Flatfish 2.0a: a spatial bioeconomic simulation model for plaice and sole

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Abstract: This article will discuss a spatial bioeconomic simulation model for flatfish and the Dutch beam trawl sector in particular. It will focus on the economic part of the model and will describe the ideas and assumptions behind the model. Two examples how the model can be used are presented. Some remarks on how this model should be used and some of its limitations are specified.

Introduction

In 1992 the National Institute for Marine and Coastal Management (RIKZ) asked the Institute for Fishery Research (RIVO-DLO) and the Agricultural Economics Research Institute (LEI-DLO) to develop a bioeconomic model for the Dutch fishery. The RIKZ wanted to use this simulation model as a tool for taking decisions in order to reach their objectives as specified in the "Water Systeem Verkenning", which is aimed at sustainable use and improvement of our (aqua) living environment.

After the first meeting it was decided that the construction for the entire North Sea fishery was neither possible because of the lack of data, nor relevant as many fisheries are of little importance to the Netherlands. Therefore it was decided to elaborate first the (beam trawl) flatfish fishery, this being a major fishery (almost 80% of the Dutch fleet).

It was decided to focus the attention on plaice and sole, because these are the (economically) most important species and there is also a lot of biological data available for those species. It was also decided that other parties were invited to discuss the construction and the progress of the model:

- The Ministry of Agriculture, Nature Management, and Fishery
- The producers organisation for fish and fish products (PVV)
- The Netherlands Institute for Sea Research (NIOZ)
- The North Sea directorate of the Ministry of Transport and Public Works

There are two good reasons to collaborate. First, the model and the discussion about it can be used to get a better insight in how biological and economic aspects are related to each other. Secondly, the model can be used by all parties as a decision support tool to take decisions and select tools to reach certain specified objects.

A timetable for the construction of the model was set and all parties had hope that at the end of 1994 their could be a useful bioeconomic simulation model. At the end of 1994 we had the first version of the model (FLATFISH 1.0). However, many improvements were made after the first introduction. At the end of March 1995 there was a workshop on the flatfish model and all parties were present. There the final version of the model was presented: FLATFISH 2.0a. The first policy questions were fed to the model and the first results were discussed.

Dimensions of the model

Before we discuss the economic part of the model in more detail we will begin by specifying the dimensions of the relevant variables.

Time — The biologic model uses differential equations and the Euler procedure to calculate the next time step. The economic model will simulate with one week as a time step. It was decided to take a week as we noticed that beam trawling is done (at least in the Netherlands) on a weekly basis. This means vessels leave on monday and often come back on Thursday/Friday. For prices we use a monthly model and for costs component a yearly one.

Space — We will use ICES-rectangles as the smallest spatial unit. See Figure 1 for a graphical map of the North Sea that is used for flatfish fishery. Note that the spatial dimension is of great importance in the model. The spatial element makes it possible to simulate: behaviour of fishermen, migration of fish, and the consequences of policy to fishery and fish.

Economic — We wanted to take a vessel as the smallest economic unit. However, we discovered that it is better to work with horsepower groups (the model will distinguish 6 HP-groups, see Table 1). The model will be about Dutch beam trawlers but the fishing effort of the other EC countries is also estimated to generate a total EU fishing mortality.

Biologic — We specify six length cohorts for plaice and seven length cohorts for sole. These cohorts will be translated respectively into six and seven market size categories.

RIVO-DLO, with their expert knowledge about plaice developed the biological part of the model, simulating growth, mortality, migration and recruitment. The model for sole is not as detailed as the one for plaice. LEI-DLO developed the economic part of the model. It was decided that the economic model would generate each week for each ICES rectangle and each HP-group the fishing effort. Also every week the effort of the other EU countries is read from a table. The biological model will use this weekly effort and generate a weekly catch (and bycatch etc.). The catches are then used in the economic-model to generate prices, costs and revenues (see also Salz 1993, 1994).

Table 1. The six horsepower groups

Group	Engine (HP)
1	1-260
2	261-300
3	301-1100
4	1101-1500
5	1501-2000
6	2001+

Economic model

The bioeconomic model we propose is very similar to the one used by Philip Rodgers (1992). The diagram that Rodgers uses can be straightforwardly applied to our model and is therefore presented in Figure 2.

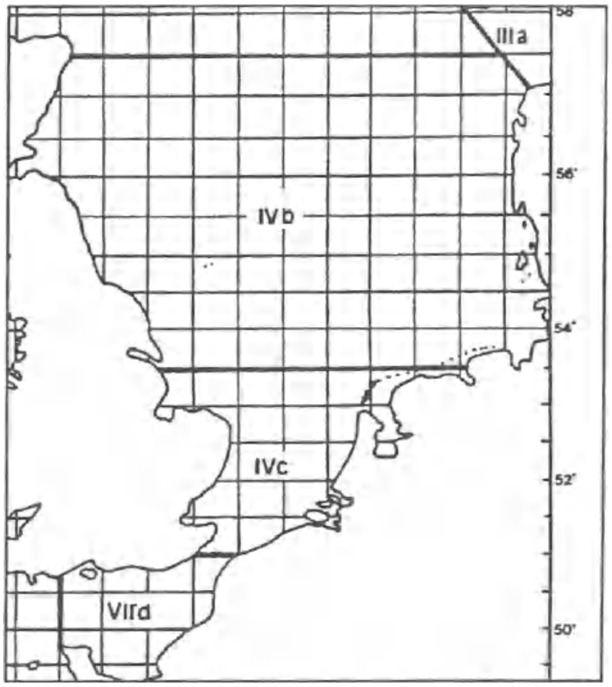

Figure 1. ICES-rectangles in the North Sea used for beamtrawl

Using monthly data on landings and prices we estimated the four common categories on plaice and the five on sole. For plaice we used monthly data from January 1981 until December 1989 to estimate the price per category and then used the data from January 1990 until May 1993 to check the performance of the estimators (see Dol, 1993). It turns out that there are two demand markets for plaice. The first one is the fresh market that mostly wants to buy plaice 1 and plaice 2. The second one is the filleting industry, mostly buying the small plaice (3 and 4). The fresh market is willing to pay a higher price for the product. The filleting industry, however, is looking at the world market for white fish and therefore for alternatives when the price is too high. Taking this into account the correlation coefficients of the estimators for plaice 1 and 2 (.847, .795) are higher than those of plaice 3 and 4 (.729, and .666). The most important explanatory variable is the price one month ago (explained by the theory of Partial Adjustment). In general the price of plaice 1 will be the highest and that of plaice 4 the lowest. There will be some substitution between the market categories depending on price and quantities landed. For the larger plaice also the quality of the meat is important (during spawning season the quality of the meat is poor and the price therefore lower). There is also a seasonal pattern in the price with one important event: in July the filleting industry closes down for a holiday, resulting in an extreme low demand for plaice.

For the price of sole we used monthly data from January 1989 until December 1994. Sole is a product that is sold to the fresh market and therefore; as with Plaice 1 and 2; has estimators with a high correlation coefficient (between .786 and .865). Explanatory variables are the quantities landed, the price one month ago, and a seasonal effect (before June the price is lower than after June).

At the LEI-DLO every year a stratified sample (panel) of approximately 25% is taken from the whole beam trawl fleet. For these vessels detailed economic variables on costs and earnings are collected. At the LEI-DLO we distinguish up to 24 different types of costs. For the simulation model we divided them into six categories (see also Dol 1994c):

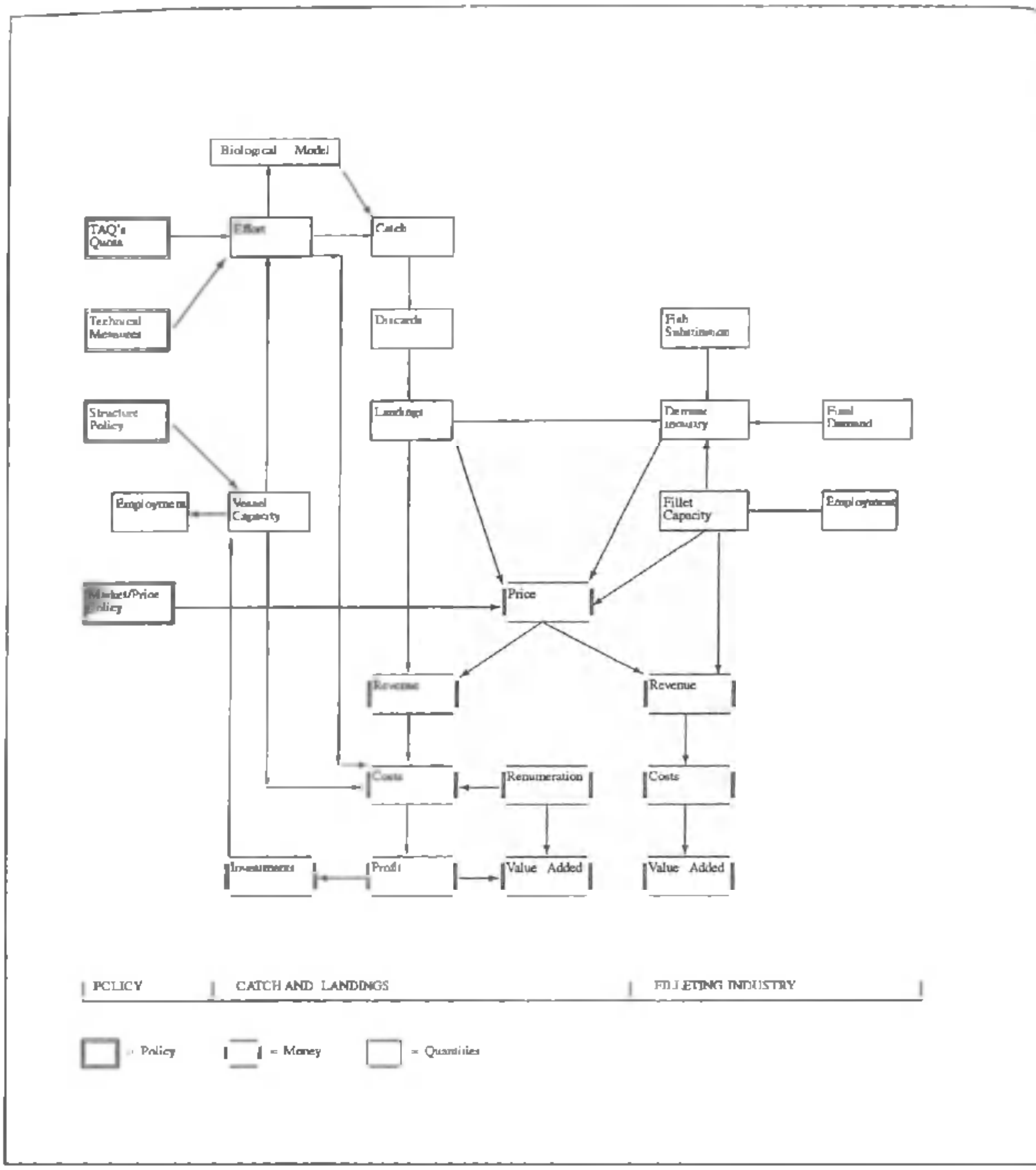

Figure 2. Structure of the bioeconomic model

1. Fuel costs
2. Costs depending on effort (excluding fuel)
3. Crew share
4. Costs depending on landings (excluding crew share)
5. Depreciation and interest costs
6. Other costs

Using the LEI-DLO data from 1990 and 1991 we got estimates of the costs categories for every vessel per year. Correlation coefficients were high (between .796 and .975), indicating useful estimators for costs. Also we estimated the employment on the vessels (correlation coefficient .856).

We did not specify any investment function yet. The main reason is that investment decisions are too complex and that we have too little data to make a reliable investment model. The economic model, however, permits the user to modify the fleet by hand (size, age vessels, age motors).

The last thing that has to be done for the economic model is to calculate/predict the effort that is spent every week, ie. to predict the behaviour of fishermen. We do not need a detailed model explaining why an individual fisherman will go fishing in a certain week or where he will go. We need to find the key variables that determine the effort per HP-group and within the simulation model it should be possible to change those key variables. We constructed a model for the effort by looking at the VIRIS database (Fish Information and Registration System) from the Ministry of Agriculture, Nature Management and Fishery. This database is set up as a result of European Union legislation and its primary task is the administration of catches and the control of TAC's. In the EU every fishing vessel has to fill in a logbook, containing all sorts of technical variables, but also the amount of fish landed (where subject to a TAC). The ICES-rectangles where the fish is caught are specified and sometimes other variables (like by-catch, amount of tracks, total hours fishing etc.). VIRIS, however, is not easily accessible and also contains all kinds of errors. Because it is the only database available that can give catches on a rectangle basis we spent a lot of time converting VIRIS into our own ASCII database (FISHBASE).

We started to look at the fraction of the capacity per HP-group that is used every week for flatfish fishing. First we calculated for every week and every horsepower-group the mean number of hours spent that week on the flatfish fishery. Knowing that the maximum number of fishing hours in one week is 168 hours we calculated a weekly capacity level for every horsepower-group (ie. the average hours divided by 168). These capacity levels differ not only within a year but also between HP-groups. We divided the fleet in six HP-groups and as an example we present the results for the 1-260 HP-group in Figure 3 and the 2000+ HP-group in Figure 4. From Figures 3 and 4 we see that the small vessels have quite a different pattern compared to the large vessels. This is mainly because the small vessels also fish for shrimps and the large vessels 'only' fish for flatfish. There is a decrease in fishing activity near the end of the year. The holidays and other festivities induce an enormous decrease in the capacity level (eg. around week 29 every year). The difference between years is small (in spite of the changing number of vessels and technical improvement). This leads us to the conclusion that the capacity level can be used in combination with the number of vessels to predict the number of hours a HP-group will spend fishing every week.

Having the amount of fishing effort for every week, we now need to specify the distribution of the effort over all the ICES rectangles. By looking at the FISHBASE database we draw the conclusion that fishermen tend to have a yearly pattern, ie. they go to the same fishing ground this week as they did exactly one year ago. Using this result we decided to use the relative monthly effort distribution of the HP-group of last year as the distribution of the effort for the model. The advantage of this approach for the effort distribution is that it becomes possible to simulate eg. closed seasons, closed areas, days-at-sea regulations etc.

The bioeconomic model (we called FLATFISH) was written in Fortran on a MS-Dos PC and contains over 15.000 lines of code (the compiled program is more than 2 MBytes). Also a lot of data files are read and a lot of economic and biologic parameters can be set (eg. the growth rate of fish and the rate of technical improvement). If one wants to do a simulation (eg. calculate the consequences of certain policy decisions) one has to change certain parameters and tables. This means a lot of bookkeeping and is certainly not a simple task. To help people a user friendly shell (called BELEID) has been written. With this program most of questions are easily translated in changed parameters and data tables.

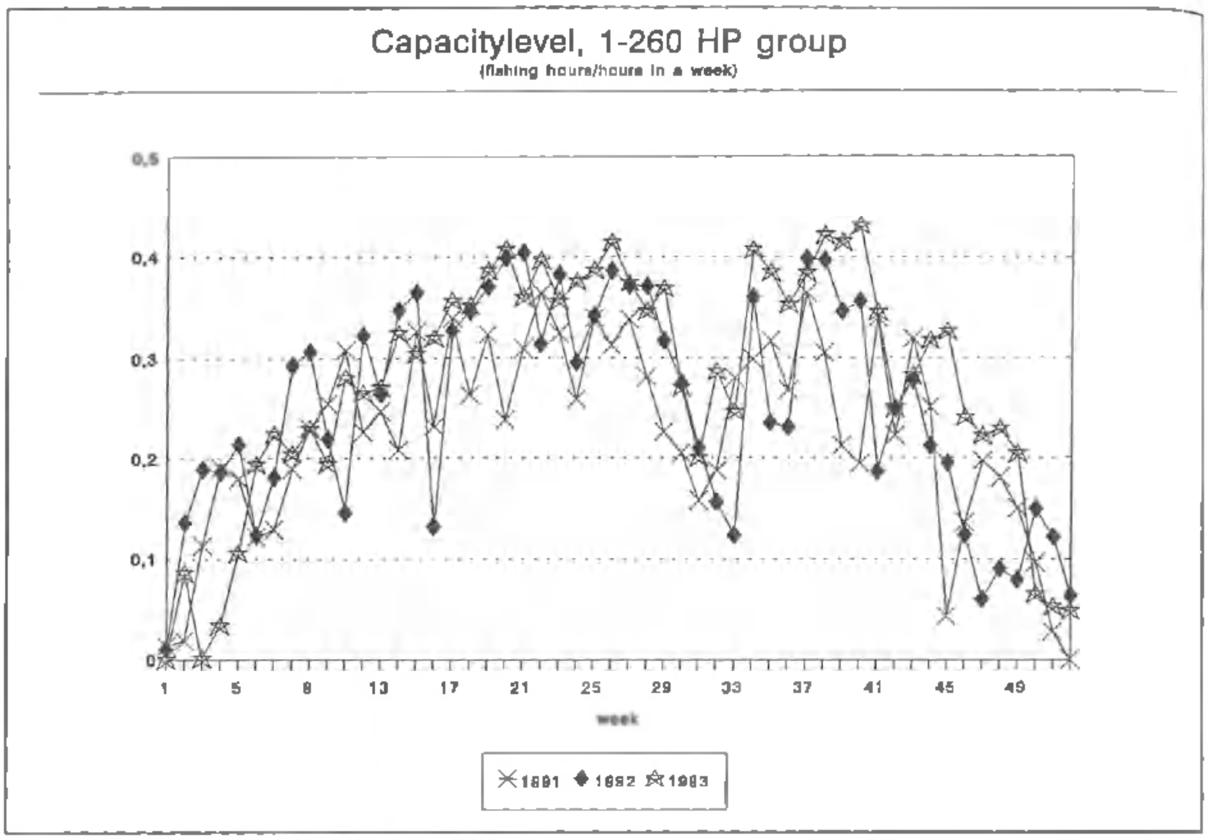

Figure 3. Fraction of the 1-260 HP group capacity that is used every week for beamtrawling

Some examples

This section will briefly discuss some examples of questions that can be answered by the FLAT-FISH model. The shell BELEID has been developed with the idea that running the model is easy. However, before running the model we should have a clear vision what parameters and tables are necessary to run the simulation. We strongly advise that a team of biologist, economists, and policy makers discuss what they want, discuss the assumptions that have to be made, then translate it into the model, run the simulation (and perhaps many others) and spend time comprehending all the output.

After this a discussion should take place as to whether the outcome of the model is usable. This means that the model itself is only a tool that lets biologist, economists, and policy makers discuss and solve problems.

The shell BELEID has a lot of possibilities to simulate the interaction between biology, (socio-)economy, and policy decisions, eg.

- TACs and Quotas
- Closed areas/seasons
- Net size, technical adjustments etc.
- Technical improvement
- Adjustment of the fleet
- Days-at-sea
- Prices
- Fuel prices

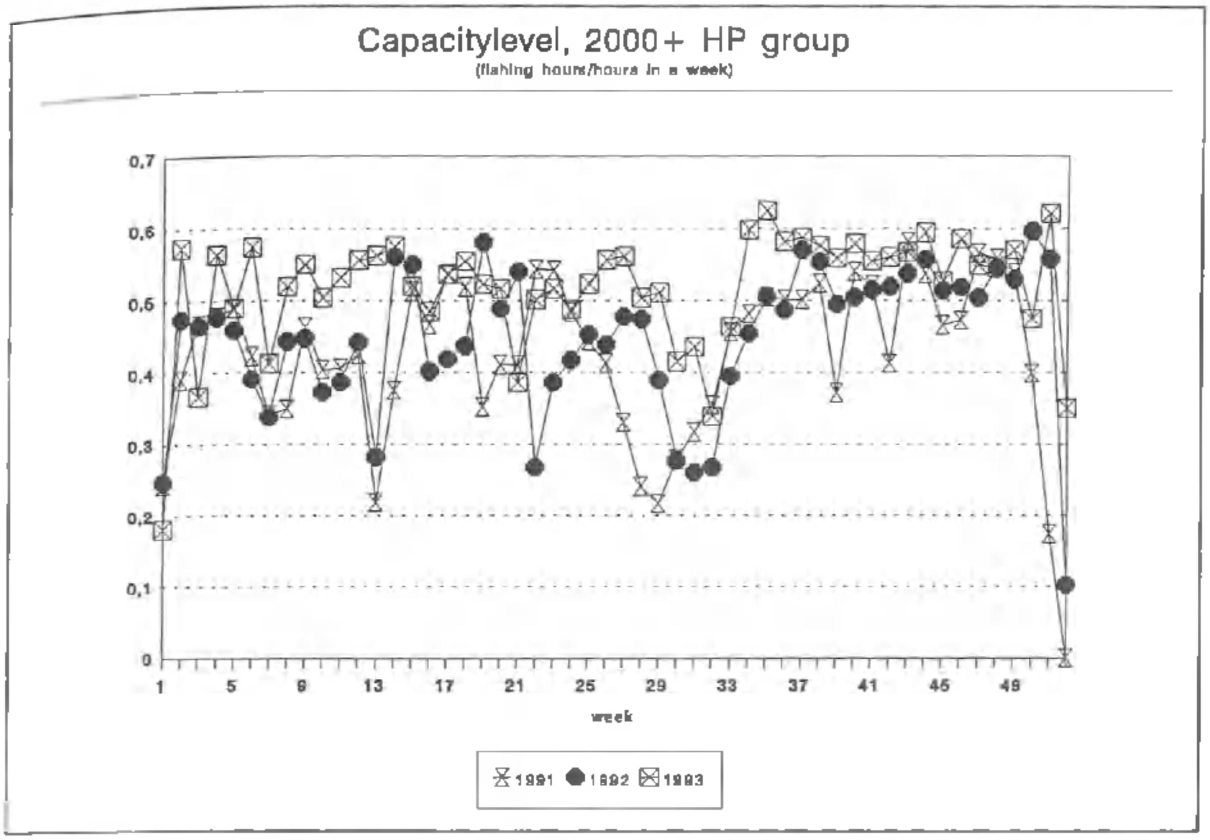

Figure 4. Fraction of the 2000+ HP group capacity that is used every week for beamtrawling

- Recruitment
- Growth

As examples of the possibilities of the FLATFISH model we will present some results of two simulation studies. One should however not forget that only part of the simulation results are shown and that one needs to have a close look at all the output before one wants to draw conclusions.

Some results of the first simulation study are presented in Figures 5, 6, and 7. Here we show the effect of the Plaice Box. The first simulation is our default run, ie. use the 1991 situation and continue to simulate for 10 years. In the years 1994 until 2000 we will use a fixed and constant number of recruitment (800.000 for Plaice and 100.000 for Sole). For the years 1991, 1992, and 1993 we use the recruitment as specified by ICES. In 1991 there was a Plaice Box in the second and third quarter but biologists state that the Box was not effective because most vessels were fishing on the edge of the Box. This means that the 1991 default run can be seen as a situation with *no* Box. In the other run we have closed the Plaice Box the whole year for every vessel. We here assume that the effort (per week and per HP-group) in the Plaice Box is homogeneous redistributed over the other ICES rectangles where the HP-group would fish that week. From the Figures we see that the spawning stock as well as the catches/revenue is much higher in a Plaice Box situation. Of course with higher catches the prices when the Plaice Box is closed are lower as with the 1991 default run.

In the second simulation study we give some results when reducing the effort or when decommissioning the fleet. Here we investigate 6 simulation runs:

- the 1991 default run
- reducing the effort every week by 25%
- reducing the effort every week by 50%
- using a Plaice Box as in 1995, ie. close the Box the whole year for vessels larger than 300 HP.
- a Plaice Box as in 1995 and also decommission the oldest 25% of the fleet in every HP-group.
- effort reduction, ie. reduce the engine power from larger than 2000 HP to 2000 HP

Some results of the second example are shown in the Figures 8, 9, and 10. One conclusion that could be drawn is that the reduction of the effort by 25% has almost no negative effect in the long run (there are considerable losses the first years). Also we can see that a Plaice Box has a much more (positive) effect than whatever effort reduction or decommissioning we tried.

Conclusions and remarks

Building a bioeconomic model for flatfish, RIVO-DLO (biologists) and LEI-DLO (economists) had the great opportunity to work together and benefit from each other. We now have a better insight in the interactions between biology, economy and policy and a wish to continue collaboration in the future.

We also had to update, rearrange and find data for our model. This data is useful to us in many other projects. Due to this project LEI-DLO has a data set of the Dutch logbooks (1990-1994) that is easily accessible by using the program FISHBASE and can answer a lot of questions within a few minutes. Also we have our own Fishery Database system LEI-DLO (VDL) containing costs and earnings of the LEI-DLO panel since 1986.

The simulation model is capable of simulating almost everything. One, however, should not forget that a simulation model is a simplification of the real world and that one should be cautious in drawing conclusions. One should never forget to clearly state all the assumption that have been made for a simulation run.

The model should be a useful tool that will bring together biologists, economists, and policy makers and let them discuss problems and possible solutions to the problems that confront the fishery. This model can be seen as a first step and needs to be regularly updated to have the latest information available to give the best possible outcomes for simulation runs.

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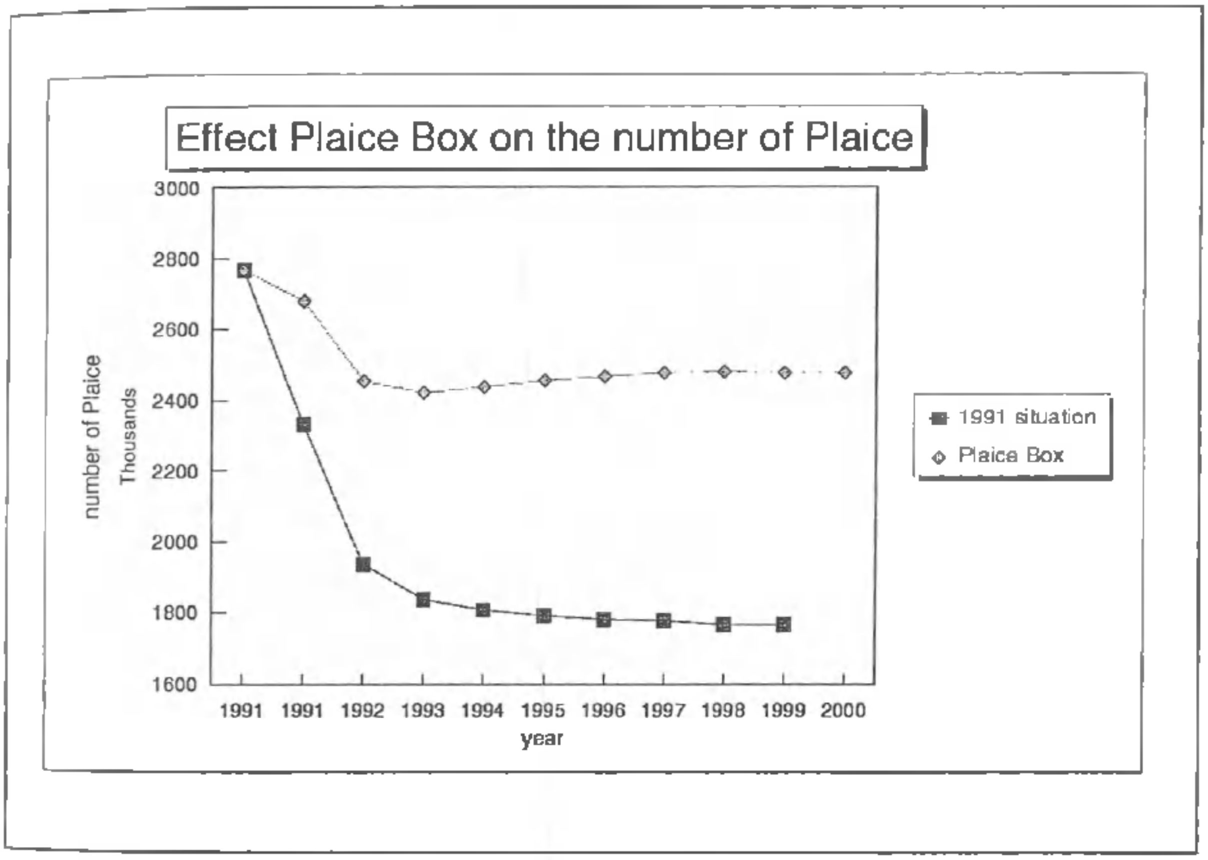

Figure 5. Number of Plaice

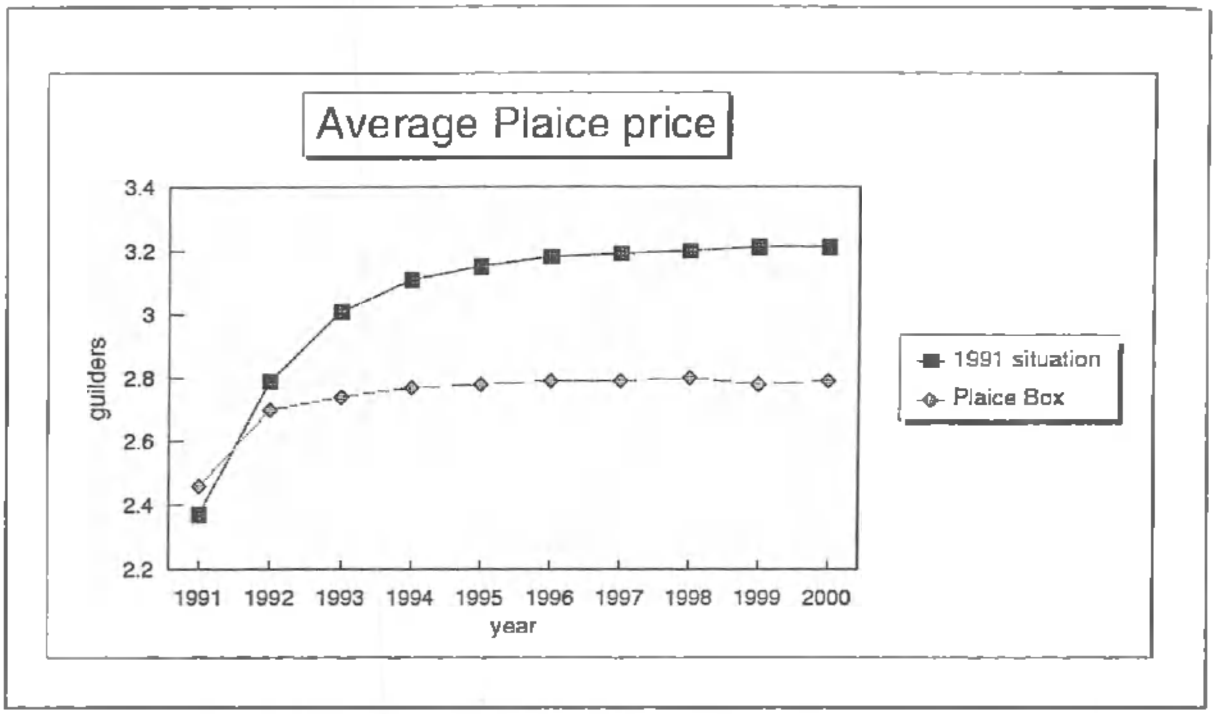

Figure 6. Average Plaice price

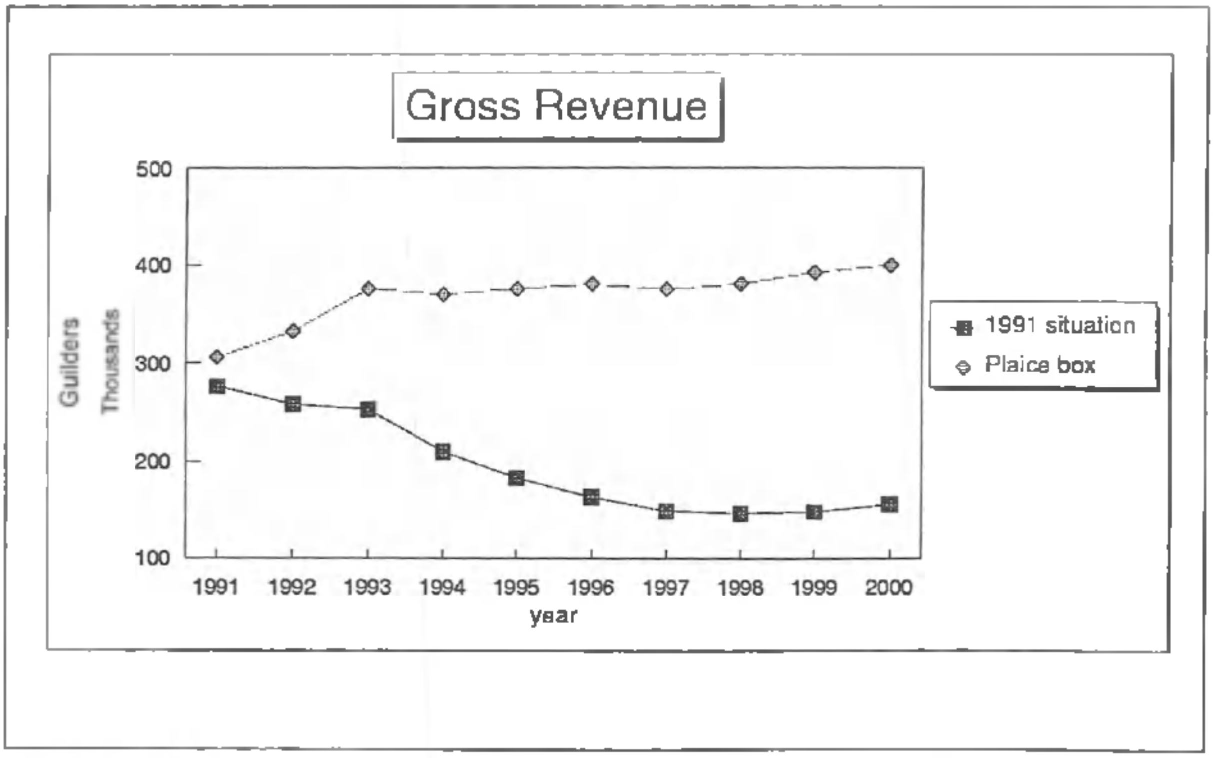

Figure 7. Gross Revenue

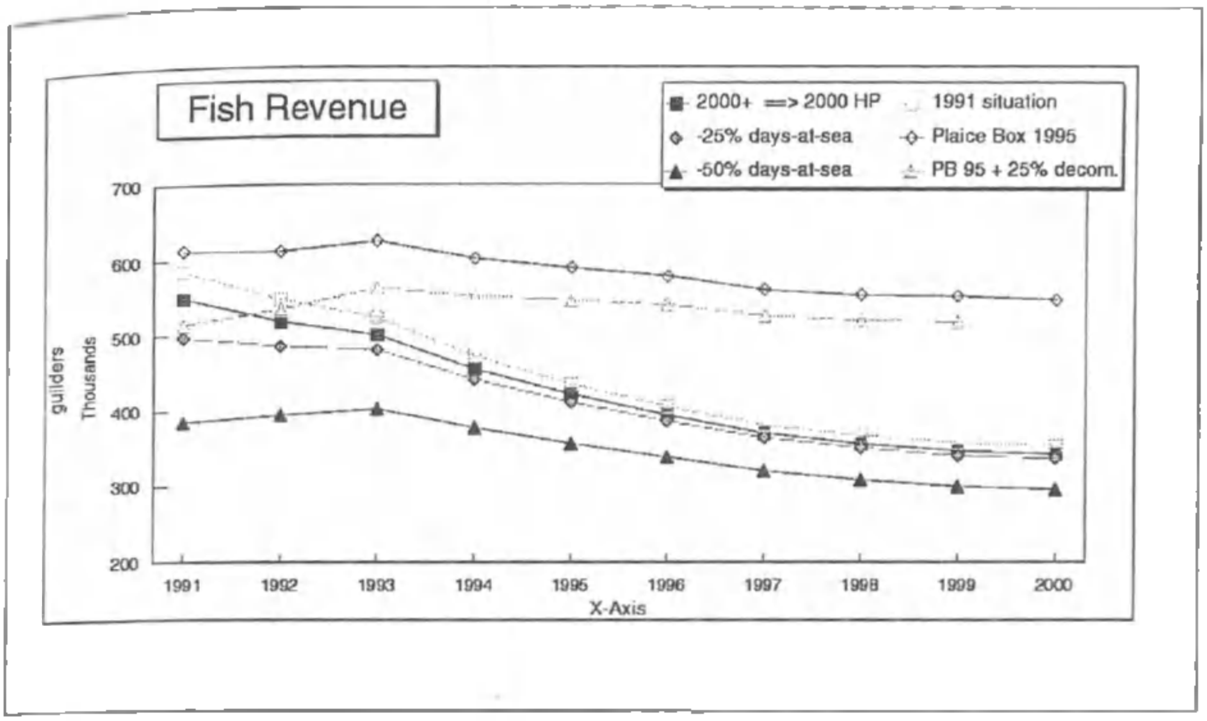

Figure 8. Fish revenue

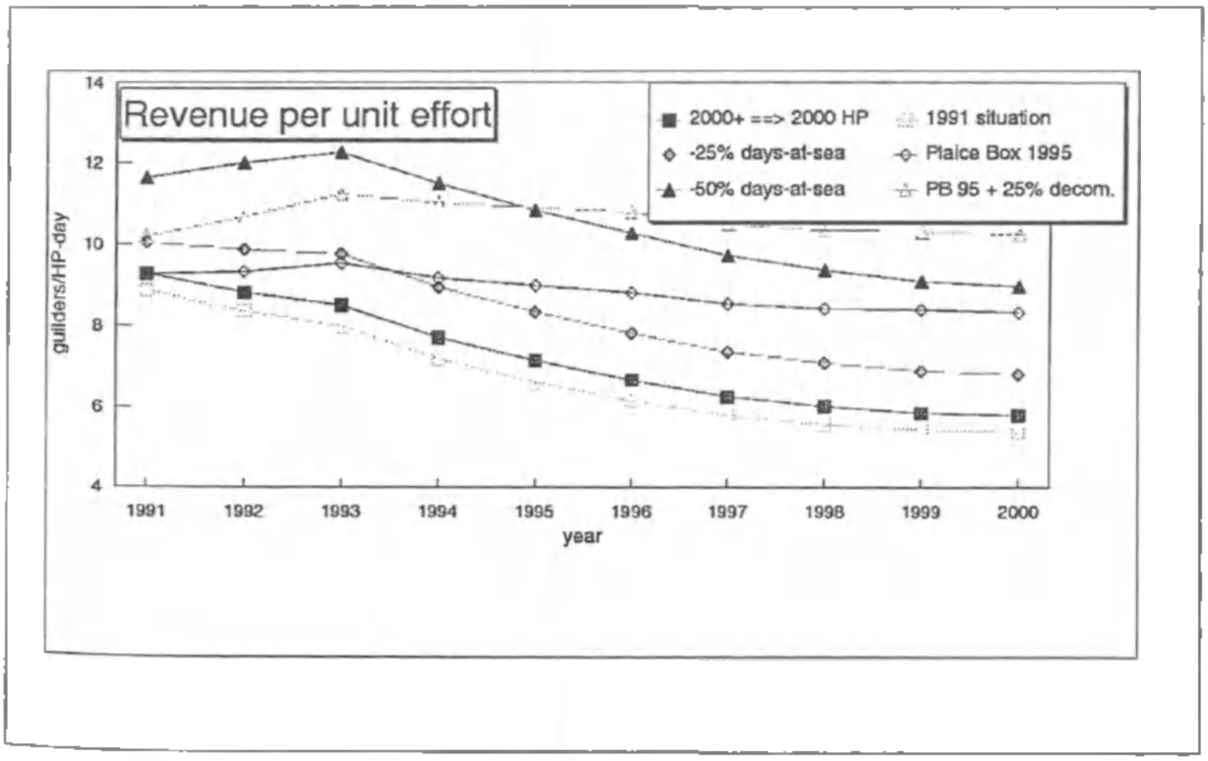

Figure 9. Revenue per unit of effort

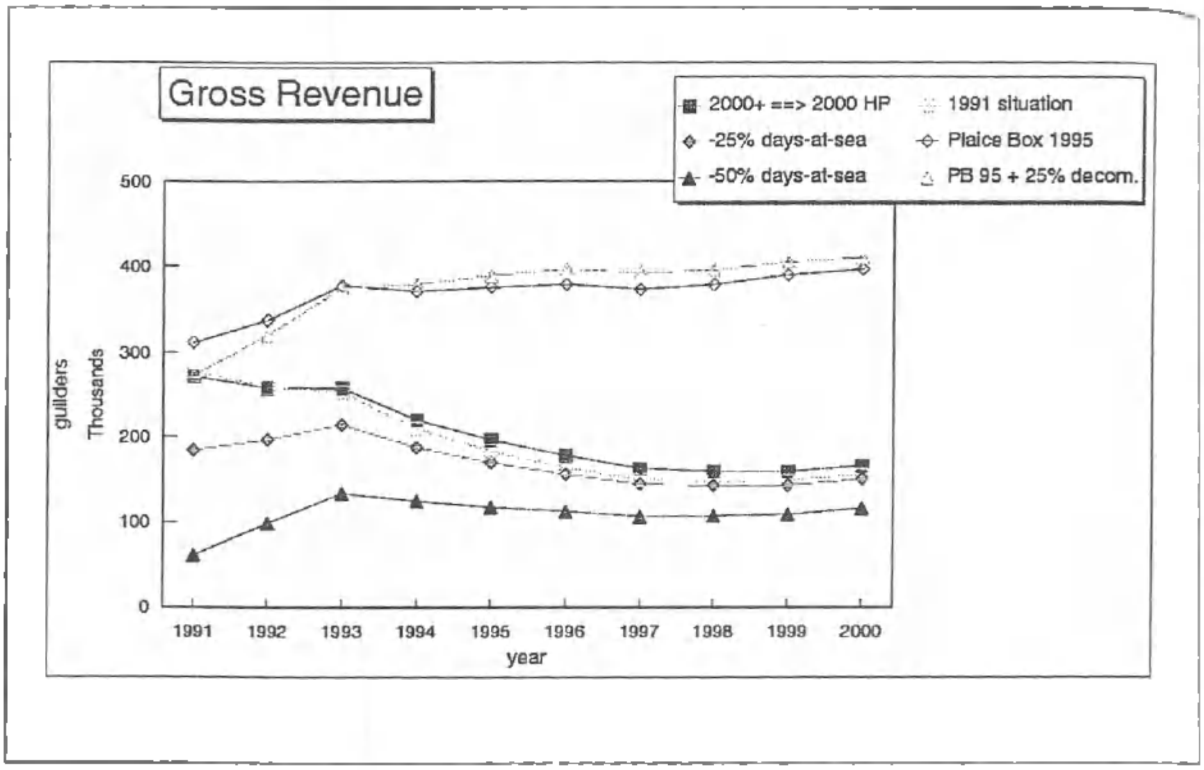

Figure 10. Gross Revenue