a number of areas including biological systems, and engineered swarm robotic systems and our evidence shows that it can be applied to complicated, complex social-ecological systems. The need for such a model is that *complicated* systems occurring in the natural world (such as ecosystems and social systems) containing many elements and also contain feedback systems that are *complex* (such as the influence of climate change on those ecosystems where we do not fully understand all the consequences). We have models or can produce models (descriptions) of many ecosystems aspects and we have confidence that we understand how they work. We also have adequate models (ABMs) of social systems and of the ecological system using the equational modelling package STELLA[6]. However, producing a model of a combined 'social-ecological' system – a system description of both the social and the ecological parts, and their interrelationships – requires an innovative, complicated, complex modelling approach. We have no model, or framework, that can encompass the components and dynamic processes in both models. But we need such a combined model to explore, for example, where interrelated feedbacks from overfishing due to population pressure and from stock reduction due to climate change might produce a catastrophic tipping point.

The outcome of this part of our project – of which we have only take the first steps in that we have not gone on to develop computer simulation (a simulation on a computer platform – see Fig. 1); nor the results model necessary to compare the simulation model with the domain model and with the domain ('real world') itself – are the series of UML diagrams. The modeller was simply given a schematic or cartoon model which had been prepared at the outset of the WD-NACE project and asked 'to populate it' – that is to unpack the twin boxes of 'Ecosystem services' and 'actors choices' in figure 3.

6 see www.iseesystems.com/softwares/education/stellasoftware.aspx

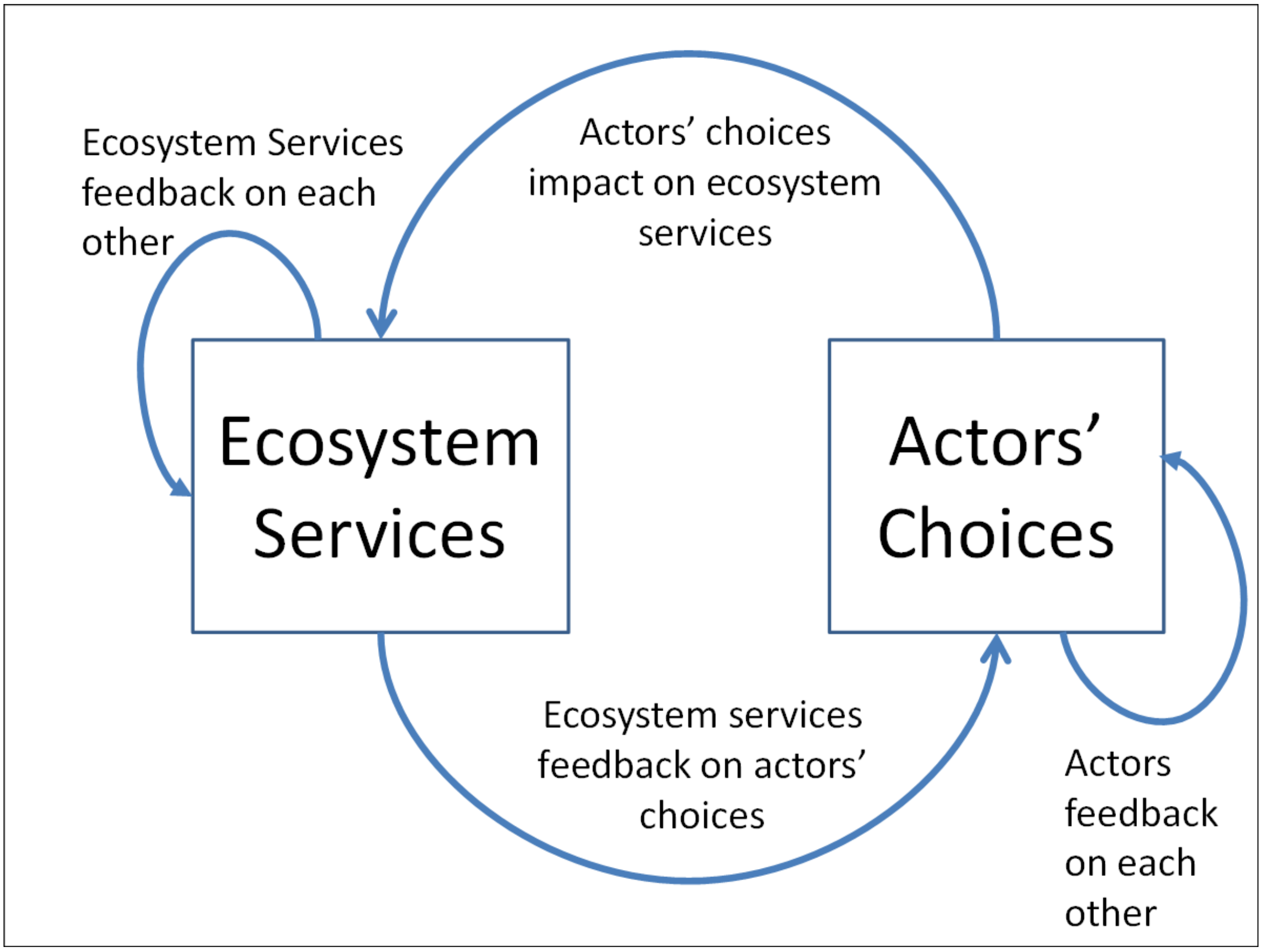

Figure 3: the original WD-NACE meta-model

This resulted in figure 4:

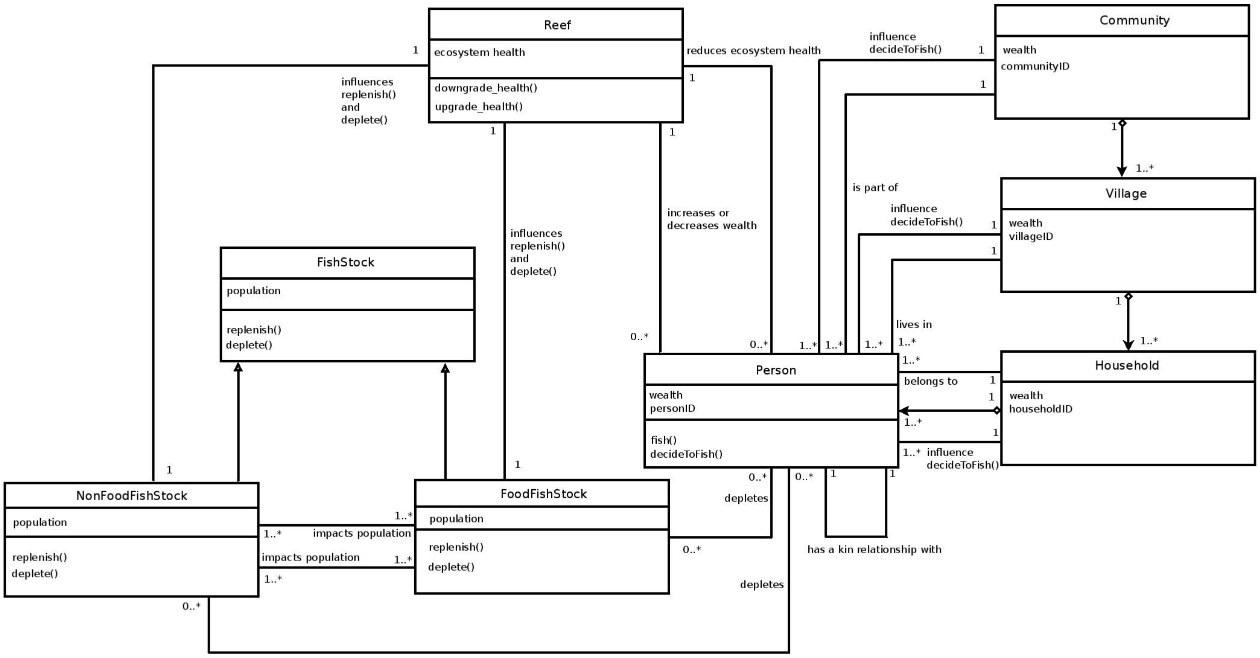

Figure 4: the computer systems unpacking of the initial WD-NACE 'meta model' aka the UML Class Diagram. Thanks to Richard Greaves, YCCSA for this figure

Which in turn is complemented by Figures 5 and 6:

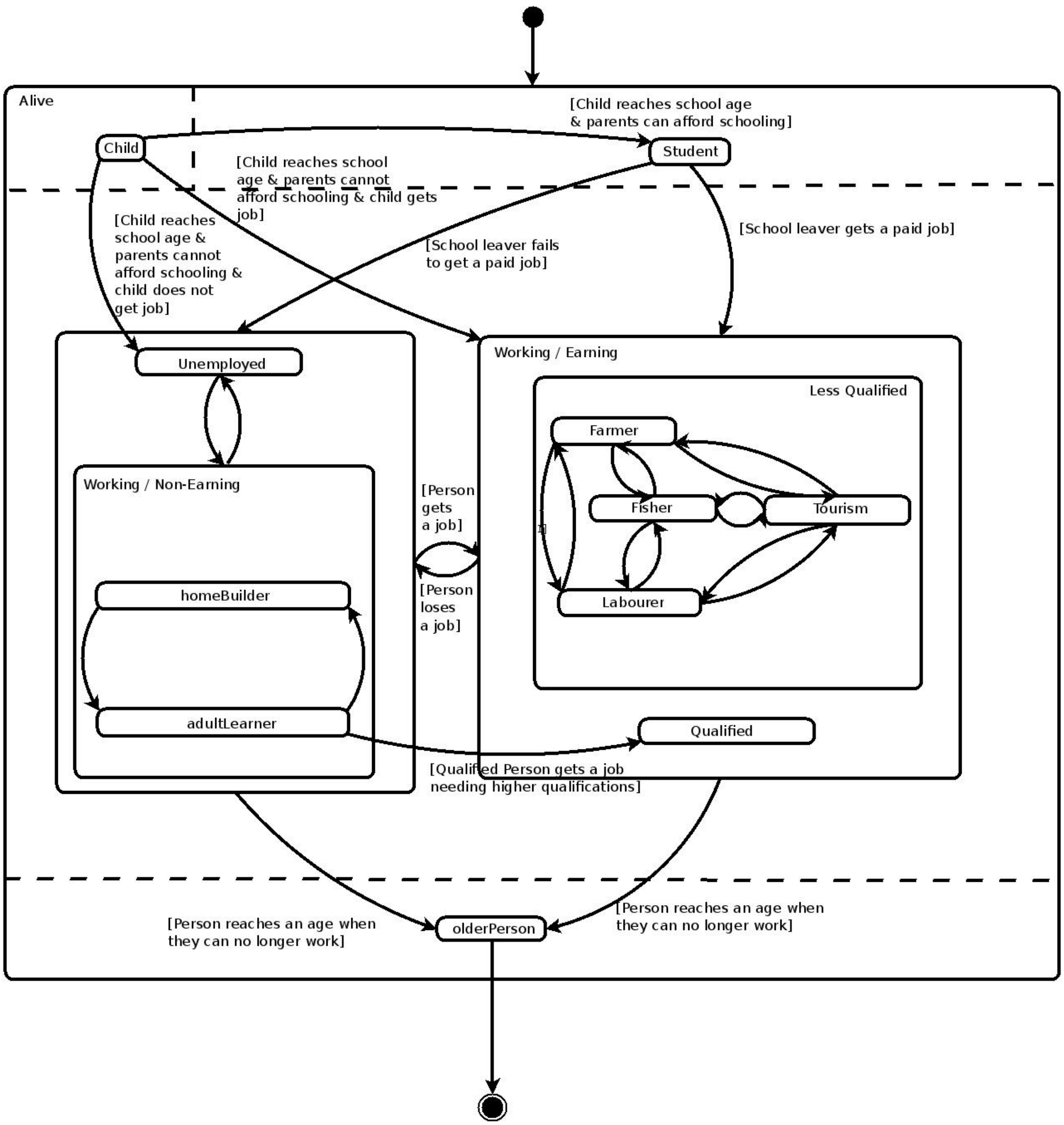

Figure 5: a person 'state' diagram. Thanks to Richard Greaves, YCCSA for this figure

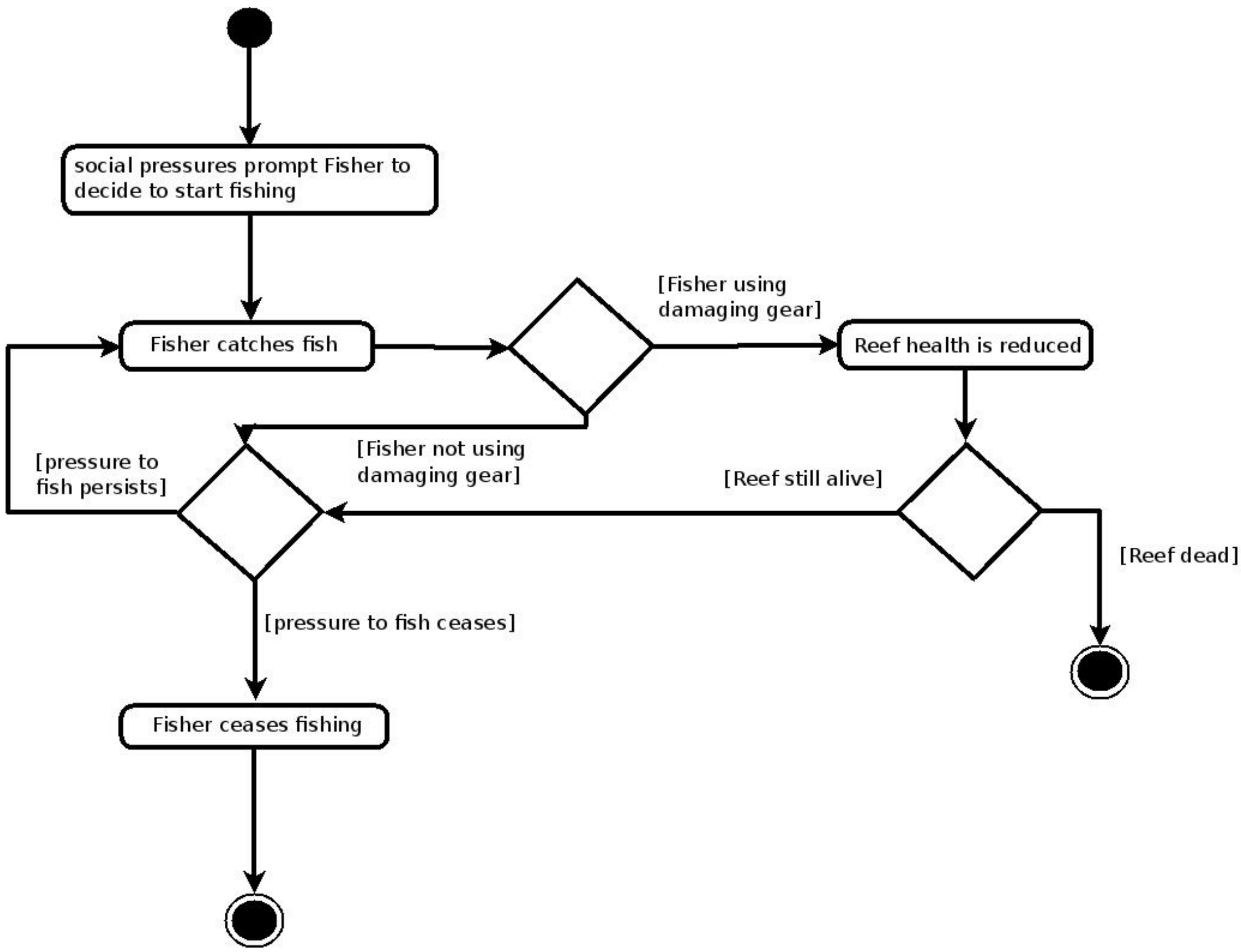

Figure 6: A UML activities diagram (for fish stock depletion): Thanks to Richard Greaves, YCCSA for this figure

We have now 'truth grounded' these diagrams and what they represent with the stakeholders who have informed the research through which they were created, and generally they hold valid. However, on publication, they have also been a useful heuristic tool ***within the WD-NACE project itself*** to allow cross-disciplinary communication both of deeper cross-disciplinary understanding of the bigger system but also communication of purpose.

Discussion

Özemi and Özemi note that 'Formal validation of these cognitive maps is not possible because the maps operate on different understandings of the system' (2004: 57). There is much truth in this and, in our context here, it must be remembered that the domain model created is really such a cognitive map – or an aggregation of several actors' cognitive maps.

This means that what we are modelling in the domain model is really rather different from the initial example we started with where the model is mimicking animal behaviour: such models seek to emulate the behaviour of their subjects, but because of the heterogeneity of human actors and the complexity of 'bashing together' two (or more) complex systems, we recognise that the domain model is an exploratory tool rather than a 'reproduction' of social-ecological life. It is useful, however, in that it can be used to generate scenarios of what might happen under certain conditions, and those scenarios can be validated.

However, the realisation is that our social ABM is also such an exploratory tool presents a different problem. Here at the 'bottom-up' end of things we are trying to understand how to link a social ABM which is not designed to replicate social life but to explore possibilities, with an ecological model which – looks like it – is designed to replicate 'reality' in computer code. Although this presents us with conceptual dilemma, in practice, once the ecological model is conceived of within the domain model then its 'scientific' characteristics (i.e. closeness, comparability to observed data) disappear and we are left with a more open system.

Thus, although we need to validate the ecological model, we do not need to validate the social-ecological model in the same way; just the scenarios it produces. Of course the modelling process needs to be validated so that the modeller has confidence in the model but for social science application we can be content with generating useful and potentially truthful scenarios.

Further, we do need a multiplicity of models rather than a single model because, traditionally, we can ultimately only validate a model is by comparison with empirical data. Thus, if we have a social-ecological model that is based on certain scientific and social assumptions and it tells us that fish stocks will go up by X% year on year, and after one year fish stocks have gone down rather than up we have less confidence in the model. We will assume that either there is an error in the model or, more likely, the model is failing to take some factor into account. Either way the model is probably 'wrong' (even though we know that there is probably much that is right within it: it is from the decision/policy making perspective not correct).

Because our modelling process is conceptually truth grounded with a relatively disparate group of stakeholders we think we should be able to have a higher level of confidence in the model. But the only way we can ultimately validate that is by testing its output (which is the scenarios it generates) against the empirical data. If our 'whole decision network' model says that fish stocks should go down rather than up, then in the scenario above we are vindicated in our confidence. We say the model is correct – but of course we know that we are really only saying that it is, under the circumstances, a closer fit with observed reality that the other model and thus a better basis upon which to make decisions and policies.

Thus, and this is the argument for multiple models, the validation in the first instance comes in the comparison between different models and empirically observed 'reality'. But there is also a validation in the comparison of models: hence the need for the CoSMoS domain model: we need a framework within which we can understand how the models of different parts of the system are interlinked. What we must understand is that the model (the overarching model, that is) is not a simulation of the system but of how the system is conceived. It is a conceptual model.

The KISS versus KIDS debate has now been relegated to a debate within the modelling team. The domain model models how people think about the system: thus it **must** contain the detailed information (and all the classes) that people use to conceive of the system (see figure 4 above). If we wanted to simulate the domain model (a stage we had never planned within the WD-NACE project) the modeller would naturally apply a KISS approach but this needs to be carried out iteratively with the domain expert(s) so as to maintain cross-disciplinary trust.

This multiple model approach also allows us to deal with emergent properties in a novel way: for example power relationships between actors obviously influence how actors behave: thus such relationships are built in to the ABM. However, the domain model, as a model of the whole system, does not have power relationships built in because here they are an emergent property of the social relationships (the right-hand feedback loop in figure 3). This makes the ABM more detailed and makes it look more like the type of ABM we started with, the animal behaviour model, but it is not. It remains a social science model; it cannot be confused with a scientific model (i.e. testable against experimental data). Modellers need to learn the difference, as social scientists need to learn the protocol and methods by which modellers can simulate. Social scientists can and should input the process (data and assumptions), and test the outputs (simulations), but leave the process itself to the disciplinary experts (modellers). This is how we believe that transdisciplinary works best, when parts of it are interdisciplinary but working towards a trans-disciplinary result.

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