Environmental and Resource Economics
September 2002, Volume 23 Issue 1 Pages 1-28
http://dx.doi.org/10.1023/A:1020273001099
http://archimer.ifremer.fr/doc/00244/35523/

Simulating the effect of regulatory systems in a fishery - An application to the French driftnet albacore fleet

Guyader Olivier [1, *]

[1] IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer), Service déconomie maritime, B.P. 70, 29280, Plouzané, France

* Corresponding author : Olivier Guyader, email address : oguyader@ifremer.fr

Abstract :

With a thin economic component, most bio-economic models of fisheries fail to assess the effects of the regulation systems on firms. In order to analyse the short term consequences of different management schemes, a simulation model is applied to the French driftnet albacore fleet: licence allocation with driftnet regulation, individual quotas, and individual transferable quotas without any input control. Vessel technology is estimated by using the data collected, and groups of vessels are distinguished according to criteria of performance. We present the adjustment within firms and between groups under different scenarios (limited entry with and without driftnet regulation, individual quotas and individual transferable quotas allocation), and we compare their results in terms of quasi-rent value and other indicators such as hake harvests or dolphin by-catches.

Keywords : albacore tuna, dolphin, driftnet, fisheries, ITQ, licence, quasi-rent, quota price, quotas, regulation, simulation

JEL classification : Q22

Introduction

Conventional economic approaches to fisheries management are designed according the wellknown model of free and open access to common-pool renewable resources. Bio-economic models are centred on the identification of a level of efficient operation, defined as providing the maximum net returns to inputs in comparison with other economic sectors (Clark 1990). These approaches aim at determining the levels of fishing mortality at which economic efficiency will be achieved, and also to identify the policy measures required to achieve such levels in the context of market failures. In fisheries where only total harvest is being restricted, it is now well understood that such management measures result in inefficient outcomes since they do not stop the race for a share of the catch. Then "too many vessels chase too few fish" leading to overcapitalisation in most fisheries (Hatcher and Robinson ed 1998). These failures result from the lack of definition of rights to the resources, the resulting absence or imperfection of markets for them, and the externalities that it entails. In order to restore efficiency in these open-access managed fisheries, economists suggested that the fishing use rights should be explicitly allocated to individual harvesters (Scott 1988)[1]. Two major forms of right-based fishing were implemented, those limiting entry to the fisheries and regulating the use of the different inputs, and those granting a right to resource flows (Christy 1973).

The objective of limited entry licence programmes is to restrict access to a limited number of incumbents, and to ration indirectly the individual production possibilities by controlling the nominal fishing effort (e.g. fishing days, number and size of the fishing gear, vessel characteristics such as engine power, length, etc). Most of them were implemented in the beginning of the 70's, and there is some evidence provided by limited entry experiences (Wilen 1988) (Townsend 1990). Even if the restrictive character of these programmes is correlated with its economic success, the main problem they face is the control of inputs and technological progress. That is why licence systems face difficulties, as they do not curb capital and labour stuffing that inevitably lead to the dissipation of resource rent. Licences may be transferable or not between fishermen. In the last case, vessel buyback programmes are usually organised by management authorities in order to adjust the fishing capacity to the available resources, and to restore the global state of the stocks. In the context of the Common Fishery Policy, this led to the implementation of a structural policy with the objective to reduce the size of the fishing fleets in the European Union (Holden 1995) (Guyader and al. 2000).

By ensuring harvesters a fixed share of the total admissible catch (TAC), individual quotas allocations may avoid the derby effect due to open access : it can generate efficiency gains given that harvest activities can be planned temporally to take advantage of market demand (Casey and al. 1995) and, in some cases, operating costs can be reduced in the absence of "race for fish" conditions. A further step towards the economic rationalisation of the fishery consists in allowing the subsequent allocations of harvest shares to be transferable between economic agents on an open market (Moloney and Pearse 1979) (Scott 1988)[2].

Several experiments of Individual Transferable Quotas (ITQ) systems in fisheries are now led around the world (Crothers 1986) (Arnason 1996) (McCay and al 1995) (Davidse 1997). Most of them have been applied to industrial countries, but at different degrees. New Zealand, Iceland and Holland tend to generalise ITQs to their fisheries, whereas others like Canada, Australia or the USA adopt mixed policies including licence allocation programmes as an additional management tool.

Individual quotas are usually "grandfathered" free of charge to eligible bodies, vessel owners or companies[3]. According to rights duration, individual quotas can be exchanged either on rental on a short term basis, or on a sale market, or both. As underlined by Squires and al (1995a), the evidence of quota market development and volume on quota trade is mixed[4]. In many cases, management authorities put limits on transactions in order to avoid the concentration of harvest shares in the hand of a limited number of operators (Macinko 1993). Yet, free market is a common practice in Iceland fisheries (Arnason 1993), as well as in the U.S. surf clam fishery (Wang 1995)

Depending upon the exchange range between firms, the subsequent allocation leads to more or less significant adjustment within firms and fleets. Yet, only few empirical studies try to assess and foresight the quantitative impact of ITQ on fleet dynamics and rents exhausted from the fishery (Weninger and Just 1997) (Guyader 2000). Nevertheless, ITQs benefits resulting from rationalisation can be counterbalanced by adverse effects such as discards, highgrading, and quota busting, that may occur in different situations (Copes 1986), (Anderson 1994) (Vestergaard 1996) (Squires and al. 1995a). On an other side, theoretical analyses show that ITQ systems do not resolve congestion or stock externalities under specific conditions (Boyce 1992). Matulich and Mittelhammer (1996) show that the exclusion of the processing sector to quotas allocation can generate inefficient outcomes. Individual quotas, as well as ITQs, may involve certain difficulties such as monitoring and enforcement problems, which may undermine the overall benefits expected from these regimes. ITQ systems cannot be assumed *a priori* as the best programmes in a perspective of efficiency, as their results, as well as those of individual quotas and licence systems, depend crucially on the context of fisheries (Copes 1997).

Only few papers in the economic literature compare the economic effects of the different regulatory regimes on fishing firms and fleets. Squires and al. (1994) (1995b), Dupont and Phipps (1991a; b) basically focus upon ITQ systems from a static analysis point of view, whereas Garza-Gil (1998) applies optimal control to assess the consequences of the implementation of ITQs. Other studies mainly provide us with qualitative indications about the potential advantages and limits of the use of ITQs (Griffin and al. 1992) (Huppert and al. 1992) (Sutinen and al. 1992 for examples).

The objective of this paper is to simulate and compare the results of different management strategies referring to the case of the French driftnet albacore fishery. Albacore is a straddling stock harvested by other different fleets, but this analysis considers the stock as a fixed factor. The French driftnet fleet is comprised of multipurpose vessels that target albacore tuna in the Northeast Atlantic, with unfortunately a certain number of dolphin by-catches. Due to these environmental externalities and other problems, driftnet fleets have been subject to regulation since 1992 in order to reduce dolphin by-catches, but no preliminary study has been conducted to assess *ex ante* the benefits and costs of the different management regulations. Five major options of management are considered in the analysis : licence allocation without driftnet regulation (1), licence allocation with driftnet regulation (2) individual quotas (3), and implementation of individual transferable quotas (4) that can be compared to the driftnet ban scenario (5). These options are the more realistic according to the fishery context. The emphasis is put on the short term economic analysis of these regulatory measures on vessels of different types, considering the possibility they have to switch to the next best fishery, the hake fishery, which is considered as overexploited. It enables regulation authorities to compare the impacts of the different scenarios in terms of quasi-rent generation in the albacore fishery, and other indicators such as dolphin by-catches, hake harvests, and to implement regulatory measures on a sounder basis. Stock effects are set aside the analysis. The main conclusion is that individual quota as well as ITQ should then be preferred from a cost-benefit analysis perspective. The individual quota system can be considered as a second best considering the non-transferability of rights in France. The future ban of driftnet is going to lead to adverse effects in terms of producer quasi rent and hake harvest levels.

The paper is organised as follows : the first section analyses the evolution of the albacore fishery exploitation in the context of a straddling stock exploitation, and considers the need for driftnet regulation. The second part of the paper describes the French driftnet fleet, and deals with technology as well as cost estimation. Then, we present the modelling approaches to assess the economic consequences of the different management options at the level of individual fishing firms, and within the fleet. The results and the analysis of the simulations are presented in the fourth section. The comparative advantages of regulatory schemes are discussed in the fifth part of the paper.

1. Regulation of the French driftnet albacore fishery in the context of a straddling stock exploitation.

The Northeast Atlantic albacore stock (*Thunnus alalunga*) is harvested by French fleets during its annual migration along the European coasts, from the Azores to south of Ireland. Spanish troll and baitboat vessels also target this species. Yet, since 1986 French fishermen have switched to more productive and profitable fishing gear after a drastic decrease in the fleets due to low profitability (Antoine and al 1998). Relatively significant income with pelagic trawl and driftnet give them incentives to enter this open access fishery. The driftnet fleet increased from 20 vessels in 1988 to 49 in 1991, and culminated at 64 in 1993. Irish and United Kingdom vessels then entered in the fishery, and the total number of vessels reached 30 units (Findlay and al 1998). With these new techniques, total catches dropped to 9,080 tons in 1994 (ICCAT 1998).

Table I. Albacore catches of driftnet and pelagic pair trawl in the Northeast Atlantic (in tons)

	France	France	Ireland	United Kingdom	European Union.
Years	Pelagic pair trawl	Driftnet	Driftnet	Driftnet	Total
1987	262	88			350
1988	1,693	753			2,446
1989	2,240	1,450			3,690
1990	1,032	2,268	40		3,340
1991	463	3,360	60		3,883
1992	2,459	4,465	451	59	7,434
1993	1,706	4,587	1,946	499	8,738
1994	1,967	3,967	2,534	612	9,080
1995	2,904	2,400	918	196	6,418
1996	2,570	2,048	874	49	5,541
1997	2,874	1,717	874	33	6,537

Source : ICCAT (1998)

In 1995, in cooperation with fishermen organisations, the French Management Authority decided to limit entry to the fishery by issuing non-transferable licences (e.g. special fishing permit by gear as in EC regulations) to 69 driftnet vessels, and 78 pelagic trawlers. These licences were allocated on an historical basis. Since the 1993 season, driftnet vessels in the European Union have been subject to gear regulation that forbid the use of driftnet length over 2,5 km[5]. However, this rule was not enforced until the monitoring level increased in 1994. This European regulation was decided as an application of the United Nation resolution (44/225). The aim of this memorandum was to ban the use of large driftnets, 40-60 km per vessels, that were deployed in the Pacific at that time. Yet, being signed by the European Union, it was politically difficult not to implement this agreement at the level of the European fishing fleets (Holden 1995). Before regulation, the French driftnet average length was about 7 km per vessel. In order to rule and ban the use of driftnets from the European waters, various considerations like cetaceans by-catches, and technical interactions between driftnet and traditional gear (e.g. baitboat and troll) have been respectively underlined by environmental organisations, and the Spanish industry. The Council of the EU decided to prohibit the use of this gear in 1998 without assessing the economic impact this regulation[6] could have. The impact on the ecosystem was a major scientific concern, and research on ecological risks revealed that the level of dolphin mortality was not significant enough to threat the dolphin populations. (Antoine and al., 1997) (Goujon 1996). It is more likely the interest in dolphin by-catches than the risk of a non sustainable dolphin population that yields strong emotion in the public opinion. Surveys made at sea assessed the rate of dolphin mortality to 1,850 individuals per year in 1992 and 1993. Of course, since the effective enforcement of this rule in 1994, the driftnet regulation through the limitation of net length has probably played a role in preventing significant dolphin mortality.

For the Spanish industry, the competition on albacore stock was considered as unfair. Indeed, in 1992 the mean catch rate of a driftnetter was 30% greater than that of a baitboat, and twice that of a troller vessel (Antoine and al. 1998). There is no serious proof of technical interaction between the French and Spanish fleets (Anon 1990). These last face economic difficulties, and Spanish landings decreased from about 30,000 to 18,000 tons between 1983 and 1993 (see table II)[7]. Such drop partly explains the continuous decline in the catches in the North Atlantic, from around 50,000 to 30,000 tons during the same period. In 1994, the Spanish albacore fleet was comprised of 700 vessels, 150 baitboats, and 550 troll vessels. They respectively target anchovy with purse-seine, and demersal species, with set and drifting outside the summer tuna season (Findlay and al. 1998)[8]. These fleets faced major economic difficulties, which explains the issue of vessel replacement, and the consecutive decrease in landings. For both fleets, remunerating labour and finding crewmembers has become a real difficulty, especially in the case of the baitboats most of which are situated in the Basque Country (Garcienda 1996). As a result, the number of Basque albacore vessels dropped from 318 to 193 units between 1987 and 1993 (Santiago 1996). More generally, a significant proportion of the landings is canned, and this product is subject to higher competition with canned tropical tunas, the prices of which have been in a decline for the past few years. This seems to cause a simultaneous decline in the price of albacore on first sale markets, as well as a new drop in the profitability of these fleets (Guyader 1998). Considering the less attractive nature of the albacore fishery, the Spanish albacore fleet will probably decline, or at best stabilise in the next years. In addition, the application of Multi Annual Guidance Plans of the Common Fishery Policy, which aim at reducing fishing capacity through decommissioning plans, may favour this decline trend.

Table II. Evolution of the albacore catches in the North Atlantic between 1983 and 1997

Years	Spain	France	Portugal	Ireland-UK	Taiwan	Others*	Total
1983	29,557	2,391	1,778		14,254	2,913	50,893
1984	15,685	2,797	775		14,923	5,274	39,454
1985	20,672	1,860	657		14,899	2,339	40,427
1986	24,387	1,200	498		19,646	1,734	47,465
1987	28,206	1,921	433		6,636	889	38,085
1988	27,547	2,805	184		2,117	1,041	33,694
1989	25,424	4,050	169		1,294	1,139	32,076
1990	25,792	3,300	3,185	40	1,651	2,619	36,587
1991	17,230	4,123	709	60	4,318	1,495	27,935
1992	18,171	6,924	1,638	510	2,209	1,291	30,743
1993	18,371	6,293	3,385	2,445	6,300	1,840	38,634
1994	16,993	5,934	974	3,146	6,409	1,442	34,898
1995	20,178	5,304	6,470	1,114	3,977	1,224	38,267
1996	16,288	4,694	1,634	923	3,905	1,262	28,706
1997	17,264	4,618	395	907	3,330	1,012	27,526

* mainly Japan, Korea, U.S.A., Venezuela.
Source : ICCAT (1998)

European Surface fleets harvest juvenile and pre-adult albacore. Since the mid 1980s, adults have not been targeted for Asiatic longliners in the North Atlantic. The introduction of deep longlines and super cold freeze vessels in the early 1980s changed the composition of the Taiwanese fleet, as well as its fishing behaviour (ICCAT 1996) that led to a dramatic decline in the catches from 14,300 tons in 1983 to 1,400 tons in 1993. The historical review of the albacore fishery exploitation reveals that in the 1960s, the fishing mortality in the fishery was higher than in recent years, and yet without signs of overexploitation. The 30,000 tons caught today are far below the sustainable historical level of 60,000 tons. The International Council for the Conservation of Atlantic Tunas concluded that the northern albacore stock is probably not overexploited, but was at, or near, the level of full exploitation. In order to prevent an increase in the fish mortality due to driftnets and pelagic trawls, the Scientific Technical and Economic Committee for fisheries of the Common Fishery Policy took into account the ICCAT recommendations that proposed to limit strictly the fishing effort of these fleets (STECF 1993).

The idea to set up a Total Allowable Catch for albacore stock was recently underlined by different ICCAT member countries, as another way to regulate fish mortality, and share the rights of catch between fishing nations. In 2001, the ICCAT decided to implement a TAC shared out in quotas between the different nations.

Tableau III. Albacore stock: distribution per country of the Total Allowable Catches in 2001

Country	T.A.C. (tons)
Ireland	3,158
Spain	17,801
France	5,599
UK	201
Portugal	1,953
Total European Union	28,712
Total T.A.C.	34,500

Source : ICCAT

From now on, it is possible to compare the economic results of alternative programmes based upon input control and output control according to different TAC recommendations. Nevertheless, the difficulties met in assessing the albacore stock do not allow us to include the resource dynamics in the analysis.

2. Description of the French driftnet fleet and technology assessment.

French driftnet vessels basically originate from harbours located on the Atlantic coast, from Brittany to the French Basque Country. Their lengths range from 15 to 25 meters, and most of the time, these fishing units are owned and operated by artisanal fishermen. On average, before regulation, they employed seven crewmembers, but the decrease in catches and turnover, resulting from the restriction of net length, gave them incentives to reduce their crews as a way to cut down their running costs. The albacore fishery is seasonal and fishermen operate between June and October. The decision of entry or exit depends upon the opportunity cost in alternative fisheries, especially in the hake fishery. The vessel's journey lasts for about twenty days, but depends on the location of the shoals, and on each vessel's hold capacity. The composition of commercial catches includes the targeted species (albacore accounts for nearly 95% of the total weight and turnover), and other by-catches are mainly bluefin tuna, swordfish and sharks. These joint products are not subject to any regulation that could generate discards, and output separability is accordingly assumed.

In order to identify firm technology, we carried out an econometric analysis of a non-asymmetric panel sample of 66 vessels on six years, that is to say 229 annual observations. The variables tested in the analysis are albacore catches as the dependant variable (y_{ia}), Time spent in the albacore fishery (T_{ia}), driftnet length (G_{ia}), vessel length (L_i) and hold capacity (H_{ia}) as the explicative variables. The functional form is represented as follows :

(0) $y_{iat} = c.T_{iat}^{\alpha}.G_{iat}^{\beta}.L_{it}^{\delta} + u_{it}$ with u_{it} the disturbance term

Taking their neperian logarithms, introducing binary variables to capture annual effects, we apply ordinary least squares with auto-correlation correction.

Table IV. Regression results explaining albacore catches. Period 1990-1995

Explanatory variables	Estimate	T student statistics*
Log linear model		
Intercept	0.00676	*3.13*
Year 1993	-0.126	*-3.04*
T_{ia}	0.838	*20.01*
G_{ia}	0.517	*13.13*
L_i	0.692	*3.25*
AR(1)	0.199	*3.00*
AR(2)	0.319	*4.75*
R^2	0.767	
R^2-*adj.*	0.760	
Stand Error.	0.261	
F	116	

* Significant at 95%

As shown in table IV, the value of elasticity catches-time in the fishery is less than one, thus reflecting the variations of accessibility to albacore tuna during the season. More generally, catches per day are at a lower level at the beginning of the season, increasing in July and august, and declining in September. Some vessels switch to the fishery during the best two months; some others choose to target albacore all over the season in order to get potential good catches, or to benefit from higher prices. In fact, because the vessels operate one to six journeys during the season, the decision to enter the albacore fishery is a discrete choice.

Different factors can explain the driftnet decreasing marginal productivity which is near 0.5. Shorter nets are of better quality, and more efficient than longer nets which are not so well-kept. On another side, reduced handling time with shorter nets gives more time to search for tuna shoals. The coefficient for the boat length variable is significant though also inferior to one. The reason is that this fixed factor is a constraint for production, since larger vessels make less journeys and thus spend more time to harvest[9]. Though the variable "year 1993" is also significant, it may not reflect the variation of stock, but more likely the negative impact of conflicts at sea between French and Spanish fishermen. Unfortunately, in this study it's not possible to understand statistically the individual capital human effects that can increase explained variance. Actually, the autocorrelation of the errors detected is likely an indicator of these effects. In fact, a graphical analysis reveals that due to the stability of the individual strategies between the different years, the individual points for each firm are very closed to them; an observation that may explain autocorrelation. Considering these results, the driftnet fleet of 1994 was divided into four categories based under vessel length, in order to reflect the difference in productive efficiency. The vessel of the first category is more efficient than a vessel of the second, third, fourth category 2, 3 or 4. Running unit costs come from firm trip accounts.

Table V. Fleet segmentation based upon vessel length and characteristics.

	Vessels number (Mean)	Length (meters) (Mean)	Age (Mean)	Cost per trip*	Hold capacity (tons) (Mean)
Group 1	19	22.35	8.27	43,200	23.3
Group 2	22	20.50	9.33	41,100	20.0
Group 3	12	19.22	17.8	35,500	17.0
Group 4	11	16.96	16.6	30,200	13.4

* excluding driftnet cost assessed at 3400francs/km (include repairs and replacement)
Source : Ifremer and fishermen organisation

Albacore landings are sold at the auction market as a fresh product, or to the canneries. Yet, in order to avoid substantial declines in prices when bottleneck appears, organisations of producers could use a withdrawal price system. Regarding quality, driftnet-caught albacore is different from those caught with other fishing gear and benefits from higher demand at the beginning of the summer season. This is the reason why driftnet current prices exceed those of pelagic pair trawlers. We assume in further simulations that driftnet price is constant and equals to 17 francs/kg.

Table VI. Evolution of the price of albacore in France (constant francs)

Years	1991	1992	1993	1994	1995	1996	1997	Average over the period
Landing price (driftnet)	17.5	17.7	17.2	16.7	15.7	15.8	17.2	16.8
Landing price (pair-trawl)	14.7	17.0	16.5	15.1	14.0	13.8	15.3	15.2
Import price	16.0	16.3	16.3	14.8	15.4	14.0	14.8	15.4

Source : Ofimer and Customs data

During the albacore season, driftnet vessels are able to switch to the hake fishery, and the calculus of the opportunity cost of capital and labour in this fishery is required in order to assess the incentive to stay in the albacore fishery, as well as to value albacore quasi-rents. We talk about quasi-rent since all production factors, like the capital, and the natural stock are not in a situation of equilibrium. Guyader (1998) led the analysis of productivity and costs in the hake fishery and found no statistical differences in opportunity cost between the vessels and between crews. In order to simulate the consequences of the different management options in the albacore fishery, the next section considers the modelling approach.

3. Short term models of fisher behaviour with or without regulatory constraints.

Based upon the previous estimation of driftnet vessel technology, we present hereafter different models of fishermen behaviour programmed on a simulation tool (e.g. Stella software). The first model considers the case of the fishing firm decision without any regulatory constraint at individual level. The analysis then focus upon licence programme including driftnet length regulation, individual quotas, and finally on individual transferable quota systems. Only the short term effects are taken into account, and potential congestion externalities as well as stock dynamics are not considered in the analysis.

3.1. Licence without driftnet regulation

At the firm level, the objective of the vessel owner (*i*) is to maximise variable profit during the albacore season. Considering the individual production function (1), annual albacore harvests (y_{ia}) depend on net length (G_{ia}), time spent at sea in the albacore fishery (T_{ia}) and vessel length (L_i) as an indicator of capital stock. (α), (β) and (δ) are the elasticity coefficients between production and the different inputs quoted before and (*c*) is the constant term. (*N*) is the number of vessels in the fishery. For simplicity, time index is excluded from equations.

(1) $$y_{ia}(T_{ia}, G_{ia}, L_i) = c.T_{ia}^{\alpha}.G_{ia}^{\beta}.L_i^{\delta} \qquad \forall \quad i = 1,...N$$

Trip duration (d_a) is supposed to be constant and (m_{ia}) is the number of trips made by each vessel in the albacore fishery. It varies from one to six so that (T_{ia}) the time spent in the albacore fishery is a discretionary variable. Albacore fishing season (T) is limited in time, and is divided in the period of time dedicated to the albacore fishery (T_{ia}) and that spent into the hake fishery (T_{ih}).

(2) $$T_{ia} = m_{ia}.d_a$$

(3) $$0 \le m_{ia} \le 6$$

In order to be relevant with the constraints fishermen face, another technical constraint represented by the inequality (2) is added to the model.

(4) $$y_{ia} / m_{ia} \le H_{ia}$$

Consequently, when fishermen chose the number of trips in the albacore fishery, they have to adjust their driftnet length to fill in the hold[10].

(5) $$G_{ia}^{*}(m_{ia}) = \left[\frac{m_{ia}.H_{ia}}{c.(m_{ia}.d_a)^{\alpha}.L_i^{\delta}}\right]^{1/\beta}$$

Then, variable profit for each vessel in the albacore fishery can be written as follows :

(6) $$\pi_{ia}(m_{ia}) = \alpha_i.\left[p_a.m_{ia}.H_{ia} - c_{ga}.G_{ia}^{*} - c_{ma}.m_{ia})\right]$$

(7) $$0 \le \alpha_i \le 1$$

(8) $\alpha_i + \alpha_c = 1$

Each vessel owner receives variable profit for the albacore activity. It is a share of turnover minus running cost where (p_a) is tuna price net of landing cost. (c_{ga}), (c_{ma}) are respectively the unit cost per kilometer of driftnet, and the cost of a trip in the albacore fishery. In this fishery, as in others, the share remuneration system is commonly used as a way to distribute the wages to the labour force, and to incite the crew to work (Sutinen 1979). (α_i) and (α_c) are respectively the share rate of the vessel owner and of the crew. In order to simplify the analysis and the calculation of wages, we assume that the share rates are exogenous.

Hake catches are obtained by multiplying catch per unit of effort (*CPUE*) in the hake fishery by time spent in this fishery so that :

(9) $y_{ih}(m_{ia}) = CPUE_{ih}.T_{ih}(m_{ia}) \quad \forall \quad i = 1...N$

With

(10) $T_{ih}(m_{ia}) = T - m_{ia}.d_a$

There is no other technical constraint for this fishery, and variable profit per vessel in the hake fishery (π_{ih}) can be defined as :

(11) $\pi_{ih}(m_{ia}) = \alpha_i \left[p_h.y_{ih}(m_{ia}) - c_{ih}.T_{ih}(m_{ia}) \right]$

With (p_h) the hake price net of landing cost and (c_{ih}) is the unit cost of a day spent in the hake fishery.

Because the objective of vessel owners is to maximise variable profit all along the albacore season, they have to choose the number of trips in the albacore fishery that maximise this value :

(12) $\max \pi_i(m_{ia}) \equiv \max(\pi_{ia}(m_{ia}) + \pi_{ih}(m_{ia}))$

With (3) $0 \le m_{ia} \le 6$

3.2. Licence with driftnet regulation.

In practice, the regulators chose this option. Their control variables are the number of vessels to which fishing permits are issued, and the driftnet length ($\overline{G_a}$) that can be used by each vessel. Then variable profit during albacore season becomes :

(13) $\pi_i(m_{ia}) = \alpha_i.\left[p_a.y_{ia}(\overline{G_a}, m_{ia}) - c_{ga}.\overline{G_a} - c_{ma}.m_{ia}\right] + \pi_{ih}(m_{ia})$

And the driftnet length is really a constraint if :

(14) $\overline{G_a} < G_{ia}^*$

Under these conditions, the unique variable choice for fishermen is the number of trips (m_{ia}) dedicated to the albacore fishery.

3.3. Implementation of individual quotas

We now assume that the regulator is able to fix a Total Allowable Catch (TAC) for albacore, for each year or season, and to share it between the fleets of the different countries. Then, the eligible driftnet vessel owners receive a quota ($\overline{y_{ia}}$) in weight, given as a percentage of the TAC or the national quota for the driftnet fleet. The endowment of quotas rations the harvests of the vessels if their allocation is lower than the vessel’s total hold capacity over the albacore season.

As in the driftnet non-regulation context, each fisherman has to choose the number of trips to the fishery in order to maximise the total variable profit during the albacore season (12). In a second stage, driftnet length must be adapted to fill in the hold.

(15) $G_{ia}^*(m_{ia}) = \left[\dfrac{m_{ia}.H_{ia}}{c.(m_{ia}.d_a)^{\alpha}.L_i^{\delta}}\right]^{1/\beta}$

Yet, the following constraint must be respected :

(16) $m_{ia}.H_{ia} \leq \overline{y_{ia}}$

Considering that each vessel fills in its hold capacity during each trip, the number of trips has to be adjusted not to go beyond the individual quota limit. If the quota limit is reached, the vessels are able to switch to the hake fishery.

3.4. Transferability of individual quotas on a rental market

A rental market for quota units gives each fisherman the opportunity – by renting or leasing - to adjust annual production at the level he desires, the one which maximises variable profit. Quotas divisibility is assumed to be perfect, and variable profit becomes :

(17) $\pi_i(m_{ia}) = \alpha_i.\left[p_a.m_{ia}.H_{ia} - c_{ga}G_{ia} - c_{ma}.m_{ia}\right] - \left[m_{ia}.H_{ia} - \overline{y_{ia}}\right]l_a + \pi_{ih}(m_{ia})$

The second term in brackets represents the individual net demand for quota, and a positive (negative) difference means that the fisherman is a renter (leaser). At each model iteration, boat owners reveal their net demand for quota units, (e.g.) the difference between the desired production level and the quota allocation. Then, rental price (l_a) adjusts itself by a walrasian system of trial and error. We assume that there is no transaction cost on the market for rights.

(18) $l_a = \lambda.\sum_{i=1}^{N}\left(m_{ia}.H_{ia} - \overline{y_{ia}}\right)$

The evolution in the price depends on the global net demand for quotas (e.g. the sum of individual net demands) and reaches equilibrium when global net demand becomes nil. In the simulation, willingness to pay for rights depends on the comparison of variable profit values. Vessel owners decide to rent or to sell quota units if the variable profit in the new situation is higher than the variable profit in relation to quota non-transferability. At margin, willingness to pay quota is the difference between the price and the marginal cost. The individual net demand for quota is positive when this marginal rent is above quota unit rental price. At equilibrium, the marginal costs of each vessel equal. The next section presents the simulation results of the cases mentioned above.

4. Simulation of short term adjustment in the driftnet fishery.

The objective of this section is to assess and compare through a simulation, the effects of the different management options implemented by the fishery regulator. The outlook is to replace the regulators in the context of the management decision-making process, that is to say between 1992 and

1995 when regulations were required in the driftnet fishery. Nevertheless, the management possibilities are enlarged, and four main management options are considered: individual licence allocation with and without driftnet regulation, individual quotas and individual transferable quotas allotment. Different options in each of these scenarios are studied and simulations are carried out to make the comparisons between the different options possible.

Different indicators are used in the analysis of the different scenarios. The total variable profit, defined before, is the optimal variable profit earned either in the albacore or in the hake fishery or both. The wage over the season of each crew member is an indicator of labour income. The value of these indicators can be compared to the quasi-rent earned by the vessel and each crew member. The vessel quasi-rent is the difference between the optimal variable profit and the variable profit in the next best fishery; the hake fishery. The crew quasi-rent is the difference between the crew wage earned with best strategy and the crew wage in the hake fishery. The firm quasi-rent is the sum of these quasi-rents.

4.1. Fleet adjustment without driftnet regulation.

As mentioned on table VII, which gives the main simulation results at equilibrium, the best solution for each ship is to deploy its own driftnet length, in order to fill in the hold capacity, and spend all the time in the albacore fishery. The total variable profit is then maximised, and the optimal driftnet reaches a length of 11.33 km for vessels that belong to the group 1, whereas this value is only 5.66 km for the fourth category with the lowest hold capacity.

Table VII. Scenario 1. Optimal driftnet length and variable profit without regulation. Driftnet fleet comprised of 64 vessels. Constant price = 17 f/kg. Utilisation rate of labour is 1km per crew member and per day.

	Number of albacore trips	Optimal driftnet length (km)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew Member Wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	6	11.33	140	1.080	12	0.075			
Group 2	6	9.36	120	0.917	10	0.076			
Group 3	6	7.23	100	0.766	8	0.082			
Group 4	6	5.66	80	0.655	6	0.085			
Total fleet			7,380	57.1	544	44.8	10.1	37.9	48.05

* Crew number in the albacore fishery if the vessel enters the fishery or crew number in the hake fishery if it does not enter.
MF : Million Francs

In such a context, harvests rise to 7,380 tons. Yet, in reality landings have never reached this level for different reasons. Bottlenecks appeared in 1993, when driftnet landings went beyond 4,500 tons, and nearly 6,300 tons for the French albacore fleets. Organisations of producers intervened on the one hand to implement vessel quotas per trip at the end of the season, and on the other hand to store products in order to clear markets and reduce the price fall. In addition, the vessels decided to leave the fishery after the conflicts that took place at sea against Spanish baitboats. These are the main reasons why simulated landings do not correlate very well with the effectively realised harvests.

Simulation results indicate that all the time is dedicated to the albacore fishery since it offers a significant differential quasi-rent to the vessel owners and to their crews. As a whole, crewmembers form a group of about 544 individuals, who share a 10.1 MF quasi rent. This is the difference between the wages earned in albacore fishery, and the opportunity cost in hake fishery; the quasi-rent represents about 23 percent of their income all along the fishing season. The total quasi-rents of vessel owners represent 37.9 MF for a total short term revenue estimated at 57.1 MF. The vessels of the first group benefit from an advantage in capacity, even if they must employ more crewmembers than the smallest vessels. Their individual variable profits reach 1.08 MF, and only 0.665 MF for the vessels of the last group, which in practice, support less fixed costs[11]. There is an economic incentive to own a larger vessel. As a result, in order to capture these infra-marginal rents, some skippers decided to build new larger vessels, or purchase them on the second hand market, in the beginning of the 90's.

In such a context, the driftnet vessels do not spend any time in the hake fishery, and there is no spillover effect resulting from the increase in hake catches in this fishery. Assuming that dolphin by-catches are proportional to tuna catches, theoretical dolphin catches may be estimated to about 3,030 individuals for 7,380 tons of albacore caught.

4.2. Licence allocation combined with driftnet regulation.

Here are considered two main options, the allocation of 64 permits with the driftnet use limited to 5 km per vessel, and the allocation of 40 permits with a driftnet net limit of 2.5 km. This last option has been applied since 1998, and will be enforced until 2002. In both options, the total quasi-rent undergoes a sharp decline to 34,2 MF (-29%) and to 2.9 MF (-94%) compared to the first scenario with no regulation. Landings fall respectively to 5,437 (-26%) and plummets to 1,838 tons (-75%) in the second and third scenarios (see table VIII and IX). Employment also decreases to 320 and 270 fishermen, and total labour remuneration falls from 31.6 to 16.4 MF. In the last scenario, the quasi-rent value for the crew is near zero (0.2 MF). Most vessel owners may adjust the share rate in order to retain the crew, so that the current wage exceeds its opportunity cost (see table IX). This behaviour is possible as vessels owners have a certain freedom in the way they can share the quasi-rent between the capital and the labour factor.

The simulation results reveal that the net regulation tends to homogenise the vessel catches and variable profits. Besides, vessels holding higher capacity are subject to a larger decrease than those with lower hold capacity, because net length is far from their optimal level. For example, the variable profit of group 1 vessels nosedives from 1.08 to 0.69 MF, and to 0.42 MF in the second and third scenarios (respectively a 36% and 61% decrease) when the variable profit of group 4 vessels declines from 0.65 to 0.58, and finally to 0.33 MF (respectively a 12% and 50% decrease). The other main point to be underscored is that the decreases noticed in variable profit and in individual vessel catches, are smaller than the reduction in net length. This results from the decreasing marginal returns of the net length.

Table VIII. Scenario 2: Licence allocation with 5 km driftnet regulation. 64 driftnet vessels.

	Number of albacore trips	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew Member Wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	6	91.4	0.688	5	0.106			
Group 2	6	86.1	0.642	5	0.099			
Group 3	6	82.3	0.624	5	0.096			
Group 4	6	75.5	0.576	5	0.089			
Total fleet		5,437	40.9	320	31.6	12.4	21.8	34.2

Table IX. Scenario 3: Licence allocation with 2.5 km driftnet regulation. 40 driftnet vessels with Proportional reduction in all categories.

	Number of albacore trips	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew Member Wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	6	63.9	0.421	5	0.067			
Group 2	4	42.8	0.396	5	0.059*			
Group 3	4	38.8	0.391	5	0.058*			
Group 4	3	29.5	0.372	5	0.058*			
Vessels excluded	0	0.0	0.330	5	0.060			
Total fleet		1,838	20.6	270	16.4	0.2	2.7	2.9

*Adjustment in share rate should be requested in order to respect model constraint.

In reality, in order to obtain higher turnover, fishermen tried to compensate reductions in catches and income by increasing direct sales of albacore to the consumers. These more expensive landings, around 30 F/kg, concern less than 10 percent of the total landings. It may be difficult to predict the behaviour of fishing firms under scenario 3, since the estimated income in the albacore fishery is very close to the opportunity cost of the hake fishery. Some slight upward or downward variations of income in the hake or in the albacore fishery may lead fishermen to switch from a fishery to another. In practice, hake yields using the gillnet gear are subject to significant variations in the stock accessibility, especially in summer, at the beginning and at the end of the albacore season. This is why the vessels can reallocate their fishing time between the two fisheries.

From the point of view of externalities, only the 2.5 km regulation leads to a reallocation of the fishing effort to the hake fishery. Vessels of the 4th group split their fishing time between the two fisheries, and only the first group does not enter the hake fishery during the albacore season. These regulations tend to limit the dolphin by-catches to 2,235 and 755 individuals under scenarios 2 and 3. Let us now consider the results of the implementation of individual quotas without any driftnet length regulation.

4.3. Implementation of individual non transferable quotas

We now assume that the national quota for driftnet is either set up at the level of scenario 2 (5,440 tons), or at that of scenario 3 (1,838 tons). "Grandfathering" quotas to vessel owners free of charge is the most common practice in this area (OCDE 1993; 1997). As a result, this option is applied here to the 64 driftnet vessels. Two options of distribution of individual quotas are considered in the next table. In the first case, vessels of the groups 1 and 2 receive respectively 2.15 and 1.75 percent of the national quota for driftnet and so on. This option corresponds more or less to an allocation based upon historical catches. The larger the vessels, the higher their allocation. The second case refers to an opposite situation, in which smaller vessels with the lowest hold capacity receive the highest allocation.

Table X. National quota share per driftnet vessel

	Allocation 1	Allocation 2
Group 1	2.15%	1.25%
Group 2	1.75%	1.50%
Group 3	1.15%	1.75%
Group 4	0.51%	2.00%

Note : the sum of individual shares is equal to one.

In each case, because these fishing use rights are not transferable, the vessels cannot adjust their production level beyond their individual quotas. The simulation results are presented in the table XI. In both scenarios with allocation 1, no vessel could achieve its six trips to the albacore fishery. Obviously, the vessels strategy is to harvest all their allocation in a minimum time, and to switch to the hake fishery from the moment that the quota is exhausted. The vessels fill in their hold at each trip, or harvest until the quota limit is reached. But for different vessel groups, it is also more interesting not to harvest all their allocation if the last trip is not profitable. That is why, the whole driftnet national quota is not always used.

As illustrated on table XI, a 5,440 tons national quota yields a lower firm quasi-rent (32.3 MF) than a 5,440 tons harvest with licence allocation, and 5 km regulation (34.2 MF). Yet, the individual quota allocation is more profitable in relative terms when the total harvest declines to 1,838 tons. The advantage is huge, and the quasi-rent is five times higher than the quasi rent of the licence system with 2.5 km regulation (15.0 MF vs 2.9 MF). Actually, the quota system gives the firms the opportunity to adjust their input in order to maximise their return, especially when the national quota is low, and when they have the possibility to switch to another fishery.

The main difference between the two system appears from the distributive effect point of view, but it is difficult to generalise the results. In the model, the licence system (scenario 3) leads to a more equitable distribution of the quasi-rents between the crew and the vessel owner, than the quota system (scenario 4). It gives about 36 percent of the quasi-rent to the crewmembers, whereas they only receive 15 percent in the last scenario. This is mainly due to the vessel's production level, the harvest of an additional quota unit requires more driftnet length, and consequently more crewmembers due to the net's decreasing marginal productivity.

Table XI. Scenario 4: IQ allocation with a national quota of 5440 tons (Allocation 1 for 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total Variable profit (MF)	Crew number*	Crew Member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	5	117.0	116.7	0.962	11	0.068			
Group 2	5	95.3	95.2	0.824	9	0.069			
Group 3	4	62.6	62.6	0.627	7	0.071			
Group 4	2	27.7	26.7	0.422	5	0.068			
Total fleet			5,355	48.6	504	37.6	4.9	27.5	32.3

Table XII. Scenario 5: IQ allocation with a national quota of 1838 tons (Allocation 1 with 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	2	39.5	39.5	0.585	9	0.071			
Group 2	2	32.2	32.2	0.529	7	0.072			
Group 3	1	21.2	16.7	0.402	5	0.068			
Group 4	1	10.1	10.1	0.374	5	0.064			
Total fleet			1,770	31.7	360	30.8	4.4	10.6	15.0

The implementation of individual quotas systems also generates more employment level than the licence systems. For a landed volume of 5,440 tons, with a quota system, vessel owners recruit 60% of additional crew (504 crewmembers), compared to the 5km driftnet regulation. This also explains why in the first scenario, the quasi rent is lower than in the second, even if the fleet's variable profit and total wage are higher.

Compared to the allocation 1, the implementation of the allocation 2 mainly produces distributive effects within the fleet, and between crews and vessel owners. As shown on the next tables, the quasi rent of the total fleet does not nosedive very much with the new allocation. It declines from 32.3 to 31.4 MF with a 5,440 tons national quota allocation, and from 15.0 to 12.1 MF with the shorter national quota. In the first case, a share of the driftnet fleet quota is misused because the vessels of the 4th group do not harvest all their allocation. In fact, because the largest vessels do not receive significant allocation, and do not require numerous crewmembers, the 2nd allocation requires less crew than the first. The quotas are reported to the smallest vessels, which hire larger crew but not in the same proportion.

Table XIII. Scenario 6 : IQ allocation with a national quota of 5,440 tons (allocation 2 for 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	3	68	68	0.713	9	0.071			
Group 2	4	81.6	80	0.727	9	0.071			
Group 3	6	95.2	95.2	0.769	8	0.072			
Group 4	6	108.8	80	0.619	6	0.086			
Total fleet			5,074	45.6	463	38.9	7.0	24.4	31.4

Table XIV. Scenario 7 : IQ allocation with a national quota of 1,838 tons (allocation 2 for 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)
Group 1	1	23.0	23.0	0.455	7	0.069			
Group 2	1	27.6	20.0	0.428	6	0.070			
Group 3	2	32.2	32.2	0.479	6	0.075			
Group 4	3	36.8	36.8	0.471	5	0.073			
Total fleet			1,668	29.0	334	27.8	4.3	7.9	12.1

Due to the new quota allocation between vessels, distributive consequence appears. Larger units earn less than with the first allocation, and the variable profits per vessel for the different groups are less heterogeneous. At the fleet level, vessel owners receive a lower quasi-rent; this indicator increases or stabilises for the crewmembers due to the adjustment of the production process on the size of the crew.

4.4. Implementation of individual transferable quotas

We now assume that the authority responsible for the fishery management authorises the transferability of quotas units on a rental market. The simulation results given in table XV and XVI are equilibrium values obtained from the moment that all the possible exchanges between vessels are realised, and all the gains from exchange are exhausted. Even if all the firms receive a quota allocation, only the more efficient, those of the first and the second group stay in the albacore fishery. They hire quota units, respectively 23 and about 25 tons to harvest beyond their quota allocation, and to reach their maximum production possibilities. Conversely, the vessels of the groups 3 and 4, which are less efficient, lease all their quota allocation to target only the hake species. The adjustment in production possibilities within fishing firms occurs because of their difference in willingness to pay for quota units; unit rental quota price is valued at 1.8 F/kg.

It is the willingness to pay of the marginal firm that also depends on the short term opportunity cost. When the national quota is reduced to 1,838 tons, only the vessels of the 1st group are able to pay for more quota units, they increase their desired production level from 39.5 to 93.3 tons, and the quota price increases to 2.8 F/kg. As the quota supply is reduced, the most efficient firms purchase quota to the less efficient that leave the fishery step by step. Quota price progresses classically in response to supply (e.g. national quota) rationing, and to the increase in willingness to pay for quota units. Consequently, the increase in quota price does not only reflect the fleet rationalisation process, but rather the adjustment in rights supply. Moreover, the infra-marginal fishermen earn quasi rents that are not captured by the rental quota price; this indicator is not relevant to assess all the rents on a short term basis.

Table XV. Scenario 8: ITQ allocation with a national quota of 5440 tons (allocation 1 for 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew Member Wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)	Quota price F/kg
Group 1	6	117.0	140.0	1.044	12	0.076				
Group 2	6	95.3	120.0	0.874	10	0.067				
Group 3	0	62.6	0.0	0.713	5	0.060				
Group 4	0	27.7	0.0	0.650	5	0.060				
Total fleet			5,300	54.8	563	39.0	5.2	33.6	38.8	1.8

Table XVI. Scenario 9: ITQ allocation with a national quota of 1838 tons (allocation 1 for 64 vessels).

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number*	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)	Quota price F/kg
Group 1	4	39.5	93.3	0.777	10	0.070				
Group 2	0	32.2	0	0.069	5	0.060				
Group 3	0	21.2	0	0.659	5	0.060				
Group 4	0	10.1	0	0.626	5	0.060				
Total fleet			1,773	44.7	415	26.8	1.9	23.6	25.5	2.8

The quasi-rents yielded by the implementation of ITQ are higher than with the IQ systems. In the case of a 5,440 tons national quota, the global quasi-rent is about 39 MF for all the fleet, and only 31 MF when transferability is not allowed. The difference between the two options, 23.6 percent, is increased to nearly 110 percent when the national quota drops to 1,838 tons. The quasi-rent rockets from 12.1 MF to 25.5 MF but does not really benefit to individual crewmembers since the fishing firms use more labour in the ITQ systems comparing to the IQ systems.

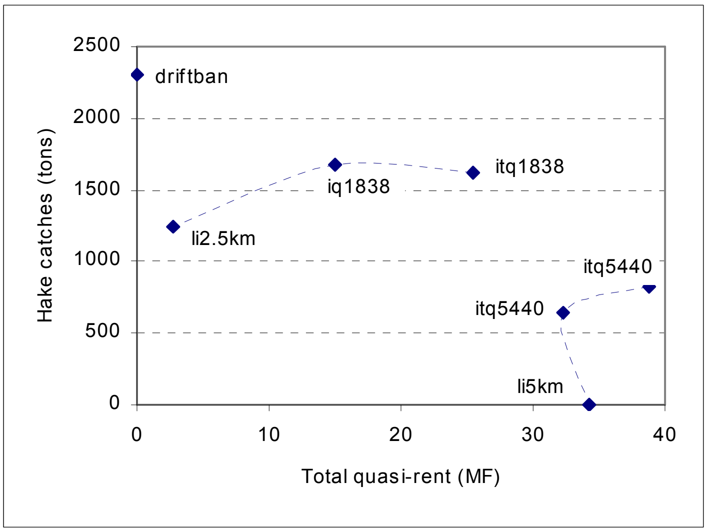
Finally, each vessel benefits from the quota exchange, the largest vessels as well as the smallest. Their variable profit is higher than the variable profit in the IQ system. This is why the final allocation is Pareto optimal with market exchange whatever the initial quota allocation. In allocation 1 or 2, the market adjustment without transactions costs provides the same optimal harvest per vessel - see annex -. Equilibrium quota rental prices reach respectively 1.8 and 2.8 F/kg. This effects is also known as the “Coase theorem” (Stigler 1966). It is clear that other fleet structures will lead to different rental prices equilibrium because of their difference in efficiency, and finally in their willingness to pay for quota units.

This section does not focus upon the specific impacts of transferability of rights, even if distributive effects within the fishing firm occur. This problem is a major concern in public regulation, and few papers address this problem (Cunningham 1993) (Palsson and al 1997). In numerous fisheries managed by ITQ's, vessel owners who want to rent quota units have the incentive to transfer the rental cost to their crew, or to change the crew share rate (Eythorsson 1996, Casey and Dewees 1995, Hoefnagel and Smit 1997). Guyader and Thébaud (1999) modelled the effects of such arrangements on the allocation of quota units and analysed how distributive constraints can influence market adjustments.

5. Comparison of the different management strategies.

Until now, management authorities have never compared the benefits and the disadvantages of the different management alternatives in the albacore fishery. They have focused on the problem of dolphin by-catches in the albacore driftnet fisheries without trying to assess the economic consequences of the regulatory measures. The previous analysis gives some economic and physical indications on the consequences of licence and driftnet regulation, as well as on the implementation of individual quotas or individual transferable quotas. These indications enable the fishery regulators to value the effects of their political trade-offs. The figure I presents the short term impacts of management strategies in terms of albacore quasi-rent, hake catches. Linked points are comparable in terms of dolphin by-catch level.

Figure 1. Albacore quasi-rent and hake catches for different levels of dolphin by-catches.



Dolphin by-catches level : Driftnet ban : $\overline{G_a}\,0km$ =0 dolphin. $\overline{G_a}\,0km$ G_{ia}2.5km=756 dolphins. $\overline{G_a}\,5km$ =2,235 dolphins.

The ban of driftnets eliminates driftnet-caused dolphin mortality, and the vessels have to switch to the hake fishery. As a consequence, albacore quasi-rent plummets to zero, whereas hake total catches increase to about 2,300 tons. Of course, a biological assessment should be required to analyse the consequence of such a mortality level on the dynamics of the stock, which is now considered as largely overexploited (Anon 1998). Nevertheless, this catch level is probably not sustainable on a long term basis. According to a national quota or effort regulation leading to 1,838 tons of albacore landings, ITQ and IQ increase slightly hake catches compared to the licence allocation, with the 2.5 km regulation. Yet, this progression is far less proportional than the increase in quasi-rent for the driftnet vessels. For a higher national quota level, the conclusions are quite different since the change in regulation – from licence to ITQ – leads to nearly proportional increase in hake catches and in albacore quasi-rent. In fact, 5 km driftnet regulation yields a 34.3 MF without giving incentive to switch to the hake fishery.

In all cases, if the objective of the regulator is to maximise quasi-rents, the ITQ system should be preferred to the other systems. The lower the national quota level, the higher the advantages of such a system. It enables the fishing firms to adjust their catch level to their optimal level. It is also the best way to match the landings with the national quota level. Globally, the IQ systems generate more or less as many quasi rents as the licence systems. They enable the vessels to harvest their quotas properly, and then to switch to the hake fishery. Conversely, the licence systems reduce the hake catches if the driftnet regulation incites fishermen to stay in the albacore fishery during the albacore season. As shown on the figure I, the ITQ system is also the best instrument to reduce the differences in quasi-rents for different levels of dolphin by-catches.

Finally, an implicit value may be given to the dolphin saved with one or another regulatory measure. This value is the loss of producer short-term surplus or quasi-rent resulting from the reduction of dolphin by-catches, though it does not represent a value for the society taken as a whole. According to this definition, the implicit value of a saved dolphin is not proportional to the reduction of dolphin by-catches. On average, it varies respectively from 15,400 to 17,400 francs as follows: the first value refers to an evolution from the licence allocation system with 5 km driftnet to the driftnet ban. The second, corresponds to an evolution from the ITQ system with a 5,440 tons national quota, to the driftnet ban. This difference outlines the value of rationalisation, and underscores the idea that in such a context, it is preferable for the fishermen to switch to an ITQ system in order to increase and demonstrate their potential losses due to environmental regulations.

Conclusion.

This empirical study reveals that in order to increase short term rents in the driftnet fishery for a defined level of dolphin by-catches, the system of individual transferable quotas is the most relevant and adapted. Due to the transferability of rights between vessels, significant gains are noticed when ITQs are implemented. In addition, the smaller the Total Allowable Catches or national quota, the higher the increase in benefit. However, the possibility to exchange rights not only on a rental market, but also on a sale market, may lead to distortion effects due to the different levels of subsidies granted between fishing firms (Guyader 1998).

The present analysis does not linger over the overall aspects of the implementation of individual quotas, and more particularly the spillover effects resulting from discards, highgrading problems, and the specific public costs linked related to the establishment and enforcement of use rights. Considering the first aspects, due to the relatively high selectivity of the driftnet gear (e.g. few joint products), and the limited difference in price within albacore catches, we may expect a few undesirable outcomes from the implementation of quotas. In the case of the driftnet fishery, quota regulation with the control of dockside landings, is less costly than licence with driftnet regulations that require enforcement at sea with patrol vessels. IQ as well as ITQ should then be preferred from a cost-benefit analysis perspective. Considering the fact that the French law prohibits the transferability of use-rights, the IQ system can be considered as a second best even if the licence system, with a 5km regulation, yields significant quasi-rents. The future ban of driftnets that is due to be applied in 2002, is going to lead to adverse effects in terms of producer quasi rent and hake harvest levels, which are probably non sustainable for both the fishing firms and the hake stock on a long term basis.

From an economic perspective, the welfare gains of this ban for the society could be compared to the reduction of the short term producer surplus assessed in this study, though no analysis has yet been carried out. If the objective of the management authorities is to maximise the collective welfare and to avoid political controversy, the best way is probably to set up a system of bid auction for albacore fishing use rights, which could be opened to both fishermen and environmental organisations. The level of albacore tuna catches and that of dolphin by-catches will then depend on the willingness to pay of the different economic agents, either to harvest tuna or to suspend tuna catches, and finally save dolphins. Then, funds collected by the public authority could be dedicated to research programmes for the improvement of driftnet selectivity. However, the decision to ban driftnets is probably irreversible for political reasons that are far beyond economic assessments.

References

Anon., (1990), *Interaction de différents engins de pêche de la pêcherie de surface de germon de l'Atlantique Nord-Est*. rapport IFREMER/IEO. Réf. CEE 2018 DB/vt 18.7. 57 p.

Anon., (1998), *Report of the Working Group on the Assessment of Southern Shelf Demersal Stocks*. ICES CM 1999/ACFM:4.

Antoine, L. and M. Goujon and G. Massart (1997), 'Captures accidentelles de dauphins dans les filets dérivants à thon en Atlantique Nord Est*'.* Conseil International pour l'Exploration des Mers. M 1997/Q:10.

Antoine, L., Guyader O., Goujon M. (1998), 'Un changement de technique de pêche est-il compatible avec une pêche responsable? L'exemple de la pêche au germon (Thunnus alalunga) au filet dérivant en Atlantique Nord*'. ICCAT Tuna Symposium. ICCAT collective Volume of Scientific Papers*. **50**(2) 651-660.

Anderson, L. G. (1994), 'An Economic Analysis of Highgrading in ITQ Fisheries Regulation Programmes'. *Marine Resource Economics* **9**, 209-226.

Arnason, R. (1993), 'The Icelandic Individual Transferable Quota System : A Descriptive Account'. *Marine Resource Economics* **8**, 201-218.

Arnason, R. (1996), 'Property Rights as an Organizational Framework in Fisheries : The Case of Six Fishing Nations'. in B. L. Crowley (ed.). *Taking Ownership : Property Rights in Fishery Management on the Atlantic Coast*. Canada : Atlantic Institute for Market Studies, 99-144.

Boyce, J. R. (1992), 'Individual Transferable Quotas and Production Externalities in a Fishery*'*, *Natural Resource Modelling*, 6(4) 385-407.

Casey, K. E., Dewees, C. M. and al. (1995). 'The effects of individual vessel quotas in the British Columbia halibut fishery', *Marine Resource Economics* **10**(3), 211-230.

Christy, F. T. Jr. (1973) *Fishermen Quotas : A Tentative Suggestion for Domestic Management*. Law of the Sea Institute University of Rhode Island. Occasional paper 19. Kingston. Rhode Island.

Clark, C. W. (1990), *Mathematical Bioeconomics. The Optimal Management of Renewable resources*. 2nd edition. John Wiley & Sons. New York.

Copes, P. (1986) 'A Critical Review of the Individual Quota as a Device in Fisheries Management' *Land Economics* **62**(3) 278-291.

Copes, P. (1997), *Alternatives in fisheries management, in UBO-ENSAR(Ed) proceedings of the IX*th annual conference of the European Association of Fisheries Economists, Quimper 28-30 April 1997, 10-35

Crothers, S. (1986), 'Individual Transferable Quotas : the New Zealand experience' *Fisheries* **13**(1), 10-15.

Cunningham, S. (1994), 'Fishermen's Incomes and Fisheries Management', *Marine Resource Economics* **9**(3) 241-252.

Davidse, W. E. (1997), Property rights in fishing ; effects on the industry and effectiveness for fishery management policy, LEI-DLO.

Dupont D. P. and S. A. Phipps (1991a), 'Individual Vessel Quotas and Income Effects', *Canadian Journal of Regional Science* **14**(2) 157-180.

Dupont D. P. and S. A. Phipps (1991b), 'Distributional Consequences of Fisheries Regulations' *Canadian Journal of Economics* **24**(1) 206-220.

Eythorsson, E. (1996), 'Theory and practice of ITQs in Iceland : Privatization of Common Fishing Rights'. *Marine Policy* **20**(3) 269-281.

Findlay M., and A.E. Searle (1998), 'The North East Atlantic Albacore Fishery: A Cornish Crisis of Confidence' *Marine Policy* **22**(2) 95-108.

Garcienda, F. (1996), *Analisis economico de la pesqueria del stock norte de atun blanco con mencion especial al caso vasco*. Tesis Doctoral. Universidas de Deusto. Facildad de CC.EE. y Empresariales (ESTE). San Sebastian.

Garza-Gil, D. G. (1998), 'ITQ systems in Multifleet Fisheries: An application for Ibero-atlantic Hake' *Environmental and Resource Economics* **11**, 79-92

Goujon, M. (1996), *Captures accidentelles du filet maillant dérivant et dynamique des populations de dauphins au large du Golfe de Gascogne*. Thèse de doctorat. Ecole Nationale Supérieure Agronomique de Rennes. France.

Griffin, W. L.. K., Roberts, A. B., Lamberte, J. M., Ward, and H. M. Hendrickson (1992), *Consideration for the Potential use of Individual Transferable Quotas in the Gulf of Mexico Shrimp Fishery*. National Marine Fisheries Service. Silver Sprind. MD. **3,** 125 p.

Guyader, O. (1998) 'Transition from Open Access to Regulatory system with Subsidies : the case of the French Driftnet Fleet' *Proceedings of the first Concerted Action Workshop on Economics and the Common Fishery Policy*, UK, 28-30 october, CEMARE Miscellaneous Publication n°44 1999, 109-124.

Guyader, O. (2000), *Evaluation économique de la régulation des pêches : le cas du stock de germon de l'Atlantique Nord-Est,* L'Harmattan, Paris, 366 p.

Guyader O. and O. Thebaud (1999), 'Distributional issues in the operation of rights-based fisheries management systems' Forthcoming in Marine Policy.

Guyader, O. Daurès, F. and F. Fifas (2000) 'A bioeconomic analysis of the impact of decommissioning schemes : application to a limited entry scallop French fishery' in *proceedings of the IIFET biannual Conference*, Corvallis, Oregon, USA, July.

Hahn, R. W. (1984), 'Market Power and Transferable Property Rights' *Quarterly Journal of Economics* 753-765.

Hannesson, R. (1993), 'Fishing capacity and harvest rules' Marine Resource Economics **8**, 133-143

Hatcher, A. and K. Robinson Ed (1998), *Overcapacity. Overcapitalisation and Subsidies in European Fisheries*. Proceedings of the first Concerted Action workshop on Economics and the Common Fisheries Policy : UK. 28-30 October. 1998. CEMARE Miscellaneous Publication no. 44.

Hatcher, A. and K. Robinson Ed (1999), *The definition and Allocation of Use rights in European Fisheries.* Proceedings of the second Concerted Action workshop on Economics and the Common Fisheries Policy : UK. 5-7 May. 1999. CEMARE Miscellaneous Publication no. 46.

Hoefnagel, E. and W. Smit (1997), 'Co-Management and Property Rights in the Netherlands'. in G. Petursdottir Ed. *Property Rights in the Fishing Industry*. Fisheries Research Institute. University of Iceland Press. Iceland. 11-24.

Holden, M. (1995), *The Common Fisheries Policy : Origin. Evaluation and Future*. Update by D. Garrod. Fishing News Books. Oxford.

Huppert, D. D. and L. Anderson and R. Harding (1992), *Consideration of Individual Fishing Quotas in the North Pacific Groundfish Trawl Fishery*. National Marine Fisheries Service. Silver Spring MD : **2** 121 p.

ICCAT (1996) *Collective volume of scientific papers, report of the final meeting of the ICCAT albacore research programme* **XLIII,** 395 p**.**

ICCAT (1998), *Statistical Bulletin of the International Commission for the Conservation of Atlantic Tunas*. Madrid 1997, **28**, 213 p.

Lindner, R. K. and H. F. Campbell and G. F. Bevin (1992), 'Rent Generation During the Transition to a Managed Fishery: the Case of the New Zealand ITQ System'. *Marine Resource Economics* **7**, 229-248.

Macinko, S. (1993), 'Public or private ? : United States commercial fisheries management and the public trust docrtine, reciprocal challenges' Natural Resource Journal **33,** 919-955.

Matulich, S. C., R. C. Mittelhammer, and al. (1996), 'Toward a more complete model of individual transferable fishing quotas : implications of incorporating the process sector' *Journal of Environmental Economics and Management* **31,** 112-128.

McCay, B. J. and C. F. Creed and al. (1995), 'Individual transferable quotas (ITQs) in Canadian and US fisheries' *Ocean and Coastal Management* **28**, 85-115.

Moloney, D. G. and P. H. Pearse (1979), 'Quantitative Rights an Instrument for Regulating Commercial Fisheries', *J. Fish. Res. Board Can*. **36,** 859-866.

OCDE (1993), *L'utilisation des contingents individuels dans la pêche*, OCDE publications, Paris.

OCDE (1997), Towards sustainable fisheries : economic aspects of the management of living marine resources. Paris, OCDE publications, Paris.

Palsson, G. and G. E. Petursdottir (1997), *Social implications of quota systems in fisheries,* Copenhague, TemaNord.

Runolfsson, B.(1999), ITSQs in Icelandic fisheries : a rights-based approach to fisheries management, in Hatcher, A. and K. Robinson Ed (1999), *The definition and Allocation of Use rights in European Fisheries.* Proceedings of the second Concerted Action workshop on Economics and the Common Fisheries Policy : UK. 5-7 May. 1999. CEMARE Miscellaneous Publication no. 46.

Santiago J. and al. (1996), *Efectos de la introduccion del arrastre por la flota vasca de bajura en las pesquerias de anchoa y atun blanco,* Informes tecnicos No. 73. Gobierno Vasco. Departamento de Industria. Agricultura y Pesca. 139p.

Scott, A. (1988), Development of property in the fishery, *Marine Resource Economics* **5**, 289-311.

Squires D., Alauddin M., Kirkley J., (1994), 'Individual Transferable Quota Markets and Investment Decisions in the Fixed Gear Sablefish Industry', *Journal of Environmental Economics and Management* **27**, 185-204.

Squires D., Kirkley J., Tisdell C. A., (1995a), 'Individual Transferable Quotas as a Fisheries Management Tool', *Reviews in Fisheries Science* **3**(2), 141-169.

Squires, D. and J. Kirkley (1995b), 'Resource rents from single and multi-species individual transferable quota programmes' *ICES J. mar. Sci*. **52**, 153-164.

Stigler, G. J. (1966), *The Theory of Price.* Third Ed. New York: Macmillan.

Stephenson, R. L., Lane D. E., Aldous, D. G., Nowak, R. (1993). 'Management of the 4WX Atlantic Herring (*Clupea Harengus*) Fishery : An Evaluation of Recents Events' *Canadian Journal of Fisheries and Aquatic Sciences* **50**, 2742-2757.

STECF (1993), 24th report of the Scientific and Technical Committee for fisheries, Commission of the European Communities, Commission Staff working paper, Brussels, 15-17 November 1993.

Sutinen, J. G. (1979), 'Fishermen Remuneration Systems and Implications for Fisheries Development' *Scottish Journal of Pol. Econ*., **26**(2) June 147-162.

Sutinen J. G., Mace P., Kirkley J., DuPaul W., Edwards S. (1992), 'Consideration for the potential use of Individual Transferable Quotas in the Atlantic Sea Scallops Fishery. National Marine Fisheries Service. Silver Sprind. MD **5**, 131 p.

Terry, J. M. (1993), Quotas individuels transférables pour la pêche à la morue charbonnière et au flétan avec des engins fixes au large de l'Alaska. L'utilisation des contingents dans la gestion des pêches, OCDE, Paris 103-130.

Townsend, R. E. (1990), 'Entry Restrictions in the Fishery : A Survey of the Evidence' *Land Economics* **66**(4) 359-378.

Wang, S. (1995), 'The surf clam ITQ management : an evaluation' *Marine Resource Economics* **10,** 93-98.

Vestergaard, N. (1996), 'Discard Behaviour. Highgrading and Regulation: The Case of the Greenland Shrimp Fishery' *Marine Resource Economics* **11,** 247-266.

Wenninger, Q. R. and R. E. Just (1997), 'An analysis of the transition from Limited entry to transferable quota: non marshalian principles for fisheries management' Natural Resource Modelling **10**(1), 53-83

Wilen, J. E. (1988), 'Limited entry licencing : a retrospective assessment', *Marine Resource Economics* **5**, 313-324.

Annex

Table XVII. Scenario 10: ITQ allocation with a national quota of 5440 tons (Allocation 2 for 64 vessels)

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)	Quota price F/kg
Group 1	6	68	140	0.956	12	0.075				
Group 2	6	81.6	120	0.849	10	0.066				
Group 3	0	95.2	0	0.772	5	0.060				
Group 4	0	108.8	0	0.796	5	0.060				
Total fleet			5,300	54.9	563	38.5	4.7	33.7	38.4	1.8

Table XVIII. Scenario 11: ITQ allocation with a national quota of 1838 tons (Allocation 2 for 64 vessels)

	Number of albacore trips	Vessel allocation (tons)	Albacore catches (tons)	Total variable profit (MF)	Crew number	Crew member wage (MF)	Crew quasi rent (MF)	Vessel quasi rent (MF)	Firm quasi-rent (MF)	Quota price F/kg
Group 1	4	23.0	93.3	0.731	10	0.070				
Group 2	0	27.6	0	0.678	5	0.060				
Group 3	0	32.2	0	0.690	5	0.060				
Group 4	0	36.8	0	0.703	5	0.060				
Total fleet			1,773	44.81	383	26.7	1.8	23.7	25.5	2.8

[1] Tax schemes are rarely used in fisheries.
[2] Market efficiency requires a number of conditions including the divisibility and transferability of rights and the presence of a sufficient number of separate owners to ensure competitive behaviour (Hahn 1984).
[3] In some limited cases, the crewmen are also eligible to individual quotas (Terry 1993)
[4] Significant exchanges are reported in Icelandic fisheries with high figures for the main species, and more than thirty percent of the quota shares for cod exchanged in 1997 (Runolfsson 1999 : 172). U.S wreckfish and surfclam fishery as well as Australian bluefin tuna fishery have active markets but Lindner and al. (1992) found only limited ITQ transactions in New Zealand. The effects due to trade restriction or to thin markets induced by high transaction costs or few participants are not self evident. When individual quotas are non transferable, fishermen face incentives to trade it on black markets as shown in the Dutch fleet before 1985 (Hoefnagel and Smit 1997) or in the Atlantic herring fishery in Canada (Stephenson and al. 1993).
[5] R. (CEE) N°345/92, January 27th, J.O.C.E N°L42/15. In spite of this rule, some of these vessels could use up to 5 km net length during the next two years. Other fleets like Italian swordfish fisheries and Baltic salmon fisheries are concerned by the use of driftnet.
[6] According to E.C. Regulation 1239/98, driftnet use will be ban the 1st January 2002.
[7] Baitboat catches count for roughly 65 percent of this last figure
[8] Driftnet is forbidden by Spain.
[9] Hold capacity is not used as an explicative variable due to the lack of information for vessels. However, there is a very good correlation between vessel length and the hold capacity.
[10] See also Hannesson (1993) Anderson (1994) and Vestergaard (1996) for models using hold capacity as a constraint.
[11] These fixed costs cannot be affected to tuna or hake fishery.