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A Cost-Benefit Analysis of Improving Trawl Selectivity: the *Nephrops* norvegicus Fishery in the Bay of Biscay

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Abstract – The mixed Shellfish fishery of *Nephrops* in the Bay of Biscay is characterized by a high level of discards of many species. *Nephrops* trawlers discard about half of their *Nephrops* catches in numbers, and a third in weight. Discarding occurs mainly in the younger age groups. Because of the low percentage of survival after discarding, this loss of *Nephrops* represents a resource that could have been caught and landed later at a larger size. This generates a waste for the stocks as well as for the fleet. A better exploitation pattern through increased size-selectivity would reduce discards leading to a more sustainable situation with a better valorization of the production potential. The paper analyses the biological and economic consequences of several scenarios of selectivity measures. The potential impacts of these scenarios on *Nephrops* biomass, landings, discards and economic indicators (e.g. rent) are analyzed and a cost-benefit analysis of each scenario is discussed. We show that in this kind of fishery, characterized by a high level of discards of the younger age groups below the minimum landing size, reducing discards does not necessarily lead to a negative net present value of rent over a ten year period of simulation. Reducing discards of non market value *Nephrops* would benefit the fishery as it would increase the yield per recruit. Since *Nephrops* is not a bycatch for other fisheries and is mainly exploited by French trawlers, the fleet targeting *Nephrops* would get the long term gains. By taking into account the consequences of the economic dynamics of increasing effort, we show however, that selectivity measures are insufficient to ensure the fishing recovery of the stock and a better exploitation of the production potential. Regulation of access to the fishery is required.

Keywords: *Nephrops* norvegicus; bio-economic simulations; cost-benefit analysis; selectivity; discards; fisheries management

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1- Introduction

Bottom trawls are known to be poorly selective gears. They induce the catch of non targeted fishes that are often discarded (Alverson *et al*., 1994). The targeting of *Nephrops* by trawlers in the bay of Biscay (ICES Divisions VIIIa,b) is characteristic of these situations where high levels of by-catches and large quantities of discards are produced, especially *Nephrops*, Hake, Anglerfish and Megrim. This is the consequence of the use of a low selective gear - bottom trawl with relatively low mesh size - in a multi-species and multi-size ecosystem. In 2004, *Nephrops* discards represented 60% of the *Nephrops* caught, in number of individuals, and 30% in weight (Talidec *et al*., 2005). Because of the high mortality of discards, only a small proportion (30%) of the *Nephrops* discarded survives (Guéguen and Charuau, 1975). This induces a high fishing mortality rate on young *Nephrops* leading to a mis-exploitation of the stock. To date, there is no available quantitative assessment of potential benefits for the fleets of an improved exploitation pattern. The paper analyses the biological and economic consequences of several scenarios of selectivity measures. The stakes of improved size-selectivity measures, aiming at improving the exploitation pattern through gear modifications, appear evident in fisheries characterized by high level of by-catches and discards (Beverton and Holt, 1957; Ward 1994; Shepherd, 1993; Suuronen, 2001, 2006; Pascoe *et al*, 1999).

Selectivity measures allow avoiding catches and discards of the youngest individuals and thus reducing the undesirable additional fishing mortality caused by the discards (MacLennan; 1995; Stergiou *et al*., 1997; van Marlen, 2000; Kvamme and Froysa., 2004; Salini *et al*., 2000). It increases the age at first capture and therefore increases the catch per unit effort and the sustainable total yield (MacLennan; 1995). From an economic perspective, the catches contain larger individuals, which generally receive better prices per weight. The increase in the catch per unit of effort can also lead to landing at a lower cost (Pascoe, 1997). Kvamme and Froysa (2004) demonstrated that a change in selectivity lead towards a more efficient exploitation of the stock's growth potential, allowing a larger amount of fish to reach mature size and spawn. This increases the spawning biomass and as a consequence the fishery is less dependent on recruitment. More stable catches are allowed. Some papers also show that selectivity measures can lead to high short term losses for the fleet (Griffin and Oliver, 1991; Ferro and Graham, 2000; Heikinheimo *et al*., 2006; Tchernij *et al*., 2004). The perspective of high short-term economic losses for the fleets, compared to uncertain long-term gains, is used as an argument by fisheries managers to reject the use of more selective gears or to negate their effect. However, reducing discards does not necessarily mean a reduction in landings. When selectivity only affect the discarded fraction of the catches, landings can be unchanged.

The objective of this paper is to provide a cost-benefit analysis of selectivity measures, using a bioeconomic model of the *Nephrops* fishery in the Bay of Biscay. Only a few papers are available in the literature on this subject (see OCDE 1997, 2000; Suuronen 2001, Halliday and Pinhorn, 2002, Freese *et al*., 1995; Lucena and O'Brien, 2005; Boncoeur *et al*., 2000). Griffin and Oliver (1991) estimated that the introduction of turtle excluding devices in the Gulf of Mexico shrimp fishery would cost an average of US$1 million calculated as the net present value of rent losses over a ten-year period. However, in this case an increase in catches and a change of the landings distribution (more larger fishes) to offset the short-term losses does not follow the adoption of the device. Hendrickson and Griffin (1993) estimated that a device that would remove some fish from the by-catch of the shrimp fishery in the Gulf of Mexico would cost between US$1.6 million and US$2.7 million a year in lost rent.

However, all the potential long-term benefits are not taken into account in these papers. High short-term losses are the consequence of the decrease in the by-catch of valuable species and sizes.

In order to assess the cost-benefit analysis of improving selectivity measures in the case of the *Nephrops* fishery, a bio-economic deterministic simulation model is developed. The model framework is based on an age-structured model for the *Nephrops* stock with several fleets targeting *Nephrops* and considers effort as exogenous or endogenous. The model is able to produce different indicators over the simulation period, such as stock biomass, catch, landings, discards, gross revenue and producer surplus (rent) used for the cost-benefit analysis.

The paper is organized as follows. The first section presents the *Nephrops* fishery in the Bay of Biscay. We describe the current structure and activity of the trawler fleet targeting *Nephrops*, the level of *Nephrops* discards and the related mis-exploitation pattern of the fishery. A short description of the different regulation measures implemented to manage the fishery is also provided. The second section presents the framework and the equations of the bio-economic model as well as the basic information used to parameterize the model. Only the dynamics of the *Nephrops* stock is included in the analysis. We then present, in the third section, the results for the relevant indicators of six selectivity scenarios, both at equilibrium and during the transition phases. The cost-benefit analysis is then assessed based on the assumption that effort is either constant or adjusted to the profitability of the vessels. In conclusion, we discuss the limits of managing fisheries with only selectivity measures and the need to also adopt right based approaches for the regulation of the fishery.

2 – The *Nephrops* fishery in the Bay of Biscay

Fleet structure and main economic indicators
Nephrops is targeted by bottom trawlers on a sand-muddy area called the “Grande Vasière” (ICES Divisions VIIIa,b). The *Nephrops* trawler fleet is one of the most important segments of the French fleet in the Bay of Biscay representing around one quarter of the french trawlers in this area (Berthou *et al*, 2004). In 2003, 234 bottom trawlers were involved in the *Nephrops* fishery (Figure 1).

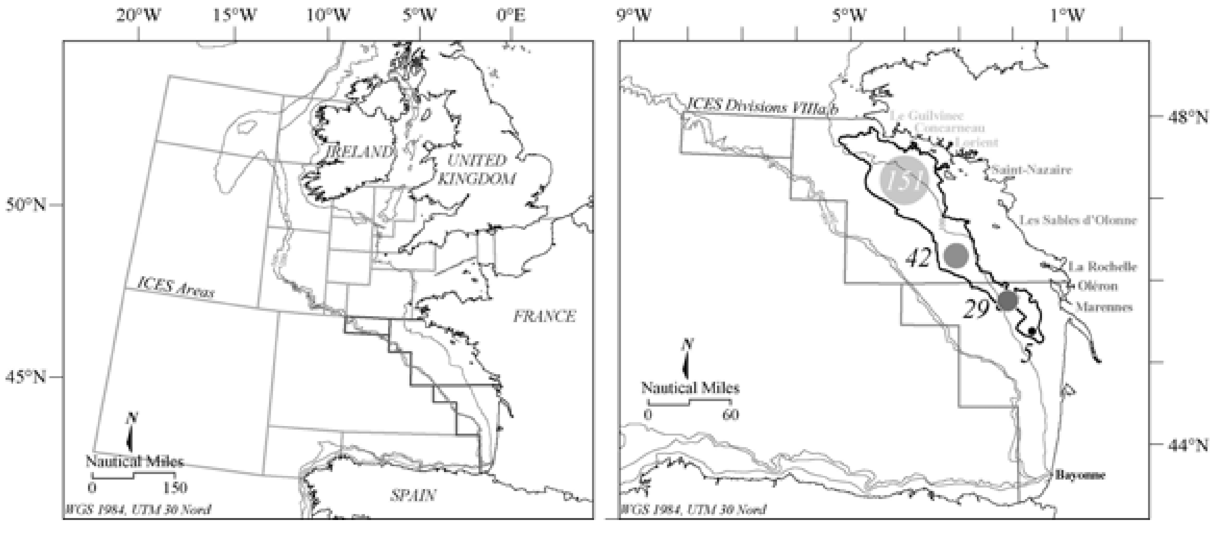

Figure 1: Nephrops Fishery in the Bay of Biscay (ICES Divisions VIIIa,b), Source: IFREMER

The fleet is composed of trawlers with an average length of 15 meters, 235 kW of engine power and a mean age of 19 years. The mean crew size is three members. *Nephrops* trawlers spend around 200 days at sea per year and the duration of the trips varies from 12 hours to 3 days. During the 1990's single trawls were replaced by twin-trawls which are now the common gear used to target *Nephrops*. Table 1 provides the key physical and economic figures about the *Nephrops* fleet[1].

Crew Categories	Number of vessels	Mean length (m)	Mean number of days at sea per year	Mean Vessel Value (k Euros)	Total Gross return (millions Euros)	Average Gross return per vessel (k Euros)
[1,2]	53	12	199	191	8	153
]2;3]	70	15	199	304	19	279
]3;4]	54	16	201	368	18	343
]4;5]	50	17	217	532	24	482
]5;]	10	18	225	801	6	630

Table 1: Distribution of the vessels per crew category and mean characteristics for 2001-2003.

The total gross revenue of the fleet was 82.4 M€ for the year 2003 for an added value of 45 M€ (Daurès *et al*., 2002). In 2003, 3900 tonnes of *Nephrops* were landed generating a gross revenue of 33.2 million €[2].
Nephrops contributes for 40% on average to the total gross revenue but varies from the North to the South of the fishery. The average proportion of *Nephrops* in the total gross revenue is 51% in the Northern part of the fishery (vessels operating from Brittany: Le Guilvinec, Lorient and Concarneau) and 25% in the other regions. The other part of the total gross revenue comes from the multi species landings that characterize this mixed fishery (Table 2). The Northern part of the fishery concentrates 72% of the *Nephrops* trawlers and catches 60% to 70% of the *Nephrops* landed.

	Production (tonnes)	Value (kEuros)	% of the Total Gross Revenue
Northern fleet			
Anglerfish	814	3896	8%
Nephrops	3053	24993	52%
Hake	934	3408	7%
Sole	332	3658	8%
Other species	5414	11852	25%
Total Northern fleet	10547	47808	100%
Fleet from other regions			
Anglerfish	268	1485	5%
Nephrops	873	7129	25%
Hake	508	1848	7%
Sole	453	4471	16%
Other species	5526	13300	47%
Total Other Regions	7628	28234	100%

Table 2: Mean Quantity, value and percentage of the total gross revenue of the main by-catches of the *Nephrops* fishery per region (2001-2003).

Nephrops discards and mis-exploitation

[1] The fleet segmentation is based on crew categories rather than on vessel length categories in order to improve the homogeneity of gross revenues and cost structure.
[2] Almost all Nephrops landings are caught by the French trawlers. 96% of the Nephrops TAC in this area is allocated to France, the remainder being allocated to Spain.

In 2004, the *Nephrops* discards were estimated at 1875 tonnes, representing 60% of the *Nephrops* caught in number and 30% in weight (Talidec *et al*., 2005)[3]. As shown in Figure 2, most of the catches of *Nephrops* of the first two age groups are discarded. 70% of the population in number (ICES, 2004) belong to the first two age groups, 11 % of those two age groups are caught and 91% of those catches are then discarded. The stock is considered too dependent on recruitment and ACFM (ICES, 2004) advised improving the survival rate of recruits in order to increase the spawning stock biomass. This would ensure sustainability of exploitation and would reduce the risk of low recruitments.

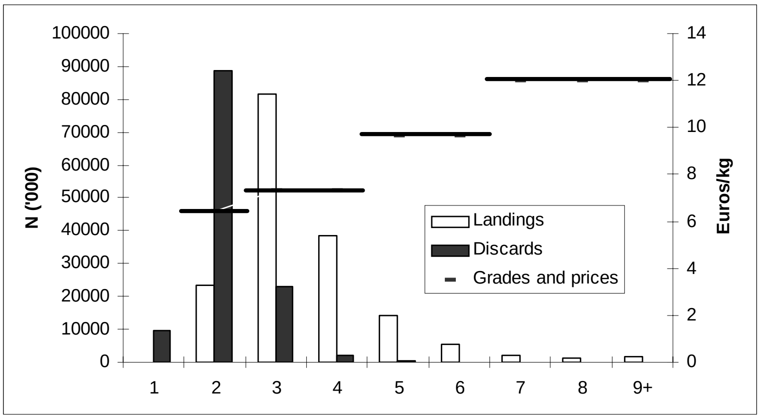

Figure 2: Landings and discards of *Nephrops* in number of individuals per age group mean 2001-2003 – Mean price per age and grade (2001-2003)

The high level of catches and discards of younger age groups below the minimum landing size also contributes to the economic inefficiency of the exploitation. Discards are made up of *Nephrops* that, if not caught, could be landed and sold later at a larger size. On this issue, the ACFM (ICES, 2004) underlined that the current fishing mortality on young age groups, especially because of discards, is too high to yield the maximum level of production. The impact is even stronger in terms of value of the production, as prices increase with the length (or age) of the *Nephrops*. Grade 40 made up of the smallest *Nephrops* in age 2 had a mean price of 6.5 euros per kilo for the period 2001-2003 compared to grades 30 (ages 3 and 4), 20 (ages 5 and 6) and 10 (ages 7, 8 and 9+) which obtained a mean price of 7.3, 9.7 and 12 euros per kilo, respectively.

The management system

The management of the *Nephrops* Fishery in the Bay of Biscay essentially relies on conservation measures (Guyader *et al*., 2005 (b)). For a long-time, a minimum landing size (MLS) of 26 mm Cephalothoracic Length, *i.e.* 8.5 cm total length, was adopted by the French Producers' Organisations. This MLS is larger than the EU MLS set at 20 mm CL *i.e.* 7 cm total length. Since December 2005, a new French MLS regulation (9 cm total length) has been established. Several regulations regarding the mesh size were adopted successively these last few years. In 2000, the minimum codend mesh size in the Bay of Biscay became 70 mm[4] instead of the former 55 mm for *Nephrops* (Council Regulation (EC) No 850/98). A Total Allowable Catch (TAC) has been in force since 1987 together with technical measures. In 2004, the TAC was set at 3100 t, which means a French quota of 2976 t (96% of the TAC).

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[3] Estimates of discards are also high for other species. Because of the overlap of the spatial distribution of the Hake nursery and the activity of the non selective Nephrops fishery, 97% of hake caught were discarded in 2004.
[4] 100 mm mesh size is required in the *Hake* box but in 2006, it should be noted that *Nephrops* trawlers are allowed to fish, for one year, in the hake box with the current mesh size of 70 mm provided that a square mesh panel of 100 mm.

The TAC is allocated by Producers Organisations but there is no individual quota allocation. Besides these conservation management measures, the *Nephrops* fleet has been submitted to national vessel decommissioning schemes that explain partially the decrease in the number of vessels targeting *Nephrops.* They were 400 vessels in 1978, 300 in 1987 and are around 230 since 2000. However the decrease in the fishing effort was compensated at least in part by gains in the efficiency of the vessels due to technical creeping (Guyader *et al.*, 2005 (a)). In 2004, licences were established and a non-constraining *numerus clausus* of 250 *Nephrops* trawlers was adopted. The fishery was in an open access situation before. However no limitation on the fishing effort (number of trips for example), gear or individual catches is implemented. The following section presents a cost-benefit analysis of different selectivity measures.

3 - The bio-economic model

A bio-economic model was developed in order to carry out a cost-benefit analysis of several selectivity scenarios. Ten sub-fleets are defined according to costs structure. We present the framework of the model defining the link between the economic situation of the sub-fleets, the dynamics of the *Nephrops* stock, and selectivity scenarios. The conceptual model is given in Figure 3.

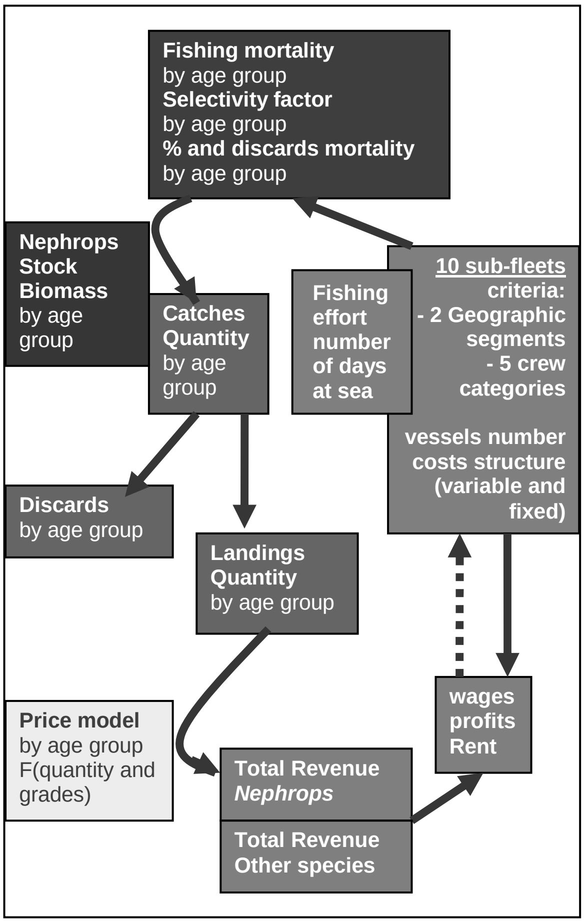


Figure 3: Schematic representation of the bio-economic model

The biological model is age-structured. All things being equal, improved selectivity reduces the fishing mortality of the *Nephrops* stock (especially the younger age groups), which is also subject to natural mortality and individual growth. The dynamics of the other species harvested by the trawlers are not taken into account in the analysis either because the mortality contribution of the *Nephrops* fleet to these species is low or the fishing mortality mainly concerns the young age groups. In such cases, the feedback effects of change in selectivity on these species should be very limited or benefit only other fleets. Based on input fleet nominal effort and gear selectivity, the model provides *Nephrops* catches, discards and landings. Total revenue per vessel depends on the *Nephrops* landings, the prices given by a price model and on the revenues of other species. Wages, profits per vessel and total surplus per sub-fleet are calculated, time step, according to the average cost structure of each sub-fleet. The economic model is static as we assume in this paper that fishermen are able to change neither their nominal effort level, nor their catch composition.

The key equations used to model the dynamics of the *Nephrops* fishery are the following.

The biological model

The dynamics of the *Nephrops* stock is represented by a biological model structured by age groups *i*. The model is annual and the subscript for time is *t*. For each age group i+1, $i \in [1,7]$ the *Nephrops* stock number for year t+1 is calculated using the survival equation of Beverton and Holt (1957) (Gulland, 1983; Hilborn and Walters, 1992):

$$N_{i+1,t+1} = N_{i,t} e^{-Z_{i,t}} \text{ if } 1 < i+1 < 9 \qquad (1)$$

where $N_{i+1,t+1}$ is the number that survives at age i, $N_{i,t}$ is the number of individuals of age i in year t and $Z_{i,t}$ is the total mortality.

$Z_{i,t} = mF_t F_{i,t} S_i + M$ with $F_{i,t}$ the fishing mortality at age i for year t [5], S_i the relative selectivity of the fishing gear at age i in percentage compared to the reference (initial selectivity being taken into account in F_i), mF_t, a multiplying factor to the fishing mortality that enables increases or decreases in fishing effort to be taken into account and M, the natural mortality, variable with age but assumed constant on the simulation period

Thus, $$N_{i+1,t+1} = N_{i,t} \times e^{-mF_t . F_{i,t} . S_i - M} \qquad (2)$$

As age group 9 is a plus group, equation (1) needs to be modified:

$$N_{9,t+1} = N_{8,t} . e^{-Z_{8,t}} + N_{9,t} . e^{-Z_{9,t}} \qquad (3)$$

The biomass of *Nephrops* in year t is calculated as follows:

$$B_t = \sum_i N_{i,t} . w_i \qquad (4)$$

with w_i the mean weight at age i, calculated by using the Von Bertalanffy growth curve and the length-weight relation parameters estimated by the ICES (ICES, 2000); it is assumed to be constant over the simulation period.

[5] The fishing mortality considered here takes into account the survival of 30% of the discards that return to the stock (see also Mesnil, 1996). It corresponds to the fishing mortality of the removals (landings and dead discards)

The stock data used in the simulation are those adopted by the ICES *Nephrops* working group for short term predictions, based on the results of the 2004 assessment (Table 3). The biological parameters of the model are presented in appendix 1.

Age groups i	Fishing mortality Fi (2003)	Mean weight Wi(2003)	Stock size Xi (2003)	Natural Mortality M	Maturity ogive
1	0.0201	0.0040	452366	0.3	0.5
2	0.2926	0.0090	380567	0.25	1
3	0.4842	0.0170	259802	0.25	1
4	0.4971	0.0260	121356	0.25	1
5	0.5149	0.0360	48339	0.25	1
6	0.4455	0.0510	19541	0.25	1
7	0.3981	0.0590	9159	0.25	1
8	0.4753	0.0640	4641	0.25	1
9+	0.4753	0.0700	6740	0.25	1

Table 3: *Nephrops* Stock data (ICES, 2004)

Catches (in numbers) of age group i during year t are calculated using the conventional catch equation:

$$C_{i,t} = X_{i,t}(1-e^{-Z_{i,t}})(mF_t.F_{i,t}.S_i)\big/Z_{i,t} \quad (5)$$

The total catch in weight for the year t, Y_t is the sum of the catches in weight per age group for the year t (Thompson and Bell, 1934) given by multiplying catches in number per age group for the year t by the mean weight at age. Discards $D_{i,t}$ per age group in weight are derived from the *Nephrops* catches $C_{i,t}$, the percentage of Nephrops discarded in number per age group $d_{i,t}$ and the mean weight at age.

Data obtained from the observations and sampling on board (IFREMER-Obsmer) give the preliminary results of discarding proportion in number per age group, presented in table 4.

Age groups i	di(t)
1	96%
2	75%
3	28%
4	7%
5	4%
6	4%
7	1%
8	1%
9+	0%

Table 4: Percentage of *Nephrops* discarded in number per age group
Source: data Obsmer June 2002 to September 2004

Landings per age $L_{i,t}$ in weight are deducted by subtracting discards from the catches. Recruitment is assumed to occur once at the beginning of the year and to be constant over the simulation to compare the potential benefits of the different selectivity scenarios. It is calculated as the geometric mean of the estimated recruitment over the last ten years (ICES, 2004; $GM_{1994\text{-}2003}$=555 millions individuals). Assuming constant recruitments over the whole simulation period is a strong hypothesis which may be reasonable for stocks exploited at a level where the spawning biomass is not reduced to a low level. While this hypothesis is probably valid in the case of constant effort, this may not be the case for the variable effort simulations. An alternative way would be to incorporate a stock-recruitment relationship which would explicitly predict the recruitment level based on current spawning stock biomass. However, at present, such a relationship has not yet been established for the

Nephrops stock (ICES, 2004). Sensitivity analyses on the recruitment level were therefore carried out.

The biological analytical model enables the catches, landings and discards of *Nephrops* per age group to be calculated for different selectivity measures simulated for each year of the simulation.

The static economic model

The economic model takes a fleet-based approach. Ten sub-fleets f are defined according to cost structure correlated with five crew size categories and the geographic area (Northern or Southern part of the fishery) (see section 2). The number of vessels and the nominal effort per sub-fleet is considered constant over the simulation period. Input values of the model are mean values for the period 2001-2003. As data on discarding rates per sub-fleet are not available, the *Nephrops* fishing mortality for the whole fleet is allocated by sub-fleet in proportion to their *Nephrops* landings from the reference period 2001 to 2003 instead of removals. Catches are then calculated using the catch equation and landings and discards are deduced assuming that the discarding rate is the same for all the sub-fleets.
From *Nephrops* landings per sub-fleet, it is possible to calculate the *Nephrops* gross revenue of the sub-fleet f for year t, $G_{N,f,t}$ defined as:

$$G_{N,f,t} = \sum_i P_{i,t} L_{i,f,t} = \sum_i P_{i,t} (Y_{i,f,t} - D_{i,f,t}) \qquad (6)$$

where $P_{i,t}$ is the *Nephrops* price of age group i as a function of the total landings of the age group, $L_{i,f,t}$ the landings of age i by sub-fleet f, $Y_{i,f,t}$ the catch of age group i and $D_{i,f,t}$ the discards of *Nephrops* of age group i caused by sub-fleet f. The proportion of discards per sub-fleet is considered to be constant in the analysis. The price model is based on the estimation by Metz (2004, personal communication):

$$\ln P_{i,t} = \alpha_{i,t} + \beta_{i,t} \ln L_{i,t} \qquad (7)$$

$\alpha_{i,t}$ is a constant for grade corresponding to age group i, $\beta_{i,t}$ is the price elasticity parameter for each grade and $L_{i,t}$ is the amount of landings of age group i for the total fleet. The price of age group 1 is assumed to be constant, equal to the mean withdrawal price applied according to the Common Fishery Policy regulation[6]. Landings $L_{s,f}$ and price $P_{s,f}$ of other by-catches species are assumed to be constant over the simulation period.
The total gross return of sub-fleet f for year t $G_{f,t}$ is then given by summing the *Nephrops* gross revenue and the gross revenue from other species.
$G_{fv,t} = G_{f,t} / V$ is the average revenue per vessel in sub-fleet f, V being the number of vessels in each sub-fleet.
The net revenue for a vessel in sub-fleet f is:

$$NR_{fv,t} = (1 - lc_{fv}) G_{fv,t} \qquad (8)$$

with lc_{fv} the landing cost rate.

[6] Nephrops of age group 1 are below the minimum landing size fixed by the Producer Organization., They should therefore not be sold on the fishing market. However, we assume here a black market that would enable the small Nephrops to be sold at the withdrawal price

The difference between the vessel net revenue and the so-called shared costs gives the return to be shared $RS_{fv,t}$ with the shared costs defined as:

$$SC_{fv,t} = fuelc_{fv} E_{fv,t} + baitc_{fv} + icec_{fv} + foodc_{fv} \quad (9)$$

Nominal effort $E_{fv,t}$ is expressed here in terms of hours at sea. Fuel costs may vary according to the effort but nominal effort is assumed to be constant in this simulation.

Crew remuneration, based upon the share remuneration system between the owner and the crew is given by multiplying the crew share rate by the return to be shared, and the Vessel Share $VS_{fv,t}$ is obtained by subtracting the crew share to the return to be shared.

The net crew share $NCS_{fv,t}$ is the difference between the crew share and the social insurance costs as a function of the social insurance unit cost, and the vessel crew size.

The labour surplus or rent earned by the crew of sub-fleet vessel can be calculated as:

$$LS_{fv,t} = NCS_{fv,t} - OCLh_{fv,t} \quad (10)$$

with $OCLh_{fv,t}$ the opportunity cost of labour defined as the product of the crew size, the hours spent at the fishing activity by the crew and the hourly unit price of labour elsewhere in the economy[7].

The vessel gross surplus is the difference between the vessel share and other variable costs $ovac_{fv}$ (gears)[8] and fixed costs $ovec_{fv}$ (insurance, firm management costs, etc.)

$$GS_{v,t} = \sum_{m \in M_v} \left(VS_{fv,t} - ovac_{fv} . E_{fv,t} - ovec_{fv} \right) \quad (11)$$

The capital surplus $CS_{fv,t}$ earned by the vessel owner is then defined as the difference between the vessel gross surplus, the capital annual depreciation and the opportunity cost of capital:

$$CS_{fv,t} = GS_{fv,t} - depc_{fv,t} - OCK_{fv,t} \quad (12)$$

with $depc_{fv} = k_{fv} . K_{fv}$, the capital depreciation calculated as a depreciation rate k_{fv} applied to the value of the vessel K_{fv} and $OCK_{fv} = oppIr_{fv} . K_{fv}$, the opportunity cost of capital K_{fv} invested elsewhere in the economy at rate $oppIr_{fv}$ [9].

Finally, the main indicator used for the cost-benefit analysis is the producer surplus or rent defined as follows:

$$PS_t = \sum_{f,v} LS_{fv,t} + \sum_{f,v} CS_{fv,t} \quad (13)$$

[7] The opportunity cost of labour corresponds to the best alternative remuneration for the fishermen. We consider that all fishermen have the same qualification that gives them the same alternatives. The opportunity cost of labour was calculated using the annual minimum net wage in force (13850.16 euros calculated on a 35 h weekly basis). The hourly unit price used is 7.19 euros.

[8] Selectivity measures can imply an increase in gear costs due to either gear change or selective device adoption. However, we assume in the model that those costs are negligible with regards to the other costs taken into account.

[9] The mean long term rate of interest in France over the 2001-2003 period (4.6%) was used as a proxy for the opportunity cost of capital (OCDE, Principaux Indicateurs Economiques, juillet 2004)

The net present value of different selectivity scenarios discounts, at a given rate r, the annual rent flows over the simulated period $n = 1,...,T$ according to the following equation:

$$NPV = \sum_{n=1}^{T} PS_t \big/ (1+r)^n \qquad (14)$$

Economic and technical parameters are derived from the surveys organized by Ifremer (Berthou *et al*. 2003). Data used for this paper were collected for the years 2001 to 2003 on a representative sample of vessels of each sub-fleet and all the parameter estimates were calculated per sub-fleet. The structure of revenues and costs per sub-fleet is provided in appendix 2.

Integration of the dynamics of effort

An alternative version of the model is provided, that assumes effort is not constant but endogenous[10]. We assumed that the number of vessels does not change[11]. We assume that the fishermen are incited to increase their effort as long as the surplus formed is higher than the surplus that they would encounter in an alternative fishery, which means, when there is a differential rent between the fisheries. When the surplus formed in the *Nephrops* fishery becomes equal to that of the alternative fishery, the effort is adjusted according to the opportunity cost of changing fishery. We assume, however, that this opportunity cost is high and that fishermen are incited to stay in the same fishery.

In the model of the dynamics of effort, the assumption is that, each year, the ship-owner is incited to adjust his nominal effort expressed in number of days at sea in the current year $Nds_{v,t}$ relative to a reference year according to the following equation:

$$Nds_{v,t} = Nds_{v,ref} \left(\frac{PS_{v,t-1} - PS_{v,ref}}{PS_{v,ref}}\right) \qquad (15)$$

$Nds_{v,t}$ varies proportionally with the growth of the producer surplus between the last period and the period used as the reference[12].

However, we assume that the number of days at sea per vessel cannot be higher than 260 days per year, which corresponds to the case where fishermen fish five days a week all the year without any inactive period or weather conditions that would not enable them to fish.

The fishing mortality $F_i(t)$ is a function of the number of days at sea in year t $Nds(t)$ for the fleet. When the effort varies, the fishing mortality is adjusted according to the following equation:

$$F_{i,t} = \frac{Nds_t}{Nds_{ref}} . F_{i,ref} \qquad (16)$$

Year 2004 is the reference for effort and fishing mortality in the dynamic model of effort and $Nds(t) = nb_{Vessel} . Nds_{v,t}$

with $Nds_{v,t}$, the mean number at sea per vessel in year t.

4 – Selectivity scenarios and simulation results

[10] This methodology has also been used in other bio-economic models (MEFISTO Guillen *et al*., 2004).

[11] Entry into the fishery is limited by licences (PPS)

[12] A reference surplus is defined as the mean surplus per vessel for 2001-2003

The selectivity scenarios studied in this paper consist in varying the selectivity factor leading to an improvement in the exploitation pattern of the *Nephrops* for the fleet. These improvements could be achieved in practice either through the adoption of selective devices or mesh size increases[13]. In the simulation model we assume that the selectivity is specific for *Nephrops* and does not affect the catch of other by-catch species. Such selectivity is close to the objectives followed by experimentations on *Nephrops* grids that aim to enable the *Nephrops* juveniles to escape, while other valued by-catches are retained in order to limit the losses on commercial catches. We assume that the same selectivity is applied to each sub-fleet. The status quo scenario 1, used as a reference scenario, does not consider any change in the fleet's exploitation pattern. Scenarios from 2 to 6 assume that there is no catch (therefore no discard) of *Nephrops* under age 2 to 6, respectively (see Table 5 for corresponding *Nephrops* lengths).

Scenario	1	2	3	4	5	6
No Catch below age	Statu quo	2	3	4	5	6
No Catch below	Statu quo	6.3 cm	8.8 cm (MLS*)	10.4 cm	11.8 cm	13.1 cm

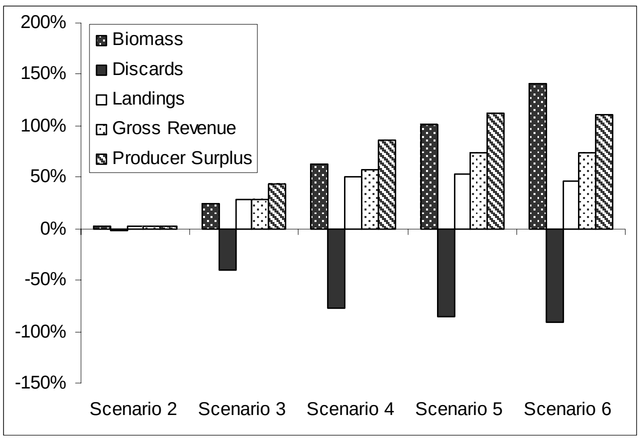
*Minimum Landing Size

Table 5: Selectivity scenarios simulated

Scenario 3 considers no catches of *Nephrops* under age 3. The limit size between age 2 and 3 corresponds to a *Nephrops* length of 8.8 cm, that is, about the minimum landing size established by the current regulation. Scenario 3 is equivalent to a scenario assuming no catch and no discard of *Nephrops* below minimum landing size. We assume that changes in the selectivity factor are implemented in 2004. The potential impacts of these selectivity scenarios on the evolution of discards, biomass, landings, gross revenue, average gross surplus per vessel, and producer surplus of the fleet are analyzed over the 2004-2015 simulation period.

Status of the fishery at equilibrium

Based on the assumptions of the biological model (in particular, a constant recruitment hypothesis) and the assumption that the fishing effort is exogenous and remains constant throughout the simulation period, equilibrium situations are reached after a relatively short time period, between 5 and 7 years. The status of the fishery in the final year is given in Figure 4 for each selectivity scenario compared to the status quo situation.



[13] Experimentations on Nephrops grids (a 13 mm gap grid, a 15 mm gap grid and recently a 20 mm gap grid) have been conducted since 2004 by Ifremer with representatives of the industry. These selective devices enable the escapement of the smallest Nephrops, other by-catches being retained. However, it is not possible, at this date, to use the results of the observations on board.

Figure 4: Indicators in the last year of simulation as a function of selectivity scenarios

Concerning discards, the status quo and scenario 2 are almost equivalent. Scenario 3 reduces discards by 40% and scenarios 4, 5 and 6 reduce the discards by 77 %, 85%, 90% respectively. These are low levels compared to the current discard of around 1200 tonnes per year. According to the simulations carried out, the change in the exploitation pattern with a constant nominal effort has a positive impact on the biomass. By adopting scenario 3, the biomass is restored up to the objective of 18000 tonnes established by ACFM (ICES, 2004). In the case of scenario 5, the biomass would be multiplied by two[14]. In terms of landings and revenues for the fleet, the consequences of scenario 2 on the landings and revenues are close to those provided by the status quo scenario. Compared to the status quo, scenario 3 provides at equilibrium, a 30% increase in landings and total revenue (4700 tonnes and 41 m€, respectively). Average gross surplus of the sub-fleets is also improved but the impact varies according to the sub-fleets. For example, the increase of the gross surplus of the 3 crew size vessels of the northern region is around 52% and only 30% for the same crew size vessels of the southern region. Vessels operating in the southern part of the fishery are indeed less sensitive to an improvement in the stock situation than vessels operating in the northern part of the fishery as *Nephrops* represent a lower share of their landings and gross revenues. Scenarios 4, 5 and 6 also benefit the different fleets at equilibrium compared to the status quo situation but, beyond scenario 5, landings decline. This decline in landings between scenarios 5 and 6 is, however, partly compensated by an increase in price implying a quasi stabilization in the fleet total revenue and producer surplus around 55 and 42 millions euros respectively. The fleet may benefit from a 112% increase in producer surplus without any change in nominal effort; however these scenarios would meet little compliance among the fishermen.

Transition phases

Despite long term benefits to the stock and the fleets, the fleet has to cope with transition phases towards equilibrium situations. The simulation of scenario 3 indicates that there is not only no short term decrease but increases in landings because escapement mainly concerns discards and the subsequent biomass increase quickly improves the catch per unit of effort of the fleet (fig.4). However, the landings reduction during the first year is 12%, 47% and 73% for scenarios 4, 5 and 6, respectively. These negative impacts on landings are smoothed in terms of revenues by positive price effects. The increase in price when quantities landed are lower can indeed contribute to the offset of the potential short term decrease in the landings[15]. However revenues changes are significant for scenarios 5 and 6. Higher is the escapement due to the selectivity; longer are of course the negative impacts on landings and revenues.

[14] However, the increase of the biomass might be limited by the load capacity of the ecosystem.

[15] Besides the elasticity price-quantity, an improvement in the quality of the landings can be observed when adopting a selective device. This can be compensated by a better price.

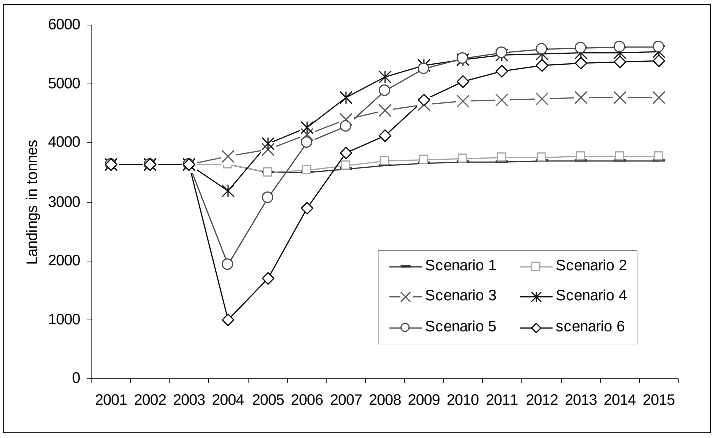


Figure 5: Evolution of the *Nephrops* landings

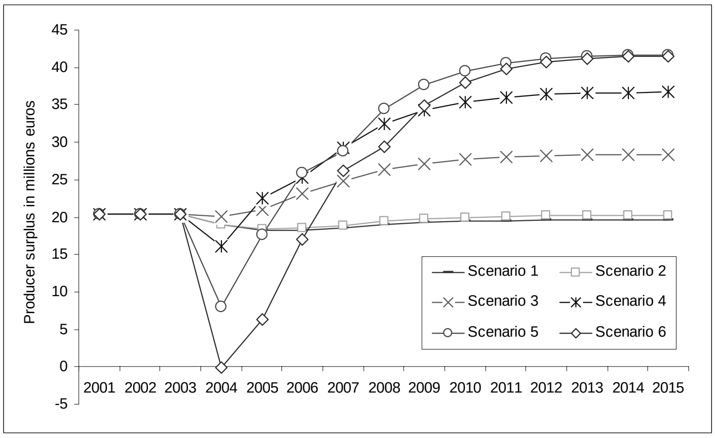


Figure 6: Evolution of the producer surplus

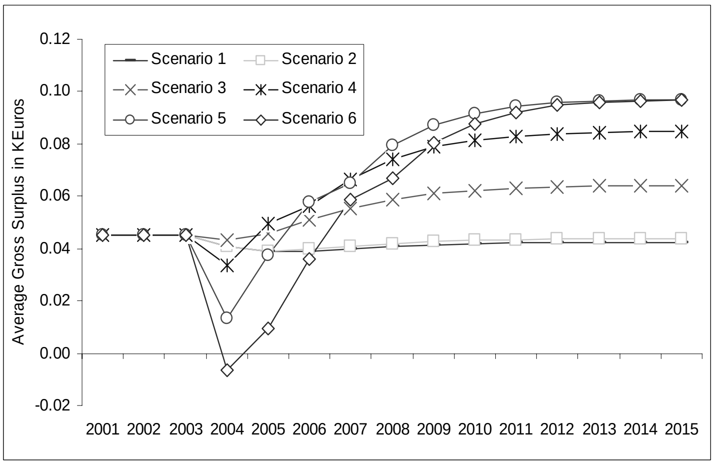


Figure 7: Evolution of the average gross surplus of the 3 crew size vessels in the northern region.

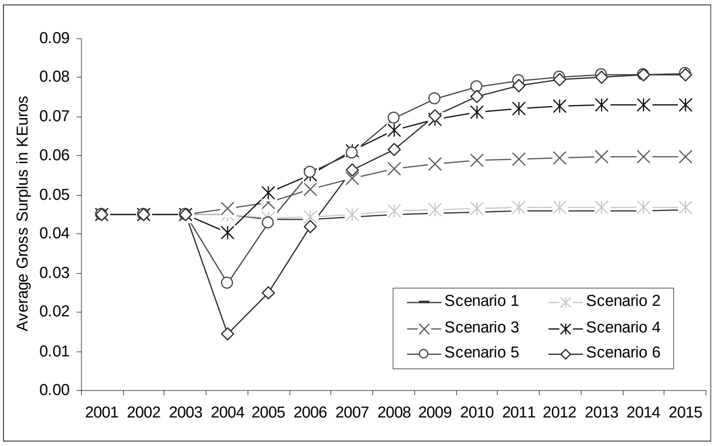


Figure 8: Evolution of the average gross surplus of the 3 crew size vessels in the southern region.

The transition phases could be critical for the short term viability of the fleets and the evolution of the gross surplus can be used as a relevant indicator for this issue (Figure 6-8). The biggest constraint for vessel owners is to pay back their loans with their current gross surplus flow[16]. If the fishing firm gross surplus is negative or too low to cover the interest payments, then the viability of the firm could be threatened. As illustrated in figure 7, the average gross surplus of the 3 crew size vessels in the northern region is negative in 2004 for scenario 6. It is below the level required to pay back the average loans level of these firms (0.02 kEuros). This means that the fishing firms would have to cope with this situation by drawing from their available treasury funds.

As shown in figures 5 to 8, significant increases in landings, gross revenues, gross surplus and producer surplus follow short term reductions even under the "reasonable" scenario 3. These long term gains may offset the short term losses if any.

Situation of the fishery when fishing effort is endogenous

In order to take into account the dynamics of fishing effort, runs assuming endogenous effort were also carried out. The model then assumes that each fisherman adjusts his effort according to the growth in this individual surplus. The total landings of the fleet in the case of endogenous effort can be compared with the landings in the case of constant effort (Figure 9).

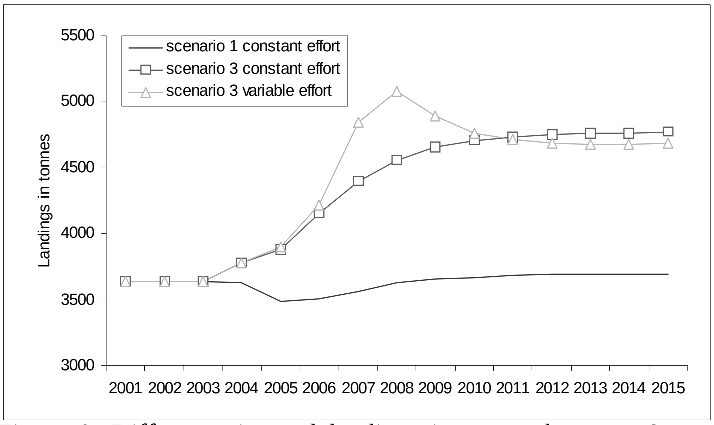


Figure 9: Difference in total landings in tonnes between Scenario 3 at constant effort and Scenario 3 with endogenous effort

[16] They also have to save funds to compensate for capital depreciation in order to have the possibility of investing in a new boat at the end of its life time, but this constraint can be delayed over several years.

We observe that an increase in effort induces higher total landings the first years of the simulation then, when effort stabilizes to the upper limit of 260 days at sea per year, the total landings decrease.
The analysis of landings per unit of effort (LPUE) shows that an increase in effort decreases the LPUE and, as a consequence, decreases the surplus per effort unit (Figure 10).

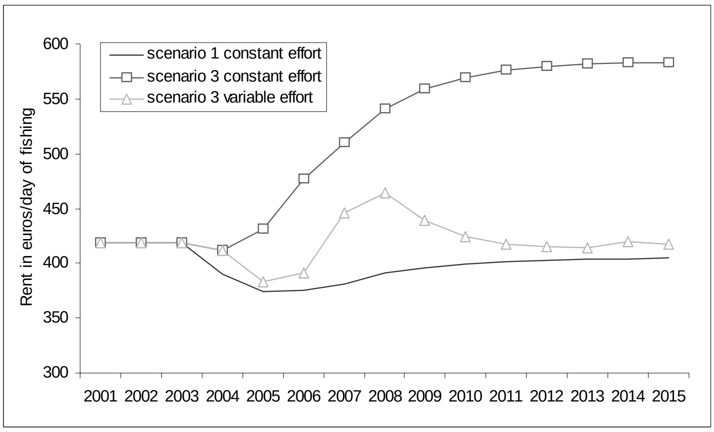


Figure 10: Difference of Surplus per effort unit (day of fishing) in euros between Scenario 3 at constant effort and Scenario 3 with endogenous effort

When fishing effort increases, the surplus per effort unit remains below the surplus corresponding to constant effort throughout the simulation periods.

Cost-benefit analysis

The cost-benefit analysis is carried out by using the classical net present value formula (see equation 14) converting the future expected flows of costs and benefits for the fleets to a present value amount. The net present value calculations for the selectivity scenarios are based on different assumptions for the discount rate. The discount rate measures the time value of money for the decision-makers or fishery managers initiating the selectivity project. In line with this, more weight is given to earlier costs and benefits than later ones by applying a discount rate. Simulation results show that whatever the scenario selected, the fishery provides positive producer surplus or rents. The net present value of producer surplus over the 2004-2015 periods is calculated for the six scenarios and according to different discount rates (Table 6).

Discount Rate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
2%	187	191	250	300	312	273
4%	167	170	222	266	274	238
6%	150	153	199	236	242	207
8%	136	138	179	211	215	182
10%	123	126	162	189	191	160
12%	113	115	147	171	171	142
14%	103	105	134	155	154	126
16%	95	97	123	141	139	112
18%	88	89	113	129	126	101
20%	82	83	104	119	115	91
22%	76	77	97	109	105	82
24%	71	72	90	101	97	74
26%	67	68	84	94	89	67
28%	63	64	79	87	82	61
30%	59	60	74	82	76	56

Table 6: Net present value of producer surplus (rent) in million euros over the 2004-2015 period according to discount rates between 2% and 30%.

We observe that for low discount rates, the net present value of producer surplus is higher when the scenario is more selective, except in the case of scenario 6 that induces important

short term losses. Adopting more selective gears may benefit the fleet but the optimal scenario changes as a function of the discount rate. When the rate becomes higher (up to 10%) it may be preferable for the producer to adopt a selectivity corresponding to scenario 4 instead of scenario 5. However we have to consider very high discount rates to find a selective scenario worse than the status quo. This case only occurs for scenario 6 and for a discount rate of 30%.
One important problem is therefore to choose the relevant interest rate; Arrow *et al*. (1996), and Portney and Weyant (1999) have discussed this issue. They suggest adopting an opportunity cost approach for the cost-benefit analysis of public projects especially to reduce environmental impacts (pollution, etc.) and to use a 4% rate[17]. Applied to our case study, the public authorities could be the European Union, the French government or regional public authorities, interested in "investing" in this type of public project by lending to the fishermen in order to compensate their short term economic losses compared to the status quo situation[18]. In this case, scenario 5 providing the highest discounted rent (274 million Euros) should be adopted (Figure 11). The net benefit of this scenario is 74%, 23%, 3%, 15% higher than the status quo, scenarios 3, 4 and 6, respectively.

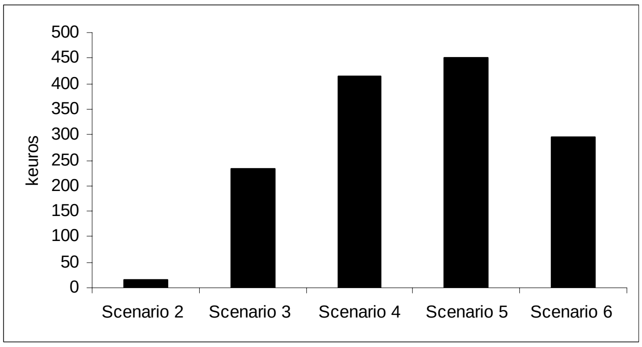


Figure 11 - Difference between the rent corresponding to a scenario of selectivity and the rent of status quo in keuros for an average vessel (discount rate 4% over the 2004-2015 period)

If fishermen or their representative organizations decide by themselves to borrow money from the banks in order to cover the short term reduction in producer surplus or gross surplus, they probably would not fund fishermen at a 4% interest rate but at a rate including a risk premium. Up to a 12% interest rate the best option is always scenario 5 that would provide 171 millions Euros rent over the 2004-2015 period. Above 12% interest rate, scenario 4 should be preferred.
Scenario 3 could lead to a recovery of the *Nephrops* stock without inducing any losses as this scenario assumes no catch on the two younger age groups that are usually discarded. Taking into account a 4% discount rate over the 2004-2015 period, a selectivity corresponding to scenario 3 would make it possible to form a rent of 25000 euros per vessel (fig.11). In this kind of fishery characterized by high levels of discard, recovering the stock and improving the valorization of the production potential might therefore induce a positive net benefit.
However, these results are to be moderated as they do not consider any increase in the effort that could occur as a response to an investment dynamic.

We have now to consider the case where fishing effort is endogenous. These simulations show that if the benefits of selectivity are reinvested to increase effort, they dissipate rapidly and the exploitation is suboptimal (see scenarios 1 to 4). For these scenarios, the rent formed

[17] This rate is also used by many public agencies to assess their project. The U.K Treasury recommended discount rate for both costs and benefits is 3.5%
[18] This type of public aid is permitted in the context of the Common Fisheries Policy, for compensations when fisheries are closed or effort reduction is imposed.

is higher in the case of constant effort than in the case of endogenous effort (Table 7). This is to be linked to the surplus per effort unit presented in the previous section.

	Constant effort	Endogeneous effort
Scenario 1 status quo	167	166
Scenario 2 age 2	170	170
Scenario 3 age 3	222	214
Scenario 4 age 4	266	260
Scenario 5 age 5	274	277
Scenario 6 age 6	238	244

Table 7: Comparison of Net present values of producer surplus (rent) assuming constant effort and assuming endogenous effort over the 2004-2015 period assuming a 4% discount rate

In the case of scenarios 5 and 6 however, the net present value of producer surplus is higher than in the case of constant effort. This is a bias induced by the model of dynamics of effort. Indeed, the increase in effort depends by assumption on the growth of surplus; therefore for these high selective scenarios inducing a decrease in the surplus in the short term, we do not observe any increase in the effort in the first years of the simulation. When the biomass recovers the landings increase and the surplus becomes higher than the initial surplus. The effort increases but quickly reaches the maximum of 260 days at sea and then remains constant. This explains that the net present value of producer surplus is higher. The increase in effort makes it possible in this case to achieve the potential of production induced by the adoption of high selectivity measures. However, assuming that the surplus is reinvested either to increase the number of days at sea or the technical progress, we would find that scenarios 5 and 6 at constant effort are preferable to high selectivity scenarios with increasing effort.

Sensitivity analyses to fishing effort versus selectivity were also carried out in order to analyze the consequences of endogenous effort and to illustrate the complementarities between selectivity and effort limitation (Figure 12).

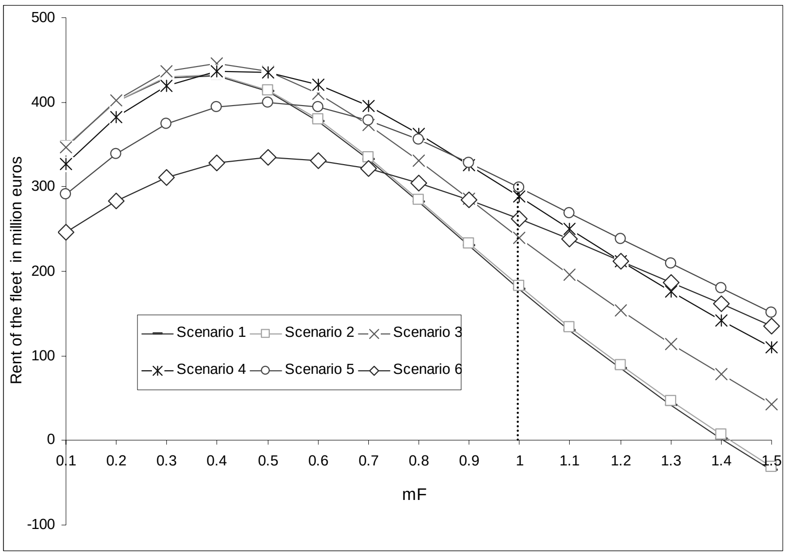


Figure 12: Net present values of producer surplus (rent) over the 2004-2015 period assuming a 4% discount rate for the six selectivity scenarios and for a multiplying factor of the fishing mortality mF varying between 0.1 (decrease in effort) and 1.5 (increase in effort).

As shown in Figure 12, representing the net present value of the producer surplus assuming a discount rate of 4%, increasing the effort for a given selectivity scenario dissipates the rent, except for low levels of fishing mortality. When comparing scenarios together, we can observe that for a range of increases in effort, the rent of selectivity measures can remain preferable to the status quo. Given a selectivity scenario, rents could be maximized with a reduction in fishing mortality – from to 0.5 and 0.4 - compared to the status quo value (mF=1). Technical measures are therefore not sufficient and a limitation in effort is required to ensure that the rent yielded by selectivity measures is not dissipated by an increase in effort.

5 - Discussion and perspectives

The cost-benefit analysis presented in this paper, under the assumption of constant effort, highlights the potential positive net benefit of selectivity improvement. It underlines the consequences of the selective scenarios both in terms of biological impact for the stock and economic impact for the fleet. It compares the potential benefits between scenarios and analyzes the transition phases.
This study focuses on the impact of selectivity improvement on the *Nephrops* stock only. Scenarios would correspond to selective devices such as the *Nephrops* grids developed to offer a good compromise between small *Nephrops* escapement and commercial losses of *Nephrops* and to not affect the selectivity of other species. The producer surplus of the fleet is studied. One of the perspectives of this study is to analyze the impact of technical measures on the other stocks affected by this mixed fishery and to assess the social cost of discarding. This social cost is calculated by taking into account the costs of discarding behaviours endured by other fleets targeting the by-catches of the *Nephrops* fishery and the impact of reducing discards on the consumer surplus through price-quantity effect or quality improvements.

As it is easy to modify gear, in such a way that it complies with legal requirements but does not produce the expected improvement in selectivity, the efficiency of technical measures depends on the “willingness of the fishing industry to accept them” (Suuronen and Sarda, 2006). The existing literature shows that there is a strong incentive among fishermen to circumvent technical measures due to the expected short-term losses (scenarios 4, 5 and 6) and cost increases (Suuronen, 2006). Ferro and Graham (2000) describe how the mesh size increase in the late 1980s and early 1990s was gradually negated in the UK North sea fishery by the codend design feature that reduced the selectivity. Suuronen and Tchernij (2003) show that in the Baltic cod fishery, widespread gear manipulation was observed to reduce the selectivity of the gear. Suuronen *et al*. (2000) and Tchernij *et al*. (2004) highlight that if the losses are too large, the gears will be manipulated and the rules will be circumvented (see also Halliday and Pinhorn, 2002).

However, this paper highlights that in a fishery like the *Nephrops* fishery, characterized by a high level of discards on the smaller individuals, the recovery of a stock through an improvement of the management of the production potential does not necessarily induce short-term losses and negative net benefit. Long-term gains can offset short term losses (if any). Thus, selectivity, adapted to the minimum landing size of *Nephrops*, which means with no catch (therefore no discard) under the MLS, would make it possible to reach a conservation objective to recover the stock to the higher biomass values observed in the series without inducing short-term losses. In this case, the improvement of the exploitation pattern, in order to obtain a better pricing of the production potential of the stock, would form a rent of 25000 euros per vessel, taking into account a 4% discount rate over the 2004-2015 period.

The problem of compliance of fishermen with selectivity measures is also linked to the length of transition period towards more sustainable stock levels. Heikinheimo *et al*. (2006) underlines the criticisms of fishermen of the pikeperch gillnet fishery against improving selectivity measures in the Archipelago Sea in Finland. They argue that it would harm the profitability of the fishery by seriously reducing the catches and decreasing the prices. Transition phase to a positive net present value is too long compared to the risks and the expected return on investment, to be acceptable for the fishermen.
In the case of *Nephrops*, however, the length of the transition phase is limited to a few years and the benefits occur quickly after the adoption of a selective device. In any case, the situation is never worse than the status quo for more than three years and the potential benefits associated are very important.

There are no short-term losses or limited short-term losses compared to the gains expected and the rapid recovery of the stock induces short length of the transition phases. This allows the selectivity measures in this kind of fishery to be efficient. A way to limit short-term losses and increase the compliance by fishermen would be to implement selectivity measures gradually, by first adopting a 15 mm gap grid then, after two or three years, a 20 mm gap grid. Given the small short-term losses and the gains predicted for the long term, the question of short term loss compensation is to be analyzed. Another outlook is to consider who would profit from such management measures and how the wealth would be distributed.

By taking into account economic dynamics of increasing effort we show however, that selectivity measures are insufficient and do not prevent the “race for fish” (see also Shepherd, 1993, Suuronen and Sarda, 2006). When effort increases the rent is dissipated. Not only the conservation of the potential of production of the juveniles is needed but also the allocation of the fishing capacity. Right-based approaches are therefore required to limit overcapacity and to ensure the efficiency of a selectivity measure. A system of individual quotas or licences with a limit on the number of days at sea would ensure that the rent formed by selectivity measures will not be dissipated by an increase in effort.

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APPENDICES

Appendix 1

Biological parameters for the *Nephrops* Stock

INPUT PARAMETERS		
Parameter	Value	Source
Discard Survival	0.30	Gueguen and Charuau, 1975
MALES		
Growth - K	0.140	after Conan and Morizur, 1979 ; plus unpublished data
Growth - L(inf)	76	"
Natural mortality - M	0.3	Morizur, 1982
Length/weight - a	0.00039	Conan, 1978
Length/weight - b	3.180	"
FEMALES		
Immature Growth		
Growth - K	0.140	after Conan and Morizur, 1979 ; plus unpublished data
Growth - L(inf)	76	"
Natural mortality - M	0.3	Morizur, 1982
Size at maturity	25 mm CL	Morizur, 1982
Mature Growth		
Growth - K	0.110	after Conan and Morizur, 1979 ; plus unpublished data
Growth - L(inf)	56	"
Natural mortality - M	0.2	based on Morizur, 1982 ; assuming lower rate for mature females
Length/weight - a	0.00081	Conan, 1978
Length/weight - b	2.970	"

Source: ICES, 2004

Appendix 2

Structure of revenues and costs per sub-fleet

mean 2001-2003 in millions euros	Fleet 1	Fleet 2	Fleet 3	Fleet 4	Fleet 5	Fleet 6	Fleet 7	Fleet 8	Fleet 9	Fleet 10
Gross return	6.72	11.77	14.06	10.75	4.51	1.43	7.66	4.38	13.31	1.46
Landing costs	0.25	0.64	0.67	0.59	0.25	0.05	0.42	0.21	0.73	0.08
Fuel costs	0.72	1.59	2.18	1.63	0.69	0.15	1.17	0.65	2.01	0.20
Bait costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food costs	0.03	0.18	0.31	0.28	0.10	0.01	0.13	0.09	0.34	0.03
Ice costs	0.00	0.04	0.08	0.08	0.06	0.00	0.03	0.02	0.11	0.01
Return to be shared RTBS	5.71	9.31	10.82	8.17	3.41	1.22	5.91	3.40	10.13	1.13
Crew share (% RTBS)	2.54	4.10	4.71	3.55	1.43	0.54	2.61	1.48	4.39	0.48
Vessel share	3.17	5.21	6.10	4.63	1.98	0.67	3.31	1.92	5.74	0.66
Crew share (% GR)	2.40	3.93	4.54	3.37	1.48	0.51	2.88	1.36	4.15	0.44
Crew Premium	0.09	0.46	0.64	0.44	0.09	0.02	0.34	0.19	0.54	0.03
Other crew costs	0.30	0.49	0.58	0.36	0.13	0.06	0.36	0.17	0.45	0.04
Other owner costs	0.25	0.54	0.64	0.42	0.14	0.05	0.39	0.19	0.51	0.04
Gear costs	0.31	0.55	0.71	0.50	0.26	0.07	0.40	0.21	0.61	0.08
Gear repair and maintenance	0.34	0.79	1.02	0.71	0.34	0.07	0.58	0.30	0.87	0.10
Social Insurance costs	0.27	0.43	0.51	0.34	0.18	0.06	0.32	0.15	0.42	0.05
Managment costs	0.26	0.31	0.39	0.34	0.11	0.05	0.23	0.12	0.42	0.03
License costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taxes	0.02	0.04	0.04	0.03	0.01	0.00	0.03	0.01	0.03	0.00
Depreciation costs	0.29	0.54	0.57	0.46	0.21	0.06	0.39	0.17	0.57	0.06
Opportunity cost of capital 1	0.15	0.31	0.35	0.17	0.08	0.03	0.23	0.10	0.20	0.02
Opportunity cost of capital 2	0.41	0.66	0.70	0.57	0.26	0.07	0.33	0.22	0.67	0.10
Opportunity cost of capital 3	0.70	1.13	1.21	0.98	0.45	0.12	0.57	0.37	1.15	0.17
Opportunity cost of labour (Wage/h)	1.61	3.13	5.26	3.93	1.49	0.26	1.58	1.55	4.70	0.63
Opportunity cost of labour (Wage/year)	1.26	1.90	2.24	1.55	0.58	0.21	0.97	0.67	1.83	0.23

Source: IFREMER

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