# Impact of human activities on a multifunctional territory, Gironde estuary (France): a bioeconomic approach

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## Abstract

Gironde estuary is a multifunctional territory which undergoes many aggressions related to human activities. These pressures correspond to physical and biological impact. An economic analysis allows to traduce them into monetary terms. Halieutic resources are at the end of the trophic chain and this position makes them an integrating component closely related to the quality of the environment. These fishes become a witness to appreciate the impacts of the other human activities on the estuary. Indeed, the impact of a human activity is estimated compared to the loss of profit that it generates for commercial fisheries. We consider a migrating specie: Allis shad (*Alosa alosa*). The objective is to estimate, by mean of a bioeconomic model, profits of fishermen in two cases: the one where the impact of a human activity is taken into account and the one where it is not. This article reveals a loss of profit for Allis shad commercial fisheries due to external activities.

**Keywords :** Bioeconomic model, Surplus variation, Commercial fishery, Gironde estuary, Impacts of human activities, Allis shad (*Alosa alosa*)

## I. Introduction

The Gironde estuary is the biggest estuary in France and one of the largest in Western Europe. It is considered to be relatively unspoilt (Lobry and *al*, 2003) but undergoes many aggressions related to human activities. It gathers, from its multifunctional character, a vast urban and agricultural basin, harbour activities, aggregate extraction, dredging, professional and recreational fishing... These pressures generate physical and biological impacts. These various impacts are being felt by the population living in the estuary and more particularly by fish species. Halieutic resources are at the end of the trophic chain and this position makes them an integrating component closely related to the quality of the environment.

In an indirect way, fishermen will be the witnesses of these impacts that affect their catches. Indeed, if a human activity destroys fish species, commercial fisheries concerned (as the entire industry) have economic losses. The impacts of human activities are evaluated and compared to the damage which it generates on commercial fisheries. This damage is expressed by a variation of surplus and more precisely by a loss of earnings.

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The model concentrates on human activities' impacts undergone by migrating specie: Allis Shad (*Alosa alosa*). Three external activities are retained: the nuclear thermal power station of Blayais (France), the elver's fishery and the shrimp's fishery. Then a bioeconomic model makes possible to connect the fish stock with the fishing activity and external activities.

The bioeconomy is used to manage the exploitation of renewable resources such as fish or forest. The first who are interested in it appeared in the Fifties (Gordons, 1954; Scott, 1955; Schaeffer, 1957). Main concepts were analyzed, developed and consolidated by C.W.Clark (1985, 1976 and 1990). The studied models often suppose that the growth of this renewable resource only depends on its size and its catchability rate. This specification doesn't take into account the external human activities i.e. others that fishing activities. The aim of this article is to integrate this new factor and to analyze its effect on the resource and more particularly on commercial fishing.

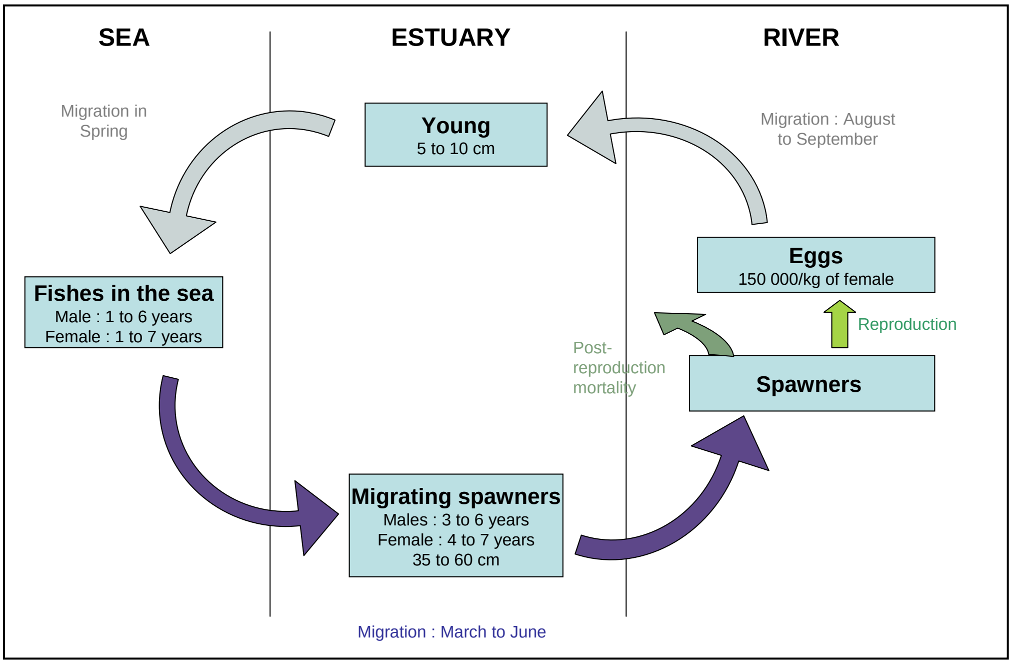
Firstly, the biological cycle of Allis shad is presented. It reveals the presence of this specie in the Gironde estuary under two stages: young and adult. After a presentation of the theoretical and the empirical model, biological characteristics of the Allis shad's stock are evaluated. Two methods are compared: equilibrium method and non equilibrium surplus-production model. The next stage consists in estimating the cost function and the price function. Finally the maximization of profits is analysed and the results are exposed.

## II. Gironde estuary and Allis shad

The Gironde estuary is located in South-west France and is formed from the meeting of two rivers, the Dordogne and the Garonne. It is the biggest estuary in Western Europe with approximately thousand square kilometers at high tide. It is 76 km long and between 3 and 11 km wide. It harbours many migrating or sedentary fish species. It is considered to be relatively unspoilt (Lobry and *al*, 2003).

Allis shad is one of the five most fished species in the Gironde estuary (with lamprey, eel, elver (young eel) and shrimp). In 2002, it was the first in volume and the third in value (Girardin and *al*., 2004). Allis shad is a migrating fish.

Its biological cycle is composed of four principal phases (Martin, 1999, Taverny, 1991) represented by the diagram below.



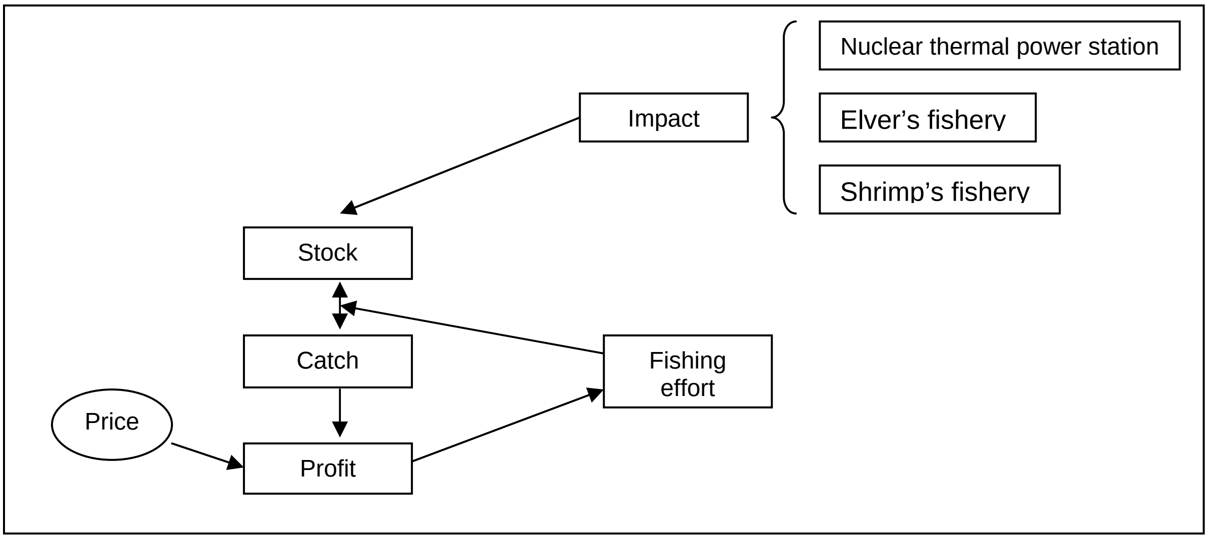
*Source*: Martin, 1999, Taverny, 1991

Allis shad migrates from the sea to the estuary then to the river and inversely. We can see on the Gironde estuary the young and the spawners. Only the adults are allowed to be captured by fishermen (decree n° 94-157 of February 16, 1994).

## III. General presentation of the bioeconomic model

The aim of the model is to estimate the impacts generated by human activities on the Gironde estuary. Of course these impacts are felt more particularly by the fish species. Halieutic resources are at the end of the trophic chain and this position makes them an integrating component closely related to the quality of the environment. In an indirect way, fishermen are witnesses of these impacts which have an effect on their possibility of capture and thus on their incomes.

Generally, bioeconomic models consider only two sectors: the halieutic sector and the economic sector. The first sector is about fish stock. The second one deals with the choices of fishermen. To highlight the impact of human activities on the Gironde estuary, a third sector is integrated: the external impact one. This impact is an exogenous factor.



*Source:* Personal elaboration

We begin with the halieutic sector. The fish stock is the middle of the model. Knowing the data available, we choose a model with a global approach i.e. the stock is considered without taking into account the internal interactions. The stock is thus regarded as a "block box" in which we only know the intrinsic growth rate. The net growth function is supposed to be the famous logistic equation.

The economic sector depends on the choices of the fisherman. It deals with investments i.e. costs (variable and fixed one) that the fisherman agrees to carry out his fishing activity. These costs are closely related to the fishing effort. Indeed, the choice of the fishing days' number, the boats and fishing gears' number, these boats and these gears' maintenance are included.

Finally an external impact is considered. It can be related to an agricultural, industrial, urban activity... This impact decreases the fish stock and represents a loss of potential capture for the fisherman. It is regarded as a loss of earnings for the profession.

To translate these interactions as well as possible, the general idea is to maximize the surplus of fishermen by taking into account fish stock dynamics. The impact is considered initially and then is isolated. Then there are two surpluses indexed or not by the impact. It is possible to compare them and to highlight a loss of earnings for fishermen.

## IV. External activity impact

The objective of this bioeconomic model is to evaluate the economic impact of the human activities on commercial fishing. Two studies[3] estimate the quantities of destroyed fishes by three human activities: the nuclear thermal power station of Blayais, the elver's fishery and the shrimp's fishery.

The nuclear thermal power station requires significant water consumption to its coolant circuit. It directly pumps this water in the Gironde estuary. This cooling water after being pumped passes through filter drums which can capture fishes.

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[3] Taverny, 1991 ; Boigontier and Mounie, 1982

Moreover, fishermen sometimes harvest another species (in addition to target specie). It is the case of two commercial fishery which capture young Allis shad: elver’s fishery, *Anguilla anguilla*, open of November 15 to March 30 and white shrimp’s fishery, *Palaemon longirostris*, open all the year.

If these activities had not taken place, these destroyed fishes could potentially be harvested by fishermen. The destroyed quantities are regarded as a “lost” part of stock for fishermen and thus represent a loss of earnings.

The nuclear thermal power station has functioned since 1982. The whole of the data obtained concerning Allis shad’s fishing activity were listed after the opening of the power station.

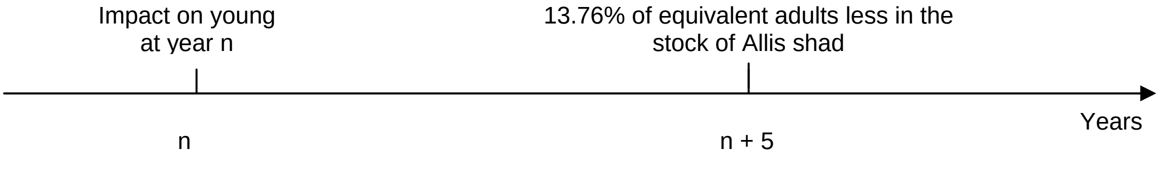
Concretely, to model the case “with impact”, we express fish stock dynamics according to the growth of stock (integrating recruitment and natural mortality), mortality due to fishing and finally that related to the external activity.

To model the case "without impact", we assume that human activities don’t destroy Allis shad’s stock. Concretely, we express fish stock dynamics according to the growth of stock (integrating recruitment and natural mortality) and mortality due to fishing.

The difference between the case "without impact" and the case "with impact" is in fish stock dynamics the integration (or not) of the mortality due to the external impact. Two cases generate two levels of comparable profits. These comparisons make possible to appreciate the impact of human activities on commercial fishing.

Three human activities are considered: the nuclear thermal power station of Blayais, the elver’s fishery and the shrimp’s fishery. Two papers are interested in the impact of the nuclear thermal power station on the Allis shad: Boigontier and Mounie (1984) and Taverny (1991). Only the last one analyses impact of the two fisheries (elver and shrimp) on the Allis shad.

It is noted that impacts estimated for the three external activities are related to the young Allis shad. The commercial fisheries of Allis shad are authorized only for adults. As the biological cycle of Allis shad shows, young Allis shad and adults are present in the Gironde estuary. Here human activities only generate impacts on young. However these destroyed young Allis shad would become adults and thus potential captures. It is thus necessary to express young in equivalent adults. Lambert and *al.* (2001) show that it takes on average five years for young to become adult and only 13.76% of young become adults.



Thus if a quantity X of young is destroyed in 1982, that corresponds to a loss of 13.76% of equivalent adults in 1987. The impacts of the nuclear thermal power station[4] were estimated in 1982, 1984, 1985,

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[4] The impact from shrimp’s fishery was estimated in 1985, 1986, 1987 and 1988. The impact from elver’s fishery was estimated in 1985, 1986 and 1987.

1986, 1987 and 1988 thus the developed model corresponds to the years 1987, 1989, 1990, 1991 and 1993.

## V. Theoretical model

We are going to expose the theoretical bioeconomic model. The aim is to maximize fishermen's profits under fish stock dynamics.

The impact is expressed in the following way:

$I = \alpha B$ with $0 \leq \alpha \leq 1$.

With $I$ the impact expressed in a number of destroyed equivalent adults and $B$ the total biomass.

In order to know the situation "without impact", we must simulate the fact that such activity didn't exist i.e. didn't destroy fishes. For that, we don't take into account the impact $I = \alpha B$.

This model is largely inspired by the model of Clark (1990). Only the case "with impact" is exposed:

$$\begin{aligned} &\underset{\{E_t\}}{Max}\ \pi = \int_0^\infty (pY_t - cE_t)\, e^{-\delta t} \partial t \\ &s.t. \quad \dot{B} = F(B_t) - Y_t - \alpha_t B_t \\ &\qquad\ 0 \leq E_t \leq E_t^{\max} \end{aligned} \qquad (1)$$

With $Y$ catch, $p$ price, $c$ cost (supposed constant), $E$ fishing effort (expressed in number of fishing days), $F(.)$ net growth function and $\delta$ discount rate.

By construction, $Y = qEB$ with $q$ the catchability rate. The rate $q$ can be interpreted as the probability that a unit of biomass is harvested when a unit of effort is deployed (Lalöe, 1990). This relation can be comparable with a function of production connecting the output $Y$ to the input $E$ (Ropars, 2002). This rate integrates at the same time accessibility into the resource and the physical and technological capacities.

The Hamiltonian is written as the following:

$$\begin{aligned} H &= e^{-\delta t}\ (pqB - c)E + \lambda\left[F(B) - qEB - \alpha B\right] \\ H &= \left[e^{-\delta t}(pqB - c) - \lambda qB\right]E + \lambda\left[F(B) - \alpha B\right] \end{aligned} \qquad (2)$$

The solution of this Hamiltonian gives the following equation:

$$F'(B) - \alpha + \frac{cF(B)}{qB(pqB - c)} = \delta \qquad (6)$$

We obtain (see the proof in the article of Conrad and Adu-Asamoah (1986)):

$$F'(.)+\frac{\frac{\partial \pi(.)}{\partial B}}{\frac{\partial \pi(.)}{\partial Y}}-\alpha=\delta \qquad (7)$$

This equation is a fundamental relation of bioeconomic models. $F'(.)$ corresponds to the variation of the net stock growth due to a variation of the fish stock. The second term of left refers to the marginal effect on stock. The last term is usually not present. It represents the effect of human activity impact on the fishery. The term of left as a whole translates the benefit rate due to the possession of the resource.

The equation as a whole means that the society must invest in the resource so that the interest rate due to the possession of the resource is equal to the social discount rate (Munro and Scott, 1985; Bjorndal and Munro, 1998).

We assume that the net growth function is the logistic equation:

$$F(B)=rB(1-\frac{B}{K})$$

With $r$ the intrinsic rate of growth of stock, $K$ the carrying capacity and $B$ the biomass.

The intrinsic rate of stock includes the growth of each fish, recruitment, mortality.... The carrying capacity, $K$, corresponds to the maximum number of fishes which the estuary can support. It indicates a limiting abundance with the top of which the growth of the population becomes negative, while with the lower part, the growth is positive. It can be interpreted like a measurement of resources available (Jost, 1998). Thus $K$ represents an equilibrium value towards which the abundance of the population converges.

The equation (6) is a quadratic form. Two solutions are obtained. One of them doesn't satisfy the positivity constraint on stock.

The solution is the following expression:

$$B^{*}=\frac{K}{4}\left[1+\frac{c}{pqK}-\frac{\delta}{r}-\frac{\alpha}{r}+\sqrt{\left(1+\frac{c}{pqK}-\frac{\delta}{r}-\frac{\alpha}{r}\right)^{2}+\frac{8\,c\,(\delta+\alpha)}{qpKr}}\right] \qquad (8)$$

Thus the optimal biomass depends on biological characteristics (carrying capacity ($K$), intrinsic growth rate ($r$) and catchability rate ($q$)), but also on economic choices (the cost $c$), and on the external impact $\alpha$.

Finally it is interesting to note the role of the discount rate.

## VI. Empirical model

For the empirical part, the model is in discrete mode. The aim is to maximize the profit under fish stock dynamics.

The profit corresponds to the difference between incomes (prices multiplied by quantities) and costs (daily costs multiplied by the number of fishing days).

The dynamics of the fish stock takes into account the growth function of this stock from which we subtract catches and destroyed fishes by human activity. If we consider the case "with impact", the model has the form below.

$$\begin{aligned} &\underset{\{E_t\}}{Max} \sum_{t=0}^{6} \rho^t \; (p_t Y_t - c_t E_t) \\ &s.t. \quad B_{t+1} - B_t = F(B_t) - Y_t - \alpha_t B_t \\ &\qquad\quad 0 \le E_t \le E_t^{\max} \end{aligned}$$

With $p$ price, $Y$ catch, $c$ unit cost, $E$ fishing effort i.e. number of fishing days, $B$ biomass, and $\alpha$ external impact.

Before beginning this maximization, it is necessary to estimate different parameters. We start with biological characteristics i.e. with the carrying capacity, the intrinsic rate and the catchability rate. These three parameters are evaluated using two methods. First the equilibrium method is employed. This last one consists in supposing that the fish stock is at equilibrium: $\dot{B} = 0$ .The second method uses non equilibrium surplus-production models which reject the equilibrium assumption. The software ASPIC of M.H. Prager is used to estimate the parameters of the fish stock.

After having considered biological characteristics, we are interested in the economic sector with the price function, the cost function and with the choice of the discount rate.

### 1. Halieutic sector

This part aims to evaluate the parameters related to the stock of Allis shad in the Gironde estuary, more particularly, the intrinsic rate of growth of stock ($r$), the carrying capacity ($K$) and the catchability rate ($q$).

Two methods are used to analyse biological characteristics.

The first one supposes that the situation is at equilibrium i.e. the biomass at the moment t+1 is equal to the one at the moment t. We suppose that $\dot{B} = 0$:

$$\dot{B} = rB(1 - \frac{B}{K}) - qEB - \alpha B = 0$$

The equilibrium biomass is written as

$$B^e = \frac{K}{r}(r - qE - \alpha)$$

By using $Y = qEB$ the capture are expressed like a quadratic function of the fishing effort.

$$Y = a\,E + b\,E^2$$

Then the parameters of this equation are estimated and make possible to find the level of the three biological characteristics ($r$, $q$ and $K$) because of $\hat{a} = qK - \frac{\alpha q}{H}$ and $\hat{b} = \frac{q^2}{H}$ (we note that $q = \frac{Y}{E\,B}$).

The second method rejects the equilibrium assumption (i.e. $\dot{B} = 0$) and then uses a non equilibrium surplus-production model. For the resolution of this model the software ASPIC of Prager is used. It allows, from initial values for $K$, $r$, $B$ and $q$, to make projections in time. The captures are calculated from definite equations. The objective function ($\sum_{t=1}^{T} \left[\log(Y_t) - \log(\hat{Y}_t)\right]^2$) is then minimized. The operation is renewed until convergence is reached.

For the two methods chosen, the data are from Girardin and *al.* (2004) where the catches and fishing effort from 1978 to 2002 are exposed. The levels of biomass are from Chanseau and *al.* (2005).

The biological characteristics are obtained by averaging the results of the equilibrium method and the non equilibrium surplus-production model. Already estimated biologic characteristics by the D. Martin (1989) are integrated.

We obtain finally:

- r = 0,298
- q = $7{,}27^{E}10^{-5}$
- K = $1{,}43^{E}10^{7}$

## 2. Economic sector

The economic sector describes fishermen and their behaviours. A cost function is estimated, it depends on the boats' characteristics. We also estimate a price function which depends on captures and on prices of two others species.

### a. Cost function

The problem concerning the fishing cost on the Gironde estuary is that few investigations were carried out on this subject. Total cost modelling is based on PECOSUDE investigation (Léauté J.P. and *al.*

2000)[5]. Two functions are estimated: one for fishing sailors[6] and one for river professionals. The model is on the year 2000.
Intermediate consumptions are expressed according to the number of boats.

For the river professionals, the model selected is as follows (R² adjusted = 0.99):

$$\ln IC = \underset{(59)}{9.2} + \underset{(1953)}{1.01} \ln(average\ \ number\ of\ \ boats\ \ per\ \ \ fisherman)$$

For the fishing sailors, the equation is written as (R² adjusted=0.99):

$$\ln IC = \underset{(68)}{10.75} + \underset{(3070)}{1.01} \ln(average\ \ number\ of\ \ boats\ \ per\ \ \ fisherman)$$

Intermediate consumptions for two categories of fishermen are expressed in francs 2000. Using a deflator, we find these consumptions in price of the year considered.

### b. Price function

Prices become endogenous by the way of a log-log relation. We analyse Allis shad's price in function of the capture and other prices. We integrate prices of other species as lamprey, eel, elver, and shrimp. Modelling is based on the data obtained in Girardin and *al.* (2004) in which prices and catches from 1978 to 2001 are exposed. Only elver's price and lamprey's price have an influence on the Allis shad's price. Shrimp and eel are harvested in the estuary all the year that can explain that a variation of their prices doesn't affect the Allis shad's price.

The estimation gives the following results (R² adjusted **=** 0.83):

$$\ln(Allis\ shad\ \ price) = \underset{(-3.315)}{-0.18} \ln(catch) - \underset{(-3.177)}{0.21} \ln(elver\ \ price) + \underset{(6.195)}{1.38} \ln(lamprey\ \ price)$$

This equation is integrated in the maximization of the profit under the dynamics of the fish stock. Prices must be expressed in euros of the year considered.
The advantage with this specification is that the estimated parameter of $\ln(catch)$ can be interpreted as the inverse of the own price elasticity. Then $e = \dfrac{\partial \ln(catch)}{\partial \ln(Allis\, shad\ price)} \approx -5$. Here, as for most species (Ashe and *al* (2005)), demand is elastic.

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[5] Study about small inshore and estuarine fishing of the South Atlantic coast of Europe and dealing with three countries: France Spain and Portugal

[6] On Gironde estuary, there are two types of fishermen having different licences and different fishing area. Only a mixed zone allows fishing activity to these two types of fishermen.

### c. Discount rate

Discount rate’s choice is at the same time fundamental and delicate in environmental economics theory. Its value is crucial in the evaluation of environmental projects. When an individual acts, its action will have necessarily some consequences in the future. An individual is supposed to take into account the concept of time and the future impact of its own actions. Time can be regarded as a rare resource and thus generates costs. That is why, all equal things an individual prefers reaching a result in the present rather than this same result in the future. It is said that the individual has a preference for the present. The discount rate corresponds to the price of time. At the aggregate level, the discount rate expresses the collective choice relating to the appreciation of the future. This rate is thus strongly related to the "right of the future generations". This right would suppose that the present generations would preserve environmental goods on the long term, so that the future generations can benefit from it.

Suppose that an individual wants to finance a project of environmental protection, which will bring a benefit to him each year from the nth year, during ten years. The stronger its preference for the present is and the longer the duration of the project is, higher the discount rate is.

Higher discount rates tend to favour lower stock levels for renewable resource. A high rate can create investments to improve or protect the environmental quality unattractive when compared to alternative investments in the private sector. It will reduce the value of investments or harvesting decisions which have a preponderance of their benefits in the distant future (Conrad, 1999).

We fix this discount rate at 5%. We will analyse its sensibility in the last section to appreciate the importance of the discount rate value in our model.

## VII. Results

The following method comes from J. Conrad (1999). The aim is to maximize the profit of fishermen under fish stock dynamics. The case exposed below is the one "with impact".

$$\underset{\{E_t\}}{Max} \sum_{t=0}^{6} \rho^t \ (p_t q E_t B_t - c_t E_t)$$

$$s.t. \quad B_{t+1} - B_t = r B_t (1 - \frac{B_t}{K}) - q E_t B_t - \alpha B_t$$

$$5000 \leq E_t \leq 10000$$

$$avec \ \rho = \frac{1}{1+\delta}$$

The discount rate retained is: $\delta = 0.05$. The fishing effort, i.e. the number of fishing days, is supposed to be between 5 000 and 10 000 days. Then the results obtained will be closer to reality and to the events which have taken place over the period considered. Indeed, Allis shad, as a migrating species, is not present the whole year in the estuary. According to Girardin and *al.* (2004), between 1986 and 1993, the minimum effort is 5 803 (1992) and the maximum effort is 9 390 (1986).

Three papers[7] reveal the quantities destroyed of youthful Allis shad by the nuclear thermal power station of Blayais between 1982 and 1988, the one destroyed by elver's fisheries between 1985 and 1987 and finally the one destroyed by shrimp's fisheries between 1985 and 1988. The results for each period are presented. To allow comparisons, it will be interesting to analyze the average differences between profits from the case "with impact" and those from the case "without impact" i.e. the loss of earnings per year.

First we consider the prices as an exogenous factor called "fixed prices". In the second time, price equation is taken into account to express the price level according to the catches.

The three followed tables resume the results obtained.

Table 1: Sum of actualised profits with fixed price from 1987 to 1993 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Nuclear thermal power station** | 81 542 | 1 128 625 | -1 047 083 | -149 583 |

Table 2: Sum of actualised profits with fixed price from 1990 to 1993 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Shrimp's fishery** | 732 881 | 906 638 | -173 757 | -43 439 |

Table 3: Sum of actualised profits with fixed price from 1990 to 1992 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Elver's fishery** | 638 764 | 738 890 | -100 125 | -33 375 |

In the case "without impact", the sum of actualised profits is higher than the one in the case "with impact". Human activity generates a loss of profit for Allis shad's commercial fishing. This loss of profit varies with the estimated impact. Indeed, the nuclear thermal power station has a higher impact than elver's fisheries and shrimp's fisheries and generates a more important loss of profit. On the other hand, the two fisheries have a similar impact and then the losses of earnings per year (average difference) that they cause are close.

Fishermen fish either 5 000 days or 10 000 days.

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[7] Martin, 1986 ; Taverny, 1991 ; Boigontier and Mounie, 1982

With the nuclear thermal power station impact they fish fewer days than in reality (i.e. estimated by Girardin and *al* (2004)): between 30% and 50% less. The catches decrease about 80% due to high impacts (more particularly in 1990) and about 60% in the case “without impact”.

With the elver’s fishery impact fishermen fish about 16% more in the case “without impact” but 4% less in the case “with impact”. The catches decrease about 48% in the case “with impact” and about 38% in the case “without impact”.

With the shrimp’s fishery impact fishermen fish less (about 8%). The catches decrease about 52% in the case “with impact” and about 48% in the case “without impact”.

Of course in all cases, catches in the case “without impact” are superior to those in the case “with impact”.

With the integration of the price function, the results obtained are the following:

Table 4: Sum of actualised profits with price function from 1987 to 1993 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Nuclear thermal power station** | 477 733 | 1 684 543 | -1 206 811 | -172 402 |

Table 5: Sum of actualised profits with price function from 1990 to 1993 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Shrimp fishery** | 892 688 | 1 045 190 | -152 502 | -38 125 |

Table 6: Sum of actualised profits with price function from 1990 to 1992 (in euros):

| | **Profits with impact** | **Profits without impact** | **Difference** | **Average difference** |
|---|---|---|---|---|
| **Elver fishery** | 793 239 | 881 124 | -87 885 | -29 295 |

The integration of the function price doesn’t change already given main conclusions with fixed prices. The profit in the situation "without impact" is always higher than the one in the case "with impact". These losses of profit stay in the same proportion and always vary with the estimated impact. In the same way, the catches are lower[8] than those estimated by Girardin and *al.* (2004). Fishermen fish only either 5 000 or 10 000 days.

In the case of the nuclear thermal power station of Blayais, the number of fishing days and the catches are constant with the introduction of the price equation. The profits are higher because of the price values: about 32% in the case “without impact”, about 60% in the case “with impact”.

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[8] about -70% for the nuclear power station ; about -45% for the elver’s fishery ; about -48% for the shrimp’s fishery

In the case of shrimp's fishery, efforts and catches stay the same. The prices vary between -4% and 44%. Finally the profits with the price equation are higher: about 18% in the case "with impact", about 16% in the case "without impact".

In the case of elver's fishery, in both cases, efforts increase the first year (1990) about 48% in the two cases and stay stable after 1990. The prices vary between 15% and 17%. Finally the profits with the price equation are higher: about 24% in the case "with impact" and about 19% in the case "without impact".

## VIII. Sensibility

In this section, we analyse how vary profits when the different parameters vary. We concentrate our study on the discount rate, the carrying capacity, the intrinsic growth rate and the catchability rate. The results are given only for the case of the nuclear thermal power station of Blayais. For the two other impacts the conclusions are very close.

### 1. Sensibility of the discount rate

We compare the results obtained previously with a discount rate equal to 0.1 (instead of 0.05).

Table 7: Sum of actualised profits from 1987 to 1993:

| | Fixed price | | | Price function | | |
|---|---|---|---|---|---|---|
| | **Profits with impact** | **Profits without impact** | **Difference** | **Profits with impact** | **Profits without impact** | **Difference** |
| **Nuclear station** | 108 113 | 1 009 731 | -901 618 | 475 361 | 1524 603 | -1 049 242 |

The augmentation of the discount rate generates a decrease of the profits about 13%. Indeed, an increase in the discount rate is equivalent increasing the cost of time in the evaluation of the future costs and benefits. That means that the same biological impact will have less monetary consequences if the discount rate is strong (i.e. more the preference for the present will be strong).

Fishermen keep their strategies and the decrease of profits is only due to the augmentation of the discount rate.

The differences between the cases "without impact" and "with impact" decrease with the augmentation of the discount rate. The stronger the preference for the present is less the economic impact is. High rates of discount will greatly reduce the value of harvesting decisions (Conrad, 1999).

The effect of the discount rate is very important in this model.

### 2. Sensibility of the carrying capacity

We compare the results obtained previously with a doubled carrying capacity (multiplied by two).

Table 8: Sum of actualised profits from 1987 to 1993:

| | Fixed price | | | Price function | | |
|---|---|---|---|---|---|---|
| | **Profits with impact** | **Profits without impact** | **Difference** | **Profits with impact** | **Profits without impact** | **Difference** |
| **Nuclear station** | 95 512 | 1 169 696 | -1 074 184 | 496 501 | 1 727 000 | -1 230 499 |

The carrying capacity is doubled but there is nearly no variation for the level of the profits: only about 4%. Fishermen don't modify their behaviour. Indeed the carrying capacity doesn't modify the level of stock available. The variation of it has few consequences on the profits.

The economic impact i.e. the difference between the two cases is nearly the same (just an increase about 2% and 3%).

### 3. Sensibility of the intrinsic growth rate

We compare the results obtained previously with an increase of 10% of the intrinsic growth rate.

Table 9: Sum of actualised profits on 1987 from 1993:

| | Fixed price | | | Price function | | |
|---|---|---|---|---|---|---|
| | **Profits with impact** | **Profits without impact** | **Difference** | **Profits with impact** | **Profits without impact** | **Difference** |
| **Nuclear station** | 170 518 | 1 375 410 | -1 204 893 | 596 797 | 1 930 632 | -1 333 835 |

The increase of the intrinsic growth rate increases profits about 20% with the price function and about 15% in the case “without impact” and about 100% in the case “with impact” with fixed prices. Indeed, if all others parameters stay stable, an increase of the intrinsic growth rate increase the stock. With a stable effort, if the stock is higher, the captures are more important and then the profits are higher.

The behaviour of fishermen doesn't vary. They keep their strategy. The difference of the profits is only due to the variation of the intrinsic growth rate.

When the intrinsic growth rate increases the economic impact increases about 30% with the fixed prices and about 11% with the price function. Indeed if the strategy (number of fishing days) stays the same, an increase of $r$ generates an increase of the stock and then an increase of the impact.

The effect of the intrinsic growth rate is important. A variation of it has some consequences on the valuation of the profits and of the economic impact.

### 4. Sensibility of the catchability rate

We compare the results obtained previously with a decrease of 10% of the catchability rate.

Table 10: Sum of actualised profits on 1987 to 1993:

| | **Fixed price** | | | **Price function** | | |
|---|---|---|---|---|---|---|
| | **Profits with impact** | **Profits without impact** | **Difference** | **Profits with impact** | **Profits without impact** | **Difference** |
| **Nuclear station** | 167 023 | 8 722 099 | -1 162 565 | 592 538 | 1 878 174 | -1 285 635 |

The diminution of the catchability rate increases the profits during the whole period. A variation of the catchability rate can have several effects. First a decrease of it increases the stock available. But a sufficient increase of the stock can increases the catches. Then the capture can be more important even if the rate decreases. It is the case here.

In the two cases the behaviours of fishermen don't change, they don't vary their number of fishing days.

A decrease of the catchability rate generates an increase of the economic impact. Indeed the diminution of the catchability rate increases the stock and then the impact (percentage of the stock available) about 11% with the fixed prices and about 6% with the price function.

The effect of the catchability rate is less important than the discount rate or the intrinsic growth rate. But this effect has to take into account.

## IX. Conclusion

The Gironde estuary is a multifunctionality area. The aim is to evaluate the impact of human activities on the estuary and on each of them. This question is a problem of use conflict.

In this paper we use a bioeconomic model to estimate the economic impacts of three human activities on Allis shad's commercial fisheries. These results are a kind of witness which reveals the impacts undergone by the Gironde estuary. The maximization of profits highlights a difference between the case "with impact" and "without impact". The studied human activities generate a loss of profit for the commercial fisheries. It would be then interesting to consider other human activities and other species to establish for each human activity, the cost which it makes support by the Gironde estuary as a whole.

## Bibliography

**Asche F., Bjorndal T. and Gordon D. 2005** *Demand structure for fish* SNF Working Paper No. 37/05 Institute for Research in Economics and Business Administration

**Bjorndal T. and Munro G 1998**. *The economics of fisheries management: a survey.* International Yearbook of Environmental and Resource Economics, pp. 153-188

**Boigontier B. and Mounie D. 1982** *Contribution à la connaissance de la dynamique de la macrofaune bentho-demersale et pélagique en Gironde. Tentatives et difficultés pour relativiser l'impact mécanique d'une centrale nucléaire : le Blayais (Gironde)*. Cemagref de Bordeaux, Division ALA/INP Toulouse, thèse doc. 3$^{ième}$ cycle, 491 p

**Chanseau M., Castelnaud G., Carry L., Martin-Vandembulcke D. and Belaud A. 2005** *Essaie d'estimation du stock de géniteurs d'alose alosa alosa du bassin versant Gironde-Garonne-Dordogne sur la période 1987-2001 et comparaison de différents indicateurs d'abondance* Bulletin Français Pêche Piscicole 374 : 1-19

**Clark CW 1985** *Bioeconomic Modelling and Fisheries Management*, New York Wiley-Interscience.

**Clark C. W. 1976 1990** *Mathematical Bioeconomics : the Optimal Management of Renewable Resources* New York : Wiley-Interscience, 1$^{st}$ et 2$^{nd}$ edition.

**Conrad J.M 1999**. *Resource Economics* Cambridge University Press

**Conrad J.M. and Adu-Asamoah R. 1986** *Single and Multispecies Systems : The Case of Tuna in the Eastern Tropical Atlantic* Journal of Environmental Economics and Management 13, 50-68

**Girardin M. Castelnaud G. and Beaulaton L. 2004** *Surveillance halieutique de l'estuaire de la Gironde : Suivi des captures 2002. Etude de la faune circulante 2003* Rapport pour EDF CNPE du Blays/ Etude CEMAGREF, groupement de Bordeaux, Cestas n°91

**Gordon H.S. 1954** *The economic theory of a common property resource : the fishery* Journal of Political Economy, 62, 124-42

**Jost C. 1998** *Comparaison qualitative et quantitative de modèles proie-prédateur à des données chronologiques en écologie* Institut national agronomique Paris-Grignon, thèse

**Laloë F. 1990** *Présentation générale des modèles globaux pour l'étude des populations marine exploitées* Chapitre 9 du livre de Brethes J.C. et O'Boyle R.N.. *Méthodes d'évaluation des stocks halieutiques*, Centre International d'Exploitation des Océans, Québec

**Lambert P., Martin Vandembulcke D., Rochard E., Bellariva J.L., Castelnaud G. 2001** *Age à la migration de reproduction des géniteurs de trois cohortes de grandes aloses (Alosa alosa) dans le bassin versant de la Garonne* Bull. Fr. Pêche Piscic. 362/363 : 973-987

**Léauté J.P. and Caill-Milly N. 2000** *Caractéristiques des petites pêches côtières et estuariennes de la côte atlantique du sud de l'Europe"*Contrat PECOSUDE – EC/DG FISH (DGXIV) : Projet N° 99/024

**Lobry J., Mourand L., Rochard E. and Elie P. 2003** *Structure of the Gironde estuarine fish assemblages: a comparision of European estuaries perspective* Aquat. Living. Resour. 16 47-58

**Martin D. 1999** *Dynamique de population de la grande alose (Alosa alosa, L. 1758) dans le bassin versant Gironde-Garonne-Dordogne (France) : analyse et prévision par modélisation.* Thèse de doctorat, Ecole Nationale Polytechnique de Toulouse, 115 p

**Munro G. and Scott A. 1985** *The economics of fisheries management* Handbook of Natural Resource and Energy Economics, vol. II, edited by A.V. Kneese and J.L. Sweeney

**Prager M.H. 1994** *A suite of extensions to a non equilibrium surplus-production model* Fishery Bulletin 92:373-389(2)

**Prager M.H. 2005** *User's manual for ASPIC: a stock –production model Incorporating covariates (ver.5) and auxiliary programs* National Marine Fisheries Service Beaufort Laboratory Document BL-2004-01

**Taverny C. 1991** *Contribution à la connaissance de la dynamique des populations d'aloses (alosa alosa et alosa fallax) dans le système fluvio estuarien de la Gironde : pêche, biologie, écologie. Études particulières de la dévalaison et de l'impact des activités humaines*, thèse Cemagref de Bordeaux/Université Bordeaux I, 450 p. + annexes

**Roppars C. 2002** *Analyse des politiques de régulation d'une ressource renouvelable : une application sur le gisement de coquilles Saint-Jacques exploité en baie de Saint Brieux* Thèse de doctorat de l'Université de Rennes 1

**Schaefer M.B 1957** *A study of the Dynamics of the Fishery fot Yellowfin Tuna in the Eastern Tropical Pacific Ocean* Bulletin of the Interamerican Tropical Tuna Commission, Vol 6, n°2, 247-285

**Scott A.D. 1955** *The fishery: the objective of sole ownership* Journal of Political Economy., 63:116-24