A note on environmental aspects of penaeid shrimp biology and dynamics

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Abstract

Shrimps are short-lived animals living in highly variable inshore areas during the juvenile phase and are therefore subject to particularly strong environmentally driven variability in recruitment and stock size. This paper examines the likely consequences of this fact on the surplus yield production and stock-recruitment modelling underlining the high risk of generating artefactual models when the data series are short.

1 Introduction

Because of their very littoral distribution the coastal penaeid shrimps are exposed to important environmental factors of continental or marine origin. These factors may vary periodically with a high (diel, lunar, tidal cycles), medium (annual, seasonal cycles) or low frequency (climatic long term inter-annual cycles, sunspots, *etc*). They may also present trends when they are related to the effects of man's activity (pollution, land reclamation, *etc*).

The effects of these variations on the shrimps biology and dynamics are important and this paper is intended to underline their main consequences regarding the use and interpretation of production models and stock-recruitment relationships.

2 Environment and production models

Changes in environmental parameters are likely to affect recruitment and the extensive use of 'predictive models' for shrimps (see Garcia and Le Reste, 1981, for a review) indicates that the yearly abundance of these animals is, in fact, affected. When working with production models, these environmental effects appear as additional variance in the catch per unit effort/effort relationship used.

The fished shrimp stocks consisting essentially in one year class, the average abundance of any year is close to the equilibrium value and it can be assumed, if no important errors are involved in the measure of catch and effort, that the departures from the equilibrium curve are linked to environmental factors. An examination of the time series of the residuals will give some indication on the trend and amplitude of the variations from the expected equilibrium line and on the variability pattern with time (see for example Garcia, 1983, or Garcia and Van Zalinge, 1982). An analysis of the correlation between the production model residuals and environmental parameters will show if a significant relationship exists between the two types of anomalies (Lhomme and Garcia, this meeting). When the residuals are important and well explained by environmental variables it would even be better to extract their effect before analysing the relationship between fishing effort and stock size.

When useful apparent correlations are identified, a multivariate regression between catch rates, efforts and environmental parameters is appropriate. The result will be a tridimensional (possibly multidimensional) 'production model' like the one proposed by Griffin, Lacewell and Nichols (1976) for *P. setiferus* in Louisiana

$$Y = 3365D^{-0{\cdot}5064}(1{\cdot}0 - 0{\cdot}994746E)$$

where D = annual river discharge and E = fishing effort. This approach has been in fact generalized to other stocks of the Gulf of Mexico (Turner and Condrey, this meeting).

An important consequence of this type of situation is that a production model for shrimps, based on a limited set of data should always be considered with caution as it can lead to wrong estimates. *Fig 1* shows the apparent production curve for a stock when recruitment increases or decreases progressively because of 'environmental' reasons. It is clear that in the absence of knowledge of the actual curves the MSY is only one value among the possible ones, that f_{MSY} is biased and that it can be over or under estimated depending on the situation considered.

In terms of management, when the effect of an increase or decrease of effort is estimated from the apparent curves the actual results may be completely different from the expected ones, either lower or much higher, depending on the recruitment variability and on the trend. The apparent model does not anymore picture a reversible phenomenon.

3 Environment and stock-recruitment relationships

There are evidences that the level of recruitment is at least partly governed by environmental condi-

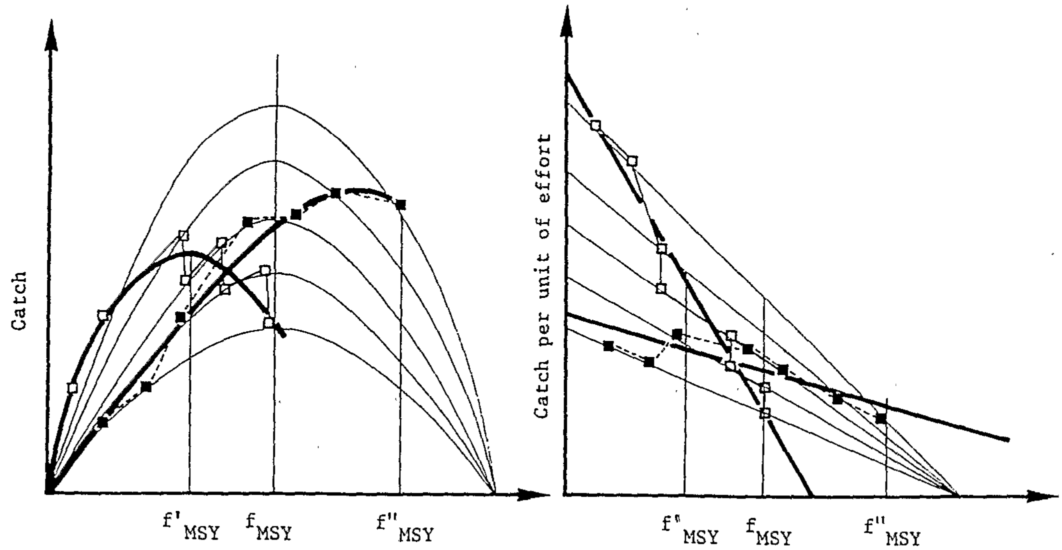

Fig 1 Actual production curves (thin lines) and apparent relationships (heavy line) when recruitment is affected by changes independent of fishing effort. Two situations are pictured, leading either to pessimistic f_{MSY} estimates (□) or to optimistic ones (■). All curves are drawn by eye

tions in the nursery areas (Ford and St Amant, 1971). There are also indications that recruitment is affected by the changes in the extension in nursery areas, (Doi *et al*, 1973; Browder and Moore, 1981; Ehrhardt *et al*, this meeting) by reclamation, damming, dredging of the lagoon passes, *etc*. In a strongly variable environment the shrimp annual recruitment should therefore be only loosely related to the parental stock size.

Very little was available before 1979 on the shape of the eventual relation. Neal (1975) and Le Reste and Marcille (1973) have speculatively suggested that it might be the case for shrimps. Hancock (1973) and Garcia and Le Reste (1981) underlined the lack of information on this subject.

More recently (Kirkwood, this meeting) has indicated that for a heavily exploited stock of *P. merguiensis* in Australia, the analysis of the residuals of the relation between rainfall and catches does not provide any evidence of trend in recruitment or recruitment overfishing despite the fact that the exploitation ratio has reached values of 0·75 to 0·85.

Bakun and Parrish (1981) indicate that, in general, when the nurseries have a limited and relatively constant biological capacity, the Beverton and Holt type of relationship is the most likely one.

The problem here is that we may have indeed a flat relationship of a Beverton and Holt type with an important environmental variability masking the existing relationship. In this last case the exact shape of the signal does not really matter because it is the 'noise' which has to be studied and eventually understood for prediction purposes.

As in the case of production models, it is important to point out that when a trend in recruitment not related to fishing occurs, the results in terms of stock-recruitment relationship are strongly biased. It is obvious that with very short lived animals like shrimps which generation time is close to the basic time interval of one year, the spawners abundance is related to the abundance of the recruits which have generated it. There is a recruitment-stock relationship (see *Figure 2*, $R \rightarrow S$) which slope will depend on the level of fishing.

If the environment has an effect on the recruitment level, it means that instead of one stock-recruitment curve there exists in fact a family of them corresponding each to a different level of environmental constraints (*Fig 2*, actual $S \rightarrow R$).

If, in a limited time series, the recruitment starts decreasing (or increasing) it will be *immediately* (within 6 months) followed by a decrease (or increase) of the subsequent biomass and spawning stock. The result will be the existence of parallel (concurrent) decreasing (or increasing) trends in R and S and, of course, any attempt to relate directly the spawning stock in year n to the recruitment at the beginning of year $n + 1$ will show a relationship (see *Fig 2*, apparent $S \rightarrow R$) which is nothing more than one trajectory across a family of stock-recruitment curves. In fact, if the effort is stable and the shift from one $S \rightarrow R$ curve to the following is very progressive, the observed apparent $S \rightarrow R$

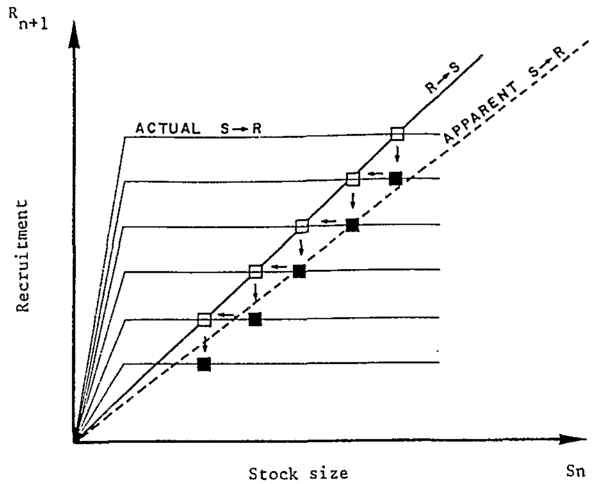

Fig 2 Actual stock-recruitment curves (thin lines) and apparent one when the recruitment drops progressively for non fishing related causes. Effort is kept constant for simplicity of the argument (only one recruitment-stock function). Progressively shifting $R \rightarrow S$ lines in relation to changes in the effort level will distort the apparent relationship and/or increase the variability without modifying the consequences. ■ = observed data points.

curve is in fact the $R \rightarrow S$ curve.

If effort and recruitment change at the same time, the apparent $S \rightarrow R$ given in *Figure* 2 will be distorted and the apparent variability of the data increased.

The important consequence of this action of environmental changes on recruitment is that the observed trajectory may not be a stock-recruitment model but instead an environment-recruitment model for a given range of fishing mortalities. The 'model' observed *is not exactly reversible* if the level of fishing changes which means that there is no reason why in case the trends in effort or in recruitment become reversed, the reversion should follow back the same trajectory. In terms of management it means also that managing the stock (by reduction of fishing mortality, closed season, *etc*) in order to improve the spawning biomass may not give the expected results in terms of improved recruitment (because its decrease may not be due to fishing). The actual results may be worse or much better than expected. In case the recruitment trend is related to progressive destruction of the nurseries (mangrove deforestation, land reclamation) this type of management measure will simply fail because the model is not reversible at all and the current actual stock-recruitment curve may be among the lowest of the potentially possible ones.

With the above in mind, it is clear that the trends in recruitment (*Fig 3*) observed in Kuwait (Morgan and Garcia, 1982), largely uncorrelated with fishing and possibly related to intensive land reclamation, or other wide scale environmental change may have produced an apparent and non reversible stock-recruitment relationship. The results obtained by Pauly (in Press) with data from 1963 to 1972 also show a downward nearly linear trend in recruitment from 1963 to 1968 and an upward one from 1969 to 1972. For the same reasons as above, the relationship given (*Fig 4*) may also be an artefact caused by trends in recruitment not related to fishing.

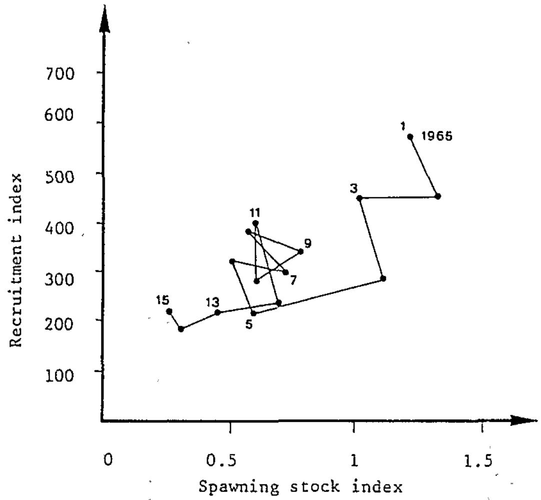

Fig 3 Apparent stock-recruitment relationship in Kuwait (from Morgan and Garcia, this meeting).

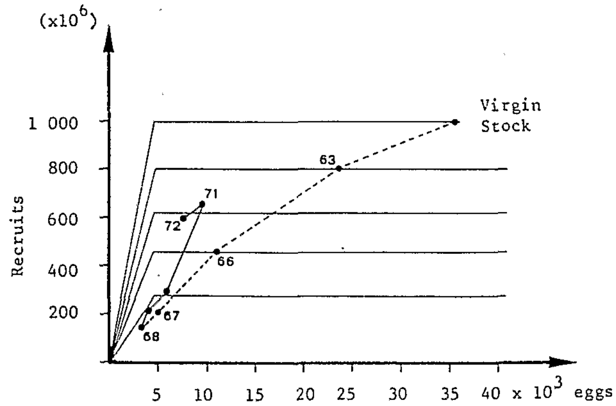

Fig 4 Stock-recruitment relationship in Gulf of Thailand penaeid shrimps (virgin stock is estimated by backward projection of the 1963–67 trend (from Pauly, in press). The dotted lines are entirely speculative and have been added by me to the original figure

Finally the stock-recruitment given by Ye (this meeting) for *Penaeus orientalis* raises the same problem because the data contain a positive trend in recruitment.[1]

The conclusion that can be drawn on this basis is that because of the fact that shrimp stocks are made by one single year class, there is a direct precise relation between the recruitment and the following stock. This relation will result with an apparent stock-recruitment relationship when a recruitment trend exists. This fact complicates seriously the stock-recruitment analysis where a limited number of years is available and leads to the necessity of using multivariate analysis involving environmental parameters.

[1]Other papers presented at the meeting on stock-recruitment of shrimps were not available to the author when preparing this note and will be analysed in a more detailed work on the subject (cf. Garcia, 1983)

References

BAKUN, A and PARRISH, R A. Environmental inputs to fishery 1981 population models for eastern boundary current regions. *In:* Report and supporting documentation on the workshop on the effects of environmental variations on the survival of larval pelagic fishes. *IOC Workshop Rep. Ser.*, (28):67–104.

BROWDER, J and MOORE, D. A new approach to determining the 1981 quantitative relationship between fishing production and the flow of freshwater to estuaries in Cross, R and Williams, D (Eds.) 1981. Proceedings of the National Symposium on Freshwater inflow to estuaries. Vol. I. USFWS. Office of Biological Services–FWS/OB5-81/04:403–430.

DOI, T. OKADA, K and ISIBASHI, K. Environmental assessment 1973 of survival prawn, *Penaeus japonicus*, in Tideland-I. Environmental conditions in Saizyo tideland and selection of essential characteristics. *Bull. Tokai Reg. Fish. Res. Lab.*, 76:37–52.

FORD, T P and ST AMANT, L S. Management guidelines for 1971 predicting brown shrimp, *Penaeus aztecus* production in Louisiana. *Proc. Gulf Caribb. Fish. Inst.*, 23:149–164.

GARCIA, S and LE RESTE, L. Life cycles, dynamics, exploitation 1981 and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Pap. No. 203:* 215 p.

GARCIA, S and VAN ZALINGE, N P. Shrimp fishing in Kuwait: 1982 methodology for a joint analysis of the artisanal and industrial fisheries. Paper presented at the workshop on the assessment of the shrimp stocks of the west coast of the Gulf between Iran and the Arabian peninsula, Kuwait, 17–22 October 1981. FI/DP/RAB/80/015:163p

GARCIA, S. The stock-recruitment relationship in penaeid 1983 shrimps: reality of artefacts and misinterpretations? *Oceanogr. trop.* 18(1): 25–48.

GRIFFIN, W L, NICHOLS, J P and LACEWELL, R D. Trends in 1973 catch/effort series: Gulf of Mexico shrimp fishery. *Tech. Rep. Texas Agric. Exp. Stn.*, 85 p.

KIRKWOOD, G P (in press). Modelling of the Gulf of Carpentaria prawn fisheries. Doc. presented at the Workshop on the scientific basis for the management of penaeid shrimps. Key West, 18–24 November 1981.

LHOMME, F and GARCIA, S (in press). Biologie et exploitation de la crevette penaeide *Penaeus notialis* (Perez-Farfante, 1967) au Sénégal. Doc. presented at the Workshop on the scientific basis for the management of penaeid shrimps. Key West, 18–24 November 1981.

LE RESTE, L and MARCILLE, J. Réflexions sur les possibilités 1973 d'aménagement de la pêche crevettière à Madagascar. *Bull. Madagascar*, (320):15 p.

MORGAN, G R and GARCIA, S. The relationship between stock 1982 and recruitment in the shrimp stock of Kuwait and Saudi Arabia. *Oceanogr. trop.* 17(2):133–137.

NEAL, R A. The Gulf of Mexico research and fishery on penaeid 1975 prawns. *In:* First Australian National Prawn Seminar, Maroochydore. Queensland, 22–27 November 1973, edited by Young, P C, Canberra, Australian Government Publishing Service, pp. 1–8.

PAULY, D (in press). A method to estimate the stock-recruitment relationship of shrimps. *Trans. Amer. Fish. Soc.*

YE, C C. The prawn (*Penaeus orientalis* Kishinouye) in Pohai 1984 Sea and their fishery. This volume.

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