Limits on Sardine Catches and the Portuguese Processing Fish Industry. A System Dynamics Study

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Some data about the recent evolution of sardina pilchardus stocks along the Portuguese coast indicates a potential danger of exhaustion. Since the Portuguese fish processing industry is totally dependent on sardine catches, an impact evaluation of the foreseeable restrictions was necessary.

An integrated system dynamics model of the supply and demand of sardine and of the production of canned sardine was developed and tested with historical data, and three different scenarios were explored.

The system dynamics sub-model of industrial production assumes that sardine price is the major variable affecting the industry performance.

The simulation results provide information on how the different groups of companies will behave, and help put in perspective the expectable social and economical effects.

1. The Portuguese Canned Fish Industry

Portuguese preserved and canned fish industry, after a centenary evolution, has hyper-specialised in sardine and tuna-fish species, with a sardine prevalence. During the last five years, it registered an annual production of 25 Kton of canned sardines, of which 55% up to 70% have been exported for a small number of countries. This situation, together with the fact that usually the sales take place under the importer's brand name or under a brand name appointed by him, has driven the industry to a vulnerable position.

At the supply side, it is important to notice that the processing fish industry in Portugal absorbs approx. 50% of the of the total sardine landed in Portuguese harbours. Since "sardine" name, in the European Union market, is legally restricted to the species *sardina pilchardus*, Walbaum, 1792, no other significant source is available. Sardine average prices at the wholesale fish market have steadily increased since 1986.

In Porter's terms (Porter, 1980), "industry falls between the devil — more and more demanding and powerful customers — and the deep blue sea — suppliers whose bargaining power is based upon EU regulations." (Dias, 1998). Additionally, the survival of Portuguese canned fish industry depends on the canned sardine production (Dias *et al*, 1998a), since the reputation earned by the latter is critically dependable on the quality and abundance of fresh sardines and the excellence of workers' skills.

2. Recent Evolution of Sardine Landings

Sardine (*sardina pilchardus,* Walbaum, 1792) has its natural environment in a large area of the Northeast Atlantic, the Mediterranean and the Black Seas. National catches, relying upon a sole fish bank, take place along the Portuguese coast and oscillate around an annual total of 80 Kton. Sardine is traditionally caught by purse-seine fleet vessels, belonging to Producers' Organisations (PO), which are associations of fishing ship owners, promoted by EU regulations; the exploitation pattern has basically remained the same, in the recent years, as was confirmed by a Box-Jenkins analysis on the data concerning sardine landings in Portugal, since 1986 (Dias *et al.* 1999a) — see Figure 1.

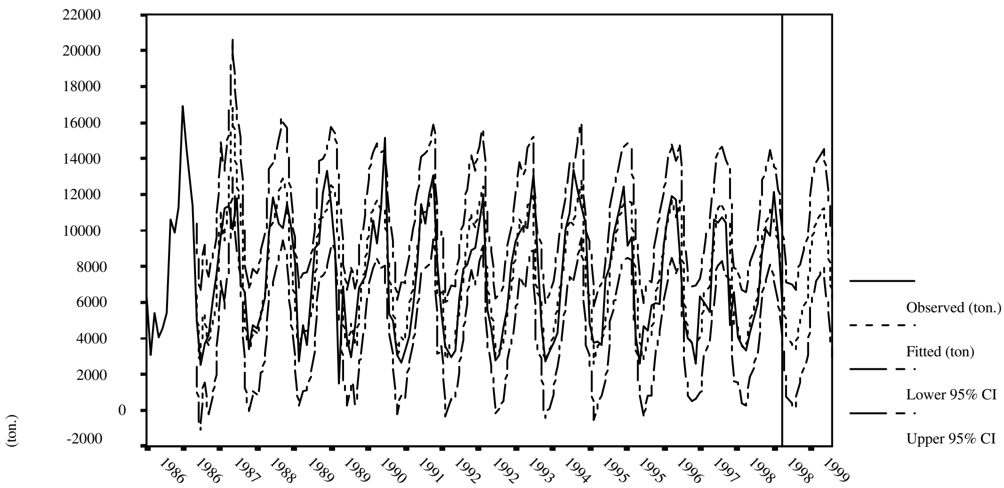

Figure 1. Pattern of sardine landings and SARIMA model $(0,0,1)(0,1,1)^{12}$ adjusted
Source: DGPA, Dias *et al.* (1999)

However, data collected during the Portuguese Institute for Fisheries and Sea Research (IPIMAR) acoustic surveys, in 1995 and 1996, caused some concern, given the signs of reduction of the spawning biomass and of the total biomass. Alterations of the sardine distribution pattern were also detected, with a higher concentration by the coast.

A recovery plan which would involve the European Commission, Portugal and Spain was launched and, in this context, the Portuguese public authorities agreed with the PO an "action plan for sardine fisheries" to be carried out between 1997 and 1999, which included among other measures, a limitation of the total catches, as described elsewhere (Dias *et al*., 1999b). An assessment about the impacts of the alleged sardine scarcity on the canning industry was also requested from ISCTE, and a part of it is presented in this paper.

After considering the whole set of available data about the situation, three alternative scenarios were set up for the evolution of landings, which, for this purpose, were assumed to coincide with the catches:

1. *The optimistic scenario*. It is a reference scenario corresponding to the 1997 actual situation. Annual sardine landings in Portugal keep oscillating around the 80 Kton, on the assumption of unrestricted total catches.
2. *The pessimistic scenario*. It is an extreme scenario corresponding to a strong reduction of the stock level, thus creating the conditions for the adoption of

precautionary measures. Annual landings reach a total of 41.5 Kton on the domestic wholesale fish markets, meaning a reduction of approx. 50% on the 1997 figures.

3. *The intermediate scenario*. It is a negotiation scenario, where a number of variables — political, economical, social and biological — play a relevant role. The total annual supply amounts to 61 Kton on the domestic wholesale fish markets, corresponding to a reduction of approx. 25% on the 1997 figures.

3. Dynamic Modelling of Industry

The assessment of the impact of sardine scarcity within each scenario was carried out using a system dynamics model and computer simulation, carried out using Vensim software, developed by Ventana Systems Inc.. Some disparities in the way the different sources organised the information about Portuguese fisheries and canning industry, made necessary a data harmonisation which was validated by industry experts in due time.

3.1 The model

For explanation purposes, we may assume the model as made of three sub-systems: (1) the wholesale fish market with its price mechanisms, which determines the quantities sold to the industry and to the fresh fish market; (2) the industry capacity sub-system, where the number of plants that remain active is determined by sardine price and companies survival potential; (3) the canning process which, taking into account the fish quantities and the production capacity available at each moment, calculates the canned fish produced.

However a main feedback loop exists, linking the three sub-models: whenever the average sardine price exceeds the threshold affordable for one group of companies, the weaker plants start to close down; demand is consequently reduced as it is the price at the wholesale fish market. At a later moment, if supply is large enough, the remaining companies increase the production rate until the maximum production capacity and then stop buying for a while and prices at the wholesale fish market go down again.

This adaptive loop provides the control mechanism that determines sardine prices, maximum production capacity and total canning, while the market and industry structure remains stable. This assumption is valid since the feedback on the fishing activity due to the alterations in industry demand — which may be of relevance at specific wholesale fish markets — was not taken into account.

The wholesale fish market

Several “supply & demand” models have been described (Mass, 1980), (Whelan & Msefer, 1996), (Ruth & Hannon, 1997); however, they are not applicable, since (1) there is no detailed study of the Portuguese wholesale fish market, (2) its basic economic indicators are not known, and (3) its market mechanisms cannot be considered as a perfect competition.

The main assumptions incorporated in this sub-system are the following:

- Industry is exclusively supplied by fish landed in the Portuguese harbours; purchases are made either at the wholesale fish markets — in competition with the suppliers of the fresh fish market, in which is, actually, an auction procedure — or within the context of an annual agreement with the PO. As a limit, it was assumed that the annual total bought from the PO cannot exceed 40% of the total sardine landings.

- Stability in the fish catching pattern was assumed. The seasonal indexes for the four yearly quarters are respectively 0.131, 0.208, 0.367, 0.294 (Dias *et al.,* 1998b).
- Rejections and withdrawals were estimated as 6% of the landings, which is the average for the period 1995-97. Withdrawals are financially supported by EU funds, according to the Common Market Policy.
- It was assumed that the demand-price elasticity coefficients in each quarter, which have been calculated for the supply of the fresh fish market, remained valid in all the scenarios analysed. Using elasticity coefficients, it is possible to calculate the average sardine price from the quantities sold for consumption in fresh by means of the relation: $P / P_0 = (Q / Q_0)^{1/\varepsilon}$. P_0 and Q_0 are parameters defined for each quarter, with the values P_0, 85.4, 82.3, 96.5 and 73.4; Q_0, 1150, 2480, 4516 and 3527.

The values obtained for the demand-price elasticity coefficients in each quarter are respectively -0.965, -0.929, -0.634, 1.061 (Dias *et al.,*1998b).

- The relation between the quantities purchased at the wholesale fish market by the industry (Q_IND_OA), the quantities sold for fresh consumption (Q_FRESH) and sardine price (PR_FRESH) was established by means of the following linear expression: Q_IND_OA = 1188 + 0.5422 * Q_FRESH - 12.989 * PR_FRESH.

The regression and all of its coefficients are significant (sign(F)=0.0000, sign(T)<0.05) and has an adjusted $R2 = 0.44769$. Colinearity among the independent variables was not found.(Filipe, 1999).

The industry capacity and the sardine price

The economic and financial situation of a large number of processing fish companies makes difficult to allow for substantial increases in the costs associated to the raw-materials — the main item in their cost structure. A detailed analysis based on the results of an extensive audit concluded that, in the actual structural industry conditions, it was valid to assume that the average level of the raw-materials costs determined the capacity of each company to survive.

In the model, the industry total production capacity — i.e. the sum of the capacities of all the plants in operation in 1997 — is related to the sardine price in the following manner:

- The total installed production capacity was estimated in 37.7 Kton, i.e. 1.5 times the total canned sardine produced in 1997. Future alterations of that capacity — either by investment, rationalisation or obsolescence — were not taken into account, except the reductions concerning plants where the production of canned sardine has become inviable (even when the plant has a multiproduct capability).
- Plants with an annual production of canned sardines above 29 Ton were divided into three groups D, C, B, in ascending order of efficiency. This efficiency was estimated taking into account the productivity and rentability levels. The plants were then ranked within each group, according to their survival potential which has been established on the basis of the economical and financial information available.

Based on the balance sheets and financial statements of some plants, a threshold of maximum acceptable cost of raw material was set for each group. Taking the price of the sardine, at the wholesale fish market, as the reference cost, the limits for the groups D, C and B were 105, 115, 150, PTE/Kg. When the six-months average cost of the raw material exceeds one of the thresholds, the plants of the group concerned begin to close down, irreversibly.

The canning process

The canning process was modelled taking into account the operational indicators in use.

- It was assumed — in accordance with Reg.(CEE) 2136/89 — that gutted fish accounts for an average 70% of the canned sardine net weight and that the sardine efficiency rate (weight of fresh fish divided by weight of canned sardine) is 1.67.
- It was considered that average production rate, stabilised by the chilling and freezing methods, is 46% of the maximum production capacity (which equals 70% of the capacity used in 1997).
- The amount of sardine being processed was modelled as a work-in-process stock, with a specified upper limit; whenever the work-in-process reaches this maximum, the industry suspends its purchases for a while.
- Taking into account the historical levels of the finished products inventory, it was assumed that the canned fish was immediately sold, with a sales price identical to the 1997 one.

A simplified causal-loop diagram of the integrated model is shown in Figure 2.

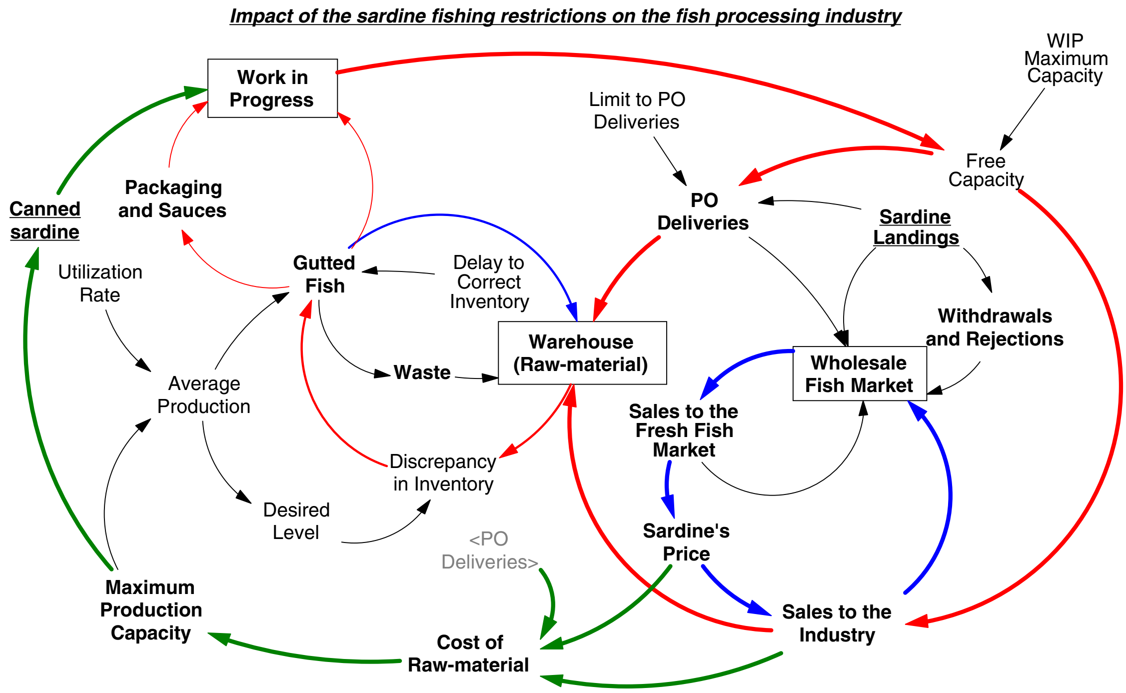

Figure 2. Causal-loop diagram

3.2 Model validation

The model was tested by feeding in the 1995, 1996 and 1997 actual landing values. The results for the annual totals, which are presented in Figure 3, meet the requirements for this kind of model; the price deviation in the third quarter of 1996 is due to anomalous actual prices registered at some places.

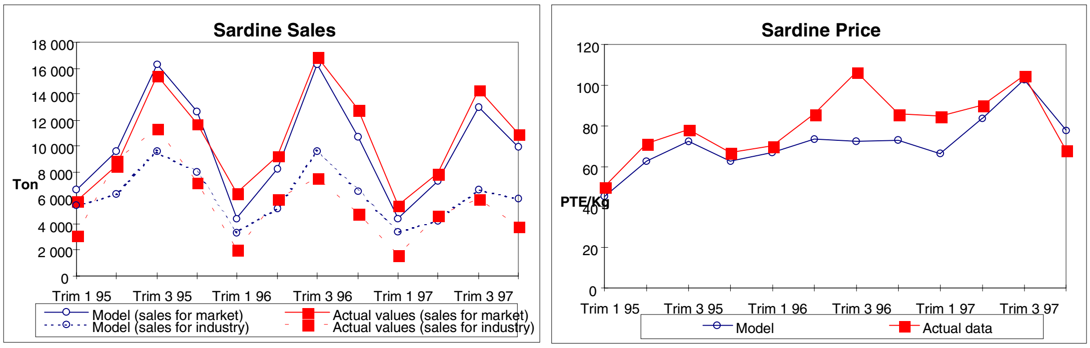

Figure 3 - Model validation

4. Results of the Simulations

The exploration of each scenario, using the system dynamics model within the framework defined by the assumptions mentioned above, was done for a three year time period. The evolution of the main variables is presented in Figure 4.

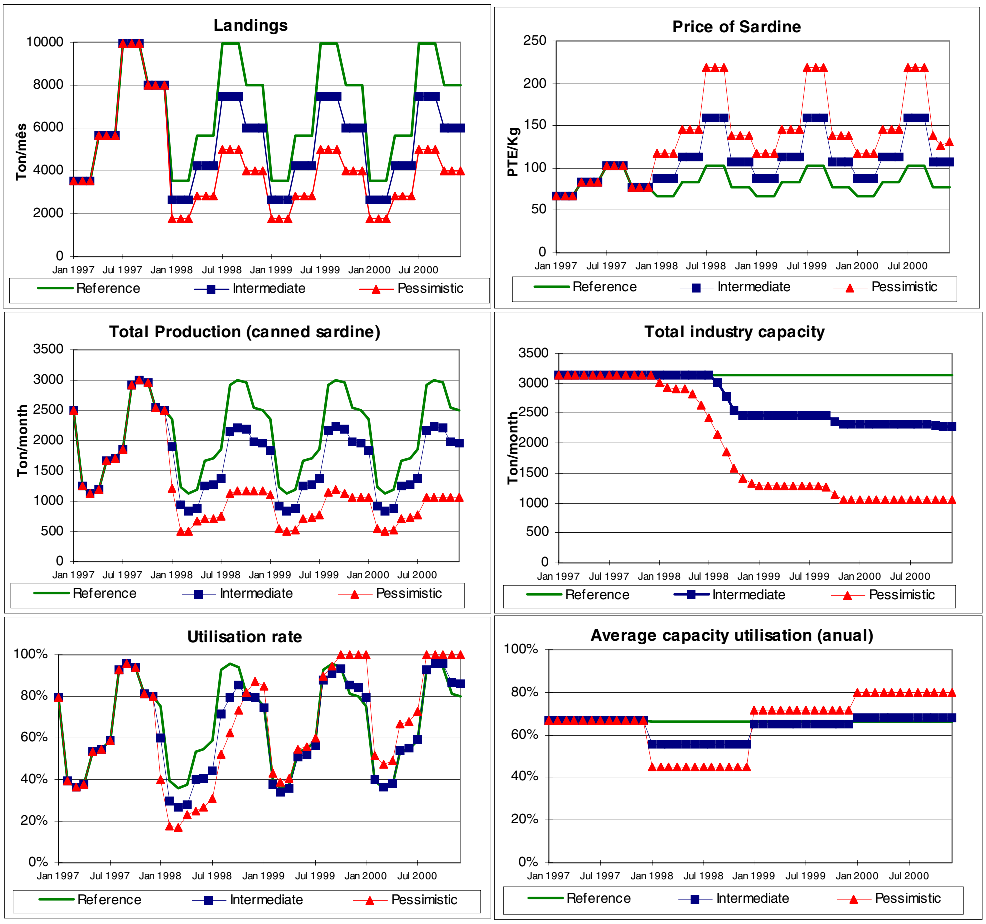

Figure 4: Evolution of the main variables in the simulation period and in the three scenarios.

The installed capacity undergoes a drastic reduction in all the scarcity scenarios; the resulting values are presented in Figure 5:

Year	Optimistic	Intermediate	Pessimistic
1998	37 692	29 568	16 020
1999	37 692	27 900	12 660
2000	37 692	27 360	12 660

Figure 5. Evolution of the Maximum Annual Production Capacity (Ton)

The division of the production plants in the D, C and B groups and its ranking within each group as a function of its survival potential, make possible to link the production capacity reductions and actual companies, plants and locations; therefore, the assessment of impacts at a regional level becomes a straightforward exercise.

The main conclusions of the impact assessment were:

- In the intermediate scenario, the sudden reduction of 25% in the fish supply brings about an equivalent reduction in the canned sardine produced and a 27% reduction of the installed capacity. An irrelevant increase of the utilisation rate in the remaining plants is observed. The total redundancies will amount to 930.
- In the pessimist scenario, the drastic reduction of 50% in the fish supply brings about a 60% reduction in the canned sardine produced and a reduction of 66% of the installed capacity. In the remaining plants, a large increase of the utilisation rate — from 67% to 80% — occurs. The job losses will amount to 1580.
- The instability at the wholesale fish markets will favour the supplying channel within the context of the agreement between the PO and the industry, which will tend to be hegemonic. At certain moments, the closing down of a plant may provoke a strong instability at the local wholesale fish market, causing a further reduction in the local supply.
- At council level, job and income reductions are, with few exceptions, of little relevance.

5. Conclusions

System dynamics proved to be an appropriate method to represent, visualise and assess the impacts of fish and seafood supply variations along the chain. It is, however, a very demanding method in what regards market and operation indicators — as it is the case of the elasticity coefficients. Appropriate modelling of the system, along with computer simulation, provides a very efficient way of anticipating the effects of different policies of resource management on the biological, social and economical variables.

In another perspective, it is important to recognise the role played by the model exploration through simulation, in the negotiation process among the intervening parts. The visibility of the feedback related to each player's behaviour — as it is the case of the very strong link between the fish markets instability and the closing-down of nearby canning plants — reinforces the awareness of their interdependence and makes the dialogue easier.

Acknowledgements

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