Economic Impacts of Sardine Scarcity on the Portuguese Canned Fish Industry: a System Dynamics Study

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In 1995 and 1996, the biological research of the evolution of *Sardina Pilchardus* stock along the Portuguese coast indicated a potential danger of exhaustion. As the Portuguese industry of canned **sardine** is totally dependent on those catches, it was necessary to evaluate the impact it will undergo under the foreseeable restrictions.

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

The simulation results provided information on how the different groups of companies would behave, with the assumptions that the sardine price was the major variable affecting the industry performance and that it was improbable the increase of the output price, because of the characteristics of the commercial structure.

The model also put in perspective the expectable employment and revenue effects in the regions where the plants were and help the partners in the chain values to assume the tight **links** between them

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1. INTRODUCTION

Sardine (*Sardina Pilchardus,* Walbaum) assessment currently considers an Iberian stock unit that includes the ICES division VIIIc and IXa. The initial reasons for this delimitation were administrative simplification, and similarities in exploitation between the Spanish and Portuguese fishing fleets targeting sardine (Pestana, 1989). While that division is often questioned, recent biological analysis did not provide strong evidence for a new delimitation.

In the period 1976- 1996 Spanish landings of sardine have reach a maximum of approximately 108 K.Ton. in 1984, decreasing from then on down to 26 K.Ton. in 1996, which is close to the minimum registered since 1940. In the analysis of the time series for the aggregated landings made by the two fleets during the period 1976-1996 two important facts emerged: while Portuguese landings stabilized around the 90 K.Ton. in the period 1986-1996, the aggregated value reached a minimum of 110 K.Ton. in 1996.

Sardine is the most important species caught in Portuguese waters (48% in terms of quantity and 17% in terms of value in 1996), and has a large impact on the canning industry. The major part of the catches is taken in the sub-area IXa, by a purse seine fleet belonging to Producers' Organisations (PO), in a directed fishery that employed approximately 4000 fishermen in 1996. The exploitation pattern of this fleet remains stable since several years ago.

The seasonal pattern of the catches — which we assumed to be identical to the landings — made by the Portuguese fleet, has remained constant, with the highest values — around 70% of the total — registered in the second half of the year. A Box-Jenkins analysis (SARIMA) on the data concerning sardine landings in Portugal, since 1986, confirmed its stability[12] (Dias, 1999).

However, data collected during the' IPIMAR (Portuguese Institute for Fisheries and Sea Research) 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.

For Borges & al (1997) the decreasing trends in the recruitment of sardine (and horse mackerel) on the ICES VIIIc and IXa seem to be related with the increase of up-welling favourable conditions in winter and early spring occurring in the Portuguese coast since 1983. According to the same authors, this effect on recruitment is probably due to the increase of conditions favourable for larvae offshore transport and consequent increase of their mortality.

Hence, ACFM came to the conclusion that the sardine's stock was at risk and recommended a reduction of fishing effort to the minimum for 1996 and a recovery plan to be developed and implemented. (In October

1997, ACFM extended its recommendation to a zero fishing effort.)

The proposal was analysed by the European Commission — Directorate General of Fisheries - who postponed a decision until new data would be available and suggested to launch a recovery plan which would involve the European Commission and the Portuguese and Spain Governments.

In this context, the Portuguese public authorities agreed with the Producers Organizations an "action plan for sardine fisheries" to be carried out between 1997 and 1999, which includes the setting of a miniium size of 11 cm for the catches, the reduction of the number of fishing days and a limitation of the total catches. In addition, the Commission for the Portuguese Canned Fish Industry (GAPIC) requested **from** ISCTE an assessment of the economic impacts of this alleged sardine scarcity on the industry, which partially is the subject of this paper.

2. *SYSTEM DYNAMICS METHODOLOGY*

The systemic approaches emerge as a reaction against analytical rationalism, as first proposed by Descartes in 1637 in *Discours de la Méthode*. Ludwig von **Bertalanffy** — who in 1954 founded the Society for General Systems Research (now the International Society for the Systems Sciences) — based its concept of a system on the principle that "the whole is more than the sum of the parts". Le Moigne (1978) enumerates the aspects that make a systemic approach different **from** the analytical view: (1) pertinence (to the researcher) versus evidence, (2) holism versus reductionism, (3) purpose versus **cause**-effect determinism, and (4) **aggregateviness** versus exhaustiveness. **Durand** (1979) bases the systemic approach in four major concepts: interaction, wholeness, organisation, and complexity. A system can be described in functional or structural terms, and a model is a simplified representation of a system by means of the analogical reasoning.

System **dynamics** was developed at the MIT (Massachusetts Institute of Technology), in the early sixties by Jay W. **Forrester (Forrester, 1961),** for the quantitative study of social and economical systems. According to system dynamics the **structure** of a system can be represented by a complex network of feedback loops **connecting** stocks and flows. Stocks are the variables representing properties that accumulate along the time, and flows are the rates of variation of those stocks, in such a way that values of the stock variables result from the time integration of the associated flows.

The behaviour of a system is related to the evolution of stock levels, and these determine the flow values in accordance with **pre-established** rules. System evolution patterns — exponential growth, oscillating movement, **"S"** curve, damped curve, **etc.** — depend on the feedback loops network and on which type of loop is dominating — either the positive (virtuous or vicious) loops or the negative (balancing) one.

Once the model has been built and validated, it can be used to simulate the system behaviour in face of external events affecting its variables. Given the existence of multiple feedback and feed-forward loops and time delays, the behaviour of a complex system — or of one of its variables — can only be determined and analysed by computer simulation.

Forrester insists since his first works on system dynamics that the purpose of a system dynamics model is policy design (Forrester, 1961). The practice of system dynamics remains to this day predominantly associated with this view, even if some models for forecasting are developed (Lyneis, 2000).

System approaches to fisheries are frequent since they may be considered as a network of interactions between natural and social systems requiring multidisciplinary approaches (Catanzano and Mesnil, 1995; Le Fur, 1998; Le Gallic and Ulrich, 1999). Typical examples of the application of system dynamics are those provided by Amaria et al. (1979), who developed a system dynamics model of the Newfoundland fishing industry, relating harvesting operations to raw-material requirements and production schedules and Tarazona et al. (1993), who applied system dynamics to problems posed by aquaculture of the rainbow trout.

In this paper, the system dynamics modelling of the Portuguese sardine canned industry and the simulation of its behaviour withii each scenario were carried out using Vensirn software, developed by Ventana Systems Inc..

3. THE PORTUGUESE CANNED FISH INDUSTRY

For over a century since its beginnings, between 1865 and 1967, and apart from those years in the aftermath of the Second World War, Portuguese preserved and canned fish industry registered a steadily increasing trend; in 1913, it was the world leader in production and exports, with approx. 25 K.Ton. Having reached, in 1967, a peak in production with 74 K.Ton., the industry dropped to a 50 K.Ton. threshold, around which it has been oscillating, with an amplitude of 10 K.Ton., for the last 25 years. At present, industry's total sales still account for 33% of the total fish processing and aquaculture industry (in revenue); nevertheless it represents leas than 0.5% of the GDP and of the Portuguese exports.

In the recent years, production has hyper-specialised in sardine and tuna-fish species (see Figure 1), with a sardine prevalence. As it is typical for industries at a maturity / decline stage, the increase of the miniium efficient scale brought **about** a reduction in the number of the production plants, which are, these days, no more than 40 (which means a 60% reduction over a period of 20 years). A consequence of this was an increased concentration in geographical and production terms and a stabilisation of the companies' ranking. The horizontal concentration levels in 1998, measured by the C_4 concentration ratio and taking corporate groups into account, were **very high: 0.57** for sardine, 0.78 for tuna, 0.64 for chub mackerel and 1 .O for anchovies.
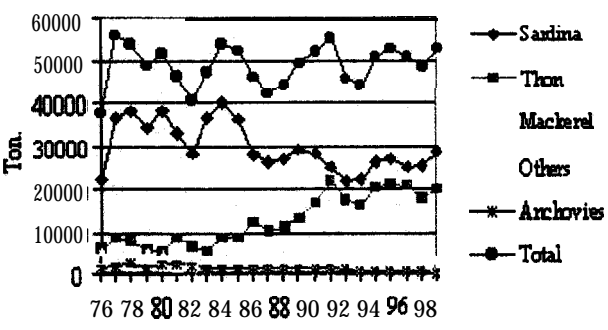

Figure 1. Portuguese Canned Fish Production
Source: DGPA ▪ Portugal

During the last five years, Portugal registered an annual production of 25 K.Ton. of canned sardines (made of *Sardina Pilchardus*, as required by CEE **Reg.2136/89**) of which 55% up to 70% have been exported. A small number of European countries, namely the United Kingdom, France and Germany, is currently absorbing more than 70% of those exports, while in 1988 it absorbed no more than 44%. The vulnerability caused by this market **hyper-specialisation** is aggravated by the fact that, as a rule, the sales take place under the importer's brand name or under a brand name appointed by him On the contrary, on **the** domestic market, well-established brand-names are still property of the producing companies and hold a large market-share. Increasing difficulties for the producer to assert his brand name will occur due to the increasing concentration in food distribution and the reinforcement of private brands, which are present in several ways in retail shops and have adopted transnational logistical platforms.

The Portuguese canned fish industry absorbs approximately 50% of the landings, since frozen sardine imports are of no relevance.

The **average** prices for sardine's first sale in the domestic market have steadily increased since 1986, owing to a conjunction of three kinds of factors: (1) **the** role played by the PO in the market regulation, resorting to COM (Common Market Organisation) mechanisms; (2) the increasing exports of frozen sardine; (3) the pressure of the demand for **fresh** fish consumption — the Portuguese accounting for the largest fish and seafood consumption per head in the EU.

The "**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). In addition to this picture, 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.

To summarise, one can say that in the case of canned **sardine** industry there are differentiation factors associated with the origin but, in what concerns tuna canning, price is one of the main differentiating elements as, for the most part, it uses frozen **fish** (with the exception of canning done in Azores, which uses fresh tuna) and its production can be **transferred** to any place. The costs of thii Portuguese production, if one ignores economies of scope obtained with sardine's production, are higher than those elsewhere, for instance in Ghana and Thailand, even taking into account the transport costs.

4. DYNAMIC *MODELLING* OF INDUSTRY

4.1 Model Assumptions and Coefficients Calculations

The disparities in the way the different sources **organised** the information about Portuguese fisheries and canning industry, made necessary a data harmoniition which was validated by industry experts. The main assumptions incorporated in the model are the following:

- Industry is exclusively supplied by fish landed in the Portuguese harbours; since the importations are very small.

- Sardine purchases are made either at the auction wholesale markets — in competition with the wholesale suppliers of the fresh **fish** consumer market — or by pre-agreements with the PO, **wich** we admit that cannot exceed 40% of the total sardine landings.

- Rejections and withdrawals wereestimated as 6% of the landings, which is the average for the period 1995-97.

- 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 **(Filipe,** 1999) [1].

- It was assumed that the demand-price elasticity **coefficients**[2] in each quarter, which have been

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[1] The **regression** and ail of its **coefficients** arc **significant (sign** F= 0.0000, sign T<0.05) and has **an** adjusted R^2 = 0.44769. **Colinearity** among the **independent variables was not found.**

[2] 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: $P / P_0 = (Q / Q_0)^{1/\varepsilon}$. Po end Q_0 am **parameters** defined for **each** quarter: Po, **85.4, 82.3, 96.5** and 73.4; Q_0, **1150, 2480, 45** 16 and 3527.

calculated for the supply of the fresh fish market, remained valid in all the scenarios analysed. The values obtained for the four quarters are respectively -0.965, -0.929, -0.634, 1.061 (Dias et *al.,* 1999).

- Stability in the fish catching pattern was assumed. The seasonal indexes for the four yearly quarters are respectively 0.13 1, 0.208, 0.367, 0.294 (Dias et *al., 1998b).*

- It was assumed that the canned fish was immediately sold, with a sales price identical to the 1997 one.

- The total installed production capacity was estimated in 37.7 K.Ton., 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 not viable (even when the plant has a multiproduct capability).

- 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 the production, stabilised by the chilling and freezing methods, uses up to 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-m-process reaches this maximum, the industry suspends its purchases for a while.

- 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 importance of the production lines dedicated to the sardine production, the structure of costs, and the evolution of productivity and rentability levels since 1992. 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 from several sources (official account documents, audit reports, interviews of the managers and experts opinions). 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. Those price levels were evaluated by experts. 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 feedback on the fishing activity due to the alterations in industry demand — which may be of relevance at certain wholesale fish markets — was not taken into account.

4.2 The model

The model consists 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.

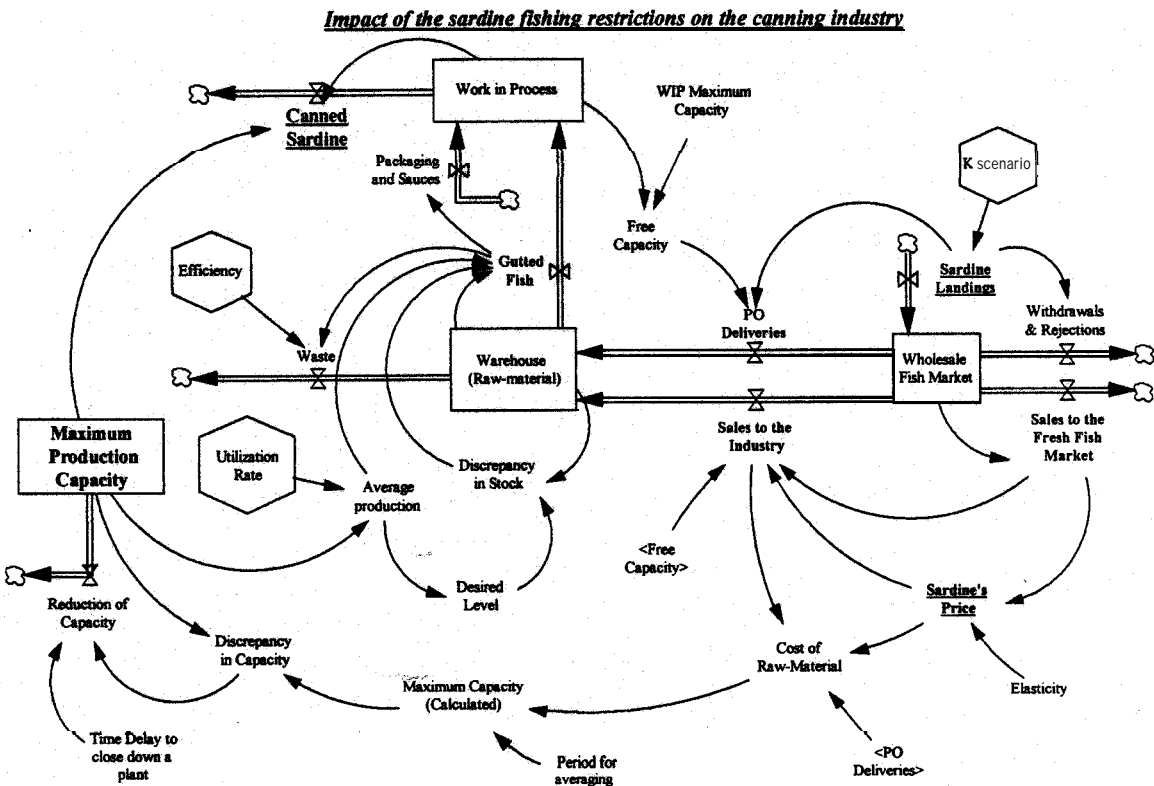A simplified stock and **flow** diagram of the integrated model is shown in Figure 2.

Figure 2. Stocks and flows diagram

4.3 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 lcmd of model; the price deviation in the third quarter of 19% is due to anomalous prices registered at some places.
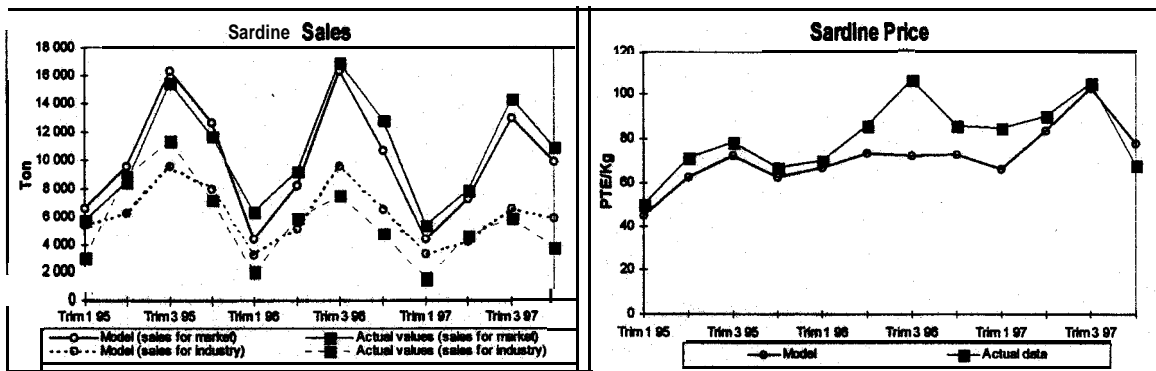

Figure 3 • Model validation

5. SCENARIOS

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

1. The **optimistic scenario.** A reference scenario that corresponds to the 1997 situation. Annual sardine landings in Spain and Portugal keep oscillating around the 100 **K.Ton.,** on the assumption of unlimited total catches.

2. The **pessimistic scenario.** A scenario corresponding to a strong reduction of the stock level, thus creating the conditions for the adoption of precautionary measures. Working witth a TAC of **67K.Ton.** (level advanced by the **Comission** in **28/May/1996)** and a quota of 62% for Portugal (in accordance with the country proportion in the period 1940-1994) we obtain a quota of 41.5 **K.Ton.,** 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. In this case we admitted that the total annual supply will reach 61 **K.Ton.,** corresponding to a reduction of approx. 25% on the 1997 figures.

6. 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.
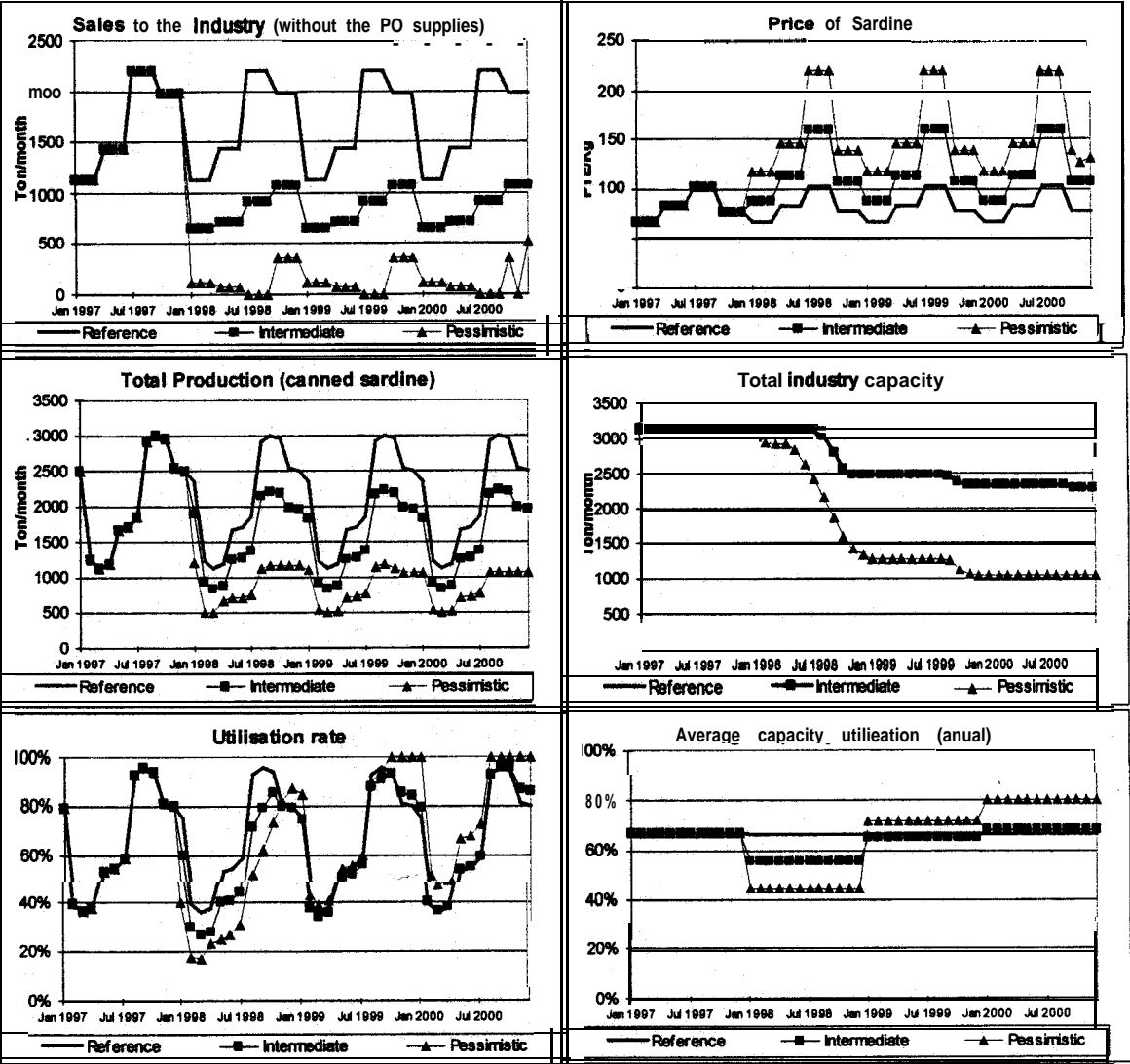

Figure 4: Evolution of the main variables in the simulation period and in the three scenarios.

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	12660
2000	37 692	27 360	12660

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 lii 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 conchsions 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 remainii 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 69% 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.

7. CONCLUSION

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 demandii method in what regards market and operation indicators — as it is the **case** of the elasticity coefficients. Appropriate modellmg 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.

As a closing remark, it must be noticed that the "1997-1999 Sardine Plan" that was implemented resulted

from a negotiation with the POs, and its provisions were significantly less drastic than the initial proposals.

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