# Perspectives of Social and Ecological Systems[1]

by

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## Abstract

ICZM depends on an understanding of the coastal zone system to be managed. During the SPICOSA project, we needed to provide an explanation of 'ecological-social-economic' coastal systems to teams applying the 'Systems Approach Framework' at project study sites. This chapter presents a conceptual model of 'social-ecological' systems that emerged from this work. The model, which takes the form of a 3-dimensional, animated object, can be seen at www.coastal-saf.eu. It draws on the perspectives of 20th Century thinkers, including the hard, thermodynamically-based, science of 'General Systems' and ecosystems theory (von Bertalanffy, Odum), the post-modern approach of 'Soft Systems Methodology' (Checkland), the ideas of Holling, Berkes and Folke about resilience in 'social-ecological' systems, Popper's '3-worlds cosmology', Habermas' 'Communicative Rationality', Luhman's theory of ecological communication, ideas about the value of nature (Costanza) and the 'value in nature' (Ralston), and Ostrom's diagnostic framework for social-ecological systems.

## Key-words

philosophy, social-ecological system, SPICOSA SAF.

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## Introduction

This chapter concerns ways of conceptualizing coastal zone systems and their problems. It draws on the SPICOSA project (Hopkins et al, 2011) and the authors' experience in preparing guides for application of the project's 'Systems Approach Framework' or SAF. The SAF is a methodology for bringing together stakeholders, scientists and representatives of governance in a multi-stage procedure (Figure 1) for identifying a dysfunction in a coastal zone system, defining alternative methods or scenarios for dealing with this, and evaluating these scenarios through simulation modelling. One of the challenges in preparing the guide was to identify what we understood as a 'coastal zone system'. Doing this required a move from the multidisciplinary perspectives of oceanography, ecology, economics and social sciences to a more integrated and participatory, which is to say transdisciplinary, perspective. We also found it useful to delve into the works of a variety of 20th century thinkers on issues epistemological, environmental and ethical.

## ESEsystems

The proposal for the SPICOSA project used the term 'economic-social-ecological system' or ESEsystem to imply that there were aspects of CZ systems that required study by the three disciplines of economics, social science, and ecology before integration into a single account of the system. Each discipline tends to hold a particular view, or perspective, of an ESEsystem in relation to the human use of, or impact on, the 'natural' component of the system. We can roughly sort theories of CZ and similar systems into three groups, depending on their main perspective:

1. **Ecologists** tend to see the ecosystem as looming large and the human sector (Figure 2) as coupled to this through inputs (such as fisheries captures) and outputs (such as waste discharges). The Driver-Pressure-State-Impact-Response (DPSIR) paradigm (Luiten, 1999)

links human pressures on ecosystem state to impact on nature's provisions and the human response. Much EU environmental legislation has been motivated by the desire to protect species and habitats, or to restore and maintain good ecological status, against human pressures.

2. Environmental **economists** consider the human-use values of ecosystem services and natural capitals (Costanza et al., 1997), in some cases under several scenarios as exemplified by the Millennium Ecosystem Assessment (MEA, 2005. The expression of these values in dollars or euros intends only to find a common currency (both metaphorically and literally) with which to account for otherwise incommensurable variables. Putting an exchange-value on an ecosystem service does not automatically require the creation of a market, but if such market comes into existence, it is supposed to provide an automatic machinery for regulating the use of the marketed service.

3. **Social and political scientists** tend to focus on the institutional (including governmental) control of access to ecosystem services and protection of natural capitals, and the content and codes of communication amongst actors about these matters. Methodologies include the 'four orders of outcomes' (on different management time-scales) of Olsen (2003) and the analysis by resource, users and governance, of Ostrom (2007).

**Ethics**

The ultimate objectives of SPICOSA were to help in increasing the (ecological) *sustainability* of ecosystem services in the coastal zone, the (economic) *efficiency* with which these services are used, and the (social) *equity* with which they are distributed amongst members of society. In all these, of course, the non-human creatures and natural processes that provide these services have a purely *instrumental* value. Rolston (1994) contrasts this (the 'value of nature') with the *intrinsic* worth of organisms to themselves (the 'value in nature'), adding that there are also *systemic* values in nature, which are emergent properties of ecosystems that benefit all components without being localized in any particular component.

**Systemic ontology**

At the commencement of the SPICOSA project, there was a debate: when we talked about 'coastal zone systems', were we dealing with 'real' or 'hard' systems (von Bertalanffy, 1968) - i.e. systems that truly existed in the physical coastal zone and its associated economy and society - or was it better to see the project's methodology as using a 'soft' systems approach (Checkland & Scholes, 1990) in which the perceived system is (no more than) a mental construct used for understanding and problem solving? By the end of the project we had reached the synthesis that: (i) real coastal zone systems exist, with biophysical and social components and the properties, including feedback loops, emergence, and subsystems, given in General Systems Theory; whereas (ii) the conceptual and simulation models built to study dysfunctions in this real coast zone, were 'virtual' or 'soft' systems, partial heuristic devices.

We found it helpful, in aiding understanding between biophysical scientists, who by and large took the hard systems view and aspired to a single best model, and social scientists, who mostly took the soft systems view in which there could be multiple alternative and valid models, to introduce the '3-worlds cosmology' of Popper (1972, 1978). In this, phenomena occur in three qualitatively different 'worlds'. These are (as restated by us):

1. the physical (natural) world, in which mass and energy are cycled;

2. the mental (interior) world of individuals, in which lie values and well-being;

3. the world of information and institutions (including the social world, the monetary economy, and models), for which world 2 is a substrate but which exists independently of any particular world 2.

Figure 3 may make the distinction between worlds 1 and 3 more clear. In world 1 there are local differences in beach topography; in world 3 there are words and meanings. The distinction between worlds 1 and 2 has been the subject of philosophical debate at least since Descartes wrote in his 'Discourse on the Method' (1637) that "je pense, donc je suis". It is the introduction of world 3 that is particular useful in understanding social-ecological systems, because it makes clear, on the one hand, the incommensurability of the natural world (which includes not only the 'natural environment' but also the human-constructed environment of farms and cities) and the social world, but, on the other hand, allows for information to cross the barrier between the worlds.

World 3, as we understand it, includes the totality of the 'social world' of Habermas (1984) and 'society' (a set of communications sub-systems) of Luhmann (1989).

**A unified view of social-ecological systems**

We came to see that it was necessary not only to convert a multidisciplinary to a transdisciplinary approach to ESEsystems, but also to conceptualize coastal zone systems as integrated wholes. For this reason we adopted the label *social-ecological system* defined in the 'Resilience Dictionary' of the Stockholm Resilience Centre (www.stockholmresilience.org), and attributed to Berkes & Folke (1998) as:

> *linked systems of people and nature. The term emphasizes that humans must be seen as a part of, not apart from, nature — that the delineation between social and ecological systems is artificial and arbitrary.*

Given Odum's definition (1959) of an *ecosystem* as

> *Any area of nature that includes living organisms and nonliving substances interacting to produce an exchange of materials between the living and nonliving parts.*

*a social-ecological system* can be understood, briefly, as:

> *an area in the physical world in which human society interacts with 'nature' or 'the environment'*

(Gilbert et al., 2011) and more rigorously,

**a spatially-bounded region in which living organisms and nonliving substances interact to produce exchanges of materials, energy and information amongst components, and in some cases across the boundary**

Figure 4 shows our conceptual model of such a social-ecological system. This has been conceived as a three dimensional object with some dynamic features, and so the figure shows still images from different stages in an animation (which can be seen at www.coastal-saf.eu/design-step/refs.shtml). Each picture shows the system from a different perspective and thus helps to make the first point in our argument, which is that views of a Coastal Zone system tend to be partial. Trans-boundary fluxes have been omitted in the interests of clarity in the diagram, so this conceptual object is more a model of 'spaceship earth' than an open coastal zone.

The social-ecological system is shown as a 4-part structure linked by arrows representing signals flowing between the parts. Two parts of the structure lie in Popper's 'world 1'. These are physico-chemical systems, characterised by Newtonian forces and flows of mass and energy. Ecosystems are (as defined above), spatially-defined regions in which living as well as non-living things take part in the flows of mass and energy, and thus include the physical aspects of human life. However, adopting the conventional anthropogenic perspective, we have divided the world 1 component into an 'ecosystem' and a 'human physical' part. The diagram labels interactions between the two parts as 'ecosystem services' and 'impacts'. As parts of 'world 1', these services and impacts are tangible things. For example, the physical services provided locally by natural ecosystems to coastal aquaculture include a supply of oxygen to farmed fish, and the removal and metabolizing of farm wastes (which can also be said to impact on the environment). An indirect service is a supply of feed, industrially processed within the 'human physical' system from fish catches elsewhere in the sea. It is on the basis of these services, as well as of human investments, that farmed salmon can be provided to consumers.

Ecosystems also provide intangible (aesthetic, cultural, spiritual) services to humans: we see these as flowing directly to minds or to society. In the diagram, 'mind' (and the whole of 'world 2') is placed at the centre of the social-ecological system because it is here that values originate and here that, according to a hedonistic ethic, lies the well-being that a utilitarian economic calculus aims to maximize. Of course, there should be many minds shown, communicating through (and acted upon by) 'society', the social network in 'world 3'. Within 'worlds' 2 and 3, signals comprise information that is interpreted as meaningful by minds or institutions, and thus results in a change of mental state or institutional state and, sometimes, in the generation of new signals that pass back into world 1 by bringing about physical actions. This is further discussed in the Appendix.

Within 'world 3', the signals can be categorized as economic or social. For example, price signals can provide information about the willingness of humans to eat farmed fish as well as about the supply of fish feed and the costs of mobilizing human effort and capital into the industry. Such signals are in principle transmitted and transformed by means of 'markets'. If we argue that 'reliable data' is that which leads to actions aimed at sustainability as well as efficiency of resource use, then signals are most reliable when markets are functioning properly and all externalities are taken into account.

There are also social signals, for example concerning whether eating salmon is perceived as healthy, whether there is concern for the welfare of the caged fish or for the employment of people by fish-farms, and what farmers must do to maintain good conditions on the sea-bed beneath their fish-pens and so satisfy the industry's regulators. As social signals, this information is propagated and transformed by various institutions, including the media, governments, non-governmental organizations, and trades unions, as well as by word of mouth amongst individuals. *Science* is a sub-set of such institutions with special rules for selecting and processing information, and claim to a high level of reliability.

In stressing the role of ‘signals’ within the social-ecological system, we are approaching the view of Nicklas Luhmann of social systems as autopoietic (self-generating) communications networks, within which the potentially overwhelming flow of information from outside the system is filtered for what is considered meaningful (Luhmann, 1989; see also Leydesdorff, 2000).

In accordance with systems theory, the social network is seen as hierarchical or recursive, i.e., containing subsystems that contribute emergent properties to higher levels and for which higher levels provide boundary conditions. We see the lowest level nodes of the social net as being the ‘lifeworlds’ of Habermas (1984), the informal domain of social life, where communication amongst individuals reflects and shapes feelings, understandings and action, and can lead to ‘communicative rationality’ (Finlayson, 2005). Lifeworlds form and dissolve according to the lives, activities, and interests of their members. Above these is what Habermas calls ‘the system’, in our terms another set of interlinked systems that are institutions, formalized originally either explicitly, as sets of rules made by individuals or by meta-rules devised by ‘collective rationality’, or implicitly by processes within society of which members are not necessarily aware. ‘Governance’ is a process of social decision making that sends (legitimately coercive) signals to individuals, and receives information from society and ecosystem.

Whereas the currency of ‘society’, we argue, is information and the rules for processing that information (which are not necessarily distinct, as Turing, 1937, showed), the ‘economy’ is more complicated. Although much GDP in modern societies is contributed by intangible services that humans perform for each other, economies must have a physical basis in tangible ecosystem services and transformations made to these within the human physical part of the ecosystem. The contributions that the results make to human well-being can be distributed in numerous ways, such as by central planning or gift exchange, but in much of the modern world the non-physical part of ‘economy’ is dominated by the institutions of money, property and the market, the latter being a cross-roads for the receipt, processing and transmission of information about resource availability and human demands (e.g. by means of price signals). Sometimes, as in the present epoch, the money economy becomes a dominant and destabilizing autopoietic sub-system, overwhelming environmental signals about the sustainability of natural resources, and dangerously damping the ability of other social sub-systems to ‘resonate’ (Luhmann, 1989) to vital messages from natural ecosystems.

A final point, which returns us to the methodology of the SAF, is that social-ecological systems can be, not only hierarchical and recursive, but also self-referential: that is to say, the ‘real’ system can be conceptualized as shown here, and this conceptualization is not only itself part of world 3 but also potentially capable of engendering change in the social-ecological system of which it is a part. Indeed, that is the point of the SPICOSA SAF.

**Discussion**

The model of social-ecological systems in Figure 4 is, of course, soft: it is only one way to conceptualize the complex pattern of relationships amongst tangible and intangible things in a coastal zone region (and any similar system). It has the advantage of blurring the old disciplinary boundaries. Instead of, for example, ecology being concerned with ‘nature’ and social sciences with ‘the human world’, the model suggests that the key distinctions are between those parts of the social-ecological system in which mass-energy-forces are the main constituents and those parts in which information flows and rule-sets are the essential elements. Indeed, as we've hinted, it is possible to go a step further and see the entire system as one in which information is the common currency: in which the signals from one part of the system to another flow through negative feedback loops providing resilience in the face of externally imposed pressures (and see Appendix). Certainly, if the model is to be implemented by computer software, then all parts of it must be represented by information, which is of course carried by the 'world 1' flow of electrons within hardware.

As we have learnt from applications of the SPICOSA SAF, however, much can be gained from conceptual models in their own right (McFadden et al, in prep). Two main implications can be drawn from the model of Figure 4.

1. Adaptability and resilience (Holling, 1973) are (best seen as) properties of the integrated system (Holling & Sanderson, 1996, and see Appendix). As the human footprint continues to increase (Hails et al., 2008) at the expense of the 'natural world', the latter has less room for adapting to changed conditions. Thus, it would seem that adaptation must take place largely in the social system. But this requires:

(a) rapid and correct economic signals (i.e. with externalities properly costed);

(b) rapid and correct social signals including scientific information.

Part of the motivation for the SPICOSA project was to find a method by which to make such signals more reliable and more rapid. The technical methodology included the use of 'quick-assembly' computer models to examine the consequences of different scenarios for a simplified computationally-realized version of problem-related features of the 'real' system (Tett et al., 2011). The social methodology included stakeholder engagement, which we have argued (Mette et al, 2011) improves reliability and legitimacy of communications and decisions (the latter seen by the social-ecological model as rule-bound transformations of the former). It also included methods for improving the science-policy interface, i.e. for dealing with social, economic and scientific signals about the state of the social-ecological system.

2. The idea that 'value in nature' (Rolston, 1994) includes 'systemic value' would seem to apply also to social-ecological systems, making explicit the argument that nature's value is not a luxury for humans but essential for human social survival.

## Conclusions

There remains more to do terms of understanding and re-designing the functions of science and governance in relation to ecological signals (the science-policy interface) and also in terms of understanding the role of the media in the transmission of social and ecological signals. Nevertheless, we think that there is much to be gained by understanding social-ecological systems better as networks of communication.

## Appendix

Drawing on the discussion of Luhmann's work by Leydesdorff (2000), we can specify the behavior of any system thus:

$$[output, TF, state] = TF(input, state)$$

Where *input* is information received across the system boundary, *state* is the current state of the system, *TF* is a transformational function, and *output* is transformed information. The transformation is supposed to result in the extraction of locally meaningful information, which may or may not be transmitted onwards as altered information or as action in the physical world. The equation suggests that the result of transformation can include a change in the local state of the system and in some cases in the transformational rules. (Thus, in the most general terms, the system is conceived of as a Turing machine.) If $output/input >= 1$, then the system 'resonates' to the signal, as Luhmann (1989) has it.

Because our model of the social-ecological system allows it to contain a hierarchy of subsystems, the equation can apply to the whole system or to any part – for example a small set of interacting biological species, a Habermassian 'lifeworld' node in the social system, or a Luhmannish communications sub-system such as that of science. Both the parts and the whole can have emergent properties. The property of *resilience* results from negative feedback loops within a system, so that the resulting outputs and state changes are minimized compared with input perturbations. The property of *adaptation* involves significant changes in state and *TR* that help to maintain the viability of the system. (These definitions may be compared with those of Walker et al., 2004, based on a state-space approach.)

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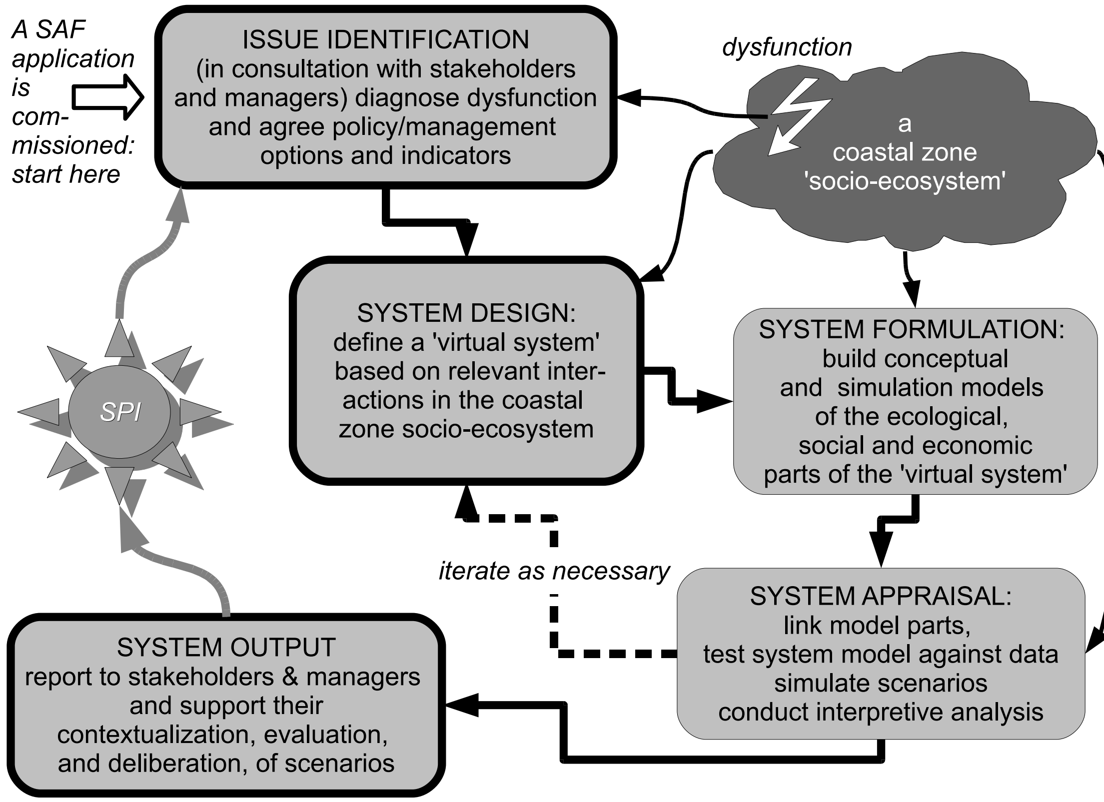
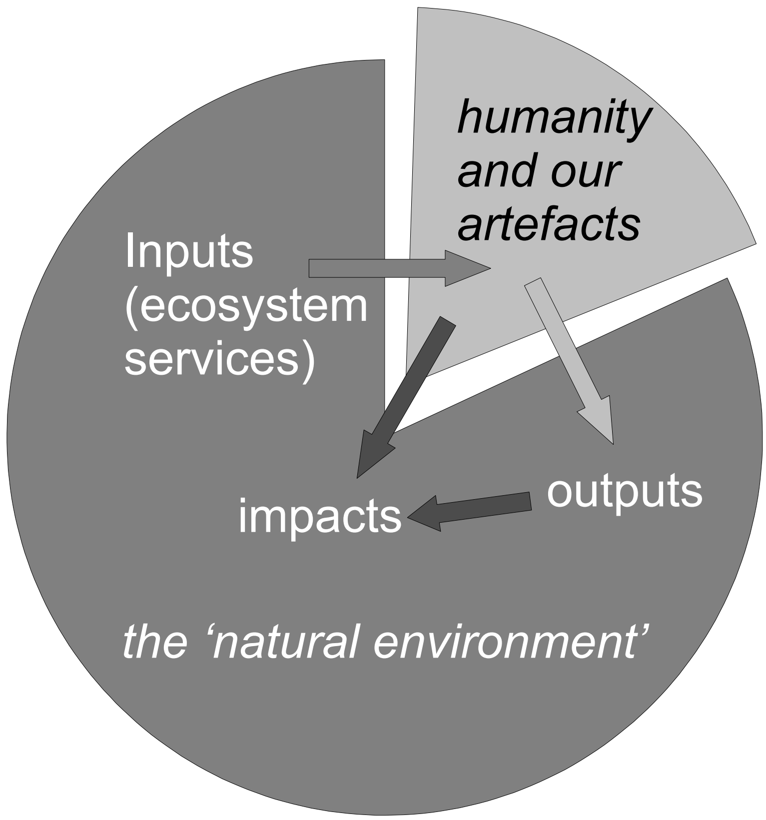
**Figure legends**

1. The SPICOSA 'Systems Approach Framework' or SAF (modified from Tett & Sandberg, 2011).
2. Humans and 'the environment' (modified from Tett & Sandberg, 2011).
3. Words on a beach. (Photograph by Tavis Potts, SAMS). As 'world 1' phenomena, these are simply local changes in the elevation of the sandy surface of the beach. As 'world 3' phenomena, they convey information that is meaningful to any 'world 2' mind equipped with the English language. Extra meaning is available to those who took part in the SPICOSA meeting in Faro in 2008 and were thus part of a finite sub-system having "a distinctive identity that is constantly reproduced in its communication and depends on what is considered meaningful and what is not" (en.wikipedia.org/wiki/Niklas_Luhmann).
4. Two views of the conceptual model of a social-ecological system. 'Ecosystem' and 'human physical world' exist in Popper's 'world 1'; 'Human mind' in 'world 2'; and 'Social System' in 'world 3'.


A SAF application is com- missioned: start here
ISSUE IDENTIFICATION
(in consultation with stakeholders and managers) diagnose dysfunction and agree policy/management options and indicators
dysfunction
a coastal zone 'socio-ecosystem'
SYSTEM DESIGN:
define a 'virtual system' based on relevant inter- actions in the coastal zone socio-ecosystem
SYSTEM FORMULATION:
build conceptual and simulation models of the ecological, social and economic parts of the 'virtual system'
SPI
iterate as necessary
SYSTEM APPRAISAL:
link model parts, test system model against data simulate scenarios conduct interpretive analysis
SYSTEM OUTPUT
report to stakeholders & managers and support their contextualization, evaluation, and deliberation, of scenarios


humanity and our artefacts
Inputs (ecosystem services)
outputs
impacts
the 'natural environment'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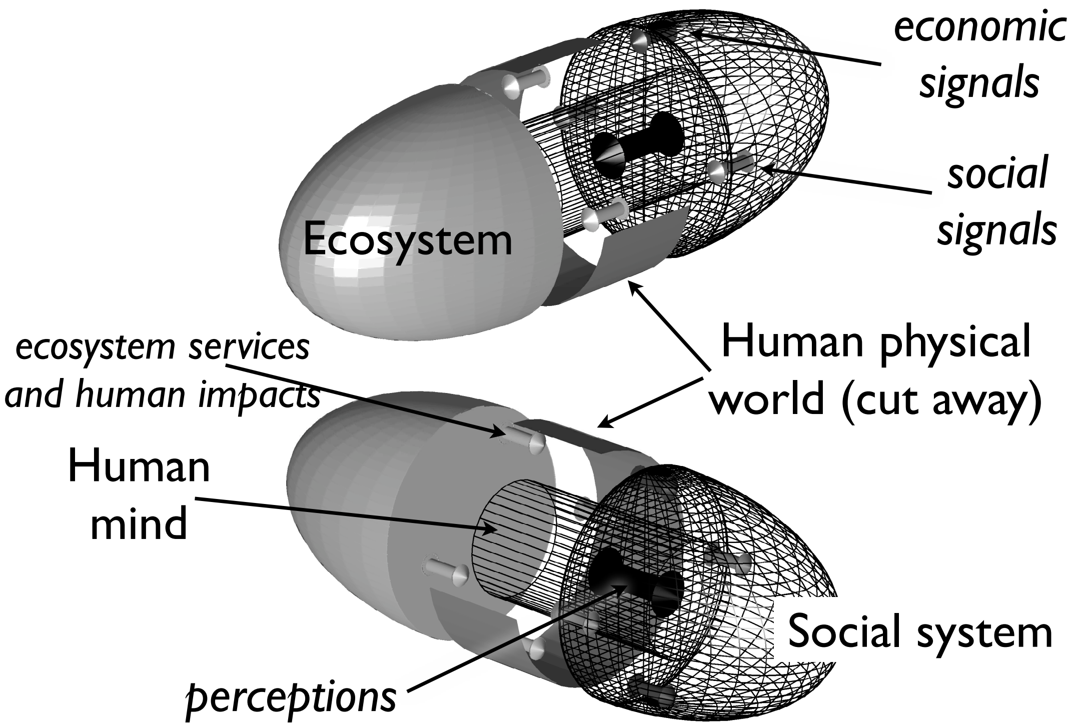
WE LOVE
SPICOSA


economic
signals
social
signals
Ecosystem
Human physical
world (cut away)
ecosystem services
and human impacts
Human
mind
Social system
perceptions