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Fisheries Biology: A New Tool Kit for Dealing with New Problems[1]

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INTRODUCTION

Fisheries biology was established as a discipline of its own near the turn of the last century, when scientists in Northern Europe and America began to ask themselves seriously why fish stocks fluctuate and, more specifically, why exploited stocks become depleted. Was it the effect of fishing or, as many argued, mainly the result of environmental fluctuations?

The International Council for the Exploration of the Sea (ICES) was founded in 1902, mainly to address this question. Because the question was broad, the initial areas of emphasis of ICES scientists were also broad, e.g., the precise estimation of salinity (hence, the "Copenhagen standard"), the study of plankton distribution and other topics now generally considered to be part of marine and/or biological oceanography but not necessarily of fisheries biology (Went 1972).

The early attempt by Baranov to demonstrate that fisheries stocks react to fishing in a predictable fashion and that this reaction could be expressed in mathematical terms was not widely accepted, perhaps because it was published too early and in Russian (Baranov 1918).

In the 1930s, the problems were reformulated by Russell (1931), who identified the "overfishing problem" through bold reductions, i.e., by neglecting the effects on exploited fish stocks of factors other than growth and mortality (fishing and natural).

Russell's concept was subsequently refined by M. Graham, but with the unscheduled "closed season" of the Second World War, it awaited Beverton and Holt (1957) to formulate a quantitative description of the dynamics of exploited fish population which inspired fisheries biologists throughout the world. The Beverton and Holt model not only provided a description of the impact of fishing on stocks but also, like any good paradigm, suggested what fisheries scientists should do: they should put their emphasis on estimating fish growth and mortality, and on quantifying the relationship between the size of captured fish and the mesh sizes of the gear that caught them.

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Another line of research, pursued mainly by Ricker (1954), emphasized stock–recruitment relationship as the key process to study. His line of inquiry was followed up mainly by researchers working on Pacific salmon, a resource which need not concern us here.

An additional area, also initially formulated by Baranov and now identified with the name of Schaefer (1954, 1957), is surplus modelling, one of the basic tools still in use in the form of refinements published by scientists such as Fox (1970), Pella and Tomlinson (1969), Schnute (1977), and Csirke and Caddy (1983).

However, fisheries research in the 1960s and 1970s was largely determined by the paradigm developed by Beverton and Holt, which among other things, led to the development of Virtual Population Analysis (VPA), now a standard tool for the assessment of long-lived, single-species fish resources throughout the world.

The approach of Beverton and Holt, as originally presented, had two "soft spots", however: (1) the lack of emphasis on recruitment variability; and (2) the assumptions of constant natural mortality. Attempts to resolve the issue in (1) led nowhere, despite continued efforts (see e.g., Cushing and Harris 1973; Rothschild 1986). The issue in (2) was remedied in the late 1970s and especially in the 1980s through the development of multispecies models, in which the variable food consumption of predatory fish stocks became the factor that modulates the natural mortality of their prey(s).

Simulations structured along these lines, such as the North Sea model of Andersen and Ursin (1977) and the more management-oriented Multispecies VPA (Magnússon 1995), are examples of this class of models. However, they are extremely complex (in mathematical and programming terms) and this limits their use to a few centres of excellence. Even more constraining is the large database on food preferences, stomach contents, catch-at-age matrices, etc., required for implementing such models. Thus; it can be expected that these models will be applied in only a few tropical sites.

APPLICATION TO THE TROPICS

The impact of Beverton and Holt's seminal work was felt not only in northern Europe and northern America and other developed areas, but also in the tropical developing world, either through national scientists with a mathematical bent, e.g., in India (Banerji and Krishnan 1973), or through fisheries development projects operated by international and bilateral agencies. Examples of the latter are Garrod's model of the tilapia fishery of Lake Victoria (see Garrod 1963 and references therein) and Munro's seminal work in Jamaica (Munro 1983).

Another line of research which had a strong impact on tropical fisheries was the rediscovery and further development by Munro and others, especially Jones (1981), of the length-based methods initially proposed by such early researchers as C. Petersen and T. Fulton. The method had initially been advocated, rather vehemently, by noted scientists such as D'Arcy Thomson, but had fallen into disuse in the 1930s at least in the developed countries (Went 1972).

The method newly developed by Jones involved, in part, a form of length-structured VPA, now widely used to assess tropical stocks (Jones 1981; Pauly 1984).

The adaptation of fish population dynamics methods for use in the tropics did not only involve methods based on the theory of Beverton and Holt. Munro, for example, turned the surplus production model of Schaefer-Fox fame, initially time-structured (one point per year, referring to the same place), into a space-structured model (where the data points stem from different places, assumed to have been similar prior to the onset of fishery). This approach was followed up by several authors, notably Marten (1979), Caddy and Garcia (1983) and Polovina (1984).

Thus, as far as the translation (for use in the tropics) of single-species analytical models and surplus-production models is concerned, one can note not only that it has occurred, but that the resulting models are now widely used throughout the developing world.

The translation of the multispecies approach for use in the tropics has been more difficult. A major advance happened only in the early to mid-1980s when Polovina and colleagues, faced with a prospect of having to assess the French Frigate Shoals, a coral reef area north of Hawaii, formulated the set of assumptions required for the construction of a simple box model of this ecosystem, an approach which led to the ECOPATH model and software (Polovina 1984; Polovina and Ow 1983).

We have followed up on this approach and coupled it with a theory proposed by Ulanowicz (1986). The resulting software is called ECOPATH II and is written such that the trophic flows linking the boxes of a box model are used to derive indices quantifying emergent properties of the ecosystem in question (Christensen and Pauly 1992). This enables quantitative comparisons between ecosystems which is of interest for many ecologists.

Fisheries biology does not operate in a vacuum. In the developed countries where fisheries biology emerged, fisheries biologists have been able to largely ignore the socioeconomic context in which fisheries operate for two reasons: (1) they can rely on an intellectual division of labour, e.g., covering those important aspects of the fisheries which fisheries biologists ignore; and (2) the developed societies in question are rich enough to allow fishers to move in and out of fisheries, the opportunity costs of the fishers' labour being high enough to do so.

In tropical developing countries in the past, there have been similar transitions between sea-based and shore-based activities, e.g., artisanal fishers would own some land and turn to farming when catches declined seasonally.

The tremendous population growth in most developing countries of the world and the frequent concentration of land in the hands of a few owners are, however, upsetting these traditional arrangements, and huge numbers of new fishers are being recruited from the masses of landless poor. Fishing thus becomes an occupation of last resort, because it taps the only resource to which these deprived people still have access.

These new fishers do not have the option of switching between fishing and farming. They must continue to fish even during the lean season. Their plight is further aggravated by the dramatic increase of large-scale commercial trawling, often conducted close inshore by entrepreneurs aiming for penaeid shrimps, a valuable export commodity. This leads to often violent conflicts for which different solutions have been proposed and implemented in various countries, e.g., the ban on trawling that was implemented in Indonesia in the early 1980s (Sardjono 1980).

Between-fisher competition (i.e., between different groups of artisanal fishers and/or between artisanal and commercial fishers) and the lack of shore-based alternatives for the poorest of them are the major causes for the increase in destructive fishing through dynamiting and the use of various poisons (such as cyanide in the Philippines and insecticides in East Africa).

These trends are not reflective of a moral problem indicating lack of respect for community rules, or for the law, but are a reflection of the simple fact that fisher communities using or tolerating these methods usually have many members, especially women and children, suffering from lack of food. Such trends, which result in what I call "Malthusian overfishing", (Pauly 1988; Pauly, Silvestre and Smith 1989) are commonly observed in several countries in Southeast Asia and in various other regions, e.g., in West Africa, the South Pacific and the Caribbean. I believe they will become a universal problem in the coming decade as even more impoverished, landless farmers are dumped into the artisanal fisheries sector. These trends will complicate enormously the task of mitigating the effects of global climatic changes.

In order of importance, I think these effects will be (a) the reduction of agriculture production in the major food-producing nations of the world and hence, increases in food price which will further exacerbate the pressure on natural resources worldwide; (b) changes in the migratory behaviour or distributional attributes of major fish resources, some of which may become inaccessible to existing fisheries; and possibly (c) rise of the sea level, which may render even more precarious the fragile hold that these new fishers have on thin strips of coastal land.

How will the various methodologies described above, which I will call here the fisheries biologists' toolkit, contribute to a response to these challenges?

My first response is to state that fisheries biologists will not be among the major scientific players in the next decade and even less in the next century; these will be climatologists, agronomists and perhaps those engineers or physicists who can contribute to the various technologies for dealing with our polluting ways.

However, fisheries biologists should contribute to this effort. For this, though, they will have to stop thinking predominantly in terms of single-species resources. Also, they will have to learn to evaluate whether the high precision provided by various costly methods (for example, counting daily rings in fish otoliths, then validating these counts using electronic scanning microscopy) is really necessary to get an idea of how the fish of a given species grow, when that species is exploited, along with a hundred others, by thousands of half-starved fishers. There are ways of using comparative methods to estimate growth parameters (based on earlier parameter estimates determined elsewhere on same or related species) which may be more cost effective (see, e.g., Pauly 1991).

Further, fisheries biologists will have to evaluate whether the study of 40,000 fish stomachs, as was done in the early 1980s in the North Sea, is necessary to legitimately construct, in their area, a multispecies model for the ecosystem from which basic management options can be derived. They will also have to evaluate whether it is really necessary to set up costly sampling schemes throughout their country to estimate fishing effort and catches precisely when most fishers in the communities in question—and especially the children—suffer from protein malnutrition (which itself indicates overfishing, i.e., the fact that so little fish is caught that none can be consumed locally!).

I believe that appropriate tools exist for fisheries biologists to perform their routine assessment work quickly and efficiently. These tools will also enable fisheries biologists to contribute their energy to analyses that take more than single-species into account, i.e., to move, on a broad front, toward multispecies modelling. However, unless emphasis is given, in the context of a broadly based fisheries science, to the social factors that contribute to the decline of developing-country fisheries, these tools will be useless, and fisheries biology will cease to attract the funding it deserves. This would be unfortunate given that fisheries now contribute, in developing countries, about half of human protein requirements.

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