enregistrement	Présentation de l'approche : *Tuning the ecoscope*	**Rédacteur :** Philippe CURY	**Date création :** 24.06.04	**Référence:** 00.004E/1
			Dernière modif. : 12/04/2005 10:58	**Nb pages :** 5

Diffusion : Documents du projet

Présentation

Ce document est repris de la référence :

> *Cury, P. (2004)* ***Tuning the ecoscope for the ecosystem approach to fisheries****. Mar.Ecol.Prog.Ser., 274:272-275, 2004*

Il décrit l'esprit de mise en place de l'« écoscope », à la suite de l'article d'Ulanowicz[1] *(voir doc. 00.001E).*

article

Tuning the ecoscope for the ecosystem approach to fisheries

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A multidisciplinary scientific approach is needed for the ecosystem approach to fisheries. The Reykjavik declaration of 2001, reinforced at the World Summit of Sustainable Development in Johannesburg in 2002, requires nations to base policy related to marine resource exploitation on an ecosystem approach. To fulfil this new requirement, a strategy based upon innovative science that will address the complexity of marine ecosystems, coupled with operational frameworks for an effective Ecosystem Approach to Fisheries (EAF) is needed. EAF must be built on a scientific rationale that will link ecological processes to ecosystem-level patterns. In doing so, it will help managers to recognize and understand ecological limits to avoid the loss of ecosystem integrity and to maintain fisheries in viable states (Fowler & Hobbs 2002, Mullon et al. 2004).

This is a challenging task, as marine ecosystems are difficult to define, having no apparent boundaries, and lacking the clear objective or purpose that can be ascribed to more tractable biological or ecological entities (e.g. individuals or populations). An ecosystem contains water, nutrients, detritus, and numerous kinds and sizes of organisms ranging from bacteria, phytoplankton, zooplankton, and fish to mammals and birds, all with their own life history traits. These living and non-living ecosystem components are interconnected through continuously changing food webs, which make ecological systems extraordinarily complex.

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[1] Ulanowicz RE (1993) Inventing the ecoscope, In V. Christensen and D. Pauly (eds) Trophic models of aquatic ecosystems, ICLARM Conf. Proc. 26:ix-x

Today, the explicit study of complexity is both necessary and timely in ecology (Loehle 2004). Emergence has replaced the earlier mostly theoretical approach to implementing classical population dynamics in ecology (Woods in press). The concept of simple cause and effect is neither adequate nor sufficient when dealing with complex systems, particularly if one accepts the principle that prediction is a pre-requisite for applied ecological research (Peters 1991). Research in ecology has been based mostly on studying processes in detail resulting in an impressive number of potential cause-effect relationships to explain emergent patterns. Emerging patterns suggest likely tendencies and possible response trajectories. A combination of the process and emergence approaches has long been advocated (Elton 1927) but with relatively little success, despite its promise of ameliorating our understanding of marine ecosystems.

Many tools, information systems and models have been developed particularly during the last decade, such as coastal hydrodynamic models, individual-based models that couple physics and ecology, Geographic Information System (GIS) and ecosystem models. These various techniques, in many cases highly sophisticated, offer a unique opportunity in ecology to address the complexity of marine ecosystems in a diverse and contrasted manner. Despite the variety of techniques that can help track spatial and dynamical changes in ecosystems, it is often unclear however, how these can be applied to solve specific scientific problems or to respond to questions of importance to society.

Using the telescope and microscope as analogies, the term ‘ecoscope’ was proposed by Ulanowicz (1993) to characterize ecosystem modelling that may be used as a tool for resolving patterns, indicative of the key ecosystem responses (that may otherwise be obscured within the complexity of marine ecosystems). Today there exists no general, unified theory of the functioning of marine ecosystems, nor a single tool on which a reliable ‘ecoscope’ can be based. Moreover, in the context of global changes (i.e. climate change and overexploitation), the exercise is even more difficult as we are facing changes and fluctuations on a global scale that have not been experienced before (Holling 1995). To respond to these challenges, the ecoscope must be operationalized into an integrative framework for studying marine ecosystems and responding to the needs of the EAF. I discuss below how we can start implementing this approach.

Linking patterns to processes. Strong ecological patterns have been described in marine ecosystems (Parson 2003). The mechanisms explaining alternation between different pelagic fish populations, synchrony between remote fish populations, and regime shifts still remains largely speculative in the marine environment contrary to studies in lake ecosystems (Carpenter 2003). I will use the example of regime shifts that represent a crucial ecological pattern for the EAF, as they are sudden changes in structure and functioning of marine ecosystems that affect several components, exploited or not. For example, shifts from demersal fish dominated to pelagic fish dominated ecosystem (or short-lived species such as shrimps, crabs or octopus) have been documented in the Atlantic and the Baltic (Worm & Myers 2003); shifts from fish-dominated to jellyfish-dominated ecosystems have been observed in the Bering Sea, the Black Sea, the Gulf of Mexico, the western Mediterranean Sea, Tokyo Bay and off Namibia (Parsons & Lalli 2002). These regime shifts have deeply modified marine ecosystems and the fisheries they sustain. EAF requires understanding the nature of those ecosystem changes, i.e. the processes that are involved, the speed at which they act, their potential reversibility and periodicity...

Linking processes to patterns. Regime shifts have been related mainly to climatic changes, but anthropogenic influences also play a major role in inducing ecosystem changes. A regime shift may be environmentally driven (e.g. through bottom-up control of the food web, or via direct effects on recruitment), ecologically driven (e.g., through competition, predation), mediated behaviourally (e.g. behavioural adaptations to habitat change) or driven by human exploitation of selected species or preferential fish size classes (Cury & Shannon 2004).

Environmental processes act at different scales and probably simultaneously affect most species within the ecosystem. Under bottom-up control, a major environmental change can alter the ecosystem's primary productivity and, thereby, the flow of energy to higher trophic levels. Climatic variability can itself trigger a series of concomitant physical and biological processes in the form of system wide "regime shifts" (Hare & Mantua, 2000). Mesoscale events can trigger huge variability in pelagic fish recruitment success (Roy et al. 2001). In upwelling systems, a small number of pelagic fish species occupy the intermediate trophic level, feeding mostly on phytoplankton and/or zooplankton. These species can attain huge biomasses, which can vary radically depending upon the strength of the environmental factors driving recruitment. The role of dominant pelagic fish has been emphasized as they might exert major control on energy flow, both up and down the food web; this has been termed wasp–waist control (Cury et al. 2000). Predation is a fundamental process that is sometimes as important as resource limitation in controlling ecosystem dynamics. As most fish species interact through predation, the existence of top-down control, through which the lower levels of the food web are regulated by one or several upper-level predators, appears to initiate trophic cascades in several marine ecosystems (Cury et al. 2003). Fisheries tend to remove top-down forces by exploiting preferentially large top predators in marine ecosystems, mechanism known as 'fishing down the food-web (Pauly et al. 2000). This mechanism can result in an increase in small forage fish (or short living species) abundance and to a stronger climatic effect on depleted marine resources (Beaugrand et al. 2003, Cury & Shannon 2004). All these processes that are associated to environmental or anthropogenic forces should be related in a more organized manner to the observed patterns of changes in marine ecosystems. In order, for example, to arrive at a useful level of generalization, the respective roles of top-down, bottom-up or wasp-waist forces need further exploration.

The 'ecoscope' as a multidisciplinary dynamical tool to move towards an EAF. Theories, models, and observations of the patterns that are important for ecosystem dynamics need to be linked (Scheffer & Carpenter 2003). Ecologists have been analysing ecological interactions in two different, and often mutually exclusive, ways using reductionist (process-oriented) or holistic (pattern-oriented) approaches. However, as stated by Elton (1927), a combination of the two methods would be better. Seventy-five years later, this remains the approach that should be applied in future research on ecosystem dynamics. The ecoscope could be one such set of tools.

We need to encourage research in this direction and assemble processes and patterns in the same framework to explore the impact of global changes in time and space. The 'ecoscope' can be tuned to disentangle realities and speculations by assembling our present biological, ecological, modelling, and operational tools (GIS, indicators) . The 'ecoscope' would not rely on a single model, but would incorporate a suite of models that can use different assumptions for depicting in a robust manner the relevant processes.

With the rapid development of models, methods and hypotheses, there already exists a large variety of complementary approaches and tools. The 'ecoscope' encompasses all of our expertise and knowledge on marine ecosystems; however, it needs to be built around key scientific questions and information systems. Global changes that affect marine ecosystems, such as overexploitation and climate change, are relevant scientific problems and effectively addressing these is crucial for sustainable development. Spatial and temporal dynamics that link the different organisational levels need to be tackled in any EAF. Dynamical information systems should represent the converging point around which specific questions can be raised and discussed within the different disciplines. It is a stimulating task for the future, as it requires macroecological studies of the oceans to characterize patterns of ecosystem components, based on large amounts of data (Parsons 2003). A suite of field, experimental and modelling approaches is required to identify, with a high degree of confidence, the underlying processes and emergent patterns. Gathering of fisheries and ecosystem data has, to date, mostly been undertaken separately and by different sub-groups of marine scientists with little exchange. To develop data bank for ecological and climatologically quality checked long-term data is needed. We also necessitate developing new observation systems by recognizing that ecological and biological data that are collected for single-species fisheries management are necessary but insufficient for understanding ecosystem dynamics. Ecosystem-based indicators can simplify, quantify and inform about the complexity of marine ecosystems. The elaboration and evaluation of ecosystem-based indicators pertains to a multidisciplinary field of research on the marine ecosystem and may constitute a central focus for fisheries management. This represents a new framework that would challenge the difficulties of understanding the dynamics of complex systems at appropriate scales by enabling repeatable patterns to be tracked by indicators, and by incorporating existing scientific knowledge on processes into models and ultimately into fisheries management.

The ecoscope for EAF should rely on three complementary components: i) a clear identification of the long-term objectives (what we want and do not want to happen in marine ecosystems and for the exploitation of marine resources); ii) a multidisciplinary scientific expertise (data, theory, experiments, models) to address impact of global changes on marine ecosystems, and that is articulated around dynamical information systems, such as maps and indicators, to stimulate interactions between disciplines; and iii) an evaluation of the performance of the ecoscope to solve scientific questions and to address management objectives for the EAF.

Building ecoscopes is a demanding way of integrating knowledge and the necessary ‘ingredients’ and tools to begin the process are already available. However, our marine and fisheries institutions are not currently organized to undertake this integration and will have to address ecosystem issues by developing a multidisciplinary scientific approach. This integration, which could be achieved in an incremental way, will substantially improve the perception of ecological research and its usefulness to society. However it is a task that will compete with other scientific priorities at national levels, as it will require mobilizing efforts. Our society seems to be more interested in, and fascinated with, developing ‘telescopes’ rather than building ‘ecoscopes’. Marine ecosystems sustain our terrestrial life and deserve priority. We need telescopes and microscopes, but we also need ecoscopes. Implementing and operationalizing ecoscopes will crystallize our present scientific knowledge. It requires agreement upon clear and perceivable objectives and adjustment of multiform scientific expertise to societal issues. The potential task is overwhelming, and we need to take pragmatic steps before fully implementing an EAF. Tuning the ecoscope should help us to move towards ‘ecosystem ecology’ as a discipline in its own right, and towards an effective EAF.

Acknowledgements. Thanks to Dr. Lynne Shannon who discussed and elaborated with me the ideas that are contained in this essay. I thank Vera Agostini, Yunne Shin, Andy Bakun, Audrey Colomb, Jean Lefur and Ian Perry for their comments.

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Rédaction : P.Cury / saisie :