On Holism, Reductionism and Working from 9 to 5

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One definition of "holism" is "the theory that whole entities, as fundamental components of reality, have an existence other than the mere sum of their parts", the term "whole" being defined as referring to "an assemblage of parts associated or viewed as one thing".

Environmental activists and many scientists nowadays stress the need, when studying ecosystems (e.g., coral reefs or estuaries) or resource systems (e.g., fisheries), to have a "holistic" view of things, i.e., to consider all aspects of the system to be studied or managed. Very rarely will one find anyone disagreeing with this at the conceptual or theoretical level. However, at the *practical* level, environmental scientists generally work on specific problems, e.g., on the physiology of *one* species of an ecosystem, or the changes of *one* rate (e.g., catch rate) in a resource system. Why so?

The answer is: because modern science, including the environmental sciences, is structured since its emergence in the mid-seventeenth century, around holism's very opposite, namely *reductionism*: "the idea that wholes should be understood by decomposition into basic units" (the phrase is from S.J. Gould[1], who, in his writings, sternly disapproves of reductionism).

Yet the systems we study are usually too large or too complex to yield their mysteries to those who merely look; you have to poke around, do something, elicit some response (e.g., perform an experiment); or you have to focus on some prominent, clearly visible aspect of the system under study and relate that aspect to the invisible rest of that system ... all of which is reductionism!

Thus, the geologist holistically studying a mountain range will have, at some point, to look at a bit of rock and relate its composition to the mountain range (taking *one* rock sample from a mountain range is not a good sampling design, incidentally!).

Similarly, the ecologist attempting a holistic study of a coral reef must, at some point, deal with its "basic units", whether species or individuals or colonies, or measure rates such as primary or secondary production.

The fisheries biologist or fisheries economist studying even highly integrated fishery or aquaculture systems also must identify, at some point, some "basic" units to measure: yields of fish, harvesting costs, whatever. The point here is that scientists must be doing something - measuring something or performing some analysis. Reductionism gives them the justification for doing something during their working hours, say from 9 to 5; "holism" as a *philosophical principle*, does not.

Science has progressed enormously in recent centuries because scientists have been able, when studying complex systems, to identify, isolate and constructively deal with the *important* and *manageable* parts of a system. Indeed, the ability to identify such parts *defines* good scientists[2].

An excellent example of this is the development of fisheries science, which became effective only when the effect of a fishery on its resource base was separated from the associated environmental effects, and especially when Raymond Beverton and Sidney Holt, following on F.I. Baranov, reduced, in a flash of genius, the "overfishing" problem to the study of fish growth, mortality and size at first capture, largely eliminating not only the environment from their consideration, but even the effects of environmental variability on fish recruitment.

As a result, the theory of Beverton and Holt, although highly reductionistic, has become an enormously powerful tool for fisheries management, still inspiring in its various transmutations (e.g., Virtual Population Analysis) the majority of fisheries scientists worldwide (see Pauly and Gayanilo, p. 14).

Another good example is Louis Pasteur (1822-1895) who developed a vaccine against rabies. Rabies is obviously a complex system, with biological and social subsystems; the biological subsystem involves a virus (*Formido inexoribilis*) and hosts such as foxes and dogs, each with their own population dynamics, while the social subsystem includes, e.g., the interaction between poor people and street dogs, etc. Pasteur is celebrated because he identified the key component of this complex system: the fact that a vaccine could be developed against the rabies virus. That's what reductionist science can do for you: overcome formidable and previously inexorable odds.

So, why does reductionism have such a bad press?

At first, no answer comes to mind, since it is not the fisheries scientists themselves who do the overfishing, or the environmental scientists who are wrecking our environment, not to speak of the demographers who can hardly be blamed for excessive human population growth, wherever it occurs.

But then, upon reflection, one begins to ask oneself why so many of the things scientists do remain unconnected, left for the general public to interpret, i.e., to turn into a "whole". Small wonder for example, that "holistic" medicine, originally based on the reasonable notion that mind and body belong together, has turned into an intellectual swamp from which chiropractors, faith healers, iridiologists, homeopaths and regular quacks rail at science-based medicine[3].

In the environmental sciences, the challenge is similar: either the environmental scientists help reconstruct the systems of which they have studied parts, explain how these parts interact and how the whole fits, or others will do it for them. This reconstruction may involve writing popular science articles, participating in public debates, interacting with politicians, etc. It can also involve doing one's science a bit differently, and in the following, I shall provide a range of examples drawn from various projects presently being conducted by ICLARM and its collaborators.

Some Examples of "Holistic" Projects

Since fisheries science emerged as a discipline of its own at about the turn of the century, an enormous amount of information on population dynamics, physiology, ecology, etc., has been amassed on various resource species complementing the mainly taxonomical, morphological and distributional information collected on these same species by earlier generations of naturalists. However, this information is largely unconnected: it is not only physically scattered (e.g., in different papers published in different journals) but also often doesn't "fit" together, because it is presented in different languages (or disciplinary jargons), in different units, for different uses, etc.

Here, the first task appears to be the reassembling of this information, i.e., the "reconstruction" of species through, e.g., carefully crafted synopses. A still pertinent guide for such reconstruction was presented in the mid-1960s by H. Rosa[4] and this has led to many synopses being published by FAO and some cooperating agencies (e.g., the Australian Commonwealth Scientific and Industrial Research Organisation, or the US National Marine Fisheries Service).

ICLARM contributes to this effort at two levels: (i) by encouraging preparation of synopses on species of interest in our collaborative activities (e.g., synopses are being prepared by Malaŵian colleagues on the tilapias *Oreochromis shiranus* and *Tilapia rendalli*, which are of great importance in Malaŵian aquaculture); (ii) by assembling in an interactive computer database for 2,500 species of tropical fish, the kind of quantitative information that is normally used for species synopses (Fig. 1).

Item (ii) is a project of ICLARM partly funded by the Commission of European Communities and FAO. It may be described as a powerful "connection machine", through which previously hidden quantitative and/or qualitative relationships between known facts and/or numbers can be made visible. It will also serve, in the libraries of cooperating developing-country institutions, as a replacement for many meters of shelves with taxonomic and other books full of information that is costly and difficult to access.

Another task is the quantitative description of aquatic ecosystems

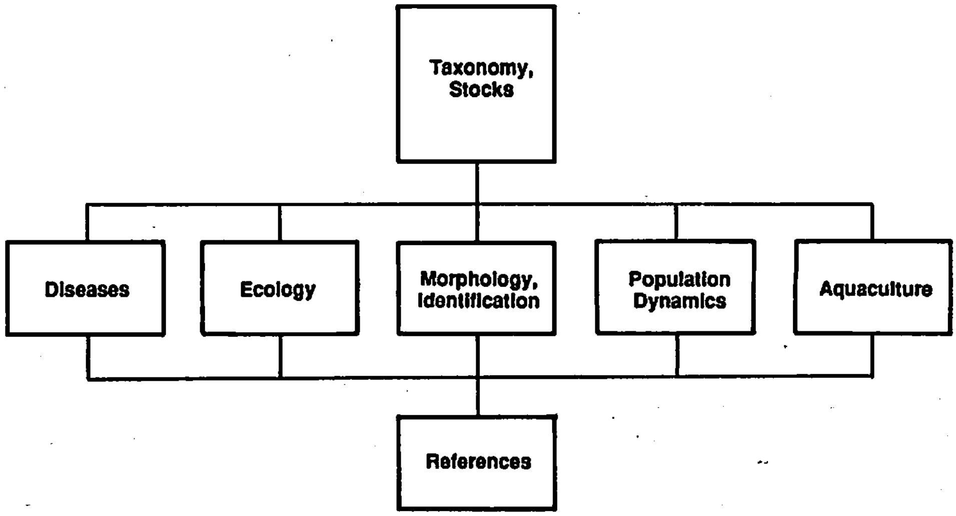

Fig. 1. Schematic representation of ICLARM's FISHBASE, an interactive database or "connection machine" for documenting the biology and nomenclature of exploited and/or cultured fishes in the tropics and subtropics.

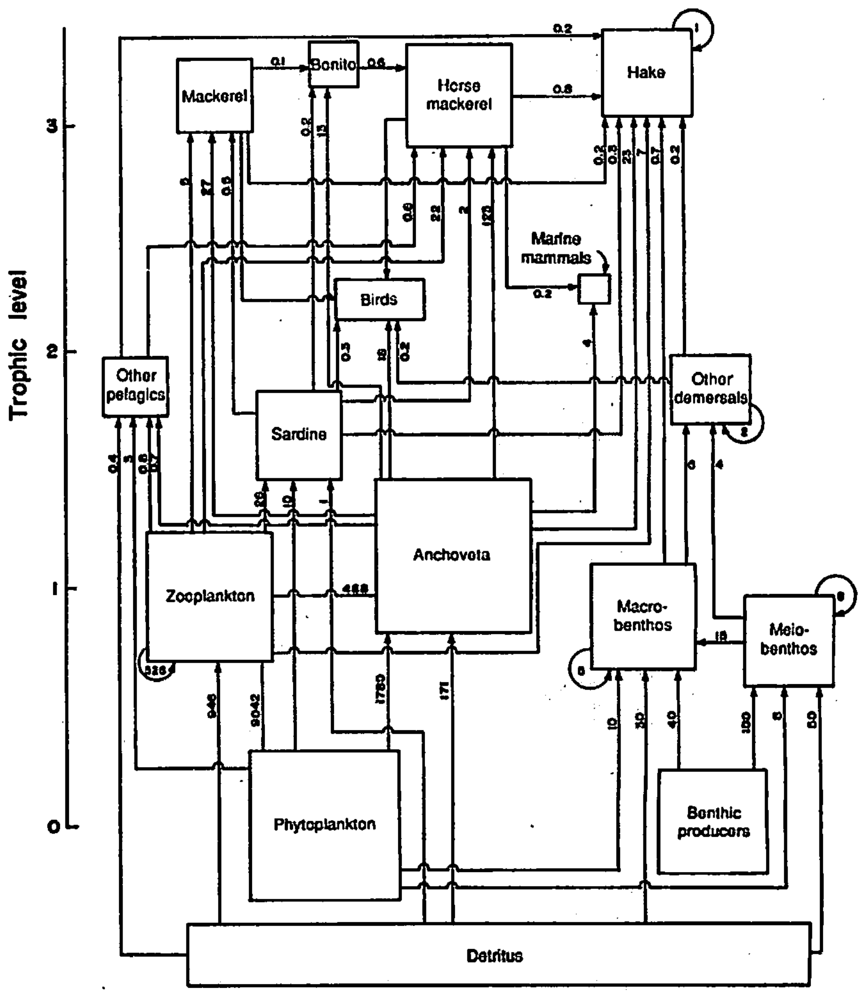

Fig. 2. A balanced trophic model of the pelagic resources in the Peruvian upwelling ecosystem for the years 1960 to 1969. The model, based on ECOPATH II, is holistic in that it (1) includes several biomass and rate estimates derived through the process of balancing the model itself, and (2) allows computation of whole-system indices describing emergent properties.

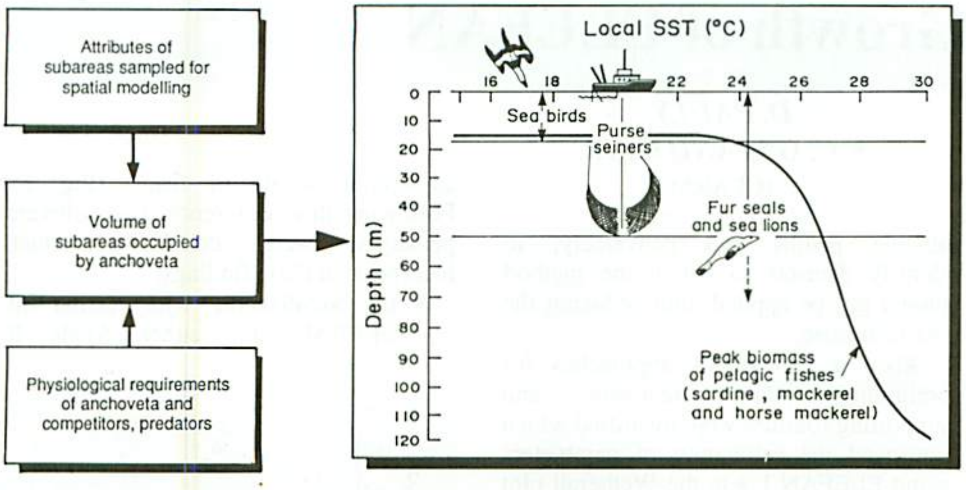

Fig. 3. Schematic representation of submodels incorporated in large simulation model of the Peruvian upwelling ecosystem presently under development. Combined, the components of the model determine whether the fish will be high enough in the water column to be caught by guano birds, marine mammals or purse seiners. SST = Sea Surface Temperature

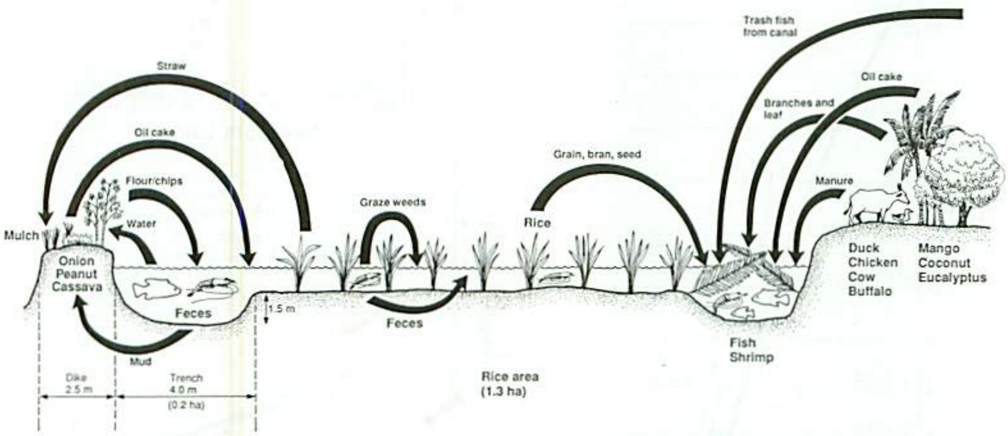

Fig. 4. Schematic representation of material flows (black arrows) in a rice-fish (and shrimp) integrated farming systems of the Mekong Delta, Vietnam, showing high degree of integrations and various cycles. The work and view of farmers and scientists involved in such systems are, or must be, holistic (figure courtesy of Dr. Clive Lightfoot, ICLARM).

(aquaculture ponds, lakes, estuaries, coral reefs and shelf seas). Such descriptions can be done using either trophic ecosystem models such as can be constructed using the ECOPATH II software described by V. Christensen (see p. 9) or by simulation modelling. ICLARM is presently undertaking a global comparison of aquatic ecosystems, based on the systematic application of ECOPATH II through a project funded by DANIDA and major results of these comparisons are expected next year. At this stage, however, one can already see that for most exploited aquatic ecosystems in the world, sufficient data on the biomass of major groups and key rate processes are available to construct at least a simple balanced trophic model of each system - leading to new insights on the functioning of aquatic ecosystems that could not be gained by dealing with exploited species and their resources in isolation from each other (Fig. 2).

Computer simulation now represents, besides *theory* and *experiments*, the (new) third pillar of the Scientific Method. Simulation modelling is also eminently holistic in that models do not "work", i.e., do not even begin to approximate real processes if they do not incorporate a large number of more or less complex submodels acting in concert, and making the overall simulation model generate outputs that are not directly deductible from the inputs (i.e., the whole here is really more than the sum of its parts).

ICLARM staff and partners in Peru are presently constructing a major simulation model of the Peruvian upwelling ecosystem, based on two highly integrative (or holistic?) volumes previously published on the subject[5,6]. This model, we hope, will be used as an aid in evaluating management options (Fig. 3).

Another bioeconomic model presently being developed at ICLARM integrates the results of a demersal survey recently conducted off Brunei Darussalam with information on the economics of the fisheries sector, including the fixed and variable costs of trawling. As for the Peruvian simulation, the results obtained with this model will be presented not only as numbers and curves, but also as *maps*, the holistic device *par excellence*.

Fig. 4 presents another example of an integrative activity: connecting previously separated rural production systems such as agriculture and aquaculture into larger, better integrated systems.

There are other holistic projects conducted by ICLARM and its collaborators, but the above samples are sufficient to suggest that holism, far from being an unattainable ideal, can be incorporated into the practical 9 to 5 activities of environmental and other scientists. Indeed, the climatic and other changes happening to the Earth as a whole would justify giving strong emphasis to projects with a strong holistic flavor (they also justify working more than from 9 to 5, incidentally!).

Further Reading

[1]Gould, S.J. 1980. The Panda's thumb: more reflections in natural history. W.W. Norton, New York. 343 p.

[2]Medawar, P. 1982. Pluto's republic - incorporating the art of the soluble and induction and intuition in scientific thought. Oxford University Press, Oxford. 351 p.

[3]Committee for the Scientific Investigation of Claims of the Paranormal. 1987. Medical controversies: chiropractic, homeophaty, alternative therapies, quackery. The Skeptical Inquirer 12(1).

[4]Rosa, H. Jr. 1965. Preparation of synopses on the biology of species of living aquatic orgnanisms. FAO Fish. Synops. No. 1, Rev. 1, Rome. 84 p.

[5]Pauly, D. and I. Tsukayama, editors. 1987. The Peruvian anchoveta and its upwelling ecosystem: three decades of change. ICLARM Stud. Rev. 15, 351 p. IMARPE, Callao, Peru; ICLARM, Manila, Philippines; and GTZ, Eschborn, Federal Republic of Germany.

[6]Pauly, D, P. Muck, J. Mendo and I. Tsukayama, editors. 1989. The Peruvian upwelling ecosystem: dynamics and interactions. ICLARM Conf. Proc. 18, 468 p. IMARPE, Callao, Peru; ICLARM, Manila, Philippines; and GTZ, Eschborn, Federal Republic of Germany.

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