C) WORK PLAN TOPIC 4b

Topic 4b) The biological impacts of discarding in selected EU Nephrops fisheries and the consequences of changes to the species selectivity of the fishing gears used in those fisheries

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4	Start date for topic	March 2006
5	End date for topic	Feb 2007
6	Methodology to be used	Main methods to be used: Method 1 Stock assessments to be run on affected whitefish stocks, with and without discards to determine effects of discarding. Process is repeated with modified discard data that comes from the using the modified fishing gears. Method 2 Alterations to catch and discard patterns is modelled using the catch / discard data (collected under the EU data collection regulations) and catch comparison data from gear trials comparing the new gears to existing gears Fish not discarded as a consequence of the new gears will be estimated and placed into a stock production model Method 3 IFREMER will focus on Hake stocks and Nephrops fisheries interactions in local waters by further developing the existing French model.

		Method 4. DIFRES will focus on the linkage between CS4 and CS2 and develop the synergistic components from both of these case studies. Method 5 CEMARE and LEI will develop economical models /undertake economic studies in relation to the synergistic linkages between CS2 and CS4.
7	Deliverables	Report on the assessments of the biological impacts of changes to patterns of whitefish discarding as a consequence of the introduction newly developed technical measures. To be delivered by Feb 2007

WP 4 Case Study

The biological impacts of discarding in selected EU Nephrops fisheries and the consequences of changes to the species selectivity of the fishing gears used in those fisheries *(France)*

Determination of the biological consequences arising from the introduction of discard mitigating trawl designs and seasonal closures in bottom trawl Nephrops fishery in the Bay of Biscay

D'Hardivillé C., Biseau A., Barthélemy P., 2006.

Index

1 Introduction

The study should permit to assess the relevance of new management rules, alternative or supplementary to the only management by TAC on this mixed fishery. The current report aims at calculating the biological impact on *Nephrops* and hake stocks in the case of :

- an application of selective devices on all the trawls of the *Nephrops* fleet
- a seasonal located closure of the fishery

For that 2 models will be used :

- The first developed by Macher Ifremer DEM (2004) (see annex 1) to evaluate the impact of selective trawl on Nephrops stocks.
- The second (ISIS-Fish) developed by the Ifremer laboratory of Nantes (see annex 2) to evaluate the impact of selective trawl on hake stocks and the consequences of a seasonal closure.

The tested selective trawls are those studied in WP3 (task 3.10 and 3.11) by Ifremer and a supplementary one tested by the laboratory of Lorient in 2006. The tested seasonal closures were determined in accordance with the conclusions of task 4.5.2.

2 Technical measures : a solution to decrease *Nephrops* and hake by-catches ?

2.1 The technical measures tested

2.1.1 combination of a square mesh panel at the top of the baitings and a 13 mm bar spacing grid

This selective trawl was tested in 2005 by Ifremer laboratory of Lorient as part of Necessity task 3.10 (NECELG2). Refer to this task for further details.

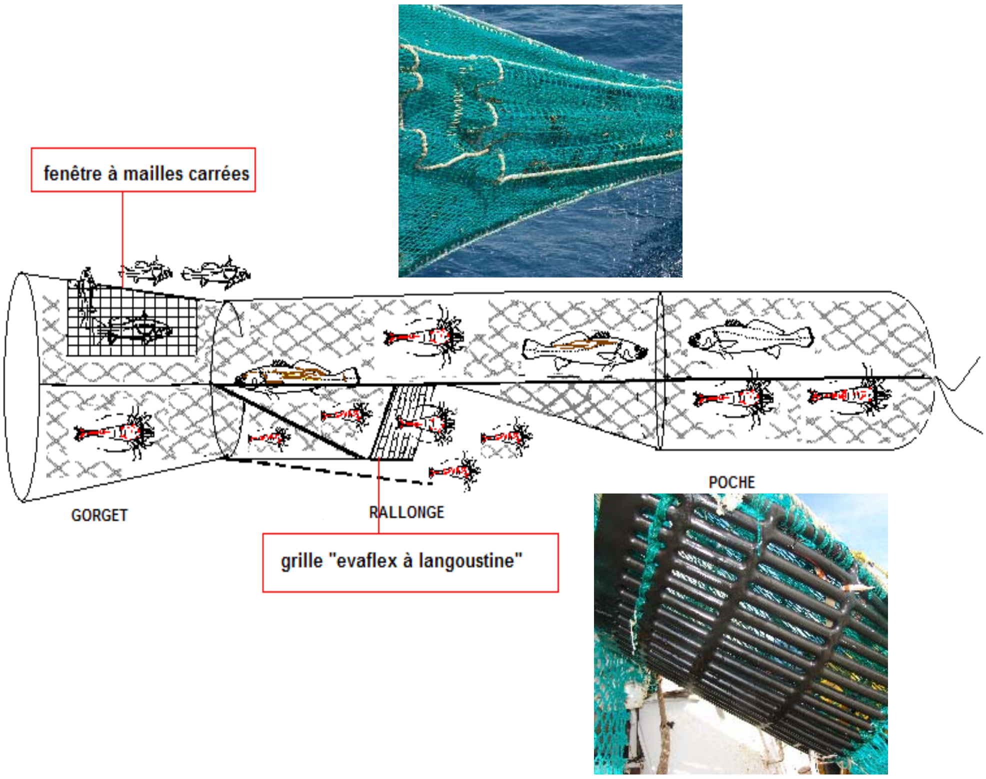


Figure 1 : *Scheme of the selective trawl fitted with a square mesh panel and a 13 mm bar spacing grid*

2.1.2 side escape square mesh panel on each side of the extension

This selective trawl was tested in 2004 by Ifremer laboratory of Lorient as part of Necessity task 3.11 (NECELG1). Refer to this task for further details.

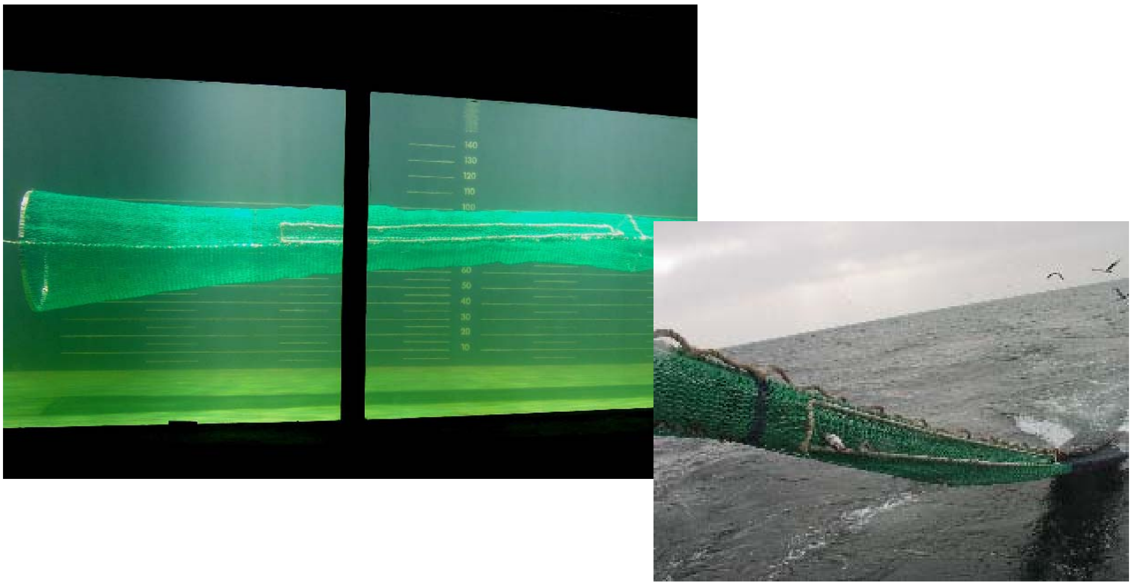


Figure 2 : *Photos of the selective trawl fitted with a side escape square mesh panes on each side of the extension piece*

2.1.3 A 20 mm bar spacing grid

This selective device was tested in 2005 by Ifremer fisheries laboratory of Lorient (LANDGRID5). The objective was to test selectivity of a new 20 mm bar spacing grid to compare the results with those obtained on the 13 mm bar spacing grid No significant effect was observed on hake selectivity in the conditions of the trials. The grid is meant to spare Nephrops under 34 mm cephalothorax length. This grid is easy and fast to implement (see figure 3). The L50 for Nephrops was 36 mm.

Figure 3 : *Photos of the selective trawl fitted with a 20mm bar spacing grid*

Results of this grid on Nephrops and Hake :
Note that the ‘Control trawl’ is not the currently used trawl but a trawl with very small mesh size.

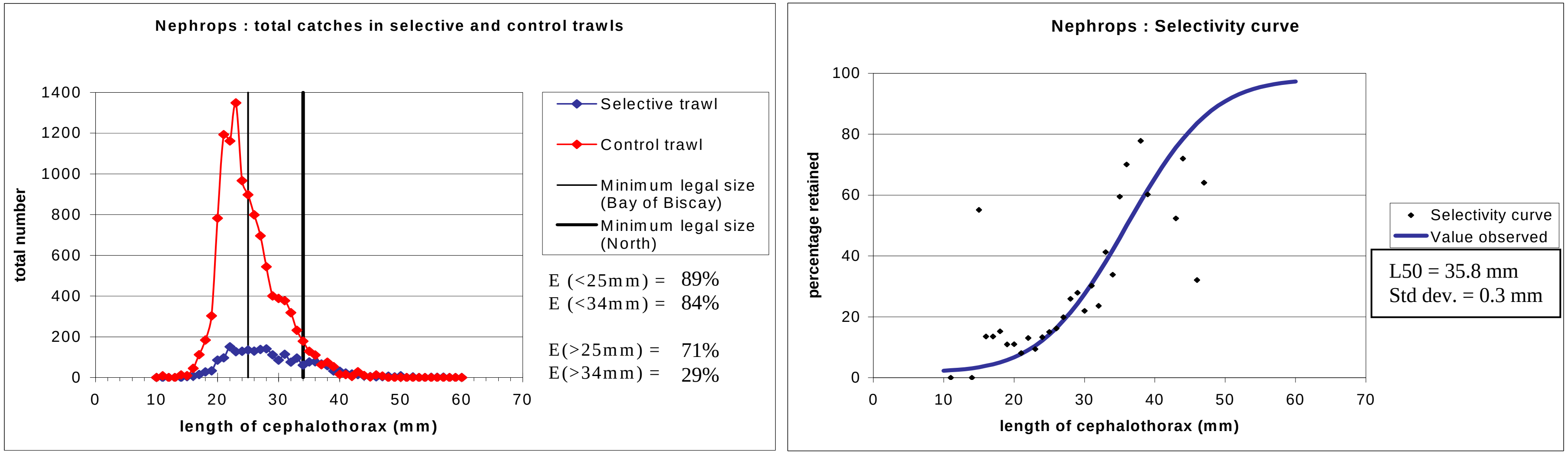


Figure 4 : *Total catches and selectivity curve for Nephrops*

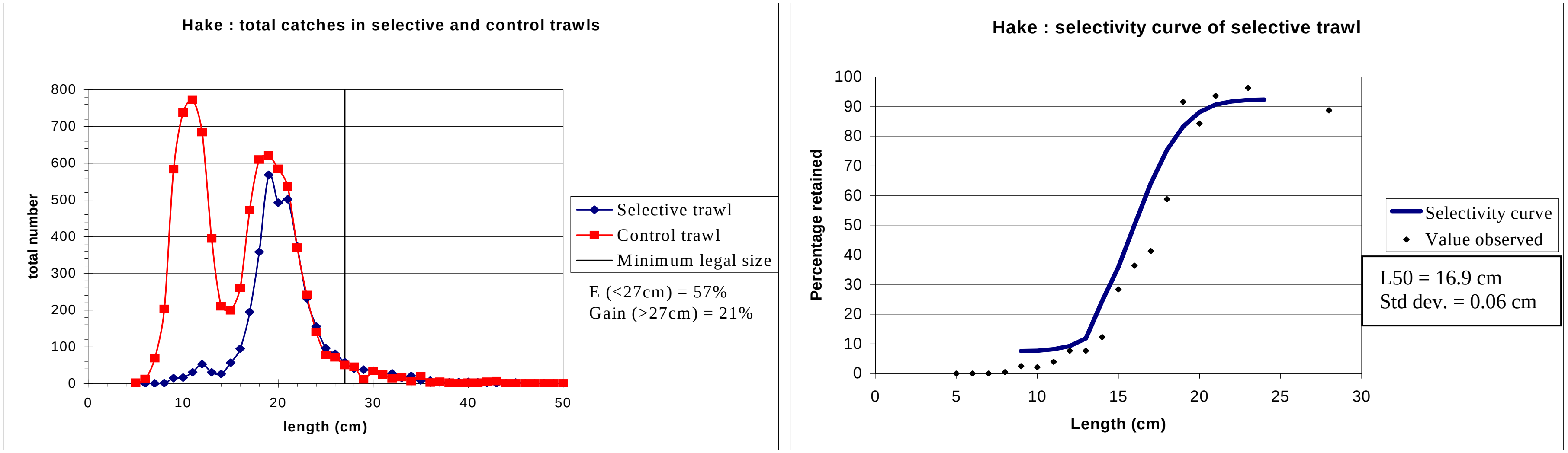


Figure 5 : *Total catches and selectivity curve for Hake*

2.2 The effect on *Nephrops* stocks

The model used is the one developed by Macher (see annex 1). It is based on the assumption that the Nephrops stock dynamic could be modelled by an age structured model which is under discussion among the Nephrops specialists. However, it is considered that these simulations provide useful results in a relative term to compare various scenarios.

The selectivity curves were obtained during the onboard experiments on the cephalothorax length. The curves were converted according to the age groups. The following table provides the length limits for each group :

Age	1	2	3	4	5	6	7	8
Male	5	7	10	12	13	15	16	17
Female	5	7	9	10	11	12	12	13

Table 1 : Connection between age and total length of Nephrops

NECELG1		NECELG2		LANDGRID5	
L (mm)	Retention (%)	L (mm)	Retention (%)	L (mm)	Retention (%)
5	10	5		5	
10	13	10	3	10	3
15	19	15	6	15	5
20	25	20	19	20	9
25	32	25	42	25	15
30	42,3	30	71	30	29
35	51	35	90	35	50
40	60	40	95	40	67
45	67	45	96	45	82
50	73	50		50	90
55	81	55		55	93
60	86	60		60	94
65		65		65	
70		70		70	

Table 2 : Parameters of the selectivity curves of the 3 selective trawls for Nephrops (source : Ifremer)

Then the biomass, landings and discards are simulated until 2015 for the 3 selective trawls.

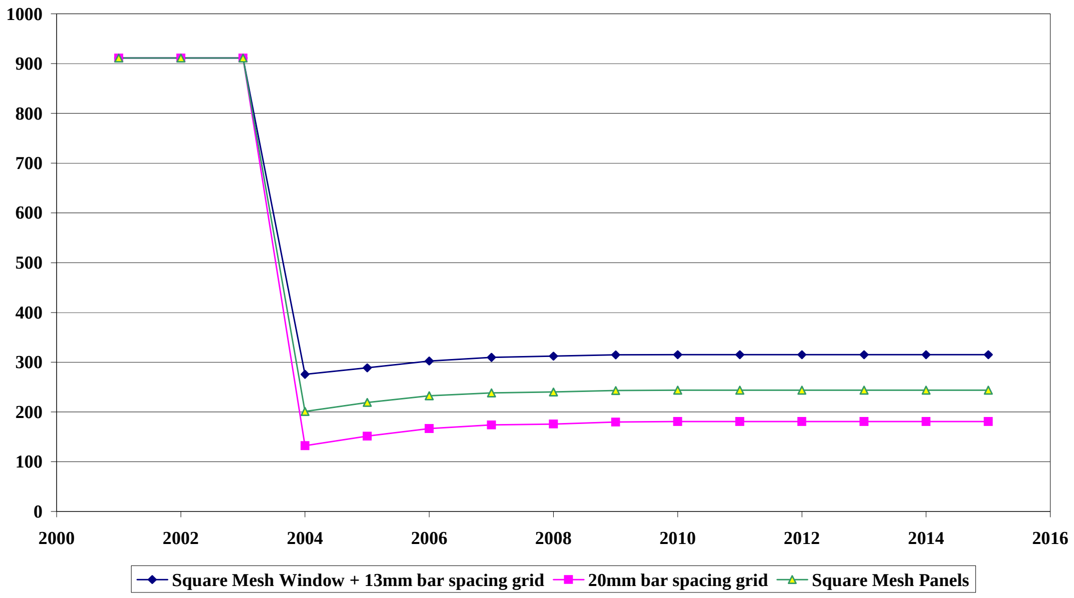


Figure 6 : *Evolution of discards (tonnes)*

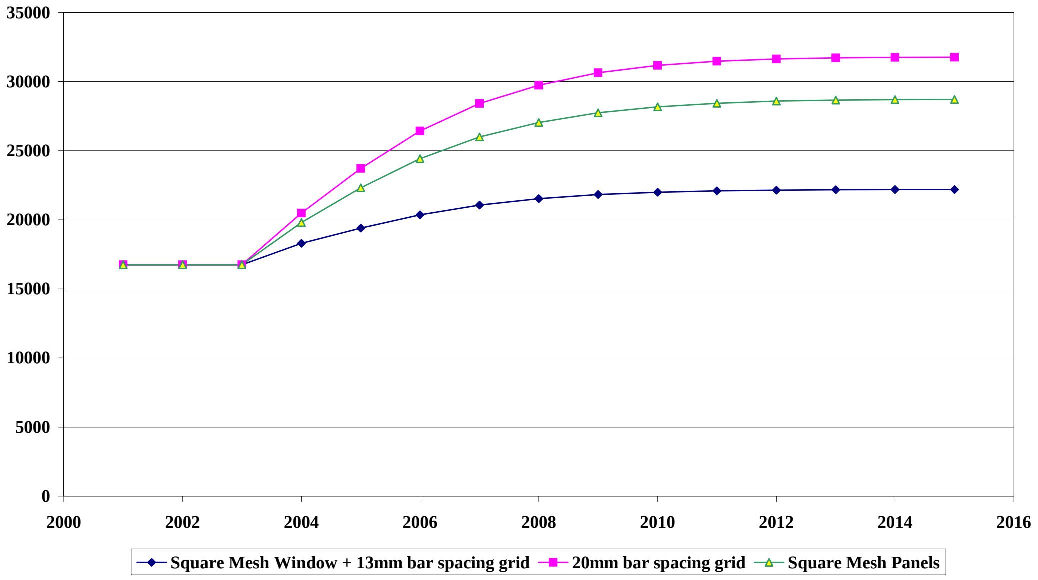


Figure 7 : *Evolution of the biomass (tonnes)*

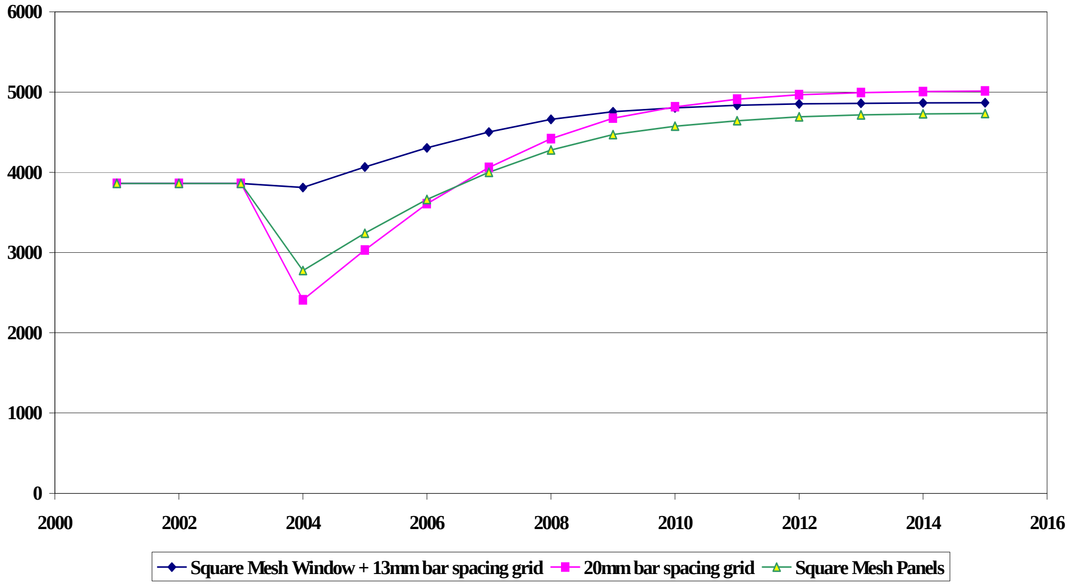


Figure 8 : *Evolution of landings (tonnes)*

2.3 The effect on hake stocks : Simulating the possible impact of a square mesh panel on the top of the baitings

The side escape panels provided mitigated results on hake escapement while no hake escapement was noted when the Nephrops grids were implemented in the conditions of the tests. It was decided with the partners to concentrate the study on the impact on hake stocks of a square mesh panel on the top of the baitings. Significant catch comparison data were collected from the national programme ASCGG. The data obtained over 568 hauls were aggregated, comparing the catches obtained with and without a square mesh panel on the top of the baitings (twin trawling operation in commercial fishing conditions).

2.3.1 Material and method

The basic data that were simulated as part of the present study are those provided by ICES working group (ICES, 2005). Actually, to achieve the relevant simulations, it was preferable that the discards be included. The members of ICES working group have attempted to build discards historical series which provided an assessment of the stock and its dynamics including discards. The model implemented to achieve the forecasts is of type Thompson and Bell (1934). It is structured by age. The average mortality by fishery (F) over the past three years along with the number of fish in the stock achieved once the assessment completed are used to assess the abundance and catches developments assuming various changes in mortality global level for each fishery and/or the management diagram. The projection model base data are given in table 1.

Tableau 1. Data of simulation base (ICES, 2005)

Age	Mortality by fishery	Average weight (kg)	Size of the stock (thousands)	Natural mortality	Maturity ogive
0	0.09710	0.03	252457	0.2	0.00
1	0.11850	0.06	189472	0.2	0.00
2	0.13820	0.19	108922	0.2	0.00
3	0.25190	0.33	120157	0.2	0.23
4	0.20290	0.59	59488	0.2	0.60
5	0.24930	0.96	31823	0.2	0.90
6	0.39380	1.40	21194	0.2	1.00
7	0.48650	1.81	12282	0.2	1.00
8+	0.48650	2.50	12318	0.2	1.00

In order to simulate the alterations of the Nephrops fleet exploitation diagrams resulting from the use of a trawl fitted with a square mesh panel, each *F* at age *a* of table 1 must be split into a fraction “Nephrops fishery” and a fraction “other fisheries”. This splitting up is achieved proportionally to the catches between FU09 (which, according to ICES assessment, almost corresponds to the Nephrops fishery) on the one hand, and the other fisheries, on the other hand :

$$F_a^{lang} = F_a \cdot \frac{C_a^{lang}}{C_a^{lang} + C_a^{autres}} \qquad \text{et} \qquad F_a^{autres} = F_a \cdot \frac{C_a^{autres}}{C_a^{lang} + C_a^{autres}}$$

Then, the projections of the development of the captures are achieved separately for each of the fleets.

The size distributions for a standard trawl and a trawl fitted with a square mesh panel achieved as part of ASCGG project (improvement of the selectivity of the trawls implemented in the bay of Biscay) were then processed to assess the *F* at age of the Nephrops fleet assuming that the fleet implement a trawl equipped with a square mesh panel. In a first step, the ratio r_l between the number of fish caught with the standard trawl and the number of fish caught with the trawl fitted with a square mesh panel as part of ASCGG project are calculated for each of the group of sizes *l*.

$$R_l = \frac{N_l^{maillecarréeASCGG}}{N_l^{standardASCGG}}$$

The ratios obtained are then used to assess the number of fish liable to be caught by a fleet implementing a trawl fitted with a square mesh panel, the number of fish per group size caught by the same fleet working with s standard trawl being already known.

$$N_l^{maillecarréeFU09} = R_l \cdot N_l^{standardFU09}$$

The size distribution of FU09 achieved in 2004 were used to calculate those assuming that a square mesh panel was used. As the distribution in size of the FU09 assuming that a square mesh panel was used is known, it is thus possible by means of the key size age obtained in 2004 to assess the relevant age distribution. The modification of the exploitation diagram of the FU09 (*F* at age) is then assessed by means of the ratio between the fisheries catches at age considering the results for both the trawls. The ratios at age between both the trawls and the new exploitation diagram are provided in table 2.

Table 2 Calculation of the new exploitation diagram

Age	Rapport	Fa (standard)	F_a (square mesh)
0	0.76	0.048	0.037
1	0.77	0.057	0.044
2	0.78	0.027	0.021
3	0.82	0.028	0.023
4	0.92	0.007	0.006
5	1.02	0.003	0.003
6	1.00	0.003	0.003
7	0.98	0.003	0.003
8+	1.04	0.004	0.004

2.3.2 Results and discussion

The results of the predictions are given in table 3 and figure 1. They confirm what the stock dynamic was thought to be in 2005. According to the simulations, the fact of implementing a trawl equipped with a square mesh panel would increase by almost 3% the yield profits to be expected when not modifying the fishing effort (mF=1) versus the use of a standard trawl (+20.3%, i.e. 59917 tonnes instead of +17.3%, i.e. 58421 tonnes).

Tableau 3 Results of the simulations with a multiplier of F equal to 1

	Tonnes		gain/loss %	
	standard trawl	square mesh	standard trawl	square mesh
2004	49800	49800	0.0	0.0
2005	51575	51134	3.6	2.7
2006	51916	51618	4.2	3.7
2007	54345	54228	9.1	8.9
2008	56534	56676	13.5	13.8
2009	56987	57414	14.4	15.3
2010	57485	58243	15.4	17.0
2011	57679	58746	15.8	18.0
2012	58117	59411	16.7	19.3
2013	58319	59748	17.1	20.0
2014	58421	59917	17.3	20.3

The gains to be expected are thus weak and result from the two main factors which are :

- Low F on groups of age 0 and 1 assessed with the model of population dynamics by 2005 working group (0.09 and 0.11, refer to table 1).
- An escapement rate which remains weak on groups of age 0 and 1 when a trawl fitted with a square mesh panel is used. The *F* at age only being decreased by 24 and 23% fro groups 0 and 1 respectively (table 2).

It should be noted that the present results must be considered cautiously :

- The reconstruction of discards historical series is most speculative as it rest on very few data. Now, a good knowledge of discards is essential to achieve such an analysis.
- The model implemented for the purpose of the study is not spatially desaggregated ; it thus does not take into account either the spatial dynamics of hake population nor the spatial distribution of the fleets which fish this species.
- The simulations have been carried out assuming that the growth was slow. It was demonstrated that the impact of a decrease of discards may be more significant when assuming a higher growth, according to the results of the trip on marking (ICES, 2005).

ICES. 2005. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim. ICES Document CM 2005/ACFM: 02

Thompson, W. F., and Bell, F. H. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. Report of the International Fisheries (Pacific Halibut) Commission, 8. 49 pp

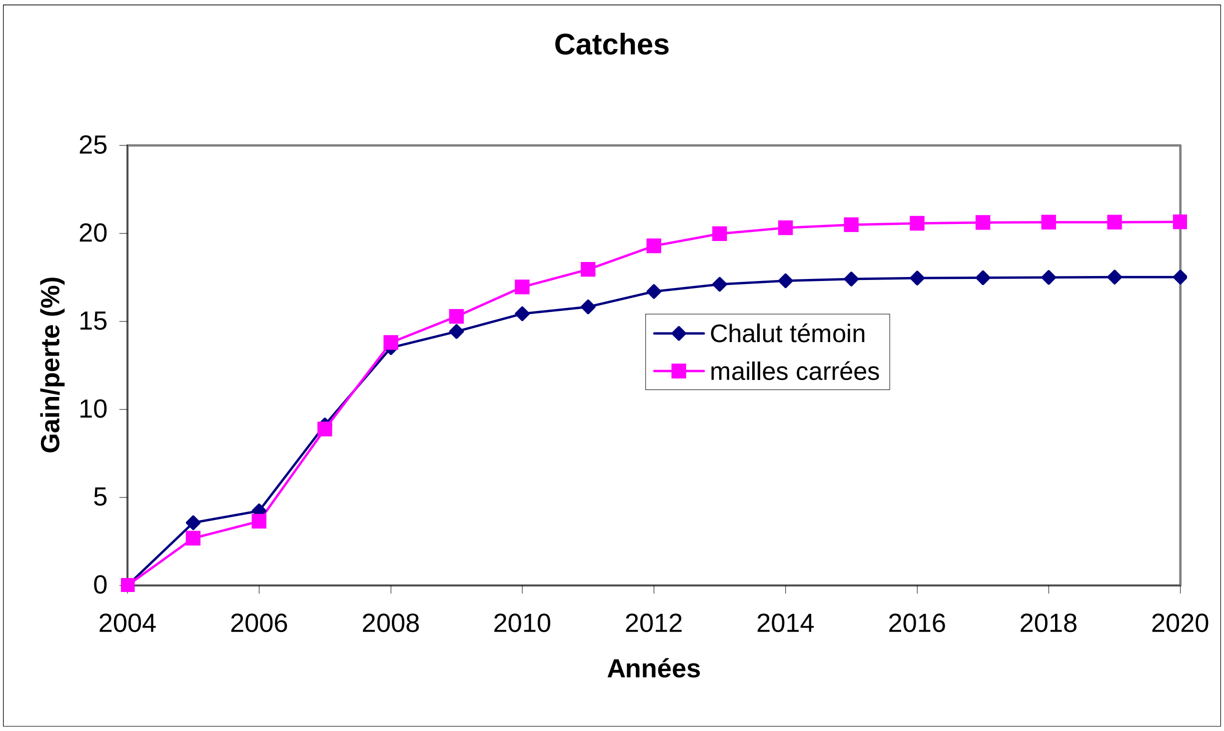
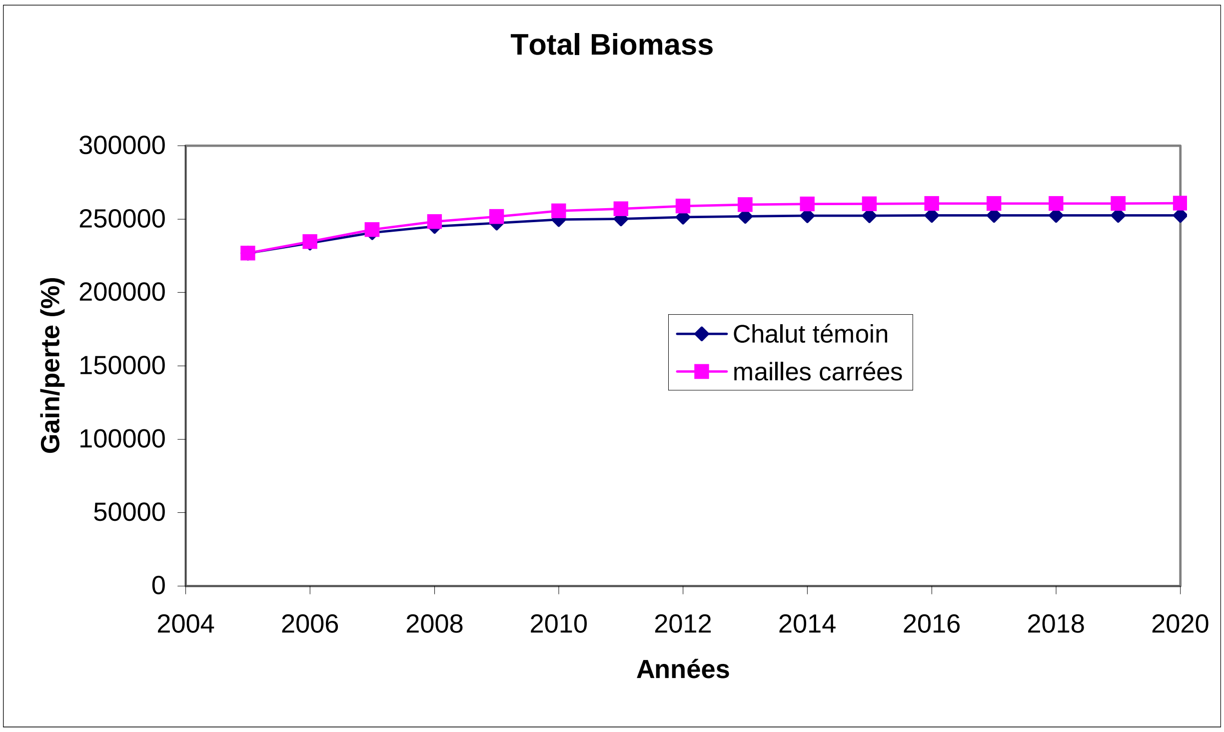


Figure 9 : *Figure 1. Gain/loss (%) of catches assuming the use of two trawls in the Nephrops fishery*



2.4 Conclusion

Discards of *Nephrops* are reduced by using selective devices as tested : the 13 mm bar spacing grid leads to two thirds (in weight) of the *Nephrops escapements*. The 20 mm bar spacing grid, obviously, provides higher escapement rates and three quarters of the *Nephrops* discarded are expected to escape. Obviously, the greater escapements lead to the greater increases in biomass in the long term.

It is also obvious that none of the devices tested can lead to a zero catch of under-sized *Nephrops*. Immediate losses in landings are obviously predicted with the most selective devices tested. These losses should be anticipated and possible compensations implemented. In the long term landings are predicted to be more or less of the same amount whatever the device tested. However, given that the total biomass is predicted to increase more with the most selective devices, individual CPUE would be much higher, and the same landings would be achieved with less effort (i.e. lower costs).

From a biological point of view regarding *Nephrops*, the most selective device seems to be the 20 mm bar spacing grid. Next comes the square mesh side escape panels and then the association of square mesh panel and 13 mm bar spacing grid.

Discards of hake are reduced by using the square mesh panel on the top of the baitings. Around 25% of under-sized hake are spared by this device.

Given the current assumption on the growth pattern for this species and the estimate (recalculated) total amount of discards, the estimate fishing mortality for the younger ages are very small and well below the assumed natural mortality. Consequently the impact of the tested selective device appears to be quite low.

Thus these results must be dealt cautiously and a firm conclusion cannot be drawn before achieving further investigations of the assumptions used. For instance, the ICES WGHMM (2005) showed that when using a higher growth pattern (deduced from tagging experiments) the impact of a reduction in discards would be more significant.

It should also be kept in mind that the length at which hake matures is well above the minimum length size. This means that even though the reduction of under sized catch is significant any mortality on fish between MLS and mature length would reduce the beneficial impact on the spawning stock biomass.

3 Seasonal closures : a solution to decrease *Nephrops* and hake bycatches?

3.1 The seasonal closures tested

The conclusions that were drawn in task 4.5.2 are given hereunder :

- For hake, a seasonal close located in the central zone (and near the coast) may be a good management decision :
    - in May or June because young hake join the coastal nurseries at that period, while at this time of the year the Nephrops trawlers have a heavy activity.Or between December and February because the discards expressed in weight by haul are at their highest, and less trawlers fish Nephrops at that time (thus this measure should not have a heavy impact on the fishermen's turnover).
- Regarding *Nephrops*, the central zone is also where the higher discards occur. The higher discard rates occurring in June, July and August, the simulations should bear on closes at that time of the year.

The model (ISISFISH) used to test these new management rules did not permit to close so precise zones. Thus the zones investigated are the ICES rectangles 24E5 and 24E6 (see Figure 11) which are the most worked by the *Nephrops* fleet.
The period which seems to be the most interesting for *Nephrops* AND hake is June. Closures could be decided during this month.
Thus three scenarios was tested :

1. Closure 1 : 24E5 in June
2. Closure 2 : 24E6 in June
3. Closure 3 : 24E5 and 24E6 in June

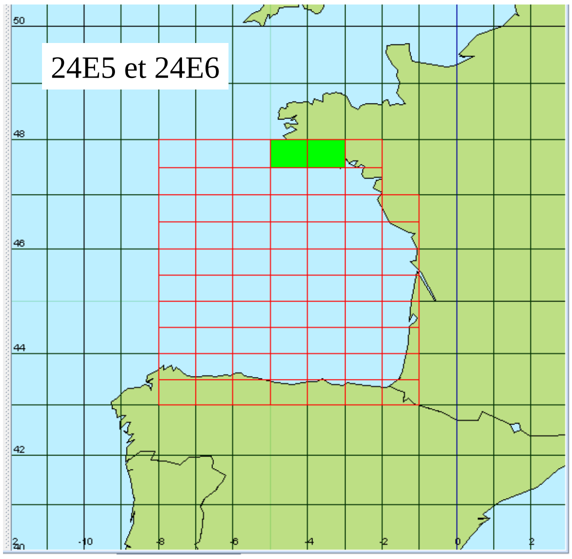


Figure 10 : *Scheme of the areas tested for seasonal closures*

It should be noted that the simulations take into account the effort transfer, in other words, the position of the fishermen in view of such a measure will be to work another zone. This is of course a strong assumption since most vessels are small vessels which could hardly go elsewhere than in the rectangles just off their home port. Thus, the results of this simulation should be treated with caution.

3.2 The effect on *Nephrops* stocks

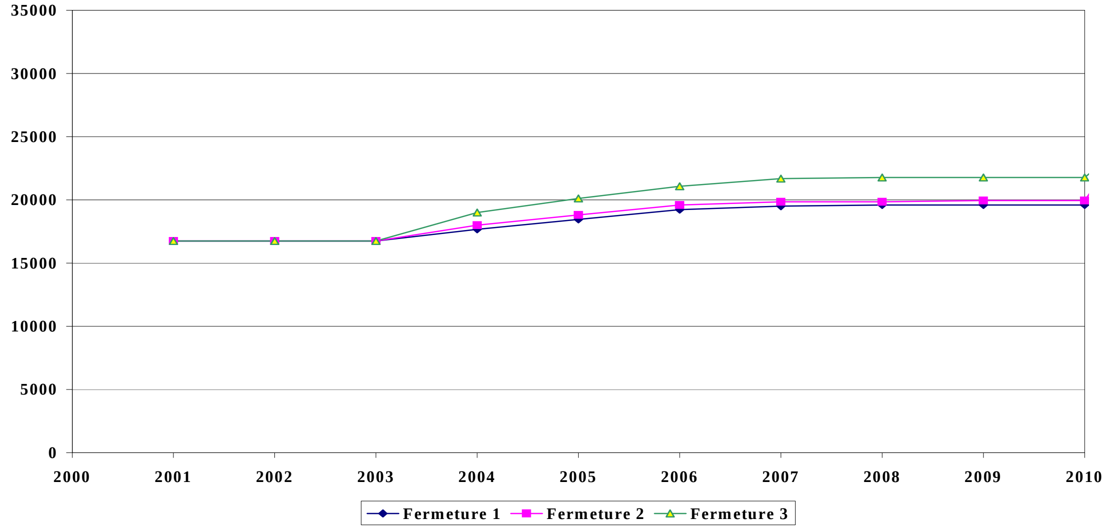


Figure 11 : *Biomass (in tonnes)*

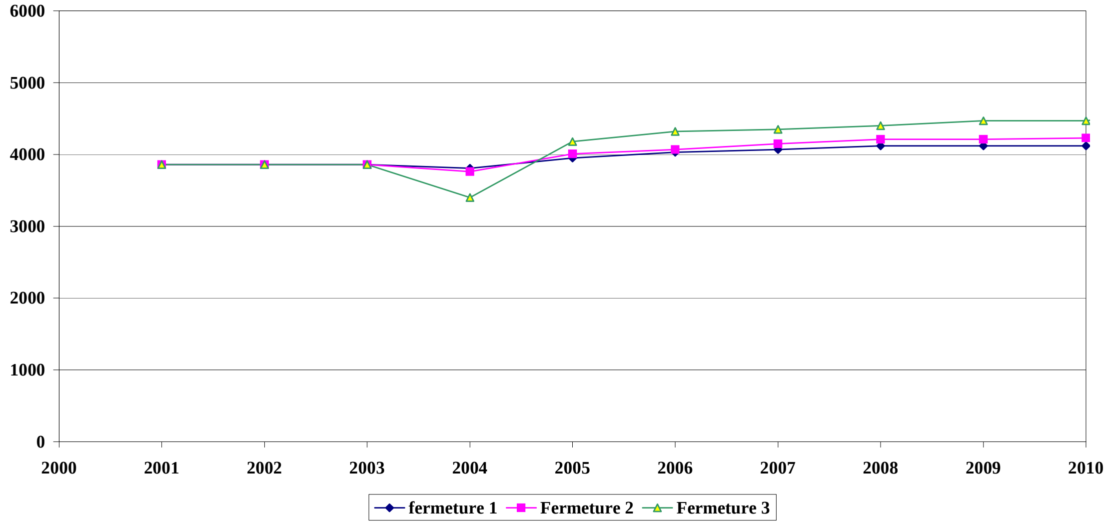


Figure 12 : *Landings (in tonnes)*

3.3 The effect on hake stocks

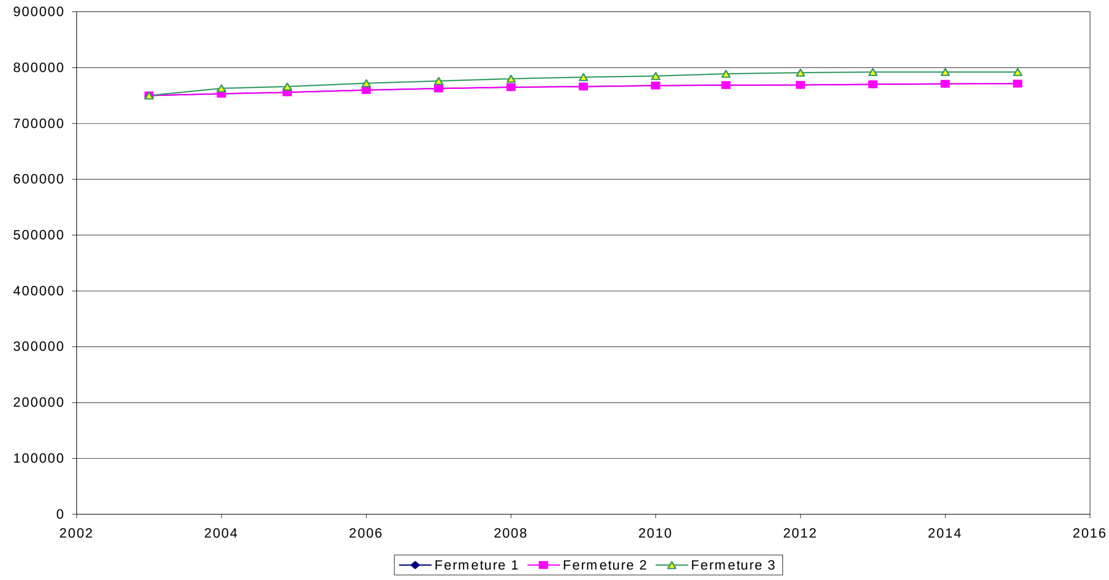


Figure 13 : *Biomass (in tonnes)*

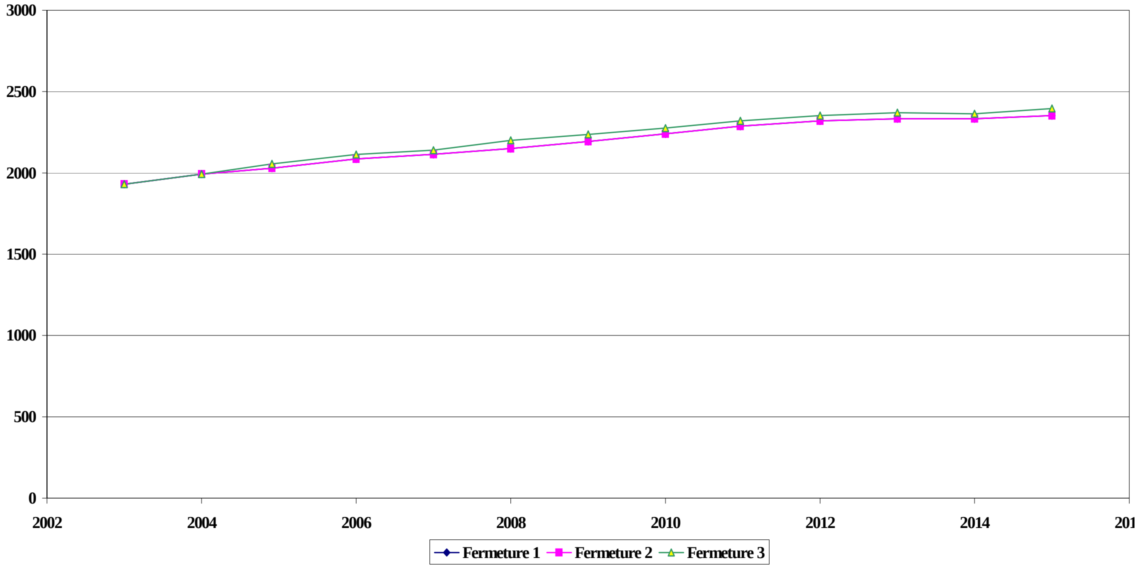


Figure 14 : *Landings (in tonnes)*

3.4 Conclusion

The results must be relativized because of the wide range of variations (Drouineau, 2004).

The simulation shows that a closure of one or two ICES rectangles would have no significant impact on the biomass and landings of Nephrops or Hake. This may be due to the fact that the fishery occurs in many other rectangles and that reports of fishing effort on others areas are assumed by the model. This is probably a strong assumption given the size of the vessels concerned by the closure tested. Anyway, such a measure should also be assessed by economical simulations which should take into account the gains and losses for the whole fleets together with the gain for the stocks and biodiversity.

4 Conclusion

The simulations performed as part of the present study should be considered as preliminary and the results only as illustrative. It is therefore not possible either to quantify the absolute impact of the measures tested or to compare the benefits from one type of measure (selective devices) to another (closure).

Furthermore, any new measure should also be assessed by economical simulations which should take into account the gains and the loss for the whole fleets together with the gain for the stocks and biodiversity.

Improving the exploitation pattern of a fishery by using selective devices or modifying the fishing strategy obviously leads to a reduction of discards. The impact of this reduction on the workload of the crew should also be taken into account, even though this ‘gain’ being difficult to quantify and to include in a model. The likely gain on the quality of the fish should also be considered as incentive.
Finally, one cannot ignore the societal pressure to reduce what appear to be a waste of biological material.

The aim of the Necessity project was to identify possible solutions to reduce discards and by-catch. It is a first step toward a better management of the fisheries considered. It should be bore in mind that the ‘MSY objective’ as defined in Johannesburg in 2002 may require a greater improvement of the exploitation pattern than the ones implemented ‘just’ to reduce discards.

5 Bibliography

Drouineau H., 2004. Paramétrage et développement d’un plan de simulation de l’outil de simulation ISIS-Fish pour évaluer l’impact de différentes règlementations de l’activité de pêche de la pêcherie mixte merlu-langoustine de la Grande Vasière. *Mémoire de Diplôme d’Agronomie Approfondie, Spécialité Halieutique, Agrocampus Rennes*, 62p.

Macher C., 2004. Contribution à l’évaluation des impacts économiques de l’amélioration de la sélectivité des chalutiers langoustiniers du Golfe de Gascogne. *Rapport Interne SEM 08/09/2004*, 70p.

Mahévas S., Pelletier D., 2004. ISIS-Fish, a generic and spatially explicit simulation tool for evaluating the impact of management measures on fisheries dynamics. *Ecological Modelling* 171, 65-84.

Pelletier D., Mahévas S., Poussin B., Bayon J., André P., Royer J.-C., 1999. A conceptual model for evaluating the impact of spatial management measures on the dynamics of a mixed fishery. *17th Lowell Wakefeld Fisheries Symposium, Anchorage, Alaska*, 53-66.

6 List of figures and tables

7 Annexes

ANNEX 1 : DESCRIPTION OF THE MODEL IMPLEMENTED FOR THE BIOLOGICAL SIMULATIONS (MACHER C., 2004)

A bio-economic model was developed in order to carry out a cost-benefit analysis of several selectivity scenarios. The framework of the model defining the link between the economical situation of the fleets, the dynamics of the *Nephrops* stocks, and selectivity scenarios are submitted hereunder. The conceptual model is given in Figure 1.

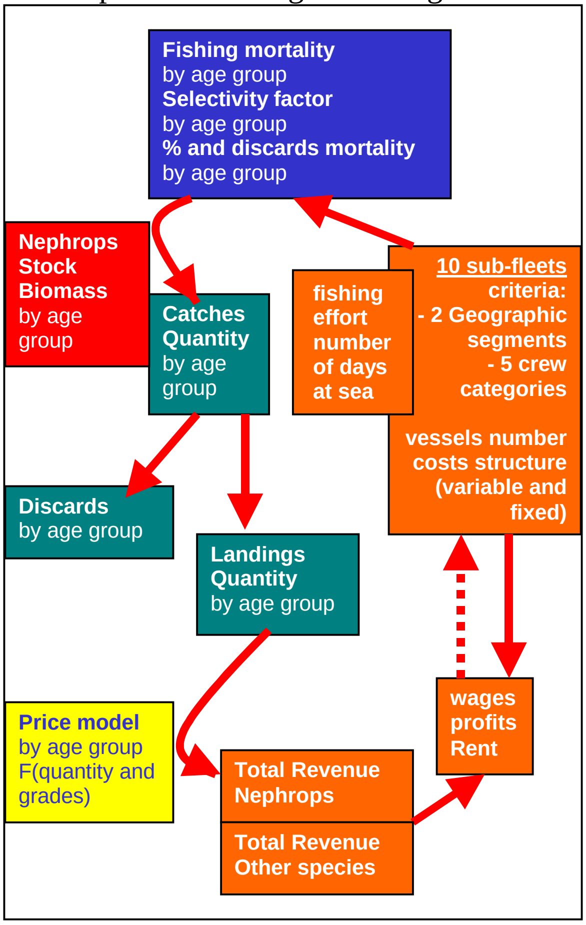


Figure 1: Schematic representation of the bio economic model

All things being equal, the improvement of selectivity reduces the fishing mortality of Nephrops stock (especially the younger ages), which is also subject to natural mortality and individual growth. The biological model is age-structured. The dynamic of the other species harvested by the trawlers is not considered in the analysis either because their mortality contribution to these species is low or the likely feedback effects on the trawler catches are limited or (very uncertain)[1]. Based on the level of the fleet nominal effort and gear selectivity, the model provides the levels of Nephrops catches, discards and landings. Total revenue per vessel depends on the Nephrops landings, price according to a price-quantity relationship and on the revenues of other species. Wages, profits per vessel and total surplus for the fleet are calculated, at each iteration, according to the average cost structure of each fleet. The economic model is considered as static as we assume in this paper that fishermen are not able to change their nominal effort level, nor their catches composition.

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[1] For example, *Nephrops* trawlers harvest only young ages and may benefit by the improvement of the stock through an increase in recruitment. However, there is no established stock-recruitment relationship in the case of this species

Description of the biological modulus

For each year of the simulation, the biological modulus provides the *Nephrops* catches, landings and discards, given by age group from the age group biomass, the mortality by fishery, and from the biological yield functions. The model, which is of the structural or analytic type, decomposes the exploitable stock in age groups. These models of population dynamics are the ones the most used (Laurec and Le Guen, 1981).

Indeed, it is most difficult to build the self-regenerating global models mainly on account of the relation stock-recruitment which is rarely significant. Considering the marine species life time and the evolution as a function of the age, the follow up must be done by cohort. Cohort analysis (Virtual Population Analysis, Gulland, 1965. Pope, 1972) and its approximations are the standard stock assessment techniques used when historical data on catches by age are available. When no such type of data being available, which is the case for *Nephrops,* Jones (1979, 1984) suggests that the analysis bear of the length of the cohorts (LCA). *Nephrops* growth follows the growth function developed by von bertalanffy (Eggert and Ulmestrand, 1999) where the length at age t L_t is calculated as follows :

$$Lt = l\inf(1-\exp^{-k(t-t0)}) \qquad (1)$$

When using the relation (1), the groups of lengths can be expressed as synthetic cohorts. There are limits to this method (Hilborns and Walters, 1992) but it has been built to achieve Nephrops stock assessment. ICES working group used a modified version of LCA so as to be able to provide an advice to ACFM in case of lack of data on age estimation (Anon, 1997). Analysis by length cohort used to assess the Nephrops stock is based on a constant recruitment (Jones, 1984). This analytic biological model is considered to assess the numbers by age group. The data provided by the working group are considered as input data.

Recruitment of year n+1 for each age group i+1, i.e. the numbers of year n+1 of Nephrops of age i+1 is calculated with the following equation :

$$N_{n+1,i+1} = N_{n,i} \times e^{(-(mF \times Fi,n \times Si \times Fdi)-M)} \qquad (2)$$

where :

$N_{n+1,i+1}$	is the initial recruitment fraction of the nth Nephrops cohort still alive at age i, expressed in number
$N_{n,i}$	is the population of age i of year n, expressed in number
mF	is a multiplier of F which can take into account of the technical advance annual rate
F_i	is the mortality by fishery at age i
S_i	is the fishing gear selectivity at age i, expressed in percentage
Fdi	is calculated from discard mortality and percentage of discard. This factor enables to take into account the fact that part of the discards do not die and return to the stock; it is thus the percentage of catches that actually die Fdi=1-(1-discard mortality)*%discards=1-discards still alive*%discards
M	is the death from natural causes

$(mF \times Fi,n \times Si \times Fdi) + M$ is thus the total mortality = Zi,n

It is assumed that the recruitment occurs only once a year at the very beginning of January. At first, the constant recruitment will be assumed to be equal to the average recruitment over the last ten years, then several recruitment hypothesis will be tested and sensitiveness analyses and even stochastic analyses will be achieved.

It is possible to express the total Nephrops catches over a period as the sum of catches over the various age groups :

$$Y = \sum_i Yi$$

The yield model by recruit developed by Thomson and Bell (1934) enables to express as follows the yield Y or Nephrops catches expressed in weight :

$$Y = \sum_i wi \times Ni \times (1 - \exp^{(-(mF \times Fi, n \times Si \times Fdi) - M)}) \times \frac{(mF \times Fi, n \times Si \times Fdi)}{(mF \times Fi, n \times Si \times Fdi + M)} \tag{3}$$

Where wi is the average weight at age i and Ni the number of individuals of age i recruited over a period.
The weight is calculated according to the growth curve developed by von Bertalanffy completed by the relation size weight of Beverton and Holt (Laurec and Le Guen, 1981) :

$$Wt = a \times Lt^b \tag{4}$$

From both yield data Y and percentage of discards by age group ri one obtains the discards Ri one obtains the discards Ri and, from the difference with the yield, the landings Di by age group of Nephrops.

which gives :

$$\mathrm{Di = Yi\ (1 - ri)} \tag{5}$$

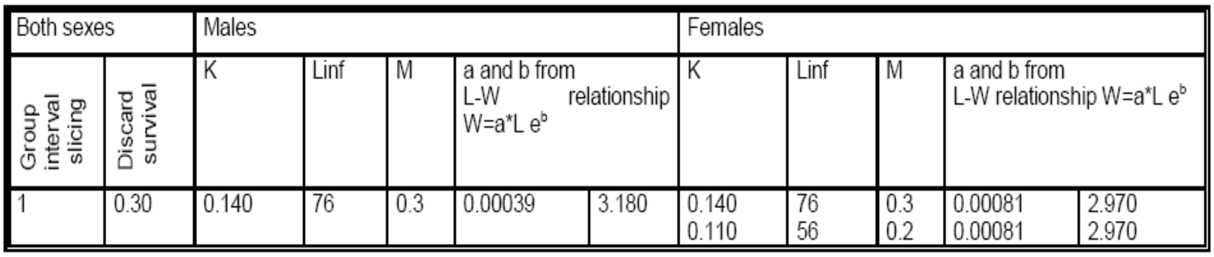
The biological model presented here thus allows to calculate *Nephrops* landings by fishing fleet for each year of the simulation.
The fishing effort applied to the other species is not taken into account; meanwhile it will be possible to alter the quantity of by-catch species landed (Qs, quantity of the species s) as a function of the selectivity. Three configurations will be studies, one of them bearing on the improvement of Nephrops trawl selectivity.

1. does not modify the catches of the three by-catch main species
2. reduces by 30% the catches of the three by-catch main species
3. reduces by 50% the catches of the three by-catch main species

Moreover, the model enables to consider that the selectivity varies according to the fleet. It may also be assumed that the fleets do not target the same size of *Nephrops*.

➢ Input data and model parameterizing

The inputs ICES working group used to achieve the analytic assessment of male and female Nephrops of the Bay of Biscay are given in the following table 1.
The parameters regarding growth and death rate from natural causes are given for immature female (top line) and mature female (bottom line).



Both sexes		Males					Females				
Group interval slicing	Discard survival	K	Linf	M	a and b from L-W relationship $W=a*L\,e^b$		K	Linf	M	a and b from L-W relationship $W=a*L\,e^b$	
1	0.30	0.140	76	0.3	0.00039	3.180	0.140 0.110	76 56	0.3 0.2	0.00081 0.00081	2.970 2.970

Source_ WGNEP. CIEM

Table 1 : biological input data

The rate of death from natural causes is assumed to be 0.30 for ages 0 and 1; it then remains constant for all sizes and for male and female M=0.25 despite the approximation it represents.
The following data are used as inputs to simulate the *Nephrops* population dynamics.

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

Table 2 : 2003 working group data (source : WGNEP. CIEM, 2004)

Discard mortality rate in trawl fisheries is around 75% (Anon, 1998). In fact the rate is higher since 10% of the *Nephrops* that escape die of the wounds caused by the trawl.
The extra mortality rate resulting from escape will not be taken into account.
On the other hand, the discard mortality rate due to the minimum size regulation in *Nephrops* fishery is taken into account. It is assumed that 30% of the discards survive (data provided by the working group).
Among the fish caught, part is landed while the other part is discarded (FAO, 1996).
The studies achieved by Ifremer on discard sampling (Biseau, Talidec, 2003) enabled to assess the ratio of discards in *Nephrops* fishery of the Bay of Biscay. The ratio of undersized *Nephrops* caught with the usual 70 mm mesh size (Eggert and Ulmestrand, 2000) amounts 55% in number and 35% in weight. The samplings achieved by Ifremer on discards of Pont-L'Abbé region harbours over terms 3 and 4 of year 2002 and 1 and 2 of year 2003 show that 50% in number 30% in weight of *Nephrops* catches were discarded. Those conducted in Lorient and Concarneau harbours show even higher a ratio with 63% in number and 45% in weight of *Nephrops* discarded. The data concerning Pont-L'Abbé region harbours will be added to the model. Subsequently, sharper an analyses of the discard data will be done as a function of the fleets and areas.

A preliminary analyses of these data provides the following matrix for discards by age group.

Age groups i	Percentage of Nephrops discarded in number di(t)
1	96%
2	75%
3	28%
4	7%
5	4%
6	4%
7	1%
8	1%
9+	0%

Table 3 : Discard data

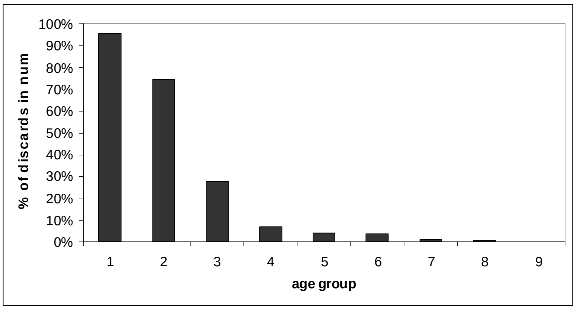


Figure 1 : Discard distribution by age group (source : Ifremer)

The following key size-age was used to convert the size group data into age group data.

Age group	Male LC mm	Female LC mm
[0,1[	17	17
[1,2[	25	25
[2,3[	32	25
[3,4[	37	27
[4,5[	42	30
[5,6[	47	33
[6,7[	51	35
[7,8[	54	38
[8,9[	57	40

Table 4 : Size-age key (source : WGNEP. CIEM)

At first, the recruitment is assumed to be constant
R = (average over 1994-2003) = 559291

There are some limits to the model proposed. From a biological viewpoint, the dynamics of Nephrops population remain unfamiliar and stock assessment entails uncertainties. In particular, the model is structured by age whereas the biological samplings collect data on length. Now, regarding species that moult when growing, the keys size-age do not enable to make an age match a length but an age group to an average length; this leads to inaccuracies. Moreover, the model considers the stock as a whole, making no difference between sexes, which would have led to a higher degree of complexity. Yet, mortality due to natural causes and female and male catchability are most different. For instance, once they are granulated, the female remain buried for several months and thus cannot get caught.

Considering the data available and the limits of the key size-age the assumptions regarding selectivity must be considered with care. At this stage the point bears on some theoretical situations considered, close to the experiments conducted on selectivity devices.

ANNEX 2 : PRESENTATION OF ISISFISH MODEL

For more details on the model and the entrance parameters refer to :

Drouineau H., 2004. Paramétrage et développement d'un plan de simulation de l'outil de simulation ISIS-Fish pour évaluer l'impact de différentes règlementations de l'activité de pêche de la pêcherie mixte merlu-langoustine de la Grande Vasière. *Mémoire de Diplôme d'Agronomie Approfondie, Spécialité Halieutique, Agrocampus Rennes*, 62p.

Drouineau H., Mahévas S., Pelletier D. and Beliaeff B., 2006. Assessing the impact of different management options using ISIS-Fish_: the French Merluccius merluccius – Nephrops norvegicus mixed fishery of the Bay of Biscay. *Aquat. Living Resour.* 19, 15–29.

Mahévas S., Pelletier D., 2004. ISIS-Fish, a generic and spatially explicit simulation tool for evaluating the impact of management measures on fisheries dynamics. *Ecological Modelling* 171, 65-84.

Pelletier D., Mahévas S., Poussin B., Bayon J., André P., Royer J.-C., 1999. A conceptual model for evaluating the impact of spatial management measures on the dynamics of a mixed fishery. *17th Lowell Wakefeld Fisheries Symposium, Anchorage, Alaska*, 53-66.

ISIS-Fish tool was developed to assess the impact of various management measures. The simulation tool is based on three submodels (figure 1) explicit in both time and space, which thus enable to test the spatial and seasonal measures (among which the protected marine areas). The submodel dedicated to population dynamics describes the biology of the different populations of the fishery (the trophic interactions not being taken into account). The submodel dedicated to fishing activity dynamics calculates a standardized fishing effort that applies to each spell of time, each zone and each species. The submodel dedicated to management dynamics describes the various management measures : the nature, the place and the time when they apply, along with the reaction of the fishermen to each measure. All three models interact in the space to calculate for each spell of time and for each fishery the mortality affecting each species and in each zone of the fishery.

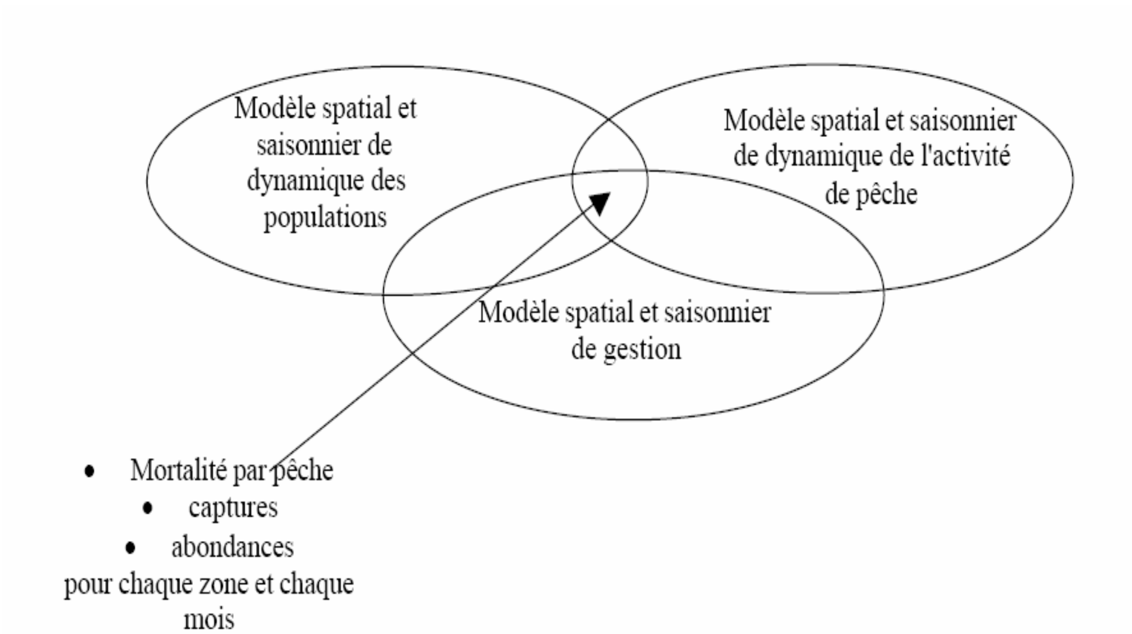


Figure 1 : model operation scheme

Detail of the submodel dedicated to population dynamics

The submodel enables to describe the dynamics of several of the populations worked. It clarifies the spatial and seasonal distribution variations in connection with the species biology, and mainly migrations. The populations are structured by stage (age or length); they are distributed over zones where populations are assumed to be homogeneous, to move from one zone to another during seasonal migrations (a season being a suite of months in relation with the biology of the species). In the course of the spell of time (the month) several successive phenomena can affect the population; these are described in figure 2.

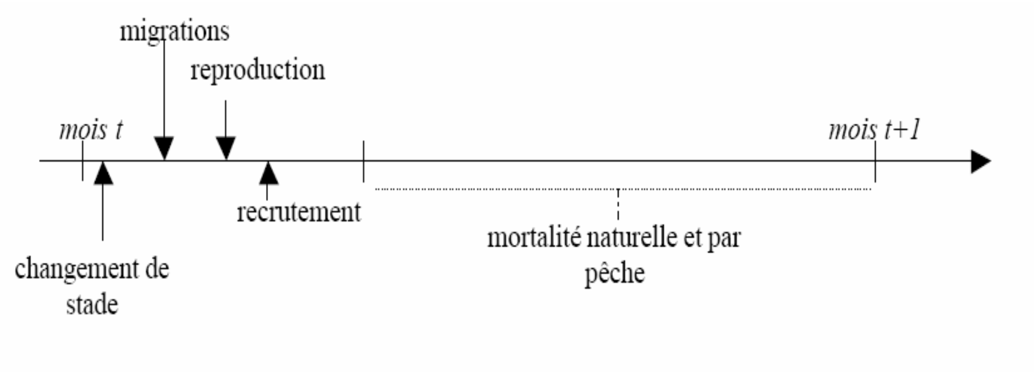


Figure 2 : the successive phenomena affecting each of the population groups every month (Mahévasandt Pelletier (2004))

Detail and definition of the objects of the submodel dedicated to exploitation

The exploitation model is the one that will enable to calculate the fishing effort, and, by compiling it with the submodel dedicated to population dynamics, to calculate the mortality for each fishery and for each group of age for each month. The model is supported by several objects which are :

- the fleets : group of boats which achieve trips of the same length (1, 5, 15, 21 days)
- the gears : these are characterized by a standardization coefficient which aims at standardizing the effort among the gears, the selectivity curves for each of the species and the parameters which can be subject to management measured (mesh, length of the net).
- the métiers : implementation of a gear, over a given zone, over a season, targeting a given species. They are usually defined at the scale of the fishing operation. Thus, they are characterized by a gear (along with the management parameter, for instance a 70 mm mesh size), target coefficients for each species (which correspond to the importance of the research on each species), areas and seasons worked (for the purpose of the present study, we have considered yearly metiers).
- the strategies : chronology of métiers practiced over a year. The strategies are characterized by a monthly distribution of the effort among the métiers which make them up and by a number of boats of each unit which practices the strategies.

Detail of the submodel dedicated to management dynamics

The management submodel enables to describe the management rules, potentially endowed with a seasonal and spatial distribution. By compiling the submodel with the fishing activity model it is possible for each month to make out then to distribute the fishing effort in the space. The management rules which are coded in ECMAScript are constituted of several parts :

- a “builder”, which is a code executed at the beginning of the simulation and which enables to recover the parameters describing the rule (gear, zone, season … concerned).
- a code which enables to recover the outputs of the simulation (abundance, catches, strategies, metiers …) for each spell of time
- a condition which enables to check whether a rule applies to a metier
- “action before” : a code which is executed prior to the calculation of the spell of time if the rule applies and which explains the changes that occur on account of the rule (change of zone, of gear …)
- “action after” : a code executed once the calculation of the month over and which explains the modifications after simulation (for instance, assigning the new catches to the discards).