The short-run viability of fishing vessels: the case of the French Norway lobster fishery in the Biscay Bay

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Abstract : The French Norway lobster (*Nephrops norvegicus*) fishery situated in the Biscay Bay is composed by about 250 costal trawlers. These boats are registered in harbours located in South Brittany (Le Guilvinec, Lorient, Concarneau) and in the Vendée (Sables d'Olonnes, La Cotinière). The main particularity of the fishery is that lobsters are landed alive, which constitutes a specific product in the Norway lobster market.

For several years, ICES members have claimed for the necessity of strongly reducing effort and immature catches for this specie (and in fact for the most important species of the area). In 2001, the ACFM recommendation was a 40% reduction of the allowed TAC for the Biscay Bay fishery. A 20% reduction was finally adopted by the Ministry Council but won't be applied by fishermen according to their public statements. As hake constitutes an important bycatch for these boats, the Hake Recovery Plan has also some repercussions on the fishery (in terms of additional technical measures)

This paper presents the first results of a bioeconomic model of the French lobster fishery. The aim of this model is to understand the short-run viability of the fishing vessels implied in this fishery and to evaluate the resilience of the whole fishery to quick regular changes, such as recovery plan or important quota reductions.

Introduction

Numerous European fish stocks are nowadays facing severe depletion such as the European hake, the cod or the sole. Recently, the implementation of recovery plans was recommended for fourteen fish and crustacean stocks while twelve other stocks were considered to be outside safe biological limits (European Commission, 2002). Two important European stocks are already managed through recovery plans : the cod in the North Sea since 2000[1] and the hake in the Biscay Bay since 2001[2].

The hake recovery plan aims at protecting immature fishes to be caught by trawlers and netter. The minimal mesh size increased from 70mm to 100mm in nursery areas (shaded and black areas on figure 1). But, hake only represents less than 10 % of the turnover for more than 75 % of the French boats which capture it (either trawlers, netters or liners) (Metz & Perez, 2001). The hake recovery plan thus targets fleets which capture hake as a bycatch.

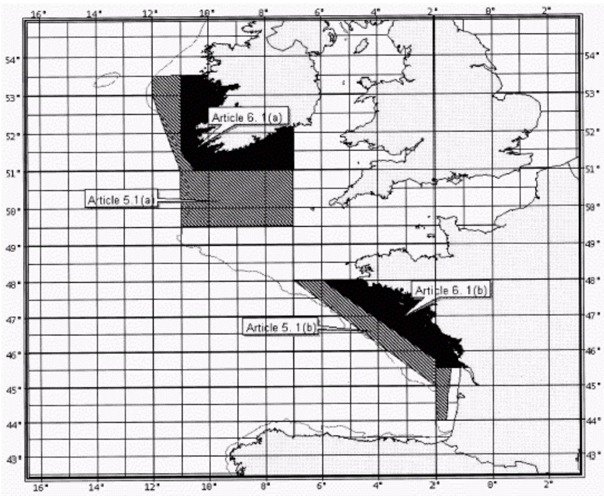

Figure 1 : the hake recovery plan restrictive zones (Commission Regulation (EC) No 1162/2001 of 14 June 2001).

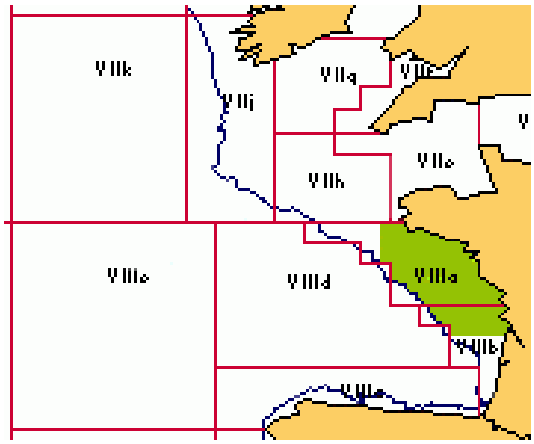

Figure 2 : the Nephrops fishing grounds in the Biscay Bay.

The French Nephrops trawlers are part of the targeted fleets, especially those working in the Biscay Bay (ICES areas VIIIab), as the hake nursery areas (figure 1) match their fishing grounds (figure 2). Often accused to catch large amount of immature hakes, these boats are also facing the depletion of their main target. The Norway lobster (also called Nephrops) is landed in several European countries. In 2002, the ACFM working group on Nephrops stocks reported fourteen management areas (which can be considered as major stocks)[3]. Three of these fourteen stocks were also considered to be in danger : in the Cantabrian Sea (VIIIc), in the Western Iberian region (IX, X, CECAF) and in the Bay of Biscay (VIIIab) (European Commission, 2002).

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[1]the major decisions were the Commission Regulation (EC) No 2056/2001 of 19 October 2001 and the Council Regulation (EC) No 2549/2000 of 17 November 2000.

[2] Commission Regulation (EC) No 1162/2001 of 14 June 2001.

[3] The ACFM report (2002) mentions four more management areas, in which no Nephrops have been caught : those areas can't thus be considered as stocks.

The purpose of this paper is to present the structure and the first results of a simulation bio-economic model of the French Nephrops fishery operating in the Bay of Biscay. The aim of this model is to study the short term effort allocation of different trawlers exploiting two resources (fish and Nephrops), as well as the redistributive aspects of management measures implementation.

The paper is thus organised as follows. First the recent history of the Nephrops fishery is presented, then the structure of the model is explicated, stressing its role as an indication of the potential consequences of quick management changes. Finally, results of simulation runs carried out with the software VENSIM™ are used to discuss the fleets short run evolution while facing the implementation of a hake recovery plan.

The Norway lobster fishery in the Biscay Bay

The recent history

Nephrops landings are known for more than fifty years. According to fishermen, they are highly variable, depending on meteorological and environmental variations. The Nephrops production still seems to be decreasing after 1990 (see figure 3). During this last period, catch per fishing hours are constant, but the concurrent fall of nominal fishing effort isn't the only explanation of this decrease. This fall seems to be compensated by the technical progress : the fleet was massively equipped with GPS, twin-trawls and sometimes rockhoppers. The boats are therefore able to fish in zones where they never worked before, near rocks or wrecks, especially when they use rockhoppers.

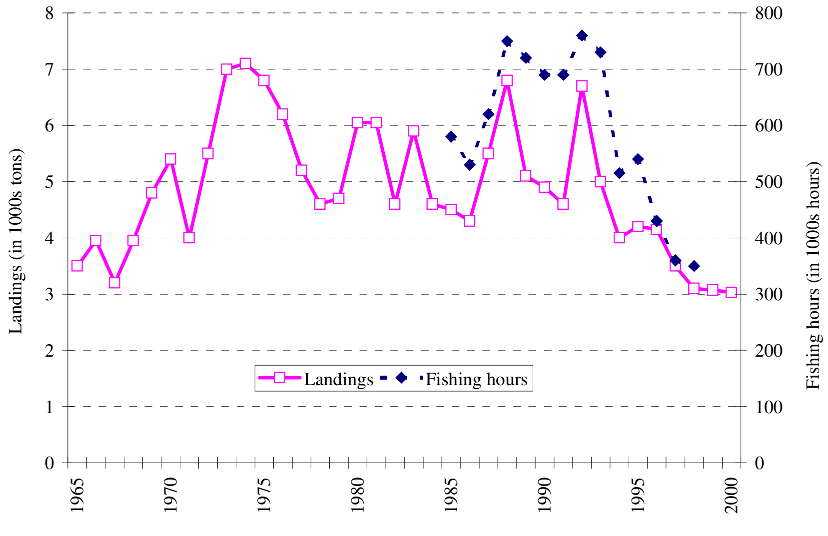


Figure 3 : Nephrops production in the Biscay Bay and fishing effort (IFREMER data)

The fleets' details

The Nephrops trawlers operating in the Biscay Bay are disseminated all over the Atlantic coast, from La Cotinière (Oléron Island) in the southern part of the bay, to Penmarch (at the south west foreland from Brittany, also called "pays bigouden") in the northern part of the bay (see figure 4 next page). The most part of the fleet is situated in Brittany and especially in the "pays bigouden" and in Concarneau : more than fifty per cent of the production is landed in this area (table 1 next page).

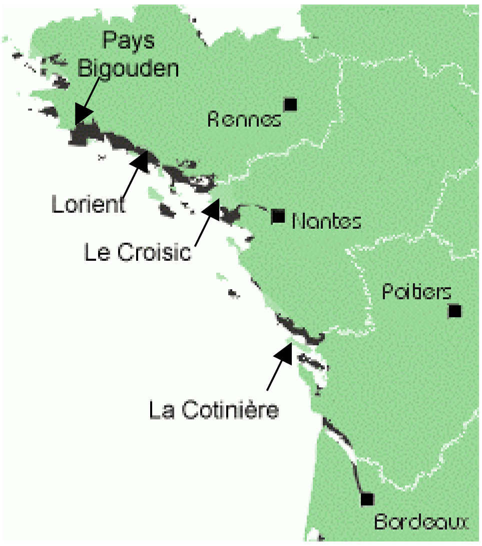


Figure 4 : The main harbours implicated
in the Nephrops fishery.

The fleet is not homogeneous all over the coast. In fact, boat's characteristics (mostly the length) are strongly correlated to the mean distance from their harbour to their fishing grounds. Roughly, the small boats (with a length under 14-15 metres) operate mostly in the northern part of the bay within a 3 to 20 miles zone.[4] Their typical fishing trip is 12 to 16 hours long. Nephrops represents the half of their total gross product (table 1).

The larger boats mainly operate in the southern par of the bay (from Lorient to La Cotinière). These boats are more polyvalent and less dependant on the Nephrops resource (which represents only 25% of their gross product, as indicated in table 1). As their fishing journey is longer (between 2 and 3 days), they need to use some specific onboard conservation systems to keep the Nephrops alive such as chilled fish-preserves or Sycocrus™ cold rooms.

	Boats	**Crew (number of men)**	**Total gross product (MF)**	**Nephrops gross product (MF)**	**Nephrops share in the total gross product (%)**
Bretagne	156	508	307,86	152,12	49%
Pays de Loire	33	158	99,54	22,85	23%
Poitou Charente	35	99	64,93	16,80	26%
Aquitaine	3	15	13,04	1,53	12%
Basse Normandie	2	8	6,35	0,84	13%
Total	**229**	**788**	**491,72**	**194,14**	**39%**

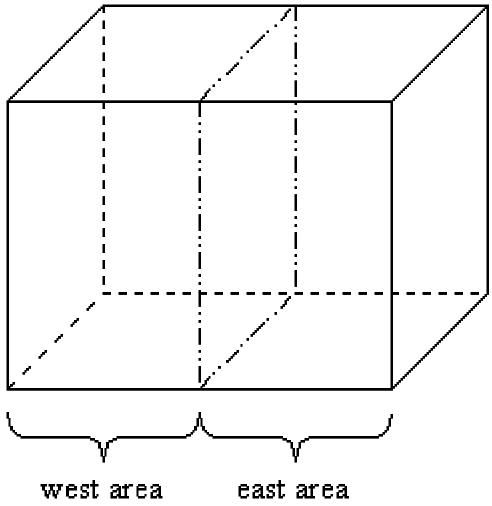
Table 1 : the geographical repartition of the French Nephrops fishery in the Bay of Biscay (IFREMER, 2001)

[4] This is a consequence of the French navigation rules which allow these boats to navigate only at a maximum of 20 miles from the coast, taking into account the fact that such boats aren't sufficiently stable to navigate farther.

Representing the fishery :

The model structure presented in this paper is quite similar to several models recently used to describe the implications of creating marine protected areas (such as Hannesson, 1998, Boncoeur & al., 2001 or Sumaila & Armstrong, 2002).

The region under survey is represented by a cube of dimension 1 in order to simplify the different equations. The whole region is supposed to be homogeneous from an ecological point of view.



The region is split into two sub-regions : the "west" sub-region representing the offshore region, the "east" side representing the coastal sub-region. The proportion of the total region assigned to west sub-region is α, with $0 < \alpha < 1$.

This model aims at describing the fishery evolution in a short run perspective. The model time path Δt is therefore expressed in fraction of year (1/4, 1/12 or 1/52).

Describing the two biological populations

The two populations (fish and Nephrops, named respectively *H* and *L*) are representing using an aged structured model (Laurec & Le Guen, 1981). This will allow the model to take into account different fishing gears or technical measures implementation such as mesh size increase. The dynamics of both stocks are modelled as follows :

It is assumed that, in each sub-region, the different stocks are homogeneously distributed and randomly dispersed at a constant density. The survival population is calculated for every combination of stock, cohort and sub-region, at every Δt period:

$$N_{t+\Delta t}^{i,a,r} = N_t^{i,a,r} \cdot e^{-M^i \cdot \Delta t} \qquad (1)$$

with:

$N_t^{i,a,r}$ the population of the a^{th} cohort of stock i ($i = L, H$) in sub-region r ($r = west, east$),

M^i the age independent mortality for stock i.

Nephrops are supposed to be pleged to the east sub-region, with no migration to the west part of the region, this implies that $N_t^{L,a,west} = 0 \quad \forall a, \forall t$.

In order to simplify the model, recruitment occurs once a year, at the very beginning of the month of January. It is calculated using the Beverton & Holt recruitment function, as a function of the stock of spawning biomass :

$$R_t^{i,r} = \frac{\alpha^i \cdot SSB_{t-\Delta t}^{i,r}}{1 + \gamma^i \cdot B_{t-\Delta t}^i} \qquad (2)$$

with:

$SSB_t^{i,r}$ the post catch spawning stock biomass of stock i in sub-region r,

B_t^i the post catch spawning stock biomass of stock i,

α^i, γ^i two constant biological parameters.

$SSB_t^{i,r}$ and B_t^i are determined as follows :

$$SSB_t^{i,r} = \sum_a d_{SSB}^{i,a} \cdot w_t^{i,a} \cdot N_t^{i,a,r} \quad \& \quad B_t^i = SSB_t^{i,west} + SSB_t^{i,east} \qquad (3) \ \& \ (4)$$

with:

$d_{SSB}^{i,a}$ the proportion of mature animals of cohort a in the stock i,

$w_t^{i,a}$ the weight of an animal of cohort a in the stock i.

Weight is calculated using a Von Bertalanffy growth curve completed by the Beverton & Holt isometric relationship between length and weight (Laurec & Le Guen, 1981).

Fish migrations occurring between the two sub areas are modelled with a diffusion model, according to Fick equation. The fish migration from the east side to the west side during a Δt period can thus be written as follows:

$$Migration_{t,\Delta t}^{H,a,east\rightarrow west} = \varphi_{\Delta t}^H \cdot \left(D_t^{H,a,east} - D_t^{H,a,west}\right) \qquad (5)$$

with:

$D_t^{H,a,east}$ the density of the a^{th} cohort of fish in the east sub-region,

$D_t^{H,a,west}$ the density of the a^{th} cohort of fish in the west sub-region,

$\varphi_{\Delta t}^H$ the age independent diffusive coefficient for stock i during a Δt period. $\left(0 < \varphi_{\Delta t} < 1\right)$

Finally, catch is assumed to be proportional to the density of animals in each sub-region :

$$Y_t^{i,a,r} = q_{\Delta t}^i \cdot D_t^{i,a,r} \cdot \sum_f E_t^{i,a,r,f} \qquad (6)$$

with:

$D_t^{i,a,r}$ the density of the a^{th} cohort of stock i in the sub-region r,

$E_t^{i,a,r,f}$ a measure of the effective effort developed by the fleet f (f = *ct, ot, lt*, see further), on the a^{th} cohort of stock i in the sub-region r,

$q_{\Delta t}^{i,a}$ a measure of the catchability coefficient for the stock i during a Δt period, which is supposed to be geographically and age independent.

The dynamics of the two stocks can thus be summarised as follows :

For the fish stock :

$$N_{t+\Delta t}^{H,a,r} = N_t^{H,a,r} \cdot \left(e^{-M^H \cdot \Delta t} - \frac{q_{\Delta t}^H}{d_1^r} \cdot \sum_f E_t^{H,a,r,f}\right) + d_2^r \cdot \varphi_{\Delta t}^H \cdot \left(D_t^{H,a,east} - D_t^{H,a,west}\right) \qquad (7)$$

with:

$$d_1^r = \begin{cases} \alpha & \text{if } r = west \\ 1-\alpha & \text{if } r = east \end{cases} \text{ and } d_2^r = \begin{cases} 1 & \text{if } r = west \\ -1 & \text{if } r = east \end{cases} \quad (8)\ \&\ (9)$$

For the Nephrops stock :

$$N_{t+\Delta t}^{L,a,west} = N_t^{L,a,west} \cdot \left(e^{-M^L \cdot \Delta t} - \frac{q_{\Delta t}^L}{1-\alpha} \cdot \sum_f E_t^{L,a,west,f} \right) \quad (10)$$

Representing the fleets' activities

Three different trawler fleets (respectively named *lt*, *ct* and *ot*) are represented in this model :

- some large trawlers which only target fish in the west region,
- several small coastal trawlers which cannot quit the east sub-region and thus target Nephrops with fish as a bycath,
- and opportunist trawlers which can choose either to target fish in the west region or Nephrops (with fish as a bycatch) in the east region.

Each type of trawler develops an effective effort on every combination of stock and age in every sub-region, at every Δt period:

$$E_t^{i,a,r,f} = s_t^{i,a,f} \cdot P_{\Delta t}^{r,f} \cdot T_t^{r,f} \quad (11)$$

with:

$s_t^{i,a,r,f}$ a selectivity index describing the potential catch achieved on the a^{th} cohort of stock i by the fleet f in sub-region r,

$P_{\Delta t}^{r,f}$ the fishing power developed by the fleet f in sub-region r, during a Δt period

$T_t^{r,f}$ the share of fleet f fishing in the sub-area r. The general conditions are: $0 \le T_t^{r,f} \le 1$ and $T_t^{west,f} + T_t^{east,f} \le 1$. Moreover, according to the former hypothesis $T_t^{west,ct} = T_t^{east,lt} = 0$

Gross products are calculated for each fleet :

$$GP_t^{r,f} = \sum_i \sum_a p_t^i \cdot q_{\Delta t}^i \cdot D_t^{i,a,r} \cdot E_t^{i,a,r,f} \quad (12)$$

with:

p_t^i the price for the catch from stock *i*.

The different prices are calculated within the model, regardless to the animal size, trough a simple linear demand equation. Further studies about Nephrops market (focusing the seasonality and the size segmentation) will help to refine the market evolution.

Then, the net profit is defined for each fleet as :

$$\Pi_t^{r,f} = \left(GP_t^{r,f} - cc_{\Delta t}^{r,f} \right) \cdot ps^{r,f} - fc_{\Delta t}^{r,f} - act_t \cdot vc_{\Delta t}^{r,f} \quad (13)$$

with:

$cc_{\Delta t}^{r,f}$ the common costs for fleet *f* in sub-region *r*. These costs are shared between the crew and the boat owner (gasoil, water, food…).

$ps^{r,f}$ the owner share for fleet *f* in sub-region *r*. Crew wage are calculated as a share of the

$fc_{\Delta t}^{r,f}$ the fixed costs for fleet *f* in sub-region *r*.

act_t a dummy variable representing the fleet activity at time *t* : $act_i = 0$ if the fleet doesn't fish (for different reasons : TAC completion before the end of the year, temporal closure…), 1 otherwise.

$vc_{\Delta t}^{r,f}$ the variable costs for fleet *f* in sub-region *r*.

If we consider the model hypothesis, the opportunist fleet can allocate its effort between the two sub-areas. Their ability to move is expressed as a function of the difference of individual net profit during the previous period (in the model, the difference is calculated for a complete year and then compared) :

$$mov_{t,\Delta t}^{east \to west} = \psi_{\Delta t}^{ot} \cdot \left(\frac{\Pi_t^{west,ot}}{boat_t^{west,ot}} - \frac{\Pi_t^{east,ot}}{boat_t^{east,ot}} \right) \tag{14}$$

with:

$\psi_{\Delta t}^{ot}$ a constant describing the ability to move from a sub area to the other ($\psi_{\Delta t}^{ot} > 0$)

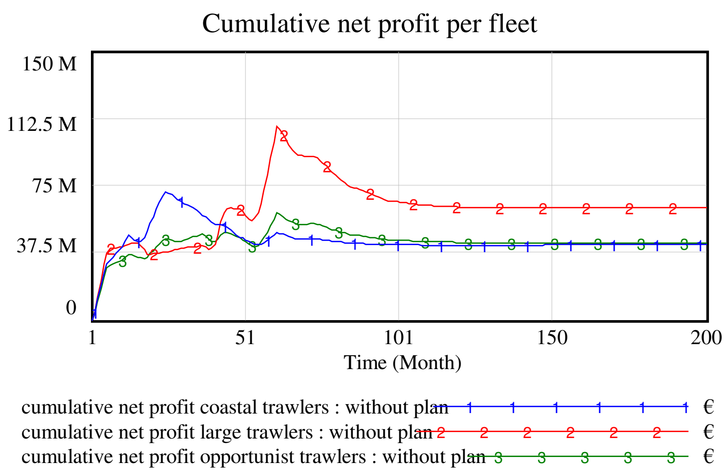
Simulation results and discussion

Here are presented the first results achieved in simulating this model using the software VENSIM[TM]. As the initial values are not realistic, the simulation results can only be considered as an idealistic view of the Nephrops fishery from the Bay of Biscay. Moreover, technical progress and discounting are considered as non existent in these runs.

The status quo situation

The first simulation run gives the starting point for further comparisons. In this run, there isn't any management system implemented. After a "realloca-tive" period from approximately hundred periods, the model achieves what can be called a stable zone (figure 5). Therefore, the management systems tested in the next parts will all begin at time = 100.

Figure 5 :

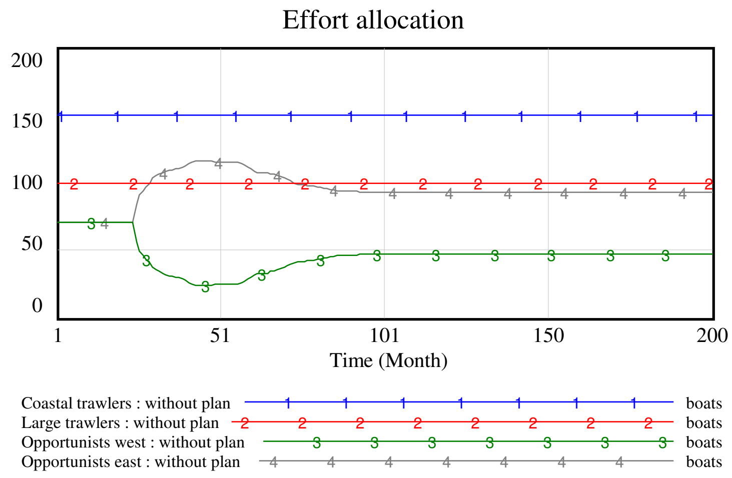


For each time period, a "cumulative net profit" is calculated, by summing the $1/\Delta t$ previous periods. This allows to avoid the seasonality while comparing the different results.

Inititally, 150 coastal trawlers, 100 large trawlers and 140 opportunist trawlers are fishing in the region (the initial allocation is 70 in west sub-area, 70 in east sub-area).

Due to parameter values, the fleet of opportunist trawlers rather works in the east sub-area, where both Nephrops and fish can be caught (figure 6).

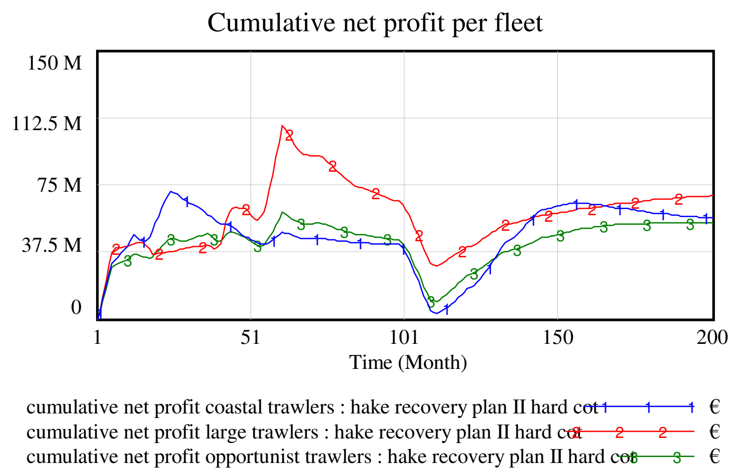
Figure 6 :



Protecting the immature fish in the entire region

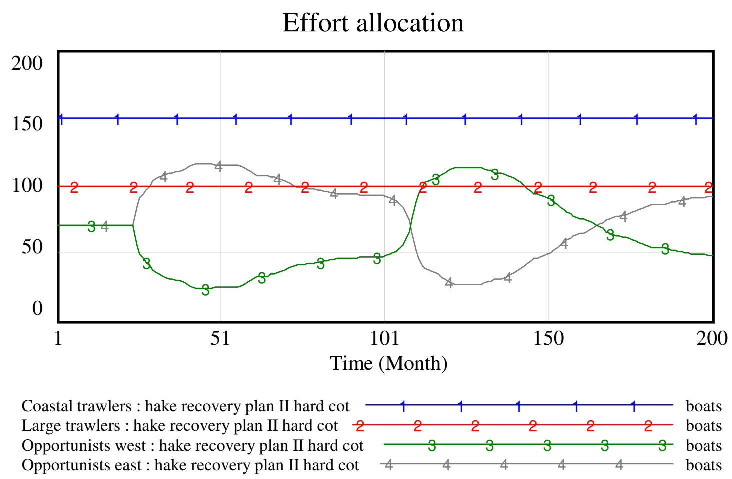
When the European Commission decided the hake recovery plan implementation, the first intentions were to increase the mesh size for all the trawlers fishing in the hake nursery area (from 70mm to 100mm), which basically include both shaded and black areas in figure 1 ; that is to say the major Nephrops fishing ground in the Bay. Such measures would have conduct to increase selectivity for all kind of trawlers. During the first three years, such measures would have strongly shorten all fleets profits (figure 7).

Figure 7 :



In such a context, the opportunists boats will first massively focus on the west sub-area because of the massive loss of Nephrops catch (figure 8). After a first period of loss, the technical measure bear fruit : working in the east sub-area is again more profitable, explaining the second shift in opportunists' effort allocation.

Figure 8 :



The hake recovery plan

In comparison with the last run, the hake recovery plan implemented by the EU presented a slight difference : coastal trawlers didn't have to change their trawl mesh size, while the other fleet did.

Within the model context, a such management tool would increase the coastal trawlers net profit (figure 9) and force the opportunist trawlers to focus on fish to remain profitable (figure 10). As the coastal trawlers are the only ones continuing on a "bad" slope (they continue to catch immature animals), they constitute the only group which really gain from the recovery plan implementation.

In the Bay of Biscay, the actual situation is quite the same. Since the recovery plan implementation, the coastal trawlers continue to work on the fishing grounds they were practicing before the recovery plan. On the contrary, the opportunist trawlers are claiming for a net loss due to the new rule.

Figure 9 :

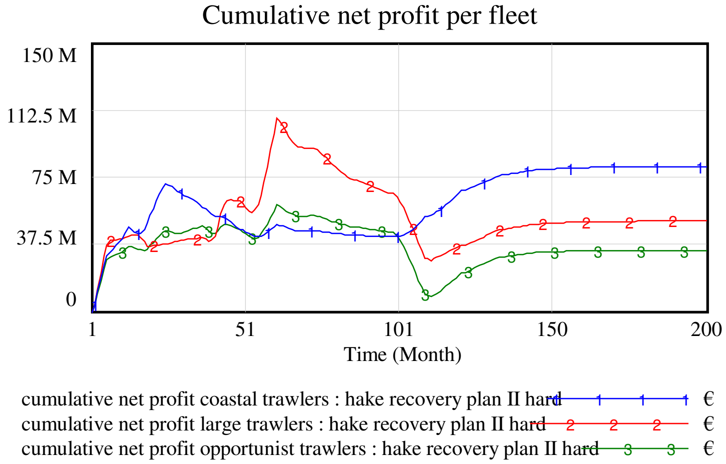
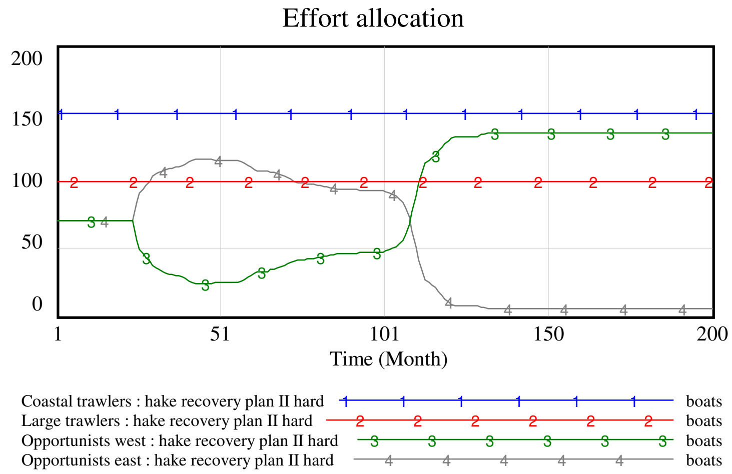


Figure 10 :



According to them, fishing Nephrops with a 100mm trawl is quite impossible. They also face a simple problem : either convince the French government to give them a special dispensation for using a 70mm trawl or target fish.

Implementing a selectivity program

In 2001, the French fishermen organisations invited Franz Fichler to embark on a coastal trawler in the pays bigouden. The purpose was to show him that selective trawls would be a good alternative to the hake recovery plan. According to fishers, this would allow the opportunist trawlers to continue to exploit the Nephrops stock.

Implementing this measure in the model give the results shown figures 11 and 12. In this context, the opportunist trawlers first focus on the west sub-region, but very quickly come back to the fish-Nephrops fishery. Compare to the two previous runs, the opportunist trawlers face lower losses in this situation.

In fact, a selectivity program was engaged six months ago by the French fishermen organisations. Its main objective is (i) to avoid further restrictive measures for coastal trawlers and (ii) to allow opportunist trawlers to catch Nephrops.

Figure 11 :

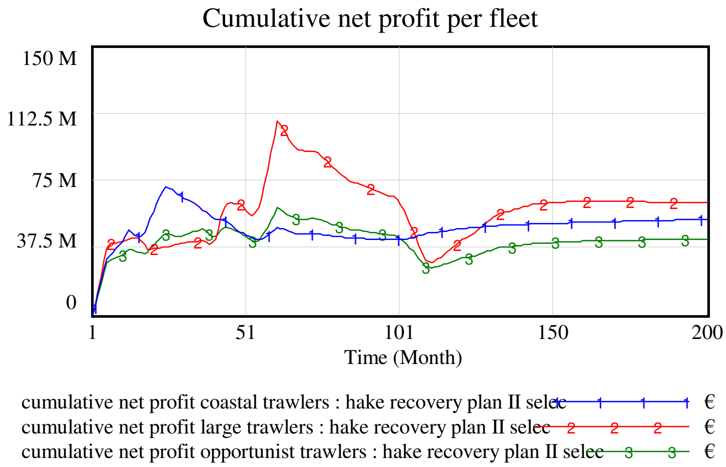
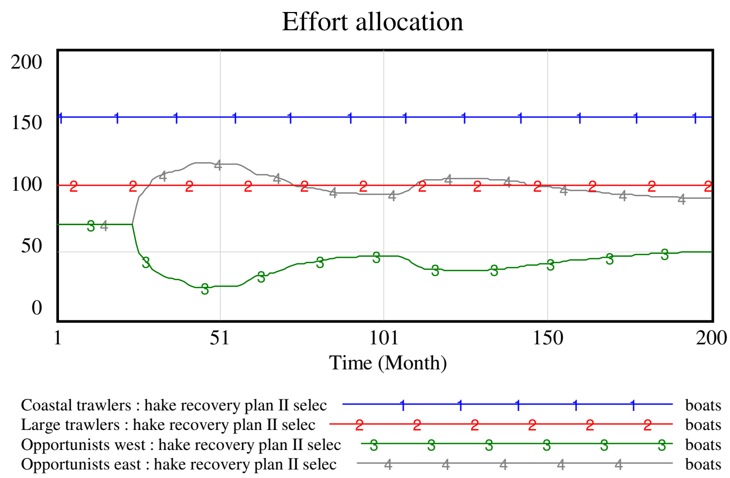


Figure 12 :



This solution would nevertheless be a second best in our model, because it wouldn't stop the catch of immature Nephrops.

Conclusion

The aim of the simulation model presented in this paper is to understand the short term effort allocation of what we call an opportunist fleet facing management measures as well as the redistributive effects of such measures .

Simulation results show that short run profit loss can be important for the opportunist trawlers while implementing hake recovery plan measures, especially when not all fleets are concerned by the new rules. Comparing this heuristic representation with the reality allow us to understand the fishermen reaction to one of the main stakes of the Nephrops fishery in the Bay of Biscay : "do everything in order to continue to fish" as some fishermen representatives like to say.

Further applications of this model should take into account more elements and mostly a better market representation as well as the “black fish” phenomenon: some fishermen representatives publicly announced last winter that they wouldn’t declare some catch if their boats viability is in danger. Nowadays undeclared Nephrops represents between 10 and 15 % of the landings. But in the future

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