Averaging the Way to Inadequate Information in a Varying World

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At the recent Benguela 86 Symposium one of the participants decided to make a very strange recantation. There was sufficient evidence, in his view, to suggest that there was no reason to do the causal research in fisheries-related marine ecology, once the conventional average fishery information or parameter estimates were available. You could be right more often using average expectations in your data than if you used any three random variables with combined explanatory capabilities of up to 75%. He then proceeded to exemplify his conclusions from his analyses.

This statement came as a surprise - and disappointment - as it came from an exceptionally talented mathematical analyst. Perhaps doubly so, since among the several dozen other presentations at this symposium there were also very memorable contributions that evidenced the value of understanding the causal sequences of climatic to, oceanographic, to ecological events and patterns, that characterize the dynamic Benguela Current Ecosystem, in particular its periodic reversion from one quasi-stable state to another.

I suspect that, once stated, such a position will make it more difficult to induce such "enlightened" folk to recognize the logical errors that lead to these wrong conclusions. As Jorge Csirke and I concluded after our 1983 review of the Changes in Abundance and Species' Composition of Neritic Fish Resources, fisheries stock assessment would be in a very different state if the North Sea were subject to El Niño events.

In retrospect, I think that any argument for use of simple averages is a strong signal that it is about time for such analysts to be removed to the back seat, or somewhere that will minimize data fatigue. Recent decades have been the hey day for the near-miss regression/correlation approach to modeling environmental affects on resources populations. There is a subtle philosophical twist attendant to the failure of these partial models to forecast ad ***infinitum*** the patterns of any populations responses to regimes outside the models' basis, of reference period.

There is no reason to expect that the low-level modeling that we have accomplished could forecast any but past responses – That is 'if' the signals were strong enough to make projections from. Yet, we assume average responses without querying the potential for any other dominant variables to emerge.

The most important realization that needs to be made is the following:
AN AVERAGE FISH DIES WITHIN ITS FIRST WEEK OF LIFE!
And - Where does this leave our mathematician?

With a lot of surviving, not-so-average fish. In fact the average, conditions of the ocean will not support most fish life at all. Therefore, there must be some alternative way to organize the science if we are ever to reach the objective of forecasting even the less subtle aspects of marine populations such as relative abundance or distribution. I think that the solution is for fisheries researchers to go back to the basic questions of elementary biology. What mechanisms do the various populations have, and at what developmental stages, that allow them to survive local environmental perturbations? What are the conditions to which these individuals are adapted, and finally, what perturbs these conditions in time and space?

We should no longer attribute meaning to the word "average" in the context of any marine population. There should be a sense of the basic fitness of individuals on local time and space scales, not of a median: or population mean. In the context of marine environments, there is neither a mean expectation, nor a sequence of biological responses that have proven to be inviolable. Once we throw away our averaged or Atlas concepts we can experience dynamic changes, be they merely subtle diel processes, lunar responses, onward to greater time and energy scales.

Any given time period as short as man's expected lifetime or less may not offer as great a spectrum of perturbations and responses as have been experienced by a particular population or ecosystem, particularly climate regimes. For example, the general heating trend that has been experienced in the eastern Pacific Ocean since the late 1960's, which culminated with the 1982-83 El Niño, not only returned the physical environment to a previous "normal" state for the epoch that ended some 5,000 years ago, but many species that had **somehow managed to retain "footholds" within the more recent habitat, that thrived** in the other warmer state, bloomed, and replaced the more recent faunas for a short period. Where is the utility of the average concept in this context?

Progress over the last two decades toward an integrated, ecologically based fisheries monitoring and management regime has resulted from the near kaleidoscopic variability of the marine environment in response to usual decadal and epochal scale climate variabilities-global and local phenomena that could not be ignored.

Why has our mathematician given in? In the Benguela Current, recorded exploitation patterns of the fisheries have provided only short and incomplete information about these cyclic and aperiodic processes. The stability of the anchovy production since the collapse of the sardine population in that system may be completely artefactual, yet it lulls those interested only in the analyses of fisheries production into a sense of security which is likely to be short-lived.

While it is plausible that averages could provide adequate protection in a system which experiences only subtle perturbations, I doubt that the Benguela or any other Eastern Boundary Current would qualify.

Fisheries management should be about tesselations; careful analysis of not only man's harvests, but also the causal physical-climatic-oceanic processes, near and remote, that initiate ecological perturbations.

Emanating from this cascade of physical and biological signals are the unique experiences of surviving individuals, not the deadly averages.

For Example:

158

COLONIZATION IN FISHES - SOME INFERENCES CONCERNING REQUIREMENTS AND OPPORTUNISM IN THE SEA

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Some of the least considered topics in fisheries research have been the initial colonizations and range extensions of species. The significance of these processes is obvious in proliferation of subspecies, and speciation and population cycles in fishes. All aspects have been treated, but a full appreciation of the spectrum of possibilities has yet to be made. The cosmopolitan species represent one extreme situation. A fundamental requirement is that there be a high degree of nomadism, with cohesion and sexual parity (similar stages of development) in the various nomadic elements (schools or shoals). The data providing insight into this process in cosmopolite species is the high degree of kinship in genetic sampling of highly mobile oceanic species (two species of tunas) (Sharp, 1978). For proliferation of the oceanic scale there must also be continuous "search and sample" processes in which the reproductive success rate is relatively high. Location of appropriate patches for larval development in oceanic species, particularly the cosmopolites, must be exemplary of opportunism in the most stringent sense. Many of the cosmopolitan species are not very long-lived, and their reproductive behaviour is relatively "cryptic". Their reproductive behaviour is different from the most discussed pelagic groups, the clupeids and engraulids, which are typically harvested most intensely during or just prior to their reproductive period due to their strong shoaling behaviour during this time. Localization of these reproductive aggregations is indicative of the tendency for these species to home on geographic phenomena which have historically provided them with successful conditions for reproduction. These conditions are just recently being subjected to vigorous examination required for determination of cause and effect relationships (Vlymen, 1977; Beyer and Laurence, this volume; Owen, this volume).

Resident or homing subspecies, races, or behavioural components in contrast to nomadic opportunists can be observed on all scales. In the California Current system, the anchovy and the sardine before its decline have been shown to have at least three geographic racial components with significant overlap between any contingent pair of genetic units (Vrooman and Smith, 1971). There is extreme racial complexity in the less mobile of the tropical tunas (e.g., yellowfin tuna in the eastern Pacific Ocean) and ocean scale population complexity of the more migratory cosmopolites such as skipjack tuna (Sharp, in preparation, Fujino, 1970). There are numerous indications of similar processes in the North Atlantic pelagics. Recolonization of fishing grounds where commercial quantities of one species or another have diminished to nil is exemplified by the Japanese sardine which has begun a slow march from its last bastion in the eastern pelagic zone of Japan to the Sea of Japan around the southern tip of Japan, nearly back to the historic range of distribution during the peak years of its exploitation (Kondo, 1978). This long slow march is characteristic of fishes with limited nomadic tendencies and exemplifies the relatively slow procession of colonization by such species in contrast to the more migratory oceanic species and forms.

The qualities of habitat which determine the population distribution are entirely distinct from those which truly determine recruitment. The larval habitat clearly has a more complex series of constraints, on smaller scales and geometries, than the adult or more mobile stages. The limited mobility, small size, and relative sensitivity of fish larvae to micro scale parameters places them in jeopardy at all stages. The homing species invest considerable energy in placing their eggs into the home habitat. If this home habitat has shifted or ceased to be appropriate

for larval survival there is no hope for reproduction. Where the population habitat boundaries shift there is generally an effective reduction or increase in the potential larval habitat which directly influences reproduction success and realization of potential. Where the adult population habitat is shrinking one would predict a decrease in realization of reproductive potential. Where the adult habitat is expanding, if the adult population is not relatively nomadic, there is a tendency to under-utilize the larval habitat potential, yielding slower population growth than one could expect. In non-nomadic species, active transport by currents, wind stress field effects, diffusion, and sheer chance ultimately determine their rates of increase in both numbers and area.

Intermediate to these cases are species whose reproduction is not localized per se, but tends to be concentrated geographically due to the requirements of the larvae, whereas the adults and juveniles may be quite diffusely distributed and/or highly migratory, resulting in very different distributions at different life stages. In this situation species can even arrive at a "cosmopolitan" distribution.

If one concludes that the egg to larval **transformation period** is the greatest potential "bottleneck" period for a fish population, then one can also conclude that the complexities of the following life stages represent an evolutionarily successful egg's way of getting itself reproduced and redeposited in an appropriate environment. The subtle generation to generation responses to environmental trends and anomalies selects for either geographic flexibility, as observed in the nomadic opportunists, or numerical swarming as observed in the clupeids and engraulids, which is restricted, for success, to areas of relative year to year stability. The rise and fall of these localized populations is probably more characteristic and dramatic than the year to year biomass or number variations in the opportunistic nomadic forms. For example Table I shows the relative abundance (catch) variations in 25 local or regional pelagic fisheries from the years 1970 to 1977. All these examples have varied by more than 5 times during this period. No oceanic fisheries exhibited this level of apparent abundance variation within this period, apart from a few cases where political or economic factors other than resource availability have affected the total landings (FAO, 1977).

Table 1. Trajectories of catch trends since 1970.

Species	Area	(A) Peak catch	(B) Low catch	Ratio	A / B
Caranx hippos	West Africa	28 221	1 036	27.	+
Orcynopsis unicolor	West Africa	2 600	100	26.	—
Trachurus capensis	Southwest Africa	690 164	62 300	11.	+
Trichiurus lepturus	Southwest Africa	28 545	3 800	7.5	+
Trachurus trecae	Southwest Africa	273 700	31 298	8.7	—
Sardinella spp.	Southwest Africa	142 200	20986	6.8	—+
Scomber japonicus	Peru	65 000	8 700	7.5	+
Scomber japonicus us	Northeast Atlantic	39 000	6 262	6.2	—
Rastrelliger spp.	Eastern Indian Ocean	16 300	2 000	9.2	+
Rastrelliger kanagurta	Eastern Indian Ocean	203 100	35 403	5.7	—
Anchovies	Western Indian Ocean	118 062	16900	7.0	+
Psenopsis anomala	Northwest Pacific Ocean	13000	1 994	7.0	—
Sardinops melanosticta	Northwest Pacific Ocean	1 420 512	16 900	84.	+
Engraulis mordax	Eastern Pacific Ocean	289 002	44 600	6.4	+
Cetengraulis mysticetes	Eastern Tropical Pacific	168 081	15 551	10.8	+
Trachurus symmetricus	Eastern Pacific Ocean	50 149	9400	5.3	+
Sarda chiliensis	Southeastern Pacific Ocean	74 700	4 341	17.2	—
Scomberomorus sierra	Peru	2 279	400	5.7	+
Engraulis ringens	Peru	13 059 900	907 175	16.	—
Sardinops sagas	Peru-Chile	1 467 555	68 600	21.	+
Trachurus trachurus	Peru-Chile	839 805	111 300	7.6	+
Thyrsitops lapidopodes	Chile	7 200	630	11.6	—
Cetengraulis edentulus	Venezuela	4965	850	5.8	—+
Decapterus russelli	Malaysia-Thailand	109 337	9 800	11.2	+
St Scomberoides spp.	Indonesia-Philippines	5 186	500	10.	+

Plus and minus signs in the Table represent directions of trends during the reference period. Changes in both directions in the order indicated. The indication -—+ implies sharp changes in both directions, in the order indicated.

The apparent relative stability of the biomass of the broad ranging opportunist populations is due to both contributions of local populations and the shared risks taken by the large nomadic portions of these populations in coursing over their ranges in search of feeding grounds and hospitable spawning habitats. The dependence of local populations of oviparous fish on the stability or continuity of local processes conducive to larval survival is well recognized. Our ability to identify many of the "critical" characteristics is developing. Until these characteristics are identified and monitored there is little hope that it will be possible to logically predict recruitment trends.

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