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System Dynamics in sea fisheries policy building

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Abstract

Due to the interaction of a changing uncertain environment and an overspecialization of the Belgian fishing fleet, the sustainability of the primary fishing sector is questioned. Therefore, a long-term strategy for the fleet structure in terms of vessel type and fishing method is required to cope with these problems.

The objective of this paper is to describe how system dynamics can be used to understand how policies can influence the decisions fishermen make. It will enable policy-makers to choose effective policies to alter the current fleet structure towards the predefined goals.

The methodology consists of four steps: setting the goals, building the model, discovering leverage points in the model to meet the predefined goals, and building a strategy upon these leverage points.

Key words: Fishermen's behavior, fleet dynamics, system dynamics, policy making

1. Introduction

The Belgian sea fishery industry lacks economical stability (company profits are decreasing) due to decreasing production and increasing costs. This is caused by a double overspecialisation of the fleet: 1) the target species (mainly sole and plaice) (Tessens and Velghe 2004, 19) and 2) the fishing method, beam trawling (over 90% of the fleet consists of beam trawlers, fuel intensive fishing method) (Tessens and Velghe 2004, 24). This increases the vulnerability of the fleet to fluctuations in quota (fish stocks) (Bjorndal and Conrad 1987) and in costs (fuel, steel, etc.).

In order to cope with this changing environment sea fishery researchers are investigating new or alternative sea fishing methods. The research is focused on passive fishing methods and gill nets have been chosen as a case study. These fishing methods have a quite different cost and revenue structure and are expected to be able to cope better with the particular circumstances encountered today and expected for the future.

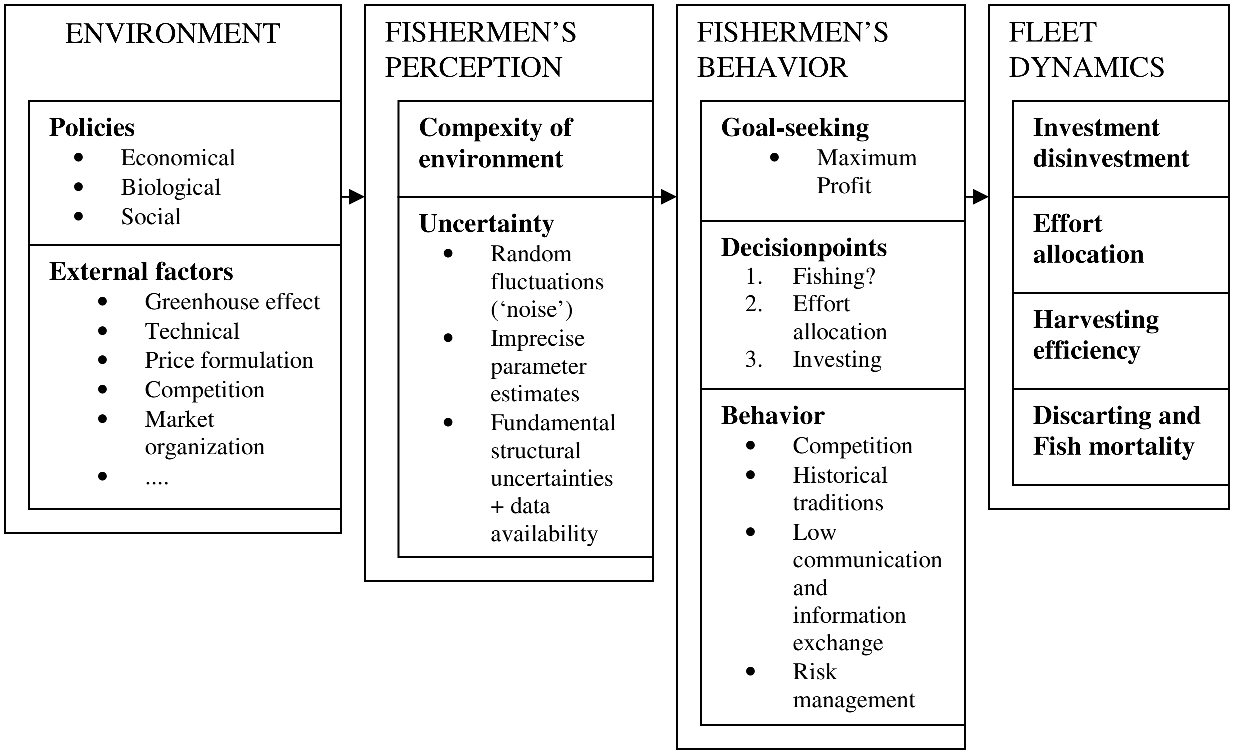
Therefore; it was decided to develop a long-term strategy for the Belgian sea fishery. The strategy is based on three parallel viewpoints: an economical, an ecological and a technical one. The main driving force is economical, and the framework where these three viewpoints integrate is legislation. This holistic approach is a reflection of the new emerging needs to manage sea fisheries (Anderson 1984; Anderson 1987; Dudley Richard 2003, 2).

2. Objectives and conceptual framework

The main objectives of the study are:

- To develop a dynamic decision-support model to create insight in parameters that can or will influence the fleet structure by influencing the decisions fishermen are making. Focusing on the behavior of individual boat owners will lead to the understanding of fishery dynamics (Helu, et al. 1999, 2)
- To develop and assess possible strategies for altering the Belgian fleet structure by using the developed decision-support model as an instrument.

The conceptual framework of the study is:



In the eighties, science started to look upon the fisheries management process holistically (Anderson 1984; Anderson 1987). This holistic approach is clearly visible in the definition of the main goal of fishery management by Helu et al. (1999). They define that goal as to ensure optimal utilization of fish resources, where optimal entails biological, economic, and social aspects (Helu, et al. 1999, 2). One of the first modelers who tried to incorporate the holistic approach in a model to predict the changes in the UK fleet structure was Shalliker (Shalliker 1987).

Since the undeniable changes in environment and climate are affecting the fisheries, there is a need for better understanding of the effects of climatic mechanisms (Dudley 2003, 3) and for taking ecosystem considerations into fisheries management.

This framework considers fleet dynamics through the behavior and decisions fishermen have to make in an uncertain and complex environment. Fishermen's perception of this complex (Healey and Hennessey 1998) and uncertain (Charles 1998; Cochrane 1999) environment leads to different kinds of decisions. In this framework uncertainty can be divided into three different types: random fluctuations, imprecise parameter estimates and fundamental structural uncertainties (Charles 1998, 38-39).

Articles dealing with fishermen`s behavior are less common in literature. The importance of vessel behavior was only recognized since the late 20th century (Gillis 2003). Bosetti and Tomberlin (2004) have developed and tested a dynamic optimization model of fishermen's investment behavior in a limited-entry fishery, since only a few studies have attempted to empirically model individual fishery investments. The profit of the fishery method depends on the threshold value for the investment. Helu et al. (1999) are sharing that thought. The fleet size grows and shrinks according to the profitability of the individual boats. They also stress the competition between fishermen. Gillis (2003) supplies the framework with three more behavioral aspects of fishermen: historical traditions, low communication and information exchange between fishermen and risk assessment.

This behavior brings us to the impact on the fleet structure. It is acknowledged (Helu, et al. 1999) that a better understanding of the behavior of individual boat owners leads to better modeling of fishery dynamics. Gillis (2003) refers in his work to Hilborn (1985) where he has identified the four main research areas on fleet dynamics: investment and disinvestment decisions, effort allocation, harvesting efficiency, discarding fish and fish mortality (Gillis 2003, 178).

3. Methodology

The methodology consists of four phases:

1. Setting the goals: What do we desire from the fleet structure?
2. A modeling phase: creating the decision-support model
3. Discovering leverage points in the model via sensitivity analysis
4. Reaching these goals by developing and assessing possible strategies/scenarios

a. Phase 1: Setting the goals

This study will look upon the underlying goals of the fishery from a bio-economical point of view. The reason for this bio-economical approach is that economical performance of the fishing fleet is strongly related to the biological conditions of the marine environment (especially stocks) (Anderson 1984; Anderson 1987; Helu, et al. 1999).

Still, the main focus in this bio-economical approach will be economical since this study looks upon quota as the only biological component. Quota equals the maximum amount of fish that can be caught in a sustainable way. Here a crucial point has been made.

The goals of the primary fishing industry are:

- To be profitable
- To employ a satisfying level of people
- To be biologically sustainable: Just fish the given quota, not more.

b. Phase 2: Modeling

The goal of this second phase is to create a dynamic model from a micro-economical point of view. It produce insight into the parameters that can or will influence the behavior and decisions of fishermen given the economical and biological objectives and constraints. Other boundary conditions that will be taken into account are technical and legal ones (policies).

The economical objectives of the model are:

- To be profitable
- To employ enough people

The economical constrain is that money can only be invested in the fleet. There is no possibility to invest in other industries.

The biological objectives of the model are:

- To be biologically sustainable
- If possible, include ecological impact of fishing methods by economical parameters in the model

Biological constrains:

- The whole biological dynamic (especially stocks dynamics) are reduced to given quotas for each fish species per fishing ground

Technical constrains:

- Only existing gears will be used in the model
- Technical issues will be incorporated in the model as reduced costs, enhancing rendability, or other economical variables

Other boundary conditions are:

- Number of target species included in the model
- Number of gear types included in the model
- Number of vesseltypes included in the model
- Number of fishing grounds included in the model
- Number of companies included in the model

c. Phase 3: Sensitivity analysis

Sensitivity analysis stands for the experimental phase in this research. Moxnes (2003) describes this phase as: "observing how behavior will change over time by varying model parameters (policies)" (Moxnes 2003, 3). The goal of sensitivity analysis lies in discovering leverage points in the dynamic model by which we can reach the earlier defined goals. Leverage points are those "most relevant hot spots" in the model that can be influenced in order to meet as efficient as possible the predefined goals.

Practically, the first step will consist of an examination of the most relevant parameters on which we will build our strategy. Once they are determined, a sensitivity analysis will be performed for each of these individual parameters. After evaluating these individual sensitivity analyses, a second phase in the experiment will start i.e. scenario building. The most goal-seeking parameters will be combined in different scenarios. These scenarios will be evaluated on the basis of how well they meet the predefined goals.

The output of this phase is thus to discover the best scenario(s) which influence the most the decisions of the fishermen towards the predefined goals and in a given time frame.

d. Phase 4: Policy-making and strategic planning

The last step in this methodology is to make the changes in leverage points, as described in the scenario(s), possible. The scenario(s) is only pointing out "what" (which parameters) has to change, not "how" these changes can be made. The main goal of this last phase is thus to translate the scenario(s) into possible strategies/policies.

A four step method is used in this phase.

1. Evaluation and learning from the current existing policies in Belgian sea fishery
    - Are the most relevant leverage points being used?
    - Can the desired goals ever be reached?
2. Suggesting and assessing new policies/strategies (thinking out of the box).
3. Evaluate the current policies versus the recommended policies.
4. Looking for possibilities to convert the current existing policies into the suggested policies.

To make this all work out, each policy will by accompanied with:

1. A feasibility assessment
2. Critical success parameters
3. Advantages and disadvantages
4. Tools assessment
5. An impact analysis

4. Towards the model

a. The scope of the model

Modeling the Belgian sea fishery as an open system is not possible due to its complexity, therefore: boundaries, constrains and simplifications are needed to construct a well defined framework (Hjorth and Bagheri 2006, 79)

The first important constraint is that we only take the primary fishing industry into account. This includes only the shipping companies and its vessels. Each company can own vessels of all the vessel types included in the model.

This brings up the second constraint: there are only vessel types included in this model that can be used in the Belgian context. These vessel types are defined by only two parameters: 1) the size (or engine power) of the vessel and 2) the fishing gear used (by which the latter can change over time on the same vessel). The number of fishing gears will also be limited.

The third constraint is that there will be only a limited number of fish species taken into account in the model (which represent the main target species in commercial fishing in Belgium). Other fish caught will be looked upon as non-commercial by-catch and will be left out of this study (assumed that they are thrown back into the water).

The fourth constraint lays in the reduced amount of fishing grounds taken into account in the model. Because it's impossible to include all of the fishing grounds relevant in the Belgian context, this study has chosen to aggregate and limit them.

This study will not consider aquaculture. Each shipping company only invests his savings into the fleet. They do not consider the option of investing money in other industries.

b. The basis of the dynamic model

The current model takes the perspective of a shipping company and the decisions that have to be made every day given the internal and external conditions. The focus of the current model lays on an investment-loop situation. This loop is by nature a reinforcing loop, namely: the more a company earns, the more it can invest, the more it can earn again. This is a loop that needs to be balanced in time. In sea fisheries the three most important components, that are able to balance this investment loop, are the cost components, the biological components (quota) and legislation (for instance: maximum allowable ships).

The current model is written with a time interval (dt) of one day. Each day, the model recalculates this output. The model 'starts' with a decision (decision point) a shipping company has to make. Is it possible and smart to send my ships out to fish? This decision will depend on various parameters, for instance: Is there still quota left?, Can I technically go fishing?, Etc. If all the answers to these questions are 'yes' for a vessel then that vessel can (it is possible to) ship off. If one of them is 'no', then the vessel stays in the port.

If the vessel has a possibility to sail, then it has to decide which gear it will and can use and where it will and can go. Here the study has to provide a dynamic table in which the skipper can search each day where the best fishing ground lays (depends on the quota per target species for each fishing ground) and which gear he has to use to be the most efficient. The fisherman is thus looking to maximize his earnings each trip he makes. If the maximal earnings are still not sufficient to meet the estimated costs, he will decide to stay in the port.

If the skipper has decided that the trip will be profitable, then he sails to the chosen fishing ground with the chosen gear. By starting this trip, variable costs and revenues (the latter is due to catches) will start running.

These trips with the catches will influence the quota per fish species per fishing ground. These quotas will decline during the simulation of a year. After each year, the model shoots new fresh quotas per fishing ground in to the model (pulse function). These combined dynamics will influence the productivity of a vessel. During the year, less quota will lead to new decisions in the use of different gears and choosing between fishing ground. The latter can be related with higher costs for each fish caught. These decisions will change again if the new quotas are shot into the system.

This above described process will lead to profit or losses for each vessel company. The latter will then have an effect on the saving accounts of the companies and the possibility to invest. If losses are very frequent, the company can also sell a vessel in combination with its license (there will be no possibility in this model for demolition of vessel and license).

Now a critical point in the model is reached, when does a shipping company invest and in what (replacement investments, making a vessel more dynamical or investing in a new vessel and if so: in which type of vessel)? This is again an important decision point in the model. A similar problem is when does a shipping company sell a vessel and its license? These are crucial question that need to get an answer in order to be able to run the model. If these last problems are solved, the loop starts again by sending the vessels back to sea, improved or not.

c. *The output of the dynamic model*

The output of the model can be summarized in a dynamical matrix per scenario.

	Cost structure	Revenues	Earnings	Savings	Employment	Discards
Company 1	∑	∑	∑	∑	∑	∑
• Vessel type 1						
• Vessel type i						
• Vessel type n						
Company j	∑	∑	∑	∑	∑	∑

• Vessel type 1						
• Vessel type i						
• Vessel type n						
Company m	∑	∑	∑	∑	∑	∑
• Vessel type 1						
• Vessel type i						
• Vessel type n						
Total fleet	∑	∑	∑	∑	∑	∑

Due to these output matrices, the best scenario(s) can be chosen to build upon the strategies.

5. Data to use

This study needs a huge amount of different type of initial data. Most of the data are readily available, but are not centralized in one organization. There is a useful database (under construction) called 'Belsamp' in the Institute for Agriculture and Fisheries Research (ILVO). Data (for the years 2001 till 2004) already found in this database are:

For each vessel of the current Belgian fleet:

- Name of the vessel
- Vessel length
- Home port
- Sum of days at sea per year
- Sum of days fishing per year
- Sum of hours at sea per year
- Sum of hours fishing per year
- Sum of landed weight per year
- Sum of live weight per year
- Fishing time with each gear during one year (in hours at Sea)

Due to contacts with the 'Belgian Sea Fishery Service', the next data is also found for a sample of 72 vessel of the Belgian fleet:

- Revenues per vessel per year
- The different kinds of cost per vessel, per year (cost structures)

But there is still a huge amount of data to be found, for example:

- Economical data of vessel types Belgium doesn't have
- Where each type of vessel goes to fish
- Investment decisions: How does this works?
- Selling vessel decisions: How does this works?
- Catch compositions per vessel type, per fishing ground and per season
- Quota per fish species per fishing ground

6. Conclusion

This conference paper offers a possible framework and methodology on how system dynamics can be used to support strategy-building in sea fishery management. In this case system dynamics is used to understand the behavior and decisions which construct the micro-economical structures in sea fishery that need to be understood before sea fishery management can be developed. By discovering leverage points in these structures, researchers are able to build up effective strategies for the future fleet structure.

Although modeling and simulation is not new in Belgian sea fishery research, it is in sea fishery economics. The latter, in combination with system dynamics and the socio-economical relevance, will give this study enough challenges to make this study an enriching journey. But since this study has just started, there are still numerous problems to solve. By posing this last statement this paper makes itself clear, write recommendations to the authors so they can improve the model and their methodology constructively.

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