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Consilience in Oceanographic and Fishery Research: A Concept and Some Digressions

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Abstract

The concept of *consilience*, describing the 'jumping together' of different scientific disciplines, and recently revived in a book of the same title, authored by E.O. Wilson, is presented, along with some of its implications for work conducted by oceanographers, marine biologists and fisheries and social scientists in the Gulf of Guinea area. It is suggested that maintenance and analysis of time series data, remote sensing of marine primary production, trophic mass balance modelling, and analysis of multi-sectoral coastal transects are eminently *consilient* in that they not only invite interdisciplinary co-operation, but also impose standards and provide common currencies that makes such co-operation meaningful.

Consilience

The text below is not an attempt to summarise the contributions to the Accra workshop documented in this volume. Rather, a few major threads - we would call them *lignes de force* in French - are brought together, showing the inherent coherence of the themes covered during our deliberations. To document this, however, I shall however, use a new, or rather newly revived concept, that of *consilience* (Wilson 1998). Most advances, within the various disciplines practised by the participants of this workshop, such as biology, or the environmental sciences have been the result of synthesis of previously unconnected data or ideas (Simonton 1988). Thus, the furious pace at which data continue to be collected and ideas continue to sprout guarantees that new knowledge will continue to be generated within our disciplines, if only by integrating these data and ideas into common explanatory frameworks.

In analogy to this, if perhaps at a grander scale, major scientific breakthroughs have often been the result of convergence among traditionally distinct disciplines. Herein, these disciplines usually articulate themselves in a hierarchy, with logic/mathematics (and the usual criterion of parsimony; Pauly 1994) providing the backbone of any given breakthrough, physics and chemistry providing the basic rules constraining the changes of its material substrate, and evolutionary biology providing the framework that constrains its living organisms (if any), including humans and their culture. Wilson (1998) called *consilience* (from 'jumping together') the explicit search for scientific explanations within the context of this hierarchy, and provided examples of research issues whose resolution, he felt, would occur faster if consilience were used as an explicit criterion - in addition to parsimony - for structuring the relevant research programmes.

My favourite examples (not Wilson's) of consilience are the Cretaceous/Tertiary (K/T) extinction of 65 million years ago, of dinosaur fame, and the origins of Homo sapiens, both of which made mutually compatible data and concepts from an enormous range of disciplines, previously not interacting with each other. A nuclear scientist, his geologist son, and two chemists colleagues proposed that the K/T extinction was caused by the impact of a large meteorite (Alvarez *et al.* 1980). This hypothesis, then based mainly on evidence from an Italian dig, was subsequently corroborated by petroleum geologists, who had previously identified, then ignored the Chicxulub impact crater, in Yucatan, Mexico. Other scientists, from astronomers to evolutionary biologists joined the fray (Raup 1986), and gradually, the `Alvarez' hypothesis was accepted by the best of them. The results of this development has been extraordinarily fruitful, "provoking new observations that no one had thought of making under old views" (Gould 1995, p.152). This led among other things, to a resolution, in evolutionary biology, of the ancient, but still acrimonious debate between *catastrophists* (Sedgwick, Cuvier, etc.) and *uniformitarianists* (Lyell, Darwin, etc.). Even popular culture was impacted (see the movies Meteor, Armageddon, and Deep Impact).

Indeed, the eventual creation of an international system for tracking potentially dangerous meteorites is not unlikely. Similarly, the evidence for a recent African origin of *Homo sapiens*, with subsequent dispersal to West Asia, Eurasia, Australia, the Americas, and finally Oceania is supported by archaeological and genetic evidence, with linguistics providing the clincher: an evolutionary tree that closely matches that generated by the physical disciplines (Cavalli-Sforza *et al.* 1988). The latter example shows that the hierarchy of sciences implied in consilience does not mean that the specific results of a more fundamental discipline are inherently more reliable that those of a more derived discipline. Rather, it only implies that the different sets of results must be mutually compatible. Thus, the linguistic evidence is, in this example, no less important than the evidence based on genetics. Similarly, when the physicist Lord Kelvin pronounced the Earth to be only a few thousands years old, based on the time required for a large sphere of burning coal to cool off, and evolution by slow natural selection thus impossible, it was he who was wrong, not Charles Darwin (Tort 1996).

The question now is whether we can make use of consilience in our work as oceanographers, marine biologists and fisheries scientists, i.e., in fields perhaps less glamorous than those in the above examples. Various concepts we may call consilient come to mind here, related to presentations at the workshop documented in this volume. The first of these is the mass-balance concept, i.e., the notion that, in a given system, mass must be conserved, irrespective of its movements and transformations. This principle is related to the First Law of Thermodynamics, which states that energy can be neither destroyed nor created (Gilmont 1959). For chemical reactions, this implies for example that "the sum of the masses of the reactants must equal the sum of the masses of the products" (Gilmont 1959, p. 146). Physical oceanographers also rely on mass-balance when calculating geostrophic flows from density fields (Sverdrup *et al.* 1942), or when calculating upwelling intensity from coastal wind stress, which implies water masses welling up to replace water blown off the coast (Bakun 1996).

On the other hand, one rarely hears biologists, or even ecosystem modellers explicitly invoke the principle of mass-balance, though it is also an absolute requirement for living things (Schrödinger 1992). An exception to this is the ecosystem modelling work of T. Laevastu and colleagues, in which mass-balance was used as a key structuring element for trophic interactions and migrations (Laevastu and Favorite 1977; Laevastu and Larkins

1981). J.J. Polovina emphasized this feature when he simplified Laevastu's model and formulated the Ecopath approach (Polovina 1984, 1985), thus giving it the feature which made it applicable to a wide range of system types (Christensen and Pauly 1993; Pauly, this volume). Ecopath uses the mass-balance approach to verify that the estimated production of the functional groups (exploited or not) of a given ecosystem matches the estimated consumption by their predators. Such verification is not ensured by the publication of individual estimates, however precise, even in the best journals catering to the different sub-disciplines of marine biology.

Rather, it is by incorporating such estimates into a mass balance ecosystem model that we render such estimates mutually compatible, and hence assure ourselves of their reliability and usefulness. This should have a beneficial impact on marine biology, whose work on different processes in an extremely wide variety of organisms is sometime perceived as lacking `relevance'. Moreover, ecosystem and mass-balance considerations should help renew fishery science as well, given that it has been too narrowly focused on the study of single species, and on industrial fisheries, usually overlooking by-catch discarding practices, non-commercial species, and other fisheries (artisanal, sport, etc.) as well.

The relation of these points to Wilsonian consilience should be obvious. Consilience also implies developing protocols for integrating the results of remote sensing studies (as illustrated here by Hardman-Mountford and McGlade or Roy *et al.*, this volume) into mass-balance trophic models of ecosystems. The key results relevant here are: (1) definition of geographic system boundaries, as in the case of the biochemical provinces of Longhurst (1998); and (2) synoptic estimates of primary production (Longhurst et al. 1995), i.e., of that which determines the boundaries of marine ecosystems in terms of the size of their biomass fluxes. Here, by constraining model size, remote sensing can link with ecosystem modelling, and thus work in consilient mode. Note also that both remote sensing and trophic modelling may be accused of being 'superficial': remote sensing because, quite literally, it cannot look deeper that a few decimetres into the sea, and trophic modelling because it does not consider interactions other than those generated by grazing and predation. Yet, when data from the two approaches are analyzed jointly, inferences can be drawn which go well beyond those based on more conventional approaches (see e.g., Pauly and Christensen 1995; Trites *et al.* 1997).

Perhaps we may infer from this issue of apparent superficiality that consilient work may suffer, at least for a while, from analogies with multidisciplinary work, wherein the methods of different disciplines are brought to bear on a given topic (e.g., as chapters in a book), without any of these methods being made to relate to each other. Such unconnected work is all too frequent, e.g., in that discipline called coastal area management, a theme to which we shall return. The concept of consilience, it seems to me, should also apply to the strengthening of inferences that results when the past is related to the present. This is what occurs when we use knowledge gathered by historians, or by scientists of past centuries, and often perceived as anecdotal, to establish stable baselines for biodiversity (Pauly 1995, 1996).

This is also what occurs when we draw inferences from time series, whose increasing length increases their contrast, and hence their usefulness for various analyses (Hilborn and Walters 1992). Thus, it is important that the physical and biological time series generated and/or used by the participants in this book be continued, and every effort should be made to ensure that this occurs. The last aspect of consilience to be covered here refers to its implications for the languages we use. Trivially, this means that we must speak the same vernacular language (English, as it mostly turns out), and only a bit less trivially, translate concepts in and out of our various discipline-specific jargons. Also, and this is where things start getting really complicated, we must identify concepts that cut across disciplines, and a multidisciplinary currency allowing for transactions between disciplines.

I shall illustrate this with reference to coastal area management (CAM), a discipline with many practitioners and applications, but whose defining tenet(s), topic(s) and technique(s) remain elusive. Indeed, some practitioners give the impression that anything that happens anywhere on or close to on any coastline is within the purview of CAM, and that any method ever used to investigate any of these things is appropriate for CAM. (The reader will understand that I could not provide references to back these claims without antagonizing people whose technical work I respect, in spite of the disorganisation of their discipline). Thus for CAM, as perhaps everywhere in science (Medawar 1967), the challenge is to identify tractable problems, related to its defining objects: coastlines.

Coastlines differ from other geographic features in that most of their different characteristics are arrayed in a single dimension, i.e., in the form of transects that are perpendicular to the coastline, and stretch from upland to the sea. On the other hand, fewer differences occur parallel to a coastline. Alexander von Humboldt, a founder of physical geography, may have been the first to use transects to document geographical variations along strong gradients (Gayet 1996). Conway (1985), on the other hand, introduced transects to agro-ecosystem analysis, as a tool to express in simplified manner the complex interactions within highly integrated farming systems. [Note, incidentally that such systems can also be described by trophic mass-balance models; Dalsgaard and Oficial 1997]. From this, it is straightforward to propose that multi-sectoral coastal transects should become a key concept in CAM, and that, suitably formalized, such transects could lead to the common currency required for comparison of coastal systems, and for comparative evaluation of various injuries to such systems (Pauly and Lightfoot 1992).

SimCoast™ (McGlade 1999; 2001) which was used in the EU Gulf of Guinea implements this coastal transect approach, and provides, via fuzzy logic, the currency that CAM had been lacking so far, enabling quantitative comparisons of impacts due to different, otherwise incommensurable agents (Nauen, this volume), ranging from upland erosion to fisheries policy. That this should lead to consilience among, and progress for, the different disciplines so far fruitlessly engaged in CAM needs little emphasis.

Another example of consilience requiring a common currency is FishBase, the electronic encyclopaedia of fishes (see www.fishbase.com), which works only because a standardised nomenclature (Eschmeyer 1998) is used to establish the links between the widely different data types included in FishBase (Froese and Pauly 1998). This is what enables FishBase to provide, among other things, a comprehensive coverage of the fishes of the Gulf of Guinea, and of their biology. As might have be noted, several of my examples (Ecopath, SimCoast, FishBase) are products of projects supported by the European Commission, particularly by its Directorate General concerned with development (i.e. VIII and XII INCO/DC), but not run by committees, or university consortia. Perhaps this indicates that such projects, providing support to participants only if they buy in the strong concept underlying such ventures, are more effective than the usual collaborative projects, where the partners agree only to share the available funds.

The ventures given as example here certainly have shown that participants from a variety of countries, both developed and developing, can contribute. And this is probably the neatest thing about consilience: it implies that we can all contribute, given some self-discipline.

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