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Estimation of technical interactions due to the competition for resource in a mixed-species fishery, and the typology of fleets and métiers in the English Channel

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Abstract − In a multi-gear and multi-species artisanal fishery, the level of technical interactions (i.e. the competitive externalities resulting from a shared exploitation of common resources or fishing grounds) among various fishing units is high. Assessing these technical interactions is of great importance for fishery management, as any control applied to one fishing unit may have positive or negative effects on others. The magnitude and direction of these effects cannot be easily measured, unless all fishing units and species in the fishery are considered simultaneously. Technical interactions are particularly important in the complex artisanal fisheries of the English Channel. Using a bioeconomic model of the English Channel that incorporates all the major fishing units (the BECHAMEL model), we describe a method for measuring and classifying the technical interactions due to the competition for resource (stock externalities). The results are used to develop a typology of métiers and fleets based on their overall level of interaction for the resource. We also define fleets and métiers as structuring, dependent, intermediate or autonomous.

bioeconomic model / competition / stock externalities / technical interactions / typology / English Channel

Résumé − Estimation des interactions techniques dues à la compétition pour la ressource dans une pêcherie plurispécifique, et application à la typologie des flottilles et métiers dans la Manche. Au sein d'une pêcherie multi-engins et plurispécifique, le niveau d'interactions techniques existant entre différentes unités de pêche (flottilles ou métiers) peut être élevé. La mesure de ces interactions techniques est capitale en termes de gestion, car une mesure de gestion appliquée à une unité de pêche aura des conséquences, positives ou négatives, sur les autres unités. Cependant l'amplitude et le sens de ces interactions sont difficiles à mesurer, car toutes les unités de pêche et les ressources intervenant dans la pêcherie doivent être prises en compte simultanément. Les interactions techniques sont particulièrement importantes dans la pêcherie artisanale de la Manche. A partir d'un modèle bioéconomique intégrant l'essentiel des unités de pêche de la Manche (le modèle Bechamel), nous décrivons une méthode pour mesurer et classifier les interactions techniques issues de la compétition pour la ressource (externalités de stock). Les résultats sont utilisés pour développer une typologie des flottilles et métiers à partir de leur niveau global d'interaction. En fonction de ce critère, on définit des flottilles et métiers dits structurants, dépendants, intermédiaires ou autonomes.

modèle bioéconomique / compétition / externalités de stock / interactions techniques / typologie / Manche

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1. INTRODUCTION

In the multi-species modelling of commercial fisheries, technical (or technological) interactions have traditionally been promoted separately from biological interactions among species (such as predator-prey relationships). Technical interactions have been considered because of the existence of 'by-catch problems'. They have historically been defined as the interactions existing between a resource and fishing activities, resulting from the same resource population (stock) being exploited as a target or by-catch species by more than one fishery unit (Pope, 1979). This definition has developed to include all the competitive interactions affecting catch or economic performance that one fishing unit may have on any other fishing unit (effects known as externalities, e.g. Milon, 1989). The main technical interactions are thus either congestion externalities, (also called ground interactions) where fishing units compete for space (e.g. Boncoeur et al., 1998; Rijnsdorp et al., 2000), or stock externalities (also called resource interactions), where different fishing units are exploiting the same stocks. In the latter case, the direction of interactions depends on whether stocks are exploited as target or by-catches. They are reciprocal when all fishing units are targeting the same stock, then their individual revenues are linked. In contrast, they are univocal when some units target the stock whereas others harvest it as a negligible by-catch, or even discard it. In such a case, the fishery may suffer a potentially important economic loss (Pascoe, 1997). Only stock externalities (discards excluded) are studied in the current study.

For the operational needs of fisheries management, estimation of the direction and magnitude of technical interactions is of key importance. Knowing to which extent a management measure dealing with any segment of the fishery might have positive or negative effects on other segments, due to change in the competition level, is essential to assess the benefits of this measure. However, such externalities are rarely taken into account in a quantitative manner during decision-making, and the implications of not estimating them in detail have lead to enforcement problems (Mesnil and Shepherd, 1990). A review of the reasons for this omission is given in Laurec et al. (1991). Essentially, if by-catch can be modelled such that the fishing mortalities directed towards target species create proportionally constant mortalities on by-catch species, the implications of by-catch are relatively easy to understand (Shepherd, 1988). However, the situation is generally much more complex and requires a more thorough analysis and accurate data. Moreover, technical interactions cannot be assessed on only one part of the fishery. A relevant analysis requires an exhaustive overview of all fleets and species involved in the fishery. This implies integrating all effort, fishing mortalities, costs and revenues data occurring not only within, but also outside the area of interest. For example the migration of resources outside of the fishery, the time spent by fleets of interest fishing on remote fishing grounds, or the presence of fishing units coming from remote harbours in the area of interest might have major importance on the level of technical interactions, although adequate data are not always available.

Furthermore, a major problem in the analysis of competitive behaviour among fishing units arises in the fishers' ability to adapt their effort to any changes occurring in the resource availability, market prices and/or fishing strategies of other fishing units, and thus to a non-stable allocation of effort. Predicting the technical interactions between fishing units implies modelling the dynamics of effort allocation. This has been undertaken by relating allocation of effort for example to historical habits ('adherence') and economic incentives ('preference'; Laurec et al., 1991, Holland and Sutinen, 1999), to fishers perception of environment and risk taking (Allen and Mc Glade, 1986), to the number of other alternative tactics possible ('flexibility'; Laloë and Samba, 1991; Pech et al., 2001), or to stock collapse (Millischer et al., 1999). All studies point out the complexity of the relationships between fishing units, and the difficulty of taking them into account in a management scheme.

The first stage towards identification of technical interactions is a precise description of fishing activity. As such, the concept of the 'métier' was advocated by EEC workshops in order to categorise the activities of the fishing fleets. A métier is usually defined by the use of a given fishing gear in a given area, in order to target a single species or group of species, e.g. inshore shrimp trawling, offshore flatfish trammel netting … (Mesnil and Shepherd, 1990; Laurec et al., 1991). This concept brings more accurate description of the fishing activity than the single 'gear' term. It is commonly used to describe the fishing effort in European waters (e.g. Marchal and Horwood, 1996; Biseau, 1998; Jabeur et al., 2000), although it is sometimes referred to as 'trip type' or 'fishing tactic' (Laloë and Samba, 1991; Pelletier and Ferraris, 2000; Pech et al., 2001). Definition and description of métiers are varied, depending on the fishery of interest, but in all cases, it is necessary to respect the rule of homogeneity assuming rigid interactions within a métier, and implying that two fishing units using a same métier at the same moment induce proportional fishing mortalities (Laurec et al., 1991). This often leads to the identification of a larger number of métiers than fishers usually do.

The importance of an improved understanding of technical interactions has already been recognised in the English Channel. Precise descriptions of métiers, and qualitative estimates of their technical interactions (with which other métiers, and to which extent, they are competing for the resource, for the fishing grounds) and complementarities (which main other métiers are also practiced by the same fishing units throughout the year), have already been made (Dintheer et al., 1995a; Tétard et al., 1995). In this area (*figure 1*), more than forty species of fish, shellfish and

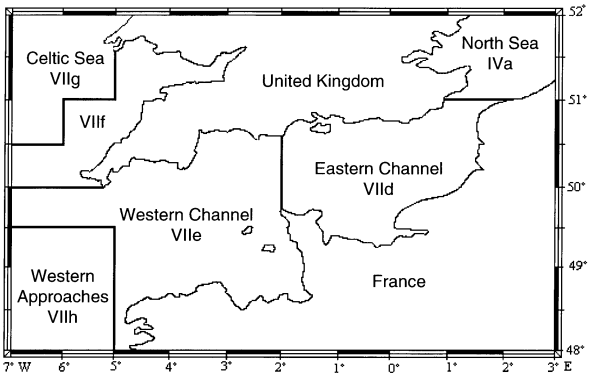

Figure 1. The English Channel and adjacent areas (ICES divisions IVa and VIId-h).

molluscs are exploited opportunistically by around 4 000 fishing units. The majority of these fishing units are small (< 16 m in length) and work inshore (< 12 miles from the coast). Most of them are polyvalent, and practice various towing and/or fixing métiers throughout the year (Ulrich, 2000). The English Channel fishery is a multi-nation, multi-gear, multi-species artisanal fishery, and the level of technical interactions is expected to be high (Tétard et al., 1995). However, these interactions have never been fully analysed and quantified, notably because of an often incomplete and heterogeneous quality of catch, effort and economic data. A recent extensive programme of data collection, collation and analysis lead to the development of the first full bioeconomic model for the region (Pascoe, 1998; Ulrich, 2000; Ulrich et al., in press). This conceptual model was developed in order to improve the quantitative understanding of the entire fishery, focusing on fleet activity and economic profitability. It is thus a particularly appropriate tool for the study of technical interactions due to resource competition. However, the model is at this stage of implementation a static model only. The potential changes of allocation of fishing effort in relation to changes of resource availability or of other fishing units effort cannot yet be measured. It is then not fully suitable to predict future interactions, but could provide an extensive quantification of the existing current ones.

In this paper, we extend the use of the model to the development of a method for estimating the direction and magnitude of technical interactions due to stock externalities. Furthermore, given the complexity of the fishery and the number of fleets and métiers involved, it is necessary to classify and describe the results in a simple and clear way. Building typologies has often proven to be a useful tool in the quantitative description and the analysis of fishing effort (Biseau and Gondeaux, 1988; Jabeur et al., 2000). The results of the method are then used to propose a new typology of fleets and métiers, based on stock technical interactions. The interest of such a typology is to clearly identify and group fleets and métiers showing similar competitive behaviour with others, and thus to understand potential externalities arising from management measures.

2. MATERIALS AND METHODS

2.1. Métiers and fleets in the English Channel

The definition of métiers within the English Channel fisheries was initiated during the 90s (Dintheer et al., 1995b; Tétard et al., 1995). In many cases, specific groups of target species were identified within a single combination of gear used and fishing area. Such métiers were given full specific names (e.g. UK west gadoid nets, French east shrimp trawls). In other cases, only one targeting strategy was identified in a given area using a given gear, or the métier was practised throughout the region. These métiers were named by their main spatial and fishing gear characteristics, e.g. French offshore longlines, UK west inshore beam trawls (*table I*).

However, the majority of fishing units take part in several métiers throughout the year, or even within a single trip. They cannot be identified to one single type of activity. The single métier concept is then not precise enough to properly describe the fishing activity in the English Channel. The fishing units practising similar groups of métiers were thus aggregated into fleets. Each fishing unit could only exist in a single fleet, but could take part in several métiers. Various fleet typologies had previously been implemented for Channel fisheries, but none of these apply at the global scale (Lemoine and Giret, 1991; Morizur et al., 1992). The common fleet typology used in the model includes all French and English fishing units in a homogeneous format (*table II*). An analysis of survey results (France) and logbook data (England) for the period 1993–1995 were then used to allocate each fishing unit to a fleet depending on their most active métier. Fleet activity was expressed in an activity matrix of mean annual percentage of time spent by each fleet in each métier. In order to allow for differences in fishing power, the fishing units were also stratified into six size classes, although the activity matrix was assumed to be the same for all size classes within the fleet. All English fishing units smaller than 10 m were aggregated into two fleets (east and west), as their individual identities and activities could not be sufficiently determined from logbook data. As a result, the resulting mean activity pattern is not representative for individual fishing units. Fishing units with home ports outside the Channel, but fishing regularly or sporadically in Channel waters, have also been included (with prefix Ex; *table II*). Such fishing units had to be included in the analysis because they imparted a fishing mortality on Channel stocks, and were in competition with local fleets. However, they could not be examined in the same detail as the Channel fleets, as their activity and bioeconomic status outside the Channel were not known. The external fleet was

Table I. Métier definition: code, fishing area (offshore and inshore are relative to the 60-m isobath, which is approximately the same as the National 12 nautical mile limits; und.: undetermined, i.e. north + west), gear and main target species.

a) Métiers operated by French fishing units

Code	Fishing area	Gear	Target species
F1.1	VIIe offsh.	Otter trawl	Groundfish, cuttlefish
F1.2	VIId offsh.	Otter trawl	Groundfish, cuttlefish
F1.3	VIIe insh.	Otter trawl	Benthicfish, cuttlefish
F1.4	VIId insh.	Otter trawl	Flatfish, cuttlefish
F1.5	VIId	Otter trawl	Shrimp
F2.1	VIId+e	Beam trawl	Flatfish
F3.1	VIIe	Midwater tr.	Pelagic fish
F3.2	VIId	Midwater tr.	Pelagic fish
F4.0	Bay of St Brieuc	Dredge	Scallop
F4.1	VIIe (excl. St Brieuc)	Dredge	Scallop
F4.2	VIId	Dredge	Scallop
F4.3	VIIe	Dredge	Clams
F4.4	VIId	Dredge	Flatfish
F4.5	VIId	Dredge	Mussels
F5.1	VIIe offsh.	Nets	Gadoids
F5.2	VIIe	Small mesh nets	Bass, pollack
F5.3	VIId+e	Large mesh nets	Benthicfish
F5.4	VIId insh.	Nets	Sole
F5.5	VIId insh.	Nets	Cod
F5.6	VIIe	Nets	Spider crab
F6.2	VIId+e	Pots	Large crustaceans
F6.3	VIId+e	Pots	Small crustaceans
F6.4	VIId+e	Pots	Whelk
F6.5	VIId+e	Pots	Cuttlefish
F7.1	VIId+e offsh.	Long lines	Dogfish, conger
F7.2	VIId+e insh.	Long lines	Bass, conger, ling
F8.1	VIId+e	Hand lines	Bass, pollack
F9.1	VIId+e	Aquaculture	Misc.
F9.3	VIIe	‘scoubidou’ line	Seaweeds
EF1.n	External north	Otter trawl	
EF1.w	External west	Otter trawl	
EF3.n	External north	Midwater tr.	
EF5.n	External north	Nets	
EF5.w	External west	Nets	
EF6.w	External west	Pots	
EF7.w	External west	Long lines	

b) Métiers operated by English fishing units

Code	Fishing area	Gear	Target species
U1.1	VIIe	Otter tr.	Ground/flatfish
U1.2	VIId	Otter tr.	Ground/flatfish
U2.1	VIId offsh.	Beam tr.	Benthicfish, cuttlefish
U2.2	VIIe offsh.	Beam tr.	Benthicfish, cuttlefish
U2.3	VIId insh.	Beam tr.	Benthicfish, cuttlefish
U3.1	VIIe	Midwater tr.	Pelagic fish
U3.2	VIId	Midwater tr.	Pelagic fish
U4.1	VIIe	Dredge	Scallop
U4.2	VIId	Dredge	Scallop
U4.3	VIId	Dredge	Oyster
U4.4	VIId	Dredge	Clams
U5.1	VIIe	Nets	Gadoids
U5.2	VIIe	Nets	Bass
U5.3	VIId	Nets	Bass
U5.4	VIId	Trammel nets	Sole
U5.5	VIId	Gillnets	Cod
U5.6	VIIe	Nets	Hake
U5.7	VIId+e	Large mesh nets	Groundfish
U5.8	VIId+e	Dift nets	Bass
U5.9	VIId	Gillnets	Flatfish
U6.1	VIId+e offsh.	Pots	Large crustaceans
U6.2	VIId+e insh.	Pots	Large crustaceans
U6.3	VIId+e	Pots	Whelk
U7.1	VIId	Longlines	Cod, dogfish
U7.2	VIIe	Longlines	Ling, conger
U8.1	VIId+e	Hand lines	Bass, mackerel
EU1.i	External und.	Otter trawl	
EU2.i	External und.	Beam trawl	
EU4.i	External und.	Dredge	
EU5.n	External north	Nets	
EU5.w	External west	Nets	
EU6.i	External und.	Pots	

Table II. Characteristics of Channel fleets. Fleet code, fishing unit nationality, fishing area (E: eastern Channel; W: western Channel), main activity (fishing gear), number of fishing units and mean annual days at sea, with the four main métiers practiced throughout the year (number in bracket represent the percentage of annual time spent in each métier). The activity called 'external' includes all fishing units operating in the Channel but with home ports elsewhere, with all gears types included.

Fleet code	Country	Area	Activity	Boats	Days	Métier 1	Métier 2	Métier 3	Métier 4
FE_Ot	France	E	Otter trawls	156	220	F1.4 (31)	F1.2 (29)	EF1.n (15)	F3.2 (9)
FW_Ot	France	W	Otter trawls	51	272	F1.1 (35)	EF1.w (32)	F1.3 (28)	F3.1 (2)
UC_Ot	UK	E+W	Otter trawls	138	189	U1.1 (53)	EU1.i (36)	U1.2 (10)	U3.1 (1)
FE_Bt	France	E	Beam trawls	86	186	F1.5 (45)	F4.4 (43)	F1.4 (9)	F2.1 (1)
UC_Bt	UK	E+W	Beam trawls	142	215	EU2.i (41)	U2.2 (15)	U2.3 (13)	U2.1 (12)
FE_Ot_Dr	France	E	Trawls-dredges	168	210	F4.2 (43)	F1.4 (29)	F1.2 (8)	F4.5 (8)
FW_Ot_Dr	France	W	Trawls-dredges	132	205	F1.3 (46)	F4.0 (22)	F4.1 (11)	F4.3 (11)
FE_Dr	France	E	Dredges	36	174	F4.2 (40)	F4.5 (31)	F5.4 (9)	F7.1 (4)
FW_Dr	France	W	Dredges	217	196	F4.0 (24)	F4.3 (18)	F6.2 (14)	F5.6 (12)
UC_Dr	UK	E+W	Dredges	45	232	EU4.i (42)	U4.1 (26)	U1.2 (13)	U1.1 (9)
FC_Pt	France	E+W	Pots	159	191	F6.2 (70)	EF6.w (22)	F6.5 (4)	F6.3 (2)
UC_Pt	UK	E+W	Pots	18	209	EU6.i (36)	U6.1 (35)	U6.2 (29)	
FE_Nt	France	E	Nets	115	212	F5.4 (55)	F5.5 (32)	F5.3 (7)	F6.5 (3)
FW_Nt	France	W	Nets	57	133	F5.3 (30)	EF5.w(29)	F5.2 (20)	F5.6 (10)
FC_Ln	France	E+W	Lines-longlines	44	173	F8.1 (49)	F7.2 (28)	EF7.w (15)	F7.1 (5)
UE_Nt_Ln	UK	E	Nets-lines	22	162	EU5.n (45)	U1.2 (20)	U5.9 (13)	U5.1 (5)
UW_Nt_Ln	UK	W	Nets-lines	104	174	EU5.w (69)	U5.1 (10)	U8.1 (6)	U1.1 (6)
FC_Wk	France	E+W	Whelk pots	51	222	F6.4 (82)	F6.2 (10)	F6.5 (5)	F5.1 (2)
FC_Ms	France	E+W	Miscellaneous	127	170	F8.1 (18)	F9.1 (14)	F4.5 (13)	F6.3 (12)
FC_Sw	France	E+W	Seaweeds	59	136	F9.3 (43)	F4.1 (30)	F4.3 (14)	F6.3 (4)
FC_Fx	France	E+W	Other fixed gears	216	185	F6.2 (25)	F7.2 (11)	F5.2 (10)	EF5.w (10)
UE_<10m	UK	E	Under 10 m	1 023	106	U5.9 (24)	U6.1 (15)	U5.4 (12)	U6.2 (11)
UW_<10m	UK	W	Under 10 m	945	106	U6.2 (36)	U1.1 (14)	U5.1 (12)	U8.1 (12)
			Total	4 111	153				
Ex_<7m	F+UK	E+W	External under 7 m	10	10	F7.2 (29)	F4.1 (23)	F5.2 (21)	F8.1 (10)
Ex_7-10m	F+UK	E+W	External 7–10 m	34	34	F4.1 (26)	F7.2 (20)	F5.2 (19)	F8.1 (14)
Ex_10-12m	F+UK	E+W	External 10–12 m	33	33	F5.4 (52)	F5.5 (7)	F5.2 (5)	F5.3 (5)
Ex_12-16m	F+UK	E+W	External 12–16 m	25	25	F3.1 (29)	F1.3 (16)	U1.1 (13)	U2.2 (10)
Ex_16-20m	F+UK	E+W	External 16–20 m	41	41	F1.1 (47)	F1.4 (23)	F3.1 (10)	U1.1 (6)
Ex_<20m	F+UK	E+W	External over 20 m	67	67	F1.1 (66)	U3.1 (14)	F3.1 (6)	F2.1 (3)

stratified only by boat size class, with an activity matrix and number of fishing units set to the mean observed effort of external fishing units for 1993–1995.

2.2. The English Channel bioeconomic model

The model used is BECHAMEL[1] (BioEconomic CHAnnel ModEL; Pascoe, 2000; Ulrich, 2000; Ulrich et al., in press). It is an equilibrium multi-species multi-fleet model composed of three components: a fishing effort component, a biological component, and an economic component. The cornerstone of the model is the métier, which is both linked to the fleet through an activity pattern matrix (expressing the percentage of total annual effort spent by each fleet in each métier), and to the stocks through an exploitation pattern matrix (stock – or age class of a stock – specific catchability coefficients by métier).

The fishing effort component estimates the level of fishing effort by fleet, métier and boat length class, expressed in days at sea per year, and calculated from the number of fishing units, the mean number of days at sea per fishing unit, and the activity matrix. The fishing effort is used in its nominal form by length class for the purposes of calculating variable costs, and is standardised across length classes within a fleet using fishing powers (derived from observed differences in total catch per unit of nominal effort by métier between each length class and the standard length class). The standardised effort applied by a fleet is hence the sum across length classes of their nominal effort times their relative fishing power.

The biological component of the model calculates the expected yield for the given level of standardised effort, using model parameters derived from reference year data (1993–1995). Each stock caught in the Channel has a separate production-effort relationship.

[1] Url model address is http://hal11.roazhon.inra.fr/projet/MODELE. Username and password might be asked by D. Gascuel (dgascuel@roazhon.inra.fr).

Table III. Species and stocks in the English Channel.

Name		No. stocks in the Channel	
English	Latin	Supposed	Evaluated
Benthic-demersal fishes			
Brill	*Scophthalmus rhombus*	1+	1
Cod	*Gadus morhua*	2	2
Conger eel	*Conger conger*	n/a	1
Dab	*Limanda limanda*	1	1
Dogfish	*Scyliorhinus, Squalus,* etc.	n/a	1
Hake	*Merluccius merluccius*	1	1
John dory	*Zeus faber*	1	1
Lemon sole	*Microstomus kitt*	1+	1
Ling	*Molva molva*	1	1
Megrim	*Lepidorhombus whiffiagonis*	1	1
Monkfish	*Lophius piscatorius*	2	1
Plaice	*Pleuronectes platessa*	2	2
Pollack	*Pollachius pollachius*	n/a	1
Pout	*Trisopterus luscus*	1	1
Red gurnard	*Aspitrigla cuculus*		1
Other gurnards	*Triglidae* sp.		
Red mullet	*Mullus surmuletus*		1
Skates	*Raja* sp.	1	1
Sole	*Solea solea*	2	2
Spurdog	*Squalus acanthias*	1	1
Turbot	*Scophthalmus maximus*	1+	1
Whiting	*Merlangius merlangus*	2	2
Pelagic fishes			
Bass	*Dicentrarchus labrax*	2	1
Black bream	*Spondyliosoma cantharus*	1	1
Herring	*Clupea harengus*	2	2
Mackerel	*Scomber scombrus*	1	1
Pilchard	*Sardina pilchardus*	n/a	1
Scad	*Trachurus trachurus*	n/a	1
Crustaceans			
Brown shrimp	*Crangon crangon*	n/a	1
Crawfish	*Palinurus elephas*	n/a	1
Edible crab	*Cancer pagurus*	1+	2
Lobster	*Homarus gammarus*	2	2
Pink shrimp	*Palaemon serratus*	n/a	1
Spider crab	*Maja squinado*	2	2
Molluscs			
Cuttlefish	*Sepia officinalis*	1	1
Queenscallop	*Chlamys* sp.	n/a	1
Scallop	*Pecten maximus*	6	6
Squid	*Loligo* sp.	n/a	1
Whelk	*Buccinum undatum*	1+	1
Others			
Seaweed	*Laminaria* sp.	1	1

Forty species, representing 53 stocks (33 fish, ten molluscs, nine crustaceans, and seaweed) are included in the model (*table III*). Four types of catch-effort relationships were developed in the model, depending on available data and on how production-effort functions were fitted (*table IV*). Twenty-seven stocks have been assessed using age-structured methods. Among these, fifteen are distributed only within the Channel, and a usual cohort analysis has been used (Method 1). The twelve other stocks are spatially distributed both inside and outside the Channel, and a specific assessment method, the 'In/Out' method (Method 2) has been developed (Ulrich et al., 1998, 2000). Production functions for the age-structured stocks are calculated with the Thompson and Bell (1934) equation. No such methods could be used for the other twenty-six stocks (mostly molluscs and crustaceans), for which the biological knowledge is often poor and little production and effort data are available and reliable. For these stocks, an empirical surplus production model curve has thus been set (Method 3), based on estimated landings and an a priori hypothesis on the shape of the

Table IV. The classification of Channel stocks in the model BECHAMEL, showing the assessment method used, and the estimated mean landings (in tonnes) over the reference period 1993–1995.

Age structured model stocks				Empirical surplus production model stocks			
Channel stocks (15)		In/Out stocks (12)		Fox model (23)		Schaefer model (3)	
Bass	1 095	Cod VIId	2 375	Brown shrimp	340	Crawfish	25
Brill	379	Cod VIIe	812	Conger eel	976	Queenscallops	1 510
Black bream	2 218	Hake	436	Cuttlefish	10 567	Skates	3 112
Dab	1 031	Herring VIId	6 650	Dogfish	3 199		
Herring VIIe	542	Mackerel	26 260	Edible crab France	3 622		
Lemon sole	1 464	Megrim	446	Edible crab UK	4 959		
Ling	1 337	Plaice VIId	5 270	John Dory	370		
Monkfish	2 007	Plaice VIIe	1 292	Lobster France	228		
Pollack	1 935	Sole VIId	4 515	Lobster UK	223		
Pout	4 566	Sole VIIe	797	Other gurnards	1 825		
Red gurnard	3 417	Whiting VIId	5 485	Pilchard	5 588		
Scallop bay of Seine	5 629	Whiting VIIe	2 107	Pink shrimp	152		
Scallop bay of St Brieuc	4 434			Red mullet	1 005		
Turbot	423			Scad	11 406		
Whelk	10 260			Scallop bay of Brest	116		
				Scallop bay of Morlaix	125		
				Scallop other VIId	6 672		
				Scallop other VIIe	9 286		
				Seaweeds	58 228		
				Spider crab France	5 460		
				Spider crab UK	844		
				Spurdog	578		
				Squid	4 063		
Total	40 737		56 445		129 832		4 647
%	17.6		24.4		56.0		2.0

curve (either a Fox (1970) or a Schaefer (1954) curve equation). Given the large number of commercial stocks involved in Channel fisheries, details of stock assessments and parameter estimations are not presented here. They are summarised in Ulrich et al. (in press), and fully detailed in Dunn (1999), Pascoe (2000) and Ulrich (2000). By using both age-structured and surplus production models, all of the commercial stocks could be integrated into a general framework, despite the variations in species knowledge and available data.

The economic component of the model is largely driven by the outputs from the effort and biological components. It transforms landings into revenue, and fishing effort into costs. The costs of fishing were calculated on the basis of fishing unit characteristics (fixed costs), effort levels (variable costs) and landings revenue (i.e. taxes and wages). These were estimated from two economic surveys carried out between 1997 and 1999 (Pascoe, 1998; Boncoeur et al., 2000a; Le Gallic, 2001). The bioeconomic model initially includes a small number of price-quantity relationships. However, the market prices were considered as constant in the current analysis of technical interactions, for modelling simplicity purposes, and because this assumption is not likely to induce major bias in the results. In most cases, landings from the English Channel represent only a small part of a well-integrated national or international market, and have no noticeable influence on prices. Prices showing significant elasticity regarding landings were found only for a very small number of stocks (CEDEM, unpubl.).

The economic model outputs can then be used to calculate various economic indicators describing fishers' income and economic profit. This economic component is however of little use in the current analysis (which deals only with catches and revenues), and is not further detailed here.

2.3. Technical interaction coefficients

Technical interactions have been measured by two coefficients, one 'active', and one 'passive'. They describe the variations of some bioeconomic variables (i.e. catch and revenue) of métiers or fleets, in relation to changes in effort of other métiers or fleets. They are calculated at both the global scale, to study all classes simultaneously, and at a specific scale, to study the reciprocal behaviour of two single classes. The variations of effort are simply simulated by using a multiplicator of effort on the total level of standardised fishing effort by métier or fleet, i.e. without any assumption on changes in number of fishing units, fishing days, activity or fishing power.

For a given class i, the coefficient of 'active interaction', called the relative impact coefficient, estimates the decrease in output of one (j) or all (J-1) of the other classes when class i increases effort by 1 %. For example, the impact of French trawlers on English longliners is measured as the relative decrease of English longliners equilibrium catches/revenues when the effort of the French trawlers increases. The coefficient is denoted r_{ij} or r_{iJ} respectively, and is expressed as a percentage. Conversely, the coefficient of 'passive interaction', called the sensitivity coefficient, measures the decrease in output by class i when one (j) or all (J-1) other classes increase effort by 1 %. The coefficient is denoted sc_{ij} or sc_{iJ} respectively:

$$\begin{cases} r_{ij} = -\dfrac{X_j(mf_i = 1.01) - X_j(mf_i = 1)}{X_j(mf_i = 1)} \times 100 \\[2ex] r_{iJ} = -\dfrac{\sum\limits_{k=1}^{k=J,\,k\neq i} X_k(mf_i = 1.01) - \sum\limits_{k=1}^{k=J,\,k\neq i} X_k(mf_i = 1)}{\sum\limits_{k=1}^{k=J,\,k\neq i} X_k(mf_i = 1)} \times 100 \end{cases}$$

and:

$$\begin{cases} sc_{ij} = -\dfrac{X_i(mf_j = 1.01) - X_i(mf_j = 1)}{X_i(mf_j = 1)} \times 100 \\[2ex] sc_{iJ} = -\dfrac{[X_i(mf_{k\{:k\,\in\,[i,J]\,where\,k\,\neq\,i\}} = 1.01) - X_i(mf_{k\{:k\,\in\,[i,J]\,where\,k\,\neq\,i\}} = 1)]}{X_i(mf_{k\{:k\,\in\,[1,J]\,where\,k\,\neq\,i\}} = 1)} \times 100 \end{cases}$$

where J is the total number of classes of the typology (métiers or fleets), X_k is the value of the output variable of interest (e.g. catch or revenue) for the fleet or métier k, and mf_k the multiplicator of effort for unit k. X_k is calculated by running the model at the mf_j input level of effort for each unit j. The sensitivity and impact coefficients are equivalent when considering only two units: the impact of the fleet i on the fleet j is equal to the sensitivity of the fleet j to the fleet i ($r_{ij} = sc_{ji}$). However they differ when considering the whole fishery scale. r_{ij} and sc_{ij} are positive except if $i = j$.

The typologies, i.e. the classification of métiers and fleets into groups showing similar competitive behaviour on the resource, are derived in a graphical manner. Métiers and fleets are plotted using the value of sc on the x-axis and r on the y-axis. Groups of fishing units can therefore be identified, by setting arbitrary relative thresholds of levels of impact and sensitivity.

3. RESULTS

The following typologies are based on the coefficients estimated at the global fishery scale, taking into account competitive stock externalities to all other métiers and fleets.

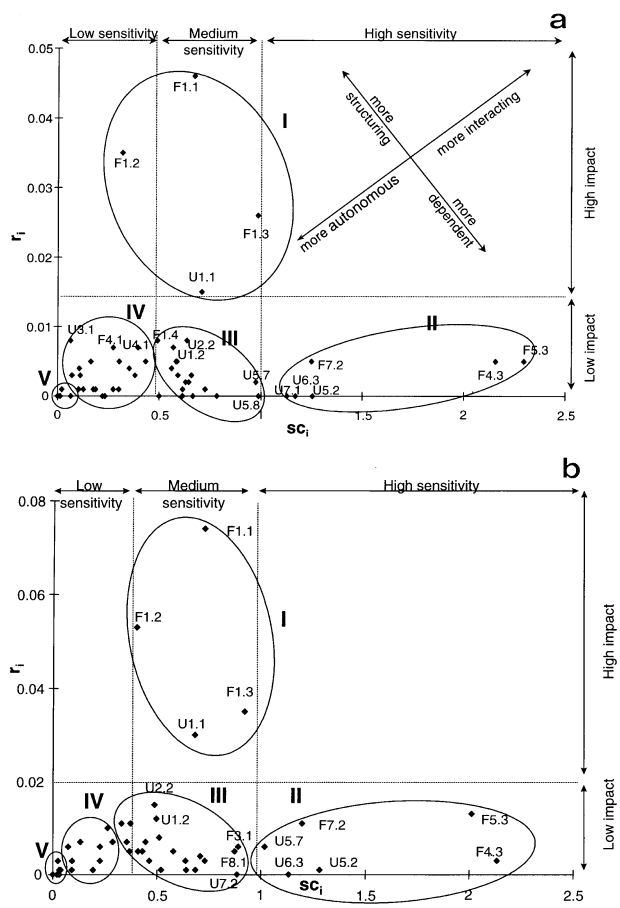

Figure 2. Plot of technical interactions among métiers. Impact coefficient (r_i) against sensitivity coefficient (cs_i) calculated using (**a**) catch weight and (**b**) gross revenue. Only the most remarkable points are named on the figure. Codes refer to métiers: F: France, U: UK; the first number indicates the main gear used: 1: otter trawl; 2: beam trawl; 3: midwater trawl; 4: dredge; 5: fixed nets; 6: pots; 7: longlines; 8: handlines.

3.1. Typology by métier

The relative impact and sensitivity coefficients are plotted for all métiers, in terms of total catches and gross revenue (*figure 2*).

Sensitivity coefficients are logically much higher than impact coefficients. For example, a single fishing unit may have negligible impact on all other units when it changes effort ($r_i < 0.1$), but it might be highly sensitive to their effort variation. This is most likely when the units target the same species, and when that species is overexploited.

Four different groups of métiers have been identified: class I includes métiers having high externalities, but whose sensitivity is medium or low. We term these 'structuring' métiers, as their activity has a significant influence on other components of the fishery. They include otter trawling, particularly French offshore trawl métiers (F1.1 and F1.2). Class II includes métiers

Table V. Métier typology based on the level of resource interaction with other métiers. The most characteristic métiers within a class are shown in bold. Codes refer to métiers: F: France, U: UK; the first number indicates the main gear used: 1: otter trawl; 2: beam trawl; 3: midwater trawl; 4: dredge; 5: fixed nets; 6: pots; 7: longlines; 8: handlines.

	I Structuring métiers	II Dependent métiers	III Intermediate métiers	IV Semi autonomous métiers	V Fully autonomous métiers
Impact	High	Low	Medium to low	Low	None
Sensitivity	Medium	High	Medium	Low	None
	F1.1	F3.1	**F1.4**	**F4.2**	**F1.5**
	F1.2	**F4.3**	F2.1	F4.4	**F4.0**
	F1.3	**F5.3**	**F3.2**	**F5.4**	**F6.3**
	U1.1	**F7.2**	F4.1	**F5.5**	**F6.4**
		U5.2	F5.1	**F6.2**	F9.1
		U5.7	F5.2	U2.1	**F9.3**
		U6.3	F5.6	**U3.1**	U4.3
			F6.5	**U3.2**	U4.4
			F7.1	U5.4	**U7.1**
			F8.1	U5.5	
			U1.2	U5.6	
			U2.2	U5.9	
			U2.3		
			U4.1		
			U4.2		
			U5.1		
			U5.3		
			U5.8		
			U6.1		
			U6.2		
			U7.2		
			U8.1		

with low impact but high sensitivity. We term these 'dependent' métiers, because their bioeconomic status depends greatly on the mean level of activity in the fishery. These métiers either target a small number of different stocks, for which they are competing with other more important métiers, e.g. French clam dredges (F4.3), English whelk pots (U6.3), or English bass nets (U5.2), or they exploit a large number of stocks in small quantities, but the same as exploited by structuring métiers (typically net métiers, e.g. French large mesh nets (F5.3)). Class III is an intermediate class having medium impact and sensitivity, and includes the majority of métiers. Finally, all other métiers have few interactions within the fishery, with low impact and low sensitivity. These are mostly monospecific métiers, and we term these 'autonomous', because their bioeconomic status does not depend on, or influence, other components of the fishery. We can separate these into two classes: 'semi-autonomous' métiers (class IV), which exploit insensitive stocks (those having flat-topped yield per recruit functions), and 'fully autonomous' métiers (class V), which are generally the dominant, or only métier exploiting the target species (e.g. seaweed).

There are slight differences in the typology depending on whether catch or revenue is used. In most cases, the impact coefficient is higher in the revenue analysis, simply due to the multiplicative effect of unit price. The difference depends on the relative importance of each species in the catches, on their relative price, and on their sensitivity to changes in effort. The impact coefficient is lower in the revenue analysis only for métiers exploiting stocks with a value < 1 euro·kg^{-1} (midwater trawls, whelk pots, clam dredges). Conversely, sensitivity coefficients are mostly lower when using revenues, because differences in the relative abundance of species when effort varies are smoothed by the difference in price, especially when catching high-priced species. However, typologies are generally consistent, and our typology using technical interactions among métiers has been given using revenue (*table V*).

3.2. Typology of fleets

The results of the analysis by fleet are shown in *figure 3* and *table VI*. Class boundaries appear less obvious than for the métier analysis, and the allocation of some fleets to a class has been more subjective. Some fleets have high impact levels, particularly in terms of revenue and, unlike in the métier analysis, some also have high sensitivity. We have therefore separated these into two sub-classes. Class Ia includes the most structuring fleets, whereas class Ib includes both structuring and dependent fleets. All French trawl fleets, for example, have similar externalities, however the western fleet (FW_Ot) is more sensitive than the eastern (FE_Ot). This difference was less clear in the

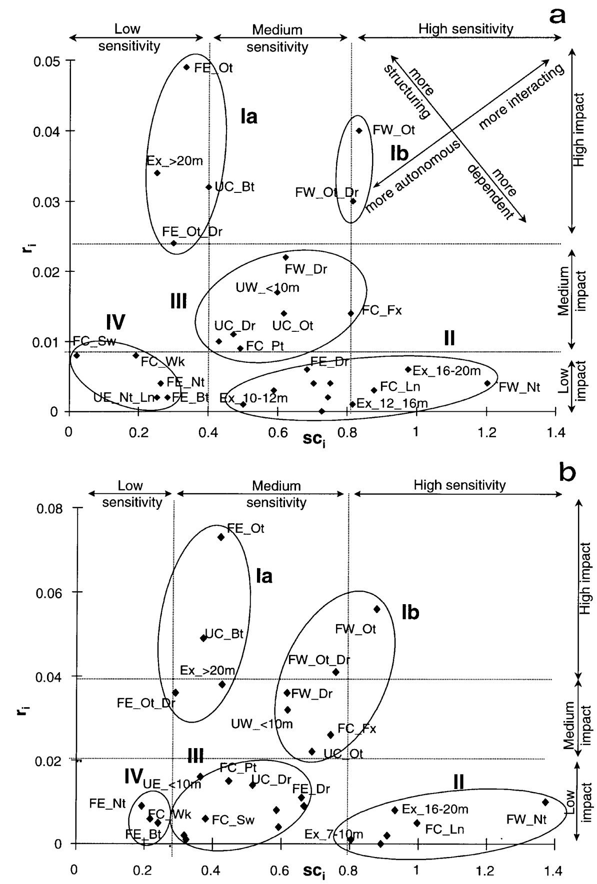

Figure 3. Plot of technical interactions among fleets. Impact coefficient (r_i) against sensitivity coefficient (cs_i) calculated using (**a**) catch weight and (**b**) gross revenue. Only the most remarkable points are named on the figure. Code refers to fleets. F: France, U: UK, E: eastern Channel, W: western Channel, Bt: beam trawlers, Dr: dredgers, Fx: other fixed gears, Ln: liners-longliners, Ms: miscellaneous, Nt: netters, Ot: otter trawlers, Pt: potters, Sw: seaweed croppers, Wk: whelk potters.

analysis by métier (métiers are F1.1 and F1.2 respectively). The largest external fishing units (Ex_>20m fleet) also have a significant structuring effect within the fishery because, although not very numerous, their fishing power is high. The most dependent fleets (class II) have little or no impact on other fleets, but are highly sensitive to overall changes in effort. These fleets practise the most sensitive métiers, for example, the French large mesh net métier (F5.3), which constitutes 30 % of the annual fishing time for the French western nets fleet.

The intermediate fleets (class III) have moderate interactions within the fishery. It includes fleets which are the primary unit exploiting their target species (e.g. pot fleets), or those which exploit relatively insensitive stocks, and are in competition with a limited number of other fleets (e.g. English dredges).

Class IV includes the autonomous fleets. These are either very specific and independent units of the fishery (e.g. fleets for whelks or seaweed), or are exploiting very insensitive stocks.

3.3. Binary relationships between fleets

Revenue sensitivity coefficients for each fleet to an effort increase of each other fleet are shown in *table VII*. In all cases, a 1 % increase in a single fleet's effort induced both a positive effect on its own revenue ($sc_i < 0$) and a negative effect on other fleets ($sc_i > 0$). This result does not necessarily imply that an increase in effort is viable, as it would also incur increased costs, and thus profit might not increase by a similar amount. Because of the high level of resource interaction the externalities are shared, and consequently the returns in revenue to the focal fleet are always greater (between 0.6 and 1.01 %) than externalities (< 0.4 %). Externalities are > 0.2 % in only six cases (for example, the English pots in competition with both English < 10 m fleets), and < 0.1 % for 95 % of fleet

Table VI. The fleet typology based on the level of resource interaction with other fleets. The most characteristic fleets within each class (I–V) are shown in bold. The fleets whose classification is more arbitrary are shown in italic. Code refers to fleets. F: France, U: UK, E: eastern Channel, W: western Channel, Bt: beam trawlers, Dr: dredgers, Fx: other fixed gears, Ln: liners-longliners, m: meters; Ms: miscellaneous, Nt: netters, Ot: otter trawlers, Pt: potters, Sw: seaweed croppers, Wk: whelk potters.

	Ia Structuring fleets	Ib Structuring and dependent fleets	II Dependent fleets	III Intermediate fleets	IV Autonomous fleets
Impact Sensitivity	High Medium	Medium to high Medium to high	Low High	Low Medium	Low Low
	FE_Ot	**FW_Ot**	**FW_Nt**	**FE_Dr**	FE_Bt
	FE_Ot_Dr.	**FW_Ot_Dr**	**FC_Ln**	**FC_Pt**	FE_Nt
	UC_Bt	**FW_Dr**	Ex_<7m	FC_Ms	**FC_Wk**
	Ex_>20m	FC_Fx	Ex_7-10m	*FC_Sw*	
		UC_Ot	Ex_12-16m	**UC_Dr**	
		UW_<10m	Ex_16-20m	UC_Pt	
				UE_Nt_Ln	
				UW_Nt_Ln	
				UE_<10m	
				Ex_10-12m	

combinations. The highest observed sensitivity (0.37 %) is between the French eastern Channel dredges (FE_Dr) and trawl-dredges in the same area (FE_Ot_Dr), although reciprocal sensitivity is low. However, in the western Channel, the equivalent fleets (French dredges (FW_Dr) and otter trawl-dredges (FW_Ot_Dr)) have similar reciprocal impacts. Many species were modelled with separate east and west stocks; however, there is still a high level of competition between two of the main Channel fleets, the French east and west trawls (FE_Ot and FW_Ot). The western fleet is more sensitive (*figure 3*), because stocks on which these fleets compete constitute 80 % of the catch for FW_Ot catches, but only 60 % for FE_Ot.

The fleet sensitivity and typology derived from this analysis are similar to those given in *table V*, where the most sensitive fleets (dependent fleets) are mostly French and external fleets using fixed gears (nets and lines-longlines), whereas fleets with the greatest impact (structuring fleets) are the French otter trawl and the English beam trawl fleets.

4. DISCUSSION

Overall, the graphical analysis of the coefficients describing active and passive interactions has provided a novel typology of métiers and fleets in the English Channel. The most structuring fleets were found to be multi-species trawls, with high levels of catch, and also diverse by-catches. The most dependent fleets are consequently those in direct competition with the trawl fleets. Although some of these overall results could have been qualitatively stated from empirical intuition, detailed outcomes (e.g. the non-reciprocal relationships between dredges and trawl-dredges fleets) could not have been guessed without a quantitative analysis. Only the classification of French eastern Channel nets (FE_Nt) as an autonomous fleet seems incorrect. This fleet is, as its equivalent in the western Channel (FW_Nt), in strong competition with the trawl fleets, and would be expected to be classified as a dependent fleet. The difference in the classification of these two fleets arises from the shape of the catch-effort functions for the stocks that they target. The western nets target high value local stocks (e.g. pollack and monkfish), whose production curves are dome-shaped (Ulrich, 2000). The high prices induce high levels of competition, and small changes in the level of effort induces significant changes of the expected equilibrium catches, and thus of the interaction coefficients. Conversely, the stocks targeted by the eastern nets are either local stocks showing flat-topped yield per recruit curves (e.g. sole and plaice; ICES, 1997), or stocks largely distributed outside the Channel (e.g. cod). Changes in effort directed towards these species do not lead to large changes in catches, and interaction coefficients are consequently low.

Shortcomings of the English Channel bioeconomic model have been widely discussed in Ulrich (2000) and Ulrich et al. (in press). Although some basic hypotheses may be considered insufficient or unrealistic, they are justified with respect to data availability and fishery peculiarity, and are characteristic of such large-scale modelling approaches (e.g. Murawski et al., 1991; Sparre and Willmann, 1993). In particular, the model is at this stage only a static equilibrium and deterministic model. It is based on equilibrium equations leading to long-term (in the biological sense) production and profit estimations. It would need further improvements on the modelling of short-term transition situations. Second, there is no attempt to model fleet behaviour and endogenous allocation of effort. The distribution of effort across métiers does not change as a function of relative profitability. This offsets widely the predictive power of the model, as the level of technical interactions changes when the fleets adapt their effort to the fishery dynamics (Laurec et al., 1991; Holland and Sutinen, 1999). For this reason, the present typologies reflect the current stock interactions within the fishery only, but do not investigate their causes and dynamics, and may not be relevant anymore in case of major changes (e.g. a stock collapse, higher prices on a species, closed area …). However, typologies were built on marginal variations of effort (1 %). It is likely that the bias induced by not taking into account the fishers' adaptation is low at that scale, and does not widely affect the outcomes of this analysis. Furthermore, it has to be noted that studies on fishing tactics and effort allocation in the English Channel are still under achievement. They may lead to relevant dynamic modelling of fleets and better comprehension of the relationships between them. The same methodology could be applied to classify the short-term technical interactions, similarly to the static equilibrium ones classified in the current analysis.

The prices have been considered as constant in the analysis, although a small number of stocks have prices showing significant elasticity to landings (CEDEM, unpubl.). The reason was that it simplified the modelling procedure without really affecting the results. The influence of this elasticity on the analysis is likely to be minor, as these stocks either represent very small landings (brill), or are mostly exploited by a small number of métiers, with little interactions (spider crab, scallops), or present flat-topped equilibrium production curves and thus almost constant equilibrium prices (sole). It is however evident that this is not likely to be the case in all fisheries (e.g. Murawski et al., 1991), and applying a similar methodology to any other case study would require a prior investigation of prices flexibility.

Although we have shown that resource competition can be effectively analysed using BECHAMEL, two potentially important sources of interactions are not presently taken into account: the interactions for space, and the interactions for resources through discarding. A quantitative approach to spatial competition requires the development of a complex small-scale spatially-

Table VII. The resource interactions between paired fleets, showing the decrease (in %) of the total revenue of each fleet (in rows) for a 1 % increase in effort by the other fleet (in columns). Pale grey shading (diagonal) indicates a marginal revenue increase by the fleet; medium grey shading indicates a > 0.1 % decrease; dark grey shading indicates a > 0.2 % decrease. Code refers to fleets. F: France, U: UK, E: eastern Channel, W: western Channel, Bt: beam trawlers, Dr: dredgers, Fx: other fixed gears, Ln: liners-longliners, Ms: miscellaneous, Nt: netters, Ot: otter trawlers, Pt: potters, Sw: seaweed croppers, Wk: whelk potters.

Fleet	FE_Ot	FW_Ot	UC_Ot	FE_Bt	UC_Bt	FE_Ot_Dr	FW_Ot_Dr	FE_Dr	FW_Dr	UC_Dr	FC_Pt	UC_Pt	FE_Nt	FW_Nt	FC_Ln
FE_Ot	**–0.85**	0.10	0.03	0.01	0.04	0.05	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01
FW_Ot	**0.22**	**–0.80**	0.05	0.00	0.09	0.05	0.08	0.01	0.03	0.01	0.01	0.00	0.01	0.02	0.01
UC_Ot	**0.16**	**0.10**	**–0.89**	0.01	**0.10**	0.03	0.03	0.01	0.01	0.02	0.00	0.01	0.02	0.01	0.01
FE_Bt	0.07	0.01	0.01	**–0.84**	0.04	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
UC_Bt	0.06	0.04	0.03	0.01	**–0.92**	0.04	0.03	0.01	0.02	0.03	0.00	0.00	0.01	0.01	0.00
FE_Ot_Dr	0.06	0.03	0.01	0.01	0.04	**–0.61**	0.02	0.06	0.00	0.02	0.00	0.00	0.01	0.00	0.00
FW_Ot_Dr	0.09	**0.11**	0.02	0.00	0.07	0.05	**–0.77**	0.01	**0.21**	0.03	0.01	0.00	0.01	0.01	0.00
FE_Dr	0.03	0.03	0.01	0.00	0.04	**0.38**	0.02	**–0.94**	0.02	0.02	0.01	0.00	0.00	0.00	0.01
FW_Dr	0.02	0.04	0.01	0.00	0.05	0.01	**0.19**	0.00	**–0.73**	0.03	0.08	0.00	0.01	0.02	0.00
UC_Dr	0.04	0.02	0.02	0.00	**0.10**	0.07	0.08	0.01	0.07	**–0.94**	0.00	0.00	0.01	0.00	0.00
FC_Pt	0.01	0.02	0.00	0.00	0.01	0.00	0.02	0.00	**0.14**	0.00	**–0.73**	0.00	0.00	0.02	0.00
UC_Pt	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	**–0.87**	0.00	0.01	0.01
FE_Nt	0.03	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	**–0.98**	0.01	0.00
FW_Nt	**0.13**	**0.17**	0.07	0.01	**0.16**	0.03	0.06	0.00	**0.12**	0.01	0.06	0.00	0.06	**–0.87**	0.01
FC_Ln	**0.17**	**0.11**	0.04	0.01	0.05	0.04	0.05	0.04	0.06	0.01	0.01	0.01	0.01	0.02	**–0.91**
UE_Nt_Ln	0.06	0.04	0.02	0.00	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
UW_Nt_Ln	0.08	0.07	0.04	0.01	0.05	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.02
FC_Wk	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.00	0.00
FC_Ms	0.05	0.05	0.01	0.02	0.02	0.03	0.02	0.01	0.08	0.00	0.08	0.00	0.01	0.01	0.01
FC_Sw	0.00	0.01	0.00	0.00	0.06	0.00	0.08	0.00	0.08	0.05	0.01	0.00	0.00	0.00	0.00
FC_Fx	0.06	0.06	0.02	0.00	0.04	0.02	0.03	0.01	0.09	0.01	**0.13**	0.00	0.02	0.04	0.02
UE_<10m	0.03	0.02	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.05	0.00	0.01	0.01
UW_<10m	0.08	0.05	0.05	0.00	0.06	0.02	0.03	0.00	0.02	0.02	0.00	0.04	0.01	0.01	0.01
Ex_<7m	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00
Ex_7-10m	0.07	0.06	0.04	0.00	**0.12**	0.06	**0.13**	0.00	**0.12**	0.07	0.00	0.00	0.01	0.03	0.02
Ex_10-12m	0.06	0.03	0.01	0.01	0.04	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.00
Ex_12-16m	**0.17**	**0.12**	0.03	0.00	0.05	0.04	0.04	0.01	0.04	0.01	0.00	0.00	0.01	0.00	0.02
Ex_16-20m	**0.21**	**0.17**	0.05	0.00	0.08	0.04	0.06	0.00	0.02	0.01	0.00	0.00	0.01	0.02	0.01
Ex_>20m	**0.11**	0.08	0.04	0.00	0.05	0.02	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01

Table VII. (continued).

	UE_Nt_Ln	UW_Nt_Ln	FC_Wk	FC_Ms	FC_Sw	FC_Fx	UE_<10m	UW_<10m	Ex_<7m	Ex_7-10m	Ex_10-12m	Ex_12-16m	Ex_16-20m	Ex_>20m
FE_Ot	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.06
FW_Ot	0.00	0.02	0.00	0.01	0.00	0.03	0.02	0.06	0.00	0.00	0.00	0.00	0.03	**0.12**
UC_Ot	0.00	0.02	0.00	0.01	0.00	0.02	0.02	0.08	0.00	0.00	0.00	0.00	0.01	0.07
FE_Bt	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
UC_Bt	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.03
FE_Ot_Dr	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
FW_Ot_Dr	0.00	0.01	0.00	0.01	0.03	0.02	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.04
FE_Dr	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02
FW_Dr	0.00	0.00	0.00	0.02	0.02	0.06	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01
UC_Dr	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.02
FC_Pt	0.00	0.00	0.04	0.03	0.00	**0.14**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UC_Pt	0.00	0.01	0.01	0.01	0.00	0.01	**0.27**	**0.28**	0.00	0.00	0.00	0.00	0.00	0.01
FE_Nt	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
FW_Nt	0.00	0.03	0.01	0.03	0.00	**0.12**	0.01	**0.10**	0.00	0.00	0.00	0.00	0.03	0.09
FC_Ln	0.01	0.04	0.01	0.05	0.01	0.10	0.06	0.08	0.00	0.01	0.01	0.01	0.02	0.08
UE_Nt_Ln	**–1.00**	0.01	0.00	0.00	0.00	0.02	0.05	0.03	0.00	0.00	0.00	0.00	0.01	0.03
UW_Nt_Ln	0.01	**–0.94**	0.00	0.01	0.00	0.03	0.05	**0.10**	0.00	0.00	0.00	0.00	0.01	0.04
FC_Wk	0.00	0.00	**–0.07**	0.00	0.02	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FC_Ms	0.00	0.01	0.00	**–0.91**	0.01	**0.12**	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.02
FC_Sw	0.00	0.00	0.03	0.01	**–0.65**	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00
FC_Fx	0.00	0.01	0.07	0.04	0.01	**–0.88**	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.03
UE_<10m	0.01	0.01	0.01	0.01	0.00	0.01	**–0.83**	**0.14**	0.00	0.00	0.00	0.00	0.00	0.01
UW_<10m	0.00	0.02	0.00	0.01	0.01	0.02	**0.13**	**–0.83**	0.00	0.00	0.00	0.00	0.01	0.03
Ex_>7m	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	**–0.67**	0.00	0.00	0.00	0.00	0.00
Ex_7-10m	0.00	0.02	0.00	0.03	0.07	0.03	0.02	0.06	0.00	**-1.01**	0.00	0.01	0.01	0.05
Ex_10-12m	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.00	0.00	**-0.99**	0.00	0.00	0.02
Ex_12-16m	0.00	0.01	0.00	0.02	0.01	0.04	0.05	0.07	0.00	0.00	0.00	**-0.97**	0.02	**0.11**
Ex_16-20m	0.00	0.02	0.00	0.01	0.00	0.03	0.02	0.05	0.00	0.00	0.00	0.00	**-0.97**	**0.11**
Ex_>20m	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	**-0.92**

structured model (e.g. Rijnsdorp et al., 2000), and therefore such interactions are often qualitatively defined only (Tétard et al., 1995; Boncoeur et al., 1998; Woodhatch and Crean, 1999). The interactions due to discards have been more widely investigated and measured (e.g. Armstrong et al., 1993; Liggins and Kennelly, 1996; Pascoe, 1997). In the English Channel, the inshore trawlers induce important negative externalities on potting fishing units through discarding summer spider crabs (Boncoeur et al., 2000b). Similarly, the French shrimp trawl métier (F1.5) has been determined as autonomous as it is singularly exploiting brown shrimp; however, it is known to take large by-catches of undersized, and thus discarded, valuable flatfish species (Tétard et al., 1995). The overall level of discards appears to be high in the English Channel (Morizur et al., 1996), and including them in BECHAMEL would provide more complete information on technical interactions, and could significantly modify the current typology. Discards were not included when BECHAMEL was constructed because, as in many other fisheries, the data on discards were scarce and thus could not be easily integrated into the assessment and management models. The method in this paper is nevertheless an original and simple way of quantifying some of the technical interactions in a highly interactive and complex fishery, and discard interactions could easily be added if they were available.

Overall, these results provide new and valuable information on the relationships existing within the English Channel fisheries. They participate in a better quantitative description and understanding of the complexity of the fisheries, by classifying the fleets in relation to their competitive behaviour and their sensitivity to the others. Some major behaviour types were identified. In spite of the poor predictive ability of the model, these results can be of direct use for management purposes, by pointing out where overall the strongest interactions in the fisheries are. However, the analysis of the stock interactions should be further extended, to investigate their dynamics through the dynamics of fishing effort allocation.

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