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A Bioeconomic Analysis of the Impact of Decommissioning Programs: Application to a Limited-Entry French Scallop Fishery

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Abstract *The objective of this paper is to assess the benefits and costs of decommissioning policies aimed at reducing fleet capacity through premiums offered by the public authority to fishermen to scrap their vessels. A case study, the limited entry scallop fishery of the Saint Brieuc Bay, France, is used to consider the problem of excess capacity and to model the bioeconomic consequences of disinvestment behavior. Special attention is paid to the assessment of fishermen's willingness to leave the fishery and to the implementation of public policy in terms of budget level and premiums offered to the fishermen. Spreadsheet simulations show that the impact of decommissioning programs is positive in terms of net surplus, even in the case of increasing technical efficiency of the vessels.*

Key words Fishing capacity, decommissioning programs, premium, willingness to leave, bioeconomic model, cost-benefit analysis.

JEL Classification Code Q22.

Introduction

There is increasing concern about excess capacity in fisheries at an international level, as well as in the European Union (FAO 1997; Gréboval and Munro 1997; Hatcher and Robinson 1998). Economic analysis of these problems has focused on the factors explaining overcapitalisation and policy options — market based or administrative systems — to control and reduce fishing capacity of the fleets (Newton 1998; OECD 1997). Within management alternatives, buyback or decommissioning programs of vessels or licences are but some of the tools used to adjust fleets in order to reach different objectives (Holland, Gudmundsson, and Gates 1999; Holland 1999; Metzner and Rawlinson 1998). They have been widely used to restore profitability to the fishery or to reach stock conservation objectives. However, they lead to distributional implications in terms of transfer payments.

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At the European level, adverse effects on fishing stocks have led to strengthening the role and hardening the constraints of Multi-annual Guidance Programs (MAGPs) within the Common Fishery Policy (Anon. 1990, 1996). Each member state has been required to adjust their national fleet through the MAGP since 1983. Their objectives expressed in engine power (kW) or gross registered tonnages of fleets are linked to a few general objectives expressed in terms of fishing mortality reduction. Faced by the increased tightening of MAGP objectives, the member states have implemented different types of public policies and decommissioning programs to fulfil fleet capacity reduction targets (Frost *et al.* 1995; Nautilus Consultants 1997).[1] In France, a sector-related policy based on entry barriers and individual permits has been used to control fleet capacity. From 1991 to present, vessel decommissioning programs, linked to a premium offered to vessel owners by the government, have been adopted to reduce fleet size (Guyader and Daurès 2000).

Despite policy interest in decommissioning programs, there are few quantitative studies of the implication of these programs from an economic point of view (Anderson 1998; Chuang and Zhang 1998; Kitts, Thunberg, and Robertson 2000). Bioeconomic analyses of fleet adjustments do not include the cost of such programs and, therefore, overestimate their social benefits. Even if there is an administrative cost for fisheries managers to organise such schemes, the main cost consists of the premiums offered by management authorities to the fishermen to scrap their vessels. Most of the approaches fail to integrate the fishermen's behavior into the analysis of fleet adjustment. As a consequence, the impact of different economic incentives, such as current returns in the fishery sector, opportunity costs, premium level, *etc.*, is not considered in the willingness of fishermen to disinvest. Few statistical studies use empirical data to examine fishers resistance to exit (Ikara and Odink 1999), and only a few recent papers on economic modelling deal with the decision whether or not to leave the fishery sector (Weninger and Just 1997; Guyader 1998, 2000). Moreover, the feedback effects of capacity adjustment on fishermen's decisions to withdraw from the industry are very rarely considered.

The main objective of this paper is to assess the benefits and costs of decommissioning policies aimed at reducing fleet capacity. In order to reach this objective, we provide a bioeconomic simulation tool in which a microeconomic approach is developed to model individual decisions whether to stay or to leave the fishery in the context of decommissioning programs. In this tool, the public authority decides to fix the premium offered in order to incite the fishermen to scrap their vessels. The model is applied to the limited-entry scallop fishery in the Saint Brieuc Bay, France.

The first part of this paper describes the fishery and management options used to control fleet fishing capacity. We then describe the bioeconomic model with its behavioral component. Thirdly, simulations are carried out in order to propose a cost-benefit analysis of different decommissioning policies with or without technical progress. The concluding section summarizes the key findings and discusses the interest of decommissioning policies for fisheries management.

The Scallop Fishery in Saint Brieuc Bay

The Saint Brieuc scallop fishery is located within the western part of the English Channel (ICES area VIIe) and is not shared with other European countries. This is one of two main scallop producing areas in France, the other being the Seine Bay.

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[1] The MAGP funding by the European Union is part of the structural policy budget that is also dedicated to the building and modernisation of the fleets (Giguelay 1999; Hatcher 2000).

Annual official landings reached around 3,800 tons in the 90s, whilst national production fluctuated around 10,000 tons per year. The area is exploited by dredging vessels from the maritime districts of Northern Brittany. The fleet is composed of small units with an average length of 10.3 meters and 127 kW of engine power. These multipurpose fishing units use different types of gear (trawls, nets, lines, and pots), especially outside the scallop official campaign.[2] The scallop turnover has oscillated between 30 and 100 million francs (base 1995) over the last 20 years (figure 1), and the fishery is a structuring activity for the coastal fleets in this area. Changes in production over the period are mainly due to modified stock productivity and changes in fishing mortality.

Scallop recruits are considered highly variable (factor 1 to 15). Based on the average situation, this is a disadvantage for long-term management of the fishery. The relation between genitors and recruits is mainly disguised by environmental factors (Fifas, Dao, and Boucher 1990). Notwithstanding the good reproductions of the early 1990s, the potential fecundity index used as a proxy of the adult biomass has plummeted in the last fifteen years. In 2000, its level was situated at about 10,000 tons as opposed to 30,000 tons in the 1970s, but the stock was not considered threatened with extinction. As a consequence, landings fell from around 10,000 tons at the middle of the 1970s to 1,500 tons at the end of the 1980s. After the increase in the 1990s and despite new management measures, the scallop fishery faced a new fall in official landings from 4,200 tons for the 1995/96 fishing season to around 2,800 tons for the 1998 and 1999 seasons.

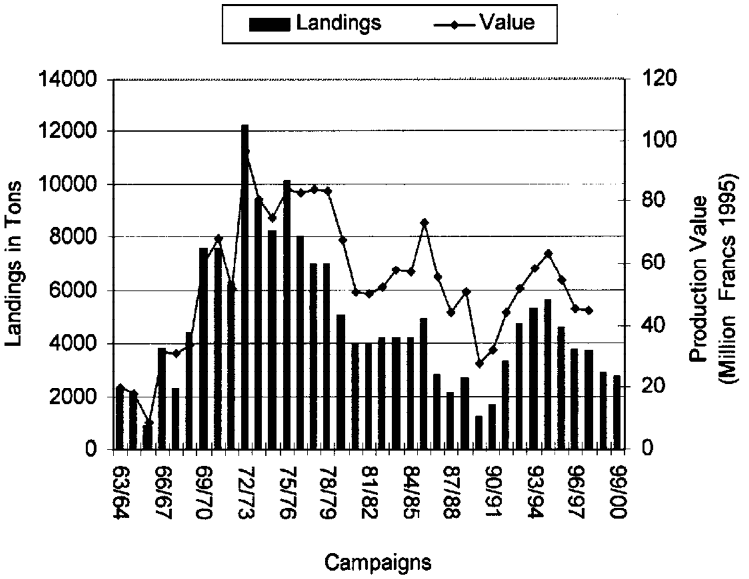

Figure 1. Evolution of Scallop Landings and Turnover
Source: IFREMER-Saint-Brieuc database; OFIMER/DPMA 2000.

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[2] In France, the scallop landings are prohibited from May to October due to sanitary considerations.

Management of the Fishing Capacity by Fleet Adjustment

The switch of coastal fleets mainly explains the development of the scallop fishery from the clam fishery, which collapsed in the 1960s. In order to avoid the same event and to control fishing mortality on the scallop stock, in 1963 the management authorities decided to limit entry into the fishery. Input regulations, such as hours at sea, maximum engine power, vessel length, and mesh size limits, were also implemented. The licence system with a *numerus clausus* was put into force in 1973 with allocations based on historical rights. For the 1975–76 fishing season, 466 licences were issued to vessels from the main maritime districts. This number declined from 447 in 1980, to 371 in 1985. The scallop fleet continued to decrease, reaching 264 units in 1990 and 253 in 1997 (figure 2). Different factors may explain the 45% reduction over this period. First, the decline of the scallop stock during the 1980s and the relative remuneration fall of the fishery gave fishers incentives to leave it to "second best" alternatives. This implies that the fishing capital has not left the fishery sector. Second, natural retirement of fishers occurred and the management authority decided not to allocate all the freed-up licences to new candidates. The exit flows lead to distributive effects because most of the vessels excluded came from maritime districts outside the Saint Brieuc Bay. Eighty-five percent of the vessels are now from the Bay, compared to 65% in 1980. Finally, scallop vessels have recently been scrapped by different French decommissioning programs. They were applied into the context of the MAGPs of the Common Fisheries Policy.[3] Decommissioning programs were not dedicated specifically to the scallop fishery because there was not a discriminative policy within the French fishery sector (Guyader and Daurès 2000). Moreover, the scallop fishery regulators did not adjust the fleet size in proportion to vessels scrapped.

The management of input regulation has not really been effective in controlling fishing power of the fleet. Even though maximum limits for vessel characteristics had been implemented, there were economic incentives for vessel owners to increase individual engine power by buying other vessels or upgrading older ones.[4] This was before the 1989 implementation of operation permits, which were aimed at controlling engine power.[5] Since this period, capital stuffing has been further increased through investment in electronic fittings and improved skills (Guyader and Fifas 1999). The increasing mean engine power does not explain global improvement of the fleet's fishing capacity. For a similar stock level, yields are better than those observed in the mid-1980s. That is why management authorities decided to re-

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[3] Decommissioning schemes organized by the Ministry of Agriculture and Fisheries consist of a premium (subsidies) delivered to vessel owners to permanently remove their fishing unit from commercial fishing activity in European waters. The decision to scrap a vessel is not mandatory, but depends on the fishermen's willingness to part with their fishing units. The design of these schemes has to comply with E.C. regulations regarding eligibility criterions, such as minimum age of the vessel and a minimum level of vessel activity over the last two years.

The premium calculation is a function of tonnage categories expressed in terms of GRT and more recently GT measures. The premium amount is composed of a fixed part depending on each tonnage category and a variable part function of the tonnage of each vessel. Decommissioning schemes have been regularly implemented to achieve the MAGP objectives when delays appeared. Over the 1991–96 period, four buyback programs were implemented. The first plan, the so-called Mellick plan implemented in 1991, was predominant and concentrated around 70% of the total public expenses to reduce the fleet capacity over the 1991–96 period. Meanwhile, the amounts allocated by the EU and French Government to decommissioning schemes represented only slightly more than 1% of the total expenditure of these authorities in aid to the fishery sector over the same period (Giguelay 1999).

[4] Since 1990, vessel size limit has been bounded at 13 meters and engine power must not exceed 185 kW, except for vessels using a licence before this date and benefiting from historical rights.

[5] Operation permits as 'Permis de Mise en Exploitation.'

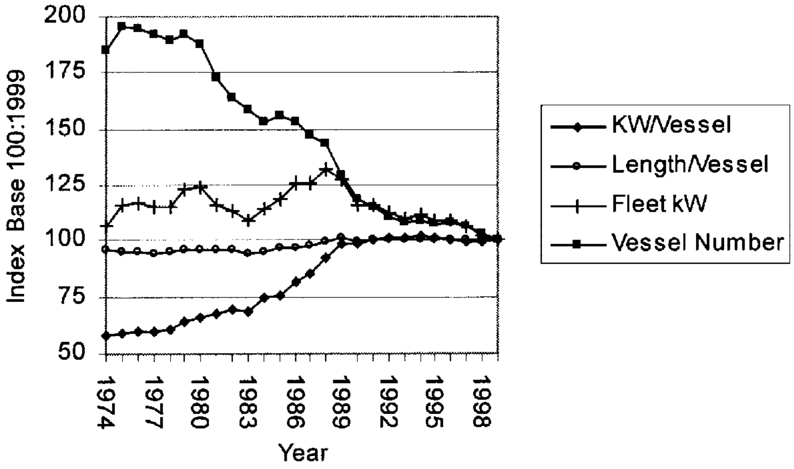

Figure 2. Evolution of Fleet Characteristics
Source: IFREMER-Saint-Brieuc database.

duce days and hours at sea (from 120 to 43 hours between 1973 and 1997) in order to adjust the level of catches to stock abundance and to balance out production over the years. By evidence, allocation of individual quotas in this single-species fishery could have prevented the dynamics of overcapitalisation of the fleet by giving a right to the catch for each fishing unit. However, this management option has always been rejected until now because of the risk of cheating behavior.

The Bioeconomic Model

We present the framework of the bioeconomic model defining the link between the economic situation of the fleet, the dynamics of the scallop stock, and decommissioning programs. The objective of decommissioning programs, defined by the management authority, is to reduce the size of the fleet by giving vessel owners financial incentives to scrap their fishing units. All things being equal, the reduction of the fleet size decreases the fishing mortality to the scallop stock, which is also subject to natural mortality and individual growth. The biological model is age-structured. If there is overcapacity in the fleet, the remaining fishing units benefit from the increased stock level according to its own biological dynamics. Almost immediately, the scallop revenue of vessels increases with mechanical positive effects on capital and labor incomes according to the share remuneration system. We then assume that the vessel owners, who are also the vessel skippers, calculate the net present value (NPV) of staying in the fishery and the opportunity cost of exiting. Calculations provide the minimum willingness to leave the fishery. This value is compared to the premium offered by the management authority by each fisherman. Then, they decide whether or not to scrap their vessel. For each iteration, the simulation model calculates the reduction (or the increase) in fishing mortality and so on. The conceptual model is given in figure 3.

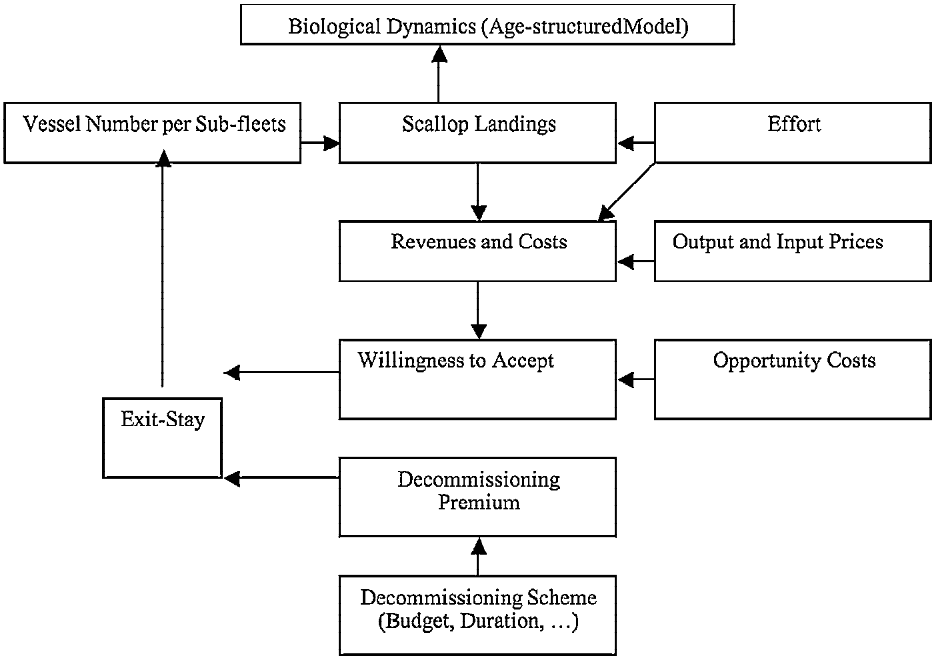

Figure 3. Main Simulation Model Components

The Standard Model

The vessel production or harvesting function is defined as:

$$y_{vjt} = q_{vjt}(N_{jt}).E_{vst}.N_{jt}. \tag{1}$$

The model is annual and subscript for time is (t). For each vessel (v) individual catches per scallop age group (j) are (y_{vj}). Basically, ages from 3 to 6 are subject to harvest. The annual legal time spent in the scallop fishery by each vessel is (E_{vs}), and (N_j) is the abundance of age-group (j). The catchability coefficient for each age group of scallops is (q_{vj}):

$$q_{vjt}(N_{jt}) = \exp\left[\frac{N_{jt}^{kWv}}{\alpha + \beta.N_{jt}^{kWv}}\right]. \tag{2}$$

The catchability coefficient depends on the level of biomass and individual vessel engine power. Coefficients were estimated by Guyader and Fifas (1999). All other biological relations, such as individual growth and natural mortality, are presented in the annex.

Technical progress in the analysis may be considered by introducing a new parameter, measuring autonomous technical progress (Δa) in the production function. Considering technical progress (Δa) each year (t) gives the equation:

$$q_{vjt}(N_{jt}) = \left[1 + \Delta a.(t - t_0)\right].\exp\left[\frac{N_{jt}kW_v.[1 + \Delta a.(t - t_0)]}{\alpha + \beta.N_{jt}kW_v.[1 + \Delta a.(t - t_0)]}\right], \tag{3}$$

(t_0) designing initial year.

Total individual vessel catch of scallops for each age-group is then defined as:

$$y_{vst} = \sum_{j=1}^{n} y_{vjt}. \tag{4}$$

On the basis of vessel production function, indicators regarding the economic situation of each vessel are calculated. We assume that the landing price of scallops (p_s) and prices of variable inputs (fuel, gears) are exogenous.[6]

The earnings to be shared (rts) between the vessel owner and the crew are defined as:

$$rts_{vt} = p_s.y_{vst}.(1 - \theta) - c_{vs}.E_{vst} + \sum_{o=1}^{N} p_o.y_{vot}.(1 - \theta) - \sum_{o=1}^{N} c_{vo}.E_{vot}, \tag{5}$$

where (y_{vs}) and (y_{vo}) represent the level of scallop catch and other species, (θ) the unit cost of landings, and (E_{vs}) and (E_{vo}) the days spent at sea in scallop and other fisheries, respectively. (c_v) is the unit cost per day at sea and mainly represents the costs linked to fuel consumption, gear repairs, and replacement. These costs depend on the activity of vessels expressed in terms of days at sea. We assume that the activity of vessels is constant in terms of targeted species and days spent in other fisheries.

According to the share remuneration system in force in the fishery, the net capital stream (ncs_v) earned by the vessel owner each year is:

$$ncs_{vt} = \lambda_v.rts_{vt} - ofc_{vt}, \tag{6}$$

where (ofc_v) are the other fixed costs, such as repairs and maintenance, loan interests, and economic depreciation of the vessel. (λ_v) and $(1 - \lambda_v)$ are the share of earnings allocated to the owner and the crew, respectively. Most of the time, vessel owners are also their skippers, which means that they are paid as part of the working force and for their skills. As a consequence, the annual net labor stream for the skipper (nls_v) is given as:

$$nls_{vt} = \left[(1 - \lambda_v).rts_{vt} - sic.C_v\right] / C_v, \tag{7}$$

where (C_v) is the crew size and (sic) the social insurance cost per crewmember.

The individual vessel producer surplus is given by:

$$ps_{vt} = ncs_{vt} - occ_{vt} + nls_{vt}.C_v - ocl_{vt}.C_v, \tag{8}$$

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[6] According to this assumption, it is not possible to calculate consumer surplus effects due to price variation.

where (occ_v) and (ocl_v) are the opportunity cost of capital and labor, respectively.

Economic and technical parameters are derived from surveys of the Channel fleet (Boncoeur and Le Gallic 1999) and from other databases (auction landings, vessel and licence register, …). When we consider fishermen behavior, the decision whether to stay or leave the fishery depends on the fishermen's estimation of their expected benefits regarding a "staying-leaving ratio."

Consideration of Fishermen Behavior: Willingness to Stay or Leave the Fishery

The NPV of fishing activity discounts the sum of annual economic net flows over a discounting period (see equation 8). The discounting period ($T_i - t$) is the length of time between the expected year of retirement of each fisherman (i) and the current period (t). (r) is the individual psychological discounting rate to consider fishermen's preference for time. Yet, we use capital cost funding rate or opportunity cost of capital in order to take care of present value of different alternatives.[7] Due to uncertainty inherent to fishing activities, it may also include a risk premium.

The NPV of staying in the fishing industry is the sum of different elements: the present value of net capital stream extracted from the fishery and the selling price of the boat (P_{vT}) on the second-hand market at the end of the discounting period (T). Even if vessel prices on the second-hand market depend on regulations and public subsidies granted to the industry, we consider that each vessel value is the deflated purchase value of the fishing unit including the value of hull, engines, electronics, and other equipment on board. We assume that vessel owners invest regularly in new equipment in order to cope with wear and obsolescence. Vessel value is then exogenous to the model in the sense that it does not depend on fishing incomes that could be capitalised in it. All model parameters come from direct questionnaires to fishermen.

Finally, the NPV of staying in the fishery includes the present value of net labor income flows for the skipper, if he is also the boat owner. Note that the basis for net capital and labor flow calculation can be changed within the model according to boat owner status. The principle of adaptive expectancies is considered for calculation so that net income of the last period ($t - 1$) or the weighted average of net income over a given past period is used to calculate expected benefits.

Consequently, the expected NPV of staying is:

$$npvf_{vt} = \sum_{t=1}^{T_i} (nls_{vt-1} + ncs_{st-1}) \big/ (1+r)^t + P_{vT_i} \big/ (1+r)^{T_i} . \tag{9}$$

On the other hand, the present value of leaving the fishery can be expressed as follows:

$$npve_{vt} = s_t .grt_v + \sum_{i=1}^{T_i} w_{vt} /(1+r)^t , \tag{10}$$

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[7] In a situation of perfect capital markets, the individual psychological discount rate and the capital cost rate are equal.

where (w_{vt}) is the opportunity cost of labor that each vessel skipper (v) may expect to earn elsewhere in the economy. The last right term of the equation represents the NPV of labor, and (s_t) is the unit premium per Gross Registered Tonnage (GRT) allotted by the administration to fishermen to decommission their boat(s). In such a situation, each vessel owner has an alternative to leave the fishery. Either he sells his boat on the second-hand market or he withdraws his boat in counterpart of the premium offered.

The decision rule whether to stay or leave the fishery at any time of the simulation depends on the form of the inequality:

$$npvf_{vt} \underset{<}{\overset{\geq}{}} npve_{vt} \qquad t = 1,...T. \tag{11}$$

The right-hand side of the inequality can be viewed as the opportunity cost of staying in the fishery. As shown hereafter, the fisherman leaves (or stays in) the fishery when the NPV of fishing is less (or more) than the NPV of leaving. Unit premium per GRT, for which the two options equal, is deducted from inequality, equation (10).

$$s^*_{vt} = \left[\sum_{t=1}^{T_i} (nls_{vt-1} + ncs_{vt-1}) \big/ (1+r)^t + P_{vT_i} \big/ (1+r)^{T_i} - \sum_{i=1}^{T_i} w_{vt} \big/ (1+r)^t \right] / \, grt_v . \tag{12}$$

Based upon agent's expectations, this quantity expresses the minimum willingness to accept (WA) per GRT necessary to incite vessel owners to leave the fishery. It should include working satisfaction bonuses or losses — as seen in Anderson (1980) and underlined by Frost *et al.* (1995) — that reflect the fishermen's interest in the job. Valuation of this component was not possible for this study, owing to a lack of information on all agents from the case study.

Consideration of Decommissioning Policy

As is common practice in the French government's decommissioning programs, the public authority decides to fix a premium per GRT in order to incite fishermen to scrap their vessels. This unit premium (s) is the same for all vessels, but it can be differentiated within the model. Annual budget (B_t) for administration is limited and is available for a certain period (D) defined as the duration of the decommissioning plan. The number of vessels (V_t) elected for the annual program is defined so that the firms with the lowest WA exit the fishery first. The rule of exit is:

$$s^*_t \equiv \min_v (s^*_{vt}) \tag{13}$$

if $s^*_t \leq s_t$ then

$$V_t \equiv \max_v \left[V(s^*_t) \right] \text{ subject to } \; s_t . grt_v . V(s^*_t) \leq B_t . \tag{14}$$

If minimum WA is lower than the premium offered by the public authority, the number of eligible fishermen is calculated in order to exhaust available budget and (or) to satisfy the applicants. This being said, the opportunities of fishermen must be reconsidered for each spreadsheet iteration in order to take into account the evolution of the bioeconomic environment. There are feedback effects of decommissioning programs on stock dynamics, catches, and fishermen costs and earnings.

Simulations and Cost-benefit Analysis of Decommissioning Programs

Bioeconomic simulations are carried out according to a relevant fleet segmentation. The scallop fleet is divided into four categories expressed in terms of engine power (kW) with different levels of turnover and costs for each sub-segment as indicated in table 1. Around 253 vessels were active over our reference period (1993–98).

We assume that capacity reduction does not lead to any effect on other stocks. There are two reasons for this assumption. First, scallop fleet catches are marginal if we consider the fishing mortality of other fleets. The second reason is that it is difficult to carry out a biological model for these stocks.

Benefits from Fleet Size Reduction

It is possible to simulate the consequence of different fleet levels on the bioeconomic situation of the fishery at equilibrium. As illustrated in figure 4, producer surplus and stock situation will be improved by fleet reduction considering other regulations as a constant. A 45% increase in producer surplus will be achieved with only 30% of the current fleet level. Moreover, improvement in stock fecundity will increase the probability of obtaining better recruits in the future.

As a consequence, fleet reduction can lead to positive effects from an economic efficiency perspective. The problem is that this valuation does not take into account the cost of public policy and overestimates the net benefits of capacity reduction.

Cost-benefit Analysis of Decommissioning Plans

The simulation output is carried out between 1998 and 2010. This time span was chosen because it is the time necessary for biomass to be stabilized so that all the effects of decommissioning schemes can be measured. Indicators such as biomass level, individual and fleet production, and fleet turnover are considered in the simu-

Table 1
Scallop Fishery Figures — Average Data over the 1993–98 Period

Fleet Segments	[0–60kW]	[60–120kW]	[120–185kW]	[>185kW]
Number of vessels/category	26	101	96	30
kW/vessel	44	92	151	242
Crew/vessel	1.5	1.9	2.5	3.5
Scallop landings/vessel (tons/year)*	7.1	20.4	22.5	23.1
Scallop turnover/vessel (KF**)*	95.1	275.6	297.4	306.9
Total turnover minus variable costs/vessel**	213	514	743	1,330

* Simulation results; ** KF = thousand francs.
Source: IFREMER-Saint-Brieuc database; Boncoeur and Le Gallic 1999.

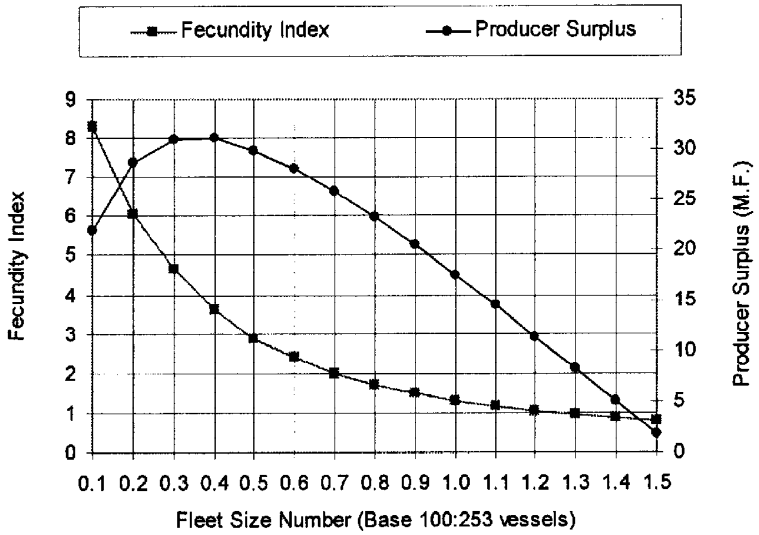

Figure 4. Long-term Effects of Different Fleet Size Levels
Note: Sustainable level with current regulation on days at sea.

lation. The next section focuses only on evolution of producer surplus and decommissioning cost indicators.

Initially, we compared *status quo* results, named scenario #0, with a specific decommissioning plan output (scenario #3). The latter scenario provides administration with a budget of 30 million francs. This budget must be exhausted in the first two years (1998 and 1999), and it is distributed in two equal parts over the two years. The premium granted by the administration to leave the fishery is allocated on an egalitarian basis and in this simulation is equal to 50,000 francs per GRT.

Tables 2 and 3 indicate the WA for each boat category and the consequent evolution of the fleet's structure during the first three years. Only the first class [0–60 kW] has a WA per GRT, with a lower value than the premium granted in 1998. This is why all boats in this segment (26 units) leave the fishery in simulation. Note that such a result can be achieved by a simplified assumption about the economic environment of firms. As boats in this segment are increasingly leaving, market conditions under which the remaining ship owners operate could change, potentially causing them to modify their expectations and decisions. Taking such a change into consideration would be another and much more complicated exercise. So, regarding our assumption, the annual budget available is sufficient to cover the cost of boat exits, which is estimated to be 6.02 million francs. The balance is reported to the second year of the plan, and 23.98 million francs are then available to be spent to withdraw 60 units of class 2. In 1999, WA declined due to lower revenues (lower stock level due to low simulated recruitment) and higher expenses resulting from replacement of different parts of vessel engines. The premium is then sufficient to incite all fishermen to leave the fishery (see table 3). Yet, the spreadsheet only excludes those who have the lower WA. They are probably the most interested in

Table 2
Evolution of Fleet Structure — Scenario #3

Fleet Segments	1998	1999	2000	Variation Rate 1998/2000
0–60 kW	26	0	0	–100.0%
60–120 kW	101	101	41	59.0%
120–185 kW	96	96	96	0.0%
>185 kW	30	30	30	0.0%
Number of boats	253	227	167	–34.0%
Total GRT	3,089	2,969	2,489	–20.6%
Total kW	32,084	30,989	25,465	–20.6%

Note: Basis for income discounting: previous year.
Discounting period = 15 years.

Table 3
Minimum Willingness to Accept (WA) to Leave the Fishery

Indicator/Year	1998	1999	2000
Average WA/GRT 0–60 kW	33.56	–	–
Average WA/GRT 60–120 kW	64.36	34.35	58.68
Average WA/GRT 120–185 kW	55.10	36.47	56.19
Average WA/GRT >185 kW	56.82	46.51	57.48
Total WA for fleet	176.5	114.9	141.7
Average WA/boat	0.698	0.506	0.848
Average WA/GRT	57.17	38.72	56.95

Figures in thousand francs.

leaving the fishery as their windfall gain per GRT, that is to say the difference between the premium and WA, is higher.

If we look at capacity adjustment, 34% of the scallop fleet and 20.6% of the total fishing capacity expressed in the form of total engine power in kW, are decommissioned by this plan. If a reduction in fishing power must reach 30%, this policy can be considered as a failure, as this objective is not achieved. The amount spent in decommissioning schemes is 30 million francs, whereas the model estimates the sum of total WA at 20.53 million francs. This difference is the total windfall gain transferred from taxpayers to fishermen. These windfall gains lead to huge distribution effects that could be analysed before public policy implementation.

From an economic point of view, the impact of *status quo* or the decommissioning scheme can be assessed at the level of the firm and also considering the fleet as a whole. At the micro-level, it appears that the mean WA per kW necessary to leave the fishery increases in both cases. Implementation of scenario #3 results in higher values than *status quo*, exceeding it by nearly 10,000 francs for a value of 80,000 francs. On another hand, producer surplus removed from the scallop activity is retained to assess the economic efficiency of these policies. Actually, boat withdrawal yields more annual economic rent than the *status quo*, except for the first two years because the decommissioning scheme has not yet produced its effects. As figures 5 and 6 illustrate, the fishery produced rents of about a million francs in 2001, and the gap will increase to reach nearly 5 million francs by 2010.

The cumulative amount for these differences represents 31.8 million francs, but annual flows can be discounted to take into account preference of public authority for time. Discount rates vary from 0 to 10 percent. For any discount rate value, NPV of producer surplus flows in scenario #3 exceed NPV of the producer surplus resulting from application of scenario #0 (see table 4). Consequently, implementation of decommissioning programs can be considered as the best policy if the public authority considers this indicator as good decision-making criteria. Moreover, the cost-benefit analysis, which relates to the public policy cost to surplus yields, shows that the balance is always positive, between 6 and 23 million francs over our reference period. This difference is only cancelled by a 20% discount rate in the simulation. The consequences of an improved stock situation on the evolution of recruitment have not been simulated in this paper. However, this basic model shows that the probability of better recruits is higher in scenario #3 than scenario #0, since the index of fecundity measuring the capacity of adults to reproduce is also higher. As a consequence, the benefits of scenario #3 based on a constant recruitment are probably underestimated.

Several conclusions can be drawn from this specific simulation. Although the decommissioning plan does not achieve its objective expressed in kW, its effects are quite positive regarding global efficiency. Producer surplus increases with the decommissioning program, and net surplus is also positive for a reasonable value of the discount rate. However, technical improvements incorporated by fishermen to their boats may lead to counterproductive effects to the decommissioning program as well as for the *status quo* situation.

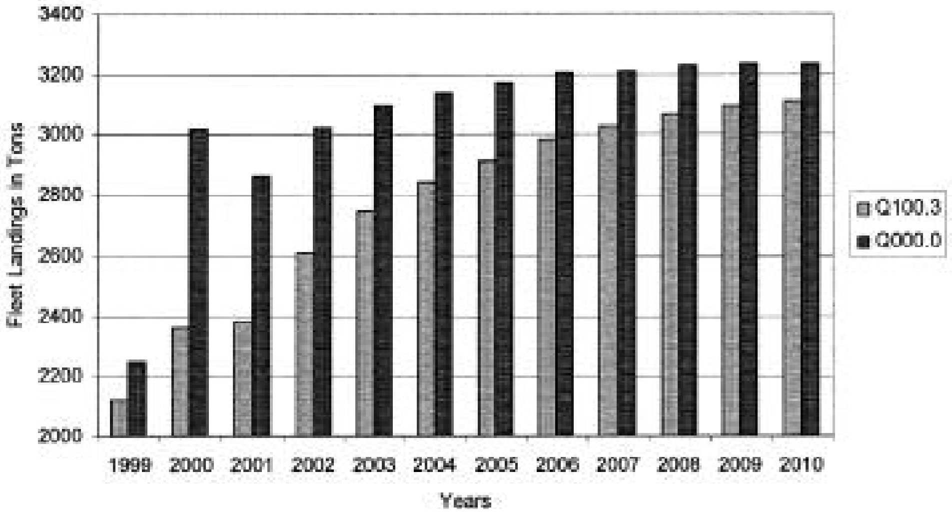

Figure 5. Total Scallop Landings (Tons) during the Transition Period (Scenarios #0 and #3)

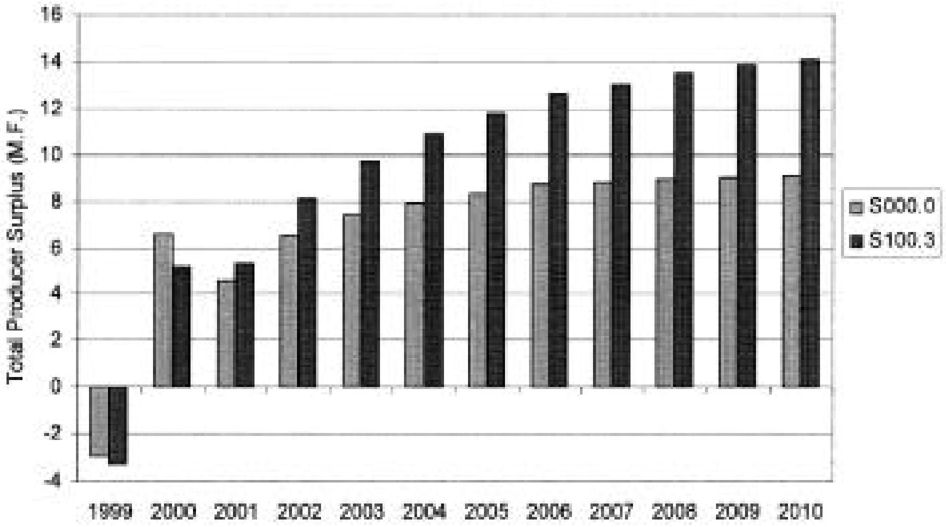

Figure 6. Total Producer Surplus Trajectory under Scenarios #0 and #3

Table 4
Producer Surplus and Net Surplus Under Different Scenarios

Discount Rate	Producer Surplus* Scenario 0	Producer Surplus* Scenario 3	Balance* S3-S0	Public Cost* Scenario 3	Net Surplus* Balance Including Policy Cost
0%	82.9	114.8	31.9	9.0	22.9
5%	57.5	77.3	19.8	8.2	11.6
8%	46.9	62.7	15.8	7.8	7.9
10%	41.3	54.9	13.6	7.6	6.0

Notes: *Figures in million francs. As scallop revenues account for 30% of the boat turnover, we assume that 30% of the total public cost plan is dedicated to this fishery. In France, the public assessment of public schemes actually uses discount rates (opportunity cost) values between 2% and 8%.

Effects of the Technical Improvement

Regarding the increase in technical efficiency of boats that results from introduction of technical improvements, figure 7 reveals scallop stock dynamics for different scenarios of technical progress (from 0 to 6% per year during the simulation period). Up to and including a 4% rate, the decommissioning program leads to positive effects in terms of stock level at the end of the transition period. A higher rate conducts progressively to a degradation of the fish stock due to consecutive increase in fishing mortality. As a result, the economic situation of the reduced fleet will be affected even if a decommissioning program is set up. However, it is more appropriate to compare relative results of different policies rather than analyse results in absolute terms. As can be seen in table 5, the decommissioning policy results in better economic outcomes compared to a *status quo* policy for a given level of technical improvement.

The results in terms of net surplus will lead to preferred decommissioning solutions. However, the problem is that increasing fishery rents from capacity adjustment will probably give rise to more and more competitive behavior between fishermen (Townsend 1985). This phenomenon may dissipate the rent created as technical progress increases. In fact, decommissioning policies do not reduce incentives to increase capacity and can be seen only as a tool to improve the situation of overcapitalized fisheries.

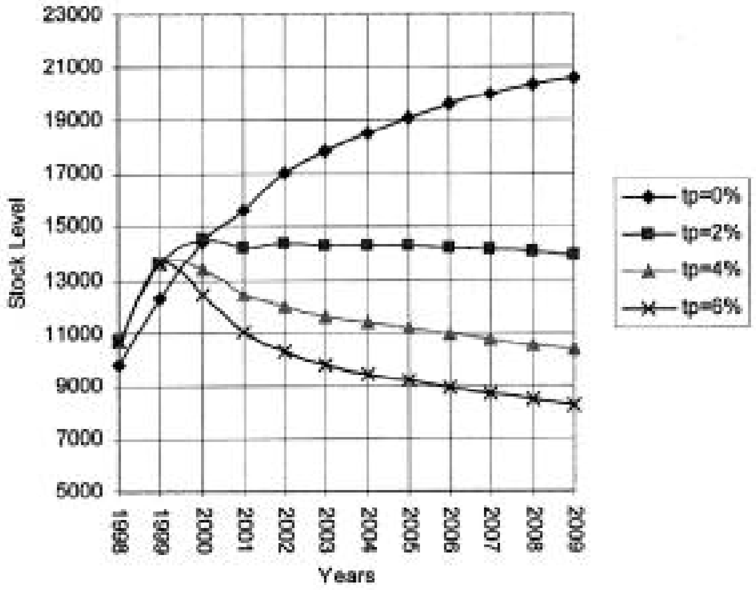

Figure 7. Evolution of Stock Level as a Function of Technical Progress Rate for a 30-Million Francs Decommissioning Program

Table 5
Discounted Net Surplus for a Six-Percent Technical Progress Level

	Net Surplus (M.F.)	
Public Discount Rate	Status Quo	Decommissioning
5%	132.0	162.9
8%	114.9	137.2
10%	105.4	123.2

Concluding Remarks

This paper provides an improved bioeconomic simulation model to assess benefits and costs of fleet reduction by a decommissioning policy. Most of the bioeconomic approaches do not include the cost of decommissioning programs and overestimate social benefits of fleet reduction. Moreover, the economic model used in this paper is dynamic by considering the behavior of fishermen, especially their decision to scrap or keep their vessel in the case of a buyback program, with different premium levels. Simulations also emphasize the consequences of different policies over a transition period. Based on the example of an overcapitalized limited-entry scallop fishery, the simulation shows that implementation of decommissioning programs increases fishery net surplus compared to the *status quo* policy. Decommissioning policies can then contribute to fleet rationalization by eliminating redundant capital. However, the benefit of such schemes could be offset by the increasing technical efficiency of the remaining vessels. Transferable rights-based systems, such as individual transferable quotas or transferable licenses, are often considered as a substitute for decommissioning schemes to reduce fishing capacity. Market signals provide incentives for economic agents to rationalize exploitation by rights consolidation. However, capacity is not necessarily scrapped by this process, especially when the opportunity cost of capital on the second-hand markets is positive. In most cases, this leads to a transfer of redundant capacity to other fisheries inside or outside the host country, but always within the fishing industry. Capacity remains on a medium- to short-term basis in the fishery sector. Even if decommissioning schemes do not reduce incentives of capital and labor stuffing, they may be seen as a necessary tool to reduce capacity and to adjust fleets to the desired levels. However, decommissioning schemes do not prevent common-pool resource dilemmas, and allocation of fishing rights must be implemented to complement such policies. Moreover, the principle of cost recovery could be used to share the cost of these programs that benefit the fishers. It may provide incentives for the implementation of a better means of controlling the increase in capacity through the implementation of rights-based fishing.

The model underlines that the core of the problem consists of matching premium level with individual minimum WA to leave the fishery. In order to spare the public budget or to better allocate these funds, the fishery regulator must adjust the administrative premium level on a trial-and-error basis in order to minimise windfall gains. Unfortunately, this behavior may lead to counter effects if it does not give fishermen the right incentives. It may postpone vessel exits, delay the achievement of decommissioning objectives, and increase the total cost of the policy. Of course, the regulator may use a tendering system to select the best offers, though it would also lead to some adverse effects when collusion occurs between fishermen.

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Appendix

Individual Growth

The individual growth model of scallops in the St. Brieuc Bay is expressed by a Von Bertalanffy modified:

$$L(t) = \left(L\infty - \frac{a.C^b}{K}\right).\left\{1 - \exp\left[-K.(t - t_0)\right]\right\}, \tag{1}$$

where $L\infty$ is the theoretical maximum asymptotical size, K the parameter associated with growth rate, t_0 is the theoretical age corresponding to $L(t) = 0$; C is the surface rate covered by *Crepidula fornicata* (competitor species of scallops), a and b are the model’s parameters. The surface rate covered by competitor species is expressed by a logistical equation not specified here.

Natural Mortality and Recruitment

In the case of exploited stocks, it is difficult to provide an instantaneous coefficient of mortality. Analogy reasoning by studying the same species located in an area not far from those considered and non-exploited is used. An annual average recruitment is considered throughout the simulation, even if a stochastic approach based on the stock-recruitment relationship is available.