An ecosystem approach to the small pelagic fisheries: From model to role playing game

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Abstract

This Working paper present a role-playing game applied to the exploitation of the small pelagic fisheries and the international market of fishmeal and fish oil (FMFO). In order to reveal the stakes in the management of this system, we have previously built a bio economic model, coupled to the ecological and the economic dynamics. The coupling is based on the computing of global equilibrium, on the network which interconnects the marine production systems (ecosystems, fisheries, manufacturing) and the fish product markets (FMFO) around the world.

The most important problem is then to coordinate all the actors in front of their needs and under the constraints of the exploitation of a common-pool resource. The stake in the exploitation of small pelagic species goes through the implementation of sustainable, collective practices of exploitation, which allow satisfying all the needs of the various actors. Role-playing games can be used to facilitate negotiation or as an experimental tool to investigate how people interact.

The role playing game suggests here that a decision taken by one of the economic agents can have repercussions on the whole system of production, whether it is small pelagic species or offer in FMFO. Roles playing games emphasize the possible convergences between economist and ecologist point of views, or between individual decisions and collective discussions. The aim of this work is to reveal the difficulties of coordinating the various communities bound up with the exploitation and the implementation of common-pool resource management.

Keywords: Bio economic modeling, Ecosystem approach, Networks economics, Small pelagic fisheries, Fishmeal & Fish oil, Role playing game.

1. Introduction: Towards global resource management

1.1. Society and resource management

It is now assumed that human activity endangers many natural resources (soils, water, most of renewable resources). Since early 1990s, and particularly since the Conference of Rio in 1992 and the Convention on Biological Diversity, there is a consensus to act in favor of a better resources use at a global scale. (United Nations 1992). This is particularly crucial concerning the right of ocean uses (Christy 1975, United Nations 1983) and exploitation of marine renewable resources because the fact 75% of stock are over or fully exploited (FAO 2010). A real awareness of a sustainable management of the marine resources was the object of the Reykjavik conference in 2001 (FAO 2002) and of the subsequent decision towards an Ecosystem Approach to Fisheries, and, more specifically the Ecosystems-based fisheries management (EFBM) (Bianchi et Skjoldal 2009). This has been one of the objectives of the Millennium assessment declaration Johannesburg (2002): to rehabilitate 24% of stocks before 2015 (United Nations 2002).

During the same period, society has experienced an important economic globalization trend, characterized by the opening of borders and the development of economic exchanges. Confrontation between economic stakes and environmental principles too led often the international authorities to set up agreements of *modus vivendi* for the management of the natural resource. In particular, the marine resources adapted particularly well to this globalization of markets (Delgado et *al*. 2003, Taylor et *al*. 2007). As an example the European Union mattered every year an average volumes amount of about 60 % of its consumption of fish during the last decade (Globefish, 2011).

Beyond principles of conservation or reconstruction of ecosystems, it is essential to consider the whole economic, social and environmental context before setting up any political decision on ecosystem management. So, the balance between fishing activities and the reproductive capacities of the marine resources must be considered under an ecosystem analysis such as sustainable management.

1.2. Global fisheries

In 1950, the landing of fishing activities represented less than 20 million tons and now they represent about 100 million tons. However, since the 1990s we can observe the stagnation of production: landings are between 90 and 100 million tons and are no longer increasing. This stagnation of the productions raises the issue of the sustainability of their exploitation. If this stagnation is due to the impoverishment of the oceans the viability of the fishing activities is not guaranteed anymore for the next decades. This eventuality must be taken into consideration: the number of over exploited stocks has considerably increased during the last two decades (FAO 2010), and, several researches underline the possibility of collapse of stocks in a near future (Mullon et *al*. 2005, Worm et *al*. 2006).

The fishing activities are thus at the intersection of two important issues: They participate to the world food security of the planet under the constraint, on the on hand, to adapt to economic exploitation of the marine resources in balance with the stock renewability on the other hand. Indeed, according to the FAO, the level of supply of the world marine resources is past to 9 kg per capita per year in 1960 to 13,7 kg in 2009 (FAO 2010).

1.3. Issues

According to the declaration of Johannesburg establishing the Ecosystem Approach on the Convention on Biological Diversity, "*The objectives of management of land, water and living resources are a matter of societal choice*" (Principe 1 (United Nations, 2002)). The sustainable management of the resources is in the heart of the socioeconomic problems. Considering the relationship between the economic development and the services returned by the ecosystems, "*Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach*" (Principe 5 (United Nations, 2002)).

Through these principles of reflection and driving, oceans take a considerable place in the human activities dynamics. It is thus advisable to guarantee a viability of the industrial systems of exploitation of the marine resources in balance with the levels of production of these ecosystems. The issue in a relevant Marine Ecosystems-Based Management (EBM) and EFBM is above all to allow an improvement of decision-making at the level of management systems.

1.4. Negotiating for a resource

If we consider the establishment of a new global way to manage a marine system, we must take advantage of recent advances of the research on participatory management. Participation is nowadays considered necessary for implementing sustainable development policies (Pretty 2003, 1995, Stringer et *al*. 2006). In the adaptive management field, it is the pragmatic argument that is often emphasized. Participation allows facilitating of appropriation, the sharing of information, the improvement of relationships and, the launching of collective learning processes (Rouwette et *al*. 2002).

One key issue is the coordination of different communities of practices to build a community of interest around the use of common pool resources and finally to improve collective management of it. Several elements are of core importance for getting efficient participatory process: among others, are the role of mediator for balancing power relationships (Levrel et bouamrane 2008), the support of specific multi-scale institutions (Gunderson et *al*. 1995) and the use of boundary objects (Bowker et Star 2000).

Here we are interested in one specific boundary object, which is the role-playing game for helping in the management of common natural resources (Barreteau et *al*. 2001). Role-playing games represent efficient tools for improving discussion and negotiation due to their specific properties (Bousquet et *al*. 2002): they are interactive, user friendly and dynamic. With the role-playing game, "*the simulation is itself the result of choices made by the players during the game. […] Role-playing in fact makes it possible to link ecological, social, and economic dynamics to individual decisions that have an impact on parameters concerning various players, which sooner or later prompt the participants to begin collective discussions with the goal of proposing and negotiating solutions to deal with these collective problems*" (Levrel et Bouamrane 2008).

Role-playing games can be used for facilitating negotiation or for experimenting how people interact (Colella 2000). Therefore, it is necessary to make this point clear and to explain how participation and role-playing game are linked together. In our case study, we have adopted an experimental perspective. Therefore stakeholders were involved as players and not in the construction of the model.

We have taken into account four "broad" communities of practices who interact through the global fish market: (1) fisheries and industries, (2) fish oil buyers, (3) scientific institutions and, (4) international organizations. These communities support different political and commercial arguments regarding pelagic fisheries management at an international scale. Because role-playing game is an online game, it is possible to play at the same time from different part of the world (Barreteau et *al*. 2007, Barreteau et Abrami 2007). Therefore it is possible to consider participation from a wide range of points of view and not only from a local scale perspective (Bousset et Taverne 2005, Kasemir et *al*. 2003, Levin 2006) by using a model and role games.

1.5. Participatory management, from local to global

Most of the role games used for the participatory management of a natural resource involve the effective stakeholders, as players. For example the fishing companies in the case of a marine resource (cf. the game Fishbanks (Meadows 2007, Meadows et *al*. 1993), dedicated to the common use of several fish's stocks). Our goal regarding a global negotiation implies changing the roles, and considering the representative of stakeholders as players. This is a new perspective, and implies some reflexion in the setting of the game. For example, what are the players' goals? Are they unique? Who is the winner of the negotiations? Is there a specific way of playing such as asking too much when in a good position?

2. The case study: small pelagic fisheries and FMFO markets

The participation of fishing activities to food security can be paradoxal because only 70 % of these productions are intended for human consumption (Alder et Pauly 2006, FAO 2011). Indeed, between 20 and 30 % of the landings are intended for processing industries. While the exploitation of stocks intended for the human consumption target essentially the top of the trophic marine food web (big predators such as: tunas, sea bass, sea breams…), the targeted fisheries for the processing industries are at the bottom of trophic marine food webs. These last species are generally called "small pelagic species". Families of species such as *engraulidae* (anchovies), *ammodytidae* (sand-eel) or still *gadidae* (blue whiting) can be found in this category. Considered individually, small pelagics are among the most

exploited species in terms of volume, in particular, the anchovy of Peru in the Pacific or the blue whiting in the North Atlantic (FAO 2010).

Two criteria distinguish small pelagic species from species intended for the human consumption: one is a biological criterion, these small pelagic species being situated at a lower level within the trophic marine food web, are considered key-preys for predator species. To simplify the economic relations in this game, the prey-predators relation is taken into account in the analysis of fishing activities. The other criterion is economic because these species are generally valued less on the seafood markets (Globefish, 2010).

2.1. Issues

We must consider that the system undergoes a risky situation (Fig. 1): due to (1) the natural variability of stocks, (2) the changing in production costs: more and more efficient gears, (3) the changing in transportation costs, (4) the intensification of demand mainly from aquaculture. Considering all these disturbances, what are the possible knock-on effect on various systems and markets? What are the environmental, economic and social impacts, of these risky or uncertain situations?

Fig. 1

2.2. An exemplar case study

Most of the issues of a sustainable management of marine resources are present in the exploitation of small pelagic fish. Their exploitation allows distinguishing two fleets of fishing: those whose productions are intended for the human consumption and those intended for the industrial reduction. This distinction is important in the management of fish stocks because almost 1/3 of the harvest volumes are not intended for the human consumption. These figures are all the more important as the statistical data show that the fleets of fishing target more and more species at the inferior level to the trophic marine food web (Pauly et *al*. 1998). Environmental constraints and economic worrisome that the quasi-totality of the stocks of small pelagic are fully or over-exploited (FAO 2010, Péron et *al*. 2009).

In this context, the system constituted by small pelagic fisheries and fishmeal and fish oil (FMFO) markets represents an exemplar ecosystem approach case study for many socio-economic and

environmental reasons. As quoted higher in this study, 30% of global marine catches are a small pelagic. As a consequence an important part of the fishing capacity use these fisheries (1) ; is characterized by the variability small pelagic catches and by reverberate of the supply (2) ; The small pelagic are intended for the industries of reduction to be transformed to the FMFO. These FMFO strongly concentrated in animal proteins serve as food raw materials used by food processing system (3). Fish farms are the main consumer of FMFO (Tacon et *al*. 2006); is characterized, these last years, by an increase of demand has the structure of a global network structure; and an important variability of the prices of the FMFO (4) (Graph. 1).

Graph. 1

2.3. Diversity of stakeholders

There are many stakeholders concerned by the management of the system constituted by small pelagic fisheries and fishmeal of fish oil markets. The most important are:

- **Small pelagic fishing companies**: At the upper reaches of model important actors are fishermen and fishing companies for small pelagic fish; the catches of small pelagic fisheries are intended to the fishmeal and fish oil industries, but do they constitute an independent fishery? We must also consider fishermen and fishing companies for other species. In fact, an important feature of small pelagic is that they are located in a lower zone of the food web chain. In this context. Overfishing of small pelagic fish may endanger the population of their predators; stopping fishing small pelagic fish may results in the intensification of the pressure on other fish;
- **Transforming companies**: The structure of the supply chain between fisheries and transforming companies is crucial; In fact, the capacities of transformation, i.e. the relation between the use of small pelagic and the fishmeal and fish oil acquire are a parameter that affect the model. How are they affected by technical progress? What is their strategy of investment?

- **Fishmeal consuming industries**: The consuming industries for fish meal (aquaculture, poultry, pigs…) (Hardy et Tacon 2002) and fish oil (aquaculture, cosmetics) represent an important economic sector; will it be possible to develop these consuming industries toward sustainable and "natural" food chains?
- **Market structures**: The organization of the markets, the role of specialized traders must be taken into account; are there specific traditions, rules, for the markets? Are they changing?
- **State Political economy**: polity is an important issue; what are the means of states (taxes, rights, subsidies) to stabilize the system?
- **Scientists**: The role of scientists is not easy to determine: what role do they have in the system?
- **Nature conservation organization**: This is the same for nature conservation organizations: what role do they have in the system?

2.4. Modeling the small pelagic fisheries and, fishmeal and fish oil markets

As it is the basis for the role playing game, we give, here, some detail about a model of the small pelagic fisheries and FMFO markets. Details about the model and results, mainly sensitivity analysis, are given in a 2009 article by Mullon and his colleagues (Mullon et *al*. 2009). The model involves two kinds of entities: “Production System” and “Market”. For example a quantity of small pelagic is harvested and transformed by the production system, and resulting fish meal is sold on a market. The sector of production systems and the sector of markets influence mutually their development (Ramos-Martin 2003). On a market the shipment are characterized by unitary price of the main producing countries of small pelagic and, of FMFO by continent (Peru, Chile; Japan, Thailand, China; USA; Denmark, Iceland, Norway; Morocco and, South Africa); fish meal markets where this raw materials is exported (China, Japan, Taiwan, UK, Germany, Chile, Norway, Denmark, Russia, Indonesia) and fish oil markets (Norway, Denmark, Chile, Japan, USA). These countries represent the most important producer of small pelagic (FAO 2011) and, in relation, of fishmeal and fish oil; and, in the same logic, for the fishmeal and fish oil market.

Modeling principle lies in the coupling (*Fig. 2*) of an economic equilibration process on the network relating these entities and some deterministic functions of changes inside entities.

Fig. 2

The equilibration process is based on the following considerations:

1. There is a price equation: relating prices and quantities on markets;

2. There are costs functions for fishing, production, shipments, taxes;

3. One must consider constraints on production;

4. There is a balance between production and consumption: the sum of output flows equals the production of production system, the sum of input flows equals the sales

5. There is complementarily: if there is a flow on a path, there is an advantage (sale price is greater than fishing, production and shipment costs), if there are positive flows on two paths starting from the same production system, their advantages are equal. It is shown that there is equilibrium and that it may be computed using the (Nagurney 1993).

Dynamics are related to the assumptions that:

1. Fish stock change according to classical production equations (Gordon-Schaefer model production (Gordon 1954, Schaefer 1957), involving climate, supposed to be exogenous;

2. Demand on market is supposed to be exogenous;

3. Fishing capacity changes according to resulting rent according to a myopic investment behavior principle (Leahy 1993).

Table 1

3. From modeling to role playing game

3.1. The role playing game

In the role game, we gather players, most of the time, around a table, sometimes on a computer network. All players communicate by the mean of a computer program. They may also communicate by chatting together.

The possible role players are: (1) Delegate of South American Fisheries and Industries, (2) Delegate of European Fisheries and Industries, (3) Delegate of fish oil buyers Europe, (4) Delegate of fish meal buyers Europe, (5) Delegate of fish meal buyers China, (6) Delegate of Atlantic scientific institutions, (7) Delegate of Pacific scientific institutions, (8) Delegate of West Pacific states, (9) Delegate of East Pacific states, (10) Delegate of European states.

They have different knowledge, different goals and different ways of acting on the system (*Table 2*). Scientists do not act upon the system. Their role is to inform stakeholders of the stock level of small pelagic, and contribute to inform the "polity" for the implementation of the frame of legislation (Pikitch et *al*. 2004). They send advices to states.

The game takes place in 10 rounds amount in ten years. Every round is determined before the begging of the game. The time of each round can be adjusted. A game progresses as follows:

- Before round 1 : Players consult their own information, made of the results of a previous run of the model (10 years)
- Round 1: Decision makers independently take their decisions, scientists publish their recommendations. Model is run during one step according to the decisions. Results of the simulations and advices of scientists are distributed to players, according to their status
- Round 2, 3, 4, 5 : same as round 1
- A discussion between players: what should be the correct level for supply (TAC) and demand that does not perturbate the system (Hannesson et Steinshamn 1991).
- Round 2, 3, 4, 5, 6, 7, 8, 9 : the same as round 1
- End of the game: a discussion about the effects of having negotiated

Table 2

3.2. Articulation between model and role playing game: Game Scenarios

The articulation of party is simple. In the model, sensitivity analyses consist in systematic changes of parameters values. Changes are the same for all time steps and all entities. In the role playing game, at any step, parameters are changed for an entity by in charge of its management. However, the uncertainty of the behavior of market, as well as the strong variations which can affect the levels of fishery productions, the game is based on various scenarios. Every played part is configured by specific scenario with specific constraints. The scenario determines the socioeconomic environment of the players, the progress of the part, as well as the appearance of specific event which are going to force the players in their behavior. The processes of functioning of the scenarios consist in modifying or in developing specific parameters of the system of production and\or the market. Concerning the production systems, we observe the dynamics of stocks, yield, fishing capacity, effective effort, profit, and concerning the markets, we observe volumes of exchanges and prices of commodities. In some scenarios the players have to reach the environmental and socio-economic objectives: sustainable income while protecting the stock. There are the objectives but there is also a method: keeping the fishing capacity, enough supply, not too costly, enough tax income, enough yield:

Impact of climate change (El Nino event)*:* Scenarios about the impact of climate change consist of changing the values of production functions parameters, with a uniform increase (or decrease) of renewal rates, assuming that it affects fish recruitment processes ; increase (or decrease) of carrying capacity, assuming that it affects the overall productivity of ecosystems; a localized increase (or decrease) of carrying capacity, assuming that it affects the productivity of ecosystems in a different manner according to their latitudinal location.

Economic globalization: Building a scenario in terms of economic globalization consists of changing production and transportation costs. We usually consider the following scenarios with a modification of shipment costs, for example through the increasing use of containers, or the increase of fuel prices; in increasing demand for forage fish.

Increase in fuel price scenario: This scenario affects a cost production and the market behaves with a fuel prices increase by 5% per year, which is rather conservative, according to what has happened in recent years. It has an effect both on fishing costs and shipping costs. At a given level of fuel prices, it is no more profitable to fish and thus boats are idled. The inefficiency of the fishery ensures that the

smaller supply is not compensated by an increase in commodity price. The increase in production costs is limited, due to the necessity of taking into account fixed prices (capital costs). Profit decreases drastically in affected countries, and even though fishing capacity decreases overcapacity reaches a high level. This causes the collapse of several fisheries, (e.g. for example, that of Peru highly affected by increase of transportation costs), a decrease in global supply to under 10 Mt, which is not enough to satisfy demand. Decreases of yield results in a continued growth of stocks, underlying that collapse of fisheries are not due only to collapses of stocks. This process will continue until a level equivalent to the carrying capacity, in support of the idea that an increase of fuel prices would contribute to fisheries sustainability (Cheung et Sumaila 2008, Harper et *al*. 2012). However, the collapse of fisheries would have catastrophic economic effects.

Global total allowable catches (TAC) scenario: This scenario concerns the dynamics of the system under the assumption that catch limits are imposed for all ecosystems at a level of 5% of the estimated carrying capacity. This is a very conservative level compared to surplus production estimates, which cannot reasonably be expected at the global level. We observe, in agreement with theory, a stabilization of stock, yield, profit and prices. Prices are 20 % higher than in the reference scenario, insuring high profit, and therefore high investment and thus overcapacity. In general terms this is similar to present conditions observed in Peru (Fréon et *al*. 2009).

Investment Rate Increase: Investment and disinvestment are critical issues in fisheries policies. The model assumes a myopic behavior of production systems: then investment or disinvestment according to their income or losses. There is an investment rate relating investment and income. The model allows studying long term effects of changes in the investment rate: what happen if production has a tendency to increase or decrease their reactivity?

3.3. Computer implementation

On a technical point of view, the role playing game works as follows: (1) the simulation model is implemented on a computer server, (2) players connect on client computers, (3) they receive an identity: function, knowledge, goals, way of acting, (4) then at each time step, they make their decision and send it to the server, (5) it results in modifying for this time step the value of one or several of the

above parameters for one entity they have some power on, (6) once all the players have sent their decisions, the server compute the resulting state of the system, (7) the server send to the players the new knowledge about the dynamics of the system.

Practically, using the principal browser (Internet Explorer, Firefox, Google Chrome or Opera), the players connect to the server according to the following procedure:

1. Go to web page (Picture 1 & 2)

   https://tomcat.devpinwar.mpl.ird.fr/fishmealEclipse/PINWAR.html

   Pictures 1 and 2

   On the web page, the players can obtain all the information on the progress of the game, the roles playing game, but also the scientific approach and the objectives.

2. Accept certificate
3. Give identification login: devpinwar, password: 2devpin!!
4. If necessary re accept certificate. They get a global view of the game. It is given in pictures (3 to 8).

3.4. Player interface

Pictures 3 to 8 present the graphic interface of the game during the progress of the one scenario.

Pictures 3 to 8

3.5. Setting Experiments

To define a game, one has to:

1. Define its environment:

- a very favorable one: increase of productivity, increase of demand
- a very unstable environment: high variability of productivity, increase of fuel prices

2. Define how to play: players do not communicate or all players can communicate during all the game.

3. Define what to observe about the strategies of players: what does it change having a strategy, compared to have done always as usual?
4. Define how to collect observation on the play: the speed of reactions of players; ask the players.
5. Define produce a synthesis about the game

4. Results: Example of a play

This game was played during the summer school of the European Institute of Marine Studies, Climeco2about the effects of global changes on marine systems. A specific workshop was organized on the thematic of environmental modeling. The PhD students participating in this workshop were issued from various sciences: biologist, economist, geographer; physicists… The opportunity was given to these students to take roles in the presented model. After a briefing explaining the scenario of the game: "Investment Rate Increase", a specific role roles player was randomly awarded to the participants.

Before the beginning of every part, all the players arrange several minutes before the first round launches ; it so that they can acclimatize with the digital environment, acquaint with information of which they had as well as their objectives.

4.1. Fisheries productions

4.1.1. Delegate of South American Fisheries and Industries

The main objectives of the countries of South America, Chile and Peru were to maintain the income of the activities of the fishing, while protecting the stock. Graphs below present the behavior of the participants as well as the consequences of the operated choices. 20 rounds appear on graphs. From 1 to 10, it is about histories of the scenarios, the other words the information which is given to the participants. From 11 to 20, the period in the course of which the participants make decisions.

At first, the representatives of the countries of South America acquaint with data relative to the stocks of pelagic. They observe a reduction of the stock (Graph. 2), to remedy this problem, the delegates reduced at first TAC. The progressive reduction of the Chile's TAC (Graph. 3) has for consequence, a

reduction of the fishing capacity on fisheries. The stabilization of stocks, then a reconstruction, observes further to this first decision. However, the withdrawal of the fishing capacity inferred echoed on the activities as well as on the income of the fishing activities.

Graph. 2 and Graph. 3

Afterward, the representatives of Chile decide to strongly increase taxes on the imports of FMFO (Graph. 4). The income of Chile increases and compensate for the losses of the sector of fishing (Graph. 5). The impact of the reduction of captures, and thus, the productions of FMFO, as well as the taxes has for incidences to increase the price of the FMFO. The delegates of South America knew how to maintain the objectives: a stable income and a sustainable exploitation of small pelagic fisheries. The actions shares and the decisions were led by analyzing according to the evolution of the situations. The past data were used to anticipate the reactions to decision-making.

Graph. 4 and Graph. 5

4.1.2. Delegate of European Fisheries and Industries

The European fisheries had more difficulties maintaining their objectives. The stocks of pelagic fisheries of Denmark, Iceland and Norway are in damages (Graph. 6). After one year three countries reduce their TAC to limit the collapse of stocks (Graph. 7). During the next years TAC will be more or less strongly decreased, with more than 100 % of reduction over 10 years

Graph. 6 and Graph. 7

However, this measure in for consequence to reduce the income by reducing on one hand the value of fisheries exploitation and on the other hand by reducing the offer of raw material necessary for industries of FMFO. In front of the continuous growth of the investments and of an overexploitation of fisheries the measures of reduction of the TAC do not allow to reduce the levels of fishing catachability. The income of Denmark and Norway tends to decrease (Graph. 8). To slow down the investment and try to make the income go back up, the delegates decided to gradually increase fishing taxes (Graph. 10). And, at the same time, Denmark and Norway increases taxes on the imports (Graph. 11).

Graph. 8 and Graph. 9

Graph. 10 and Graph. 11

Iceland better supports the slowing down of the productions of its fisheries. A great part of Iceland income is based on the FMFO import/export. The increase of the price of the FMFO allows compensating national income. However, at the end of the seventh year this compensation cannot make it any more and the income of both sectors is going to collapse (Graph. 8). The delegate decided to reduce strongly TAC to preserve the resource and the raw materials supply. It has a beneficial effect on stocks but it slows down the exploitation of fisheries considerably. After this decision and, with a high level of FMFO price, the national income increase. But, by reducing the offer of small pelagic, Iceland has considerably decreased the offer FMFO. The price of these materials increased to reach about $2,100 a ton (1,600$ at the beginning of the game) (Graph. 9). This increase in prices affected global market price of the Europe FMFO, affecting the levels of import of the other countries.

In the case of the fisheries of Europe, the players made choices abrupt to cancel the negative effects of the scenario. The indicator which the most influenced the players is the conservation of the stock. Without taking into account the optimum of exploitation of small pelagic fisheries the measures were to force as much as possible the fishing activities by the reduction of the TAC. These choices are echoed in a too strong and too fast way and one had for consequence of the important variations of the main parameters income and fish stock.

4.1.3. Delegate of Asian Fisheries and Industries

The delegates of the Asian producers (China, Japan and Thailand) arrange the same information of departure as the other players. If Japan and Thailand have stocks of small pelagic stable, China has a resource which tends to decrease over past period (Graph. 12). During the first two years no decisions is taken. The first measure was to reduce the percent of catchability, at first for Japan then for China (Graph. 14). Afterward, a drastic measure was imposed in China by reducing almost totally TAC (Graph. 13). It allowed slowing down the collapse of the stock of small pelagic of China, but, in return, the income knew a strong decline (Graph. 15).

Graph. 12 and Graph. 13

Graph. 14 and Graph. 15

To compensate for the impact on the fishing activities the delegates of China decide to reduce taxes on this sector, and, in a protective measure of the activities, taxes on the imports are strongly increased.

We observe a clear increase of the national income but the falling trend of the levels of stocks is always present. It is also necessary to note the strong constraint of exploitation which always presses on the fishing sector because of TAC at a low level.

4.2. Delegate of fish meal and fish oil buyers

The Delegate of fishmeal and fish oil buyers represents the buyers for Europe (Norway, Denmark, UK, and Germany), US, and China. They have the possibility of modifying Intensity of FMFO and Flexibility of FMFO (Graph. 16 and 17). And, their main objective is to stock up with FMFO in the lowest market price.

In this part, the delegates of FMFO buyers have to focus their actions on fish oils to try to reach their objectives. The players operated strong variations of the control levers of action, but by keeping coherence in the regionalization. Firstly, a strong reduction of the intensity of the demand is made to reduce the increase of fish oil price

The report is that the actions are too rough. The variations are made in drastic ways. It has the important effect of slowing down, more especially in Europe.

Graph. 16 and Graph. 17

Concerning the fish meals price, it is possible to observe the impact of a local mismanagement on the international markets, in fact, the mismanagement of the Iceland stock, and thus the availability of raw materials, observes by a sharp increase of the fish oil prices. It has the effect of increasing all the international prices (Graph. 18 and 19).

Graph. 18 and Graph. 19

Globally, every delegate has data to understand the economic environment. Within the framework of natural resources it is indispensable to intervene to guarantee a sustainable exploitation. Several tools were given to the delegates. These economic and political tools represent the means of action which the decision-makers have in the reality to guarantee a sustainable exploitation of the resources and markets

stability. Two type of control lever can be identified. Either they have a legal reach (TAC), or they affect the economic behaviour (Tax). In this game context, very specific parameters encouraged the players to intervene. The first objective that the delegates wanted to reach was the conservation of the stock. The environmental and the conservation of the resource is the parameter which dominated. For it all the delegates of the fishermen used at first the legal tool of the TAC. This tool seems the simplest to be used and the most effective in the short term. It is only secondly, when income collapses that taxes are used. However, a very specific behaviour appears because the taxes which are the most used rest taxes in the import. The notion of protectionism is thus strongly joined into the national activities. The players thus privileged the local decisions, protecting at first resources then their industries. The international consequences of the actions and the theory of network have here only not enough influence on the behaviour.

5. Discussion

The peculiarity of small pelagic species exploitation can be found in the relation that exists between an economic activity subject to an increasing demand of FMFO, and, a system of primary production of small pelagic species which is subject to strong landing fluctuations (Hannesson et *al*. 2006).

The most important problem is then to coordinate all the actors in front of their needs and under the constraints of the exploitation of a common-pool resource (Hardin 1968). The stake in the exploitation of small pelagic species goes through the implementation of sustainable, collective practices of exploitation, which allow satisfy all the needs of the various actors (Dietz et *al*. 2003).

The role playing game suggests here feigning these interactions and advancing the fact that a decision taken by one of the economic agents can have repercussion on the whole system of production, whether it is small pelagic species or offer of flours and fish oils. Roles playing game emphasize the possible relations that exist from an ecological, social and economic point of view, between individual decisions and collective discussions. Through these simulations, the game allows to show the negotiations which can be set up between the various agents to find solutions for the exploitation of a common-pool resource (Roth et Erev 1995). Beyond the objective of simulation, the game is an example

of pooling of the knowledge of economist and ecologist (Wam 2010), so allowing to consider different points of view in the construction of a global knowledge (Colella 2000, Kasemir et *al*. 2003).

The aim of the role playing game is to bring to light the difficulties of coordinating the various communities bound to the exploitation of the small pelagic fisheries (Dodds 2005). It has been designed to make explicit the asymmetries of information between the actors but also to show the complexity of relationships between the various socio-economic and environmental levels. This game, is before all, intended for the students and PhD students, and so that they understand all the problems and implication related to the implementation of standard of management of the resources (Pretty 2003, Dieleman et Huisingh 2006), in order to develop good practices and public interest for the exploitation of a common-pool resource.

Several parts were already organized in various universities for developed the concept and to bring in students stemming from different training and from different sciences, in particular: Euroceans Winter school (2009), Summer school Climeco2 on the European Institute of Marine Studies, Brest (2010) ; Master AERME on the Montpellier2 University (December 2010), and Master ETADD, Saint Quentin en Yvelines University (February 2011).

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References

Alder, J., Pauly, D. 2006. On the multiple uses of forage fish: from ecosystems to markets. Fisheries Centre Research Reports. University of British Columbia. 14(3). Canada.

Barreteau, O., Bousquet, F., Attonaty, J. 2001. Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to Senegal River valley irrigated systems. *Journal of Artificial Societies and Social Simulation* 4(2).

Barreteau, O., Le Page, C., Perez, P. 2007. Contribution of simulation and gaming to natural resource management issues: An introduction. *Simulation Gaming* 38: 185-194.

Barreteau, O., Abrami, G. 2007. Variable time scales, agent-based models, and role-playing games: The Pieplue River basin management game. *Simulation Gaming* 38: 364-381.

Bianchi G., Skjoldal, H.R. 2009. The Ecosystem Approach to Fisheries. Edited by G Bianchi. CABI Edition. P.384.

Bousquet F., O. Barreteau, P. d'Aquino, M. Etienne, S. Boisseau, S. Aubert, C. Le Page, D. Babin and J.C. Castella. 2002. Multi-agent systems and role games: collective learning processes for ecosystem management. In M. A. Janssen (ed.) Complexity and Ecosystem Management: The Theory and Practice of Multi-agent Systems, pp. 248–85. Cheltenham: Edward Elgar.

Bousset, J.P., and Macombe, C. Taverne, M. 2005. Participatory methods, guidelines and good practice guidance to be applied throughout the project to enhance problem definition, co learning, synthesisand dissemination. SEAMLESS Report 10, SEAMLESS integrated project, EU 6th Framework Programme.

Bowker, G. C. and Star, S. L. 2000. Sorting Things Out. Classification and Its Consequences. MIT Press. 389p.

Butler, D.J. 2005. A reality check for game theory. *Journal of Economic Surveys* 19: 137-147.

Cheung, William W.L. and Sumaila, U. R. 2008. Trade-offs between conservation and socio-economic objectives in managing a tropical marine ecosystem. Ecological Economics. 66: 193–210

Christy, F.T. Jr. 1975. Property Rights in the world ocean. *Natural Resources Journal* 15: 695-712.

Colella, V. 2000. Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *Journal of the Learning Sciences*. 9: 471-500.

Delgado, C.L., Wada, N., Rosengrant, M.W., Meijer, S., Ahmed, M. 2003. Fish to 2020, supply and demand in changing global markets. International Food Policy Research Institute and WorldFish Center. Washington DC.

Devetag, G., Ortmann, A. 2007. When and why? A critical survey on coordination failure in the laboratory. *Experimental Economics* 10: 331-344.

Devetag, G., Warglien, M. 2008. Playing the wrong game: An experimental analysis of relational complexity and strategic misrepresentation. *Games and Economic Behavior* 62: 364-382.Dieleman, H., Huisingh, D. 2006. Games by which to learn and teach about sustainable development: exploring the relevance of games and experiential learning for sustainability. *Journal of Cleaner Production* 14: 837-847.

Dietz, T., Ostrom, E., Stern, P.C. 2003. The struggle to govern the commons. *Science* 302: 1907-1912.

Dodds, W. K. 2005. The commons, game theory, and aspects of human nature that may allow conservation of global resources. *Environmental Values* 14: 411-425.

Food and Agriculture Organization, 2002. Report of the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, Reykjavik, Iceland, 1-4 October 2001.

Food and Agriculture Organization. 2010. The State of World Fisheries and Aquaculture. FAO Fisheries Department. 197p. Rome.

Food and Agriculture Organization. 2011. FishStatJ. Universal software for fishery statistical time series. Fisheries Department, Fishery Information, Data and Statistics Unit, Rome.

Fréon, P., Barange, M., Arístegui, J. 2009. Eastern Boundary Upwelling Ecosystems: Integrative and comparative approaches. *Progress in Oceanography*. 83: 1-14.

Globefish datas, 2011. Fish Oil and Fishmeal Commodity Update. FAO, Fish Products and Industry Division, Rome.

Globefish datas, 2010. European price report. FAO, Fish Products and Industry Division, Rome.

Gordon, H.S. 1954. The economic theory of a common property resource: the fishery. *Journal of political economy*. 62: 124-142.

Gunderson, L.H., Holling, C.S., Light, S.S. 1995. Barriers and bridges to the renewal of ecosystems and institutions. *Columbia University Press*. New York. 593p.

Hannesson, R., Steinshamn, S.I. 1991. How to set catch quotas: constant effort or constant catch? *Journal of Environmental Economic and Management* 20: 71-91.

Hannesson, R., Barange, M., Herrick, S.F. 2006. Climate change and the economics of the world's fisheries: examples of small pelagic stocks. Vol. XVII. Edward Elgar. Cheltenham.

Hardin, G. 1968. The Tragedy of the commons. *Science* 162: 1243-1248.

Hardy, R.W., Tacon. A.G.J. 2002. Fish meal: historical uses, production trends and future outlook for sustainable supplies. In: Stickney, R.R., McVey, J.P. (Eds.), Responsible marine aquaculture. New York: CAB International, pp. 311–26.

Harper, S., Bevacqua, D., Chudnow, R., Giorgi, S., Guillonneau, V., Le Manach, F., Sutor, T. and Sumaila, U.R. 2012. Fuelling the fisheries subsidy debate: Agreements, loopholes and implications. Fisheries Research. 113(1): 143-146

Kasemir, B., Jäager, J., Jaeger, C., Gardner, M. T. (Eds.) 2003. Public Participation in Sustainability Science: A Handbook. Cambridge University Press, Cambridge.

Lane, D. C. 1995. On a resurgence of management simulations and games. *The Journal of the Operational Research Society* 46: 604-625.

Leahy, J.V., 1993. Investment in Competitive Equilibrium: The Optimality of Myopic Behavior. *The Quarterly Journal of Economics* 108: 1105-1133.

Levin, S., 2006. Learning to live in a global commons: socio-economic challenges for a sustainable environment. *Ecological Research* 21: 328-333.

Levrel, H. and Bouamrane, M. 2008. Instrumental learning and sustainability indicators: outputs from co-construction experiments in West African biosphere reserves. *Ecology and Society* 13(1): 28p.

Levrel, H., Etienne, M., Kerbiriou, C., Le Page, C., Rouan, M., 2009. Co-Modeling Process, Negotiations, and Power Relationships: Some Outputs From a MAB Project on the Island of Ouessant. *Society and Natural Resources* 22: 172-188.

Meadows, D. 2007. A brief and incomplete history of operational gaming in system dynamics. *System Dynamics Review* 23: 199-203.

Meadows, D., Fiddaman, T., Shannon, D. 1993. Fish banks, ltd. a micro computer assisted group simulation that teaches principles of sustainable management of renewable natural resources. Tech. rep., Laboratory for Interactive Learning, University of New Hampshire, Durham.

Mullon, C., Fréon, P., 2005. Climate change and the economics of the world's fisheries: examples of small pelagic stocks. Edward Elgar Publishing, New horizons in environmental economics, Cheltenham, UK, Ch. Prototype of an integrated model of the worldwide system of small pelagic fisheries, pp. 262-295.

Mullon, C., Mittaine, J.F., Peron, G., Thebaud, O., Merino, G., Barange, M. 2009. Modelling the fishmeal and fish oil markets. *Natural Resource modeling*. 22: 564–609.

Mullon, C., Freon, P., Cury, P. 2005. The dynamics of collapse in world fisheries. *Fish and Fisheries*. 6: 111-120.

Nagurney, A. 1993. Network Economics. A variational inequality approach. Kluwer Academic Publishers, Dortmund.

Oilworld The Independent Forecasting Service for Oilseeds, Oils & Meals 2011. Database Prices of Major Commodities Archive.

Pahl-Wostl, C. 2007. The implications of complexity for integrated resources management. Environmental Modelling & Software. 22: 561-569.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F. Jr. 1998. Fishing Down Marine Food Webs. *Science*. 279: 860-863.

Péron, G., Mittaine, J. F., Le Gallic, B. 2010. Where do fishmeal and fish oil products come from? An analysis of the conversion ratios in the global fishmeal industry. *Marine Policy*. 34 : 815–820.

Pikitch, E.K., Santora, C., Babock, E.A., Bakun, A. Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E.D., Link, J., Livingston, P.A., Mangel, M., McAllister, M.K., Pope, J., Sainsbury, K.J. 2004. Ecosystem-Based Fishery Management. *Science* 305: 346-347.

Pretty, J. 1995. Participatory learning for sustainable agriculture. *World Development* 23: 1247-126.

Pretty, J. 2003. Social capital and collective management of resources. *Science* 302: 1912-1916.

Ramos-Martin, J. 2003. Empiricism in ecological economics: a perspective from complex systems theory. *Ecological Economics* 46: 387-398.

Ravetz, J.R. 2006, Post-normal science and the complexity of transitions towards sustainability, *Ecological Complexity* 3: 275-284.

Rouwette, E., Vennix, J., van Mullekom, T. 2002. Group model building effectiveness: a review of assessment studies. *System Dynamics Review* 18: 5-45.

Roth, A.E., Erev, I. 1995. Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. *Games and Economic Behavior* 8: 164-212.

Shaefer, M.B. 1957. Some considerations of population dynamics and economics in relation to the management of marine fisheries. *Journal of the fisheries research Board of Canada* 14: 669-81.

Sterman, J.D. 1994. Learning in and about complex systems. *System Dynamics Review* 10: 291-330.

Stringer, L.C., Dougill, A.J., Fraser, E., Hubacek, K., Prell, C., Reed, M.S. 2006. Unpacking "participation" in the adaptive management of social-ecological systems: a critical review. *Ecology and Society* 11(2): 39.

Tacon, A.G.J., Hasan, M.R., Subasinghe, R.P. 2006. Use of fishery resources as feed inputs to aquaculture development: trends and policy implications, Food & Agricultural Organisation, Fisheries Circular N°1018, Rome.

Taylor, W.T., Schechter, M.G., Wolfson, L.G. 2007. Globalization: Effects on Fisheries Resources. Cambridge University Press. New York.

United Nations 1983. The Law of the sea. United Nations Convention on the law of the sea, with index and final act of the third United Nations conference on the law of the sea. New York.

United Nations 1992. United Nations Conference on Environment and Development, Convention on Biological Diversity. Rio de Janeiro.

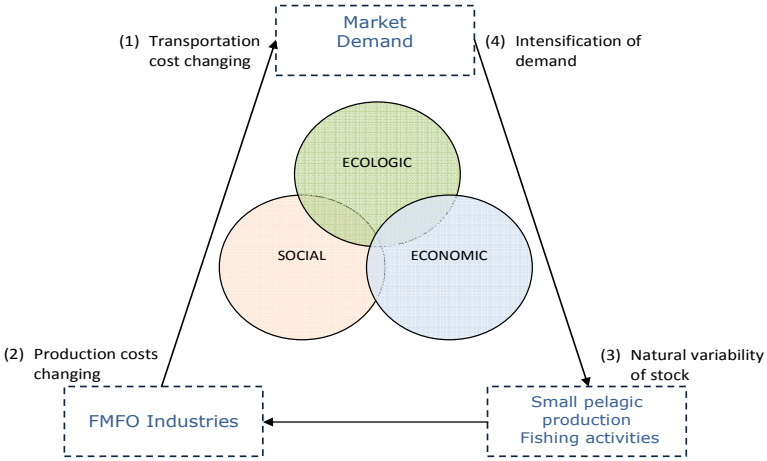
United Nations 2002. World Summit on Sustainable Development, Fifth Ordinary Meeting of the Conference of the Parties to the Convention on Biological Diversity. Johannesburg.

Wam, H.K. 2010. Economists, time to team up with the ecologists!. *Ecological Economics* 69: 675-679.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, E.J., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Fiorenza, M., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowizc, J.J., Watson, R. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science* 314: 787-790.

Figures and Tables

***Fig. 1**:* Small pelagic activities considering Ecosystems-based fisheries management



Graph. 1: Fishmeal and fish oil prices evolution since 2001 (Source: Oilworld, 2011)

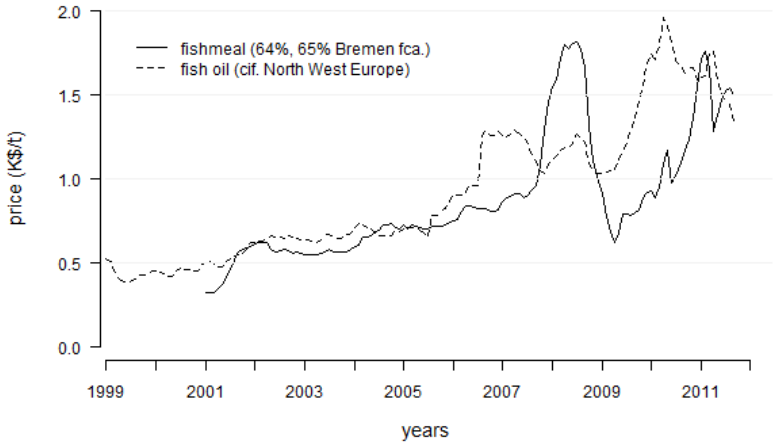


Fig. 2: Simplified low chart of the model

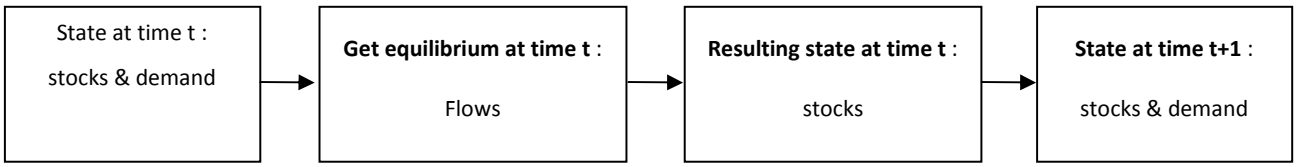


Table 1: Parameters of the model

Parameters related to climate changes	Parameters related to economic changes	
	Production system	Market

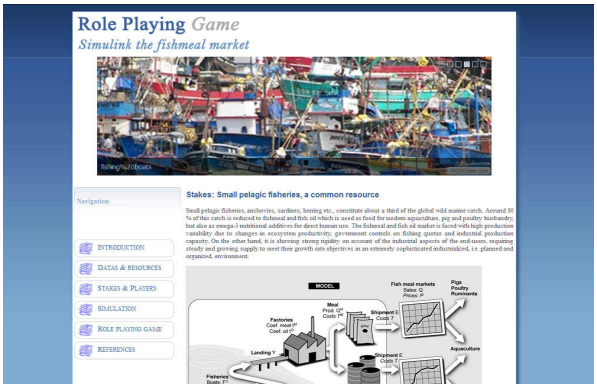
Carrying capacity Renewal rate changes Latitudinal climate changes ENSO Event	Adaptation of fishing capacity Capital remuneration rate Catchability changes Total allowable catch Fuel prices changes Fishing rights Importation taxes Depreciation rate	Changes Demand intensity Changes Demand flexibility Growth of fish meal markets Growth of Chinese demand

Table 2: Different characteristics of players

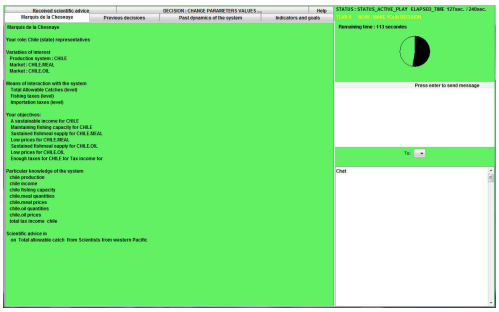
Players	Countries	Players actions & Decisions	Players Knowledge
Delegate of South American Fisheries and Industries	Chile, Peru	Investment, Capital Remuneration, Compliance	Production, Effort, Sales
Delegate of European Fisheries and Industries	Norway, Iceland, Denmark	Investment, Capital Remuneration, Compliance	Production, Effort, Sales
Delegate of fish oil buyers Europe-US	Norway, Denmark, USA	Demand Parameters	Buying, Rates
Delegate of fish meal buyers Europe-US	UK, Germany, Norway, Denmark, US	Demand Parameters	Buying, Rates
Delegate of fish meal buyers China	China	Demand Parameters	Buying, Rates
Scientific Institutions South America	Peru, Chile	Warnings, Recommended level of TAC	Yield, Fishing capacity
Scientific Institutions Europe	Iceland, Norway, Denmark	Warnings, Recommended level of TAC	Yield, Fishing capacity

Picture 1 & 2: Web page to reach the game

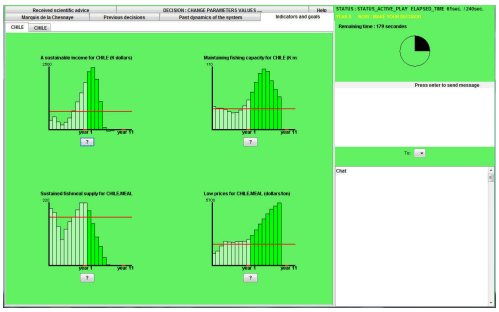
Picture 3: Player's identity



Picture 4: The past dynamics information of the system

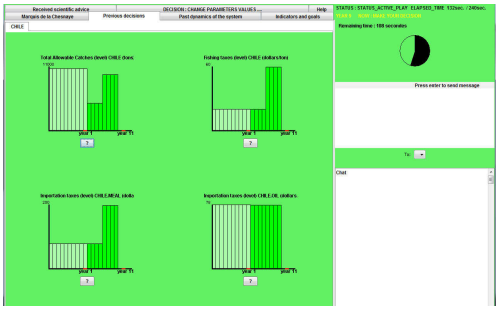


Picture 5: Decisions of a player

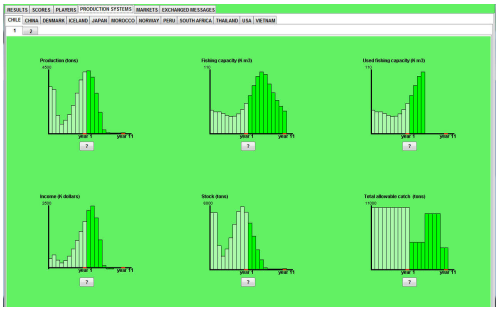


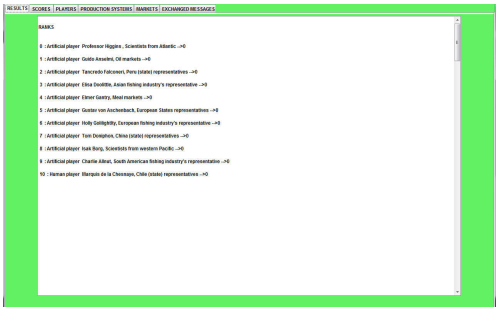
Picture 6: Past & present decisions of a player

Picture 7: Game's results concerning the production systems

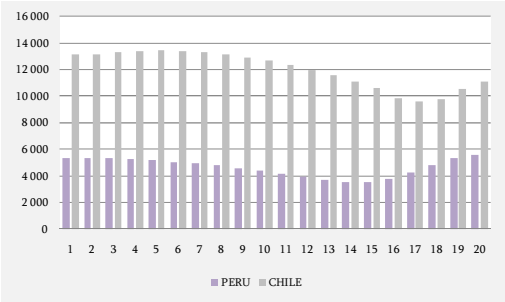


Picture 8: Game's results concerning all the players

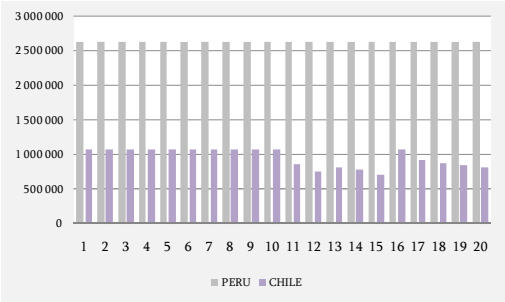




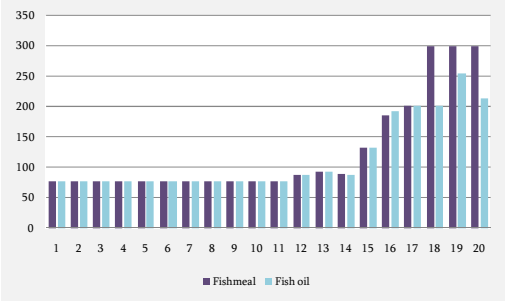
Graph. 2: South America - Fish stock



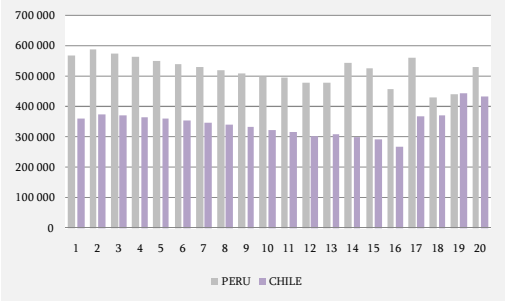
Graph. 3: South America – TAC



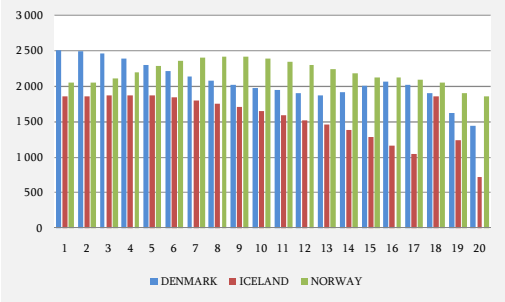
Graph. 4: Chile – Importation taxes



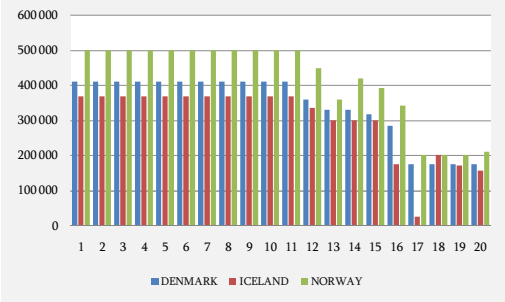
Graph. 5: South America - Income



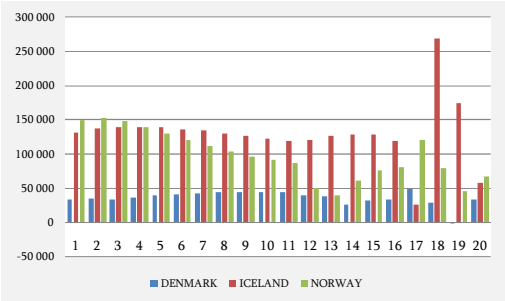
Graph. 6: North Europe – Fish stock



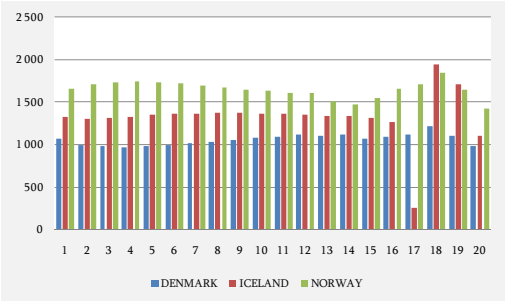
Graph. 7: North Europe – TAC



Graph. 8: Europe – Income

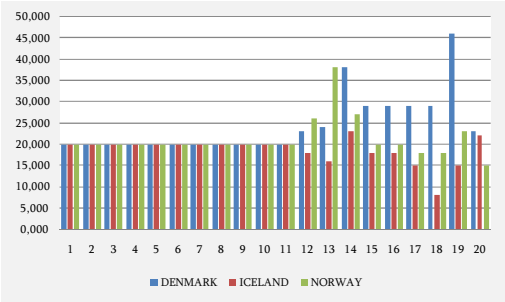


Graph. 9: Europe – Production

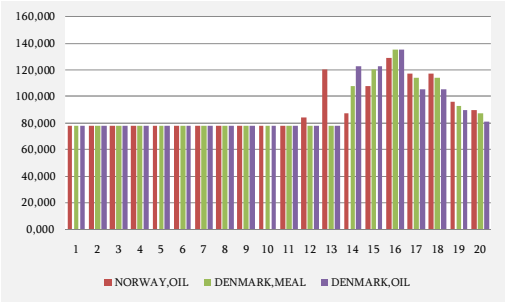


Graph. 10: Europe – fishing taxes

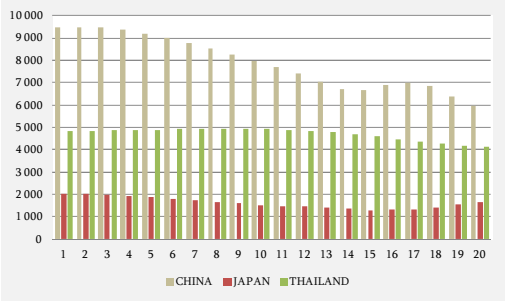
Graph. 11: Europe – Importation taxe



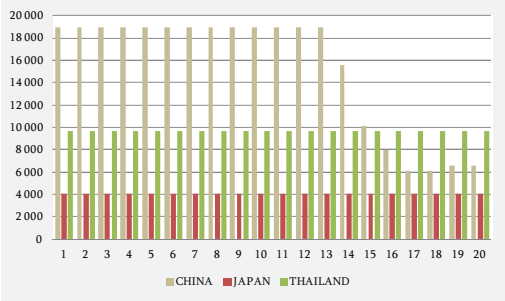
Graph. 12: Asia - Fish stock



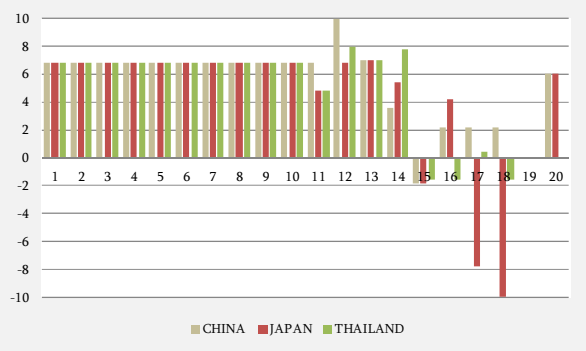
Graph. 13: Asia – TAC



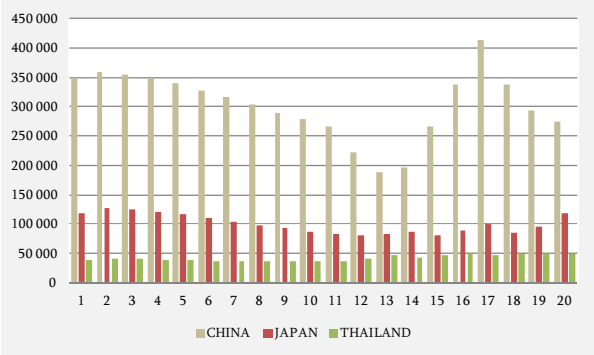
Graph. 14: Asia - Catchability



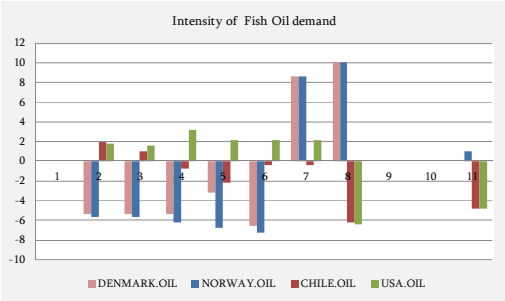
Graph. 15: Asia – Income



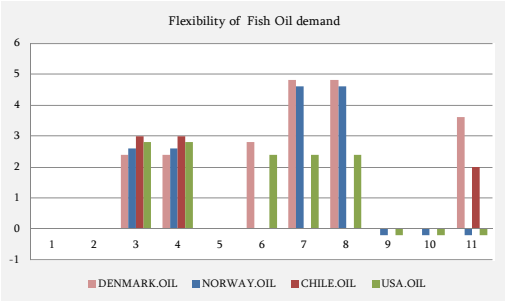
Graph. 16: Intensity of Fish Oil demand



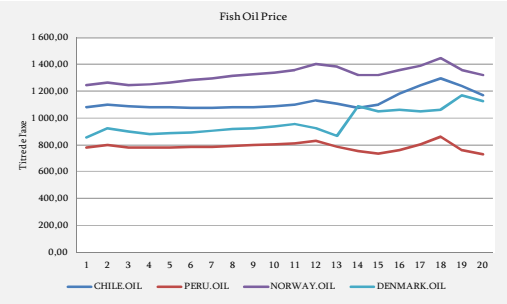
Graph. 17: Flexibility of Fish Oil demand



Graph. 18: Fish Oil Price



Graph. 19: FishMeal Price


Fish Oil Price
Titre de l'axe
1 600,00
1 400,00
1 200,00
1 000,00
800,00
600,00
400,00
200,00
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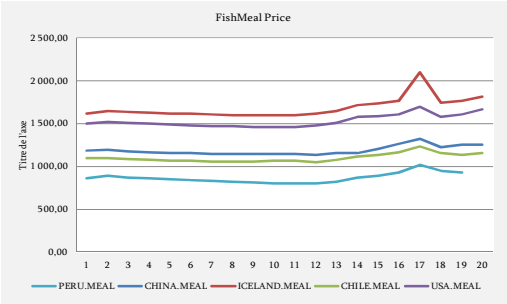
CHILE.OIL
PERU.OIL
NORWAY.OIL
DENMARK.OIL


FishMeal Price
Titre de l'axe
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1 500,00
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PERU.MEAL
CHINA.MEAL
ICELAND.MEAL
CHILE.MEAL
USA.MEAL