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Chapter1. The Normand-Breton gulf case[1]

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Introduction

Located in the western part of the English Channel (ICES VIIe), the Normand-Breton gulf (or gulf of St-Malo) is entirely within the 12 NM zone of France and the UK Channel Islands (mainly Jersey and Guernsey)[2]. It is a rich, complex and conflictual fishery. A good part of the fisheries conflicts characterising the area set against each other fishermen using towed gears (mainly trawls) and fishermen using fixed gears (mainly pots and nets).

Not only is the cohabitation between gears a source of conflicts because of incompatibility of their use at the same time in the same place. The use of poorly selective gears gives rise to important discards (Morizur et al., 1996) which are a cause of economic losses for the fishery as a whole, hitting more particularly (but not exclusively) fishermen using more selective gears. The problem gets specially acute when low selectivity gears are used in nursery areas, a phenomenon which is not uncommon in the Normand-Breton gulf (Berthou et al., 1996).

This situation obviously calls for management measures preventing the use of the least selective gears in the most sensitive areas. Some of them are presently discussed within the « Bay of Granville committee », a consultative body where government representatives and fishermen organisations of both France and Jersey Island elaborate proposals concerning the management of fishing activities in the south-east part of the Normand-Breton Gulf.

The study presented here focuses on a scenario of seasonal trawl ban within the gulf, intended at preventing discards by trawlers of bycatches of juveniles belonging to various species, mainly black sea- bream and spider-crab. The case study is organised as follows :

1. Description of fishing activities within the Normand-Breton gulf
2. Analysis of the problem of discards by trawlers operating in the gulf
3. Modelling of a seasonal trawl-ban scenario

1. Fishing activities inside the Normand-Breton gulf

The fishery of the Normand-Breton gulf at first looks quite complex (1.1). Despite a deficit of comprehensive and reliable data, various elements suggest that the fishery as a whole is characterised by overcapacity (1.2). Some knowledge of the economic performance of the French fleets operating the fishery may be obtained through the results of a field survey of skippers (1.3).

1.1. Complexity of the fishery

[1] The authors are in considerable debt towards the late Jean-Luc Prat, an elegant specialist ot the law of the sea and good friend who departed prematurely in 2001.
[2] For the sake of the present analysis, the Normand-Breton gulf is understood as the interior and territorial waters of UK Channel Islands and France, between the *cap de la Hague* (Lower-Normandy) and the *sillon de Talbert* (Brittany).

This complexity has a biological and technical basis, which is the diversity of its fauna (1.1.1) and of the fishing activities it shelters (1.1.2). It is also due to its management regime (1.1.3).

1.1.1. Diversity of fished species

As a consequence of hydrological and sedimentary characteristics, biodiversity is higher in the Normand-Breton gulf than in other parts of the Western Channel (Berthou et al., 1996). Benthic populations, specially, are very important. These diversity and abundance also characterise exploited species. In the last century, dredging of flat oyster *Ostrea edulis* was the basis for fishing activity of many boats. Warty venus *Venus verrucosa* and scallop *Pecten maximus* have been deeply exploited since 1950. Queen scallops *Chlamys opercularis* also support fishing activity. Biomasses of the clams *Glycymeris glycymeris*, *Ruditapes rhomboïdes* and *Spisula ovalis* are very high. Beside these suspension feeders, others molluscs are the basis for important fishing activity, such as the whelk *Buccinum undatum* (most of French landings come from the Normand-Breton gulf) and the cuttle fish *Sepia oficinalis* which comes annually, in spring, for reproducing in shallow waters.

The mixture of soft and rocky grounds is also favourable to crustaceans and Normand-Breton gulf is the French most important production area for lobster *Homarus gammarus* and spider crab *Maja squinado*. Although they are of lesser importance, velvet crab *Necora puber*, edible crab *Cancer pagurus* and common prawn *Palaemon serratus* are fished by many potters.

Many species of finfish also find favourable grounds in the gulf, specially for nurseries. The most important species in the landings are the rays *Raja clavata* and *R. naevus*, common sole *Solea solea*, red gurnard *Aspitrigla cuculus*, sea bream *Spondyliosoma cantharus*, sea bass *Dicentrarchus labrax*.

Landings data are not complete. There are a lot of landings spots, and the majority of fishing boats operating the fishery are too small to have an obligation to fill log-books. French fishermen have a legal obligation to weight and declare their landings, but the enforcement of this rule is variable. The statistical knowledge of the landings is variable as regards species and fishing activities. The landings of molluscs, as well as the landings of finfish realised by trawlers, are generally well known because most of them are commercialised through auction markets. In the case of crustaceans and, more generally, in the case of products of potting and netting activities, landings are mainly commercialised directly by the fishermen. As a consequence and because of the lack of declarations, official statistics are often underestimated with a year-to-year variable degree of uncertainty. Another problem is the difficulty to sort out, in some cases (mainly finfish), the catches realised inside and outside the gulf.

1.1.2 Diversity of fishing activities

The Normand-Breton gulf is operated by Channel-Islands and French boats. At the beginning of the 90’, the Channel-Islands fishing fleet was composed of approximately 670 inshore boats and 35 offshore boats (Tétard, Boon et al, 1995). The inshore boats operate only inside the gulf. Most of them are potters and handliners, small-sized (4 to 11 metres), and many are operated by non-professional fishermen with only a seasonal activity. The offshore fleet is composed of potters, trawlers and longliners. These boats range from 9 to 21 metres and operate mainly out of the gulf.

In 1994 there were about 650 French professional[1] fishing boats operating inside the gulf (Berthou et al., 1996). Though the majority comes from harbours bordering the area, some boats of external ports are met seasonally, targeting scallop, cuttle fish or spider crab. Most of the boats operating inside the gulf are strongly dependent of this area : 50 % operate in the gulf all the year round, and 35% between 6 and 10 months a year.

The French fleet operating inside the gulf is basically small scale (average length : 10.8 metres) but the number of boats over 16 metres is increasing. Boats under 13 metres operate mainly in the coastal parts of the gulf. Boats between 13 and 18 metres are more scattered in the gulf and, with a few exceptions, the largest boats (18-25 metres) operate only part time this area.

More than 20 *métiers*[2] were observed in 1994, and each French boat operating inside the gulf was involved in 2.1 *métiers* per year on average. There are 3 main *métiers* : crustaceans potting, scallop dredging and bottom trawling. Each one concerns 30 % of the total fleet and together they represent a number of months of activity amounting to 60 % of the total activity of the French fleet in the gulf. Five secondary *métiers* (whelk potting, small mesh netting, warty venus dredging, spider crab netting, cuttle fish potting) concern 10 % of the boats each, and represent 30 % of the total activity. The total French fleet may be split into 7 subsets according to the main important fishing strategies :

Table 1. Description of the French fleet operating the Normand-Breton gulf in 1994 (Berthou et al., 1996)

type of boats	number of boats	mean length (m)	mean HP (kw)	Remarks
Trawlers	76	19.4	372	Mainly bottom trawlers, but also a few midwater trawlers. Boats operating only part time inside the gulf. 24 boats coming from outside the gulf (district of Caen)
Trawlers-dredgers	118	12.3	174	Boats involved both in dredging (scallops, warty venus) and inshore trawling.
Dredgers	63	9.4	102	Boats specialised in dredging *métiers* all the year.
Dredgers + fixed gears	110	10.0	118	Dredgers completing their activity with various activities, mainly crustacean *métiers* and bass longlining.
Crustacean potters	150	8.5	79	Some of these boats complete their activity with other fixed gears (nets or lines).
Whelkers	65	8.5	100	Full-time whelk potters.
Miscellaneous	70			Spider-crab netters (11), finfish netters (22), shellfish-farming / fishing boats (9), handliners and longliners (28).

The numerous *métiers* operated in the Normand-Breton gulf are strongly interactive. They interact in three different ways. The first type of interaction is a relation of complementary, when the same boat operates several *métiers* (see above). The two other types connect different boats, and are generally of negative character : they concern the use of space and the exploitation of fish resources.

The space interactions (table 2) are due to technical incompatibilities between the use of different gears in the same area and at the same time. They are usually not very important between the towed gears, can be more developed between the fixed gears but reach a climax between towed and fixed gears :

[1] Unlike UK non-professional fishermen, French recreational fishermen are not allowed to sell their landings. Their activity, which is in principle strictly non-commercial, is out of the scope of the present survey.
[2] Combination of gear, targeted species and fishing area (Tétard, Boon et al., 1995).

Table 2. Main space interactions between *métiers* (Berthou et al., 1996)

	1	2	3	4	5	6	7	8	9
1. Crab and lobster potting	X			X				X	
2. Whelk potting		X					X	X	X
3. Small mesh netting			X				X	X	
4. Spider-crab netting				X				X	
5. Cuttlefish potting					X			X	
6. Bottom longlining							X	X	X
7. Scallop dredging									
8. Otter trawling									
9. Warty venus dredging									

The resource interactions (table 3) are due to the fact that some *métiers* target the same species as others, or discard species which are targeted by others. Few resource interactions are generated by the *métiers* using fixed gears (with the exception of small mesh finfish netting). Between the *métiers* of mobile gears, the bottom trawl is the most interactive in the area ; it interacts on the 8 species selected (see frame below). Discards of spider crab, bream, rays, gurnards and red mullets are important. The midwater trawling interacts on sea bass and bream (the later being partly discarded).

Table 3. Main resource interactions between *métiers* (Berthou et al., 1996)

Species caught / Activity	Spider-crab	Scallop	Sea-bream	Sea-bass	Sole	Skates	Gurnard	Red mullet
crab and lobster potting	L							
whelk potting	d							
Cuttlefish potting								
small mesh netting	l d		l	L	L			L
spider-crab netting	L							
Bottom longlining				L				
scallop dredging	L d	L						
warty venus dredging								
otter trawling	l D	L	l D	L	L d	L D	l D	L D
Midwater trawling			L D	L				
recreational fishing	L			L				

Key : L or l = landing ; D or d = discarding ; upper or lower case letter refers to major or minor interaction.
Notes : 1) in the table above, midwater trawling and recreational fishing were added to the 9 main *métiers* in the gulf, because the interactions which they generate are substantial for certain species ; 2) The by-catches of some species used as baits for other activities were classed as discards.

1.1.3 Institutional complexity of the fishery

The complexity of the fishery also stems from the impressive variety and overlapping character of the legal rules concerning its management (Prat, 1996 ; Curtil, 1996 ; Prat and Curtil, 1997). The remarkable complexity of the legal status of the Normand-Breton fishery has several origins : the variety of species targeted and of *métiers*, but also the coexistence of different national jurisdictions and, within each one, the multiplicity of competencies implied in the management of the fishery.

The Normand-Breton gulf is entirely within the 12 NM zone, but it is characterised by the cohabitation of two different State jurisdictions : France and the UK, who has the sovereignty over the Channel Islands (however, these islands do not belong to the EU). The intricacy of the maritime zones under the jurisdiction of the States bordering the gulf has for long necessitated the setting up of mechanisms of international co-operation. Though both Jersey and Guernsey are under UK sovereignty, the cases of the relations between France and each of these two islands are different (Prat, 1996).

The coexistence of two different State jurisdictions within the gulf is not the only factor complicating the legal status of its fishery. A multiplication of administrative competencies creates a very intricate legal situation (Curtil, 1996).

Being inside the EU fishing zone (even for the part bordering the Channel Islands), the gulf fishery is subject to the general CFP regulations which apply to this zone (legal sizes of catches, European quotas, etc.). But since it is entirely inside the 12 NM zone, the access to the fishery may be, in the present state of the CFP (subject to revision in 2002) reserved by the coastal States to their nationals, and the management of its « strictly local » stocks (important in the area) is delegated to these States.

As regards France, the Regional Prefects are in charge of the administrative competence in their region. As the Normand-Breton gulf is bordered by two different regions (Brittany and Lower-Normandy), this is a non-negligible cause of heterogeneity in the management system of the fishery. This factor is amplified by the role of the so-called « Interprofessional Organisation of Maritime Fisheries » in the management of fisheries. This organisation, which exists at the national, regional and local levels, is composed of representatives of professional fishermen and of other professions involved in the fishing industry, and may take decisions (formally, at the national and regional levels only) that State Authorities (Minister or regional prefects) have the faculty to make compulsory. The regional committees manage, for instance, the license system. Two different regional committees are thus involved in the management of the Normand-Breton gulf fishery. On a local scale, fishermen themselves create informal cohabitation agreements between *métiers* (Prat and Curtil, 1997).

The fishing activities of the gulf are thus submitted to an inflation of norms coming from various authorities. The resulting confusion certainly does not help the implementation of the rules. However, several arguments exist to consider the gulf as an interesting zone for new management approaches :

- it is an ecological entity, relatively isolated from the rest of the Western Channel by the currents ;
- the zone is entirely comprised within the 12 NM of either France or Channel Islands ;
- several stocks among the most interesting for local fishermen are totally included in the gulf, some of which are sedentary or low mobile resources ;
- a majority of boats operating the fishery belong to neighbouring harbours and strongly depend on the fish stocks of the area ;
- there are many important interactions between the fishing activities inside the gulf ;
- notwithstanding the frequent conflicts within the fishery, local fishermen have some significant common interests, concerning conservation and limitation of access to the fish resources of the area.

A first step towards the creation of a common management system of the gulf fishery was taken in 1996 with the creation of a joint consultative committee for the management of fishing activities inside the Bay of Granville (Southeastern part of the Normand Breton Gulf). More specifically, this committee is in charge of elaborating proposals for the management of the fishing activities within the so-called « common sea » between France and Jersey Island.

It is composed of representatives of government authorities of both countries, regional fisheries committees of Brittany and Lower-Normandy, the Jersey Fishermen Association, and scientists (without voting right).

1.2. The equilibrium between fishing capacities and resources

It is suspected that the various conflicts affecting the fishery are boosted by a common factor which is the existence of an overall excess fishing capacity in the area (Boncoeur et al., 1998). The low availability of reliable data is an obstacle to the testing of this hypothesis. The problem has several sides. For some species (mainly crustaceans), the level of knowledge of the landings is poor. For other species (mainly finfish), the geographical origin of the catches is not known with enough accuracy. As regards the fleet, there are time series (not fully homogenous) concerning the boats registered in the maritime districts bordering the gulf, but this set of boats does not fully corresponds to the fleet operating the fishery. It is therefore unavoidable to rely on partial, approximate and indirect indications (the data which are used in the three tables below come from French governement statistics).

Table 4. Evolution of the landings and of the fishing fleet in the 4 maritime districts bordering the Normand-Breton gulf* between the mid 70' and the mid 90' (Boncoeur et al., 1998)

Value of landings (constant francs)**	+ 3 %
Number of boats registered***	- 48 %
Average HP***	+ 119 %
Cumulated HP***	+ 27 %

* Districts of Paimpol, St-Brieuc, St-Malo and Cherbourg. ** Average 1991-95 compared to average 1974-78. Products of far-away fishing, mussels and sea-weeds excluded. ***1993 compared to 1976. Vessels under 25 meter long.

The above table shows an overall stability of the global value of landings in the harbours bordering the gulf[1] over two decades, to be compared with a division by 2 of the number of boats, but with an increase of ¼ in the cumulated engine power of the fleet (the average HP per boat has more than doubled during the period). This suggests that, irrespective of the sharp diminution in the number of boats, the fishing capacity around the gulf has significantly increased during the period, a conclusion which would be strengthened by considering the effect of technical progress. The available data allow a more precise description of landings for the period starting in the mid 80' :

Table 5. Main species targeted in the Normand-Breton gulf*. Evolution of landings in the 4 bordering maritime districts, 1986-94 (Boncoeur et al., 1998)

	1986	1991	1994
[1] Number of tons landed	100	115	134
[2] Value of landings (constant francs)	100	87	82
[3] Average price of landings (constant francs)	100	75	61
[4] Synthetic index (Laspeyres) of the prices of the landings (constant francs)	100	90	85
[5] Effect of the change of the structure of landings. [5] = 100.[3] / [4]	100	83	72
[6] Synthetic index (Paasche) of the volume of landings. [6] = 100.[2] / [4]	100	106	97

* By decreasing order of landed value (in 1991) : common scallop, spider-crab, whelk, warty venus, cuttle, sea-bass, sole, rays, pollack, lobster, sea-bream, red gurnard (the total amounts to 60% of the value landed in 1991 in the 4 districts bordering the gulf, boats over 25 meters excluded).

The above table is dedicated to the landings, in the districts bordering the gulf, of the 12 main species targeted in this area. For shellfish, landings generally correspond to catches realised inside the gulf. The situation is not so clear with finfish : rays, for instance, are caught inside

[1] In this table, data that could clearly be regarded as having no connection with the gulf fishery have been excluded.

the gulf, but also outside. At least, the panel depicted in the above table eliminates the influence of species which, though representing a significant part of the landings in the bordering districts, are poorly represented in the gulf (sharks in the district of Cherbourg for instance).

The table shows a growth of 1/3 approximately in the weight of the landings during the period 1986-94, altogether with a decrease of almost 20% in their global value. The meaning of the drop of the average price of landings during the period (around 40%) is not clear because two different phenomena may interact : a change in the individual prices, and a change in the structure of the landings. To separate this two factors, a Laspeyres price index has been calculated. The calculation indicates that only a minor part of the drop in the average price of landings can be attributed to the decrease in individual prices : the major part is due to the degradation in the species-structure of landings, high value species being replaced by lower value species as the former ones get progressively exhausted (replacement of warty venus by whelk for instance). Taking into account the Laspeyres synthetic price index allows the calculation of a synthetic (Paasche) volume index of the landings, which depicts the evolution of the value of the landings assuming given individual prices. The result shows a global stability of the volume of the landings during the period 1986-94, to be compared with the evolution of the fleet in the 4 maritime districts bordering the gulf in the same period :

Table 6. French fishing fleet registered in the 4 maritime districts* bordering the Normand-Breton gulf Evolution 1986-94 (Boncoeur et al., 1998)

	1986	1990	1994
Number of boats	100	92	77
Average GRT	100	128	148
Average HP	100	141	160
Cumulated GRT	100	118	114
Cumulated HP	100	130	123

* Cherbourg, St-Malo, St-Brieuc, Paimpol.

Here again, the growth in the cumulated horse power (and GRT) of the fleet underestimates the growth in the effective fishing capacity, because of the technical progress which has been particularly important during the period (especially as regards electronic detection devices). To sum up, the historical outlook suggests the following trends :

- sharp decrease in the number of boats registered in the districts surrounding the gulf ;
- significant increase in their cumulated fishing capacity ;
- stability of the global volume of the landings ;
- degradation of the structure of these landings as regards their unit weight-value.

1.3. Economic survey of the French fleets operating the Normand-Breton gulf fishery

In 1997, an economic sample survey of the French commercial fleets operating the Normand-Britton Gulf fishery was realised by CEDEM (Boncoeur and Le Gallic, 1997). The main population which served as a basis for sampling was given by Berthou et al., 1996. With 66 boats in the sample, the sampling rate was slightly over 10%. The quota method was used for selecting the sample, according to a simplified fleet typology[1]. The 3 following tables

[1] For the purpose of the sampling, 5 fleets were distinguished : trawlers (pure trawlers and trawlers-dredgers), dredgers (pure dredgers and dredgers also using fixed gears), crustacean potters (including potters also using other fixed gears), whelk potters, miscellaneous.

compare the characteristics of the main population and of the sample, and their respective structures by fleet and by maritime district :

Table 7. Economic survey : compared characteristics of the main population and sample (Boncoeur and Le Gallic, 1997)

Boat characteristics	Main population	Sample		
	Mean value	Mean value	Relative standard error(a)	Confidence limits, 5% risk (b)
Length (metres)	10,8	11,4	3 %	10,7 - 12,1
GRT	18,6	16,3	11 %	12,7 - 19,9
HP (Kw)	142	156	7 %	134 - 178
Age (years)(c)	15	17	7 %	14,6 - 19,4
Crew size (number of persons)	2,8	3,0	5 %	2,7 - 3,3

(a) Standard error / sample mean. (b) assuming conditions of a random sampling. (c) sample : 1997 ; main population : 1994.

Table 8. Economic survey : compared fleet structures of the main population and sample (Boncoeur and Le Gallic, 1997)

Fleets	Main population	Sample
Trawlers and trawlers-dredgers	30%	35%
Dredgers and dredgers + fixed gears	26%	32%
Crustacean potters	23%	18%
Whelk potters	10%	12%
Miscellaneous	11%	3%
Total	100%	100%

Table 9. Economic survey : compared geographical structures of the main population and sample (Boncoeur and Le Gallic, 1997)

Maritime districts	Main population	Sample
Cherbourg*	39%	41%
Saint-Malo**	12%	18%
Saint-Brieuc**	27%	35%
Paimpol**	14%	6%
Others (districts not bordering the gulf)***	8%	-
Total	100%	100%

* Lower-Normandy. ** Brittany. *** Mainly Caen (Lower-Normandy)

The survey was limited to the French harbours bordering the Normand-Breton gulf (8 harbours were surveyed) and to boats with a significant part of their activity inside the gulf (at least 40% of their total fishing time), which resulted in under-representing pure trawlers. It was realised by means of direct interviews of skippers (most of them being skipper-owners). The questionnaire was composed of four parts : type of activity, fixed capital, fishing and marketing behaviour, revenues and costs.

The five following tables present the main results. Due to their limited number in the sample (2 in each case), pure trawlers and boats belonging to the « miscellaneous » group have been excluded. In the course of the survey, it appeared useful to split the « crustacean potters » group into two subgroups (potters-netters, and other crustacean potters).

Table 10. Economic survey results : fixed capital and crew (Boncoeur and Le Gallic, 1997)

Fleet	Boat age (years)		Insured value (1000 FF)		Crew size (fishers)*	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	20,1	8,2	1394	933	3,2	0,9
Other dredgers	20,8	9,1	652	465	2,5	1,0
Potters-netters	10,4	7,6	1796	689	3,7	1,1

Other crustacean potters	12,0	5,7	708	791	2,8	1,6
Whelkers	12,6	6,0	571	242	2,6	0,7

* including skipper.

Table 11. Economic survey results : fishing behaviour (Boncoeur and Le Gallic, 1997)

	Time at sea (days / year)		% of total fishing time inside the gulf	
Fleet	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	224	22	74%	22%
Other dredgers	213	25	88%	22%
Potters-netters	204	29	100%	0%
Other crustacean potters	198	11	97%	5%
Whelkers	240	31	100%	0%

Table 12. Economic survey results : landings and sales (Boncoeur and Le Gallic, 1997)

Fleet	Main landed species	Yearly turnover (1000 FF)		% of sales through auction markets
		mean	std. dev.	
Trawlers-dredgers	scallop, warty venus, sole, cuttle fish	1350	598	81 %
Other dredgers	scallop, warty venus, spider crab, lobster, bass	812	466	36 %
Potters-netters	spider crab, lobster, rays and other finfish	1900	783	0 %
Other crustacean potters	lobster, spider crab, edible crab	1046	847	4 %
Whelkers	whelk	1094	426	53 %

Table 13. Economic survey results : yearly costs (1000 FF) (Boncoeur and Le Gallic 1997)

	Variable costs*		Wage costs**		Fixed economic costs***	
Fleet	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	334	166	651	246	160	85
Other dredgers	171	94	443	255	80	48
Potters-netters	430	252	878	287	140	60
Other crustacean potters	226	228	580	465	75	72
Whelkers	288	133	511	165	63	21

* non durable goods (including fishing gears replacement and repairs), 75% of boat maintenance and repairs, landing taxes. ** net wages (including skipper owner's wage) + national insurance contributions. *** 25% of boat maintenance and repairs, insurance and management costs, yearly fishing licences costs, economic depreciation of fixed capital..

Table 14. Economic survey results : performance indicators (Boncoeur and Le Gallic 1997)

	Yearly gross margin* (1000 FF)		Profit rate**		Skipper-owner's yearly net activity income*** (1000 FF)	
Fleet	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	1017	489	15%	10%	335	209
Other dredgers	641	396	18%	20%	231	174
Potters-netters	1470	625	25%	25%	625	445
Other crustacean potters	820	662	23%	41%	296	248
Whelkers	805	303	41%	17%	413	194

* Turnover - variable cost (1000 FF). ** (Gross margin - wage cost - fixed economic cost) / Boat insured value. *** Full equity profit + skipper-owner's net wage - opportunity cost of capital (5.7% of boat insured value) (1000 FF).

2. Analysis of the problem of discards by trawlers inside the Normand-Breton gulf

Discards in the coastal fisheries of the Western part of the English Channel are due to different types of gears (Morizur et al., 1996). Among these, trawling is in the forefront, because of its poor selectivity and importance in the total fishing activity (according to Berthou et al., 1996, some 30% of all commercial French fishing boats operating the Normand-Breton gulf fishery make use of trawls, either part-time or full time). The Normand-Breton gulf, which shelters an important number of nurseries, is particularly concerned by this phenomenon.

Trawling inside the Normand-Breton Gulf results in various types of discards. Some are due to commercial reasons (species with low commercial value, such as spotted dogfish, red gurnard, pout whiting), others to legal reasons (undersized fish, such as juveniles of black sea bream, sole, red mullet), or to the physical condition of the individuals that are caught (soft-shell spider-crabs). The two last types of discards were surveyed by Fifas (1998), who focused on the three following species : black sea bream (*Spondyliosoma cantharus*), sole (*Solea vulgaris*) and spider crab (*Maja squinado*).

2.1. Sole

This species is mainly targeted by inshore bottom-trawlers from the harbours of Granville, St-Malo and around St-Brieuc, operating in the bay of Mont-St-Michel or in the bay of St-Brieuc. Some offshore bottom-trawlers occasionally catch soles, either as bycatches, or as targeted species. Most of the soles landed in the harbours bordering the Normand-Breton Gulf were fished inside the gulf. During the 90’, these landings amounted approximately to 300-400 tons on the average.

Sole is a highly valued species. « Individual portion » soles are particularly sought-after, a phenomenon which presses for catching and marketing soles under legal size : according to data collected by Morizur et al. (1996), the critical length for hand-sorting of individuals onboard of inshore trawlers of St-Malo and St-Brieuc is around 18-20 cm., while the mimimum legal length is 24 cm. This results in marketing individuals, approximately 10% of which are under legal size.

Not all undersized soles are landed. Trawling in the nurseries of the bays of St-Brieuc and Mont-St-Michel generates important discards of juveniles (under 18 cm.), whith a high rate of mortality (larger individuals are stronger, and their rate of survival is higher when they are discarded). This phenomenon is linked to the wide use of trawls with undersized mesh (50-60 mm., instead of 80 mm.), and is responsible for some 25% of the total fishing mortality concerning sole in the Normand-Breton gulf.

Enforcing legal mesh size would result in cutting by 50% the number of discarded individuals. A Beverton-Holt type structural analysis suggests that the average yield per recruit would then rise by 18%, even with a slightly higher effort level. In the same time, the spawning stock biomass per recruit would increase significantly, shifting from 14% to 20% of the unexploited biomass equilibrium level. According to the same analysis, the maximum increase in yield per recruit would be obtained with an increase in mesh size up to 105 mm. : the average yield per recruit could then increase by 32%, and the spawning stock biomass per recruit could reach 37% of the unexploited biomass equilibrium level.

2.2. Black sea bream

This second species is mainly targeted by pelagic trawlers from the harbour of Granville. It is also a bycatch for inshore bottom-trawlers of St-Brieuc and St-Malo. The resource is characterised by high fluctuations of recruitment (at the end of the 90', the abundance was high, resulting in landings around 1000 tons per year). Juveniles stay close to the shore up to 20 cm. long, then progressively reach deeper waters. During this first phase of their life cycle, they are accessible to inshore bottom-trawlers, specially at the end of summer, when concentration of juveniles in nurseries is maximal. Adults are mainly accessible to pelagic trawlers, except in spring when they reach the coastal spawning areas.

Concerning black sea-bream, the critical length for hand-sorting of individuals on pelagic trawlers is around 18 cm., while the mimimum legal length is 23 cm. As a result, around 5 to 8% of all marketed individuals are undersized.

Though the legal 80 mm mesh size is usually enforced onboard pelagic trawlers, these boats discard approximately 10% of all the individuals they catch. The rate of discard is much higher with inshore bottom-trawlers (operating with 50-60 mm. mesh), where it represents up to 90% of all the individuals caught. This phenomenon reaches a climax at the end of the summer, where the rate of discards is almost 100%. The rate of mortality of discarded individuals may itself be considered as 100%. The estimated mortality of sea bream due to discards of juveniles is presented in the following table :

Table 15. Estimation of fishing mortality of black sea-bream by French trawlers operating the Normand-Breton Gulf fishery (Fifas, 1998)

	Catches (10^6 individuals)	Discards (10^6 individuals)	discards / catches
Pelagic trawlers (whole year)	2.49	0.27	11 %
Inshore bottom trawlers (August-September)	1.58	1.57	99 %

The analysis conducted by Fifas suggests that a seasonal bottom-trawl ban during the months of August and September, combined with the enforcement of the legal mesh size, could increase the total landed weight by nearly 20%, as compared to the situation prevailing at the end of the 90'. However, this policy mix would benefit to pelagic trawlers, but not to inshore bottom trawlers, the landings of which would be reduced because of the increase in mesh size.

2.3. Spider-crab

Spider-crab is targeted by some 300 netters and potters of the Normand-Breton gulf, which concentrates approximately 70% of the total landings of this species at the national scale. The fishing period takes place in winter and spring. Each year, around 80% of the newly recruited individuals are fished, which makes this fishery highly dependent on recruitment.

During August and September, juveniles concentrate in the nurseries of West-Cotentin and bay of St-Brieuc where they perform their terminal molt[1], before migrating, in large herds, towards deeper waters. At this time when they are particularly vulnerable and void of commercial value, bottom-trawling realises massive bycatches of spider-crabs, some 90% of which are discarded with a high mortality rate. As a result, around 25% of the individuals to be recruited each year are destroyed by trawlers in two months. This represents, on the

[1] Unlike other crabs, spider crabs perform their successive molts during the 2 first years of their life cycle. The diversity of size at the age of the terminal molt is important.

average, a loss of catches of 1100 tons a year for the netters and trawlers, to be compared with average landings ranging between 3000 and 4000 tons in the 90'.

3. Modelling a seasonal trawl-ban scenario

The cases of discards described in the former section call for different management measures. In the case of sole, it appears that enforcement of the legal mesh size would significantly improve the situation. This is partly so with sea bream, but, as regards this second species, the concentrated time-pattern of the bulk of juvenile discards also induces a potential interest for a seasonal restriction to the activity of trawlers. The spider crab case strengthens the interest of this option, all the most since the seasonality of discards is very similar in both cases.

The scenario of a seasonal bottom-trawl ban[1] within the gulf was studied by Boncoeur, Fifas and Le Gallic (2000). The survey was conducted on the basis of the spider crab case, but the description of the sea bream case indicates that the same scenario is relevant for the two species : in both cases, the concentration of discards by trawlers in August and September suggests that an effective trawl ban during these two months might significantly improve the situation concerning the landings of these two species. The ban would have to apply only to bottom-trawling, since midwater trawling has no responsibility for the spider crab discards, and plays only a marginal role in the sea bream discards (see above). The survey considered a bottom-trawl ban over the whole Normand-Breton fishery, though significant results might probably be obtained with a more localised restriction, if properly enforced.

In order to evaluate the scenario of a 2 months bottom-trawl ban in the Normand-Breton gulf, a bioeconomic model was elaborated. Its purpose is to estimate, in a cost-benefit perspective, the impact of the trawl-ban on three categories of stake-holders : trawlers, crustacean potters and netters, and consumers. The data used in the model are the following :

- biological data provided by stock assessments and discards estimations (Ifremer campaigns at sea over 11 years), plus data about the biology of *Maja squinado* (Le Foll, 1993) ;
- boat cost and revenue data provided by the above mentioned economic field survey of the fleets operating the Normand-Breton gulf (Boncoeur and Le Gallic, 1997), complemented by another survey realised at a broader scale (Boncoeur and Le Gallic, 1998)[2] ;
- price and landings data : government estimations (*Affaires maritimes* statistics)[3].

The general structure of the model is depicted by figure 1 below. We shall first describe the biological component of the model[4], then its economic component. Finally, the results of simulations realised with the help of the model will be presented.

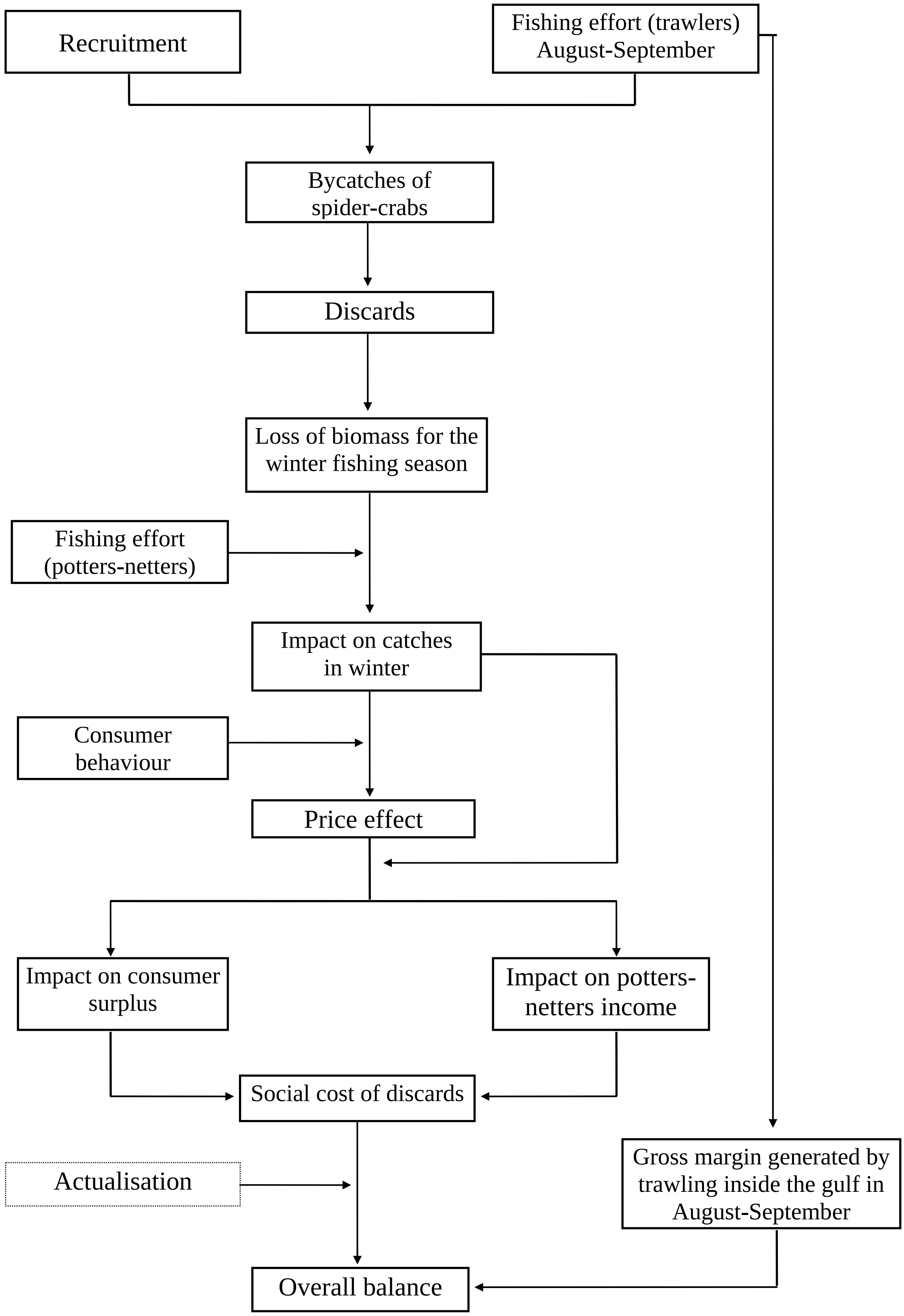
[1] According to French rules, trawling is forbidden within the 3 miles line, and, in Brittany, an additional rule bans pelagic trawling within the 12 NM (this rule applies to the Brittany part of the Normand-Breton gulf). However, numerous impairments result in significantly weakening the actual scope of this restriction.

[2] For practical reasons, these data are restricted to French commercial fishing boats : due to lack of data, Channel-Islands fishing boats and recreative fishing boats could not be included in the model.

[3] The quality of these statistics is questionable, because most landings of spider-crabs are not sold through public auction markets.

[4] This component is presented with more detail in Fifas, 1998.

Fig.1 Structure of the Normand-Breton Gulf spider-crab model



3.1. Biological component

Bycatches of spider crabs by trawlers in August-September mainly depend on two parameters : recruitment (most of the bycatches concern 2 years old juveniles, i.e. individuals that are about to be recruited), and activity of bottom-trawlers in the area during the two critical months. As regards activity, the model relies on the average level of activity during the 90', which results in catching approximately 10% of the stock of juveniles per week, during August and September. Concerning recruitment, three possibilities are considered :

- average recruitment (such that the probability of a higher recruitment is 0.5) ;
- high recruitment (such that the probability of a higher recruitment is 0.05) ;
- low recruitment (such that the probability of a higher recruitment is 0.95).

(these values were calculated by adjusting a log-normal law of probability to the stock assessment data obtained on the basis of 11 years of campaign at sea).

Around 95% of the spider crabs caught by trawlers during August and September are discarded. The resulting mortality depends on the condition of the concerned individuals : while 80 to 90% of the soft shell crabs are killed (the model assumes a rate of 80%), the rate of mortality of discarded hard shell crabs varies according to their size (larger individuals are more fragile than smaller ones), with an average of 12%. Molting is more precocious with smaller individuals (Le Foll, 1993). The probability of molting according to size was simulated with the help of a decreasing logistic curve, parametered in such a way that 95% of the cohort has molted before the end of September, when no trawling occurs. In all, it is estimated that 20 to 25% of the population concentrated in coastal nurseries at the end of the summer is destroyed by trawling.

This mortality reduces the stock biomass which is exploited by potters and netters during the following fishing season (november to april). To estimate the deficit, it is necessary to take into account the increase in size of individuals at the moment of their terminal molt[1] (for the part of the cohort which is destroyed before achieving its molt), and the natural mortality between the end of summer and the crabing season[2] (part of the individuals which are destroyed by trawling would have died anyway before being targeted by potters and netters).

For a given fishing effort, the biomass deficit generates a deficit in catches, estimated by applying, on the whole duration of the fishing season, an instantaneous fishing rate of mortality equal to 3.7 (an estimation consistent with the observed 80% exploitation rate[3]).

3.2. Economic component

The deficit in catches of spider crabs induces a loss of income for potters and netters[4]. But the two phenomenons are not necessarily proportional, as the deficit in catches due to summer discards may influence the price of spider-crabs. The Normand-Breton gulf concentrates 70 to

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[1] The increase in size at the moment of the terminal molt represents between 25% and 40% of the pre-molting size, and is usually more important with small individuals thab with larger ones (Le Foll, 1993).

[2] The model relies on a 0.3 instantaneous coefficient of natural mortality.

[3] Let m be the instantaneous rate of natural mortality, f the instantaneous rate of fishing mortality, and Δt the duration of the fishing season. The rate of exploitation, i.e. the percentage of the recruited cohort which is fished during its first year, may be written as :

$$[\, f / (m + f)].[1 - e^{-(m+f).\Delta t}]$$

With $m = 0.3$, $f = 3.7$ and $\Delta t = 0.5$, the rate of exploitation is 0.8.

[4] Because of the so-called « share system » characterising the remuneration of the crew in artisanal fisheries, this loss affects both skipper-owner and the members of his crew (if any).

80% of the national supply for this species, for which imports are marginal (contrasting with edible crab). The hypothesis of a price effect is confirmed by an examination of landings statistics over 2 decades concerning the maritime districts bordering the gulf (Paimpol, St-Brieuc, St-Malo and Cherbourg). This examination displays a significant sensitivity of landing prices (expressed in constant francs) to landed quantities (tons). The use of a log-linear model for the testing of the price-quantity relation gives the following results :

$$\ln P = -0.414 . \ln Q + 5.924$$

where :

P = average yearly landing price (4 districts), in constant francs (1995) per kg.

Q = yearly landed quantity (same districts), in tons.

with :

number of observations : 20

determination voefficient (r^2) : 0.66

residual standard deviation : 0.110

Regression coefficients	Student T	Confidence limits, 5% risk
a = - 0.414	- 5.922	[- 0.562 ; - 0.267]
b = 5.924	10.897	[4.782 ; 7.066]

While reducing the economic loss for fishers, the price-effect induces a decrease in the consumer's surplus, which is to be accounted for in the estimation of the social cost of discards. This decrease is calculated on the basis of the above log-linear price-quantity relation, which implies two simplifications : 1) no difference is made between Hicksian and Marshallian demand, and 2) no difference is made between landing price and retail price. The first simplification is of no consequence, due to the very low importance of the considerered commodity in the consumers budget. The second simplification is more questionable, as the *level* of retail price is usually very different from that of landing price, and it is not proved that the *change* in landing price in case of a decrease in discards would result in an equivalent change in retail price. In fact, the variation of surplus which is here called, for the sake of simplicity, « consumer's surplus », concerns both consumers and marketing activities.

In order to assess the economic value of a seasonal bottom-trawl ban in the Normand-Breton gulf, it is also necessary to estimate the impact of this measure on trawlers operating inside the gulf. These boats belong to two distinct fleets (Berthou et al., 1996) :

- inshore trawlers-netters (118 units, with an average length of 12.3 metres in 1994), which may be considered as entirely dependent on the gulf fishery ;
- offshore « pure » trawlers (76 boats with an average length of 19.4 metres in 1994), most of them operating mainly out of the gulf (and for a large part coming from harbours located outside the gulf).

For the first fleet, the main database was provided by the economic field survey realised in 1997 (see above). For the second fleet, the results of this survey had to be complemented by additional data, which were obtained through a broader field survey, realised the same year and according to the same methodology at the scale of the whole English Channel, French side (Boncoeur and Le Gallic, 1998). This allowed the building up of a sample containing 30 boats with a trawling activity inside the gulf (21 trawlers-dredgers, 9 offshore trawlers[1]). The impact of the trawl-ban scenario on these boats was estimated as follows :

[1] Some of these boats combine bottom-trawling and midwater-trawling.

1. Isolating, inside the annual total turnover and variable cost of each boat, the share due to bottom-trawling. As regards turnover, this operation was directly realised on the basis of answers to the field survey, which included a question concerning the distribution of annual turnover according to *métiers*. The split of total variable costs was based on an analysis of costs relative to each *métier* (for specific costs), and of the yearly activity calendar, which indicates the allocation of total fishing time betwee *métiers* (for non-specific costs)[1].
2. For trawlers operating only part-time in the gulf, isolating the share of the bottom-trawling activity which is realised inside the area. This second step was realised on the basis of answers to the field survey, which included a question concerning the space distribution of yearly fishing time.
3. Determining the shares of annual turnover and variable costs related to bottom-trawling inside the gulf that may be imputed to the two months of August and September. This third step was realised with the help of monthly landings statistics (showing good reliability in this case, since most landings of trawlers are sold through auction marlets), and boat activity calendars.
4. calculating, for each fleet, the gross margin due to bottom-trawling inside the gulf during the period corresponding to the trawl-ban scenario.

Variation of consumer's surplus may be neglected as regards trawling. This is due to the fact that, contrasting with spider-crabs targeted by netters and potters, most species targeted by trawlers in the gulf (finfish and cephalopods) are also fished in large quantities in other places. As a consequence, when yearly data are considered, no significant price-quantity relation may be established at the local scale for trawlers landings.

The global economic value of the seasonal trawl-ban scenario is established by comparing :

- the producers surplus generated by bottom-trawling in the gulf in August and September,
- and the social cost of discards (deficit in producers and consumers surplus) that would be prevented by a trawl ban during these two months.

The time-interval between discards of juveniles by trawlers and the exploitation of the stock by potters and netters calls for an actualisation of the social cost of discards. However, in the present state of the fishery, this interval is very short (6 months on the average), because the stock is basically reduced to the last recruited cohort. Therefore, considering the limited accuracy of part of the data used in the model, actualisation may be regarded as a superfluous refinement.

As mentioned above, the social cost of discards was calculated for spider-crab only[2], a calculation which underestimates reality since it does not account for other discards the scenario would prevent, specially concerning black sea-bream. It must also be stressed that the calculation is limited to the direct impact of the scenario, i.e. does not integrate indirect effects due to reallocation of effort by fleets affected by the trawl-ban (for an analysis of this question, see Le Gallic, 2001, chapter 7, section 2).

3.3. Simulation results

[1] For these costs, it was assumed that the share of each *métier* was proportional to fishing time. Wage costs were not included, a choice which is consistent with the « share-system » characterising the remuneration of the crew in artisanal fisheries.
[2] excluding landings in the Channel-Islands and by French recreative fishers.

The results of the simulation concerning the trawl ban, realised with the help of the above described model, are summed up in the four following tables. The first table is dedicated to the biological component of the model, the three following ones to its economic component. The actual situation is compared to an hypothetical situation incorporating a simulated seasonal bottom-trawl ban, under three assumptions concerning recruitment (see above 3.2).

Table 16. Simulated seasonal bottom-trawl ban . Estimation of consequences on biomass and catches of spider-crabs* (Boncoeur, Fifas and Le Gallic, 2000)

	Recruitment hypothesis		
	normal	high	low
1. Actual situation			
End of summer biomass of juveniles	2613	5782	1181
End of summer discards by trawlers	1190	2634	538
Exploitable biomass in November	4264	9436	1927
Winter catches by potters and netters	2871	6353	1298
2. Trawl ban scenario			
End of summer biomass of juveniles	2613	5782	1181
End of summer discards by trawlers	0	0	0
Exploitable biomass in November	5906	13067	2669
Winter catches by potters and netters	4015	8885	1815
3. Impact of shift from 1 to 2			
End of summer biomass of juveniles	0	0	0
End of summer discards by trawlers	- 1190	- 2634	- 538
Exploitable biomass in November	+ 1642	+ 3631	+ 742
Winter catches by potters and netters	+ 1144	+ 2532	+ 517

* Unit : metric ton.

Table 17. Simulated seasonal bottom-trawl ban . Estimation of social cost of discards (Boncoeur, Fifas and Le Gallic, 2000)

	Recruitment hypothesis		
	normal	high	low
1. Actual situation			
Winter catches of spider-crabs by potters and netters (tons)	2871	6353	1298
Yearly average landing price of spider-crabs (kf / ton)	13,84	9,96	19,22
Yearly revenue of potters and netters due to spider-crabs (kf)	39734	63286	24954
2. Trawl ban scenario			
Winter catches of spider-crabs by potters and netters (tons)	4015	8885	1815
Yearly average landing price of spider-crabs (kf / ton)	12,05	8,67	16,73
Yearly revenue of potters and netters due to spider-crabs (kf)	48364	77032	30371
3. Impact of shift from 1 to 2			
Winter catches of spider-crabs by potters and netters (tons)	+ 1144	+ 2532	+ 517
Yearly average landing price of spider-crabs (kf / ton)	- 1,80	- 1,30	- 2,50
Yearly revenue of potters and netters due to spider-crabs (kf)	+ 8629	+ 13747	+ 5417
Consumers surplus (kf)	+ 6085	+ 9692	+ 3821
Social cost of discards (kf)	14714	23439	9238

Table 18 . Simulated seasonal bottom-trawl ban . Estimation of gross margin generated by bottom-trawling in the gulf during the months of August and September* (Boncoeur, Fifas and Le Gallic, 2000)

	Trawlers-dredgers			Pure trawlers		
	Mean	Standard deviation	Total fleet**	Mean	Standard deviation	Total fleet***
Turnover						

Yearly total	1350	598	159300	4704	888	357500
among which : bottom-trawling	564	510	66552	3647	1456	277160
among which : Normand-Breton gulf	564	510	66552	388	509	29480
among which : August-September	113	102	13334	65	85	4913
Variable cost						
Yearly total	338	162	39884	1835	416	139449
among which : bottom-trawling	156	97	18408	1469	630	111649
among which : Normand-Breton gulf	156	97	18408	143	169	10900
among which : August-September	36	22	4248	24	28	1817
Gross margin						
Yearly total	1012	489	119416	2869	626	218051
among which : bottom-trawling	408	395	48144	2178	847	165551
among which : Normand-Breton gulf	408	395	48144	244	356	18580
among which : August-September	77	91	9086	41	59	3097

* 1997 survey data. Unit : kf. ** 118 boats. *** 76 boats.

Table 19. Simulated seasonal bottom-trawl ban . Estimation of the economic value of the trawl-ban* (Boncoeur, Fifas and Le Gallic, 2000)

	Spider-crab recruitment hypothesis		
	normal	high	low
[1] Increase in yearly revenue of potters and netters	8629	13747	5417
[2] Increase in consumer surplus	6085	9692	3821
[3] Trawlers-netters gross margin	9086	9086	9086
[4] Pure trawlers gross margin	3097	3097	3097
Overal balance ([1] + [2] - [3] - [4])	2531	11256	- 2945

* Unit : kf.

Comments :

- At the level of activity prevailing in the 90’, end-of-summer discards of spider-crabs amount to 1200 tons per year on the average. For potters and netters targeting this species, the resulting mortality generates a deficit of catches and landings close to 40% of total actual landings.
- The price-effect resulting from this deficit of landings represents 13% of the actual landing price at the end of the 90’; it limits the economic loss for potters and netters to 22% of their actual revenue, ie. approximately 8.6 million francs (1.3 million euros) for an average recruitment year.
- To this loss of producers surplus must be added a loss of consumers surplus, representing approximately 6 million francs (0.93 million euros) for a year of average recruitment. Therefore the social cost of end-of-summer discards of spider-crabs represents 14.7 million francs (2.2 million euros) during a year characterised by an average recruitment. In case of high recruitment, this cost may become higher than 23 millions francs (3.6 million euros), and, in case of low recruitment, their is little probability that it gets under 9 million francs (1.4 million euros).
- The gross margin generated by bottom-trawling in the gulf during the months of August and September is estimated at 9 million francs (1.4 million euros) for trawlers-dredgers and 3 million francs (0.5 million euros) for pure trawlers at the end of the 90’. These figures may overestimate reality, considering coefficients which were used in the model for the space-time distribution of the yearly activity of trawlers.

- As a result, under normal circumstances this activity may be profitable only because it does not bear the social cost of the discards it generates : with an average recruitment, the overall balance between the gross margin generated by trawling and the social cost of discards gives a positive value to the seasonal trawl-ban, amounting to approximately 2.5 million francs (0.4 million euros) per year.

It seems reasonable to regard this estimated economic value of the trawl-ban as underrated, for the following reasons :

1. Spider-crab mortality is not the only negative effect of bottom-trawling in the gulf (and particularly in its coastal areas) during the months of August and September ; as was noticed in § 1.2.2 above, this activity also generates a considerable amount of discards of juvenile sea-breams, associated with a mortality approximating 100%. According to Fifas (1998), a seasonal trawl-ban associated with an enforcement of legal mesh size could improve, with unchanged effort on the rest of the year, the annual harvest of adult sea-bream in the gulf by 190 tons on the average. Assuming a landing price of 12 F/kg (1.83 euro / kg)[1], this would generate an additional income of approximately 2.3 million francs (0.35 million euros) for fishers.
2. Considering other species, the annual loss of income borne by trawlers as a consequence of the seasonal trawl-ban would not be at the level of the gross margin formerly realised during this period, because part of the corresponding catches would simply be posponed to the following months.
3. The cost for trawlers would vary according to fleets. For trawlers-dredgers, which are almost entirely dependent on the gulf fishery, the seasonal trawl-ban could imply a temporary stop in their activity (assimilating the cost of the measure for trawlers to their seasonal gross margin is then accurate). But for pure trawlers, which are larger offshore units operating only occasionally inside the gulf (with a few exceptions)[2], the seasonal bottom-trawl ban would simply mean a limited change in the geographical distribution of their fishing effort during two months of the year[3]. It is likely that the cost of this reallocation would be significantly smaller than the gross margin realised in the gulf.
4. The positive effect of the seasonal trawl ban on the landings in the Channel Islands and on the activity of French recreational fishers is not taken into account in the above scenario.

These elements strengthen the case for a seasonal bottom trawl-ban in the Normand-Breton gulf (or part of it). However, the overall benefits that may be expected from a trawl-ban are challenged by its distributional effects, which, if not properly addressed, may hinder the adoption of a globally efficient management measure. Moreover, whatever its specific interest, this measure will prove disappointing if it is taken as a substitute for the treatment of the problem of overcapacity in the fishery (see above § 1.1.2), which it is not.

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[1] Average price in 2000 and 2001 at the auction market of Granville, which is the main landing harbour in the gulf for this species.
[2] These exceptions apply to midwater trawlers, rather than to bottom-trawlers.
[3] For boats combining midwater and bottom-trawling, the ban would concern only their bottom-trawling activity.

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Chapter 2. The Bay of Brest case[1]

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Introduction

In the middle of the last century, the Bay of Brest (Western Brittany, France) was one of the main common scallop fisheries in Europe. The increase in fishing effort, jointly with a climate accident, resulted in a collapse of landings during the 60'. Since that time, the natural stock never recovered (Boucher and Fifas, 1995). During the last two decades, the local organisation of fishermen attempted to restore the fishery by two means (Boncoeur and Guyader, 1995) : improving the management system of the fishery, and setting up a restocking program.

One of the characteristics of the restocking program is the use of a marine reserve, managed on the basis of a crop rotation system : juveniles are sown intensively in a zone where fishing is banned for several years (usually three), and are allowed to grow before being harvested by fishermen.

After describing the fishery, this study intends to assess the impact of the program on the fishery, including the use of the marine reserve as a fishery management tool.

1. Description of the fishery[2]

This section first describes the present state of the fishery (landings and prices, fleet and jobs, management system), then highlights its historic background, and finally presents the restocking program and associated reserve system.

1.1. Present state of the fishery

Shellfish dredging is a winter activity in the Bay of Brest. Four species are targeted : common scallop *Pecten maximus*, warty venus *Venus verrucosa*, variegated scallop *Chlamys varia* and queen scallop *Aequipecten opercularis*. However, nowadays only the two first species play a significant role :

[1] Thanks are due to the Local Committee of Fisheries of North Finistère (*Comité Local des pêches du Nord Finistère*) for providing useful data and helping to realise the field survey, and to Jean-Claude Dao (Ifremer) for documentary help.
[2] Unless otherwise mentioned, statistical data were provided by the local committee of fisheries.

Table 1. Shellfish dredging in the bay of Brest : landings, 2000-2001 campaign

	Common scallop	Warty venus	Variegated scallop	Queen scallop	Total
Sales through Brest fish auction market					
Quantities (tons)	190	91	0	5	286
Values ('000 FF)*	5515	3490	0	63	9068
Average prices (FF / kg)	29.01	38.44	-	12,67	31.72
Total estimated landings (tons)	346	112	na	na	458**
% marketed through auction market	55%	81%	-	-	61%**

* 1000 FF = 152.45 euros. ** Not including queen variegated and queen scallops. Sources : Brest fish auction market / Local fisheries committee.

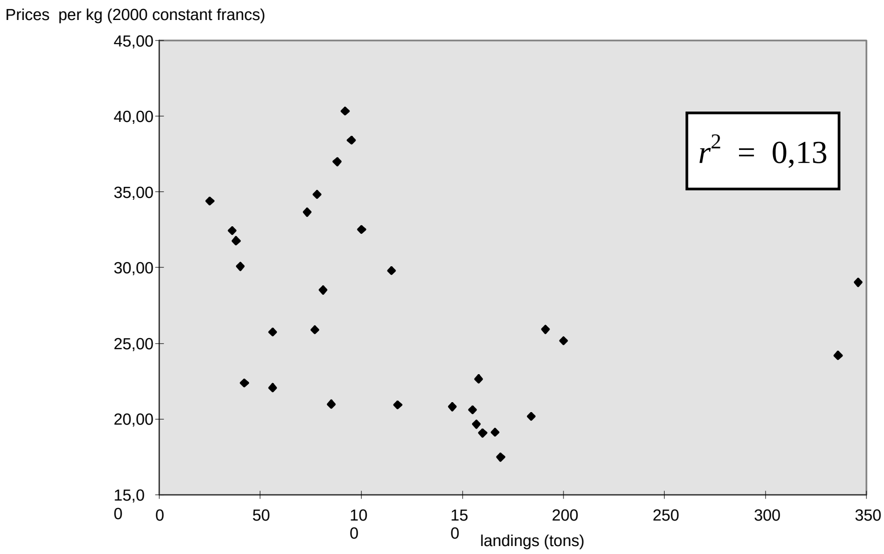
Compared to other similar fisheries in France, the level of landings in the bay of Brest is very limited :

- for common scallop, national fish auction market data (*Réseau inter-criées*) show that the landings marketed through the Brest market represented, in 2000, 1.4% of the total weight marketed through French fish auction markets, and 2% of the corresponding value (Ofimer, 2001) ;
- as regards warty venus, the share of the bay of Brest is more significant (18% of the total weight marketed through French fish auction markets in 2000), but the global market is much narrower than for common scallop : the overall value of warty venus marketed through fish auction markets in France was 17.9 million francs in 2000, against 196 million for common scallop (*Ibid.*).

As a result, even though common scallops coming from the bay of Brest are usually sold at a higher price than their competitors from the main French scallop fisheries, the changes in their landing price are more dependent on exogenous than on local factors. Attempting to correlate local yearly landings to local yearly average landing prices does not lead to any significant result

fig. 1

Bay of Brest common scallop :
landings and average landing prices (constant francs) per dredging campaign, 1970-2001
(sources : CLPM, wholesalers, Brest auction market, INSEE)



On the other hand, it has been shown that average yearly landing price of the bay of Brest common scallop significantly varies according to the price of the bay of St-Brieuc (the main scallop fishery in Brittany, and second largest common scallop fishery in France), which is itself highly correlated to landed quantities (Boncoeur, Divard and Guyader, 1997).

During the 2000-2001 season, the fleet operating the bay of Brest shellfish fishery was composed of 66 boats. These are small boats, normally under 11 metres long, owned by their skipper. The crew (skipper included) is composed of 1 or 2 persons. Due to the seasonal character of shellfish dredging in the bay of Brest, boats operating the fishery are also implied in other fishing activities. The fleet may be subdivided into two groups :

- a group of 40 boats (in 2000-2001) complement their dredging activity inside the bay by the use of various fixed gears and, in some cases, by shellfish dredging out of the bay ; these various activities usually take place in the Iroise Sea, a coastal sea which is the natural outlet of the bay ;
- another group, representing 26 units in 2000-2001, is composed of seaweed harvesting boats originated from the north coast of Finistère, which come into the bay during winter for shellfish dredging ; the seasonal patterns of the two activities show a good complementarity, as seaweed harvesting is usually a summer activity (Arzel, 1998).

The number of jobs directly generated by the fishery is very limited (approximately 100). These jobs are only seasonal, but shellfish dredging in the bay of Brest contributes to the yearly overall economic equilibrium of the boats operating this fishery in the winter season, a tribute which is probably a necessity for most of these boats. Taking into account related downstream and upstream activities, plus jobs locally induced by the expenditure of incomes generated by the fishery, leads to a total number of jobs not exceeding 180 persons in the Brest employment zone, a figure to be compared with the total number of 135,000 people employed in this zone in 1990 (Alban et al., 2001).

The bay of Brest fishery is under the scope of the Common Fisheries Policy. However, being entirely located within the 12 NM and exploiting only « strictly local » stocks of non-quota species, it is mainly regulated by internal rules (Curtil, 1996) : minimum landing size of common scallops (100 mm) is the only specific European rule applying to the fishery[1].

The main national rules applying to the activities that characterise the bay fishery are the following :

- minimum size of catches (10.2 cm for common scallops, for the Western Channel and Atlantic fisheries ; 4 cm for other scallops and warty venus) ;
- seasonal closures (fishing forbidden between May 15 and September 30 for common scallops) ;
- fishing gears (exclusively dredges[2], the characteristics of which are fixed by national regulations) ;
- landing conditions (shelling onboard is prohibited).

These national rules may be complemented by local regulations. The fact that the bay of Brest was declared a « registered site » (*gisement classé*) for scallops and warty venus in 1964 gave the possibility of adopting additional local rules for the sake of resource conservation. Taking

[1] This constraint is not really binding for the fishermen of the bay of Brest, since local rules are tighter (see below).
[2] Scuba-diving is prohibited for fishing. Snorkelling is normally restricted to recreational fishing.

advantage of this possibility, the local committee of fisheries introduced a limited entry licence system in 1985[1]. Under this system (which has somewhat changed since 1985)[2], the main management rules are the following :

- number of boats : only 110 boats were authorised to operate the fishery in 1985 ; this number was gradually decreased to 75 ;
- boat size : licensed boats were limited to 10 GRT in 1985, a regulation which was replaced by a 11 metres length limit (except for previously licensed boats) in 1994 ;
- horse power : a maximum of 100 HP (73.6 KW) was set for each licensed boat in 1985 (the average HP of boats operating the fishery was around 50 HP at that time) ; however, this maximum was cancelled in 1989, and only in 1994 another limitation concerning HP was introduced, but at a significantly higher level (150 KW, i.e. 204 HP)[3] ;
- gears : specific regulations concerning the number and technical characteristics of the dredges (size, number of teeth, weight, mesh size) have been adopted ; the maximum weight, which was initially 125 kg, was increased up to 170 kg in 1996[4] ;
- fishing time and fishing zones : the local fisheries committee fixes each year the activity calendar for the dredging season ; the season duration is usually between 40 and 60 days ; the number of fishing hours per day is usually limited to 2 hours on the average, and the zones open to fishing are fixed day by day at the beginning of the season (with a possible readjustment during the campaign) ;
- landing conditions : the minimum landing size was locally increased to 10.5 cm for common scallops in 1997, and to 4.3 cm for warty venus in 1998 ; the number of authorised landing places was limited, and filling a daily track record was made compulsory[5].

For licensed fishermen, the institutional cost of operating the fishery is composed of three elements :

- the yearly cost of the license *stricto sensu*, between 45 and 105 euros according to boat HP ;
- a yearly lump sum for the financing of the restocking program (see below), which was progressively increased from 500 FF (76 euros) to 34,000 FF (5,200 euros) ;
- a tax which is paid when landings are weighted in the Brest auction market ; this tax was introduced in 1999, in order to finance the monitoring and surveillance of the fishery ; it was initially set ar 1FF (0.15 euro) per kg, and in 2000-2001 it was supposed to be calculated at a rate varying between 4.12% and 5% of the value of landings, according to the marketing channel adopted by fishermen[6].

It should be stressed that this cost is unusually high according to French standards.

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[1] According to French law, fishing licenses are yearly, personal and non-transferable, a principle which was reasserted by the 1997 law on fisheries. Under the 1991 law on professional fishermen organisations, the license system is nowadays formally controlled at the regional level : decisions are taken by the regional committee of fisheries and become compulsory after they have been approved by govenrment authorities (*Préfet de région*).

[2] Partly in relation to the entry of seaweed harvesting boats in the fishery during the 80’ (Boncoeur and Guyader, 1995).

[3] This maximum is still lower than the one applying to boats operating in the bay of St-Brieuc (250 HP).

[4] Dredge regulations are generally stricter in the bay of Brest than in the bay of St-Brieuc (see Pennanguer et al., 2001).

[5] In 1999, a similar decision concerned the weighting of landings at the auction market of Brest, but the compliance of fishermen with this new regulation is questionable.

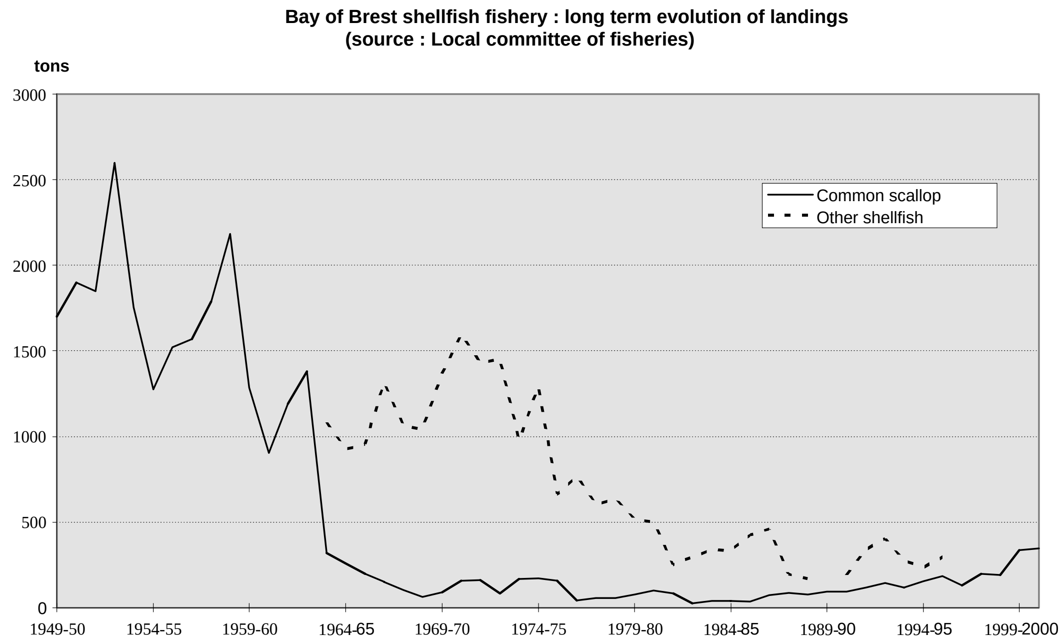
[6] This differenciation was meant to prompt fishermen to sell their landings through the auction market. The system did not work as initially planned, due to the national temporary tax cut decided by French governement in order to compensate for the fuel cost increase. Moreover, a comparison between landings data provided by the fish auction market and estimations of the Fisheries committee suggests that not all fishermen comply with the rule concerning weighting of landings.

1.2. Historic background

Shellfish fishing has existed for a long time in the bay of Brest (Cadoret et al., 1985). During the XIXth century, oyster (*Ostrea edulis*) fishing was combined with seaweed harvesting and *maerl* extracting (used as fertilisers by agriculture). At the beginning of the XXth century, common scallop dredging was boosted by a cluster of innovations : the improvement in means of transportation (railway) and the creation of canneries broadened the market, and the introduction of a new type of boat (sloop) allowed a significant increase in yields. During the years following World War II, the fleet operating the fishery was composed of some 150 sloops, and was then one of the most important sail-operated fishing fleets in North Western Europe (*Ibid.*).

Later than in any other French fishery, mechanisation of the fleet happened in the 50'. At first, it resulted in a dramatic development of the activity, due to the increase in CPUEs, fishing time and fishing capacity. The number of boats rapidly increased, up to a maximum of 289 units in 1958. During the 50', the average yearly landings of common scallops were around 1800 tons, which made the Bay of Brest the main scallop fishery in France. Taking into account other species leads to a rough estimation of 2500 tons of shellfish landed a year (on the average) by the Bay of Brest dredging fleet during the 50', an activity which employed seasonally some 840 fishermen (Carval, 1995).

figure 2



The rapid increase in fishing effort[1] was soon followed by a drop in landings of common scallops, which fell from 2600 tons in 1952-53 to less than 1400 tons 10 years later. The unusually cold weather during the 1962-63 winter caused a high mortality, particularly among

[1] According to Boucher and Fifas (1995) fishing effort reached a climax in 1957-58. But these authors refer to *nominal effort*, i.e. cumulated fishing time per fishing season. Such an indicator does not provide for the increase in fishing power, first boosted by mechanisation, then by a continuous increase in the average boat HP : while the average HP of the first mechanised boats in the 50' was around 20 KW (Cadoret et al., 1985), it reached 40 KW in 1986, and 66 KW in 1995.

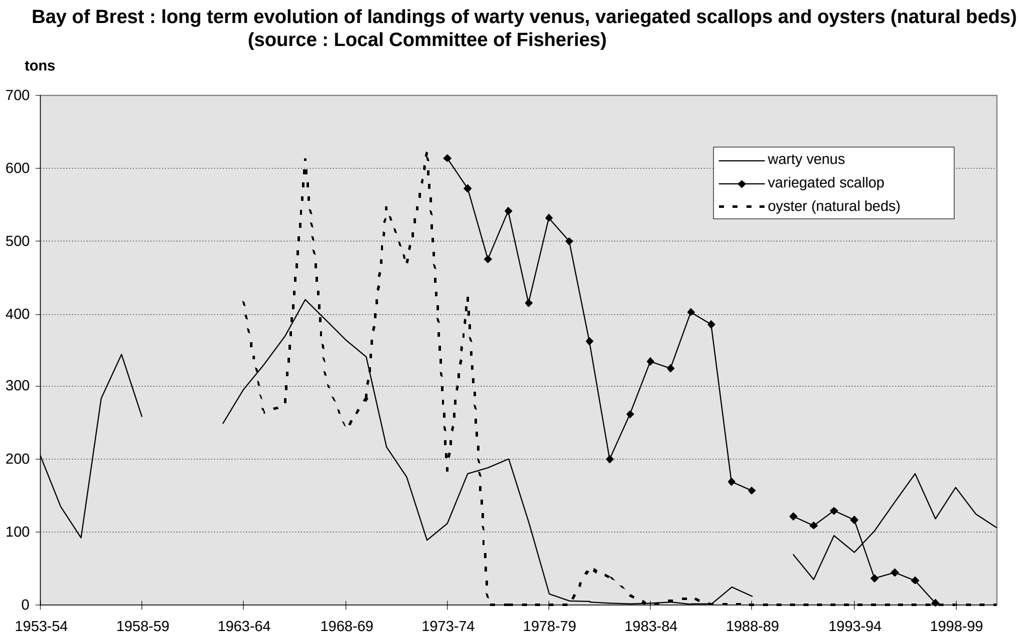
juveniles, which resulted in a collapse in landings during the following year (320 tons landed in 1963-64). This climate accident is the milestone of a breaking off in the history of the fishery (fig. 2) : landings of common scallops continuously declined after 1963, and almost disappeared at the beginning of the 80' (official landings during 1982-83 were only 25 tons).

Fishermen reacted to the common scallop collapse by transferring their fishing effort towards other shellfish, but also, for some of them, by developing a part-time oyster-farming activity. This adaptation first gave some good results :

- in 1970-71, total landings of warty venus, oysters (coming from natural beds), variegated and queen scallops reached 1600 tons, i.e. more than the landings of common scallops ten years earlier ;
- oyster-farming, a new activity in the bay of Brest, rapidly increased in the 60', and the production of oyster-farms in the Bay of Brest reached a peak of 5236 tons of *Ostrea edulis* in 1973, representing approximately one third of the total French production for this species at that time.

As a consequence, some 170 boats and 440 fishermen could be kept in the fishery at the beginning of the 70'. However, the respite was short (fig.3) :

figure 3



- landings of warty venus started to decline as soon as the 60', and almost disappeared in the 70'[1] ;
- asimilar trend affected variegated scallops in the 70', leading to landings close to zero in the 90'[2] ;
- *Ostrea edulis* was successively struck by two parasites in 1973 and 1980, which resulted in an almost total disappearance of this species in the bay of Brest (CLPM, 1974 and 1977)[1].

[1] A part recovery of this stock happened in the 90', but recent landings are far from reaching the level of the 60' (180 tons in 1996-97, to be compared to 420 tons 30 years before).
[2] As regards queen scallops, a species with a short life span and a highly instable recruitment (Quéro et al., 1992), the evolution is not regular. It is sometimes difficult to distinguish queen scallops and variegated scallops in landings statistics.

During the 80', the shellfish dredging activity in the bay of Brest seemed to approach complete extinction : in 1982-83, the cumulated landings of shellfish were 320 tons, i.e. approximately 10% of the total of landings realised 3 decades earlier, a period corresponding to the mechanisation of the fleet ; in 1988-89, the cumulated landings (all species) fell for the first time below the level of 250 tons.

The 4 decades of decline of the Bay of Brest shellfish fishery are summed up in the following table :

Table 2. Shellfish dredging in the bay of Brest : long term evolution of landings and fleet. Estimated mean values per decade.

		1950-60	1960-70	1970-80	1980-90
Yearly landings (tons)					
	Common scallop	1712	576	112	58
	Other scallops	124	366	639	300
	Warty venus	219	345	130	7
	Flat oyster (natural beds)	440	519	220	10
	Total	2495	1806	1101	375
Number of boats		260	200	140	110
Number of fishermen		840	580	300	130
Average number of fishermen per boat		3,2	2,9	2,1	1,2
Total average landings (tons) per boat		9,6	9,0	7,9	3,4
Total average landings (tons) per fisherman		3,0	3,1	3,7	2,9

Source : Carval, 1995.

The causes of the decline are still not fully clarified. Beyond the accidents that caused a breaking off in the landings of common scallops and oysters, two major hypothesis have been raised :

- overfishing : making use of historical stock assessment data concerning the biomass of common scallop in the bay of Brest, Boucher and Fifas (1995) conclude that, during the 50', fishing mortality (F around 0.20) was probably too high according the recruitment potential of the stock[2] ; comparing catches and estimated stock biomasses, these authors exhibit a similarity of fishing mortality rates in 1948-50 and in 1994, both landings and biomasses being divided approximately by 10 between these two periods ; overfishing also affects the age structure of the stock, which tends to be concentrated on the recruitment age, thus increasing the instability of the fishery and its vulnerability to exogenous shocks (probably a major factor explaining the collapse of 1963) ;

[1] Oyster dredging has completely disappeared, and farming of *Ostrea edulis* is nowadays limited to a few tons a year in the bay of Brest. A new species (*Crassostrea gigas*) was introduced in the bay during the 70', which allowed for a survival of the oyster-farming activity in this area, at a much lower level than the peak reached in 1973.

[2] A problem with this type of analysis is the high variability of recruitment, compared to the the spawning stock biomass (SSB). This high variability was depicted, in the case of the stock of common scallop of the Bay of St-Brieuc, by Boucher and Dao (1989). However, despite the instability affecting the relation between recruitment and SSB for most species targeted by the fishing industry, it was empirically demonstrated that maintaining the SSB at a low level increases significantly the probability of poor recruitments (Myers and Barrowman, 1996).

- environmental factors : the bay of Brest is located in the midst of a highly populated area (220 inhabitants per km^2 in the Brest employment area in 1990), with various economic activities generating waste products for which the bay of Brest is a natural outlet (commercial and military harbour and shipyards, marina, intensive farming...), and the resulting damage to the ecosystem of the bay is considered a possible cause of decline for some of the shellfish stocks it shelters.

These two types of explanation are not contradictory, and the observed decline may be the result of their combined action. One possible factor is the reduction in the surface suitable for scallops (Berthou, *pers.com*), due *inter alia* to the fact that the habitats which were occupied by this species before the 1963 collapse have been progressively colonised by an other species (*Crepidula fornicata*), the proliferation of which is probably stimulated by the increasing rate of nitrates in the water of the bay[1].

Notwithstanding the fact that the causes of the decline were not completely clarified, the local fishers organisation attempted in the 80' to restore the fishery. The response was both institutional and technical. The first part of the plan was to improve the control of fishing effort and catchability by introducing a limited entry licence system in 1985 (see above). The second part consisted in a restocking program, including the use of a rotating marine reserve as a fishery management tool.

1.3. Restocking program and rotating reserve system

As soon as 1973, the local committee of fisheries, with scientific support of CNEXO[2], realised various experiments of stock enhancement for common scallop, by collecting or importing juveniles in the bay of Brest (CLPM, 1977). The results of these experiments were not regarded as concluding, which led to the decision, in the early 80', to produce larvae in a hatchery.

The philosophy of the program, which was officially launched in 1983, has somewhat changed over time. Initially, it was aimed at restoring the spawning stock biomass (SSB), in order to increase the natural production of scallops of the bay. The lack of evidence of any significant link between SSB and recruitment for *Pecten maximus* (Boucher and Dao, 1989) led to a reorientation of the program towards a so-called « sowing-recatching » strategy, aimed at circumventing the problem of high mortality of juveniles during their first year of existence. For this purpose, the following operational chain was organised (Dao, Fleury and Paquotte, 1992) :

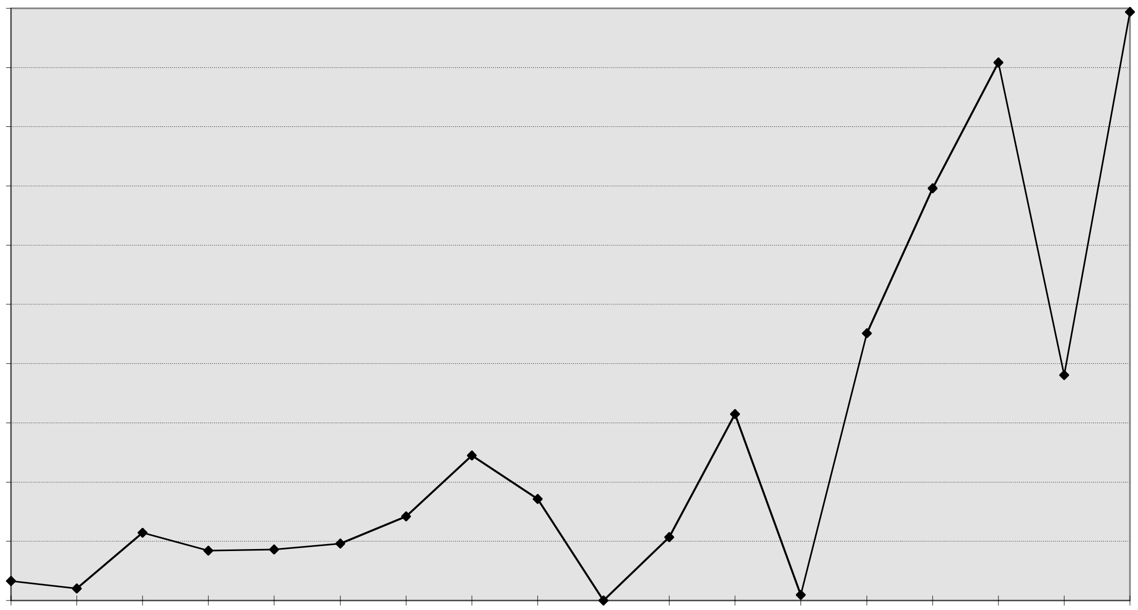
1. maturating genitors caught in the bay (3 months) ;
2. spawning and growing larvae in a hatchery (23 days on the average) ;
3. growing post-larvae[3] in a nursery up to the size of 2 mm (4 to 6 weeks) ;
4. growing juveniles in a natural protected environment (cages at sea), up to 3 cm (around 9 months) ;

[1] The local committee of fisheries is presently planning a program for reducing the biomass of *Crepidula* in the bay. However, the question of excess nitrates produced by intensive agriculture is still unsolved.
[2] Which was later merged with an other scientific institution (ISTPM) and became Ifremer in the early 80'.
[3] Metamorphosis is the stage that transforms larvae into post-larvae.

5. sowing juveniles in the bay, and growing in a natural environment (2.5 to 3 years) ;
6. recruitment and fishing.

After a long trial-and-error process due to the innovating character of the program[1], the production of juveniles has increased rapidly in the second part of the 90 ', which allowed to top the target of 6 million juveniles per year that had been fixed at the beginning of the decade (Carval, 1996) :

figure 4



Two methods for sowing are used in parallel :

- extensive sowing on natural beds, realised in spring, after the closing of the dredging campaing ;
- intensive[2] summer and early autumn sowing in a marine reserve, where dredging is prohibited for several seasons (usually 3).

Intensive sowing is normally realised in a different place each year, following the principle of crop rotation in agriculture, in order to allow a harvest each year. Five reserve sites have been selected, representing a total surface of 5.5 km^2 (to be compared with the total surface of the bay, 180 km^2). The choice of the sites is the result of a compromise between different considerations : suitability of the habitat (e.g. the zone should not be invaded by *Crepidula*),

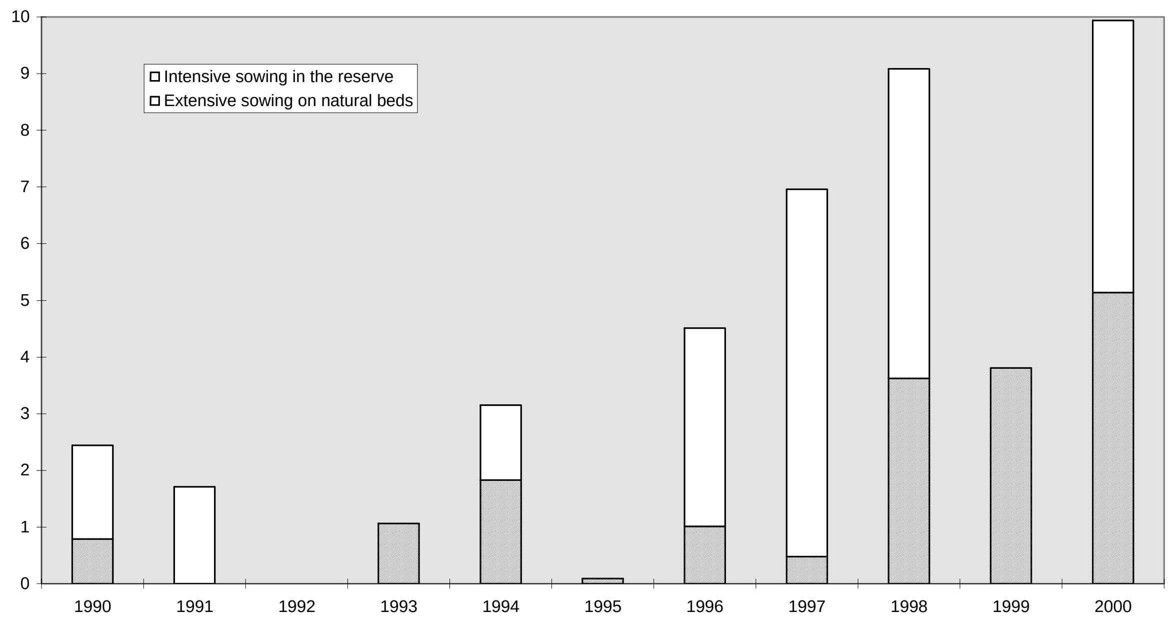
[1] Pectinid aquaculture in Japan was initially used as a model. However, the species cultivated are different, which imposed to invent an original model. Mastering the technical parameters of this model proved to be a longer process than had been initially foreseen (Dao et al., 1992 ; Dao, 1995 ; Dao et al., 1996). The irregularity of the curve on figure 4 suggests that this stage is not yet fully achieved.

[2] After its larval phasis, common scallop is a sedentary species. The density on natural beds is on the average 1 individual per 10 to 25 m^2 , but may reach in some places 1 individual per m^2 (Quéro et al., 1992). In the case of intensive sowing on the reserve, the sowing density reaches 4-5 individuals per m^2.

compatibility with other human activities, easiness of monitoring and surveillance. Normally two thirds of the total area covered by the reserve sites are closed to fishing each year, but in practice the crop rotation system is not regular. The proportion of the total quantity sown intensively in reserve sites varies according to years (fig.5). Globally, over the 90', some 60% of the total number of juveniles sown in the bay of Brest were sown intensively in reserve areas.

figure 5

Yearly sowing of common scallop juveniles on natural beds and inside the reserve, 1990-2000 (million individuals). Source : Tinduff Hatchery-Nursery



The two sowing methods result in two different systems of exploitation by fishermen :

- in the case of extensive sowing on natural beds, juveniles coming from aquaculture get mixed with « wild » individuals, and, after their recruitment, both types of scallops are exploited in the same conditions by fishermen (see above the management system of the fishery) ;
- in the case of intensive sowing in areas closed to fishing for some years, each reserve site is open to fishing by a decision of the local fisheries committee, and fishing in such areas has been managed since 1994 on the principle of a yearly individual quota (IQ) for each licensed boat[1]. Initially fixed at 200 kg per boat in 1994, the IQ progressively reached 2,300 kg per boat in 2000-2001.

The mechanism of the rotating reserve was first introduced as a technical experiment, but soon it was strongly conforted by « political » considerations : it appeared that the IQ system related to the reserve helped fishermen to accept paying for the restocking program (see above), because it created a clear link between two well-identified money flows. This

[1] This measure is the only output-control regulation in a fishery where the management system relies basically on effort-and-catchability control regulations (see above, § 1.3.).

acceptability is critical, since the program, initially funded by public money, was bound to get self-financed by fishermen. On the other side, linking the yearly contribution of fishermen to the program with the revenue they get from the IQ may turn be a dangerous feature, if some year the income fishermen get from the reserve cannot match the cost of the licence (*lato sensu*).

2. Assessing the impact of the restocking program and rotating reserve system

Landings data and financial results of the program form a first set of elements that may be used to assess the performance of the above described program and related management system (2.1.). Additional information is provided by a field survey of fishermen (2.2.). It may be used to simulate the impact of the restocking program and related management system on the economic situation of fishermen (2.3.).

2.1. Landings and financial results of the program

As may be seen from figure 2 above, the negative trend that had affected common scallop landings since the early 60' reversed in the 90': after a historic minimum of approximately 50 tons per year in the 80', landings of common scallops grew steadily in the 90' up to some 340 tons in 2000-2001, a level that had never been reached since the climate accident of 1962-63. But the volume of landings is still far behind the level that prevailed before that breaking off in the history of the fishery (see fig.2), and it is also far behind the hopes that had been put in the development of aquaculture 25 years ago (CLPM, 1997). Furthermore, the growth of scallop landings in the 90' cannot be attributed without qualification to the restocking program : it may also be the result of a better natural recruitment, a hypothesis to be considered seriously due to the high instability of natural recruitment of *Pecten maximus*. In the case of warty venus (a species with a strictly natural recruitment), the increase in landings that was observed during the same period (see fig. 3) is clearly the result of a better natural recruitment.

The fact that shells of aquaculture-originated scallops bear a « stress ring » formed at the time of sowing of juveniles in an unprotected natural environment makes it possible to estimate the share of landings which is due to aquaculture-originated scallops[1] (see fig. 6 below). According to data provided by the local fisheries committee, these scallops plaid an important role during the 90', representing approximately 50% of the total landings of common scallops during this decade. During the two campaigns 1999-2000 and 2000-2001, the share rose to 70%.

During the 90', landings from the reserve represented approximately 1/3 of total scallop landings, and more than 70% of all aquaculture-originated scallops that were landed. During the period 1999-2001, scallops from the reserve represented more than half of all scallops landings, and more than ¾ of landings of aquaculture-originated scallops.

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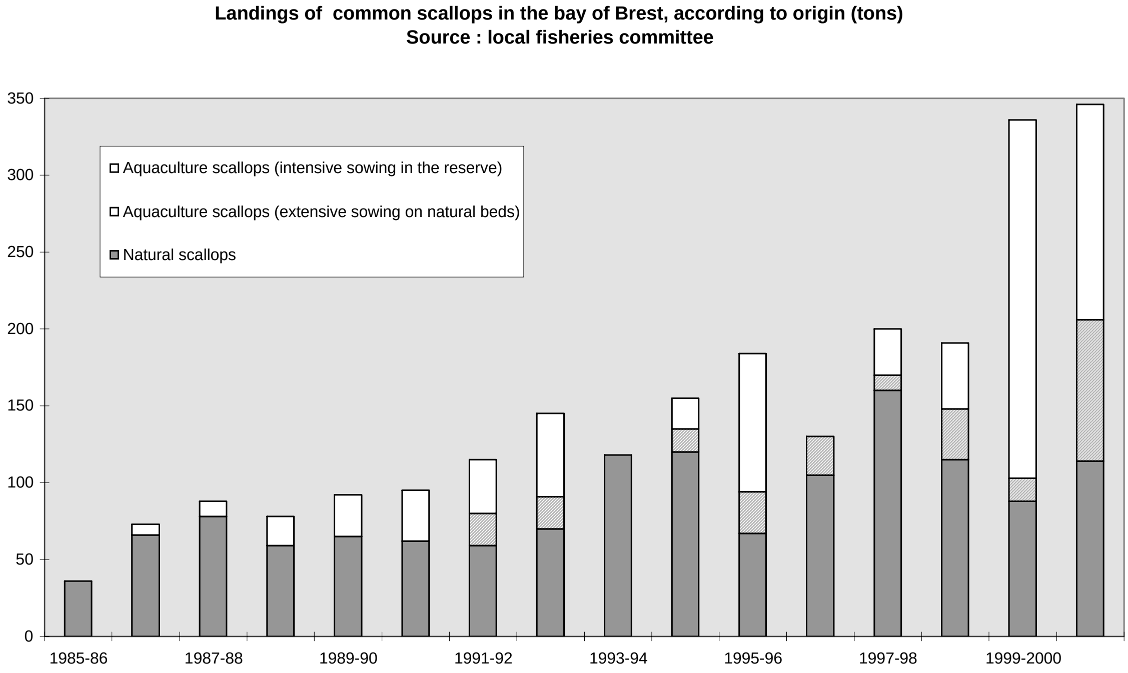
[1] This estimation does not take into account the indirect effect of aquaculture on landings, through increase of SSB. As was mentioned before, this effect is difficult to estimate, due to the high instability of the stock-recruitment relationship in the case of common scallop. This does not mean that the effect is zero. Therefore, the estimation presented here probably underrates the actual effect of aquaculture on landings.

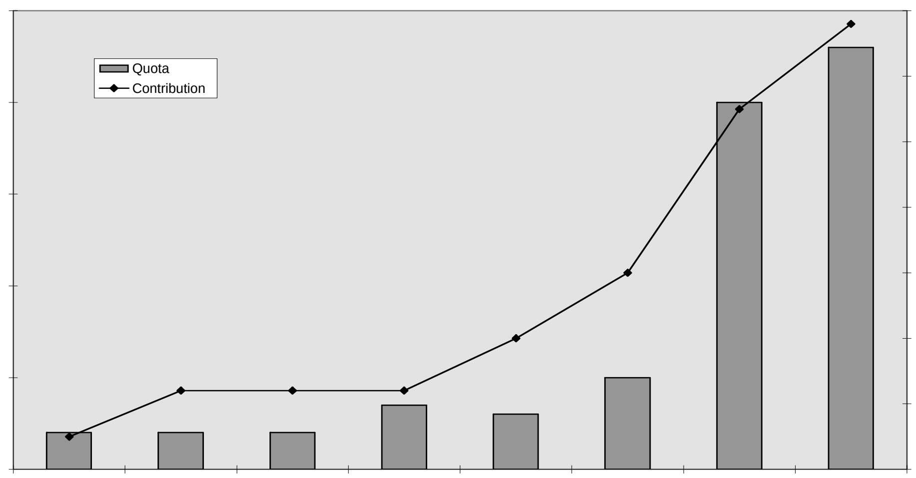
These data suggest that aquaculture-orginated scallops, and more specifically scallops that were sown intensively in the rotating reserve areas have come to play a prominant role in the fishery during the recent years.

figure 6



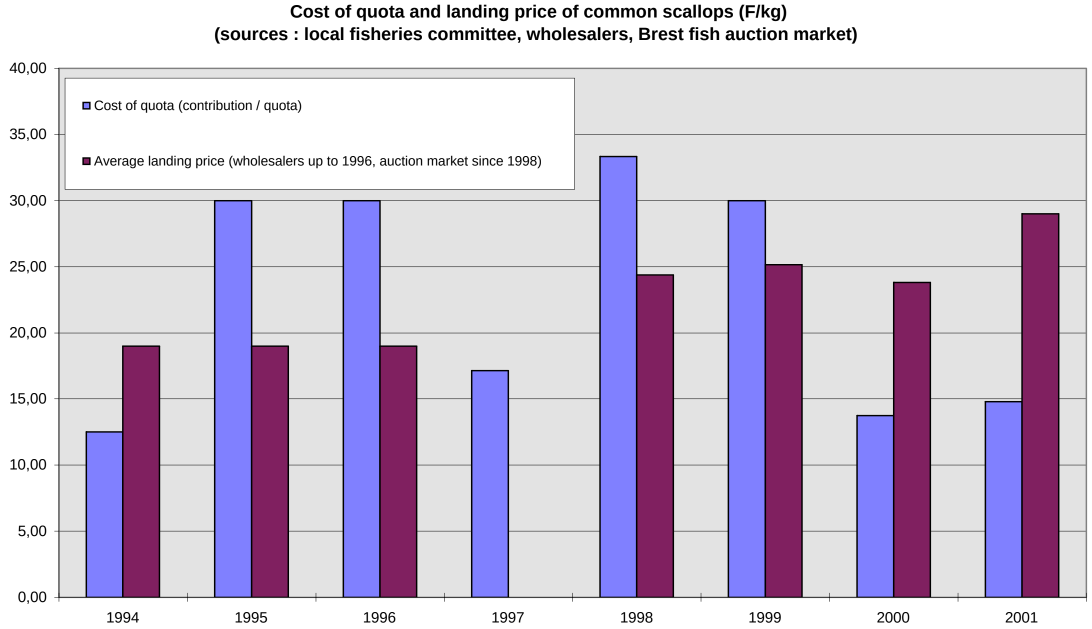
The important harvests in the reserve during the recent years helped fishermen to accept a dramatic increase in the yearly contribution they are asked to pay for the financing of the program. Initially set at 500 FF, the amount of this contribution rose from 6,000 FF in 1994 (year of introduction of the IQ system) to 34,000 FF in 2001 but, in the same time, the IQ rose from 200 kg to 2,300 kg :

figure 7



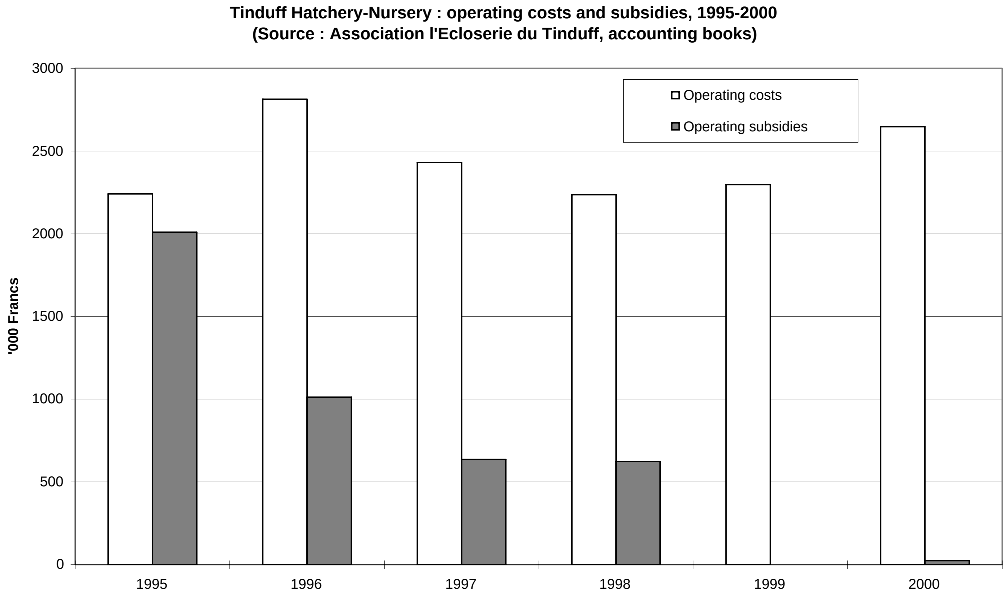
As a result, the « quota cost », as it is perceived by fishermen, i.e. the yearly individual contribution divided by the number of kg of the IQ, could be significantly lowered in the recent years, despite the strong increase in the contribution. It also became significantly lower than the average landing price of scallops, a tendency which was helped by the upward trend of this price during the last decade :

figure 8



The substantial increase in the contribution paid by fishermen made it possible to balance the operating costs of the hatchery-nursery, a condition which had become necessary for its survival, in a context of diminishing public subsidies (fig. 9).

figure 9



These results suggest that the rotating reserve system, together with its associated IQ management plan, were in the recent years a useful device helping the whole program to reach financial equilibrium. This is by itself a significant result, since failure to comply with the budget constraint would have threatened the survival of the program in the short term (Boncoeur and Guyader, 1995).

The positive results obtained by the restocking program and associated management system did not stop the decline in the number of boats operating the fishery, which was cut by 25% during the last decade. In 2000-2001, the actual number of licensed boats (66) became significantly lower than the potential number of licences (75). This phenomenon is partly related to exogenous factors, *inter alia* the effect of decommissioning schemes adopted by French government in order to comply with the EU MAGPs. It may also be related to the increase in the institutional cost of access to the fishery (contribution to the restocking program *plus* landing taxes), which is to be considered as a part shift toward a management system based on taxes and IQs rather than on quantitative restriction on fishing capacity.

The rotating reserve system, with its associated management and financial plan, nevertheless raises some problems which are left unsolved at the beginning of the years 2000.

One of these problems is the distortive character of the uniform contribution to the program, in a context where fishing powers and fishing strategies of boats operating the fishery are different. The restocking program does not affect only the reserve areas (where fishing is controlled by the IQ system), but the rest of the fishery (no IQ), due to the sowing operations on natural beds (see fig. 5), and also to the possible impact of increasing SSB on recruitment. Moreover, paying the contribution to the program is a necessary condition for getting a licence which gives access to several stocks, among which only one is concerned by the program[1].

Up to now, the consequences have been kept at a tractable level by the rotating reserve and IQ policy. However, this policy has recently raised some questions, both in terms of efficiency and sustainability.

The efficiency question was raised in 2000-2001 by the high rate of broken shells of scallops harvested in the reserve. Up to now, this rate was estimated at 3%, but during the 2000-2001 campaign a rate of 15% was observed. This phenomenon was attributed to the high density of scallops in the reserve, and to the unsuitability of gears used by fishermen for this type of harvest. It resulted in an economic loss for fishermen (scallops with a broken shell are not marketable), increased by a loss of time (sorting marketable and non-marketable scallops is a time-consuming operation).

The sustainability question was raised, in 2001, by a high mortality of juveniles recently sown in the reserve, due to predation (probably by sea-breams). Even if this just turns out to be an accident[2], it represents a threat to the economic sustainability of the program, since up to now the financing of the program relies on a year-by-year contribution of fishermen, exclusive of any long-term commitment. Contrasting with other financial schemes[3], this system is highly vulnerable to short-term opportunistic behaviours, some fishermen being prone to take a

[1] Fishing effort is selective, which implies that fishing actions in the fishery may be directed towards a particular species.
[2] Similar accidents may affect the upper part of the production process, such as the presence of a toxic microalgae (*Gymnodinium*) in the water of the bay that caused a high mortality of larvae in 1995.
[3] In Canada for instance, the fishermen involved in the scallop (*Placopecten magellanicus*) restocking program of the *Iles de la Madeleine* (St-Lawrence Gulf) participate in the financing of the program as share-holders.

licence at the beginning of a given season only if the short term prospect concerning the harvest in the reserve (IQ level and landing price) is good enough.

2.2. Field survey of fishermen

Additional information for the assessment of the restocking program and associated reserve system may be obtained from a field survey of skippers-owners of boats operating the bay of Brest shellfish fishery (Alban et al., 2001). This survey covers boats characteristics, skipper's professional activity (inside and outside the fishery), economic performance and opinions concerning the fishery, its management system and the restocking program.

The survey method beneficiated from past experience accumulated in CEDEM (e.g. Boncoeur and Le Gallic, 1998). The questionnaire was designed to be filled through face-to-face interviews, between 1 and 2 hours long. At least 40 interviews were to be realised, implying a minimum sampling rate of 60%. This rate was to be achieved for both subfleets operating the fishery (seaweed harvesters, and other boats). The interviews were realised during the winter 2000-2001[1]. Their number rose to 48, mainly due to an overiding of the objective concerning seaweed harvesters. This feature was caused by the necessity of having a sample of seaweed harvesters large enough for another survey (Alban et al., 2002). It does not distort the results of the survey, since these are presented separately for each group.

Table 3. Survey sample and sampling rate

Fleet	Main population	Theoretical sample	Actual sample	Sampling rate
Seaweed harvesters	26	16	23	88.5%
Others	40	24	25	62.5%
Total	66	40	48	72.7 %

Source : Alban et al., 2001.

The first part of the questionnaire was designed to get information concerning technical and economic charasteristics of boats operating the fishery (table 4) :

Table 4. Boat and crew

		Seaweed harvesters	Others
Length (metres)	– mean	9.9	9.1
	– standard deviation	1.1	0.8
GRT	– mean	11.0	7.8
	– standard deviation	4.8	2.7
Horse Power (kw)	– mean	78.7	84.6
	– standard deviation	32.3	31.6
Boat age in 2000 (years)	– mean	17.0	25.2
	– standard deviation	7.8	8.7
Boat insured value (1,000 FF)	– mean	613	454
	– standard deviation	306	288
Crew size (number of men) skipper included	– mean	1.3	1.7
	– standard deviation	0.3	0.5

Source : Alban et al., 2001.

All boats operating the fishery are under 13 metres long, with an average length under 10 metres. Seaweed harvesters are larger on the average than other boats, but their HP is usually lower (these differences may be explained by the characteristics of summer activities of boats:

[1] Interviews were realised by Frédérique Alban.

seaweed harvesting requires a large carrying capacity rather than a high HP). Seaweed harvesters are also more recent on the average than other boats (17 against 25 years), and their insured value is higher (613 KF against 454 KF on the average). They are operated by a crew of 1.3 men on the average, against 1.7 men for other boats (a difference which is due to the fact that, during the seaweed harvesting campaign, seaweed harvesting boats are operated only by 1 man in most cases).

Table 5. Activity

	Seaweed harvesters	Others
Yearly number of days at sea		
– mean	151	185
– standard deviation	49	53
Trip length (hours)		
– mean	8.3	8.1
– standard deviation	2.3	3.4
% of time at sea within the 12 NM	100%	100%

Source : Alban et al., 2001.

All boats operating the fishery are strictly inshore. Their average yearly number of days at sea is between 151 (seaweed harvesters) and 181 (other boats), among which some 55 days on the average are dedicated to shellfish dredging in the bay of Brest. The average length trip is slightly over 8 hours for both fleets. But trips are significantly longer during the summer season than in the winter time, when dredging in the bay is usually limited to 2 hours per day. As a result, boats operating the Bay of Brest shellfish fishery devote less than 10% of their total fishing time to this activity[1].

Table 6. Landings and sales (reference period : october 1999 to october 2000)

	Seaweed harvesters	Others
Yearly turnover (1,000 FF)		
– mean	472	599
– standard deviation	212	395
Composition of turnover, by activity		
– Shellfish dredging (bay of Brest)	41%	35%
– Seaweed harvesting	57%	0%
– Other fishing activities	2%	65%
Tendency of tunover over the last 5 years*		
– increase	39%	44%
– stable	48%	44%
– decrease	13%	12%
Marketing channels (seaweed excluded)**		
– fish auction markets	74%	34%
– direct sales to wholesalers	13%	49%
– other direct sales***	13%	17%

* Skipper's opinion concerning the evolution of his turnover (frequencies of answer). ** as a percentage of turnover, seaweed excluded. *** retail fishmongers, restaurants, households. ε : percentage under 0.5%. Source : Alban et al., 2001.

[1] During the 2000-2001 dredging campaign, the total number of authorised fishing hours (harvesting of the reserve not included) was 115 per boat, spread over 54 fishing days. Taking into account time devoted to the harvesting of the reserve would increase the total fishing time by some 4 hours per boat on the average. On the other side, for various reasons some boats did not make full use of their total authorised fishing time. The rate of use of total authorised fishing time is around 80%. As a result, actual fishing time during the dredging campaign probably does not exceed 100 hours per boat. In the same time, answers to the survey display, on the average, a total yearly fishing time close to 1200 hours per boat for seaweed harvesters, and to 1500 hours per boat for other boats taking part in the bay of Brest shellfish fishery.

Contrasting with the limited amount of time devoted to dredging in the Bay of Brest, this activity contributes substantially to the boats yearly revenue : according to the survey results, the share is 35% for non seaweed harvesting boats, and reaches 41% for seaweed harvesters[1].

In both fleets, only a minority of skippers mentioned a decreasing trend in their yearly turnover over the five years preceeding the survey. The relative majority of answers mentioning an upward trend is specially noticeable in the case of seaweed harvesters, considering the stagnation and decline in seaweed crops during the recent years (Alban et al., 2002).

Landings (seaweed excepted)[2] are sold either through fish auction markets, or directly to wholesalers, retail fishmongers, restaurants and households. Contrasting with seaweed harvesters that mainly sell their landings (almost exclusively shellfish) through the Brest fish auction market, other boats taking part in the bay of Brest shellfish fishery sell only one third of their total landings (shellfish, finfish, crustaceans, cephalopods) through fish auction markets. As a result, information concerning sales is more reliable for the first group of boats than for the second.

Table 7. Yearly costs and economic performance, per boat

		Seaweed harvesters		Others	
		1,000 FF	% of turnover	1,000 FF	% of turnover
Turnover	mean	**472**	100%	**599**	100%
	std-dev.	212		395	
Intermediate consumptions[a]	mean	**129**	27%	**139**	23%
	std-dev.	60		101	
Added value[b]	mean	**343**	73%	**461**	77%
	std-dev.	179		315	
Wage costs[c]	mean	**228**	48%	**290**	48%
	std-dev.	87		166	
Taxes[d]	mean	**46**	10%	**49**	8%
	std-dev.	8		13	
Gross operation margin[e]	mean	**69**	15%	**122**	20%
	std-dev.	96		150	
Fixed capital depreciation[f]	mean	**34**	7%	**32**	5%
	std-dev.	14		15	
Full equity profit[g]	mean	**35**	7%	**90**	15%
	std-dev.	87		143	
Profit rate[h]	weighted mean	**6%**		**20%**	
	weighted std-deviation	20%		26%	

[a] Non durable goods (fuel, bait, ice, gears...) and external services (management, insurance...) consumed in the productive process. [b] Turnover - intermediate consumptions. [c] Including skipper. [d] Yearly cost of licence and contribution to the restocking program + landing taxes + other taxes. [e] Added value - wage costs and taxes. [f] Estimated on the basis of normal life span of fixed capital. [g] Gross margin - capital depreciaiton. [h] Full equity profit / boat insured value. Source : Alban et al., 2001.

[1] Answers to the survey are normally based on the results of the 12 months period preceeding the 2000-2001 dredging campaign. Taking into account this campaign would probably lead to a larger share of turnover related to shellfish dredging in the bay, due to the substantial increase in the landings of scallops (sea above).

[2] Seaweed landings are sold to processing plants.

The above table displays revenues, economic costs (intermediate consumption, wage costs, taxes and fixed capital depreciation) and the resulting economic performance indicators : added value (revenue minus intermediate consumption), gross operating margin (added value minus wage costs and taxes), full equity profit (gross operating margin minus fixed capital depreciation), and profit rate (ratio of full opportunity profit to boat insured value)[1]. The following methodological points should be stressed :

- in the so called « share system » characterising labour remuneration within artisanal fisheries, wages are calculated as a predefined share of the balance of net sales (gross sales minus landing taxes) and some so-called « common costs » (usually fuel, food, ice, bait - if any -) ; in French fisheries, the skipper receives a part of the « crew share » even if he is the owner of the boat ; however, when he is alone on board, the share system is not always used ; in order to prevent resulting distorsions, it has been assumed in the survey that the share system was always used ; as a result, the major part of the wages costs in the above table are non cash costs ;
- wage costs include national insurance contribution ;
- taxes are composed of landing taxes, yearly license costs (including contribution to the aquaculture scallop production program) and other taxes ;
- capital depreciation was calculated according to an economic method based on the average economic life span of fixed capital (see Boncoeur and Le Gallic, 1998), and not to book-keeping methods.

Due to the particular features of small-scale fisheries, the economic significance of classical indicators such as the rate of profit is questionable (Boncoeur et al., 2000). An alternative performance indicator is the so-called « skipper-owner's net activity income », composed of net incomes received by the skipper-owner both through the crew-share (net wage) and the owner-share (full equity profit), minus the opportunity cost of capital invested in the boat. This income represents the remuneration the skipper-owner gets form his fishing activity, both as a fisherman and as an entrepreneur. In the following table, the opportunity cost of capital was estimated multiplying the boat insured value by a 8% interest rate (for a discussion of the interest rate to be taken in such calculations, see Boncoeur et al., 2000).

Table 8. Skipper-owner's net activity income (1,000 FF / year)

		Seaweed harvesters	Others
[1] Skipper's net wage*	– mean	**133**	**134**
	– standard-deviation	52	65
[2] Full equity profit	– mean	**35**	**90**
	– standard-deviation	87	143
[3] Total ([1]+ [2])	– mean	**168**	**224**
	– standard-deviation	118	193
[4] Capital opportunity cost**	– mean	**49**	**36**
	– standard-deviation	24	23
[5] Skipper-owner's net activity income ([3] - [4])			
	– mean	**119**	**188**
	– standard-deviation	106	177

* Gross wage minus national insurance contribution. ** 8% of boat insured value. Source : Alban et al., 2001.

[1] The reliability of information concerning revenues and costs has been tested by comparing the survey results to book-keeping data (Alban et al., 2001).

Comparing figures in the preceding tables suggests that the major part of the gap between the average economic performance indicators level of seaweed harvesters and of other dredgers is due to fishing activities other than dredging in the bay of Brest : while the value of shellfish landings, as well as intermediate consumption and taxes, are between 5 and 8% higher for non seaweed harvesting boats than for seaweed harvesters, the gap concerning total turnover reaches 27% (close to the one concerning total fishing time : 25%).

The last part of the survey questionnaire was devoted to skipper's opinions concerning the bay of Brest shellfish fishery, its management system and the restocking program.

Table 9. Opinions concerning the dependence of fishing activity on the bay of Brest shellfish fishery and on common scallop dredging*

	Seaweed harvesters	Others
Boat economic sustainability requires dredging in the bay	83 %	84 %
Common scallop is critical to the bay shellfish fishery	83 %	60 %

* Frequencies of answers agreeing with the stated opinion, per fleet. Source : Alban et al., 2001.

The above table shows that a large majority of fishermen operating the bay of Brest shellfish fishery consider this activity as critical to the sustainability of their business : in both fleets, this opinion is accepted by more than 80% of interviewed persons. A similar result is obtained about the role of common scallop in the fishery. However, concerning this second question, the majority is not so massive among skippers of non seaweed harvesting boats (60%) as among skippers of seaweed harvesters (83%). This difference may be related to the fact that shellfish dredging is traditionally more diversified among the first fleet, while seaweed harvesters mainly concentrate on common scallop.

Table 10. Answers to the question :
« Are you confident in the future concerning dredging in the bay ? »*

	Seaweed harvesters	Others
Yes	87 %	64 %
No	4 %	28 %
Do not answer	9 %	8 %
Total	100 %	100 %

* Frequencies of answers, per fleet. Source : Alban et al., 2001

In both fleets, a majority of skippers state that they are confident in the future of dredging in the bay. Here again however, the majority is more massive among skippers of seaweed harvesters than among skippers of other dredging boats.

Table 11. Preferences concerning management tools for the fishery *

	Seaweed harvesters	Others
Present system	61 %	56 %
Generalisation of individual quotas	30 %	36 %
Other answers	9 %	8 %
Total	100 %	100 %

* Frequencies of answers, per fleet. Source : Alban et al., 2001.

In both fleets, a majority of skippers declare they are happy with the present management system of the fishery. However, the majority is not massive, and one third of interviewed skippers would like the individual quota system (up to now in use only for the harvesting of the rotating reserve) to be generalised. A possible reason for the limited supporting of an IQ system is the prevailing scepticism about the transparency of landings (see below).

The opinions regarding the obligation to bring shellfish to the Brest auction market (for weighting) are mitigated. Few fishermen believe that it fills its main purpose, which is to bring more transparency to the fishery., or that bringing shellfish landings to the auction market creates better opportunities for profitable sales. However, a majority of skippers of seaweed harvesting boats consider that it simplifies marketing operations. This opinion is not shared by other skippers, who are more prone to insist on the additional resulting constraints. Such a discrepancy is first related to a difference in the geographical origins of the boats : while seaweed harvesters come from the outside of the bay, and are sheltered in the harbour of Brest during the dredging season, other dredgers come from various places around the bay, and coming to the harbour of Brest for landing shellfish is not natural to them. This geographical difference is strengthened by a difference in the marketing habits of fishermen. While skippers of non seaweed harvesting boats are accustomed to sell their landings, all the year round, through various channels (see above), skippers of seaweed harvesting boats do not have the same tradition : they sell their summer landings (seaweeds) directly to processing plants, and the bulk of their winter landings (shellfish) through the Brest fish auction market, close to the place where they land their catches.

Table 12.Opinions regarding compulsory weighting of landings in the fish auction market*

	Seaweed harvesters	Others
Bringing shellfish landings to the auction market creates :		
• more transparency	22 %	16 %
• additional contraints	17 %	48 %
• simplification of marketing operations	61 %	20 %
• better marketing opportunities	13 %	12 %
• other answers	4 %	16 %

* Frequencies of answers agreeing with the stated opinion, per fleet (non additive, due to possibility of multiple answers).
Source : Alban et al., 2001.

Four questions were more specifically related to the scallop restocking program. The first one was designed to test the confidence of fishermen in the technical performance of the program, the second one dealt with the mechanism of the rotating reserve, and the two last ones addressed the problem of the contribution of fishermen to the financing of the program.

Table 13. Answers to the question « Is the restocking program a technical success ? »*

	Seaweed harvesters	Others
Yes	87 %	64 %
No	4 %	8 %
Do not answer	9 %	28 %
Total	100 %	100 %

* Frequencies of answers, per fleet. Source : Alban et al., 2001.

The program is regarded as a technical success by a majority of the interviewed skippers, and very few assert the opposite opinion. However, the majority is not so massive among skippers of non seaweed harvesting boats thant among skippers of seaweed harvesters, and, in the former fleet, more than 25% of interviewed skippers refused to answer.

Table 14. Opinions regarding the dual system for sowing of juveniles (rotating reserve + natural beds)*

	Seaweed harvesters	Others
The present system is satisfactory	78 %	84 %
The system should be improved	22 %	12 %
Do not answer	0 %	4 %
Total	100 %	100 %

* Frequencies of answers agreeing with the stated opinion, per fleet. Source : Alban et al., 2001.

A majority of skippers, in both fleets, declare they are happy with the dual system for sowing of juveniles, implying the existence of the rotating reserve altogether with stock enhancement of natural beds. This opinion is to be related with the one concerning the method of contribution to the financing of the program (see below).

Table 15. Opinions regarding the principle of self-financing of the program

	Seaweed harvesters	Others
Fully agree	39 %	72 %
Rather agree	57 %	28 %
Disagree	4 %	0 %
Total	100 %	100 %

* Frequencies of answers agreeing with the stated opinion, per fleet. Source : Alban et al., 2001.

Table 16.
Opinions concerning the principle of a contribution based on a uniform lump sum

	Others	Seaweed harvesters
Agree	72 %	78 %
Disagree	24 %	22 %
Do not answer	4 %	0 %
Total	100 %	100 %

* Frequencies of answers agreeing with the stated opinion, per fleet. Source : Alban et al., 2001.

Self financing of the restocking program is more or less admitted by fishermen. If very few interviewed skippers openly reject the principle, a substantial part accept it only with provision. The present method of contribution to the financing of the program, based on a uniform lump sum paid each year by each licensed boat owner (irrespective of its landings), is accepted by some three quarters of interviewed skippers. In a situation where scepticism prevails about the transparency of landings (see above), this may be regarded as a « second best » by some fishermen, and is consistent with their attachment to the reserve system : during the harvesting of the reserve, catches are well controlled, and each licensed boat gets an equal right to the resource (IQ system), which is considered as the direct counterpart of the individual contribution to the program.

2.3. Simulating the impact of the program on the economic situation of fishermen

A simulation may be used to assess the contribution of the restocking program and associated management system (including the rotating reserve) to the situation of the fishery and fleet. The simulation consists in building a scenario that assumes there is no restocking program. The contribution of the program is assessed by comparing the simulated situation of the fishery and fleet to the actual one. Of course the validity of this assessment depends on the relevance of the auxiliary assumptions that are used for building the scenario.

The scenario presented here is fairly simple. It only aims at assessing the direct, so-called « mechanic » effects of the program, i.e. it does not pay attention to the possible indirect effects due to the dynamics of the exploited resource, or to the adaptation of human behaviour to changing relative profitability of various fishing activities (adressing these questions will require the building of a bioeconomic model at a later stage of the investigation).

The basic assumptions of the scenario presented here are the following :

- no sowing of scallop juveniles ;
- fishing effort left unchanged, except for the disappearing fishing effort in the reserve ;
- no financial contribution of fishermen to the program ;
- comparative statics, where the reference level is given by the situation of the fishery during the 2000-2001 dredging campaign[1].

Figure 10 below presents a schematic view of the simulation. The relations visualised in this figure are explicited hereafter.

License costs

Due to the third hypothesis above, the scenario implies that no financial contribution to the program is paid by the owners of licensed boats (34 KF per boat in 2000-2001).

Fishing effort

According to the second hypothesis, the only change in fishing effort concerns the rotating reserve. The average CPUE during the harvesting of the reserve is kg per hour and boat (Dao and Carval, 1999). Since the actual harvest in the reserve in 2000-2001 was 2.12 tons per boat (for a quota set at 2.3 tons), the time necessary for harvesting the reserve may be estimated at 4.24 hours per boat on the average. For a fleet of 66 boats in 2000-2001, the scenario therefore implies a decrease of 280 hours in total time devoted to scallop dredging.

Catches

The first hypothesis results in a decrease of scallop catches both in the reserve and on natural beds. As regards the reserve, the rate of decrease is 100%, i.e. 2.12 tons per boat.

Concerning the scallops on natural beds, the scenario assumes that CPUEs vary proportionally to the stock biomass. As effort is supposed to be unchanged (see above), catches are supposed to vary proportionally to stock abundance. Only the direct effect of sowing of juveniles is considered in the scenario, which ignores indirect impact through SSB. During the 2000-2001 campaign, aquaculture-originated scallops represented 45% of all scallops dredged on natural beds (see fig.6 above). Taking this situation as the reference level, the scenario assumes that cancelling extensive sowings on natural beds would result in a decrease in catches of 45%, with a constant fishing effort.

Catches of other species are supposed to be left unchanged.

Turnover and net sales

Due to the lack of correlation between landings and average annual prices of scallops at the scale of the fishery (see fig.1 above), it is realistic to treat this price as an exogenous variable. The reference level is the average price in the Brest fish auction market during the 2000-2001 season, i.e. 29 F / kg. The rate of landing taxes is assumed to be 4% of landed value.

Variable costs

The decrease in fishing effort due to the end of the rotating reserve system induces a change in variable costs, i.e. those intermediate consumptions which depend on the level of fishing effort in the short run. The following costs are considered to be variable : fuel costs, gear maintenance and replacement costs, 75% of boat maintenance and repair costs.

[1] Information on the state of the fishery provided by the local fisheries committee is completed by the results of the December 2000 field survey of skipper-owners.

For the type of boats operating the bay of Brest fishery, the estimated average fuel consumption is 20 litres per hour when the boat is dredging. Taking an average price of gasoil of 1.5 F / litre (year 2000) leads to an estimation of an average 127 F fuel cost per boat for the harvesting of the reserve.

Gear maintenance and replacement costs are estimated at an average 215 F per dredging day, (Le Gallic, 2001). Harvesting the reserve represents the equivalent of 2 normal dredging days (usually 2 hours of dredging per day), which results in an average 430 F gear cost per boat for the harvesting of the reserve.

The field survey of the fleet operating the bay of Brest fishery indicates that annual boat maintenance and repair costs are 28,6 KF per boat on the average. As the number of hours at sea is 1368 hours per boat for this fleet, it follows that the maintenance and repair of boats represents a cost of 21 F per hour and per boat on the average, of which 75% (16 F) is regarded as variable. Therefore the average boat maintenance and repair (variable) cost is 67 F per boat for the harvesting of the reserve.

Wage costs

Due to the share-system, the scenario has indirect consequences on wage costs, through its incidence on on net sales and variable costs. Among variable costs, in the case under investigation only fuel costs are « common », i.e. play a role in the calculation of wage costs. Wage costs (not including the part of the national insurance contribution which is born by boat owner) represent on the average 45.6% of the difference between net sales and common costs. Only part of wage costs are cash costs, 65% of the crew-share on the average corresponding to the imputed wage of the skipper-owner of the boat[1]. National insurance contributions are made of two parts, one of which comes from the crew-share, the other from the owner-share. In the present simulation, it is realistic to consider both as exogenous.

Full equity profit and skipper-owner's net activity income

The variation of full equity profit is the result of the changes in net sales on one side, and in variable costs, wage costs and license costs on the other side (other components are assumed to be fixed). Adding changes in full equity profit and in skipper's net wage give the variation of the skipper-owner's net activity income (the third element playing a role in this income, which is the opportunity cost of capital, is by assumption left unchanged).

Tables 17 and 18 present the results of the simulation. Though the scenario is based on the hypothesis of a cancelling of the program, the results are presented as positive variations, i.e. they are treated as contributions of the restocking program to the reference state of the fishery. In both tables, the contribution of the part of the program which is related to intensive sowing of juveniles in the rotating reserve is distinguished from that which is related to extensive sowing on natural beds.

[1] Part of this imputed wage results in a cash cost, since a national insurance contribution is levied on all wages coming from the crew-share. However, since this contribution is treated as exogenous in the present scenario, the *variation* of the skipper's wage is totally non-cash.

Figure 10. Schematic view of the impact of the restocking program on the economic performance of the fleet

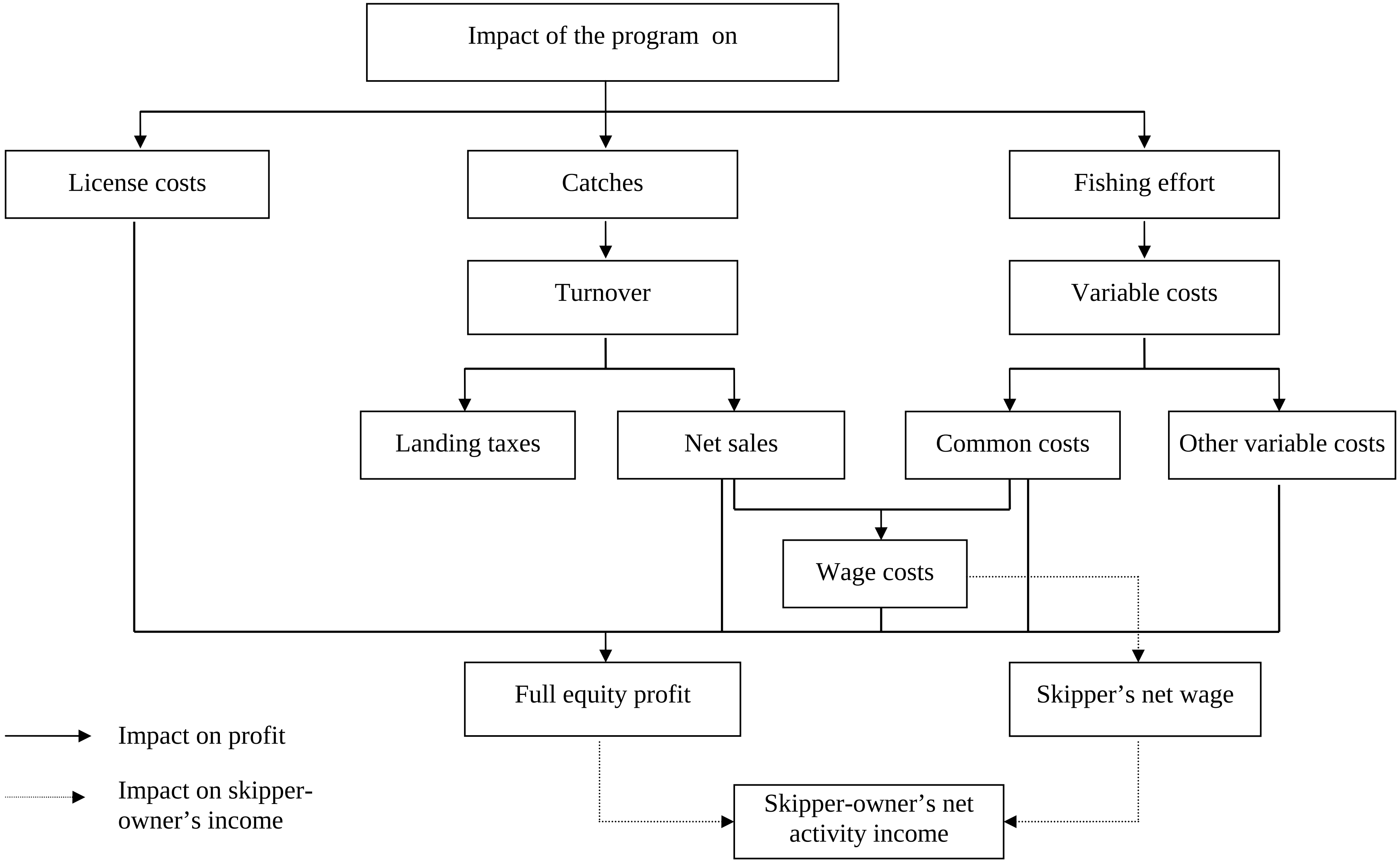


Table 17. Contribution of the program to the activity of the common scallop fishery of the bay of Brest

	Reference level	Contribution of intensive sowing in the rotating reserve		Contribution of extensive sowing on natural beds		Total contribution of the program	
		absolute	relative*	absolute	relative*	absolute	relative*
Effort devoted to scallop dredging (hours)	4232	280	7%	0	0%	280	7%
Yearly catches of common scallops (tons)	346	140	40%	92	27%	232	67%

* % of reference level.

Table 18. Contribution of the program to the economic performance of the fleet

	Reference level*	Contribution of intensive sowing in the rotating reserve		Contribution of extensive sowing on natural beds		Total contribution of the program	
		absolute*	relative**	absolute*	relative**	absolute*	relative**
Total yearly turnover	37200	4060	11%	2668	7%	6728	18%
Landing taxes	608	162	27%	107	17%	269	44%
Net sales	36592	3898	11%	2561	7%	6459	18%
Variable costs	5741	41	1%	0	0%	41	1%
Wage costs							
Skippers net imputed wages	9172	1153	13%	759	8%	1912	21%
Cash wage costs	8806	621	7%	409	5%	1030	12%
Total	17978	1774	10%	1168	6%	2942	16%
Yearly operating cost of the program	2244	1346	60%	898	40%	2244	100%
Full equity profit	4718	737	16%	495	10%	1232	26%
Net activity income of skipper-owners	11161	1890	17%	1254	11%	3144	28%

* ‘000 FF. ** % of reference level.

Figure 17 is dedicated to the impact of the restocking program on the activity of the bay of Brest scallop fishery (effort and catches).

Under the assumptions that were made for building the scenario, the contribution of the program to fishing effort is limited to some 7% of the total fishing time devoted to scallop dredging, and wholly corresponds to the estimated time which is necessary for harvesting the rotating reserve. This contribution would appear more limited if this additional effort was compared to total dredging effort in the bay, all species included (4%), or to the total yearly time at sea of the boats involved in the fishery (0.3%).

Contrasting with these figures, the contribution of the program to the catches represents two thirds of the total landings of scallops, of which some 40% are provided by the rotating reserve (reference year : 2000-2001). Taking total shellfish landings[1] as a calculation basis would bring these figures down to 50% and 30% respectively.

The discrepancy between figures concerning effort and catches is due to the fact that CPUEs are considerably higher[2] in the reserve that on natural beds, and to the assumption that CPUEs on natural beds vary proportionally to stock abundance. It suggests that the scallop restocking program substantially affects the economic performance indicators of the fleet. The contribution of the program to these indicators is described in figure 18.

According to the simulation, the program contributes to 18% of the total yearly turnover of the fleet involved in the bay of Brest fishery, among which 11% may be attributed to the harvest of the stock in the rotating reserve. On the other side, the contribution of the program to boat variable costs is very limited (1%). This is due to the fact that, according to the scenario under investigation, the influence of the program on fishing effort is limited to the harvesting of the reserve, an operation which does not consume much fishing time due to high CPUE.

Wage costs are more significantly affected, due to the share system that relates this type of costs to the difference between net sales (turnover minus landing taxes) and common costs, a subset of variable costs. The gap between the relative impact of the program on skipper's net income (21%) and wage cash costs (12%) is due to the fact that the latter include national insurance contribution, which are not affected by the program.

The contribution of fishermen to the program, which in the recent period has been high enough to balance its operating cost, is split into two parts, one related to intensive sowing of juveniles in the reserve, the other to extensive sowing on natural beds. These parts have been calculated proportionnally to each type of sowing (an average 60% in the reserve and 40% on natural beds during the 90').

Notwhistanding the unusually high cost of access to fish resource according to French standards, the simulation indicates that the program contributes to 26% of total full equity profit of the boats involved in the fishery (the average rate of which is 13.8% of insured boat value). The reserve system alone contributes to 16% of total full equity profit. The contribution of the program to skipper's income is similar : 28% of total net activity income (skipper's wage, plus full equity profit, minus opportunity cost of capital), among which 17% may be attributed to the results of intensive sowing in the rotating reserve system.

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[1] i.e. mainly adding warty venus to common scallops landings (other scallops play but a marginal role in the fishery in 2000-2001).

[2] approximately 10 times higher in 2000-2001.

Comparing the « rates of return » of money invested by fishermen in intensive sowing in the reserve and in extensive sowing on natural beds leads to the conclusion that, in the present situation, these two alternatives give similar results in terms of profitability : according to the simulation, each money unit spent by fishermen in the financing of the program yields 2.4 money units of additional skipper-owner's net income[1], wether scallop juveniles are sown extensively on natural beds or intensively in the rotating reserve. This result confirms that the justification of the rotating reserve system, up to now, mainly relies on « political » grounds, even if does not contradict economic efficiency.

However, the balanced result concerning the relative profitability of the two alternatives is due to the fact that only marginal revenues and costs are compared : in both cases, additional variable costs of catching aquaculture-originated scallops are negligible[2], either because CPUE is high (reserve), or because it is supposed to increase according to stock abundance (natural beds). If it turns out that the bulk of catches on natural beds durably comes from aquaculture-originated scallops, it will be necessary to take into account full costs of fishing on natural beds in order to assess the relative profitability of the two management alternatives. This should normally favour the reserve system, since CPUE is approximately 10 times higher in the reserve than on natural beds. On the other side, the situation concerning the restocking program and, more specifically, the reserve system cannot be regarded as stabilised nowadays. The control over the rate of mortality of aquaculture post-larvae and juveniles is still questionable, and concern about waste during the harvest and predation in the reserve has recently developed (see above). Moreover, the profitability of the whole program depends on the landing price of scallops, a variable governed by factors which are external to the fishery, and rather unstable according to historical records. This is also a subject of concern, particularly in a situation where the institutional committment of fishermen in the program is subject to revision based on short term considerations (the program is financed by fishermen exclusively on the basis of a yearly contribution, which does not imply any formal right to its long term benefits).

Relaxing some of the oversimplifying assumptions that had to be made in the above described scenario is the purpose of a bioeconomic model of the fishery, the building of which is in progress at the time of writing the present report. The main characteristics of this model are presented in the following appendix.

[1] calculated before deducing the cost of the contribution to the program.
[2] This does not include the cost of monitoring and surveillance of the reserve, which is covered by landing taxes. These taxes are used to pay for the general monitoring and surveillance costs of the fishery, among which it is difficult to isolate the specific costs induced by the reserve.

Appendix :
main characteristics of a bioeconomic model of the Bay of Brest shellfish fishery

The biological component of the model designed for simulating the fishery has the following characteristics :

- two species (common scallop *Pecten maximus* and warty venus *Venus verrucosa*)
- no biological interaction between the two species
- total area divided into « regular » fishing grounds for both species, and rotating reserve for scallops
- aged structured representation of both stocks (Beverton-Holt type)
- recruitment : exogenous for warty venus ; partly endogenous (B-H type stock-recruitment relation) and partly exogenous (restocking) for common scallops
- space mobility of scallops (between reserve and regular fishing grounds) limited to larvae.

The basic relations concerning scallops are presented in fig.11. The vision given by this figure is highly simplified (it does not take into account, e.g., the age structure of the stock and restocking outside the reserve). For each species, CPUEs per age class are supposed to be proportional to stock abundance (with a distinction, for scallops, between CPUEs on natural beds and in the reserve).

The economic component of the model takes into account :

- the economic factors affecting profitability : landing prices (exogenous for both species), fishing costs, landing taxes and licence costs (supposed to cover the operation costs of the program) ;
- the behaviour of fishermen : the relative effort directed toward each species is supposed to depend on the relative abundance and price of each species at the beginning of the dredging season.

The main control variables of the model are :

- quantities of juvenile scallops sown, and size of the reserve ;
- harvesting age of scallops in the reserve ;
- limits to fishing effort outside the reserve, for each species ;
- landing taxes and licence costs.

The main economic results of the model are the net benefits of the restocking program and fisheries management system, under various assumptions.

Available data

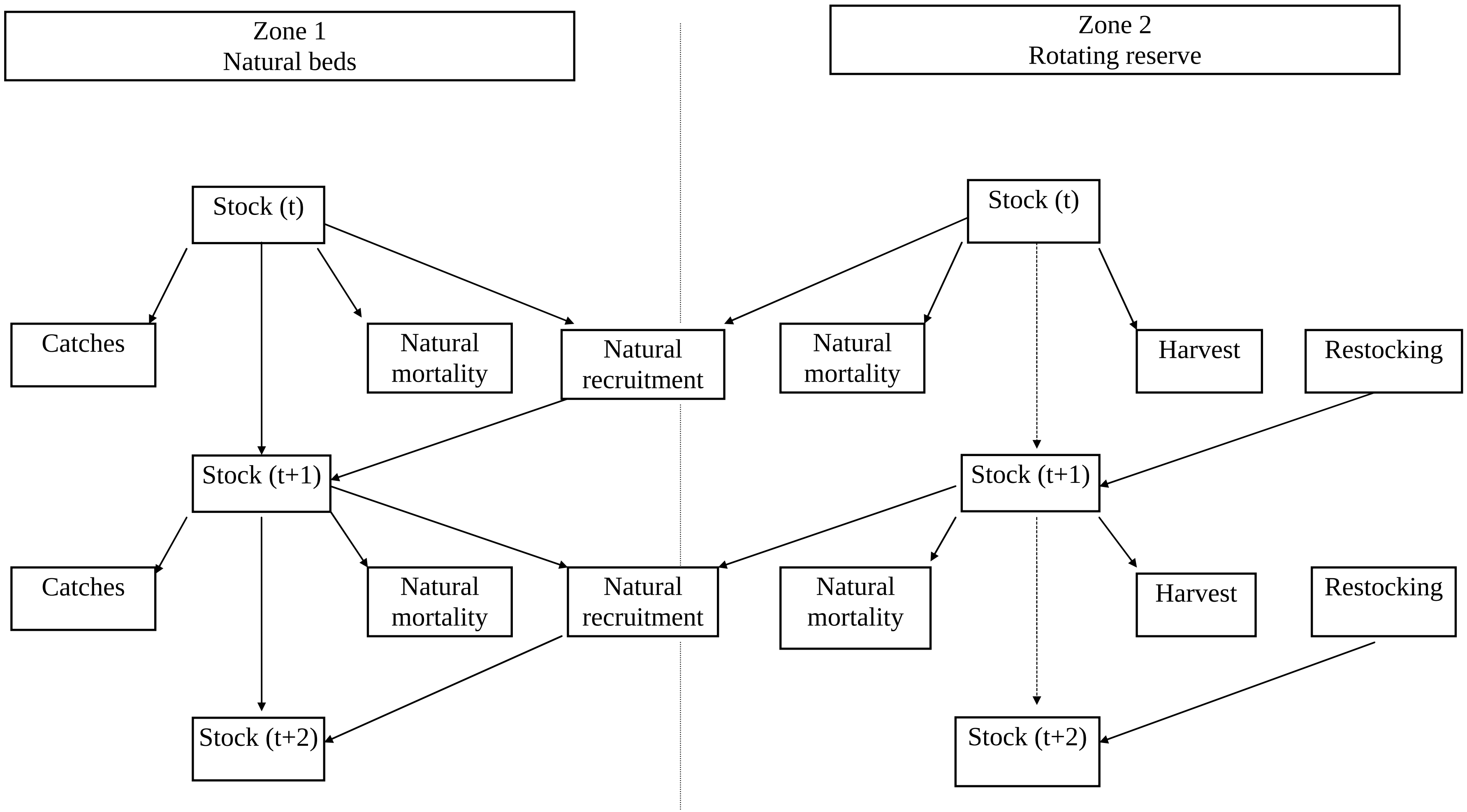
<u>Biological / technical data</u>

- episodic scallop stock assessment in the bay of Brest ;
- catch and effort data series, with gaps and possible inaccuracies ; good knowledge concerning harvest of the reserve, less good for the other part of the fishery ;
- natural mortality and growth : data available from the bay of Brest + other comparable fisheries ;
- quantities of juveniles sown and estimation of rates of recapture.

<u>Economic data</u>

- prices data series, with possible inaccuracies ;
- cost of effort : survey of the fishery realised in 2000 by CEDEM + accounting data (time series) ;
- cost of the restocking program and monitoring system of the fishery.

Figure 11. Biological component of the bay of Brest scallop fishery model (simplified, draft)



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Chapter 3. The Iroise Sea case

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Introduction

The ongoing project of creating a marine national park in the Iroise Sea, a coastal sea west of Brittany, raises many unsolved questions as this would be the first park of this type created in France (Anon., 2000/1). The main stakes are ecosystem conservation, fishing (both commercial and recreational) and tourism. The fishery is a multi-species multi-gear fishery, and up to now the regional organisation of fishermen (*Comité régional des Pêches Maritimes et des Elevages Marins*) has been backing the project, because representatives of local fishermen regard it as an opportunity to improve the management of the fishery.

The design of possible fishing exclusion zones within the park has not yet been officially discussed[1], but it might be one of the measures taken by the future park management authority, both for ecosystem conservation and fishing management reasons. Fishermen, however, fear that too much attention be paid to « nature conservation » and tourism compared to fisheries management.

After describing the fishing and recreational activities taking place in the Iroise Sea area, this study presents a bioeconomic model intending to simulate the possible impact of creating a fishing exclusion zone on both fishing and ecotourism. The possibility for commercial fishermen to participate in the benefits generated by the development of ecotourism is discussed in the last section of the report.

1. Fishing and recreational activities in the Iroise Sea[2]

The following description is composed of three parts :

1. main characteristics of the ecosystem and of its interactions with fishing activities ;
2. professional fishing activities ;
3. recreational activities.

[1] Two areas of « special conservation interest » have been designed, but nothing has yet been decided concerning fishing in these areas.
[2] The following description is mainly based on Boncoeur, Alban, Appéré et al. (2002), complemented by Alban et al. (2001/1 and 2001/2) and some unpublished estimations realised by CEDEM.

Insert here Map 1 and Map 2

1.1. Ecosystem and interactions with fishing activities

1.1.1 Main characteristics of the ecosystem[1]

Located at the western extremity of Brittany, Iroise is a coastal sea located on the frontier between the English Channel and the Atlantic Ocean. It is bounded in the North by the Isle of Ouessant (48°30'N) and the Molène archipelago, in the South by the Isle of Sein and the rocks located west of this island[2] (48°N). In the east, the Iroise Sea communicates with the Bay of Brest and the Bay of Douarnenez. In the west, it is admitted that the limit between the Iroise Sea and the Celtic Sea is the 100 metres isobath (map 1). The whole area is included within the 12 NM French coastal waters. The limits of the future National Marine Park (map 2) approximately correspond to the geographical definition of the Iroise Sea. They include the Bay of the Douarnenez but not the Bay of Brest, a much more industrialised area.

Several small islands, only three of which are inhabited[3], are located in the area, altogether with many islets and rocky bottoms that are generally the underwater extensions of continental capes. The Iroise Sea is submitted to tidal currents which are among the strongest in Europe, and play a critical role in the hydrodynamism of the area. The primary production is important, as planctonic algae may find there both light and nutriments that are necessary for their growing.

The shallowness of the area, the diversity of its beds and its specific hydrodynamism cause a high diversity of habitats, and explain the presence of an important number of remarkable animal and vegetal species. For these reasons, the UNESCO labelled the Iroise Sea c « Man and Biosphere » (MAB) reserve in 1989.

Down to the 25 metres isobath, rocky bottoms are colonised by large seaweeds used by many marine species as food or shelter. More than 300 species of seaweeds are present in the Iroise sea, which contains the largest kelp fields in Western Europe (mainly around the Molène archipelago and the island of Sein). Beyond 25 metres, the flora gets more scattered. All types of animal species targeted by fishers are found there, particularly crustaceans. These beds are also colonised by sedentary species of high patrimonial interest (sponges, sea anemones, corals, etc).

In the intertidal zone, the most common sedimentary habitat is composed of sandy beaches facing the open sea. This habitat is colonised by small bivalves such as *Donax trunculus*, a shellfish which is targeted by professional fishermen operating on foot. In deeper zones, sedimentary habitats are colonised by a variety of seaworms and shellfish, which attract predators such as starfish and flatfish. Various species of seagrass are met in sheltered sandy bays. The Iroise Sea contains three beds of maerl, one of which is commercially exploited.

The Iroise Sea shelters a high variety of fish of commercial interest. With 126 registered species, nearly all species of finfish that can be met near the French Atlantic and English Channel coasts are present. The most important species of commercial interest are demersal or benthic species, such as monkfish, pollack, rays, conger, turbot. Some pelagic species are also targeted (mainly pilchard, mackerel and anchovy). Except for Norway lobster, the main species of crustaceans targeted by French fishermen are met in the Iroise Sea (edible crab, spider crab, lobster, spiny lobster). As regards shellfish, the main species of commercial interest are common scallop and donax. Occasionally significant beds of other bivalves (such

[1] The summary presented in this section is mainly based on Le Duff et al. (1999).
[2] *Chaussée de Sein*.
[3] Ouessant, Molène and Sein.

as queen scallop *Aequipercten opercularis* or dog-cockle *Glycimeris glycimeris*) are also exploited by commercial fishermen.

For various reasons, the permanent, seasonal or occasional presence of some vegetal and animal species in the Iroise Sea is considered as remarkable by scientists or by the public (or both). Among these species, some of them have received a particular media coverage, such as marine mammals (dolphins, seals, otters) or sea birds.

1.1.2. Interactions with fishing activities

The Iroise Sea is also a highly anthropised area. A traditional activity in the area, and still an important one, is fishing. The impacts of fishing on marine ecosystems are both direct and indirect. Direct impacts are due to fishing mortality (including the consequences of discards), but also to the mortality among sea birds or marine mammals and the mechanical disturbance of benthos caused by some fishing gears. Indirect impacts are due to changes in the structure of the ecosystems, particularly food chains. A recent analysis of literature concerning the impact of fishing on marine environment in Europe (Heaps, 1999) shows that the main subjects of concern are linked with overfishing of targeted species, bycatches and discards. The topic of the impact of towed gears on the benthos is also well documented, while literature concerning pelagic species and fixed gears is less abundant.

Knowledge concerning the impact of fishing on the Iroise ecosystem is mainly qualitative. Available information concerning seaweeds, fish, birds and marine mammals is summed up hereafter.

- *Seaweeds*

The Iroise Sea is famous for its seaweeds fields (see above). This component of the ecosystem interacts with fishing for several reasons. Directly, because seaweeds are harvested by fishermen[1] operating on boats or on foot. Indirectly, because seaweed fields are a habitat for various species targeted by fishing. More generally, seaweeds participate in the equilibrium of the coastal ecosystem, and therefore in the sustainability of its uses.

Kelps are the main commercially exploited species of seaweeds in the area. The bulk of landings is provided by one species, *Laminaria digitata*. However, the most important kelp fields in the area are composed of another species, *Laminaria hyperborea*, which is the subject of some experimental harvesting (Arzel, 1998). One of the problems related to the development of this activity is the impact on the ecosystem of the gear used for harvesting *L. hyperborea*, which is a towed mechanical comb. This problem is potentially serious since the main *L. hyperborea* fields are located in an area which is regarded as the zone of « special conservation interest » for the future National Marine park.

The ecosystem of kelp fields shelters a specific fauna, permanently (abalone, swimming crab, conger...), seasonally (spider crab) or during a particular phase of their life cycle (edible crab, pollack, bass). However, the level of dependency of these species on the kelp field is not precisely known. The relations are probably complex and sometimes indirect. In the case of finfish, the kelp field increases the food potential (invertebrates). For some nesting species, it provides a building material. Even if seaweeds are seldom consumed by finfish in temperate waters, they contribute to the maintenance of their biodiversity and biomass (Wheeler, 1981). The direct role of seaweeds in the food chain gets significant when they are untied by storms and torn in a multiplicity of fragments. Scattered on the bottom by currents or stranded on the shore, these fragments are attacked by various organisms and micro-organisms.

[1] Seaweed harvesting is treated as a fishing activity in France.

- *Fish*

Though fishermen organisations are involved in the process of creating a marine park in the Iroise Sea, the design of the future marine park is not mainly (or at least not only) led by fisheries management considerations, and its borders do not correspond to the space limits of fish stocks. As a result, it is not easy to assess the consequences of fishing on targeted stocks at the scale of the park[1].

A great variety of fish are targeted by fishermen in the Iroise Sea. Their degree of dependency on the area varies according to species (table 1). Few stocks are entirely located within the area. For some stocks, the area plays an important role, in particular as a breeding area and nursery.

- *Birds*

Birds in the Iroise Sea area belong to several categories (Anon. 1997, Offredo 1999):

- sea birds, some of them breeding in the area (13 species), while others just frequent it for feeding (4 species) ;
- coastal birds, some of them sedentary (8 species), others migratory (9 species), frequenting the sandy beaches or cliffs ;
- inland birds (sedentary or migratory) that can be met on the islands or on the mainland.

When seabirds frequent the same zones as fishermen, some are liable to be caught accidentally, mainly by nets. The main potential victims are cormorants and guillemots. Other types of interaction between birds and fishermen are possible, including the predation of small bivalves (Donax) in the bay of Douarnenez.

- *Marine mammals*

The last three decades have been characterised by increasing concern for marine mammals in fisheries management. Interactions between fisheries and marine mammals may be significant (Beddington, Beverton and Lavigne, 1985). Two types of interactions may be distinguished :

- « technical » interactions due to the presence of marine mammals in fishing areas, and even in fishing gears. These interactions are frequently double-sided, i.e. have consequences for both fishermen (damage to fishing gears) and marine mammals (injuries and mortality) ;
- trophic interactions due to direct or indirect[2] competition for fish between fishermen and marine mammals.

As regards the Iroise Sea, knowledge concerning these two types of interaction is summed up in table 2 (information was provided by courtesy of Sammi Assani, from the marine mammals laboratory of Oceanopolis, Brest). The table describes not only interactions with commercial fishing, but also with recreational activities including ecotourism.

[1] Estimated landings will be presented in the following section, dedicated to the description of commercial and recreational fishing.
[2] through the impact on food chain.

Table 1. Biological parameters of main fish species targeted in the Iroise Sea

Species	**Monkfish**	**Turbot**	**Pollack**	**Sole**	**Bass**	**Edible crab***	**Spider crab***	**Spiny lobster***	**Common scallop**
Space distribution	from Barents sea to gulf of Guinea Mediterranean and Black Sea 0-800 metres.	from Norway to Morocco, Mediterranean and Black Sea 10-150 metres.	from Norway to North Africa 0-150 metres	from south of Norway to Senegal, Mediterranean and Black Sea, 0-200 metres.	from Norway to Morocco, Mediterranean and Black Sea	from Scandinavia to Morocco, 0-200 metres.	from Ireland to Guinea, Mediterranean, 0-120 metres.	from Hebrides to North West Africa and Azores, Western Mediterranean 0-150 metres.	from Norway to Morocco 0-200 metres.
Preferred habitat	50-800 metres Sand and mud.	Sand and gravel.	0-20 metres during the 2 first years, then 50-100 metres. Neighbourhood of wrecks.	0-130 metres Sand and mud.	coastal species, troubled water (oxygenated) along rocky coasts and sandy beaches.	0-200 metres, hard bottom (males), light bottom (females).	0-20 metres (juveniles), 0-70 metres (adults).	50-100 metres, rocky bottom.	10-80 metres, light but non muddy bottom.
Nurseries	not individualised.	Coastal (0 to 10 metres) sandy zones during the 2 or 3 first years.	Juveniles live close to the shore during the 2 first years.	Estuaries and bays during the 2 first years.	Estuaries and shallow bays.	Juveniles live close to the shore during the 2 or 3 first years.	Sandy or muddy bottom of estuaries and bays (0-20 metres).	-	-
Breeding	February to August	May to July	January to March	January to March	December to April in the English Channel	Females carrying eggs from December to May	Females carrying eggs from March to May	Females carrying eggs from September to May	June to September
Sexual maturity	6 to 7 years	3 to 5 years	3 to 4 years	3 to 4 years	4 to 6 years	200 -300 grams (males) 400 g. (females)	2 to 3 years	Length ≈ 28 cm., weight around 650 g.	3 years

(continued next page)

Table 1 (continued)

	Monkfish	**Turbot**	**Pollack**	**Sole**	**Bass**	**Edible crab***	**Spider crab***	**Spiny lobster***	**Common scallop**
Pelagic larval phase	-	3 to 6 months	a few months	3 weeks	-	6 to 8 weeks	2 to 3 weeks	over 6 months	3 to 4 weeks
Migrations	No migration related to reproduction.	Migration towards high sea in the course of development.	Inshore sea (less than 20 metres) during the 2 first years. 50 to 100 m later.	Towards the shore in May-June, back to high sea in October-November.	Probably limited. There are some individualised populations.	From coast to high sea in the course of development of juveniles, towards South West in the Iroise sea (adults). Females are more mobile than males.	Migration towards offshore winter quarters (depth > 50 m), usually located west of nurseries.	Rather sedentary.	Sedentary.
Growth	Slow	Quick during the 2 first years.	Rather quick.	Quick during the 4 first years.	Rather slow.	Slow.	Quick until maturity.	Slow.	Quick.
Life expectancy	over 20 years.	up to 50 years.	over 15 years.	25 years	20 years	around 20 years.	7 to 8 years	over 20 years	12-15 years
Fishing gears and methods	**C.** nets, trawls.	**C.** nets, trawls. **R.** handlines and snorkelling.	**C.** handlines, nets, trawls. **R.** handlines, nets, snorkelling.	**C.** nets, trawls. **R.** nets, handlines.	**C.** handlines, longlines, nets, pelagic trawls. **R.** handlines, snorkelling.	**C.** pots. **R.** pots and fishing on foot.	**C.** pots, nets. **R.** pots, nets, snorkelling.	**C.** nets	**C.** Dredges **R.** Snorkelling.
Fishing zone in the Iroise Sea	North West of the Ouessant trough.	60 to 80 metres isobath.	Whole area	Bay of Douarnenez, Crozon peninsula.	East of Sein, West of Ouessant, bay of Douarnenez.	North of Ar Men, north-west of Ouessant.	North of Four to Sein island (winter).	North of Sein, trough of Ouessant, north-east of Molène.	North of Ouessant to South of Sein.

Source : Ifremer.
* The growth regime of crustaceans does not allow to determine precisely their age of maturity and life expectancy.
C. = commercial fishing, **R.** = recreational fishing.

Table 2. Interactions between marine mammals and fishing + recreational activities in the Iroise Sea

Type of behaviour	**Species**	**Estimated population**	**Trophic interactions**	**Technical interactions (commercial fishing)**	**Technical interactions (recreational activities)**
Sedentary	Great dolphin	Strictly coastal species (<20m). Two distinct groups : - Molène archipelago : 50-60 individuals. - Sein Island : 18 individuals.	Possible competition for some species, but its nature and intensity is unknown.	Presently no interaction during the daytime, fishermen and dolphins not operating in the same zones; uncertainty concerning night time.	The only documented interactions concern dolphins accompanying recreational boats, which is a partial base for a local activity of ecotourism (individual and commercial).
	Porpoise	Anecdotal since the 70'.	The general decreasing trend of observed populations along the French coasts is probably related to a strong sensibility to disturbance created by anthropic activities.	?	?
Open	Grey seal	Around 50 individuals in the Molène archipelago. Exchanges of population with the British Isles.	Seals feed on species with a potential commercial interest, though usually of low unit value (congers for instance). Estimated consumed biomass is around 330 tons a year.	Accidental catches of seals, mainly juveniles, in large mesh nets. Little information is available on this type of interaction. Predation and damage to fishing gears by seals : no quantitative information on this interaction is available for the Iroise Sea.	Interaction with recreational fishing : no available information. The presence of grey seals is a partial base for the development of a local activity of ecotourism (individual and commercial)
Seasonal	Common dolphin Blue and white dolphin Risso dolphin Globicephale	?	Seasonal competition during the migration of these species towards the coast, mainly concerning cephalopods and small pelagic fish.. No quantitative estimation available	Interaction with gears (fixed nets, pelagic trawls) : mortality has been estimated at the scale of the Brittany region. No available information concerning damage caused to fishing gears.	Anecdotal interactions except for the accompanying of recreational boats.

Source : laboratoire d'étude des mammifères marins, Océanopolis, Brest.

1.2. Description of commercial fishing activities

The following description is composed of two parts :

1. activity of commercial fishing boats operating in the Iroise area ;
2. economic survey of the commercial fishery.

1.2.1. Activity of commercial fishing boats operating in the Iroise area[1]

Administrative statistics are unfit for describing commercial fishing in the Iroise Sea : boats are described according to place of registration and physical characteristics, but not to type(s) and place(s) of activity ; landings are described according to species and landing harbours, but not to places of catches and type of gears used. These drawbacks are increased by some specific characteristics of the Iroise Sea : it is an open area, with many biological, technical and economic interactions with surrounding areas ; the fishery is a multi-species and multi-gear, mainly operated by small boats the landings of which are geographically scattered, and only partly marketed through fish auction markets[2].

In order to overcome these drawbacks, a spatialized database of commercial fishing activities of the Iroise area was created by Ifremer. It relies on the exhaustive treatment of activity calendars of fishing boats, which has been realised for the years 1996 and 2000[3]. For these two years, the activity of fishing boats has been treated on a monthly basis. For each month, the information in the database concerns the activity or inactivity of the boat, the total number of men onboard, the landing places, the gear(s) used and targeted species, the fishing area(s), and the gradient of activity (within the 12 NM or not). Landings are estimated on the basis of auction market data, logbooks, and production declaration records for boats under 10 metres. However, the inaccuracy of part of these data calls for a statistical rectification sequence which is presently experimented.

- Global description of the commercial fleet operating the Iroise fishery

The total number of commercial fishing boats operating in the Iroise area was estimated at 344 in 2000, against 364 in 1996 (- 5.5%)[4]. More than two thirds of these boats (69%) come

[1] This section is based on a survey realised by Patrick Berthou.
[2] Seaweed harvesting is a special case, the resource being purely sedentary, the fleet purely local and all landings being directly sold to two processing plants (Arzel, 1998).
[3] The fishery under survey, being entirely within the 12 NM line, is operated by French boats only.
[4] Due to statistical constraints, the zone under survey does not correspond strictly to the geographical definition of the Iroise Sea (see above), and therefore will be named here « Iroise area » rather than « Iroise sea ». One of the differences is due to the fact that it includes the Bay of Brest.

from the maritime districts bordering the Iroise Sea (Brest, Camaret, Douarnenez, Audierne). The bulk of the other boats come from the neighbouring districts of Guilvinec (south) and Morlaix (north). The main physical characteristics of the Iroise fleet are summed up in the table below.

Table 3. Physical characteristics of the fleet operating the Iroise Fishery in 2000 (344 boats)

	Boat age (years)	Length (metres)	GRT	HP (kW)
Mean	19	11,69	22,92	156
Standard deviation	8	5,12	30,04	126
Minimum	1	4,15	0,94	6
Maximum	47	24,95	147,47	552

Source : Ifremer

The majority of the fleet is composed of small units : 70% of the boats are under 12 metres long, and only 18% are 16 metres long or more. No boat is over 25 metres long. The distribution by maritime district shows that most of the largest boats operating the fishery (boats 16 metres long and over) come from non-bordering districts (mainly the district of Guilvinec).

A comparison between years 1996 and 2000 shows an increasing trend in the average physical characteristics of boats : + 15% for the length, + 34% for the HP, and +54% for the GRT. This trend seems to be mainly due to an increased participation of larger (external) boats in the fishery.

The seasonal pattern of fishing activity in the Iroise area shows an overall stability through the year, with a minimum of 220 boats in December and a maximum of nearly 260 boats in June-July. Dividing, for each boat, the total yearly time at sea by the time spent in the Iroise area gives an estimation of the rate of dependence of the boat on the fishery. The average rate is 74%. Boats coming from bordering districts depend more on the fishery than other boats operating in the area. For the first group, fishing in the Iroise area represents the bulk of the activity (usually more than 80% of total fishing time), while it is a more occasional activity for the second group (usually under 40% of total fishing time).

- Description of the fleet according to « métiers »[1]

A majority (59%) of boats operating the Iroise fishery exert more than one *métier*, and the average is 2.1 *métiers* per boat. A total number of 25 *métiers* has been identified, but 12 *métiers* represent 95% of total fishing time in the Iroise. The main *métiers* are described in table 4 below. Analysing the combination of *métiers* adopted by each boat leads to a partition of the total fleet into 10 groups of boats which are homogenous in terms of fishing strategy. These groups are presented in table 5[2].

[1] Basically, this expression represents the combination of a gear and a targeted species (or group of targeted species). For a more detailed definition, see Tétard, Boon et al., 1995.
[2] Two groups of boats have been recently surveyed in greater detail : seaweed harvesters and dredgers (including dredgers-longliners). See Alban et al., 2001/1 and 2001/2.

Table 4. Main *métiers* exerted by the fleet operating the Iroise fishery in 2000 (344 boats)

Name	% of total fishing time in the area	Number of boats	Main species targeted	Main districts (% of total fishing time in the *métier*)	Remarks
fixed nets with large mesh (finfish)	16.4%	74	monkfish	Brest (64%) Morlaix (22%)	
fixed nets with small mesh	14.6%	97	bass, pollack, hake, other gadidae spp., sole	Brest (51%) Audierne (18%)	
Handline	13.3%	64	bass, pollack, mackerel	Audierne (46%) Brest (41%)	
Longline	10.5%	58	bass, conger, seabream	Brest (49%) Camaret (15%)	
dredge (common scallop)	9.9%	83	common scallop	Brest (81%) Camaret (7%)	Seasonal (winter), mainly in the bay of Brest
pots (large crustaceans)	9.4%	63	edible crab	Brest (82%) Morlaix (11%)	Strong decrease between 1996 and 2000 (fishing time - 47%)
dredge (other shellfish)	6.6%	59	warty venus, queen, dog-cockle	Brest (72%) Douarnenez (15%)	For most boats a complement of scallop dredging in the bay of Brest
« scoubidou »* (seaweeds)	5.1%	42	*L. digitata*	Brest (93%) Morlaix (6%)	Seasonal (summer), often complemented by scallop dredging in winter
bottom trawling	4.6%	43	Various demersal and pelagic fish	Guilvinec (83%) Douarnenez (6%)	Still marginal in the area, but increase since 1996 (fishing time +22%)
fixed nets with large mesh (large crustaceans)	2,0%	14	spider-crab, spiny lobster	Brest (79%) Camaret (14%)	Usually a complement of the *métier* targeting finfish with same type of gear
purse seine (pelagic fish)	1,2%	10	pilchard	Douarnenez (60%) Others** (28%)	Seasonal (October to April)
pots (cephalopods)	1,1%	16	cuttlefish	Brest (59%) Camaret (24%)	
Others	5.3%	55	miscellaneous		

* mechanical spin turning in the weeds and pulling them away from the bottom. ** Districts of South Brittany. Source : Ifremer.

Table 5. Components of the fleet operating the Iroise fishery, defined on the basis of fishing strategy

Name	Origin : main maritime districts*	Number of boats		Boat length (metres)		Effort :	Declared landings**		Main species landed
		in 2000	Variation since 1996	mean	Standard deviation	% of fishing time in Iroise	Total (tons)	of which : % Iroise	
Purse seiners	GV, CC, DZ	10	- 2	15.8	2.0	51%	5167	30%	Pilchard
Trawlers	GV	54	+23	20.8	3.3	32%	15484	17%	Anchovy, gadidae spp., rays, monkfish
Dredgers	BR, CM, DZ	40	- 1	9.8	2.2	76%	2069	40%	Queen, dog-cockle, common scallop
Dredgers-longliners	BR, DZ, CM	23	- 4	8.7	1.0	85%	305	84%	Conger, common scallop, warty venus
Longliners	BR, CM, DZ	23	- 4	9.5	4.4	78%	1470	37%	Conger, gadidae spp., sharks, bass
Handliners	AD, BR	37	- 1	8.0	0.9	84%	155	98%	Bass, pollack
Potters	BR	17	- 8	11.7	6.1	54%	1280	22%	Edible crab
Potters-netters	BR	28	- 14	9.2	3.4	85%	965	81%	Great crustaceans, monkfish, rays
Netters	BR	70	- 2	10.9	3.3	81%	2071	67%	Monkfish, great crustaceans, rays
Seaweed harvesters	BR	42	- 7	9.8	1.5	95%	44000	99%	*L. digitata*
Total fleet		344	- 20	11.7	5.1	74%	72966	71%	

* Maritime districts : AD = Audierne ; BR = Brest ; CC = Concarneau ; CM = Camaret ; DZ = Douarnenez. ** based on auction market data, logbooks, individual production declarations. Source : Ifremer.

- Landings by species

The first table below presents, by group of species, the landings declared in 2000 by boats operating the Iroise fishery. The second table displays the same type of information for the main animal species caught in the Iroise Sea.

Table 6. Declared landings by group of species, Iroise fleet, 2000 (tons)

Origin of catches / Group of species	All areas	Iroise area*	Iroise share**	Bay of Brest
Finfish	22483	6081	27%	17
Crustaceans	2782	1332	48%	6
Shellfish	2019	838	42%	368
Cephalopods	1653	305	18%	15
Total (without seaweeds)	28937	8556	30%	406
Seaweeds	43924	43342	99%	0
Total (including seaweeds)	72861	51898	71%	406

* including Bay of Brest. ** Iroise area / all areas. Source : Ifremer

Table 7. Main animal species caught in Iroise according to declared landings, 2000 (tons)

Origin of catches / Species	All areas	Iroise area*	Iroise share**	Bay of Brest
<u>Finfish</u>				
Pilchard	4685	1352	29%	0
Monkfish	2127	862	41%	1
Rays	1819	545	30%	2
Mackerel	973	508	52%	0
Conger	1125	427	38%	2
Miscellaneous Gadidae spp.	2028	421	21%	0
Dogfish spp.	964	393	41%	0
Pollack	625	288	46%	1
Gurnards	905	246	27%	0
Miscellaneous flatfish	872	234	27%	0
Bass	255	156	61%	5
<u>Invertebrates</u>				
Edible and spider crabs, lobster	2578	1285	50%	6
Dog-cockle	407	407	100%	38
Common scallop	368	268	73%	203
Cuttlefish	1192	201	17%	15
Warty venus	131	131	100%	131
Squid	459	103	22%	0

* including Bay of Brest. ** Iroise area / all areas. Source : Ifremer

Expressed in tons, the most important group of species exploited in the Iroise area is by far seaweeds (mainly *Laminaria digitata*), the landings of which were above 43000 tons in 2000. Seaweed harvesting is a speciality of the Iroise area, which represents the bulk of the regional and national output of kelps[1]. This activity is operated seasonally by a specialised fleet of seaweed harvesting boats (42 units in 2000), often complementing their summer activity of seaweed harvesting by scallop and warty venus dredging inside the Bay of Brest during the winter season.

Declared landings of animal species caught in the Iroise area represented some 8500 tons in 2000. Finfish contributed to this total up to 6000 tons, and invertebrates (mainly crustaceans)

[1] Kelps are industrially processed in order to extract alginates.

up to 2500 tons. The main finfish species (in tons) are pilchard, monkfish, rays, mackerel and conger. For invertebrates, the main species are edible and spider crabs, bivalves (dog-cockle *Glycimeris glycimeris*, common scallop *Pecten maximus*, warty venus *Venus verrucosa*) and cephalopods (cuttlefish, squids).

As regards declared landings of animal species, the overall rate of dependence on the Iroise area of the fleet operating the fishery is only 30% (with an important variability according to groups of boats - see table 5 above -). It is higher for crustaceans and shellfish (45%) than for finfish and cephalopods (26%). Among animal species with significant landings, the only ones with a 50% or more rate of dependence are warty venus (100%), dog-cockle (100%), common scallop (73%), spiny lobster (74%), bass (61%), mackerel (52%) and the group of large crustaceans[1] (50%).

The Bay of Brest, a rather closed area which is off the limits of the future marine park, has been isolated in the two tables above. Compared to the rest of the Iroise area, it plays a minor role in declared landings, except for 2 shellfish species (common scallop and warty venus).

The incomplete character and inaccuracy of the declarative system on which landings data are based has led to an operation of statistical rectification. This operation, presently realised by Ifremer, is based on the knowledge of boat monthly activity calendars, on the definition of groups of boats which may be considered homogenous as regards fishing strategy (see above), and, inside each group, on the selection of a sample of boats which may be considered fairly reliable in terms of declared landings data (for more detail, see Boncoeur et al., 2002). The first (provisional) results of the process[2] lead to an overall increase of approximately one third in the landings of the fleet, all origins included (seaweeds excluded).

Table 8. Declared and estimated landings of some species caught by the Iroise fleet. Provisional results (all areas, year 2000)

Species	Landings (tons)	Declared [1]	Estimated [2]	lower limit*	upper limit*	multiplier (2] / [1]
Finfish						
	Pilchard	4685	6405	6025	6784	1.37
	Monkfish	2127	2696	2649	2742	1.27
	Rays	1819	2094	2065	2124	1.15
	Mackerel	973	1221	1118	1323	1.25
	Conger	1125	1183	1055	1311	1.05
	Miscellaneous Gadidae spp.	2028	2269	2214	2324	1.12
	Dogfish spp.	964	1202	1149	1255	1.25
	Pollack	625	902	880	923	1.44
	Gurnards	905	1157	1113	1200	1.28
	Miscellaneous flatfish	872	997	981	1012	1.14
	Bass	255	410	397	422	1.61
Invertebrates						
	Edible and spider crabs, lobster	2578	5604	5348	5860	2.17
	Common scallop	368	405	363	447	1.10
	Cuttlefish	1192	1374	1343	1405	1.15
	Squid	459	533	519	546	1.16

* 0.95 probability that estimated landing is above lower limit and under upper limit. Source : Ifremer.

[1] Edible crab, spider crab, lobster and spiny lobster. For this last species, the rate of dependence reaches 74%, but the landed quantities are limited (a total of 49 tons was declared by the fleet in 2000).

[2] Some methodological improvements are still ongoing at the time of writing this report (see Boncoeur et al., 2002).

The above described rectification affects mainly groups of small boats (which are the most dependent on the Iroise area) : the increase is only 13% for the group of trawlers, but reaches 85% for the group of handliners, and 154% for the group of potters. As a result, for catches realised in the Iroise area, estimated landings (seaweeds excluded) are some 43% over declared landings : a reasonable estimation for total catches realised in this area in 2000 (seaweeds excluded) is around 12.2 thousands of tons (to be compared with the figure of 8.5 thousands of tons resulting from declared landings).

1.2.2. Economic survey of the Iroise commercial fishery[1]

The following economic survey of the Iroise commercial fishery contains two parts :

- the first one estimates the value of landings and of jobs generated by the fishery ;
- the second part is an estimation of the profitability of groups of boats operating the fishery, based on a sample field survey.

- Estimating the value of landings and jobs generated by the Iroise commercial fishery

Estimating the value of the catches realised by commercial fishermen in the Iroise area mainly relies on a combination of landings data presented in the above section, with information concerning landing prices. It is complemented by some field information about the activity of professional fishermen operating on foot.

A problem for estimating the value of landings is caused by the variety of marketing channels used by fishermen, and the lack of available records for many of them. Facing the impossibility of getting detailed information on all these channels, the solution adopted here has been to rely mainly on auction market prices. For each species, a weighted average price was computed on the basis of landing data for the year 2000 provided by the fish auction markets of the Iroise area (Brest, Audierne, Douarnenez) and the neighbouring maritime districts (mainly the Guilvinec district : fish auction markets of St-Guénolé, Guilvinec, Loctudy, Lesconil). In a few cases, ad hoc solutions had to be adopted. The first table below presents the method of valuation adopted for each species and the resulting price. The three following tables are dedicated to estimating the value of catches obtained by combining these prices with landing data presented in the former section of this report.

In these three tables, the fleet operating the Iroise fishery is divided into three groups (each one is obtained by aggregating some of the 10 groups defined at the former section). These groups of boats are differentiated on the basis of their physical characteristics, their fishing strategy and their degree of dependence on the Iroise area :

- Trawlers and purse seiners are the largest boats, and the less dependent on the Iroise ; they target essentially finfish[2].
- Liners, potters and netters make use of fixed gears only, and target finfish and crustaceans ; most of them are highly dependent on the Iroise area.

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[1] This section is based on economic estimations and a field survey realised by Frédérique Alban, Jean Boncoeur and Pascal Le Floc'h, with inputs provided by Pierre Arzel, Patrick Berthou, Olivier Guyader, Olivier Thébaud and Gérard Véron.

[2] Trawlers from South Brittany also target Norway lobsters, but seldom in the Iroise area.

- Dredgers and seaweed-harvesters are the group with the highest degree of dependence on the Iroise area. These boats target shellfish with dredges (except for « pure » seaweed harvesters), altogether with a great variety of other fishing activities (longlines, pots, nets, seaweed harvesting).

Table 9. Estimated landing prices (year 2000)

Species	Estimated price		Calculation base*
	FF / kg	Euro / kg	
Finfish			
Pilchard	3.12	0.48	Douarnenez, St-Guénolé, Concarneau
Monkfish	37.28	5.68	Brest, Audierne, Douarnenez
Rays	13.29	2.03	Douarnenez, St-Guénolé, Guilvinec, Loctudy
Mackerel	5.90	0.90	St-Guénolé, Concarneau
Conger	12.61	1.92	Audierne
Gadidae spp.	16.92	2.58	national average estimated landing price (fresh)
Dogfish spp.	8.40	1.28	national average estimated landing price
Pollack	24.77	3.78	Audierne
Gurnards	6.52	0.99	national average estimated landing price
Flat fish	34.50	5.26	national average estimated landing price
Bass	81.39	12.41	Brest, Audierne
Scad	6.99	1.07	national average auction market price
Anchovy	10.25	1.56	national average auction market price
Whiting	12.03	1.83	Douarnenez, Audierne, St-Guénolé
Sole	67.07	10.22	Guilvinec
Hake	29.64	4.52	St-Guénolé, Guilvinec, Loctudy
Red mullet	43.91	6.69	Guilvinec, Loctudy
Black sea bream	30.12	4.59	St-Guénolé
Saith	6.30	0.96	national average estimated landing price (fresh)
Albacore tuna**	16.33	2.49	national average estimated landing price (fresh)
Miscellaneous finfish	23.80	3.63	Audierne, Brest (average « other species » price)
Crustaceans			
Edible crab	15.41	2.35	national average estimated landing price
Spider crab	12.07	1.84	national average estimated landing price
Lobster	127.06	19.37	national average estimated landing price
Spiny lobster	213.38	32.53	Audierne
Small crabs***	14.86	2.27	national average estimated landing price
Norway lobster	50.83	7.75	St-Guénolé, Guilvinec, Loctudy, Lesconil
Cephalopods			
Cuttlefish	8.51	1.30	Guilvinec
Squids	25.17	3.84	Guilvinec
Shellfish			
Dog-cockle	1.77	0.27	national average estimated landing price
Common scallop	27.33	4.17	Brest
Warty venus	36.13	5.51	Brest
Queen scallop	6.43	0.98	national average estimated landing price
Variegated scallop	33.0	5.03	national average estimated landing price
Seaweeds			
Kelps	0.248	0.038	National board of seaweed processing industries

* Name of the auction markets, or other source. ** *Thon germon.* *** velvet crab, swimming crab.
Sources : Anon. 2001/1, Anon. 2001/2, Chambre Syndicale Nationale des Algues Marines.

Table 10. Estimation of the value landed by the Iroise commercial fleet, year 2000 (unit : million FF)

Species	Finfish		Crustaceans		Cephalopods		Shellfish		Seaweeds		All species	
Boats	all areas	Iroise	all areas	Iroise	all areas	Iroise	all areas	Iroise	all areas	Iroise	all areas	Iroise
Trawlers, purse seiners												
declared landings	251.8	41.1	7.5	0.3	21.0	3.9	-	-	-	-	280.2	45.3
estimated landings	284.3	47.0	8.4	0.3	23.7	4.4	-	-	-	-	316.5	51.7
Liners, potters, netters*												
declared landings	79.8	57.3	52.2	27.6	0.1	0.1	-	-	-	-	132.0	85.0
estimated landings	130.2	97.7	114.2	54.7	0.1	0.1	-	-	-	-	244.6	152.5
Dredgers**, seaweed harvesters												
declared landings	11.9	7.6	3.0	2.5	0.6	0.3	23.0	13.3	10.9	10.7	49.4	34.5
estimated landings	20.3	13.8	6.1	5.6	1.3	0.7	31.8	20.9	10.9	10.7	70.4	51.7
Total fleet												
declared landings	343.4	106.0	62.7	30.4	21.7	4.3	23.0	13.3	10.9	10.7	461.6	164.7
estimated landings	434.9	158.5	128.8	60.6	25.1	5.2	31.9	20.9	10.9	10.7	631.6	255.9

* Longliners, handliners, potters, potters-netters, netters. **Dredgers, dredgers-longliners. Sources : Ifremer / Ofimer / own elaboration.

Table 11. Structure of the Iroise fleet and structure by group of boats of the catches realised in the Iroise area*

	Iroise fleet		Value of landings from the Iroise area : structure by group of boats					
	Number of boats	Structure	Finfish	Crustaceans	Cephalopods	Shellfish	Seaweeds	All species
Trawlers, purse seiners	64	19%	30%	1%	86%	-	-	20%
Liners, potters, netters	175	51%	61%	90%	2%	-	-	60%
Dredgers, seaweed harvesters	105	30%	9%	9%	12%	100%	100%	20%
Total fleet	344	100%	100%	100%	100%	100%	100%	100%

* Calculation based on estimated landings. Sources : Ifremer / Ofimer / own elaboration.

Table 12. Dependence of the fleet on the Iroise area and structure by group of species of the catches realised in the Iroise area*

	Dependence on the Iroise area**	Value of landings from the Iroise area : structure by group of species					
		Finfish	Crustaceans	Cephalopods	Shellfish	Seaweeds	All species
Trawlers, purse seiners	16%	91%	1%	8%	-	-	100%
Liners, potters, netters	62%	63%	36%	1%	-	-	100%
Dredgers, seaweed harvesters	73%	27%	11%	1%	40%	21%	100%
Total fleet	41%	62%	24%	2%	8%	4%	100%

* Calculation based on estimated landings. ** Value of catches in the Iroise area / value of total catches. Sources : Ifremer / Ofimer / own elaboration.

In table 10, two values are given for each category of landings : one is based on declared landings, the other on estimated landings (see former section). According to the method adopted, the overall value of catches realised by commercial fishing boats in the Iroise area is estimated at 165 or 256 million FF (25 or 39 million euro) in 2000, represent respectively 36% and 41% of the total estimated value of the catches realised by the fleet in all areas. Revaluing landings affects more catches which are realised in the Iroise area than other catches, because the groups of boats with the lowest quality of declared landings statistics are usually the most dependent on the area (excepted for seaweed harvesters). Figures in tables 11 and 12 have been calculated on the basis of estimated landings.

According to this basis of calculation, finfish represent 62% of the overall value of the catches realised in the Iroise area. The second group of species is crustaceans, with 24% of the overall value of catches realised in the area. They are followed by shellfish (8%), seaweeds (4%) and cephalopods (4%).

Trawlers and seiners, which form 19% of the total number of boats in the fleet, represent a similar proportion of the overall value of catches realised in the Iroise area. Their contribution to landings is concentrated on finfish (some 90% of the total value of their catches in the area, and 30% of the total value of finfish caught in the area). Cephalopods are a secondary target (8% of the total value of their catches in the area, but 86% of the total value of cephalopods caught in the area). The dependence of trawlers and seiners on the Iroise area is low : this area contributes only to 16% of their total turnover.

Liners, potters and netters form half of the total number of boats in the fleet, and contribute to some 60% of the overall value of catches realised in the Iroise area. This contribution is concentrated on finfish (63% of the total value of their catches in the area, and 61% of the total value of finfish caught in the area) and crustaceans (36% of the total value of their catches in the area, representing up to 90% of the total value of crustaceans caught in the area). The degree of dependence of liners, potters and netters on the Iroise area is important on the average (62% of their total turnover).

Dredgers and seaweed harvesters form 30% of the total number of boats in the fleet, but contribute only to 20% of the overall value of catches in the Iroise area. This contribution is diversified, with shellfish in the first place (40% of the overall value of their catches in the area, representing 100% of the total value of shellfish caught in the area), followed by finfish (27% of the overall value of their catches in the area, but only 9% of the total value of finfish caught in the area), seaweed (21% of the overall value of their catches in the area, representing 100% of the total value of kelps harvested by boats in the area), and crustaceans (11% of the overall value of their catches in the area, and 9% of the total value of crustaceans caught in the area). The dependence of dredgers and seaweed harvesters on the Iroise area is high (73% of their total turnover). For seaweed harvesters, the dependence is almost 100%.

According to a sample survey realised by Ifremer in 2001, an average of some 900 fishermen worked onboard the ships composing the Iroise fleet in 2000[1]. 43% of this number, i.e. some 390 men, worked on boats under 12 metres long, and therefore had a job highly dependent on the Iroise fishery.

Table 13. Estimation of the number of men working on board the ships composing the Iroise fleet (2000)

[1] Data provided by Olivier Guyader and Olivier Thébaud.

Boat length class	Boats		Fishermen		Average crew size
	Number	%	Number	%	
under 12 metres	240	70%	389	43%	1.6
12 to 16 metres	39	11%	144	16%	3.7
16 metres and over	65	19%	370	41%	5.7
Total	344	100%	903	100%	2.6

Source : Ifremer.

Commercial fishing and seaweed harvesting in the Iroise area are also exerted by fishers and harvesters operating on foot on the strand or in shallow coastal waters. These activities concern shellfish dredging along the sandy beaches of the Bay of Douarnenez (targeted species is *Donax trunculus*) and harvesting of various seaweeds on the rocky coast of the north of the Iroise area. Estimations concerning these activities are summed up in the table below[1]. For the year 1998, the global revenue they generate these is estimated at some 10 million FF (1.5 million euro), i.e. approximately 4% of the value of the catches realised in the Iroise area by commercial fishing boats (year 2000)[2]. The number of jobs generated by Donax dredging was 25 in 1998. Assessing the number of jobs generated by seaweed harvesting is uneasy, due to the part time (seasonal, occasional) character of the activity.

Table 14. Activity of commercial fishermen operating on foot. Estimation, year 1998

Harvested species	Number of harvesters*	Harvested quantities (tons)**	Unit price (FF / kg)	Revenue (million FF)
Seaweeds (North Finistère)				
Laminaria digitata, L. hyperborea (wrecked)	51	1214	0.22	0.27
Chondrus crispus, Mastocarpus stellatus	800	1295	1.32	1.70
Ascophyllum nodosum, Fucus vesiculosus, F. serratus	39	7000	0.20	1.40
Edible seaweeds	*n.a.*	293	2.50	0.73
Total	-	9802	0.42	4.11
Shellfish (bay of Douarnenez)				
Donax trunculus	25	290	20.00	5.80

* seaweeds : seasonal or occasional (figures should not be aggregated). ** seaweeds : fresh weight. Source : Ifremer.

Commercial fishing generates also indirect jobs in upstream and downstream activities. In the most favourable cases, these jobs may be assessed directly. The only such case concerning the Iroise fishery is constituted by 140 jobs (year 2000) in the two plants which process the kelps landed by seaweed harvesting boats (plus a part of the seaweeds collected by harvesters operating on foot). Other indirect jobs (fish auction markets, wholesalers, shipyards, ship chandlers...) have to be assessed indirectly. According to a recent survey (Anon., 2000/2), the number of such jobs in the employment area of Brest (a coastal area the coast of which corresponds approximately to that of the Iroise Sea) amounted to 30% of the total number of direct jobs in the local fishing industry. Applying this ratio to the number of jobs which are highly dependent on the Iroise fishery leads to a rough assessment of some 120 indirect jobs generated by the Iroise fishery. The following table sums up the estimations concerning the number of direct and indirect jobs which may be considered as highly dependent on the fishery.

Table 15. Estimation of the number of jobs highly dependent on the Iroise commercial fishery

Type of jobs	Estimated number

[1] Pierre Arzel provided data concerning seaweeds, and Gérard Véron data concerning Donax.

[2] The area covered by data concerning seaweeds is more extensive than the shore of the Iroise sea *stricto sensu*, but it corresponds approximately to that of the area called « Iroise area » in this section.

direct	onboard ships under 12 metres long	390
	fishers and harvesters operating on foot (full time equivalent)	50
indirect	kelps processing plants	140
	Other	120
Total		700

Source : own elaboration.

- Estimating the profitability of groups of boats operating in the Iroise area

In order to assess the economic performance of boats operating the Iroise fishery, a twofold economic sample survey was realised by CEDEM in 2000 : the first part[1] was dedicated to boats using only fixed gears (nets, pots, handlines, longlines), and the second part[2] to the interrelated fleets of shellfish dredgers and seaweed harvesters. The survey covers the part of the fleet operating exclusively or mainly in the Iroise area (including the Bay of Brest). It leaves trawlers and purse-seiners out of its scope, these boats frequenting more occasionally the area. A more comprehensive sample survey was realised in 2001 by IFREMER. Its results are still in process at the moment of writing the present report.

Both surveys were realised according to a unified methodology, based on face-to face interviews of skippers-owners. The questionnaire is of the same type as the ones used by CEDEM and IFREMER in more general field surveys of French commercial fishing fleets of the English Channel and Atlantic (Boncoeur and Le Gallic, 1998 ; Boncoeur, Le Floc'h, Le Gallic and Giguelay, 2000 ; Berthou, Daurès and Guyader, 2001). It is mainly aimed at getting information on the following topics :

- boat activity (gears used, fishing time and area) ;
- turnover and operating costs, by type of activity ;
- marketing channels ;
- physical description and economic valuation of capital ;
- crew and crew costs.

The two following tables present the sample of the CEDEM survey, and compare it to the main population :

Table 16. Sample and main population of the economic field survey of the Iroise fleet (CEDEM, 2000)

	Number of boats		Sampling rate
	[1] Sample*	[2] Main population**	[1] / [2]
Seaweed harvesters	35	42	83%
Dredgers*	25	63	40%
potters, netters, liners***	29	175	17%
Total	89	280	32%

* Dredgers and dredgers-longliners. *** Potters, potters-netters, netters, handliners, longliners.
Sources : CEDEM (sample) / IFREMER (main population).

Table 17. Compared length and age of the boats of the sample and main population

[1] realised by Pascal Le Floc'h and Michel Le Duff.
[2] realised by Frédérique Alban.

	Average length (metres)		Average building year	
	Sample	Main population	Sample	Main population
Seaweed harvesters	10.1	9.9	1982	1983
Dredgers	9.1	9.4	1975	1978
Fixed gears	8.8	9.9	1981	1980

Sources : CEDEM (sample) / IFREMER (main population).

The gap between sampling rates is mainly due to the fact that surveying dredgers and seaweed harvesters could make use of additional means, provided by the funding of two specific surveys (Alban 2001/1 and 2001/2). The average length and age of boats in the sample are close to that of the main population, with a provision for the group of netters / potters / liners, where the average length is only 8.8 metres in the sample, against 9.9 metres in the main population.

The survey results are presented hereafter according to the following criteria :

1. main activity or combination of activities :
    - seaweed harvesting ;
    - seaweed harvesting, in combination with dredging in the Bay of Brest ;
    - dredging (usually in combination with fixed gears) ;
    - fixed gears (nets, pots and lines) only.
2. length class :
    - under 10 metres long ;
    - 10 metres long and over.

Making use of the first criterion results in splitting the group of seaweed harvesters into two parts, an operation which is justified by the fact that seaweed harvesters usually have only a seasonal activity, except for the ones which combine their summer seaweed harvesting activity with winter shellfish dredging (usually in the Bay of Brest). The second criterion is applied to all groups of boats except dredgers, since only 2 units in this group are over 10 metres long, and none is over 11 metres long.

The following tables describe the production factors used for fishing, the activity resulting from their combination, the sales which this activity provides, and some indicators of the resulting economic performance of the fleet.

Table 18. Economic field survey of the Iroise fleet : technical characteristics of the boats

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Length (metres)							
– **mean**	**8.8**	**11.7**	**9.0**	**10.8**	**9.1**	**7.8**	**11.4**
– standard-deviation	0.7	0.7	0.6	0.8	0.8	1.0	0.9
GRT							
– **mean**	**8.8**	**17.3**	**8.6**	**13.7**	**7.8**	**4.5**	**14.2**
– standard-deviation	1.2	7.1	1.1	5.9	2.7	1.5	4.6
HP (kW)							
– **mean**	**45**	**113**	**55**	**105**	**85**	**64**	**168**
– standard-deviation	9	31	16	24	32	37	69
Age in 2000 (years)							
– **mean**	**19.4**	**18.3**	**17.6**	**16.7**	**25.2**	**21.5**	**12.5**
– standard-deviation	4.0	9.3	7.7	8.6	8.7	10.2	5.6

Source : CEDEM.

According to the above table, the physical characteristics of the two groups of seaweed harvesters are similar, with a provision for the largest « pure » seaweed harvesters, which are too large for being authorised to participate in the Bay of Brest shellfish fishery. The main difference between seaweed harvesters (lato sensu) and the other boats in the fleet is a higher ratio of GRT to HP. Dredgers are the oldest group in the fleet (25.5 years old on the average) and, at the opposite, netters / potters / liners over 10 metres long are significantly more recent (12.5 years old on average) than the rest of the fleet. For every physical characteristic, the relative difference between the two length classes is more important among netters / potters / liners than among the rest of the fleet.

The following table describes the insured value of boats, the average size of their crew and the resulting capital / labour ratio :

Table 19. Economic field survey of the Iroise fleet : fixed capital and manpower

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Boat insured value (‘000 FF)							
– **mean**	**284**	**607**	**468**	**772**	**454**	**269**	**1425**
– standard-deviation	181	223	221	315	288	174	625
Number of men on board*							
– **mean**	1.0	1.2	1.1	1.5	1.7	1.1	3.4
– standard-deviation	0.0	0.6	0.3	0.4	0.5	0.3	0.9
Capital /labour ratio**							
– **mean**	**284**	**472**	**410**	**524**	**270**	**245**	**422**
– standard-deviation	181	221	223	234	175	179	103

* average, including skipper.** Insured boat value / number of men onboard. Source : CEDEM.

The average insured boat value spreads from 269 thousands of French francs (41000 Euros) for netters / potters / liners under 10 metres to 1425 KF (217000 Euros) for the same type of boats, over 10 metres. The average number of men on board is between one and two for all groups of boats, except for netters / potters / liners over 10 metres, where it reaches 3.4. As usual, the capital / manpower ratio tends to increase with the size of the boats.

Table 20. Economic field survey of the Iroise fleet : activity

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Yearly number of days at sea							
– **mean**	**77**	**100**	**145**	**156**	**185**	**190**	**186**
– standard-deviation	29	37	44	56	53	34	22
Yearly number of hours at sea							
– **mean**	542	1046	1000	1214	1483	1729	2063
– standard-deviation	186	575	152	323	744	588	320
Hours at sea / day (average)							
– **mean**	**7.0**	**10.4**	**6.9**	**7.8**	**8.1**	**9.1**	**11.1**
– standard-deviation	1.3	2.7	1.5	1.8	3.4	2.3	1.7
% of fishing time in the 12 NM	100%	100%	100%	100%	100%	98%	64%

Source : CEDEM.

All boats under survey, except the largest netters / potters / liners, are purely inshore. Even these last ones spend approximately two thirds of their fishing time within the 12 NM limit of territorial waters. The average duration of trips reflects this pattern, with days at sea between 7 and 10 hours on the average, except for netters / potters / liners over 10 metres long, where it reaches 11 hours. The yearly number of days at sea is significantly lower for « pure » seaweed harvesters than for other boats, because of the seasonal character of this activity. Even for seaweed-harvesters dredgers, it is somewhat shorter than for other dredgers or boats using fixed gears, because of the periods of inactivity between the campaigns of seaweed harvesting and shellfish dredging.

Table 21. Economic field survey of the Iroise fleet : sales

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Yearly turnover (‘000 FF)							
– **mean**	**139**	**434**	**338**	**618**	**599**	**251**	**1436**
– standard-deviation	33	249	113	199	395	127	766
Average per day at sea (FF)							
– **mean**	1800	4323	2321	3953	3243	1325	7711
– standard-deviation	724	2196	805	1506	2075	642	3961
Average per hour at sea (FF)							
– **mean**	**256**	**414**	**338**	**509**	**404**	**145**	**696**
– standard-deviation	103	113	108	218	174	75	348

Source : CEDEM.

Annual sales stretch between 139 KF (21000 euros) for the smallest seaweed harvesters and 1436 KF (219000 euros) for the largest netters / potters / liners. The limited amount of sales realised by « pure » seaweed harvesters is related to the seasonal character of their activity. Taking time at sea into account reduces the spread between lower and higher average turnovers. Annual turnover is significantly lower than boat insured value for seaweed harvesters (specially « pure » ones), approximately at the same level for netters / potters / liners, and significantly higher (by 32%) for dredgers.

Table 22. Economic field survey of the Iroise fleet : composition of sales by groups of species*

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Seaweeds	100%	89%	56%	56%	-	-	-
Shellfish	-	6%	40%	42%	35%	-	-
Finfish, crustaceans, cephalopods	-	5%	4%	2%	65%	100%	100%
Total	100%	100%	100%	100%	100%	100%	100%

* % of total sales. Source : CEDEM.

For « pure » seaweed harvesters, the bulk of revenue is provided by kelps (mainly *L. digitata*). For seaweed harvesters-dredgers, shellfish landings (mainly common scallops and warty venus) provide some 40% of the annual revenue. This share is more important than among other dredgers, where it reaches no more than 35%. These boats get approximately two thirds of the annual revenue from landings of finfish, crustaceans and cephalopods caught in the Iroise Sea during the summer season. The same type of landings provides 100% of the annual revenue of netters / potters / liners.

Table 23. Economic field survey of the Iroise fleet : opinions of skippers-owners concerning sales trend over the last 5 years

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
upward*	40%	43%	42%	36%	44%	43%	75%
stable*	0%	29%	41%	55%	44%	38%	25%
downward*	60%	28%	17%	9%	12%	19%	0%
Total	100%	100%	100%	100%	100%	100%	100%

* Frequencies of answer. Source : CEDEM.

In the group of « pure » seaweed harvesters under 10 metres long, 60% of skippers-owners consider the evolution of their revenue has been negative over the last 5 years. This percentage is only 28% among skippers-owners of « pure » seaweed harvesters over 10 metres, and is under 20% in all groups of boats. The negative opinion concerning the evolution of sales is particularly low in the groups of seaweed harvesters-dredgers over 10 metres (9%), dredgers (12%) and netters / potters / liners over 10 metres (0%). In this last group, the frequency of positive opinions reaches 75%. These answers reflect both a specific problem concerning the seaweed harvesting industry (Alban et al., 2001/1) and, more generally, a better ability of larger boats to take advantage of the conditions prevailing in the area[1].

Table 24. Economic field survey of the Iroise fleet : marketing channels*

Activity	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
Length class	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
Processing plants	100%	89%	56%	56%	-	-	-
Fish auction markets	-	3%	36%	30%	34%	65%	12%
Direct sales to wholesalers	-	7%	3%	7%	49%	16%	88%
Fish mongers, households, restaurants	-	1%	5%	7%	17%	19%	0%
Total	100%	100%	100%	100%	100%	100%	100%

* % of total turnover. Source : CEDEM.

All kelps landed by seaweed harvesting boats are directly sold to two processing plants located in the area. Other types of landings are sold through different marketing channels : fish auction markets or direct sales to wholesalers, retail fishmongers, households or restaurants. The variety of these marketing channels is not a favourable condition to the transparency of landings (see former section).

The following table displays revenues, economic costs, and the resulting economic performance indicators. The following methodological points should be stressed :

- in the « share system » characterising labour remuneration within artisan fisheries, wages are calculated as a predefined share of the balance of net sales (gross sales minus landing taxes) and some so-called « common costs » (usually fuel, food, ice, bait - if any -) ; in French fisheries, the skipper receives a part of the « crew share » even if he is the owner of the boat ; however, when he is alone on board, the share system is not always used ; in order to prevent resulting distortions, it has been assumed in the survey that this system

[1] Part of these conditions may be the result of non-neutral regulations (Alban, Le Floc'h and Boncoeur, 2002).

always applied ; as a result, the major part of the wages costs in the above table are non cash costs ;

- wage costs include national insurance contribution ;
- taxes are composed of landing taxes, yearly license costs (including, for boats participating in the Bay of Brest shellfish fishery, a special contribution to the aquaculture scallop production program) and other taxes ;
- capital depreciation was calculated according to an economic method based on the average economic life span of fixed capital (see Boncoeur and Le Gallic, 1998), and not to book-keeping methods.

Table 25. Economic field survey of the Iroise fleet : costs and economic performance, per boat

	Seaweed harvesters				Seaweed harvesters - dredgers				Dredgers		Netters, potters, liners			
	< 10 m.		≥ 10 m.		< 10 m.		≥ 10 m.				< 10 m.		≥ 10 m.	
	KF	%*	KF	%*	KF	%*	KF	%*	KF	%*	KF	%*	KF	%*
Turnover														
- mean	**139**	100%	**434**	100%	**338**	100%	**618**	100%	**599**	100%	**251**	100%	**1436**	100%
-std.dev.	33		249		113		199		395		127		766	
Interm. consumption[a]														
- mean	**42**	30%	**113**	26%	**111**	33%	**148**	24%	**139**	23%	**67**	27%	**347**	24%
-std.dev.	26		49		60		55		101		28		88	
Added value[b]														
- mean	**96**	70%	**321**	74%	**226**	67%	**470**	76%	**461**	77%	**184**	73%	**1089**	76%
-std.dev.	18		209		83		170		315		110		715	
Wage costs[c]														
- mean	**78**	56%	**211**	49%	**173**	51%	**288**	47%	**290**	48%	**133**	53%	**672**	47%
-std.dev.	18		99		50		79		166		59		372	
Taxes[d]														
- mean	**3**	2%	**8**	2%	**41**	12%	**51**	8%	**49**	8%	**15**	6%	**58**	4%
-std.dev.	ε		4		4		7		13		11		24	
Gross operation margin[e]														
- mean	**16**	12%	**102**	23%	**13**	4%	**131**	21%	**122**	20%	**36**	15%	**360**	25%
-std.dev.	13		115		37		105		150		46		334	
Capital depreciation[f]														
- mean	**16**	12%	**39**	9%	**25**	8%	**43**	7%	**32**	5%	**23**	3%	**63**	4%
-std.dev.	8		19		9		13		15		11		23	
Full equity profit[g]														
- mean	**0**	0%	**63**	15%	**-13**	-4%	**88**	14%	**90**	15%	**13**	5%	**297**	21%
-std.dev.	12		105		36		98		143		42		320	
Profit rate[h]														
- weighted mean	**0%**		**10%**		**-3%**		**11%**		**20%**		**5%**		**21%**	
- weighted std.dev.	5%		11%		7%		12%		26%		18%		15%	

* % of turnover. [a] Intermediate consumption = non durable goods (fuel, bait, ice, gears...) and external services (management, insurance...) consumed in the productive process. [b] Turnover - intermediate consumptions. [c] Including skipper. [d] Yearly cost of licence, landing taxes and other taxes. [e] Added value - wage costs and taxes. [f] Estimated on the basis of normal life span of fixed capital. [g] Gross margin - capital depreciation. [h] Full equity profit / boat insured value. Source : CEDEM.

According to the above table, two main features concerning boat profitability may be noted :

- profitability is lower in seaweed harvesting than in other activities[1] ;
- whatever the activity, profitability is higher among boats over 10 metres than among smaller boats.

[1] The profitability of « pure » seaweed harvesters is affected by the fact that most of these boats are used only seasonally. The negative impact of seaweed harvesting on boat profitability may be better appreciated by comparing the profitability of seaweed harvesters-dredgers with that of other dredgers.

Due to the particular features of small-scale fisheries, the economic significance of classical indicators such as the rate of profit is questionable (Boncoeur, Coglan, Le Gallic and Pascoe, 2000). An alternative performance indicator is the so-called « skipper-owner's net activity income », composed of net incomes received by the skipper-owner both through the crew-share (net wage) and the owner-share (full equity profit), minus the opportunity cost of capital invested in the boat. This income represents the remuneration the skipper-owner gets form his fishing activity, both as a fisherman and as an entrepreneur. In the following table, the opportunity cost of capital was estimated multiplying the boat insured value by a 8% interest rate (for a discussion of the interest rate to be taken in such calculations, see Boncoeur Coglan, Le Gallic and Pascoe, 2000).

Table 26. Skipper-owner's net activity income ('000 FF / year)

	Seaweed harvesters		Seaweed harvesters - dredgers		Dredgers	Netters, potters, liners	
	< 10 m.	≥ 10 m.	< 10 m.	≥ 10 m.		< 10 m.	≥ 10 m.
[1] Skipper's net wage*							
– **mean**	**57**	**122**	**114**	**153**	**134**	**88**	**200**
– standard-deviation	16	42	58	37	65	58	92
[2] Full equity profit							
– **mean**	**0**	**63**	**-13**	**88**	**90**	**13**	**297**
– standard-deviation	12	105	36	98	143	42	320
[3] Total ([1]+ [2])							
– **mean**	**57**	**185**	**102**	**241**	**224**	**101**	**497**
– standard-deviation	18	138	84	108	193	97	320
[4] Capital opportunity cost*							
– **mean**	**23**	**49**	**37**	**62**	**36**	**22**	**114**
– standard-deviation	15	18	18	25	23	14	50
[5] **Net activity income ([3] - [4])**							
– **mean**	**34**	**136**	**64**	**179**	**188**	**79**	**383**
– standard-deviation	28	133	80	100	177	94	374

* Gross wage minus national insurance contribution. ** 8% of boat insured value. Source : CEDEM.

The results displayed in the above table confirm the main features that were obtained before :

- net activity income is lower on the average in seaweed harvesting than in other activities (however, it should be reminded that for most « pure » seaweed harvesters - specially the ones under 10 metres long -, the income provided by the operating of the boat is only seasonal) ;
- taking into account capital opportunity cost does not prevent the net activity income of skipper-owner to be significantly higher on boats over 10 metres than on smaller boats : 4 times higher on the average in the group of « pure » seaweed harvesters, 2.8 times higher for seaweed harvesters-dredgers, and up to 4.8 times higher in the group of netters / potters / liners.

1.3. Description of recreational activities

The following description is composed of three parts, devoted to partly overlapping activities:

1. tourism ;
2. yachting ;
3. recreational fishing.

1.3.1. Tourism[1]

Tourism is an important activity in Brittany, and the creation of a marine national park in the Iroise sea might influence the frequenting of the nearby area by tourists[2].

Assessing the importance of tourism and related economic activities in a given area often raises difficult problems, concerning the measurement of the presence of tourists, or due to the fact that no well defined industry corresponds to « tourism ». This section sums up available information concerning the tourists housing capacity, the number, profile and behaviour of tourists, and the economic impact of tourism in the area neighbouring the Iroise sea.

A survey realised during the preliminary phase of the process leading to the creation of a marine park in the Iroise Sea gives some information concerning the tourists housing capacity of the Iroise islands and mainland coastal zone (Anon., 1999/1).

Table 27. Identified tourists housing capacity in the Iroise neighbouring area

	Whole area			Islands		
Type of housing	number of persons	structure	% Finistère	number of persons	structure	% Iroise
Hotels	3 098	3 %	23 %	142	4 %	5 %
Labelled camping grounds	23 778	23 %	23 %	300	8 %	1 %
Labelled rooms for rent	3 292	3 %	26 %	54	1 %	2 %
Collective housing	5 933	6 %	*n.a.*	85	2 %	1 %
Total identified commercial housing	36 101	35%	23% [a]	581	15%	2 %
Second homes	66 515	65 %	25 %	3 345	85 %	5 %
Total identified housing	102 616	100%	24% [a]	3 926	100%	4 %

[a] Collective housing excepted.. Source : Anon., 1999/1.

With an identified tourists housing capacity of more than 100 000 persons, the coast of the Iroise sea concentrates approximately 25% of the total identified capacity of the department of Finistère (western end of Brittany). More than 95% of this capacity is located on the continent. The bulk of identified capacity consists in second homes, and labelled camping grounds. The ratio of tourist housing capacity to permanent population (97 500 persons in 1999) is slightly above 1 in this area, i.e. twice the average ratio for the whole region of Brittany. Moreover, the above figures underrate reality, because they leave some types of housing out of their scope. Probably the most important one is the housing provided by family or relatives who live in the area (at the national scale, more than half of all French tourists make use of this type of housing for their holidays, according to Anon., 1999/1).

The number of tourists visiting the inhabited islands of the Iroise sea (Ouessant, Molène and Sein) may be assessed on the basis of the statistics held by the maritime and air transport companies[3]:

[1] This section, based on literature review, was written by Jean Boncoeur.
[2] In French statistics, tourists are defined as persons out of their home for at least 24 hours and no more than 4 months, whether for personal, leisure or business reasons (Anon., 1979).
[3] Tourists may be distinguished from islanders because they pay different prices for their tickets.

Table 28. Number of tourists visiting the Iroise Sea inhabited islands (year 1998)

Means of transportation	Ouessant	Molène	Sein	Total
Boat	203 689	46 877	97 053	347 619
Aircraft	9 945	-	-	9 945
Total	213 634	46 877	97 053	357 564

Source : Anon., 1999/1.

Visiting the islands is highly concentrated during the summer season. If a majority tourists do not stay overnight in the island they visit, between 5900 and 6600 persons are estimated to live on the islands during the months of July and August, i.e. more than four times their permanent population.

Except for the islands of Ouessant, Molène and Sein, there is no quantitative knowledge of the frequenting of the Iroise neighbouring area by tourists. For the mainland part of this zone, only an indirect, incomplete and rough estimation may be given. This estimation is based on the tourists housing capacity of the area (see above) and a field survey of the frequenting of department of Finistère by tourists (Anon., 1998/1) based on the so-called « flow method », implying an exhaustive counting, during a long time period, of the number of persons entering and leaving the area under survey (Carreno, 1988). According to this survey, the number of overnight stays by tourists coming from outside the department was the following in 1996 and 1997 :

Table 29. Department of Finistère : overnight stays by tourists from outside the department

Year		1996	1997
Total overnight stays[a] (million)		34.155	32.340
Seasonal pattern :	January-February-March	5 %	6 %
	April-May-June	21 %	19 %
	July-August	63 %	62 %
	September	6 %	8 %
	October-November-December	5 %	5 %
	Total	100 %	100 %

[a] 1 overnight stay = 1 person during 1 night. Source : Anon., 1998/1.

Amounting to some 33 million overnight stays per year in 1996-97, the frequenting of Finistère by tourists coming from outside the department is mainly concentrated on the summer season : nearly two thirds of the total overnight stays are in July-August (so called « high season »). The so-called « tourism season », which, *lato sensu*, covers the period between April and September, concentrates some 90% of the frequenting of Finistère by tourists.

According to above mentioned statistics, (identified) housing capacity in the Iroise neighbouring area (a subset of department of Finistère) represents some 25% of the total capacity of the department. Assuming that the yearly occupation rate of tourists housing capacity is similar in both areas, we may roughly estimate that the number of overnight stays was around 8.3 million per year in the Iroise neighbouring area during the years 1996-97. During the « high season » the same method leads to an estimation of some 83000 overnight stays *per day* (i.e. approximately twice the permanently resident population of the area). It should be stressed that these estimations are dependent on assumptions of homogeneity between the Iroise zone and the whole department of Finistère. Moreover, they do not take into account the frequenting of the zone by tourists coming from inside the department (« neighbourhood tourism »), a significant phenomenon in the area under survey.

Shifting from the number of overnight stays to the number of tourists implies taking into account the duration of overnight stays. No information on this subject is available at the scale of the Iroise neighbouring area, and the closest available proxy is to be found in the results of a sample survey conducted at the scale of the Brittany region during the April to September period in 1997 (Anon., 1998/2). According to the results of this survey, tourists visiting the department of Finistère during this period stayed there for 8.9 days on the average. Making the same homogeneity assumption as above leads to an estimation of some 800 000 tourists (from outside the department) staying in the Iroise neighbouring area during the « tourist season » in 1997. The approximate character of this result is increased by the heterogeneity of the populations concerned by the two surveys on which it is based : while the Finistère 1996-97 « flow » survey concerns all tourists from outside the department of Finistère, the scope of the Brittany April-to-September 1997 sample survey is limited to the population of tourists coming from outside the Brittany region.

The main source of information concerning the profile, motivation and behaviour of tourists visiting Finistère is to be found in the above mentioned Brittany April-to-September 1997 sample survey, the results of which are detailed according to the department of stay (4 tables below).

Table 30. Profile of tourists from outside Brittany visiting Finistère, April to September 1997.

		% of total answers
Geographic origin	France	77 %
	Foreign countries	23 %
Age of answering person (years)	15-25	7 %
	25-34	17 %
	35-44	28 %
	45-54	23 %
	55-64	13 %
	65 and over	12 %
Socio-economic category of answering person	Farmers	1 %
	Other entrepreneurs	8 %
	White collars (senior and non-wage)	24 %
	White collars (intermediate)	24 %
	Employees	11 %
	Blue collars	8 %
	Retired	17 %
	Other	7 %
Persons travelling together	travelling alone	9 %
	Couple	34 %
	With children	48 %
	Other groups	9 %
Main reason for the visit	Leisure / holidays	76%
	Family reasons	16%
	Visiting friends	3%
	Business	2%
	Other	3%

Source : Anon. 1998/2.

Table 31. Tourists from outside Brittany visiting Finistère, April to September 1997 : consumption related to the stay

Average daily expenditure, per person	170 FF
Average duration of the stay	8.9 days
Average number of persons in the group	2.4 persons
Average budget of the group for the stay	3600 FF
Total number of groups of tourists visiting Finistère during the tourist season	1 million
Cumulated expenditure during the season	3.6 billion FF
Structure of the expenditure related to the stay :	
– Food	39%
– Housing	32%
– Consumption goods other than food	13%
– Travelling inside the department	9%
– Leisure and entertainment	7%
– Total	100%

* All types of expenditures within the department, except entry and exit transportation costs. Source : Anon. 1998/2.

Table 32. Tourists from outside Brittany visiting Finistère for leisure / holiday, April to September 1997 : main motivations concerning the staying place (two answers)

	1st answer*	2nd answer**	average***
Natural heritage	29 %	0 %	14.5 %
Practice of sea related activities	26 %	11 %	18.5 %
Cultural heritage	9 %	3 %	6.0 %
Family or relatives living in the area	6 %	26 %	16.0 %
Architectural heritage	6 %	3 %	4.5 %
Climate	6 %	5 %	5.5 %
Food	3 %	6 %	4.5 %
Not too many tourists in the area	2 %	4 %	3.0 %
Proximity of home	2 %	6 %	4.0 %
Festivals, celebrations, etc.	1 %	2 %	1.5 %
Good prices	1 %	1 %	1.0 %
Discovering a new place	1 %	24 %	12.5 %
Other	0 %	1 %	0.5 %
No answer	7 %	7 %	7.0 %
Total	100 %	100 %	100.0 %

* % of total first answers. ** % of total second answers. *** average of answers 1 and 2. Source : Anon. 1998/2.

Table 33. Tourists from outside Brittany visiting Finistère for leisure / holiday, April to September 1997 : main activities practised (two answers)

	1st answer*	2nd answer**	average***
Outing, hiking	39 %	22 %	30.5 %
Staying on the beach and sea bathing	19 %	15 %	17.0 %
Visiting beauty spots and places of interest	12 %	24 %	18.0 %
Relaxing	11 %	13 %	12.0 %
Sports	6 %	4 %	5.0 %
Festivals, shows	2 %	4 %	3.0 %
Visiting the islands	1 %	3 %	2.0 %
Meeting family and friends	2 %	0 %	1.0 %
Sailing	1 %	1 %	1.0 %
Other	6 %	11 %	8.5 %
No answer	1 %	3 %	2.0 %
Total	100 %	100 %	100.0 %

* % of total first answers. ** % of total second answers. *** average of answers 1 and 2. Source : Anon. 1998/2.

According to the above tables, for most tourists visiting Finistère during the April to September season (which, as noted before, concentrates the bulk of tourists visits to this department), the main reason for the visit is related to leisure and holidays. Business tourism represents only a marginal proportion of the overnight stays. The main declared motivations for staying in Finistère are natural heritage and the possibility of practising sea related activities. The main declared activities during the stay are outing and hiking, staying on the beaches and sea bathing, and visiting beauty spots and places of interest. The global estimated expenditure of these tourists in the department is 3600 million FF (550 million euros), mainly consisting in food and housing expenditures. Making the same homogeneity assumption as above leads to a rough estimation of 900 million FF (137 million euros) for the overall consumption expenditure of tourists (from outside Brittany) in the Iroise neighbouring area during the tourist season.

According to a survey realised by INSEE, tourism in the department of Finistère generates, on a yearly average basis, some 6700 wage jobs, representing 2.62% of the total number of wage jobs in the department (Kerouanton, 1998). This employment is strongly influenced by the seasonal pattern of tourism : during the so-called « high season » (July-August), the number of wage jobs generated by tourism reaches a peak of 16370, according to the same survey. The INSEE estimation is detailed by municipalities. For the municipalities belonging to the Iroise surrounding area, the corresponding estimation is 1024 wage jobs on a yearly average basis, and 2457 wage jobs during the « high season » (Anon., 1999/1). Making use of the proportion between non-wage jobs and wage jobs in the main activities concerned by the consumption of tourists[1] leads to an overall estimation of some 1500 jobs generated by tourism in the Iroise neighbouring area on an average calculation basis, and 3500 jobs during the « high season ».

1.3.2. Yachting and sailing[2]

This section sums up recent available information concerning the leisure boat harbouring capacity of the Iroise area, the number of resident leisure boats in the area, the number of visiting leisure boats, the activity of sailing clubs, and estimations of the economic impact of yachting in the Iroise area.

The leisure boat capacity of marinas in Brittany has been surveyed in 2001 by the regional association of marinas (APPB). In this survey (Anon., 2001/3), data concerning marinas have been complemented by an estimation of harbouring capacities outside marinas. In the following table, figures concerning the Iroise area have been extracted from the survey :

Table 34.
Overall leisure boat harbouring capacity in the Iroise area and in Brittany (1998-99)

Number of boat places	Iroise area	Brittany	Iroise / Brittany
Marinas	4813	33025	15%
Other organised moorings	3129	18693	17%
Individual authorised moorings	461	4177	11%
Authorised capacity (total)	8403	55895	15%
Unauthorised moorings	2215	*n.a.*	*n.a.*
Total capacity	10618	*n.a.*	*n.a.*

Source : Anon., 2001/3.

[1] Housing and catering, retail stores, leisure, transportation. In these industries, non-wage jobs represent approximately 30% of total employment, on the average.
[2] This section, based on literature review, was written by Jean Boncoeur.

The harbouring capacity of marinas in the Iroise area amounts to 4813 places, representing 15% of the regional capacity. But the estimated overall capacity for the Iroise area is 10618 places, due to an important number of mooring places outside marinas (5805), many of them (2215) settled without administrative authorisation[1]. The importance of these unauthorised settlements in the Iroise area might be a cause of concern for the regulating authority of the future national marine park.

The number of resident boats in the area is unknown. Administrative statistics of registered leisure boats are of little help, because they scarcely take into account the decommissioning of older units (specially the smallest ones[2]), and therefore strongly overvalue the actual number of boats in a given area. The problem mainly lies with boats moored outside marinas, as the fleet harboured in marinas is well documented (Anon., 2001/3). The estimation in the table below is based on the following assumptions[3] :

- the census realised by Anon., 2001/3 gives an accurate view of resident boats in the Iroise area, as far as marinas are concerned ;
- all identified mooring places outside marinas are in use, at least seasonally ;
- 75% of these places are used by boats under 6 metres long, 24% by boats between 6 and 10 metres long, and 1% by boats over 10 metres.

Table 35. Estimation of the number of permanent leisure boats in the Iroise area (1998-99)

Usual harbouring place \ Length class		under 6 metres		6 to 10 metres		≥ 10 metres		Total	
		number of boats	%	number of boats	%	number of boats	%	number of boats	%
Marinas	number of boats	1419	*25%*	2661	*66%*	223	*78%*	4303	*43%*
	%	*33%*		*62%*		*5%*		*100%*	
Other	number of boats	4353	*75%*	1393	*34%*	58	*21%*	5804	*57%*
	%	*75%*		*24%*		*1%*		*100%*	
Total	number of boats	5772	*100%*	4054	*100%*	281	*100%*	10107	*100%*
	%	*57%*		*40%*		*3%*		*100%*	

Sources : Anon., 2001/3, own elaboration.

According to this estimation, the total number of resident leisure boats in the Iroise area is slightly over 10 000 units, 57% of which are under 6 metres long, and only 3% over 10 metres. If more than 75% of boats over 10 metres are harboured in marinas, the proportion is only 25% for boats under 6 metres.

Table 36. Visiting boats in Iroise area and Brittany marinas (1999)

	Iroise area	Brittany	Iroise / Brittany
[1] Yearly number of calls*	15318	110362	14%
[2] Yearly number of nights**	21627	218066	10%
[3] Average duration of a call, in nights ([2] / [1])	1,41	1,98	71%
[4] Number of places in the marinas	4813	33025	15%
[5] Index of pressure exerted by visiting boats ([2] / [4])	4,49	6,60	68%

* Call = stay of at least one night in a marina by a visiting boat. ** Night = stay of one night in a marina by a visiting boat.
Source : Anon., 2001/3.

Only visiting boats that stay in marinas are documented. According to the above mentioned survey of marinas in Brittany, the number of calls in marinas of the Iroise area was slightly

[1] Estimating the number of unauthorised mooring places was based on a census by government services at the department level (DDE). Data are not available for the whole Brittany region.
[2] Unlike smaller units, boats over 3 GRT are liable to pay a yearly tax, which creates a natural incentive to declare decommissioning (before 1986, the limit was 2 GRT).
[3] The reliability of these assumptions is discussed and tested in Boncoeur et al., 2002.

above 15000 in 1999, representing 14% of the total equivalent number at the region level, a ratio close to the one characterising the number of places (15%). However, the average duration of a call in the Iroise area was shorter than the regional average (1.41 nights against 1.98 nights). As a result, the average pressure exerted by visiting boats on the harbouring capacity of marinas (measured by the ratio of the total number of nights per year to the total number of places) was somewhat lighter in the Iroise area than at the regional level. But the dispersion is high, and two marinas in the Iroise area are characterised by a very important activity of visiting boats (Camaret, L'Aber Wrac'h).

The activity of sailing clubs and schools in the department of Finistère is documented by statistical records held by their professional association (*Nautisme en Finistère*). The following table sums up information concerning these institutions and their activity in 1997, at the department level and for the Iroise area (unlike the above mentioned survey of marinas, it does not include the bay of Brest in the « Iroise area » set). According to these statistics, in 1997 some 22000 persons participated in the activities of sailing clubs and schools of the Iroise area, representing 16% of the department total.

Table 37. Sailing clubs and sailing schools in the Iroise area* and in Finistère, year 1997

	Iroise area*	Finistère	Iroise* / Finistère
Number of sailing clubs and sailing schools	16	73	22%
Yearly number of persons taking part in the activities	22 000	136 000	16%

* Municipalities bordering the Iroise sea (Bay of Brest excluded). Sources : Anon., 1998/3 ; Anon., 1999/1.

The following table presents two types of indicators of the estimated economic impact of yachting and sailing in the Iroise area : turnover of related economic activities, and employment in these activities. Due to the frequently seasonal character of the concerned activities, the number of jobs has been converted in yearly full time equivalent. Three types of activities are taken into account : direct activity of marinas, sailing clubs and schools, and miscellaneous activities related to the so-called « yachting industry » (maintenance, repairs, fittings, trade...). The geographical scope of these data is not fully consistent, since data related to sailing clubs and schools do not include the bay of Brest. The accuracy of data is also variable : if data related to marinas and sailing schools and clubs are fairly precise and reliable, data related to other activities are only based on very rough estimations. The yearly turnover of boat maintenance activities has been estimated on the basis of 5% of the estimated value of the resident fleet, a ratio considered as standard in the industry (Anon., 1989)[1]. The number of local jobs in the « yachting industry » has been estimated on the basis of an average regional ratio of the number of jobs to the number of harbouring places (Anon., 2001/3).

Table 38. Indicators of the economic impact of yachting and sailing in the Iroise area

	Turnover (million FF / year)	Number of jobs*
Marinas	20.4	30
Sailing clubs and schools**	19.7	100
Other activities	44.0 ***	500 ****

* Yearly full time equivalent. ** Bay of Brest excluded. *** Maintenance of resident leisure boats. **** Upstream activities of the « yachting industry ». Sources : Anon., 1999/1 ; Anon., 2001/3 ; own elaboration.

[1] The value of resident boats has been estimated on the basis of second-hand price data collected in specialised yachting journals.

1.3.3. Recreational fishing[1]

In non-professional fishing, selling catches is prohibited by law. However, the enforcement of this regulation is a controversial subject, which contributes to blur the estimation of non-professional fishing effort and catches. Three types of activities are investigated in this section : fishing on board leisure boats ; underwater fishing (snorkelling) ; picking shellfish and small crustaceans on the strand at low tide[2]. Summing up available information on these activities will be followed by an assessment of their economic importance in the Iroise area, and of their interaction with commercial fishing.

- Recreational fishing on board leisure boats

Most recreational fishers operating from a boat make use of their own boat. Contrasting with river angling, no license is required for recreational sea fishing[3]. As a result, the number of recreational sea fishers is not precisely known. At the regional level, a survey realised by Ifremer in 1997 by means of a questionnaire distributed through leisure boat owners associations concluded that some 40% of all leisure boat owners in Brittany made use of their boat for fishing (Véron, 1999). At a more local level, according to a postal sample survey realised at the beginning of the 90' (Bernard, 1993), one third of the owners of leisure boats harboured in the marinas of Finistère declared that recreational fishing was the main motivation for the use of their boat, and in the Iroise area, this proportion reached 43%. Applying this ratio to the estimated total of leisure boats harboured in the Iroise area leads to an estimation of some 4500 recreational fishers operating from their boat in this area. This estimation should be regarded as a minimum, for the following reasons : 1) boat owners having their boat moored outside marinas are probably more oriented towards fishing than the ones who harbour their boat in a marina ; 2) several persons may fish from the same boat ; and 3) some boat owners who did not declare fishing as their main motivation may be occasional fishers.

A subset of 155 recreational fishers operating in the Iroise area was extracted from the sample of the regional Ifremer survey. The two following tables sum up their answers.

Table 39. Sample of leisure boat owners using their boat for recreational fishing in the Iroise area

Fisher characteristics	
• Gender (% of males)	100%
• Mean age (years)	53
• % of fishers with experience over 20 years	42%
Boat characteristics (mean)	
• Length (metres)	5.5
• HP (KW)	17.4
• Age (years)	16
Main gear used during the trips (as a % of total number of trips)	
• Handline	36%
• Nets	23%
• Pots	23%
• Longline	18%
Average range of operation (NM from the shore)	2.6
Yearly boat and gear maintenance expenses (FF)	6500

Source : Ifremer sample survey (*n* = 155).

[1] Main contributors to this section are Gérard Véron and Gildas Appéré.
[2] Due to lack of information, angling from the shore will not be considered.
[3] Except underwater fishing (see below).

According to the results of the survey, leisure boat owners making use of their boat for recreational fishing in the Iroise area are in most cases males (100% of the sample)[1], fairly old (mean age 53), often retired, and experienced (42% of them with more than 20 years of practice). They usually fish on small boats (5.5 metres long on the average), and stay close to the shore (2.6 miles on the average). They use various fishing gears (with a priority to handline), and their yearly budget for boat and gear maintenance is 6500 FF on the average (990 euros).

Table 40. Estimated yearly catches of recreational fishers operating from a leisure boat in the Iroise area

Species	Proportion of fishers declaring catches of the species	Average declared catch, (fishers declaring catches of the species), kg / year	Average declared catch, (whole sample)*	
			kg / year	%
Mackerel	59%	23.5	13.9	23%
Pollack	46%	12.3	5.6	9%
Spider crab	42%	22.4	9.4	15%
Bass	37%	16.5	6.2	10%
Sea bream	36%	16.7	6.0	10%
Squid	32%	14.0	4.4	7%
Wrasse	26%	15.1	4.0	6%
Sole	24%	2.7	0.6	1%
Cuttlefish	23%	8.4	1.9	3%
Edible crab	23%	6.8	1.5	2%
Conger	19%	24.7	4.8	8%
Rays	18%	6.1	1.1	2%
Red mullet	18%	3.3	0.6	1%
Pout whiting	17%	6.2	1.0	2%
Swimming crab	14%	2.7	0.4	1%
Shrimps	10%	0.5	ε	ε
Lobster	7%	1.7	0.1	ε
Total	-	-	61.8	100%

* 155 answers. Source : Ifremer sample survey.

Five species are targeted by more than one third of all fishermen in the sample : mackerel (targeted by 59% of fishermen), pollack, spider crab, bass, and sea bream. For three species, the average level of declared catches (for fishermen targeting the concerned species) is over 20 kg per year : mackerel, spider crab, and conger. As a result, mackerel represents nearly one quarter of all declared landings, followed by spider crab (15% of total declared landings), bass, sea bream, pollack and conger (between 8 and 10% of total declared landings for each species). The cumulated declared landings of these 6 species represent 75% of all declared landings, which amount to 62 kg per fisherman on the average.

Recreational fishers operating from a leisure boat were also asked about possible cohabitation problems and about their views concerning the management system of the fishery.

Only 12.5% of the answers mentioned serious cohabitation problems with commercial fishers. These problems appear to be more frequently related to space interactions (competition for the use of space when using fixed gears) than to stock interactions (competition for the same targeted species). However, competition for bass and sea bream was sometimes mentioned. Some 5% of people in the sample also mentioned cohabitation problems with underwater fishers, charging them of illegal actions such as « plundering » of pots.

[1] Which does not mean that no female participates in the activity : several persons may fish on the same boat.

As regards the management of the fishery, most answers are in favour of a stricter enforcement of present rules, but oppose to the creation of a fishing licence for recreational sea fishers : 81% of answers are against such a measure, and the proportion reaches 92% if the license is not free. One quarter of all answers favour increasing minimal catch sizes and / or implementing daily limitations of catches.

- Recreational underwater fishing

Recreational underwater fishing is authorised only by snorkelling. This activity requires a yearly license, which is delivered freely and without limited entry. Registered members of skin diving clubs are automatically licensed, and non-members are simply required to make a notification to government administration. Contrasting with other types of recreational sea fishing activities, the license system makes it possible to assess the number of underwater sea fishers. This number is growing fast : in the maritime district of Brest for instance, the number of individual authorisations has increased by 50% in ten years. For the year 1999, 6800 individual authorisations have been issued in the maritime districts bordering the Iroise sea[1]. Taking into account fishers belonging to diving clubs leads to an overall estimation of some 7500 underwater fishers in the Iroise area.

Similar to the sample survey of recreational fishermen operating from a boat, a sample survey of underwater recreational fishers was conducted by Ifremer at the regional scale (Véron, 1999). The survey questionnaire was distributed through government administration (at the occasion of issuing the license) and diving clubs. A total number of 380 questionnaires was collected, of which 164 concerned underwater fishers operating in the Iroise area. The two following tables sum up their answers.

Table 41. Sample of underwater recreational fishers operating in the Iroise area

Fisher characteristics (mean)	
• Gender (% of males)	96%
• Age (years)	34
• % of fishers with experience over 5 years	70%
Use of a boat	
• never	39%
• occasionally	42%
• often	14%
• always	5%
• Total	100%
Yearly number of trips (as a % of total number of answers)	
• Under 20	52%
• 20 to 40	32%
• over 40	16%
• Total	100%
Yearly average cost*, according to the number of trips (FF)	
• Under 20	2300
• 20 to 40	5200
• over 40	11300

* Diving equipment replacement, boat maintenance and amortisation. Sources : Ifremer sample survey (*n* = 164), complemented by information provided by diving equipment retailers.

[1] Brest, Camaret, Douarnenez and Audierne. This number represents 45% of the total number of individual authorisations issued at the regional level.

According to the survey, underwater fishing is essentially practised by males (96% of the sample). Underwater recreational fishers are significantly younger than recreational fishers operating on board leisure boats (34 against 53 years old on the average), and most of them have a job. Some 60% make use of a boat, but most of them only occasionally. For half of the sample, the number of fishing trips is under 20 a year, and only 16% mention more than 40 trips a year. According to the yearly number of trips, the yearly average estimated cost of the activity varies from 2300 FF (350 euros) to 11300 FF (1720 euros). For the whole sample it amounts to 4668 FF (712 euros).

Table 42. Estimated yearly catches of recreational underwater fishers in the Iroise area

Species	Proportion of fishers declaring catches of the species	Average declared catch, (fishers declaring catches of the species), kg / year	Average declared catch, (whole sample)*	
			kg / year	%
Spider crab	60%	29.2	17.4	38%
Wrasse (seawife)	41%	14.9	6.2	14%
Bass	37%	14.3	5.2	11%
Flat fish	32%	16.6	5.3	12%
Pollack	32%	13.2	4.2	9%
Grey mullet	22%	8.5	1.9	4%
Conger	11%	29.3	3.2	7%
Edible crab	9%	13.6	1.2	3%
Common scallop	6%	15.1	0.9	2%
Total	-	-	45.5	100%

* 164 answers. Source : Ifremer sample survey.

Five species or groups of species are targeted by more than 30% of all underwater fishers in the sample : spider crab (targeted by 60% of underwater fishers), wrasse, bass, flat fish, and pollack. Average yearly declared catches are generally between 10 and 20 kg per species, for fishers targeting the concerned species. However, for spider crab and conger they almost reach 30 kg. As a result, spider crab represents almost 40% of all declared landings, far beyond wrasse, bass and flat fish (between 10 and 15% of total declared landings each). The cumulated declared landings of these 4 species represent 75% of all declared landings, which amount to 45.5 kg per underwater fisher on the average.

Like fishers operating from a leisure boat, recreational underwater fishers were also asked about possible cohabitation problems and about their views concerning the management system of the fishery.

One third of the underwater fishers in the sample mentioned negative interactions with fishing boats (whether commercial or recreational). The main subject of concern is competition for space close to the shore, due to the presence of fixed gears, and also (concerning leisure boats) the non compliance with neighbouring safety rules. This subject of concern is also mentioned about sailboards and sailing boats (the absence of engine noise being an additional cause of danger for underwater fishers). If a majority of underwater fishers in the sample consider that fish stocks are stable or fluctuate with no established trend, a significant proportion believe that fish is becoming scarcer (38%, against 1% with the opposite opinion). For most of them, this is mainly a consequence of overfishing by professional fishing boats, but other factors are also mentioned, such as pollution, indirect consequences of seaweed harvesting, and an increasing pressure exerted on fish stocks by recreational fishers (including underwater fishers). A frequently mentioned reaction of underwater fishers to fish stocks depletion is to go fishing farther from the shore, which creates additional opportunities of interaction with fishing boats.

Most underwater fishers in the sample agree with the license system applying to their activity (92%), since, to their mind, it contributes to a better information of fishers about fishing and safety rules. Most of them also would refuse to pay for it (88%). If 60% of them consider that the frequency of administrative controls is satisfactory, only 52% believe that these controls are efficient. Two thirds of fishers declare that they agree with the idea of a logbook. Concerning other types of recreational fishing, 60% consider that a license system should also apply to fishers operating from a boat, and 52% that their daily catches should be limited. As regards these fishers, the main subject of concern mentioned by underwater fishers is the question of illegal selling of catches (87%).

- *Picking shellfish and small crustaceans on the strand at low tide*

Picking shellfish and small crustaceans at low tide is a popular recreational activity in Brittany, involving both resident population, and tourists during the holidays. Spring tides are the main periods of activity for this type of recreational fishing. According to photographic censuses realised by aircraft, the number of fishers may reach some 5000 persons in the Iroise area during the most important spring tides. Concerning the Bay of Brest part of the area, more detailed information was collected by Ifremer through field surveys realised in 1994-95 (Véron, 1997). According to censuses realised during 4 spring tides, the daily number of fishers was 1640 on the average during these periods[1]. The following table displays the type of species targeted by these fishers :

Table 43. Census of recreational fishers picking shellfish and small crustaceans on the strand at low tide. Bay of Brest, average of 4 spring tides, 1994-95.

Main species targeted	Number of fishers	% of the total
Carpet shells	655	40%
Oysters	178	11%
Winkles	135	8%
Shrimps	124	8%
Warty venus	86	5%
Razor shells	61	4%
Swimming crabs	49	3%
Cockles	30	2%
Sea worms	24	1%
Abalones	19	1%
Variegated scallops	18	1%
Otter shells	13	1%
Other species	6	ε
Undetermined	242	15%
Total	1640	100%

Source : Ifremer.

The variety of targeted species is high, but 4 species concentrate the effort of at least two thirds of all fishers : carpet shells (targeted by at least 40% of all fishers), oysters, winkles and shrimps. Contrasting with other coastal zones, there is no significant interaction between this

[1] The « peak » period usually lasts 2 days.

type of recreational fishing and commercial fishing in the Iroise area, since the main targeted species and fishing places are different.

A recent field sample survey provides additional information on the profile and activity of recreational fishers catching shellfish and small crustaceans on the strand at low tide (Appéré, 2002). This survey was conducted in 2000, by means of face-to-face interviews of fishers in various places on the coast of Brittany during spring tides. As the interviews were realised between January and March, the population surveyed included very few tourists. The size of the sample was 500 persons, with a subset of 138 persons concerning the Iroise area. The table below sums up their answers.

Table 44. Sample survey of fishers picking shellfish and small crustaceans at low tide on the strand. Iroise area, winter 1999-2000 (*n* = 138)

Gender		
	• Female	49%
	• Male	51%
Age (% of total answers)		
	• under 30	19%
	• 30 to 39	18%
	• 40 to 49	20%
	• 50 to 59	17%
	• 60 to 69	15%
	• 70 and over	11%
Monthly household income (FF)		
	• Mean	9445
	• Standard deviation	5486
Distance between home and fishing place (km)		
	• Mean	9.9
	• Standard deviation	15.9
Monthly number of fishing trips		
	• Mean	1.2
	• Standard deviation	0.8
Average catches per trip (kg)		
	• Mean	2.1
	• Standard deviation	1.5

Source : Appéré, 2002.

Contrasting with other types of recreational fishing, picking shellfish and small crustaceans on the strand at low tide is well balanced as regards the participation of both genders. The age of participants is diversified (mean : 47), with a significant proportion of participants over 60 (26%). Their average declared monthly household is significantly lower than the national average[1], which may be explained by the important proportion of retired people, students and unemployed persons in the sample (47%).

For most persons in the sample, the fishing spot is not far from home : the distance is 10 km on the average, and, for 46% of the interviewed persons, it is shorter than 5 km ; only 1% of all interviewed fishers mentioned a distance over 100 km. The declared fishing practice is slightly above one trip per month, the rhythm of fishing trips usually corresponding to that of spring tides. For two thirds of the sample, the monthly number of fishing trips is one or two.

[1] In 1999, the average gross available income of French households was 19500 FF (2973 euros) per month, according to national accounting (INSEE, 2001).

Declared catches (all species) are slightly over 2 kg on the average, and are mainly composed of shellfish (clams, oysters, winckles). These answers imply a yearly individual volume of catches amounting to 30 kg on the average.

- Assessing the importance of recreational fishing and of interactions with commercial fishing in the Iroise area

Assessing the catches due to recreational fishing in the Iroise area and the economic value of this activity raises several difficulties. One is caused by the lack of knowledge about part of the activities pertaining to recreational sea fishing, such as angling from the shore. In other cases, the number of persons involved by the activity is not known. In the cases of fishing from a leisure boat and underwater fishing, the number of persons involved may be estimated (with a broader range of uncertainty in the first case than in the second), and the above presented Ifremer sample surveys provide fairly detailed information. However, the representativeness of the samples is questionable, and therefore the extrapolations based on the information they provide should be considered cautiously. This caveat applies to the following estimations.

Extrapolating the catches declared by the fishers in the two samples (figures 45 and 47 above) to the whole estimated population of recreational fishers operating in the Iroise area, either from a leisure boat (4500 persons) or underwater (7500 persons), leads to an overall estimation of catches amounting to 620 tons a year for these two activities, representing some 5% of the total estimated catches realised in the same area by commercial fishing boats :

Table 45. Estimated yearly catches by recreational fishing (from a boat or underwater) in the Iroise area

Group of species	Estimated catches by recreational fishers		as a % of catches by commercial fishing boats*
	tons	%	
Finfish	394	63%	5%
Crustaceans	191	31%	7%
Cephalopods	29	5%	8%
Shellfish	7	1%	1%
Total	621	100%	5%

* seaweeds excluded. Source : own elaboration., based on Ifremer estimation of commercial catches and surveys of recreational fishing.

For some species, the competition between recreational and commercial fishers may be more acute than suggested by the above table. The intensity of competition concerning a given species depends on the relative share of recreational fishers in the overall catches of this species, but also on its commercial importance. The following table classifies species targeted in the Iroise area according to two criteria :

- the share of overall catches realised by recreational fishers (operating from a boat or underwater) ;
- the estimated share of the concerned species in the global revenue provided to commercial fishing boats by the Iroise fishery.

Table 46. Competition between recreational* and commercial fishing in the Iroise area, according to relative commercial importance of targeted species

Relative importance of catches by recreational fishing / Relative importance of species for commercial fishing	**High** (≥15% of total catches in the Iroise area)	**Moderate** (5 to 15% of total catches in the Iroise area)	**Low** (under 5% of total catches in the Iroise area)
High (≥15% of total value of commercial landings from the Iroise area**)	-	Large crustaceans	Monkfish
Moderate (5 to 15% of total value of commercial landings from the Iroise area**)	Bass	Pollack, Flat fish	-
Low (under 5% of total value of commercial landings from the Iroise area**)	Wrasse, Sea bream, Grey mullet, Small crustaceans	Mackerel, Conger, Squid, Red mullet, Pout whiting	Other species

* Fishing from a leisure boat and underwater fishing. **Seaweeds excluded. Source : own elaboration., based on Ifremer estimation of commercial catches and surveys of recreational fishing.

According to the above table, the share of recreational fishing in overall catches is high (above 15%) for the following species : bass, wrasse, sea bream, grey mullet and small crustaceans (swimming crabs, shrimps). But only bass plays a significant role in the catches realised by commercial fishing boats in the Iroise area. If the share of bass is around 10% of the overall revenue of the Iroise commercial fishery, this species plays a critical role for a specific group of commercial fishing boats, handliners, for which it represents more than 75% of total revenue on the average.

The share of recreational fishing in overall catches realised in the Iroise area is between 5% and 15% for the group of large crustaceans, and for pollack, flat fish, mackerel, conger, squid, red mullet and pout whiting. Most of these species are of limited importance in the commercial fishery, except for pollack, flat fish and, most of all, large crustaceans. This group represents nearly 25% of the total value of commercial landings from the Iroise area, but nearly two thirds of the revenue of potters-netters, and up to 100% of the revenue of « pure » potters. Competition between recreational and commercial fishers is likely to be significant for two species : spider crabs and lobsters.

Catches realised by recreational fishers may be valued on the basis of market prices of commercial landings. Making use of the same prices as the ones used for estimating the revenue of the commercial fishery (see above, table 9) leads to an overall estimation of 14.7 million FF (2.24 million euros) for the catches of recreational fishers operating underwater or from a leisure boat in the Iroise area, representing some 6% of the overall value of landings from the commercial Iroise fishery. But this way of estimating the value of recreational fishing is open to criticism, since recreational fishing is a leisure which is prized for itself, and not only for the food it provides. A better approach is based on the cost born by recreational fishers for the practice of their hobby. Making use of the cost estimations presented above leads to a rough estimation of 63 million FF (9.6 million euros) for the cost of recreational fishing (underwater or from a leisure boat) in the Iroise area[1], amounting to 25% of the estimated revenue generated by commercial fishing in the same area.

2. A bioeconomic model simulating the economic impact of a fishery exclusion zone in a multispecies and multi-activity context[2]

The process of creating a national marine park in the Iroise Sea, which was launched in the early 90', is still ongoing at the moment of writing the present report. In September 2001, a Prime Minister order stressed that the marine park should promote both protection of natural heritage and sustainable development of human activities, provided these activities are consistent with the protection objective (*Arrêté du 25 septembre 2001 portant prise en considération du projet de création du projet de création d'un parc marin en mer d'Iroise,* JORF du 28 septembre 2001). However, up to now nothing precise has been decided concerning the management of human activities inside the park. Concerning fisheries management, only the principle of a fisheries management plan for the park area has been decided (Anon., 2000/1). In this context, it is only possible to try and simulate the potential impact of hypothetical management scenarios.

One of these scenarios might be to create, within the park area, one or several reserves, or fishing exclusion zones (FEZ).

Various achievements are expected from the creation of marine reserves (Shackell et al., 1995 ; Murray et al., 1999). The objectives pursued can usually be classified under one of the following three categories : ecosystem preservation, fisheries management, and development of non-extractive recreational activities. At a general level, the degree of compatibility between these objectives is difficult to assess. It is bound to vary from case to case, depending on local conditions. The variety of interests at stake is a source of potential conflicts during the process of creating a marine reserve (Dixon et al., 1993 ; Polunin et al., 2000), which calls for the development of tools helping a global assessment of its impact (Hoagland et al., 1995), both in terms of efficiency (global surplus) and equity (distributional effects among the various categories of stakeholders).

Up to now, the economic discussion concerning marine reserves has mainly focused on their use as a fisheries management tool. Making use of a single-species multiple-cohort model incorporating a stock-recruitment relationship, Holland and Brazee (1996) have shown that marine reserves could improve sustainable catches in overexploited fisheries, given a fixed level of fishing effort. Introducing uncertainty into the harvested fraction of the stock and using a global discrete-time logistic model, Lauck et al. (1998) have advocated marine reserves as a way of implementing the precautionary principle in fisheries management. Also using a global logistic model, Hannesson (1998) and Anderson (2000) have questioned the usefulness of marine reserves as a tool for fisheries management in a deterministic context, as

[1] This estimation does not include fuel.
[2] Contributors to this section are Jean Boncoeur, Frédérique Alban, Olivier Guyader and Olivier Thébaud. The model it describes was first presented at the Conference on Economics of Marine Protected Areas held in Vancouver, July 2000 (Boncoeur et al., 2001). A revised version was published in *Natural Resource Modelling* (Boncoeur, Alban, Guyader and Thébaud, 2002).

long as free access is accepted outside the reserve. The assumption of space homogeneity inside the fishery, which is common to the above mentioned papers, was relaxed by Sanchirico et al. (1999).

Marine reserves may also have an economic impact on ecotourism (Agardy, 1993), a term being used here for naming non-extractive recreational activities related to the ecosystem. Studies considering this question mainly deal with tropical areas (see e.g. Kenchington, 1993 ; Dixon et al., 1993 ; Davis and Harriot, 1995 ; Buerger, Hill et al., 2000), and treat the consequences of marine reserves on ecotourism as a direct corollary of their impact on fish biomass. The standard case is that of a coral reef, which becomes more attractive for snorkellers and scuba-divers if a fishing ban increases the number and / or size of fish within the reef or close to it. Models used for assessing reserves as fisheries management tools may be used to study this case, provided a relationship between fish abundance and tourist frequentation is worked out. Once such a relationship is incorporated, these models may be used to investigate the question of optimal reserve design and appropriate supplementary measures within the general framework of cost-benefit analysis (Hoagland et al., 1995).

However, the coral-reef case is hardly transferable to temperate areas, where observation of fish in their ecosystem (by diving, tours in glass-bottom boats or other means) in most cases cannot be regarded as a major opportunity for the development of ecotourism. If marine wildlife observation has proved to be an important attraction for ecotourism in many of these areas, the link with fish biomass, if any, is usually indirect, i.e. operates through the ecosystem. One interesting case is that of marine mammal watching, which has become a significant source of incomes in some areas (Anon., 1994 ; Hoyt, 1995 ; Hvenegaard, 1997). In the case where the diet of these mammals makes them competitors of fishers[1], implementing a marine reserve in part of a fishing zone may have indirect economic consequences both on the fishing industry and ecotourism, through its impact on the stock of marine mammals. Making use of multispecies modelling is helpful to investigate such indirect consequences.

Though addressing a problem of equilibrium between commercial fishing and ecotourism that is clearly related to the Iroise case, the bioeconomic model presented in this section relies on some oversimplifying hypothesis, and therefore does not intend to give a « realistic » view of the situation prevailing in the Iroise sea. Its purpose is essentially heuristic, i.e. it is intended to explore some indirect consequences of creating a marine reserve when several stocks and several anthropic activities are interacting. To be more specific, the model describes some consequences of implementing a FEZ in part of an area where fishing is conducted under a limited entry licence system (which is already the case for some fishing activities in the Iroise sea[2] and is likely to be generalised once the marine park is created), and which is inhabited by two interacting stocks : a stock of prey (fish) and a stock of predators (seals). While the former is targeted by fishers, the latter is not subject to harvest but is a potential basis for the development of ecotourism (seal watching)[3]. First the structure of the model is described, then the results of some simulations are presented. These results are used to discuss the direct and indirect impacts of the FEZ on both fishing activities and ecotourism.

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[1] The case of direct competition for fish, which will be considered here, is not the only type of interaction between marine mammals and fisheries (Beverton and Beddington, 1985 ; Trites et al., 1997)
[2] Scallop dredging and seaweed harvesting.
[3] In the case of the Iroise sea, seal watching already exists, both as a commercial and non commercial activity. Fishers worry about the possibility of « overprotecting seals » in the future national marine park.

2.1. Description of the model

2.1.1 Hypothesis

The model presented here combines two topics which are usually treated separately : marine reserve modelling and multispecies modelling. The treatment of each of these topics is highly simplified, and based respectively on Hannesson (1998) and Flaaten (1989). The main biological and technical assumptions of our model follow the hypothesis made by these two authors :

- deterministic, continuous time[1] self-regenerating model, applied to a zone considered ecologically homogenous and relevant for the management of the living marine resources inhabiting it ;
- distinction between two stocks, related by a prey-predator relationship where the instantaneous mortality rate of prey by the predators is supposed to be proportional to the biomass of predators, and the predator carrying capacity of the area is supposed to be proportional to the biomass of prey (Flaaten) ; in our model, prey will be called “fish” (stock F) and predators “seals” (stock S)
- global representation of each stock (or each substock in the case of fish), the natural dynamics of which follows a logistic curve ;
- tendency of the fish stock to spread uniformly over the area under survey, at a rate which depends on an exogenous mobility coefficient (Hannesson)[2] ;
- proportionality of CPUE to fish density inside the fishing zone (Hannesson).

However, our institutional / economic hypothesis are slightly different :

- like Hannesson, we suppose that the area under survey is split into two subspaces : a reserve, or fishing exclusion zone (zone 1) and a zone open to fishing (zone 2) ; but unlike that author, we assume a limited entry licence system, or some other regulation resulting in an effective control over fishing effort ; however, we acknowledge that, due to political / social considerations, the regulator’s ability to lower fishing effort is limited[3].
- unlike Flaaten, we suppose that only one of the two interacting stocks is harvested : while fish are targeted both by seals and fishers, seals are not harvested, but may have some economic value as a resource for a non extractive recreative use (seal watching)[4]. We assume that the demand for seal watching is a non-linear increasing function of the stock of seals in the area under survey.

All prices are treated as exogenous.

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[1] As in Hannesson (1998) and Anderson (2000), a discrete time version of the model is also built for the purpose of simulations. See Appendix I.

[2] For the seal stock, we assume ubiquity over the whole area, i.e. we admit that seals can move instantly from any part of this area to another and exert on each substock of fish a predation which is proportional to its biomass. Therefore no distinction is made between seals inside the reserve and seals inside the fishing zone.

[3] This hypothesis seems realistic as regards a number of inshore fisheries, among which the Iroise fishery. In France, there is an increasing tendency for fisheries within the 12 NM to have limited entry licence systems, managed by fishers organisations under the supervision of the state (Pennanguer et al., 2001). When such a system is introduced into a fishery, the aim is clearly to prevent any further increase in fishing effort, and possibly to gradually decrease it. However, in practice this decrease may only be achieved by attrition.

[4] A realistic assumption in the Iroise context. Non-extractive use value may be associated with a non-use value (existence value), not taken into account here.

2.1.2 Equations

The dynamics of both stocks is modelled as follows :

(1) $$\frac{dX_{F1}}{dt} = r_F.X_{F1}.\left(1-\frac{X_{F1}}{\alpha.X_{F\max}}\right)-T-\beta.X_{F1}.X_S$$

(2) $$\frac{dX_{F2}}{dt} = r_F.X_{F2}.\left(1-\frac{X_{F2}}{(1-\alpha).X_{F\max}}\right)+T-\beta.X_{F2}.X_S-Y_F$$

(3) $$\frac{dX_S}{dt} = r_S.X_S.\left(1-\frac{\gamma.X_S}{X_{F1}+X_{F2}}\right)$$

with :

X_{Fi}	the fraction of the fish stock biomass in sub-region i (i = 1, 2)
X_S	the seal stock biomass
r_F	the intrinsic growth rate of the fish stock biomass
r_S	the intrinsic growth rate of the seal stock biomass
X_{Fmax}	the fish carrying capacity of the total region under survey
T	the net instantaneous transfer of fish from the reserve to the fishing grounds
Y_F	the instantaneous catch of fish by fishers in the region open to fishing
α	the share of the reserve in the total region under survey
β	the predation coefficient (instantaneous fish mortality rate per seal biomass unit)
γ	the equilibrium ratio between fish biomass and seal biomass

The net transfer of fish from the reserve to the fishing grounds, T, is supposed to be proportional to the difference between the fish biomass in the reserve and what it would be assuming uniform spread of fish over the whole area under survey :

(4) $$T = \sigma.[X_{F1}-\alpha.(X_{F1}+X_{F2})] = \sigma.[(1-\alpha).X_{F1}-\alpha.X_{F2}]$$

with σ a coefficient describing the space mobility of fish[1].

The catch per unit of effort is supposed to be proportional to the density of fish in the fishing zone :

(5) $$\frac{Y_F}{E_F} = q.D_{F2} \Leftrightarrow Y_F = q.E_F.\frac{X_F}{(1-\alpha).A}$$

[1] This is equivalent to assuming that fish migration depends on relative density between the two areas : let A be the total surface of the area under survey, ($D_{F1} = X_{F1}/\alpha.A$) and ($D_{F2} = X_{F2}/(1-\alpha).A$) be the densities of fish in the reserve and fishing zone respectively, then we get from (4) : $T = s.(D_{F1} - D_{F2})$, with $s = \sigma.\alpha.(1-\alpha).A$.

with :

q	the catchability coefficient (instantaneous fish mortality rate per unit of fishing effort and per unit of surface)
E_F	the fishing effort
D_{F2}	the fish density inside the fishing zone
A	the surface of the total area under survey

Ecotourism is supposed to be the result of combining two partly substitutable factors : natural resource (the seal stock) and production effort (an index of the anthropic inputs devoted to the promoting of ecotourism in the area under survey). For the sake of simplicity, we will assume a Cobb-Douglas type production function :

(6) $$Y_s = a.X_s^b.E_s^c$$

with :

Y_S	the flow of ecotourism visits of the area
E_S	the effort devoted to the ecotourism industry
A	a positive dimension parameter
B	the elasticity of visits with regard to the abundance of seals
C	the elasticity of visits with regard to the effort devoted to promoting ecotourism

The fishing and ecotourism rents are defined respectively as follows :

(7) $$R_F = P_F.Y_F - C_F.E_F$$

(8) $$R_S = P_S.Y_S - C_S.E_S$$

with :

P_j	the unit price of the product of activity j ($j = F, S$)
C_j	the unit cost of effort devoted to activity j ($j = F, S$)

For given effort levels in both activities, the system reaches equilibrium when the following conditions are satisfied simultaneously :

(9) $$\frac{dX_{F1}}{dt} = 0$$

(10) $$\frac{dX_{F2}}{dt} = 0$$

(11) $$\frac{dX_S}{dt} = 0$$

2.2. Simulations

Various simulation experiments with the model were carried out using softwares Excel and Stella. For this purpose, a discrete time version of the model was built[1]. In these simulations, the equilibrium was calculated as the asymptotic result of the dynamics of the system, assuming given initial conditions[2]. Although the path towards equilibrium displays some interesting features, only equilibrium results are presented here. All the figures belong therefore to comparative statics, i.e. they link various equilibrium situations but give no information about the actual move from one equilibrium to another. We shall start with a version of the model where parameter β is set equal to zero (no mortality of fish by seals), in order to display what can be expected from the reserve in terms of fisheries management, when the ecosystemic interaction between the two stocks is not taken into account (direct effect of the reserve). Then we shall give a positive value to parameter β, which will depict how the impact of the predator-prey relationship mitigates the direct effect of the reserve for the fishing industry, and in the same time affects ecotourism. As parameters of the model are not based on real-world observations, the main features described by the simulations presented hereafter should be considered from a qualitative, rather than quantitative point of view.

2.2.1 Reserve effects without predator-prey interaction

In this first series of simulations, $\beta = 0$, which means no predation by seals. Under this hypothesis, the simulations are interesting only from the point of view of fisheries management (Figures 1 to 4).

Figure 1 depicts the basic effect expected from the creation of a reserve on fish biomass : while the fraction of the stock in the fishing zone tends to zero as effort increases, the fraction inside the reserve is safe, which may give some protection against stock collapse due to overfishing. This presentation is greatly simplified, as fish transfers between zones link the dynamics of the two fractions of the stock. The critical ratio here is between the intrinsic growth rate of the stock (r_F) and its space mobility coefficient (σ) : as pointed out by Anderson (2000), the safe minimum biomass level (SMBL) achieved by the reserve will be positive only if $\sigma \leq r_F$ or, in the opposite case, if the proportion of the reserve in the total area, α, is larger than $[1 - (r_F / \sigma)]$. The simulations presented here are compatible with a positive SMBL, as parameter values have been selected so that $\sigma \leq r_F$.

Figure 2 exhibits, in flow terms, what was presented in Figure 1 in terms of stocks. Under equilibrium conditions, catches realised in the fishing zone have two origins : the flow of natural increase of the fraction of the stock in this zone, and the flow of net transfer from the reserve. The first flow is the main source of catches when the fishery is lightly fished, because then net transfer from the reserve is not important. This is due to the fact that the densities of fish biomasses in both zones are close to each other when fishing mortality occurring in zone 2 is low. The net transfer from the reserve becomes more important as the increase in fishing

[1] See the equations of the discrete time version of the model, the values of the parameters and the initial values of the state variables in Appendix I.

[2] The simulations presented here were calculated with Excel, and equilibrium was considered as reached after 50 periods.

effort broadens the gap between the densities inside the two zones. The density inside the fishing zone tends to zero, and the flow of transfer tends towards a limit proportional to the SMBL in the reserve. When the fishery is heavily fished, most of the catches come from transfers from the reserve.

Figures 3 and 4 compare several scenarios concerning the relative size of the reserve and fishing zone. As shown by Figure 3, the level of the SMBL (the asymptotic value of fish biomass in the reserve and, by extension, in the whole area when fishing effort grows indefinitely) is an increasing function of the ratio α representing the share of the reserve in the whole area. This protection effect of the reserve has a counterpart in terms of catches, which appears in Figure 4. Protecting the stock against the risk of a collapse, the reserve also secures catches if fishing effort becomes very important : as was shown on figure 2, the flow of catches becomes close to the flow of net transfer from the reserve, which itself depends on the ratio α. However, the relation is not monotone, because, when the fraction of the stock inside the fishing zone tends to zero, the net flow of transfer from the reserve comes close to :

$$T^* = \sigma.(1 - \alpha).X_{F1}^*$$

where X_{F1}^* is the SMBL. The higher α, the higher is also X_{F1}^* (cf. Figure 3), but the lower is $(1 - \alpha)$, the share of the fishing zone in the whole area. These two factors act in opposite directions on T^* : the flow of transfer from the SMBL, which is low when the ratio α is close to zero, increases with α up to some point, after which it starts decreasing as α tends to 1. On figure 4, T^* increases when α goes from 30% to 50%, but decreases if α goes from 50% to 80%.

For a lightly fished fishery, the volume of sustainable catches corresponding to a given level of effort and the ratio α vary in opposite directions. This is so because in this case, net transfer from the reserve is unimportant (see Figure 2), and the main consequence of increasing α is to diminish the biomass directly exploitable by fishermen.

The value of α maximising catches varies according to the level of fishing effort. Low or even zero when fishing effort is not important, this value shows a tendency to rise (up to some limit) as fishing effort increases. If fishing effort and its impact on fish biomass are under perfect control, there is little to expect from the creation of a marine reserve as regards fisheries management : the *maximum maximorum* of catches (and, a fortiori, of fishing rent[1]) is achieved with a zero α. However, as was stated by Holland and Brazee (1996), if the control of fishing effort is bounded by social / political constraints, the creation of a reserve may in some cases be regarded as a second best solution, because once a certain level of effort is attained, sustainable catches become more important with a reserve than without it, caeteris paribus. This feature, added to the benefits of "bet-hedging" advocated by Lauck et al. (1998), suggests that in many real world cases, characterised both by the existence of some control of fishing effort and by the political inability of the regulator to bring it down to the "first best" level, marine reserves should be regarded as a useful tool for fisheries management. The benefits of this solution are jeopardised if the creation of the reserve is followed by an increase in total fishing effort, which is the type of problem addressed by Hannesson (1998) and Anderson (2000), when they make the hypothesis of free access to the resource outside the reserve.

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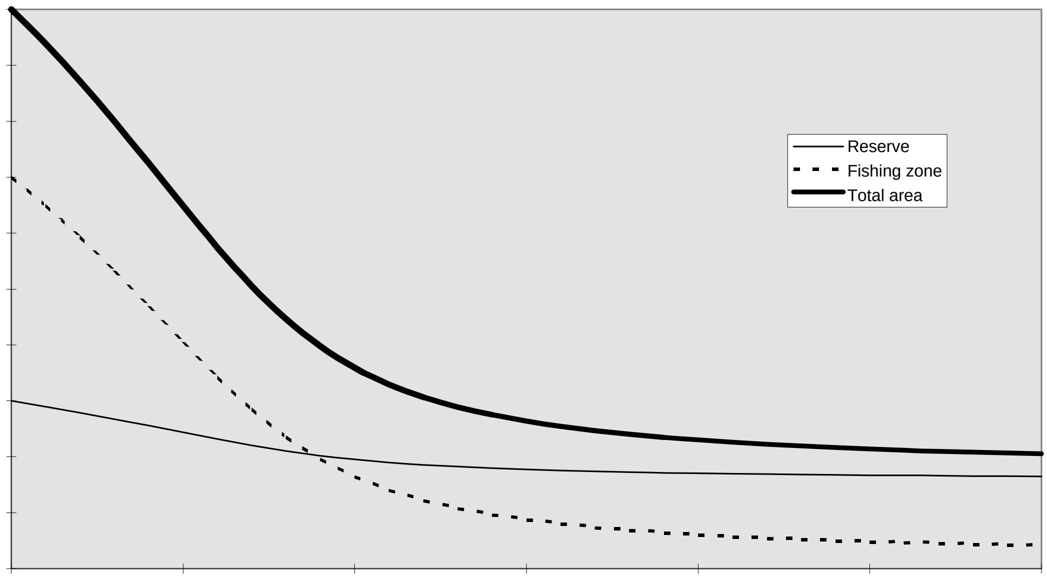
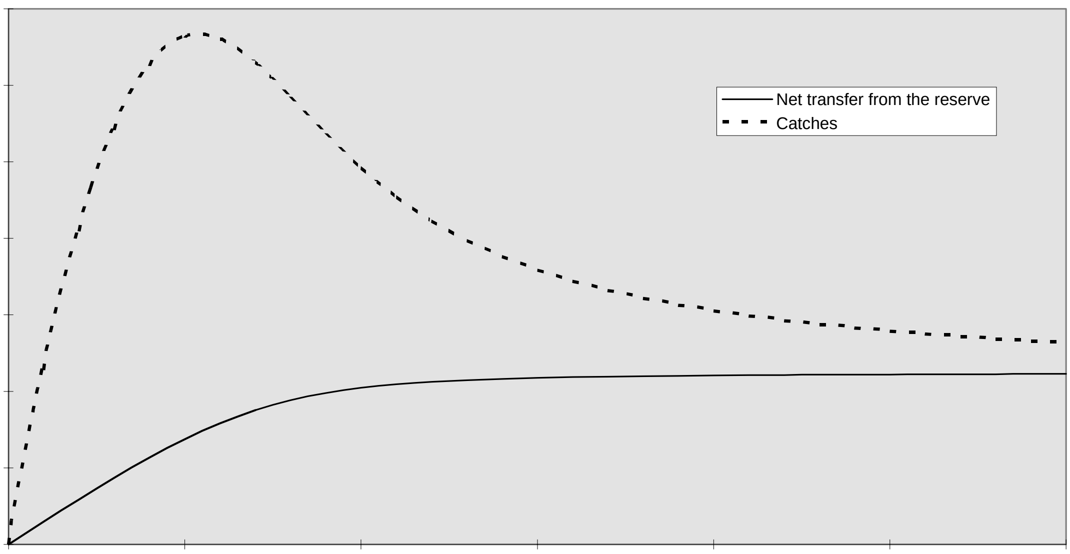
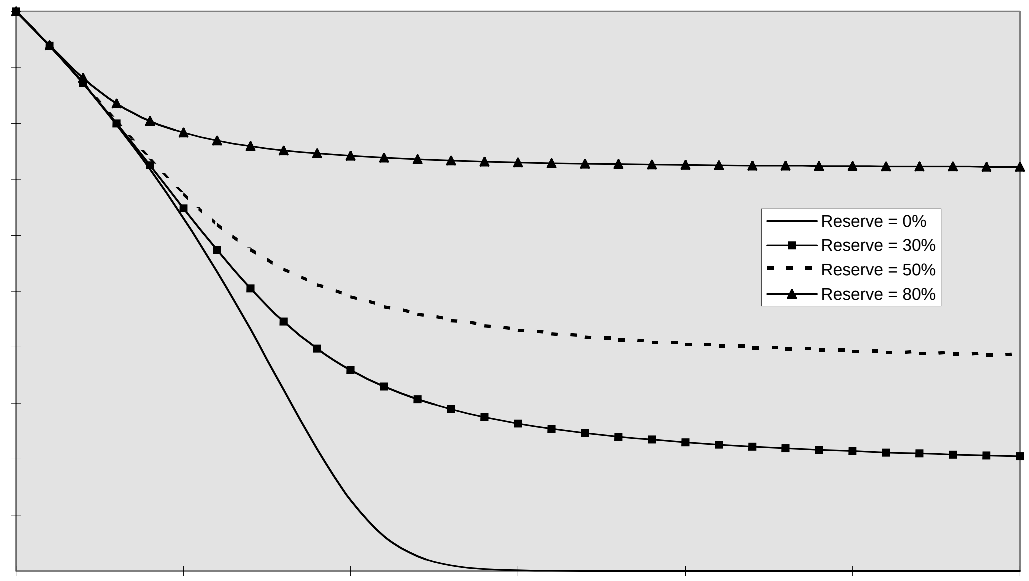
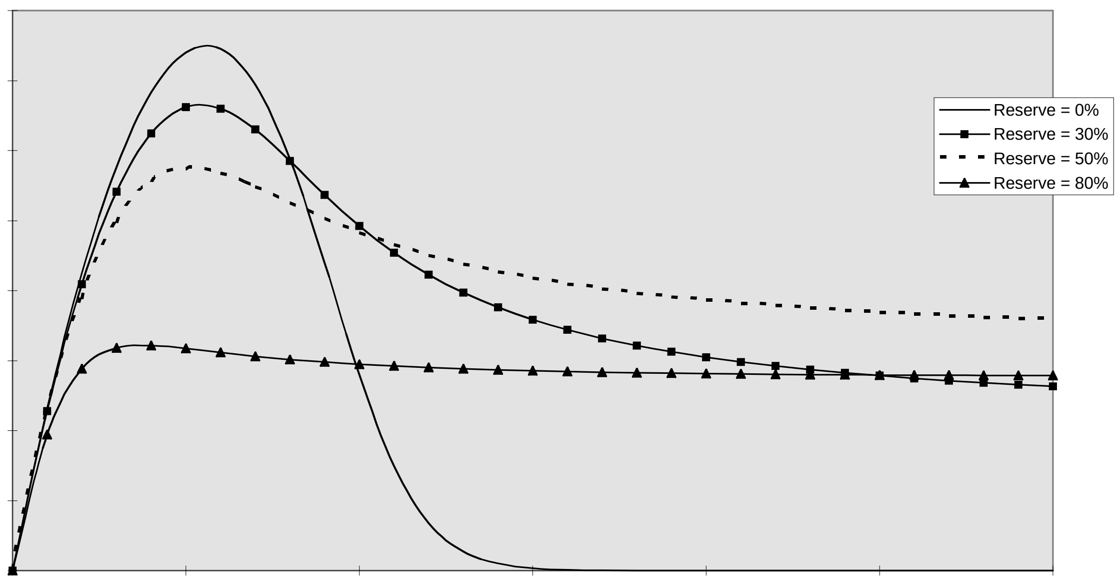
[1] The level of effort maximising rent being systematically lower than the one maximising catches, as soon as the marginal cost of fishing effort is positive.


Reserve
Fishing zone
Total area


Net transfer from the reserve
Catches


Reserve = 0%
Reserve = 30%
Reserve = 50%
Reserve = 80%


Reserve = 0%
Reserve = 30%
Reserve = 50%
Reserve = 80%

2.2.2. Consequences of the predator-prey interaction

We now turn to the case where $\beta > 0$, i.e. we suppose that seals, along with fishers, exert some predation on the fish stock (Figures 5 to 9). Compared to the former simulations, those performed under this hypothesis will help to assess the indirect impact of the reserve on the fishing industry (i.e. the consequences due to ecosystemic interactions), as well as the impact of the reserve on ecotourism (seal watching). The dotted line on each figure recalls the situation when there is no predation by seals ($\beta = 0$).

Figures 5 and 6 illustrate the impact of the predator-prey relation on biomasses and catches in relation to fishing effort, for a given size of the reserve. The comparison between the dotted line and the continuous line on Figure 5 shows that taking into account the prey-predator relation lowers the level of equilibrium fish biomass for each level of fishing effort. In particular, the SMBL is lower when the predator-prey interaction is taken into account, and varies inversely to the rate of predation by seals (see Appendix II for a demonstration). However, the negative effect of the predator-prey interaction, which is the consequence of predation by seals, becomes less important when fishing effort grows, because the food shortage which this growth induces for seals results in a decrease of their equilibrium stock (see lower line on Figure 5).

Figure 6 illustrates how, under equilibrium conditions, the flow of natural growth of the fish biomass is shared between fishermen and seals, for various levels of fishing effort and for a given size of the reserve. The flow of predation by seals, which is equal to the total flow of natural growth of the fish biomass when there is no fishing effort, decreases both in absolute and relative terms when fishing effort grows, making the competition for food tougher for seals, and thereby diminishing their stock (see Figure 5). Figure 6 also shows that, for any given level of effort, taking into account the prey-predator relation results in lowering the level of equilibrium catches by fishermen.

Figures 7, 8 and 9 display some consequences of the prey-predator interaction in relation to the size of reserve, for a given level of fishing effort.

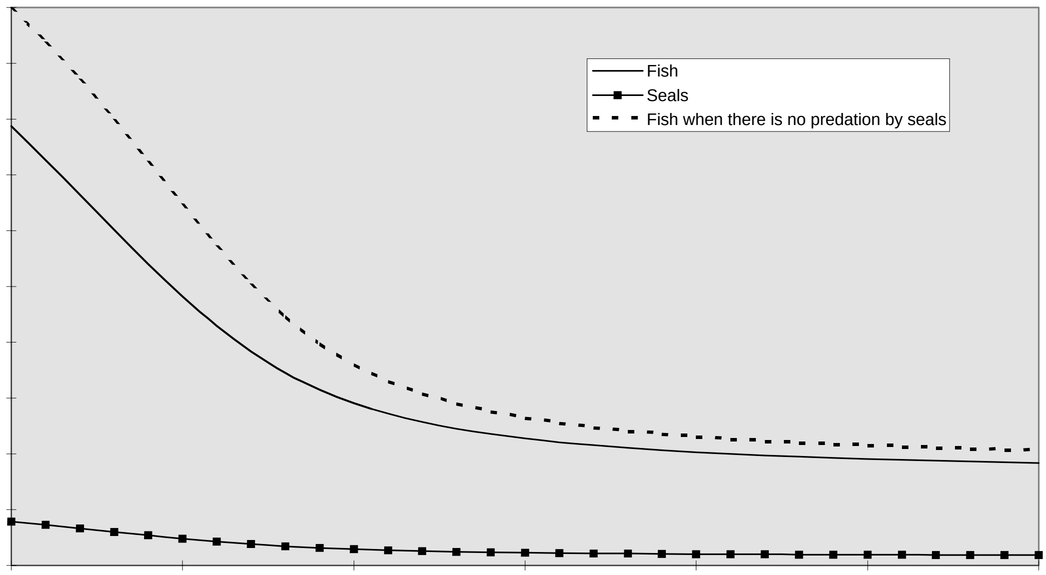
Figure 7 shows that the impact of this relation on the equilibrium fish biomass is more important when the share of the reserve in the total area is large. This is due to the fact that any increase in food abundance (a consequence of increasing the reserve size with a given level of effort) results in increasing the seal stock : under the assumptions of the prey-predator model used here, not only do seals eat more when there is plenty of food, but they become more numerous[1]. While the predator-prey interaction may be regarded as an unnecessary refinement of the analysis in the case of a small α, this parameter becomes critical if the relative size of the planned reserve is large, a condition which is often regarded as necessary if the reserve is meant to generate significant impacts on the situation of the fishery (Lauck et al., 1996 ; Sladek Nowlis and Roberts, 1999).

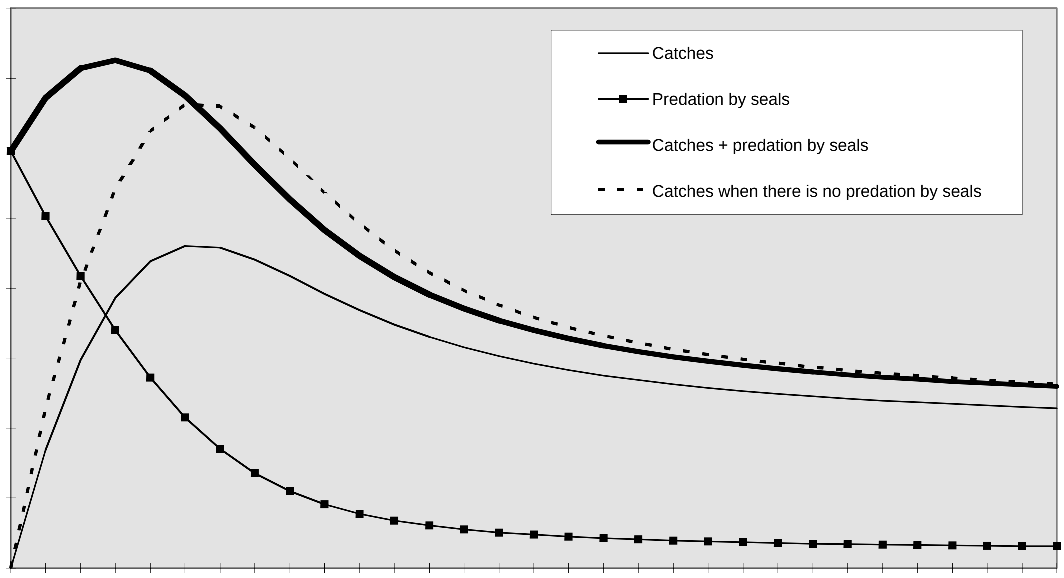
[1] Joining equations (1), (2), (3) and (11) shows that, under equilibrium conditions, predation by seals is proportional to the square of the fish biomass.

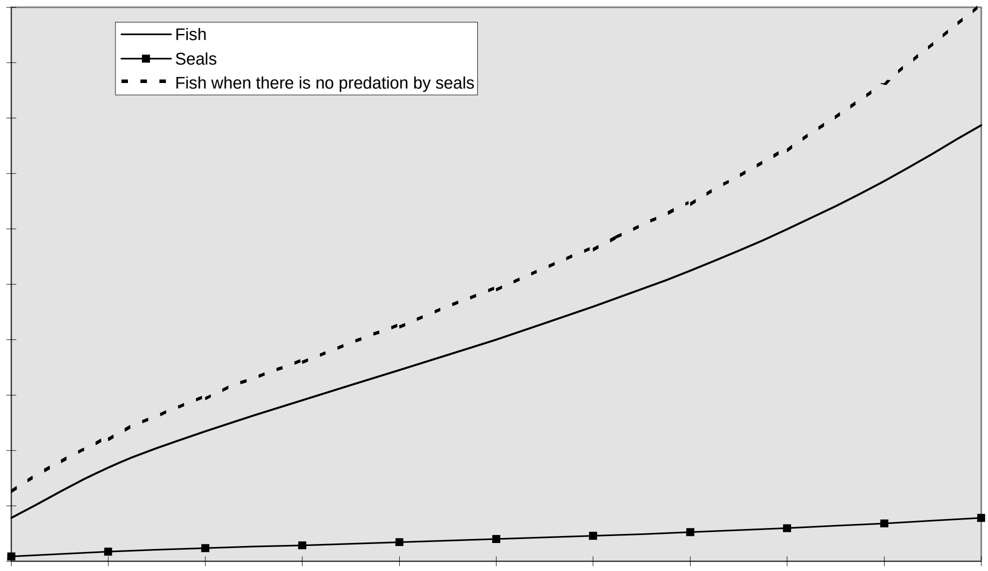
Figure 8 depicts the consequences in terms of flows. It shows that, while the total flow of increase in fish biomass is a monotonically growing function of the relative size of the reserve, for large values of α this phenomenon benefits seals rather than fishers. Two factors explain this feature : 1) the switch to a larger relative size of reserve increases the seal stock (see Figure 7), while fishing effort is assumed to be unchanged ; 2) while fishermen respect the fishing ban inside the reserve (also by assumption), seals ignore it and pursue their prey over the whole area, whatever the level of α adopted by the fishery regulator.

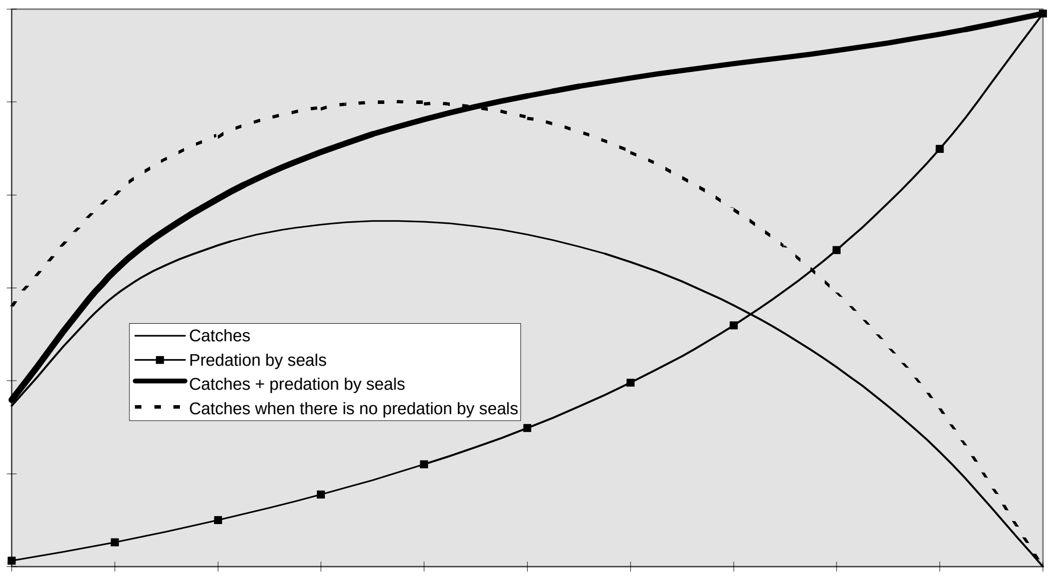
Figure 9 translates the features displayed by Figure 8 in terms of economic rent, and illustrates the trade-off between the fishing industry and ecotourism according to the relative size of reserve which is adopted. It should be stressed that, because the values of parameters are arbitrary (and in particular the prices and unit costs of each activity), the indications given by the figure are qualitative. The economic parameters of the model have been fixed at levels such that the fishery rent is zero when there is no reserve, and the break-even point for the ecotourism industry corresponds to a 10% relative size of the reserve. This case is of course just an example.

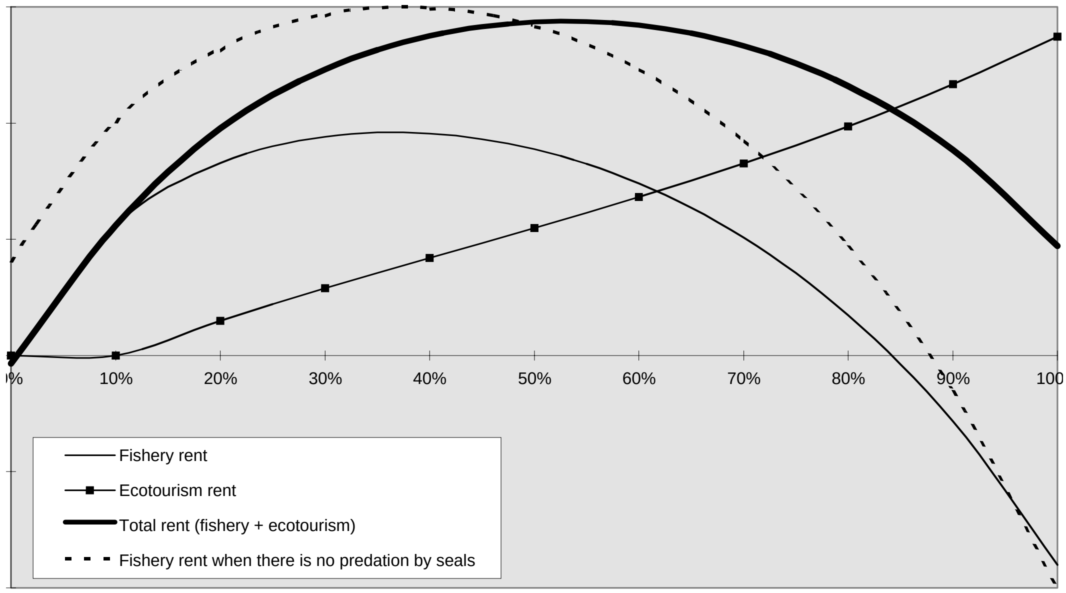
According to Figure 9, the steady-state rent derived from the fishery increases with the relative size of the reserve, for an unchanged level of effort, up to an α, between 30% and 40% of the total area in the case illustrated here. This is the direct consequence of the increase in catches (see Figure 8), which is itself the result of the increase in the fish biomass protected by the reserve. However, beyond this level of α, catches decrease because the net transfer of fish from the reserve is not important enough to compensate for the negative impact of the decrease in the size of the fishing zone. So does the fishery rent, the level of effort and unit prices being unchanged by assumption. The comparison of the fishery rent curve with the dotted line (fishery rent when $\beta = 0$) shows that, for any value of α, the predator-prey interaction reduces the benefits of the reserve for fishers (the importance of this effect will depend on the actual size of the impact of predation by seals on fish biomass). At the same time, the growth in the seal stock generated by a higher relative size of the reserve increases the opportunity of making money through ecotourism. Unlike the relation between fishery rent and α, the relation between ecotourism rent and α is monotone, because 1) the seal stock increases monotonically with α, and 2) the number of visits by ecotourists is assumed to be an increasing function of the seal stock. As a result, the higher is α, the larger the gap is between the total economic surplus generated by the marine reserve and the fishery rent. A corollary is that the optimal reserve size, according to a global cost-benefit analysis, is larger than the one which looks optimal if fisheries management is the only objective (within the interval between the two corresponding αs, the net marginal loss for the fishing industry induced by an increase in the relative size of the reserve being lower, in absolute value, than the corresponding net marginal gain for the ecotourism industry). As long as the reserve size is kept below the level maximising fishery rent, any marginal increase in α benefits simultaneously both activities (Pareto-improving change). Beyond this level, any further increase in the reserve size will still improve overall efficiency of the reserve, provided α is kept below the level maximising global economic surplus. However, this improvement will be realised to the detriment of the fishing industry, which suggests that the fishing sectors might seek compensation of some sort for lost revenues. A such, policy makers seeking to put marine reserves in place may need to be sensitive to these losses, in order to enlist necessary support.


Fish
Seals
Fish when there is no predation by seals


Catches
Predation by seals
Catches + predation by seals
Catches when there is no predation by seals


Fish
Seals
Fish when there is no predation by seals


Catches
Predation by seals
Catches + predation by seals
Catches when there is no predation by seals



0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100
Fishery rent
Ecotourism rent
Total rent (fishery + ecotourism)
Fishery rent when there is no predation by seals

2.3. Conclusions of the model

The aim of the simulation model presented here is to develop further insights to the economics of marine reserves, from a multispecies perspective and taking into account non-extractive uses of marine ecosystems. The complexity of ecosystemic interactions is sometimes advocated for keeping up with monospecific modelling, because little advantage is expected from the integration of trophic competition or predator-prey relations between stocks as far as economic assessment of marine reserves is concerned (Holland and Brazee, 1996). In some cases however, multispecies modelling is necessary to deal with the economic problem which is addressed. A case in point is the situation where a marine reserve is planned inside an area sheltering a stock of fish targeted by fishers and a stock of predators which is protected by law from any extractive use, but which may provide benefits from non extractive uses. Though based on real world considerations (both as regards biology and institutions), the model presented here does not pretend to entirely capture the complexity of ecosystemic interactions at stake[1]. Moreover, due to the arbitrary parameter values used in the simulations, the significance of the conclusions which may be drawn from these simulations is mainly qualitative. These conclusions may be summed up as follows :

1. The model supports the idea that implementing a marine reserve in part of a highly fished fishery may constitute a second best solution as regards fisheries management, in the case where the entry into the fishery is limited but the regulator's ability to lower fishing effort is bounded by social / political constraints. This idea, which was put forward by Holland and Brazee (1996) in a monospecific context, still holds when the area is inhabited by a non-harvested stock of predators competing for fish with fishers and taking advantage of the creation of the reserve.
2. The predator-prey interaction results in lowering the benefits of the reserve for fishers. This affects the steady-state fishery rent for any given level of fishing effort, but also the expected results of the reserve in terms of conservation effects, as the safe minimum fish biomass level provided by the implementation of the reserve is reduced by the fish mortality due to the unharvested stock of predators.
3. If the stock of predators may be economically valued by means of a non-extractive use (ecotourism), the implementation of the reserve generates additional incomes through this channel. According to local circumstances, these extra incomes will partly or totally offset the negative impact of the predator-prey interaction on the fishery rent.
4. In this case, the model suggests that the optimal relative size of the reserve, from a global cost-benefit analysis point of view, is larger than when only fishery rent is considered.

Conclusions 3 and 4 raise the issue of the distributional impact of the reserve, and of the possibility for fishers to participate in the benefits generated by ecotourism. This issue could be addressed by incorporating some relations into the model that depict more explicitly the costs and benefits to fishers of diversifying their activity.

[1] For instance, the global treatment of fish does not allow the model to deal with the fact that, in most marine systems, the largest predator of fish are other fish, not marine mammals. However, the reasons why we give a special treatment to the seal-fish relation in the model are not biological, but institutional and economic : we suppose that, as opposite to various fish stocks, marine mammals are protected by law and may derive an economic value from non-extractive uses. These seem to be realistic assumptions in a number of temperate inshore waters cases.

3. Assessing potential diversification of commercial fishing towards recreational activities[1]

In its present state, the bioeconomic model presented in the former section is by several ways highly speculative. Some of its parameters, such as fishing costs and landing prices, could be given realistic values on the basis of field information collected about the Iroise area (section 1). But other parameters, such as mobility coefficients, seem more difficult to quantify. Moreover, several assumptions of the model are dangerously oversimplifying as regards the Iroise case. To this category belong the assumptions of space homogeneity and closeness of the area corresponding to the future marine park.

However, the model points out a major problem to be addressed by the future marine park management authorities, which is related to the distributional implications of attempts to conciliate environment conservation, commercial fishing and recreational activities. As regards commercial fishing, this problem is likely to be critical for the fraction of the commercial fleet which is highly dependent on the Iroise area fishery, i.e. mainly the groups of liners, dredgers, seaweed harvesters, and small netters and potters (see section 1).

A possible way to overcome the opposition to fishing restrictions is to associate fishers to the economic surplus generated by environment conservation and the development of recreational activities. The last section of this report investigates the potential of diversifying the activity of commercial fishermen towards boat-chartering, whether for recreational fishing[2] or for ecotourism. The results of two field studies give some information concerning the degree of realism of this approach, in the Iroise case. One of these studies deals with the demand side, the other with the supply side.

3.1. Interest of tourists for recreational tours on commercial fishing boats

In order to assess the potential interest of tourists frequenting the Iroise area for recreational tours on small-scale commercial fishing boats in the Iroise area, a sample field survey was realised during the « high season » of 1998, by means of direct interview of persons randomly met in three spots highly frequented by tourists[3] (Alban, 1998). Two types of tours on commercial fishing boats were considered : half-day or one-days trips for recreational fishing with a guide ; half-day trips for discovering the area with a guide, without fishing. The potential interest for these types of tours was investigated as follows :

- each type of trip was described (without price information), and, for each one, a general question concerning a possible interest was asked ;
- in case of a positive answer, a list of prices was presented and the interviewed person was asked to indicate what is, to her or his mind, the approximate usual price level ;
- at the following step, the actual approximate price was announced[4], and then the interviewed person was asked if she or he would accept to pay the price ;

[1] Contributors to this section are Frédérique Alban and Jean Boncoeur. Part of the results it contains have been presented at the *People at Sea Conference* held in Amsterdam, August-September 2001 (Alban and Boncoeur, 2001).

[2] Recreational fishing is an extractive activity, just as commercial fishing. However, the ratio of the quantity of fish extracted to economic value created is very different : according to estimations presented in section 1, the average unit value of fish landed by recreational fishers (assessed on a cost basis) is approximately 5 times as high as that of commercial fishers operating in the Iroise area.

[3] Fishing harbour of Le Conquet, parking lot of the *Océanopolis* Ocean discovery centre in Brest, boat providing regular service between mainland and the islands of Ouessant and Molène.

[4] An average of 26 answers given by previously interviewed fishing guides and charter boat operators.

- in case of a positive answer, some complementary questions were asked, among which the number of persons of the family (if any) who were liable to attend the tour with the interviewed person.

For material reasons, the number of interviews was only 159[1], which limits the statistical significance of its results. Unlike surveys mentioned in section 1, the survey described here covers « neighbourhood tourism ». It also includes residents of the area : 41% of interviewed people declared that they live inside the Brest district.

The first table below sums up the characteristics of the sample, and the next one indicates the characteristics where statistically significant differences were noted between interviewed people living in and out of the Brest district :

Table 47. Field survey of potential interest for recreational tours on fishing boats : sample description*

Gender	Female	45 %
	Male	55%
Age	under 20	9 %
	20 to 30	36 %
	31 to 55	39 %
	over 55	16 %
Permanent living place	Brest district	41 %
	Other	59 %
Household size	1 person	14 %
	2 persons	21 %
	3 persons	14 %
	4 persons	29 %
	over 4 persons	22 %
Occupation	Farmer	1 %
	Entrepreneur	4 %
	Blue collars, employees and intermediate white collars	34 %
	Senior and non-wage white collars	36 %
	No professional activity	25 %
Type of personal relation to the sea**	Recreational fishing	47 %
	Water sports	32 %
	Visit of maritime museums, of fishing harbours...	74 %
	hiking on the shore	86 %
	Family origin (fishermen, sailors...)	42 %
	Holiday on the seaside	89 %
	Other	7 %

* Percentages of the whole sample (n = 159). ** Possibility of multiple answers. Source : Alban, 1998.

Table 48. Field survey of potential interest for recreational tours on fishing boats : characteristics of the sample with statistically significant differences* between people living in and out of the Brest district**

		Brest district (n_1 = 65)	Other living places (n_2 = 94)
Occupation	Senior and non-wage white collars	23%	45%
	No professional activity	32%	19%
Type of relation to the sea***	Recreational fishing	69%	31%
	Family origin	54%	34%
	Holiday on the seaside	82%	94%

* Probability over 95% that the two main populations are different as regards the considered character (t > 1.96).
** Percentages in each subset. *** Possibility of multiple answers. Source : Alban, 1998.

[1] Representing approximately 70% of the total number of persons who were asked to answer the questionnaire. The main reasons given for refusing to answer were lack of time and lack of interest for the subject.

The next table sums up the results of the survey concerning the interest declared by people in the sample for guided boat tours, and more specifically tours on commercial fishing boat for recreational fishing and / or discovering the Iroise area :

Table 49. Field survey of potential interest for recreational tours on fishing boats : declared interest and willingness to pay for a boat tour with a guide for visiting the Iroise area and / or recreational fishing*

1. On a non-specified type of boat	
Persons declaring they are interested in a one-day or a half-day boat tour with a guide	75 %
2. On a small-scale commercial fishing boat	
Persons declaring they are interested in :	
– a one-day or a half-day guided recreational fishing tour	22 %
– a half-day guided discovery tour	30 %
– at least one of the two above mentioned performances	41 %
Persons declaring they would accept to pay the announced price for :*	
– a one-day or a half-day guided recreational fishing tour	19 %
– a half-day guided discovery tour	28 %
– at least one of the two above mentioned performances	38 %

* Percentages of the whole sample (*n* = 159). ** 220 FF (33.5 euros) for a half-day recreational fishing trip, 350 FF (53 euros) for a one-day recreational fishing trip, 80 FF (12 euros) for a two-hour discovery trip. Source : Alban, 1998.

The table displays a high percentage of people declaring a general interest for boat tours with a guide (75%). The percentage is still high if only tours on commercial fishing boats are considered (41% of the whole sample). Among the subset of people declaring they are interested in such tours, more people are interested in discovering the area (73% of the subset) than in fishing (54%), but these two types of performance do not necessarily exclude each other : 27% of the subset are interested by both.

A total of 38% of the persons in the whole sample declared they would accept to pay the announced price for a one-day or half-day guided tour with on a commercial fishing boat. This ratio is only slightly below the percentage of people simply declaring they are interested (41%), a phenomenon which may be explained by two different types of considerations :

1. the knowledge of actual prices is rather good among the persons of the sample, as show the answers concerning the lists of prices that were presented to the interviewed persons (in particular, few people heavily underestimated the actual prices) ;
2. the acceptance of payment is only virtual, since no actual transaction was, of course, proposed during the survey. Quite possibly, actual payments would be lower. This so-called « hypothetical bias » is inherent in all surveys about the willingness to pay for a hypothetical good or service and, more generally, in surveys where people are asked to imagine what they would do if they were in a different situation from the actual one. All that can be done is to minimise this bias, by avoiding to ask questions on subjects people are really unfamiliar with. This condition may be considered as reasonably fulfilled in the present case, due to the places where people were interviewed, to the characteristics of the people in the sample and to the explanations given in the course of the interview concerning the performances under investigation.

Persons declaring they would accept to pay the announced price for a guided tour on a commercial boat for recreational fishing or / and visiting the area were asked some additional questions concerning their attitude towards this type of trip. This attitude varies according to the trip. In particular, the number of persons per household who are liable to be involved is not the same for recreational fishing tours and discovery tours : 71% of all persons declaring they would accept to pay the price for a 2-hour guided tour devoted to the visit of the area said that they would come « with their family » (average household size of the sample : 3.4

persons), while the corresponding percentage is only 35% for the people declaring they would accept to pay the price for a one-day or half-day recreational fishing trip.

The table below indicates the characteristics where statistically significant differences were noted between the subset of the sample willing to pay the announced price for a guided tour on a commercial fishing boat and the rest of the sample :

Table 50. Field survey of potential interest for recreational tours on fishing boats : statistically significant differences* between the subset of people willing to pay for the announced price for a tour on a commercial fishing boat and the rest of the sample (percentages of each subset)

		Subset 1 : persons accepting the price** (n_1 = 61)	Subset 2 : other persons*** (n_2 = 98)
Age	over 55	8%	21%
Living place	Brest district	31%	47%
	Other places	69%	53%
Occupation	Senior and non-wage white collars	51%	27%
	No professional activity	13%	32%

* Probability over 95% that the two sets are extracted from different main populations as regards the considered characteristics. ** People declaring they would accept to pay the announced price for a one-day or a half-day tour on a commercial fishing boat for discovering the area and / or recreational fishing. *** Rest of the sample. Source : Alban, 1998.

Statistically significant differences between the two subsets concern the geographic origin, the age structure and the profession. In the subset of people declaring they would accept to pay the announced price, the proportion of people living in or around Brest is significantly lower than in the rest of the sample. So are the proportion of people over 55 years old and the proportion of persons without professional activity. On the contrary, the proportion of senior white collars is higher than in the rest of the sample. These differences are interconnected. An important proportion of the people in the sample who live in or around Brest have their own boat. They frequently use it for recreational fishing, and few of them are willing to pay for a guided tour on a commercial fishing boat. These people are often retired, hence the important proportion of persons over 55 and without professional activity in the subset of people unwilling to pay the announced price for a guided tour on a commercial fishing boat. On the contrary, a high proportion of people declaring they would accept to pay the announced price do not live in the Brest area, where they spend their holidays. They are interested in fishing and / or « ecotourism », but usually do not own a boat. The high representation of senior white collars in tourists visiting Western Brittany has been depicted by Anon. 1998/2, and this phenomenon is emphasised in the present case.

Taking the yearly number of visitors of the *Océanopolis* Ocean discovery centre as a proxy variable for the main population of the sample[1], and taking into account persons who refused to answer the questionnaire[2] leads to a rough estimation of some 37000 persons declaring they would accept to pay the announced price for a guided tour on a commercial small-scale fishing boat in the Iroise area. Due to the limited size of the sample as well as the uncertainty concerning the size of the main population, this result mainly suggests that there is a substantial amount of economically realistic interest of the public (mainly tourists) for such trips, oriented towards ecotourism and / or recreational fishing.

[1] The parking lot in front of *Océanopolis* was only one of the three spots where the interviews were realised. But the answers did not show statistically significant differences according to the places of interview.

[2] These persons, who represented approximately 30% of the total number of persons with whom the interviewers got in touch, were considered as not interested by boat tours.

3.2. The supply side

The likely existence of a significant demand for guided tours on commercial fishing boats in the Iroise Sea does not imply that it would meet a corresponding supply. Fishermen may be unwilling to diversify their activity, for various reasons among which economists are prone to privilege the lack of economic incentives. On the supply side, previous economic field surveys provide some information about the potential interest of commercial fishermen for diversification towards boat-chartering, and the potential profitability of this diversification.

3.2.1. Potential interest of commercial fishermen for diversification

Two of these surveys, realised in 1999-2000 in South Brittany and Iroise area[1], included a question related to the interest of skippers for a potential diversification of their activity towards boat-chartering for a recreational activity. The question did not mention any price consideration. Its purpose was just to test the *a priori* attitude of artisan fishermen towards an activity which is commonly considered as quite far from their own culture.

Table 51. Interest of skipper-owners of commercial fishing boats for a potential diversification (South Brittany and Iroise, 1999-2000, boats under 25 metres. Positive answers, as % of the sample*)

Whole sample		27%
According to boat length class		
	under 10 metres	35%
	10 to 16 metres	25%
	16 to 25 metres	5%
According to type of activity		
	Trawlers, purse seiners	10%
	Dredgers, seaweed harvesters, elver catchers	28%
	Netters, liners, potters	41%
According to skipper-owner's net annual activity income		
	under 100 KF	30%
	100 to 150 KF	39%
	150 to 200 KF	26%
	200 to 250 KF	15%
	over 250 KF	10%
According to skipper's age		
	under 30	57%
	30 to 40	39%
	40 to 50	23%
	over 50	11%

* *n* = 222. Source : CEDEM.

Slightly over one fourth of the skippers in the whole sample mentioned a potential interest for diversification. But this ratio is significantly differentiated according to various characters.

Unsurprisingly, the size of the boat plays a major role in this differentiation : skippers of smaller boats, whose activity is mainly inshore and come back to harbour every day, are more interested than skippers of larger boats, whose activity is mainly offshore and relies on trips lasting several days. While the percentage of positive answers is only 5% for boats between 16 and 25 metres, it rises up to more than one third for boats under 10 metres.

A second key factor of differentiation is the type of activity of the boat : the proportion of positive answers is much lower among skippers of boats using mainly trawls and purse seines (11%) than among skippers of boats mainly using lines, nets and pots (41%). This factor is

[1] The South Brittany survey is presented in Boncoeur, Le Floc'h et al., 2000. The Iroise survey is the one presented in the first section of this report.

partly correlated to the former one, since the class of boats between 16 and 25 metres is largely dominated by trawlers, a type of boat almost non-existent in the class under 10 metres. However, inside each class, a differentiation exists according to the type of activity. If only for technical and safety reasons, boats using towed gears are generally much less adapted to boat-chartering than boats using fixed gears, and the answers of skippers probably reflect this reality.

Skipper’s net income is also highly correlated to the size of the boat. However, the rate of positive answers to the question of interest for diversification does not vary monotonously according to this variable. The rate is almost 40% in the class of income between 100 and 150 KF (15000 and 23000 euros) per year, while it is only 30% for skippers earning less than 100 KF (15000 euros) per year. This result suggests that interest for diversification is not simply regarded as a possible solution to the problem of low incomes.

Such a conclusion is strengthened by the differentiation of answers according to skipper’s age. The trend is here clearly monotonous, with a sharp differentiation between young skippers and older ones : while only 11% of the skippers over 50 declare to be interested by diversification, the rate of positive answers rises to 57% among skippers under 30. It would be useful here to be able to distinguish the relative importance of two effects. The most obvious one is the age effect, which is due to the fact that fishermen, as other people, are probably less prone to change their habits when they grow older. But the answers might also include a generation effect, consisting in a change of attitude towards ecotourism and recreational activities among younger generations of professional fishermen. There seems to be here a potential for integrating fishermen in the process of management of MPAs.

However, some matter-of-fact considerations are likely to be powerful brakes to diversification. The most obvious one is the present state of administrative and fiscal rules, which in the French case make it uneasy for a professional fisherman to combine boat-chartering with his basic activity (Alban, 1998). Another possible impediment is the lack of economic stimulus.

3.2.2. Profitability of diversification

Chances of diversification are related to the expected profitability of this operation. The process of assessing the profitability of diversification towards boat-chartering is visualised on figure 10. It consists in the following steps :

1. multiplying the individual price paid by a customer for a chartered trip by the passenger capacity of the boat gives the maximum revenue per trip ; passenger capacity is limited by technical and safety considerations, usually according to the following rule : a maximum of 1 person on board (including crew) per metre of boat length ;
2. multiplying the maximum revenue per trip by the estimated average boat occupancy rate gives the average revenue per trip;
3. subtracting variable costs (fuel, bait...) from revenue per trip gives the direct gross margin per trip ;
4. making use of the boat for a chartered trip instead of a commercial fishing trip generates an opportunity cost, which is to be taken into account for assessing the profitability of diversification ; assuming a maximum of one chartered trip a day, the opportunity cost of such a trip consists in the average daily gross margin generated by commercial fishing (seasonal considerations should be taken into account here) ; the difference between the direct gross margin which was computed at the former step and the opportunity cost of a

chartered trip may be called the full gross margin ; it represents the profitability of diversification (per trip), as far as only variable costs are considered ;

5. multiplying the full gross margin per trip by the yearly number of chartered trips gives the yearly full gross margin generated by diversification ;
6. subtracting fixed specific annual costs of boat chartering (specific gear and safety costs, additional insurance costs, advertising...) from yearly full gross margin gives the net profitability of diversification for the boat-owner.

For the sake of illustration, a diversification scenario has been tested on the basis of the economic sample survey of the Iroise fleet (see above, section 1). The scenario has been applied to the group of netters / potters / liners under 10 metres long, i.e. to boats the skippers of which are the most likely to be interested by diversification (see table above). It relies on the following assumptions :

- half-day guided tour on a commercial fishing boat, for recreational inshore fishing ;
- fishing gear and bait provided ;
- price : 220 FF (33.5 euros) per customer, i.e. the price used as a basis for testing customers willingness to pay (see above) ;
- technical and economic characteristics of boat are equal to the mean values of the subset of 21 netters / potters / liners in the Iroise sample field survey ;
- during the chartered trip, boat is operated by only one person (skipper) ;
- gross margin generated by commercial fishing is supposed to be evenly distributed throughout the year.

The table below sums up the results of the diversification scenario built on these assumptions. According to these results, there does not seem to be a clear economic incentive to diversification for a large class of boats.

Balancing the average opportunity cost of boat chartering by the direct gross margin it generates necessitates a high occupancy rate for each chartered trip (minimum 86% on the average, according to the scenario). Moreover, even assuming a 100% boat occupancy rate, the full gross margin of diversification is rather thin on the average (under 180 FF, or 27.4 euros per trip, according to the scenario), which makes it difficult to cover its specific fixed cost : in the case of a boat chartered 50 days a year (i.e. approximately full time during the « high » tourist season), the net result of diversification is negative on the average, even assuming a 100% boat occupancy rate. According to the scenario, the minimum number of chartered trips for allowing the full gross margin of diversification to cover its fixed specific costs is over 100 per year (with a 100% occupancy rate), i.e. more than half of the average total number of days at sea of the considered type of boat (190 days per year, according to the field sample survey of the Iroise commercial fleet). This number is probably difficult to achieve, due to the length of the « high » tourist season and to weather conditions.

Fig. 10. Profitability of diversification

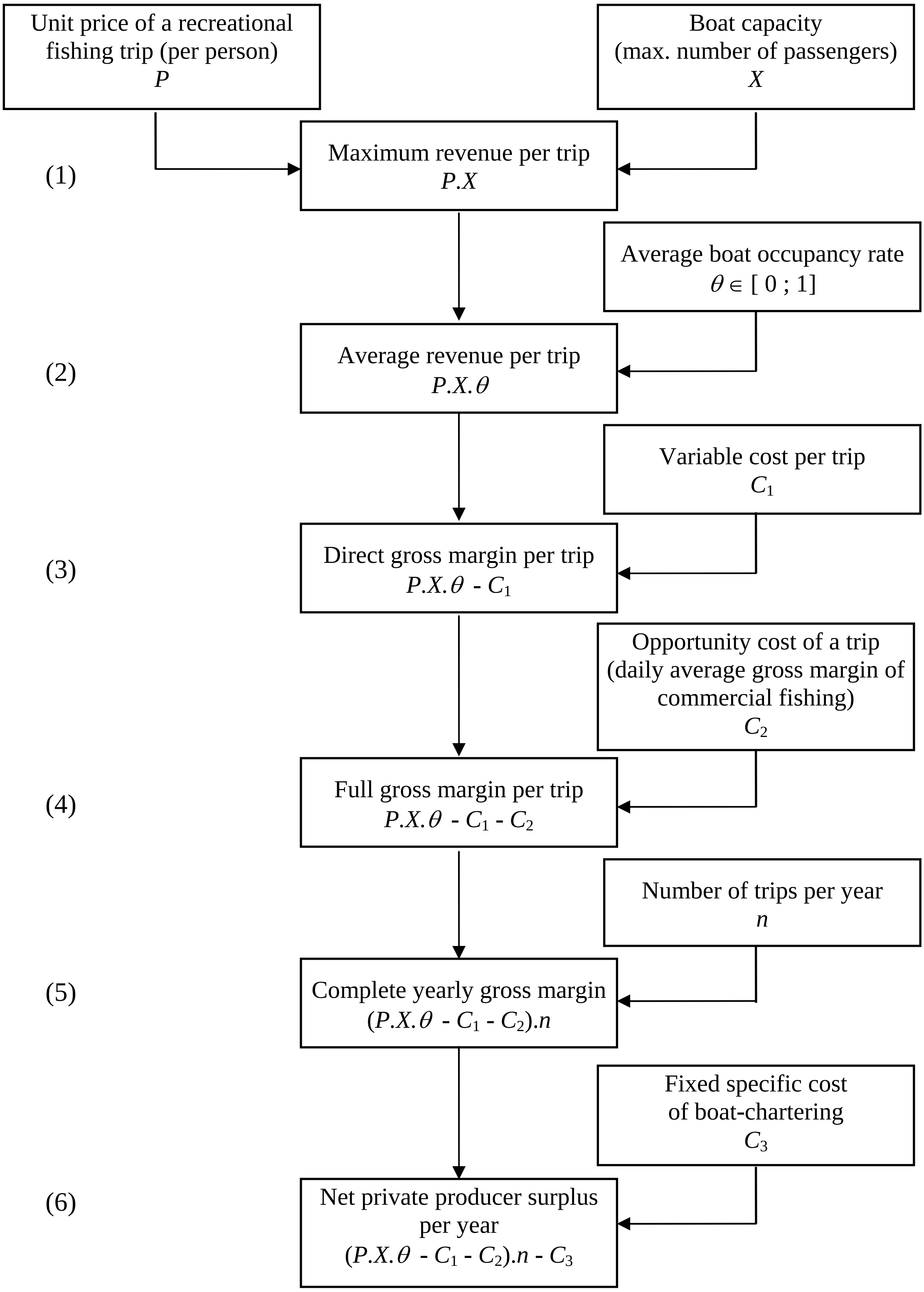


Table 52. Diversification scenario for a line / potter / netter under 10 metres long operating in the Iroise area

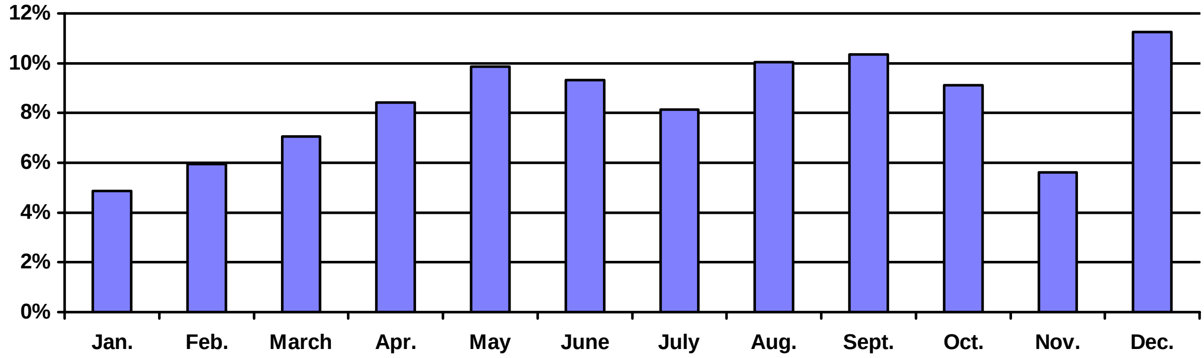
Boat characteristics		
	Length (metres)	7.8
	HP (kW)	64
	Boat capacity (max. number of passengers)	6
Revenue per chartered trip (KF)		
	maximum	1.32
	average[a]	$1.32 \times \theta$
Estimated variable costs per chartered trip[b] (KF)		0.10
Direct gross margin per chartered trip (KF)		
	maximum	1.22
	average	$(1.32 \times \theta) - 0.10$
Opportunity cost of boat chartering, per trip[c] (KF)		1.04
Full gross margin per chartered trip (KF)		
	maximum	0.18
	average	$(1.32 \times \theta) - 1.14$
Break even point, in terms of occupancy rate[d]		0.86
Estimated fixed yearly specific cost of boat chartering[e] (KF)		20
Yearly net private profit of diversification (KF), assuming 50 days of boat chartering per year		
	maximum	- 11
	average	$(66 \times \theta) - 77$
Break even point, in terms of yearly number of trips[f], assuming ($\theta = 1$)		113

[a] θ = average occupancy rate. [b] Fuel, bait, small supplies. [c] Daily average gross margin generated by commercial fishing (costs considered as variable are landing taxes, fuel, bait, ice, food, gear maintenance, wage costs except skipper).
[d] Minimum value of θ for a non negative full gross margin per chartered trip. [e] Specific gear and safety costs, additional insurance cost, advertising costs. [f] Minimum yearly number of chartered trips for a non negative net profit of diversification.
Sources : own elaboration, based on CEDEM sample survey of skipper-owners of commercial fishing boats operating in the Iroise area (restricted to a subset of 21 netters-potters-liners under 10 metres long), and interview of 9 recreational fishing guides (Alban, 1998) for specific boat chartering specific costs.

Seasonality considerations might affect the profitability of diversification. The highly seasonal character of tourism in the area (see above, section 1) as well as weather conditions imply that most chartered trips are likely to take place during July and August. Therefore, the relevant opportunity cost of a chartered trip is the daily average gross margin of commercial fishing during this period. The sample survey of commercial fishing boats which was used for building the scenario presented here does not provide detailed information on the seasonality of boats turnover. Indirect information may be found in the monthly variation of sales in fish auction markets of the Iroise area[1]. According to the figure below, July and August sales in the Brest fish auction market (shellfish excluded) represent 18.19% of the yearly total average for the period 1999-2001, i.e. are slightly above the average for 2 months (16.67%). The figure also suggests that the opportunity cost of boat chartering would be substantially lowered if chartered trips could take place during the months of November, or January to March, which is an unlikely hypothesis.

[1] This proxy is imperfect, since a large part of landings (specially of smaller boats) is not marketed through auction markets. This is particularly the case for crustaceans. Shellfish, which are not targeted by the type of boats considered here, have been excluded from the statistics.

Fig. 11. Time distribution of sales in the Brest fish auction market (shellfish excluded). Monthly sales as a % of the total value of yearly sales, average of years 1999 to 2001. (source : Brest fish auction market)



The poor economic performance of diversification depicted by the above described scenario should be balanced by two considerations :

1. The results presented here concern an average boat, the characteristics of which are derived from a mixture of different types of boats, with different fishing activities. Moreover, the statistical dispersion of individual values concerning the economic performance of these boats is high, as was shown in section 1. It is quite possible that diversification towards boat chartering is a profitable alternative for a limited number of boats inside the fleet operating in the Iroise area.

2. The opportunity cost which was considered in assessing the profitability of diversification is purely private, i.e. does not account for externalities due to the common pool character of fish stocks. If part of the boats operating the fishery are seasonally engaged in boat chartering instead of commercial fishing, this creates for other fishermen a positive externality which makes the social opportunity cost of diversification lower than its private cost[1]. Accounting for this positive externality would improve the overall economic balance of diversification. A system internalising the positive externality due to diversification could be set up, in order to translate it into private profit for fishermen practising pluri-activity.

[1] Provided catches generated by boat chartering (in the case of chartering oriented towards recreational fishing) are lower than the commercial catches they replace.

Appendix I : the discrete time version of the model

A discrete time version of the model was built for the sake of simulations. The transition from the continuous to the discrete version rests on some simplifying assumptions. Following Hannesson (1998) and Anderson (2000), we assume that, for each period, natural growth and migration of fish biomass take place after catches and are independent (they are in fact treated as discrete jumps at the end of each period)[1]. Moreover, we assume that catches by fishers and predation by seals are simultaneous, and that the natural growth of seal biomass also takes place at the end of each period. Under these assumptions, the equations of the discrete time version of the model may be written as :

(1') $$X_{F1(t+1)} = \left(X_{F1(t)} - Z_{1(t)}\right).\left[1 + r_F.\left(1 - \frac{X_{F1(t)} - Z_{1(t)}}{\alpha.X_{F\max}}\right)\right] - T_{(t)}$$

(2') $$X_{F2(t+1)} = \left(X_{F2(t)} - Z_{2(t)} - Y_{F(t)}\right).\left[1 + r_F.\left(1 - \frac{X_{F2(t)} - Z_{2(t)} - Y_{F(t)}}{(1-\alpha).X_{F\max}}\right)\right] + T_{(t)}$$

(3') $$X_{S(t+1)} = X_{S(t)}.\left[1 + r_S.\left(1 - \frac{\gamma.X_{S(t)}}{X_{F1(t)} + X_{F2(t)}}\right)\right]$$

(4') $$T_{(t)} = \sigma.\left[(1-\alpha).\left(X_{F1(t)} - Z_{1(t)}\right) - \alpha.\left(X_{F2(t)} - Z_{2(t)} - Y_{F(t)}\right)\right]$$

(5') $$Z_{1(t)} = X_{F1(t)}.\left(1 - e^{-\beta.X_{S.(t)}}\right)$$

(6') $$Z_{2(t)} = \left(\frac{\beta.X_{S.(t)}}{\beta.X_{S.(t)} + \frac{q.E_F}{(1-\alpha).A}}\right).X_{F2(t)}.\left(1 - e^{-\beta.X_{S.(t)} - \frac{q.E_F}{(1-\alpha).A}}\right)$$

(7') $$Y_{F(t)} = \left(\frac{\frac{q.E_F}{(1-\alpha).A}}{\beta.X_{S.(t)} + \frac{q.E_F}{(1-\alpha).A}}\right).X_{F2(t)}.\left(1 - e^{-\beta.X_{S.(t)} - \frac{q.E_F}{(1-\alpha).A}}\right)$$

(8') $$Y_{s(t)} = a.X_{s(t)}^{b}.E_s^{c}$$

(9') $$R_{F(t)} = P_F.Y_{F(t)} - C_F.E_F$$

(10') $$R_{S(t)} = P_S.Y_{S(t)} - C_S.E_S$$

Endogenous variables :

$X_{Fi(t)}$	Fish biomass inside zone *i* (*i* = 1, 2) at the beginning of period [*t* ; *t*+1[
$X_{S(t)}$	Seal biomass at the beginning of period [*t* ; *t*+1[
$Z_{i(t)}$	Predation of fish by seals inside zone *i* (*i* = 1, 2) during period [*t* ; *t*+1[
$Y_{F(t)}$	Catches of fish by fishers during period [*t* ; *t*+1[
$T_{(t)}$	Net transfer of fish from zone 1 to zone 2 at the end of period [*t* ; *t*+1[
$Y_{S(t)}$	Seal watching visits during period [*t* ; *t*+1[
$R_{j(t)}$	Rent generated by activity *j* (*j* = *F* , *S*) during period [*t* ; *t*+1[

[1] Anderson (2000) considers that they follow semi-continuous time processes (each period being divided into a fishing time and a growth-and-migration time, which makes it more difficult to consider growth and migration processes as independent).

Exogenous variables and parameters :

r_j	intrinsic growth rate of biomass j ($j = F$, S)
X_{Fmax}	fish carrying capacity of the whole area (zones 1 and 2)
α	share of the reserve in the whole area
A	surface of the whole area
σ	fish mobility coefficient
β	predation coefficient
γ	equilibrium ratio between fish biomass and seal biomass
q	catchability coefficient
E_j	anthropic effort in activity j ($j = F$, S)
a	Dimension parameter of the ecotourism attraction function
b	elasticity of visits with regard to the abundance of seals
c	elasticity of visits with regard to the ecotourism attraction effort
P_j	unit price of the product of activity j ($j = F$, S)
C_j	unit cost of effort devoted to activity j ($j = F$, S)

The simulations presented in the paper were based on the following initial conditions and parameter values :

Initial conditions			**Values of parameters and exogenous variables**		
$X_{F1(t=0)}$	=	$0,5.\alpha.X_{Fmax}$	r_F	=	0,3
$X_{F2(t=0)}$	=	$0,5.(1-\alpha).X_{Fmax}$	r_S	=	0,1
$X_{S(t=0)}$	=	$0,5.X_{Fmax} / \gamma$	X_{Fmax}	=	1000
			α	=	0 to 1 according to simulations
			A	=	1
			σ	=	0,2
			β	=	0,001
			γ	=	10
			q	=	0,0025
			E_F	=	0 to 300 according to simulations
			E_S	=	1
			a	=	1
			b	=	0,8
			c	=	0,2
			P_F	=	5
			P_S	=	6
			C_F	=	0,9
			C_S	=	60

Appendix II : the effect of the predator-prey interaction on the safe minimum fish biomass level provided by the reserve

Joining equations (1) and (9), we get the equilibrium condition of the fish biomass inside the reserve :

$$(12) \quad 0 = r_F . X_{F1} . \left(1 - \frac{X_{F1}}{\alpha . X_{F\max}}\right) - T - \beta . X_{F1} . X_S$$

In the same way, joining equations (3) and (11) gives us the equilibrium condition of seal biomass :

$$(13) \quad 0 = 1 - \frac{\gamma . X_s}{X_{F1} + X_{F2}} \quad \Leftrightarrow \quad X_s = \frac{X_{F1} + X_{F2}}{\gamma}$$

Joining (12), (13) and (4), we then get :

$$(14) \quad -\left(\frac{r_F}{\alpha . X_{F\max}} + \frac{\beta}{\gamma}\right) . X_{F1}^2 + \left(r_F - \sigma .(1-\alpha) - \frac{\beta}{\gamma} . X_{F2}\right) . X_{F1} + \sigma . \alpha . X_{F2} = 0$$

Solving this quadratic polynome in X_{F1} and selecting the relevant solution gives the equilibrium relation between the two fractions of the fish stock :

$$(15) \; X_{F1} = \frac{\left(r_F - \sigma .(1-\alpha) - \frac{\beta}{\gamma} . X_{F2}\right) + \sqrt{\left(r_F - \sigma .(1-\alpha) - \frac{\beta}{\gamma} . X_{F2}\right)^2 + 4 . \left(\frac{r_F}{\alpha . X_{F\max}} + \frac{\beta}{\gamma}\right) . \sigma . \alpha . X_{F2}}}{2 . \left(\frac{r_F}{\alpha . X_{F\max}} + \frac{\beta}{\gamma}\right)}$$

The fish SMBL is the equilibrium level X_{F1}* of fish biomass inside the reserve which is observed when the fish biomass in the fishing zone (X_{F2}) falls to zero, i.e. :

$$(16) \quad X_{F1}{}^* = \frac{r_F - \sigma .(1-\alpha)}{\frac{r_F}{\alpha . X_{F\max}} + \frac{\beta}{\gamma}}$$

In the particular case where β is equal to zero (no predation by seals), the expression of the SMBL becomes :

$$(16\text{-a}) \quad X_{F1}{}^* = \alpha . X_{F\max} . \left(1 - \frac{\sigma .(1-\alpha)}{r_F}\right)$$

which is the expression obtained by Anderson (2000). In the general case ($\beta \geq 0$), expression (16) shows that the SMBL is positive provided :

$$\alpha > 1 - \frac{r_F}{\sigma}$$

a condition which is always satisfied in the case where $\sigma \leq r_F$, and which is independent of the predator-prey interaction (parameters β and γ). However, when the above condition is satisfied, the level of the SMBL is a decreasing function of the ratio (β / γ), which means that the predator-prey interaction has a negative impact on the protective effect of the reserve, as regards fisheries management.

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