Biosemiotics and ecological monitoring

Luis Emilio Bruni
Institute of Molecular Biology, University of Copenhagen
Sølvgade 83, DK 1307 København K, Denmark
e-mail: bruni@mermaid.molbio.ku.dk

Abstract. During the recent decades, a global cultural-institutional network has gradually grown up to project, implement, and use an enormous technological web that is supposed to observe, monitor, communicate, inventory, and assess our environment and its biodiversity in order to implement sustainable management models. The majority of "knowledge tools" that have been incorporated in the mainstream of this "techno-web" are amply based on a combination of mechanistic biology, genetic reductionism, economical determinism and neo-Darwinian cultural and biological perspectives. These approaches leave aside many of the qualitative and relational aspects that can only be grasped by considering the semiotic networks operative in complex ecological and cultural systems. In this paper, it is suggested that a biosemiotic approach to ecology may prove useful for the modelling process which in turn will allow the construction of meaningful monitoring systems. It is also advanced that it may as well serve to better integrate our understanding and monitoring of ecosystems into the cultural process of searching for (human) sustainability.

A short note on the *eco* prefix

To the extent that ecosemiotics deals with the semiotic ways in which organisms interact with their natural environment (Nöth 1999) it may be seen as a branch of a general biosemiotics: the analysis of semiotic networks operative in ecosystems (Hoffmeyer 1997a), or the horizontal aspects of semiosis in the ontogeny of organisms and ecosystems (Emmeche 1992).

Ecology, originally a branch of biology, has had an enormous transdisciplinary influence on other fields of study as scholars have become aware of the world-wide ecological crisis and as the *eco* prefix has spread into philosophy, aesthetics, anthropology, literature, history, linguistics, psychology and ethology (Nöth 1999). This development may seem to corroborate Gregory Bateson's observation that if there is a crisis, it is not just ecological but also epistemological. It is not only the ecosystem that is in crisis (although it manifests the consequences of such a crisis) but deep-rooted cultural values, some of which are also operative inside science itself:

> Epistemological error is often reinforced and therefore self-validating. You can get along all right in spite of the fact that you entertain at rather deep levels of the mind premises which are simply false ... circuits and balances of nature can only too easily get out of kilter, and they inevitably get out of kilter when certain basic errors of our thought become reinforced by thousands of cultural details. (Bateson 1972: 480–485)

The spreading (and often the banalization) of the *eco* prefix has not done a good service to the epistemological grounds of the science of ecology. If anything it has encouraged the discipline to rigidly retreat to its physicalist-positivist origin. So the ideologies and contra-ideologies that have risen from the cognition of an "ecological crisis" have tended to deviate our attention from where the real crisis lies. The crisis is in reality a cultural crisis. This is why it is important that we delineate fields of study that deal with the nature-culture interface, or the ecological-anthropological realm, and semiotics looks like a privileged tool in this endeavour.

Nöth (1999: 80) refers to the semiotics of the "interior Umwelt" of the organism (endosemiotics) and states that at this level ecosemiotics begins with the processes of cognition and recognition between genes, other genes, and antigens in their molecular biological environment. Interestingly, the American biologist Leo Buss introduced the term "somatic ecology" to describe the bodily dynamics that continuously regulates potential conflicts between the cell and the individual (Buss, 1987: 139). The immune system plays a central role in this dynamic and at this level there would be no distinction between biosemiotics and ecosemiotics apart perhaps from the implicit goal of "sustainability" sometimes implied by the *eco* prefix.

In accordance with this, Kalevi Kull (1998) has observed that Nöth's definition of ecosemiotics looks like a synonym for biosemiotics, and he places ecosemiotics (and also ecology in general) somehow out of the range of biosemiotics, more towards human ecology and cultural semiotics applied to the study of the culture-nature interface (both, historically in different cultures, and in relation to the contemporary "ecological crisis"). The existence of these two definitions may require some clarification when elaborating a research agenda to apply biosemiotics to the ecosystem-ecological level.

Thus, summing up the above contributions, we can distinguish between (1) ecosemiotics proper — biosemiotics at the ecosystem level, synchronic exo-biosemiotics, and (2) ecosemiotics as a second order notion that reflects on the way we relate to nature through our culture (our knowledge, science, technology, art, etc.), i.e., culture-nature relations, including epistemological considerations on the knowledge tools we use in ecology and environmental sciences.

Notice that "ecosemiotics proper" could be a subject of study for this "second order" ecosemiotics which would then look like "system-observer semiotics"[1] applied to the basic knowledge tools that allow us to relate to nature and to simply be part of it.

In this paper, I will be referring to both levels of analysis in order to (a) identify what is the mainstream trend in ecosystem modelling and monitoring from a system-observer semiotics point of view, and (b) suggest a direction for how biosemiotics research at ecosystem level could be of help in ecological monitoring.

According to the standard definition, "monitoring" consists in the observation, recording or detection of an operation or condition in a system with instruments that have no effect upon the operation or condition of the system. Modelling, on the other hand, is basically a process of understanding, and it is my assumption in this paper that the design of any monitoring device or system (conceptually or mechanically) implies a previous understanding of the process to be monitored, but then again, the "understanding" requires also some observation, which is in turn a sort of monitoring. Given this circularity, I will often be referring to "modelling and monitoring" as one single process (however it is possible to conceive modelling without monitoring, but the contrary seems not possible to me).

Modelling of complex ecological systems may incorporate rigorous assumptions of functional relationships or empirically determined relationships. "The purpose of these models may be to test particular assumptions about system dynamics, give insight into relationships difficult to measure or test under actual conditions, or *indicate the*

[1] "System-observer semiotics" (Emmeche 1992: 78): "the critical inquiry into the nature of the modeling relation to the various systems we can observe, describe, conceptualise and construct theories about. It is a semiotic of scientific experiment, observation, interpretation, operation upon and measurement of various systems".

specific kinds of data needed for a more complete understanding of system function" (Collier et al., 1974: 14, my italics). It is precisely in this last purpose of a model that I think biosemiotics can be of help to ecological monitoring.

Sensory apparatuses and "fine-tuned internal impressions"

Epistemologically, ecology as science, like many other knowledge tools is a specific case of nature-culture communication. It involves our conception of explicative models that simulate nature and yield (and make necessary) further artifacts to monitor and manage (i.e. make decisions about) nature. Ecological modelling and monitoring is a clear example of such a technological interface, i.e., a direct and explicit search for a human dialogue with nature.

In this sense, our empirical data can be seen like "words" with which nature speaks to us. Data is good for monitoring and decision making. But these are not words invented by nature but by ourselves (or us as nature), thanks to the explicative models that we previously constructed.

Biosemiotics sees organic evolution as a gradual build-up of semiotic networks of organisms covering the totality of the surface of the Earth and thus giving rise to an autonomous sphere of communication: the semiosphere (Hoffmeyer 1994). The term *semiosphere* was originally suggested by Yuri Lotman (1990), but here I shall use the concept in the broader conception developed by Hoffmeyer that includes both biosemiosis and anthroposemiosis. In Hoffmeyer's (1997a) perspective, the semiosphere is a sphere like the atmosphere, the hydrosphere or the biosphere. It penetrates these spheres and consists in communication: sounds, odours, movements, colours, electric fields, waves of any kind, chemical signals, touches etc.

Once higher complexity was achieved it became possible to develop a more "sophisticated sensory apparatus and corresponding nervous system which would enable animals to form fine-tuned internal impressions of what lay round about them (the subjective experience of the world, the Umwelt)" (Hoffmeyer 1996: 33).

When we consider the keen sensorial capacity of many animal species it becomes clear that the human sensorial mechanisms are not at the top of the sophistication scale. Instead of sensorial keenness *Homo sapiens* has evolved a well developed "cultural keenness" through which human beings have ingeniously managed to create technological extensions in order to increase their sensorial resolution. Most certainly this fact has played an important role in the evolution of the "technosphere".

One might draw an analogy between the evolution of biological sensorial apparatus in species and the evolution of the "environmental monitoring techno-web" that we have been constructing throughout the past century. This "techno-web" allows us to acquire, store and manipulate an enormous quantity of data. However, it is probable that our capacity to "form fine-tuned internal impressions" of the quality of what lay round about us may have not evolved *pari passu*, or may even have involved.

Through recent decades a global cultural-institutional network has gradually grown up to project, implement and use the enormous technological web that is supposed to observe, monitor, communicate, inventory and assess our environment and its biodiversity in order to implement sustainable management models. This web has been growing through the proliferation of structures that include a great variety of artifacts, hardware, software and implementable conceptual tools of diverse typologies and degrees of sophistication. This "structure" includes networks of monitoring and communication satellites and a great variety of remote-sensing techniques, aerial reconnaissance, groundtruthing techniques, data acquisition, manipulation and display through large-scale computing and modelling (such as the popular multilayer Geographical Information Systems), *in situ* sensors for advanced site characterization and monitoring, complex systems dynamics modelling, ecosystem analysis models, expert systems and artificial intelligence decision making technology, information-sharing technology and the like. We can refer to this structure in general as "information and monitoring systems".[2]

The technological mutation implicit in these global monitoring systems is the consequence of the development and integration of various technologies such as: remote sensing, data telecommunication, technology for the manipulation and "intelligent" management of data, aerospace and military technology. This technological integration is being used as a source of information and automated interpretation of local/global processes to conform natural, military, economic, social, agricultural and infrastructure databases.

---

[2] See World Conservation Monitoring Centre 1996a, 1996b.

It is important to understand how this grand technological web is itself generated by, and in the same time lodges, a mental process inherent to the theoretical developments. There is an inescapable circularity between the design of technology and the kind of theory that can "flow" within it. This in spite of the claims made by many empiricists who may be lead to believe that they do not need theory or that their science does not presuppose any ontological positions.

As Hoffmeyer has observed:

> In actual fact, what biologists work with is not living things but *data* ... one could easily be misled into believing that data is something hidden within the natural world, something which the good experimentalist goes out and most cunningly coaxes out of it [...] To the scientist, reality amounts to data plus those theories which make sense of the gathered data. [...] Despite the impressive volume of data which biology and medicine can produce, it is impossible to rid oneself of the suspicion that there is a chronic gap in all the information they keep churning out. (Hoffmeyer 1996: 90–92)

Considering the alleged amplitude of the "biodiversity" concept (genes, species, ecosystems and cultures), one realizes that it is almost equivalent to the concept of "living nature". The difference between the biodiversity and the biosphere concepts lies in the fact that the former puts its emphasis in taxonomic quantification, while the latter concentrates on the process of interdependent relations between such diversity of taxa. The mainstream approach in the study of biodiversity has been that of making species inventories and taxonomic quantification, while the one that predominates in the study of the biosphere have been the quantification of mass-energy conversions in ecosystems.

The majority of "knowledge tools" that have been incorporated in the mainstream of the cultural-institutional-technological web that is supposed to "manage" the sustainable use of biodiversity and ecosystems world-wide, are amply based on a combination of mechanistic biology, genetic reductionism, economical determinism and neo-Darwinian cultural and biological perspectives. These epistemological stands may each have their theoretical merits, but taken in combination and determining "thousands of cultural details" it may be suspected that they have a counterproductive effect on common sense and everyday management. At the very best, this combination may provide only a partial picture of what is going on in ecosystems, and in the worst case it may give rise to misleading guiding principles if we want the goal to be "sustainability".

We can thus conclude that Modernity has produced some cultural premises which have determined an ecological crisis. Among these premises figures the environmentalist's myth of an external environment that we have to save without questioning the cultural aspects that have compromised it. This is how we end up developing a cultural-institutional-technological web for the sustainable management of global biodiversity based almost exclusively on the epistemological scaffolding born from the very process of modernity that in the first place has determined the cultural-ecological crisis.

The goals of ecological monitoring

Since the international community became aware of the ecological crisis in the early 1970's (particularly since the Stockholm Conference in 1972) different concepts have been implemented to characterize the kind of interdisciplinary effort needed for a healthy social-ecological management. Among these "sustainability" is probably most widely accepted at the international level, and the goals of ecological monitoring should therefore coincide with those of "sustainable development". However, even its supporters acknowledge that the concept still remains vague and elusive, and this of course affects its practical implications. There appears to be consensus on the need to emphasize ecological, economic and social indicators of sustainability. A definition considered as one of the most comprehensive and insightful says that sustainability is a state in which human life can continue indefinitely, human individuals can flourish (economic), human cultures can develop (social), but in which the effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system (ecological) (Herkert et al. 1996). At present, "sustainability" studies seem to have trouble in moving ahead from this initial definition, which risks becoming an inoperative cliché.

Almost three decades ago Bateson gave us some hints as to how to proceed along a sustainable path (without ever using the word "sustainability"), and how to define a healthy ecology of human civilization:

> It would be convenient to have an abstract idea of what we might mean by ecological health. Such a general notion should both guide the collection of data and guide the evaluation of observed trends. [...] A single system of *envi-*

> *ronment combined with high human civilization* in which the flexibility of the civilization shall match that of the environment to create an ongoing complex system, open-ended for slow change of even basic (hard-programmed) characteristics. (Bateson 1972: 494)

Among the different characteristics listed by Bateson in his attempt to work towards a definition of "high" we have: "A 'high' civilization should therefore be presumed to have, on the technological side, whatever gadgets are necessary to promote, maintain (an even increase) wisdom of this general sort. This may well include computers and complex communication devices" (Bateson 1972: 495).

More recently, Hoffmeyer adds further hints in order to move on from operative definitions:

> Sustainable resource utilization presupposes that natural systems are allowed to follow their own complex and diverse regulatory mechanisms. And this is where information techniques enter the scene. So far we have simplified nature to match our heavy technical system. With the information techniques we would be able to fit our technical system to match the complexity and refinement of living nature. [...] Basically two kinds of information techniques should be distinguished. Techniques for manipulating, transferring and storing culturally derived informations, i.e. microelectronic techniques, and techniques for manipulating, transferring and storing biologically derived informations, i.e. bio-information techniques (e.g., gene splicing). (Hoffmeyer 1993a)

But even though new information techniques (both types) may constitute the technological basis for a production system which could better match the complexity of ecosystems we should bear in mind that "... several of the premises which are deeply ingrained in our way of life are simply untrue and become pathogenic when implemented with modern technology" (Bateson 1972: 502).

System-observer semiotics

Environmental sciences and engineering (extended to sustainability studies) deal with the attenuation and balance of anthropogenic impacts on the "natural life-support systems" (i.e., ecosystems). They act in the interface between culture and nature. This means that the design and choice of technology should include considerations about such an interface.

At present, major approaches dealing with this interface, particularly with monitoring, tend to preserve the discontinuity between the two realms which the interface should bring into interactive play, nature and culture. This is the reason why it might be useful to introduce an approach that can cope equally well with the semiotic aspects of both realms and specially the semiotic aspects of the interface. Such an approach would seem to make the "knowledge transfer" from the natural to the cultural — "capturing data" (i.e., monitoring) — smoother, since it would not reduce the analogical-digital communication, i.e. the code-duality that characterizes all living systems and human cognition (see below), to digital, quantitative data, which then paradoxically must in a later stage be "re-analogised" for the human mind to capture its meaning.

The processes of interest are not linear, and the variables are so many and so entangled that the broader balance may easily be lost out of sight. Thus, for instance, people doing work on ecosystem network analysis, attempting to trace and quantify the trophic connections among the populations (who eats who and how much carbon, nitrogen and phosphorus is transferred from one place to another), often complain that even in the simplest ecosystems the emerging picture soon comes to resemble a hopeless jumble, sometimes referred to as a "bird's nest" or "spaghetti diagram".

When the technology designer sets out a goal of sustainability in his design, he immediately bumps into the "cultural issue" since the design of "environmental friendly" technology necessarily involves cultural aspects. Thus we find different approaches in the literature such as "design for the environment", "life cycle design", "green engineering", "industrial ecology" "sustainable development and technology" or "environmentally conscious design" (Coulter et al. 1995) where the "conscious" part seems to be related to the "sustainability" notion.

The general trend of globalization has implied that also the spatio-temporal scope of environmental planning and technology design has expanded its range of action, creating a massive techno-web to manage biodiversity resources and anthropogenic impacts on ecosystems. It is in this technological sphere — right at the interface between the natural system and our cultural "planning" — that we encounter monitoring technology.

But monitoring implies a previous step, which is sensing, and sensing in turn implies a range of semiotic processes of different sorts: sensing data and sensing a difference that has to make a difference to whoever designed and implemented the sensing device and its data codification and manipulation procedure. The empirical ecologist might therefore ask himself two different questions implying two different epistemological attitudes:

(1) what can I sense with all this technology that I have available and that keeps arriving to me?

(2) what kind of technology (i.e. knowledge tools) do I really need to sense what is supposed to be important?

Obviously the design of "sensing" has to precede the actual activity of "sensing". And the design of "sensing" consists not only in structuring and codifying the data but also in the design of all the procedures to manipulate those data in order to grasp their significance.

Many research programs recognize that complex systems exhibit chaotic and non-linear behaviour, recognize the complexity of feedback loops that make it difficult to distinguish cause from effect, and recognize the existence of thresholds and emergent qualities that make difficult the aggregation of small scale behaviour to arrive at large-scale results. However, many of these approaches seem to put excessive confidence in large scale computing (such as parallel super computers or advanced numerical computation algorithms) hoping thereby to obtain integrated models of systems that independently and on their own would be extremely complex. An example of this could be the integration of computerized models for ecosystems dynamics with economic system simulation and climatic systems in order to compound an unitary model of incredible complexity. To move towards this goal, it is claimed that it is necessary to mobilize the academic community in a global collaborative effort based on the new information sharing technology in order to reunite the leaders of advanced computing and software development with the leaders in global biological, ecological and socioeconomic modelling and data collection.

These approaches risk transforming complexity into complication. They leave aside many of the qualitative and relational aspects that can only be grasped by considering the semiotic networks operative in the complex systems constituted by the ecological and the cultural processes. As Hoffmeyer has warned:

> Environmentalists have generally considered ecological complexity to be a positive value and logically, at least, complexity would seem to be the opposite of simplicity. But the problem with this concept (complexity) may well be that our scientific tradition has tended to treat it in a simplifying way, i.e., through definition in quantitative terms. (Hoffmeyer 1993b: 162)

Thus in most of mainstream monitoring networks information is perceived through a filter of "cultural structuring", that converts it into a digital form amenable to sophisticated computational treatment even before it reaches the retina of the "someone" to whom it was supposed to make a difference. It follows from this that the kind of information we will get by the monitoring procedure is buried in the computational setting of the situation and thus in our prefigured notions of "sustainability" and "conscious". Therefore it is important that decisions on what direction we want to take when defining terms such as "sustainability" or "conscious" precede the designing of parameters (the differences!) to be sensed.

A view from biosemiotics

There are at least two ways in which the information techniques could help us to fit our technical systems to match the complexity and refinement of living nature. And these two ways correspond to the two basic kinds of information techniques distinguished by Hoffmeyer (1993a), namely techniques for manipulating, transferring and storing culturally derived information, as in the case of ecological monitoring, and techniques for manipulating, transferring and storing biologically derived information as in the case of biotechnology (while in this paper I'm concentrating on the former, I will take on the latter in a separate work). In both these applications of information techniques biosemiotics is involved.

Moreover, as biotechnology advances, the genetic (and thus also the evolutionary) level will increasingly be included in the ecological monitoring. Here the challenge to biosemiotics is to assist in creating an explanatory sphere that will allow for the passage from the "one gene-one enzyme" approach to approaches based on the multifarious developmental trajectories in organisms and ecosystems. Both molecular biology and biotechnology might profit from this (Emmeche 1999; Sarkar 1996).

Besides being potentially able to help to refine our mapping techniques of biological processes, a biosemiotic approach to ecology, if carried out further, may serve to better integrate our understanding and monitoring of ecosystems into the cultural process of searching for (human) sustainability.

Several different concepts have been used during the 20th century to represent the totality of living nature: from the biosphere to biodiversity to the more comprehensive semiosphere. These constitute different approaches to biological complexity, but they all have in common the fact that they focus our attention upon a network that includes everything from genes to ecosystems. While biodiversity has been understood in terms of its "components", ignoring the relations between them, the biospheric approach has surrendered to the strategy of explaining life as "nothing-but-interacting-molecules" resulting in an explanation of life as trophic chains and mass-energy exchanges at ecosystem level. And so once again the reductionist research strategy leaves out a whole dimension of life that it has itself helped digging out: the dimension of semiosis. "Surprisingly then", writes Hoffmeyer, "from a biosemiotic point of view the biosphere appears as a reductionist category which will have to be understood in the light of the yet more comprehensive category of the semiosphere" (Hoffmeyer 1997a: 934). The biosphere is bio-sphere because from it emanates a semiosphere in which it is itself immersed and by which it is permeated, Life is an ancient semiotic web.

A few years before presenting the new concept, biosphere, Vernadsky himself apparently already spoke in terms of the Biosphere's "mental process", in which the human "mental process" is immersed, as is evident in the following quote made by Lotman, who tells us that Vernadsky, in his notes dating from 1892, described human intellectual activity as a continuation of the cosmic conflict between life and inert matter:

> The seeming laws of mental activity in people's lives has led many to deny the influence of the personality on history, although, throughout history, we can in fact see a constant struggle of conscious (i.e. not natural) life-formations with the unconscious order of the dead laws of nature, and in this effort of consciousness lies all the beauty of historical manifestations, the originality of their position among the other natural processes. A historical epoch can be judged by this effort of consciousness. (Lotman 1990: 125)

It is evident that Vernadsky is referring to the semiotic process inherent to the living world and its relation to the "dead nature" that serves as a substrate through which it manifests itself.

Bateson used the notions of *pleroma* and *creatura* to describe how the "mental process" in nature unfolds in a historical perspective. For him the word *pleroma* describes "the material world, characterized by the kinds of regularities described in the physical sciences". Whereas *creatura* refers to "all processes in which the analog of cause is information or difference [...], the entire biological and social realm, necessarily embodied in material forms subject to physical laws of causation as well as the distinctive processes of life", i.e. the world of communication. The distinction between *pleroma* and *creatura* "is blurred by the fact that human knowledge of Pleroma is entirely mediated by Creatural processes of response to difference" (Bateson, Bateson 1989: 207–211). So for Bateson, "there is an underlying notion of a dividing line between the world of the living (where *distinctions* are drawn and *difference* can be a cause) and the world of nonliving billiard balls and galaxies (where forces and impacts are the 'causes' of events)" (Bateson 1979: 7).

The revolutionizing effect of Bateson's innovative notion of "information" in life sciences as opposed to the physicalist and mechanistic, or computabilistic, philosophies that cannot encompass the semantic aspect of information and cognition has been discussed by Brier (1998: 185). For Bateson, the smallest unit of mental process, is a difference or distinction, or news of a difference. So information means a difference that makes a difference to somebody. But for there to be a "difference", news of a distinction, there has to be "somebody" to perceive it. It has to be in relation with "a system with interpretative power, or a subject to whom these ostensible signs could make a difference (if we say that sign, or information, is a 'difference that makes a difference for some interpretant', to cross ideas of C. S. Peirce and Gregory Bateson)" (Emmeche 1994: 12).

In a biosemiotic understanding biological information is inseparable from its context, it has to be interpreted in order to work, and Bateson's approach to information, context and analog/digital communication has been recognized as highly relevant to a more fully developed semiotic approach to biology (Hoffmeyer, Emmeche 1991).

Views like those of Vernadsky (the "consciousness" of historical manifestations), Bateson (nature's "mental process" in a historical perspective) or those of Lotman and Hoffmeyer (the semiosphere), have in common the necessity of maintaining synchronicity and diachronicity together. The interplay of what Hoffmeyer has termed horizontal and vertical semiosis in evolution. From a biosemiotics point of view, this dynamic can be grasped through the concept of "code-duality" which allows the consideration of historical and evolutionary aspects in the semiotic networks "horizontally" operative in ecosystems.

Thus "code-duality" (Hoffmeyer, Emmeche 1991) becomes a key concept in biosemiotics: life exhibits a semiotic interaction between two states, the analog coded state of the organism itself and its redescription in the digital code of DNA. As analog code the organisms recognize and interact with each other in the ecological space giving rise to a horizontal semiotic system (or ecological hierarchy), while as digital codes (after eventual recombination through meiosis and fertilization in sexually reproducing species) they are passively carried forward in time between generations, the vertical semiotic system (or genealogical hierarchy).

This leads Hoffmeyer to say that the necessary but sufficient condition for a system to have the ability to transform the differences in its environment into distinctions is that it has developed self-reference based on code-duality, i.e. the continued chain of digital-analogue (i.e. DNA-cell) re-interpretations guiding the genealogical descent (Hoffmeyer 1993b, 1997a, 1995, 1996; Hoffmeyer, Emmeche 1991). The notion of "code-duality", like other biosemiotic terms, such as "semiotic freedom", "Umwelt", "swarm semiotics" and "semiogenic scaffolding" may have fruitful explanatory potential at the ecosystem level. This is not the place, however, to engage in a more systematic analysis of these concepts in relation to ecosemiotics.

The most important step for the conservation and sustainable use of biodiversity is often assumed to be the identification and elaboration of exhaustive taxonomic inventories. Many scientists are worried about the extinction of thousands of species yearly before anybody even had a chance to classify them! It has been estimated that about 1 million species have been taxonomically labelled and frequently it is repeated that there may exist five, thirty or even eighty millions of species yet to be "discovered". But while taxonomy is of course necessary and useful, the understated goal of exhaustibility seems a bit awkward. Most of the resources spent on species conservation are being allocated to this immense work of identification.

Also much effort goes to the mapping and quantifying of trophic networks and biomass. According to Emmeche (1998), ecology addresses the specificity of individual species in terms of niches, where the niche is the mode of functioning of the individual species in the ecosystem, its special contribution to the network of energy and matter. Emmeche claims that, after all, biomass is organized in other far more ingenious ways than the simple dyadic-ecological relations of the type illustrated by the figure "tiny fish is eaten by little fish is eaten by fish is eaten by large fish is eaten by". The fact that food chains are not just simple and dyadic actions[3] but complex relations

[3] Emmeche (1998: 75): "There are two kinds of actions in our universe, dyadic and triadic. Dyadic action is mechanical or dynamic, and is concerned with efficient causa-

dependent on constant communication among organisms (of different or the same species), represents the semiotic dimension. So it becomes hard to imagine that (bio) mass phenomena are exclusively governed by the laws for the particles of which they are composed. Thus mass "becomes a macroscopic phantom with no meaning, for it is the dynamics at the micro level that have been the causal moving force for the system as a whole" (Emmeche 1998: 76).

Quantification of biomass production has been used to monitor the "vigor" of large ecosystems, like for example the transnational effort launched by UNESCO at the beginning of the 1980s to monitor ecosystem "vigour" and "function" of the main ecosystems of the Caribbean Sea. A project like this consists in setting up a certain number of measuring stations (23 in 19 countries), establishing a standard measuring protocol for consistency and over the years create a historical-statistical data-base for comparison purposes (UNESCO-CSI, 1997).

But seen as an ecological indicator mass growth may not be good enough. Thus even though it may be a good indicator of "vigour" it does not necessarily reflect "health" or "balance", as may for instance be observed in an eutrophic mangrove lagoon where sturdy marine birds activity on the expanding mangroves does not guarantee that fishery, reptiles and water freshness are not at risk.

This is where biodiversity enters into ecological monitoring. Measurements of biodiversity comprises the identification and quantification of species and the recording of population dynamics. In large, complex and diverse ecosystems, as for instance a tropical rainforest, such measurements take on enormous proportions. Therefore modelers try to design monitoring systems that rely on what are considered "indicator species", a notion which obviously already has an explicit semiotic connotation.

The mere number of specimens of an indicator species will probably not in general give a truly reliable idea of what is going on in a larger dynamic. Or to put it in another way, the selection of a "sensible" species as an indicator cannot be based solely on the easiness of observation of the specimens but must also rely on knowledge that we can obtain about its Umwelt and its semiotic niche, and on an understanding of how that borderless-sphere relates to the network of semiotic relations that include other "indicator" species or events.

---

tion as described for example in ecology in connection with the biomass. The triadic action type is semiotic, or intelligent; it concerns final causation as described in biosemiotics. The two kinds of action are irreducible, but inseparable and superimposed".

For illustration let us consider the eventual monitoring of the effects of gaps produced by forest clearance in large tropical rainforest extensions. The gaps are known to disrupt the “normal” pattern of species dissemination in the forest surrounding the gap. The main question here will be how small patches of forest can possibly be if retainment of its primary diversity, vigour, function or health shall be assured. What are the signs that disorient birds in their disseminating of tree seeds? Why should we care?

A strategy like this would more truly vindicate the role of the so-called “parataxonomist” in western globalized culture, that is, the role of native people that in their everyday life are used to handle a great amount of data relative to the species, their trails, their utterances, their habits and their relations with other habits, other utterances and other trails in the ecosystem.

Here, if a tree needs to rely on certain bird’s airmail service for success in reproduction, where would that information be found? In the tree’s DNA? or in the bird’s? would it be foolish to talk about the ecosystem’s DNA?

Semiotics, trophic chains and biomass growth and decay are not mutually exclusive explanatory tools:

> To the extent evolution favors the establishment of refined semiotic interaction patterns between species, it will also tend to open the way for a multitude of physical interactions between species... In this perspective symbiotic relations are not to be considered just funny accidents, rather they constitute a systematically occurring phenomenon in the semiosphere. (Hoffmeyer 1997b: 367)

Any primitive biological organism already interacts semiotically with its environment when it selects or avoids energetic or material objects in its environment (Nöth 1999: 78). But the semiotic interactions of organisms are by no means limited to physical dependence modes. There are other possibilities for semiotic mutualism in which one organism uses regularities exhibited by other organisms as cues (e.g., for orientation, play, safety and even sexual intercourse) just in the same way it may use perceived regularities from the abiotic world for similar purposes (as, e.g., when migratory birds find their way by reading the configuration of stars) (Hoffmeyer 1997b: 367–368).

Semiotic interactions will tend to combine different species into integrated functional networks which cannot be analysed in terms of two-species interaction models. Hoffmeyer has claimed that semiotic interactions between species very likely, when analyzed in more detail, "will produce an explosive change in our conceptions of symbiosis and thereby put the symbiotic theory of evolution to the forefront of evolutionary theory" (Hoffmeyer 1995: 377).

In conclusion then, we shall suggest that an understanding of nature's semiotic ways of controlling the interactive behaviour of individuals, populations and species may prove useful or even necessary for the modelling process, which in turn will allow the construction of meaningful monitoring systems.

References

Acock, B.; Reynolds, J. F. 1990. *Model Structure and Data Base Development: Process Modelling of Forest Growth Responses to Environmental Stress.* Portland: Timber Press.

Bateson, Gregory 1972. *Steps to an Ecology of Mind.* New York: Chandler Publishing Company.

— 1979. *Mind and Nature: A Necessary Unity.* New York: Bentam Books.

Bateson, Gregory; Bateson, Mary Catherine 1989 [1987]. *Dove gli angeli esitano. Verso un'epistemologia del sacro.* Milano: Adelphi Edizioni.

Brier, Søren 1998. Cybersemiotics: A transdisciplinary framework for information studies. *Biosystems* 46: 185–191.

Buss, Leo 1987. *The Evolution of Individuality.* Princeton: Princeton University Press.

Collier, Boyd D.; Cox, George W.; Johnson, Albert W.; Miller, Philip C. 1974. *Dynamic Ecology.* London: Prentice/Hall International editions.

Costanza, Robert; Wainger, L.; Folke, C.; Mäler, K.-G. 1993. Modeling complex ecological economic systems: Toward an evolutionary, dynamic understanding of people and nature. *Bioscience* 43(8): 545–555.

Coulter, Steward; Brass, Bert; Foley, Carol 1995. A lexicon of green engineering terms. In: Hubka, V. (ed.), *International Conference on Engineering Design, ICED 95*. Praha: Heurista, 1033–1039.

Eichler, Arturo 1987. *S.O.S. Planeta Tierra.* Caracas: Fuerzas Armadas de Cooperación de Venezuela.

Emmeche, Claus 1992. Modelling life: A note on the semiotics of emergence and computation in artifitial and natural living systems. In: Sebeok, Thomas A.; Umiker-Sebeok, Jean (eds.), *Biosemotics. The Semiotic Web 1991.* Berlin-New York: Mouton de Gruyter Publishers, 77–99.

— 1994. The computational notion of life. *Theoria-Segunda, Epoca* 9(21): 1–30.

— 1998. The agents of biomass. In: Jurgensen, Andreas; Ohrt, Carsten (eds.), *The Mass Ornament: The Mass Phenomenon at the Turn of the Millennium.* Odense: Kunsthallen Brandts Klaedefabrik, 64–79.

— 1999. The Sarkar challenge to biosemiotics: is there any information in a cell? *Semiotica* 127(1/4): 273–293.

Emmeche, Claus; Hoffmeyer, Jesper 1991. From language to nature: The semiotic metaphor in biology. *Semiotica* 84(1/2): 1–42.

Herkert, Joseph; Farrell, Alex; Winebrake, James 1996. Technology choice for sustainable development. *Institute of Electrical and Electronics Engineers' Technology and Society Magazine* 15(2): 11–20.

Hoffmeyer, Jesper 1993a. The changing concept of information in the study of life. Paper presented in the Symposium *Nature and Culture in the Development of Knowledge. A Quest for Missing Links*. Uppsala, 8–11 September 1993 (http://www.molbio.ku.dk/MolBioPages/abk/PersonalPages/Jesper/ History.html).

— 1993b. Biosemiotics and ethics. In: Witoszek, Nina; Gulbrandsen, Elisabeth (eds.), *Culture and Environment: Interdisciplinary Approaches*. Oslo: Centre for Development and the Environment, University of Oslo, 152–176.

— 1995. The semiotic body-mind. In: Tasca, Norma (ed.), *Essays in Honour of Thomas Sebeok*. Porto: Cruzeiro Semiótico No. 22/25, 367–383.

— 1996. *Signs of Meaning in the Universe: The Natural History of Signification*. Bloomington: Indiana University Press.

— 1997a. The global semiosphere. In: Rauch, Irmengard (ed.), *Proceedings of 5th Congress of The International Association for Semiotic Studies, Berkeley, 1994*. Mouton Gruyter, 933–936.

— 1997b. Biosemiotics: Towards a new synthesis in biology. *European Journal for Semiotic Studies* 9(2): 355–376.

— 1998. The unfolding semiosphere. In: Vijver, Gertrudis van de; Salthe, Stanley; Delpos, Manuela (eds.), *Evolutionary Systems: Biological and Epistemological Perspectives on Selection and Self-Organization*. Dordrecht: Kluwer, 281–294.

Hoffmeyer, Jesper; Emmeche, Claus 1991. Code-duality and the semiotics of nature. In: Anderson, Myrdene; Merrell, Floyd (eds.), *On Semiotic Modelling*. New York: Mouton de Gruyter, 117–166.

Kull, Kalevi 1993. Semiotic paradigm in theoretical biology. In: Kull, Kalevi; Tiivel, Toomas (eds.), *Lectures in Theoretical Biology: The Second Stage.* Tallinn: Estonian Academy of Sciences, 52–62.

— 1998. Semiotic ecology: Different natures in the semiosphere. *Sign Systems Studies* 26: 344–369.

— 1999. Umwelt and evolution: From Uexküll to post-Darwinism. In: Taborsky, Edwina (ed.), *Semiosis, Evolution, Energy: Towards a Reconceptualization of the Sign.* Aachen: Shaker Verlag, 53–70.

Lotman, Yuri 1990. *Universe of the Mind: A semiotic Theory of Culture*. Bloomington: Indiana University Press.

May, Robert (ed.) 1976. *Theoretical Ecology: Principles and Applications.* Oxford: Blackwell Scientific Publications.

Nöth, Winfried 1999. Ecosemiotics and the semiotics of nature. In: Taborsky, Edwina (ed.), *Semiosis, Evolution, Energy: Towards a Reconceptualization of the Sign.* Aachen: Shaker Verlag, 73–87.

UNESCO-CSI 1997. Coastal Ecosystem Productivity Network in the Caribbean (http://www.unesco.org/csi/act/caricomp/projec15.htm)

World Conservation Monitoring Centre 1996a. *Assessing Biodiversity Status and Sustainability.* Cambridge: World Conservation Press.

World Conservation Monitoring Centre 1996b. *The Biodiversity Information Clearing House: Concept and Challenges.* Cambridge: World Conservation Press.

Биосемиотика и экологический мониторинг

В последние десятилетия глобальная культурно-институциональная сеть постепенно развилась до того, чтобы начать проектировать, оборудовать и вводить громадную технологическую сеть, которая призвана наблюдать, контролировать, инвентаризировать и оценивать нашу окружающую среду и ее биологическое разнообразие, чтобы обеспечить создание модели экономичного хозяйствования. Большинство "инструментов знания", применяемых в главном направлении этой "техносети", основывается на комбинации механистической биологии, генетического редукционизма, экономического детерминизма и неодарвинистских культурных и биологических перспектив. Такие подходы игнорируют многие качественные и реляционные аспекты, которые можно понять, лишь учитывая действие семиотических сетевых структур в комплексных экологических и культурных системах. Автор статьи считает, что биосемиотический подход к экологии может оказаться полезным при моделировании процессов, что, в свою очередь, позволит конструировать оптимальные системы мониторинга. В статье утверждается, что биосемиотический подход может способствовать интегрированию нашего понимания экосистем и наблюдения за ними в общекультурный процесс поиска (человеческой) стабильности.

Biosemiootika ja ökoloogiline seire

Viimastel kümnenditel on globaalne kultuurilis-institutsionaalne võrgustik hakanud kavandama, seadmestama ja rakendama tohutut tehnoloogilist võrku, mis peaks tegelema meie keskkonna ja selle bioloogilise mitmekesisuse vaatlemise, järelevalve, vahendamise, inventeerimise ja hindamisega, et kasutusele võtta säästliku majandamise mudelit. Valdav osa sellesse "tehno-võrku" kaasatud "teadmise tööriistadest" põhineb suuresti mehhanitsistliku bioloogia, geneetilise reduktsionismi, majandusliku determinismi ning neodarvinlike kultuuriliste ja bioloogiliste väljavaadete kombinatsioonil. Need lähenemised eiravad aga mitmeid kvalitatiivseid ja suhtumuslikke aspekte, millest võib aru saada üksnes arvestades semiootiliste võrgustike toimimist komplekssetes ökoloogilistes ja kultuurilistes süsteemides. Artikli autor arvab, et biosemiootiline lähenemine ökoloogiale võib osutuda kasulikuks protsesside modelleerimisel, mis omakorda võimaldab konstrueerida mõttekaid monitooringusüsteeme. Veel väidetakse artiklis, et biosemiootiline lähenemine võib soodustada meie ökosüsteemidest arusaamise ja nende järelvalve integreerimist kultuuriprotsessidesse, milles toimub jätkusuutlike võimaluste otsing.