

# Interactions and Dynamics of the Peruvian Upwelling System: A Postscript\*

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## Abstract

The interrelationship of the various contributions in this volume are briefly reviewed as are some errors in this volume's predecessor. Some aspects of the modelling work presently underway on the Peruvian upwelling system are presented.

## Resumen

Las inter-relaciones entre las diversas contribuciones en éste volumen son brevemente revisadas al igual que algunos errores en el precesor a éste volumen. Se presentan además, algunos aspectos del trabajo de modelación actualmente en desarrollo acerca del sistema de afloramiento peruano.

## Introduction

The book of which this is the last contribution represents the proceedings of the "International Workshop on Models for Yield Prediction in the Peruvian Upwelling Ecosystem", held at the Instituto del Mar del Perú, Callao, Perú, 24-28 August 1987, and the first contribution, by Csirke et al., presents the report of this workshop.

This book, however, includes more contributions than those which were prepared for presentation and formally presented at the said workshop. It also includes a paper that was conceived and essentially written during the workshop (Mendo et al., this vol.) in response to one of the formal presentations, as well as a number of papers that could be written only after the workshop was held. This applies particularly to the reestimation of anchoveta monthly biomasses from 1953 to the 1980s (Pauly and Palomares, this vol.) and of their reproductive output and egg mortality (Pauly and Soriano, this vol.). The former analysis could be performed only after the anchoveta consumption by hake had been estimated for that same period (Muck, this vol.), which itself could be estimated only after the available estimates of the biomass of hake of Northern/Central Peru had been extended from the last decades all the way back to 1953 (Espino and Wosnitza-Mendo, this vol.). In other words, this book presents a collection of closely integrated papers, of which the majority use time series data either derived or also considered in other contributions. Combined with the fact that the bulk of the contributions included here deals with *change*, this explains the subtitle of this book: "Dynamics and Interactions".

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The aim of the above-mentioned workshop was to examine whether sufficient information exists on the Peruvian upwelling system for a simulation model of that system to be developed which would be usable for purposes of fisheries management.

The answer was a guarded "Yes". Yes, because the predecessor of this volume (Pauly and Tsukayama 1987) considered a "formidable collection of papers" by one reviewer, indeed presented a vast amount of data in both raw and analyzed forms - enough to provide the basis for a serious modelling effort. This was a *guarded* "yes" however, because a large fraction of the variability of the physical components of the Peruvian upwelling system have the characteristics of an unpredictable "random walk" (Bohle-Carbonell, this vol.). Still, it is apparent that the anchoveta population off Peru is capable of stabilizing its biomass despite environmental variability. In fact, the consensus that emerged is that it is mainly the purse seine fishery which, in concert with predators such as the horse mackerel *Trachurus picturatus murphyi* (see Parrish, this vol.), nowadays prevents the anchoveta from reestablishing itself to the high levels prevailing, e.g., in the 1960s (see Muck's contribution on trends from the early 1950s to mid 1980s, this vol.).

Previous simulation models of the Peruvian ecosystem, notably that of Walsh (1975), emphasized primary and secondary production, and nutrient recycling, while giving scant attention to the species composition and biomass variability of the exploited fishes (anchoveta, sardine, mackerel, horse mackerel, bonito, etc.) of that system, not to speak of the guano birds and sea mammals (see also Walsh 1981).

Explicit consideration, in a simulation model of the Peruvian ecosystem, of the fishes and higher vertebrates requires that the various rates affecting their dynamics be precisely estimated; this pertains to growth and mortality rates, food consumption rates, etc. Hence, we have included contributions on some rates (e.g., the growth and food consumption rates of anchoveta) already considered in this book's predecessor, but reestimated them, using improved methods and/or new data (see e.g., contributions of Morales-Nin and of Pauly et al., this vol.).

We are well aware that none of the contributions included in this book and its predecessor, nor the planned modelling exercise, could make full use of all the information available from the Peruvian upwelling system (especially those on anchoveta, see Jarre et al., this vol.). For this reason, we document in Appendix I of this book a collection of fourteen 5 1/4" MSDOS diskettes (for IBM PC and compatible microcomputers) which contain all the time series and other data upon which the contributions in this book and its predecessor are based. Interested colleagues are invited to request copies of these diskettes from ICLARM, which is authorized to distribute them (for a small fee) throughout the world.

This form of data exchange is quite new; we hope it will contribute to the reestablishment of an important principle of science - now seriously endangered by massive databases analyzed with undocumented software - i.e., that the readers of a paper should be able to reproduce the results included in that paper *both in principle and in practice*.

We assume, obviously, that a wide dissemination of these data will encourage their further analysis, and hence will eventually benefit Peru, e.g., through elucidation of the mechanisms which determine the variable level of her fisheries resources. A recent contribution by Cury and Roy (1989), based on data presented in this book's predecessor, illustrates the process we have in mind here.

Another principle of science which is often neglected is the explicit correction of known errors in one's earlier publications. In this book, two chapters provide corrections for important errors in three earlier contributions (Table 1). I fear that while some will appreciate this information as an improvement to the book to which they refer, some others will feel that the existence of such errors - corrected or not - reduces the value of the previous book, and perhaps of this as well. Clearly, what we have here is a case of not being able to please all at the same time (see also Fig. 1).

As suspected by Cushing (1988), the data in this volume and its predecessors are presently being used for multispecies modelling. This proceeds along two lines of inquiries:

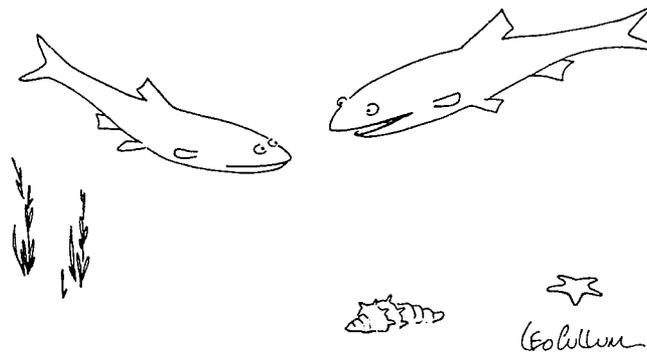
- construction of a successive steady-state model covering relatively short periods during which the Peruvian upwelling system maintained identifiable states (e.g., early to mid-1960s or mid- to late 1970s).

Table 1. Some errors in contributions included in Pauly and Tsukayama (1987).<sup>a</sup>  
 Tabla 1. Algunos errores en las contribuciones en Pauly y Tsukayama (1987).

Error	Author, page and exhibit no.	Remedy
Programming error in estimating wind stress on sea surface	Bakun (1987, Figs. E, F and G)	See Bakun and Mendelsohn (this vol.)
Numerous erroneous values due to misalignment of entries	Santander (1987, Table 3)	Corrections included in Table 2 of Pauly and Soriano (this vol.)
Underestimation <sup>b</sup> of anchoveta egg mortality	Pauly (1987, p. 329-330, equation (4), Table 2 and Fig. 4)	See Pauly and Soriano (this vol.)

<sup>a</sup>This table does not cover the various misspellings and unimportant typographical and other errors that may be found upon close reading of this book.

<sup>b</sup>Interestingly, Cushing (1988) suggested that anchoveta egg mortality may be overestimated.



"Some will love you, son, and some will hate you.  
 It's always been that way with anchovies."

Fig. 1. Drawing by Leo Cullum; © 1989. Reproduced by permission of the New Yorker Magazine, Inc.

Fig. 1. Algunos te amarán hijo, y otros te odiarán. Siempre ha sido así con anchovetas.

- development of a simulation model of the Peruvian upwelling ecosystem, in which key processes are expressed through coupled differential equations, parameterized using the rate estimates time series and other data presented in this volume and its predecessor.

The first of these approaches, presently emphasized by Ms. A. Jarre, is intended to serve two major aims:

- i) estimating, for various time periods the average biomass and/or production of elements of the system for which these characteristics are not available;
- ii) linking up the studies conducted to date on the Peruvian upwelling system with the theory of ecosystem phenomenology developed by Ulanowicz (1986), as initiated in Pauly (1987, Table 1).

The second modelling approach, emphasized by Dr. P. Muck, is both time- and space-structured: the Peruvian upwelling ecosystem has been divided up into nearly 200 squares, whose (SST-mediated) suitability for anchoveta, sardine, horse mackerel and other fishes is reassessed on a monthly basis and into which a purse seiner fleet can be deployed. The catch of

the fleet is then modelled, for each square fished, as a function of the biomass of various fish species which are themselves functions of the previous fishing and environmental regimes.

This approach, which is reminiscent of earlier work by Sharp (1979), is documented in Muck et al. (1989) and Jarre et al. (1989), where the abovementioned steady-state approach is also presented. Software and documentation for these models will become available in 1990, and readers may write to the author for information on this.

In conclusion, I wish to thank on my behalf and on behalf of my co-editors, the many colleagues and other friends who have made this book, and the workshop upon which it is based, possible, particularly:

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