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Definition of a directed fishing effort in a mixed-species trawl fishery, and its impact on stock assessments

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Abstract – Catch-per-unit effort (CPUE) has frequently been used as an index of abundance and more specifically to calibrate virtual population analysis (VPA). In multi-species fisheries, CPUE calculated from fishing trips targeting the species seems to be more effective for calibration than the classical ratio total landings/total effort. Target species are determined from an analysis of the composition of catches (landings) of each fishing trip, each trip being categorised as to whether it targets the given species or not. It is obvious that existing but not reported discards would affect these results. Classification of trips can be achieved on a single-species basis, each species being considered successively and each trip possibly being relevant for more than one species. Using a more general approach, classification can be achieved by métiers, each of these being determined by one or a group of target species and each trip being categorised into one and only one métier. This method of categorising trips is based on thresholds of target species contribution to the catch and on an overall explanatory level. For the main species of the French demersal fishery off the west coast of Scotland and in the Celtic Sea, CPUEs are calculated using different methods to define the trips used to calculate fishing effort and associated landings. Besides important differences in actual values, CPUEs may also differ in their trends depending on the definition of directed effort. Tuned VPA, carried out for some species, shows that large variations in population estimates, fishing mortality or short-term predictions could occur when using directed effort, while the catchability model fits the data better. © Ifremer/Elsevier, Paris

Multi-species fisheries / directed effort / target species / métier / tuned virtual population analysis / stock assessment / NE Atlantic

Résumé – Définition d'un effort de pêche dirigé dans une pêcherie pluri-spécifique, et son impact sur l'évaluation des stocks. Les captures par unité d'effort de pêche (CPUE) sont fréquemment utilisées comme indice d'abondance et servent notamment à la calibration des analyses de cohortes (VPA). Plutôt que le simple rapport entre la production et l'effort total développé sur une zone de pêche, les CPUE calculées à partir de « marées » ciblant l'espèce considérée semblent plus pertinentes. À partir de l'analyse de la composition des débarquements de chaque « marée », il est possible de déterminer des espèces cibles et de classer les « marées » selon que le pêcheur recherche ou non ces espèces. Cette classification des marées peut se faire soit en considérant chaque espèce successivement, une marée pouvant être pertinente pour plusieurs d'entre elles, soit plus globalement, en référence à des métiers, chacun étant défini par des seuils d'une ou plusieurs espèces cibles, chaque marée étant alors dédiée à un métier et un seul. Cette étude présente la méthode utilisée, basée sur des seuils d'espèces cibles et un niveau global d'explication. Pour les pêcheries françaises de l'ouest de l'Écosse et de la mer Celtique, les CPUE de trois espèces principales (lieu noir, lingue bleue et merlan) sont calculées à partir de l'effort de pêche et des débarquements des marées qualifiées par diverses méthodes. Outre les différences évidentes dans les niveaux absolus des CPUE, des variations inter-annuelles contradictoires peuvent être observées selon les méthodes utilisées. L'emploi de séries de CPUE calculées à partir de marées dirigées améliore sensiblement la qualité de l'ajustement du modèle de capturabilité utilisé lors de la calibration des VPA. Les estimations de la population, de la mortalité par pêche ou des prédictions à court terme qui en résultent peuvent être très différentes de celles obtenues à partir d'une CPUE « non dirigée ». Ainsi pour le lieu noir, les prédictions peuvent varier du simple au double. © Ifremer/Elsevier, Paris

Pêche pluri-spécifique / chalutage / effort de pêche / espèces-cibles / métier / calibration de l'analyse de cohorte / Atlantique NE

1. INTRODUCTION

In multi-species fisheries, the definition of effective effort presents a well known but persistently serious problem [5, 9, 10, 14, 23, 25]. Within a given fishing area, the status of the various species caught, i.e., whether they are target species or by-catch, may not be easy to determine, and can vary depending on the time period and the fishing fleets. The amount of effort directed to each species is therefore difficult to estimate. Since Catch Per Unit of Effort (CPUE) is frequently used as an index of the relative abundance of

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fish, and notably to calibrate Virtual Population Analysis (VPA) [16, 21], the more accurately the CPUE data reflects relative abundance, the better the assessments would be. This paper shows how to calculate directed efforts and associated landings in order to provide CPUEs which are preferable to the classical ratio 'total landings/total effort' which may not be a reliable measure of the abundance of a species because of possible changes in species preferences by fishermen.

The identification of target species is the first step of this process. Principal components analyses of catch composition were first used [6, 17] to divide fishing activities into a small number of groups - called 'métiers' - and to classify vessels according to species fished, and has since been commonly applied [19]. This method is neither very practical nor objective and it is always tedious. However, it does provide a clear description of a fishery and some helpful indications on species. Since the resulting classes of vessels are based on catches of the most discriminant species which are not necessarily the targeted ones, CPUEs calculated within each group of vessels cannot be considered as actual directed CPUEs. This paper proposes a quicker and simpler method relying on catch analysis by fishing trip to identify target species.

By definition, the status of a target species in a fishery is decided by fishermen. In a multi-species, multi-métiers context, these decisions may only be guessed at from the resulting catch, and for this purpose some of the following general criteria can be used: (i) a target species must be representative of a single métier, and targeted by only a small number of vessels during a given time period; (ii) to lead to meaningful métiers, target species must have rather large total landings or very high market value; however, this does not mean that all species landed in quantities should be treated as target species; (iii) furthermore, a species could not be considered as a target species if none of the trips provided more than, say, 50 % of this species in their landings. This point depends largely on the spatial distribution of the species (schools, aggregation, concentration, etc.), and a distinction should be made between species that school and those which are more uniformly or randomly distributed.

In this study, the status (target or by-catch) of each species is examined in relation to their proportions in the catches (landings) of trips and to the relative fishing effort dedicated to them. Trips directed to a species could easily be selected when the species' contribution to the landings is above a given threshold. Subsequent directed CPUEs could then be calculated, on a single-species basis, even though they are of low interest in a multi-species context. This threshold is called the 'qualification level' [15, 23] and its use is recommended for defining directed CPUE, considering that data for a given species from vessels targeting other species may not be an accurate reflection of the abundance of that non-targeted species.

In a multi-species fishery, a single-species approach to estimating fishing effort is too restrictive. Once the target species are identified, a small number of métiers must be outlined, each of them defined by one or several target species [1, 18]. A global approach to fishery can therefore be achieved by sharing the total fishing activity in the relevant métiers, each trip being allocated to a single one. The landings by species and the fishing effort can easily be summed within métiers. CPUEs for each species in the relevant métiers can then be calculated. This paper presents a method to categorise trips, based on thresholds of target species' contribution to the catch of the trip.

Finally, examples are taken from the French demersal fishery off the west coast of Scotland and in the Celtic Sea. Trends of CPUE are examined using different ways of selecting fishing effort and associated landings. For each, re-computed CPUEs at age are used to tune VPA; populations estimates together with catch predictions are then compared.

2. MATERIALS AND METHODS

Fisheries statistics are available for French vessels for the years 1983 to 1995 (at least for the offshore fisheries) and provide for each fishing trip the duration, the fishing effort devoted to each area (statistical squares), the gears used and the species caught (as reported in the European Union log-book). Very detailed information relating to individual hauls is not available, since skippers must fill the EU log-book only once a day if they use the same gear in the same area. Furthermore, daily information is summed up for each trip, square and gear. These data are added to sales records which give the landings by volume, price for each species and commercial category.

In this study, data from bottom-trawl vessels in the west coast of Scotland fishery (Int. Council for the Exploration of the Sea, ICES Sub-area VI) and in the Celtic Sea (ICES Divisions VIIfgh) were used. Each fishing trip was split into as many 'sub-trips' as there were squares visited. The catch of each of these 'sub-trips' was reconstructed using the information reported in the log-book on the location of the main species catch by statistical squares. For the species with no information on catch location, the same catch rate was applied to the landings of the trip to provide estimates of the catch for each square visited.

About 60–70 French trawlers, from 30 to 55 m long, usually fish off the west coast of Scotland, and about 300, from 15 to 35 m, in the Celtic Sea, resulting in 3 500–4 000 and 8 500–11 000 'trips x squares' each year, respectively. Landings for the main species and fishing effort are given in *table I*. Each of these 'sub-trips' is considered as a trip in the following sections.

The analysis presented below is based on landings in weights, as discussed later. Possible discards are assumed to be negligible or at least of no influence on

Table I. Landings (tonnes) of the main species and fishing effort over the 1983-1995 period from the west of Scotland (ICES sub-area VI) and the Celtic Sea (ICES divisions VIIfgh) fisheries. * partial, ** provisionnal data.

Off the west coast of Scotland	1983	1984*	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995**
Fishing time (10^3 h)	937	922	1 427	1 204	1 240	1 375	1 306	1 378	1 463	1 535	1 522	1 307	1 495
Effort (10^3 h·kW)	10 629	10 158	14 582	13 399	14 398	15 771	15 143	15 015	15 082	15 298	14 894	12 101	12 523
Landing all species (tonne)	51733	49 890	68 562	63 294	59 119	58 359	47 827	42 696	42 506	35 445	39 294	32 810	32 534
Megrim (*Lepidorhombus whiffiagonis*)	1 531	1 424	1 425	796	1 015	1 285	684	634	547	515	518	409	602
Grenadier (*Coryphaenoides rupestris*)	0	0	0	0	0	0	2 219	5 510	7 341	6 465	6 439	5 900	6 309
Hake (*Merluccius merluccius*)	1 893	3 630	5 671	2 309	1 581	1 590	933	661	745	1 194	999	582	539
Cod (*Gadus morhua*)	8 615	7 239	7 376	4 620	4 794	7 175	5 868	4 408	2 635	2 044	3 048	2 482	2 535
Haddock (*Melanogrammus aeglefinus*)	4 603	5 906	6 011	4 617	4 858	2 820	1 759	1 302	958	801	1 133	754	668
Whiting (*Merlangius merlangus*)	1 685	1 498	1 469	837	1 248	1 013	238	403	223	115	150	192	322
Saithe (*Pollachius virens*)	16 370	12 468	20 043	28 841	24 828	24 630	18 076	13 938	10 414	7 180	10 222	8 470	6 166
Ling (*Molva molva*)	5 227	5 515	6 203	4 641	4 315	5 371	3 369	2 553	1 789	1 285	1 581	1 710	1 967
Blue ling (*Molva dypterigia*)	5 138	6 018	11 866	9 778	9 389	7 076	7 241	4 575	5 768	3 737	3 714	2 610	3 030
Orange roughy (*Hoplostethus atlanticus*)	0	0	0	0	4	2	5	8	376	1 297	429	179	74
Anglerfish (*Lophius piscatorius* + *L. budegassa*)	1 552	1 623	2 039	1 563	1 436	1 992	2 434	2 836	2 464	2 342	2 473	2 384	2 566
Black scabbard (*Aphanopus carbo*)	0	0	0	0	0	0	141	1 034	2 309	3 111	2 944	2 388	2 616
Dogfish (*Squalus acanthias*)	1 824	1 568	2 001	1 315	1 208	781	681	419	372	379	214	85	130

Celtic Sea Fishery	1983	1984*	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995**
Fishing time (10^3 h)	6 879	5 202	6 534	6 683	6 667	7 190	8 053	8 323	7 750	7 888	7 763	6 987	7 062
Effort (10^3 h·kW)	28 064	20 229	26 048	27 543	28 003	30 983	35 165	35 566	33 022	33 299	32 428	29 106	29 014
Landing all species (tonne)	65 124	47 046	55 404	53 983	54 258	63 593	67 090	58 650	45 974	43 304	46 172	46 981	49 370
Megrim (*Lepidorhombus whiffiagonis*)	3 591	2 930	3 858	3 413	3 219	3 485	3 641	2 896	2 347	2 692	2 589	2 300	2 624
Sole (*Solea vulgaris*)	140	109	138	139	110	130	143	157	146	179	148	126	126
Hake (*Merluccius merluccius*)	5 790	3 479	2 871	2 433	2 571	2 629	2 062	1 545	1 405	1 501	1 215	900	820
Cod (*Gadus morhua*)	4 903	4 561	5 647	7 469	7 168	12 013	14 252	8 364	5 424	6 179	7 863	6 930	7 416
Haddock (*Melanogrammus aeglefinus*)	893	579	844	748	928	2 314	2 052	866	685	1 019	1 335	2 142	2 498
Whiting (*Merlangius merlangus*)	8 278	6 010	7 021	6 566	8 407	9 701	10 880	9 562	8 748	8 209	10 086	11 708	11 871
Pollack (*Pollachius pollachius*)	2 667	1 423	1 837	2 347	1 815	2 017	1 858	1 656	1 353	935	782	738	690
Saithe (*Pollachius virens*)	1 694	1 206	1 826	2 332	2 068	2 353	2 798	2 679	1 394	622	538	502	429
Ling (*Molva molva*)	3 759	2 064	2 806	2 989	2 502	2 602	3 089	2 864	2 139	1 443	1 290	1 367	1 457
Orange roughy (*Hoplostethus atlanticus*)	0	0	0	0	0	0	0	0	0	32	40	18	12
Anglerfish (*Lophius piscatorius* + *L. budegassa*)	9 443	7 588	10 012	8 047	5 893	6 488	7 259	7 421	5 342	4 295	4 440	5 606	6 905
Dogfish (*Squalus acanthias*)	7 490	3 924	3 416	2 704	5 152	3 859	2 385	2 096	1 429	940	657	530	597
Cuckoo ray (*Raja naevus*)	1 378	1 706	2 876	2 947	2 686	2 766	2 629	2 593	2 168	1 872	1 620	1 809	1 930
Norway lobster (*Nephrops norvegicus*)	3 510	3 399	3 465	2 639	3 087	3 005	3 240	3 810	2 708	3 400	3 828	3 721	3 811

the analysis, and the term catch is used as a synonym for landing. Scientific names of the species studied are also given in *table I*.

2.1. Identification of target species

2.1.1. Single-species approach to identify target species, and general method to select trips

Each fishing trip, i, can be categorised by the percentage, $c_{i,s}$, of a species, s, in its total landings, $T_{i,.}$. The category, j, of the trip is the truncated value of the percentage $c_{i,s}$. Thus, landings of the species, $T_{i,s}$, can be summed for all the trips within each category, j. Dividing this sum, $TC_{j,s}$, by the total landing of the species over all trips, $T_{.,s}$, gives the relative contribution of this category to the total landings of the species. Finally, these contributions can be summed category by category from 0 to 100 %, providing, for each category, the cumulative relative contribution, $P_{j,s}$, to the total landings of the species.

$T_{i,s}$ = Landing of species s in the trip i

$T_{i,.} = \sum_{s=1}^{\infty} T_{i,s}$ = Total landing of the trip i (over all species)

and $T_{.,s} = \sum_{i=1}^{n} T_{i,s}$ = Total landing of the species s (over all trips)

$c_{i,s} = \frac{T_{i,s}}{T_{i,.}}$ = Percentage of species s in the landings of trip i

j = truncated value of $c_{i,s}$ = qualification level, j = 0, ..., 100

then $TC_{j,s} = \sum_{i=1}^{n} \alpha_{i,j,s} \times T_{i,s}$

$$\text{with} \begin{cases} \alpha_{i,j,s} = 1, & \text{if } c_{i,s} = j \\ \alpha_{i,j,s} = 0, & \text{if not} \end{cases}$$

= Sum of the landings of species s for a category j

and $P_{j,s} = \frac{\sum_{k=0}^{j} TC_{k,s}}{T_{.,s}}$

= Cumulative relative contribution of fishing trips of categories from 0 to j to the total landings of the species s

where : i = index of trip

s = index of species

n = total number of trips

When, for a species, the trips are categorised as mentioned above with respect to the contribution of a species to the trip landings, it becomes easy to treat the corresponding fishing effort, E_i, in the same way and to calculate the contribution of trips, $PE_{j,s}$, from categories 0 to j to the total fishing effort, $E_.$.

$$PE_{j,s} = \frac{\sum_{i=1}^{n} \alpha_{i,j,s} \times E_i}{E_.}$$

$$\text{with} \begin{cases} \alpha_{i,j,s} = 1, & \text{if } c_{i,s} < j+1 \\ \alpha_{i,j,s} = 0, & \text{if } c_{i,s} \geq j+1 \end{cases}$$

= Cumulative relative contribution of fishing trips of categories from 0 to j to the total fishing effort.

Three indicators could be used to determine whether or not a species should be considered as a target species and to what extent fishing effort is directed or not.

– The cumulative relative landings of each species, $P_{j,s}$, compared to the percentage, j, of this species, s, in the landings of the considered trips (*figure 1*a) show both the degree of specialisation of trips and the level of efficiency in catching the considered species. If appropriate, it could also provide indication on the size of schools, as CPUE and, hence, the estimated abundance of some species depends on both the number and the size of schools [10].

– The cumulative relative fishing effort allocated to trips, each of them characterised by the percentage of each species (*figure 1*b), shows the importance of specialised trips in terms of directed effort and not only in terms of catch.

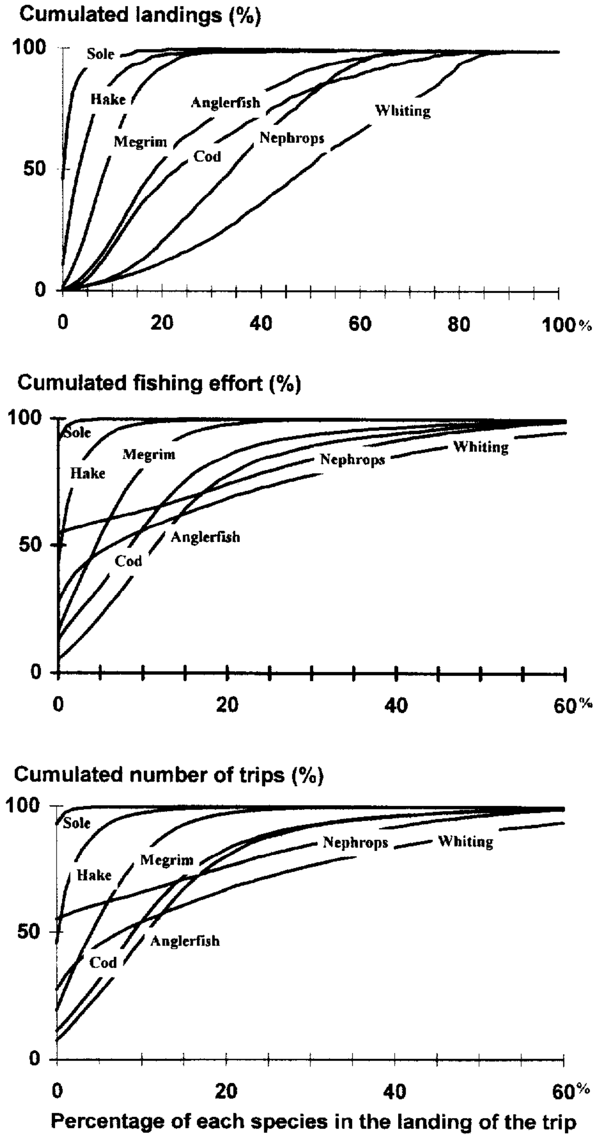

Figure 1. Example of three types of graph showing; (a) the cumulative relative landings; (b) the cumulative relative fishing effort; (c) the cumulative number of fishing trips. X-axis is the percentage of each species (in weight) in the landings of each fishing trip (truncated value). Y-axis is the cumulated percentage of landings, effort or number of trips, for trips for which the species represents less than the given (in abcissa) in the fishing trip landings.

– The cumulative number of trips for which the percentage of each species in the total landings is given in abscissa (*figure 1*c) is very similar to the previous one, since the average duration of a trip in a square does not vary too much.

The levels of the thresholds could be set either to qualify trips with at least a fixed part of the studied species ($j = 0.25$ in [15]) or, select data from trips with qualification levels set in order to assure a given percentage, called explanation level (EL), of the total landings of the species in the qualified trips. These latter thresholds can be called the 'EL explanatory qualification levels' (EQLs) j, (j is set as $1 - P_{j,s} \geq \mathrm{EL}$, with EL = 0.75 or 0.90 for instance). For a given value of EL for a species, the thresholds j may vary from year to year due to fluctuations in relative abundance of this species. The actual value of EL is of little importance since a large part of the catch is considered, and trips with catches of only a few percent of the studied species are ignored.

2.1.2. Approach by métiers to calculate 'directed CPUE' in a multi-species context

Previously identified target species can be associated in order to define métiers as exclusively as possible. Each trip of each vessel in a specified fishing area (Celtic Sea, west coast of Scotland) and with a specific gear (bottom trawl), is classified into a 'target métier' in accordance with the relative amounts of the previously identified target species (or group of species) in its catches (landings), each of these percentages being compared to the appropriate thresholds. As for the single-species approach, the thresholds applied to the target species (or group of species) are 'explanatory qualification levels' (EQLs) varying with time, according to fluctuations of the relative abundance of each species.

For practical reasons and for clarity of interpretation, the number of targets within an area should not be too large, each of them defining a fishing tactic or a métier, with possible interactions between them: 3 targets lead to 8 'métiers' (3 'pure' métiers, 1 'other' métier, 3 'mixed' métiers defined by combinations of 2 targets and 1 'very mixed' métier represented by the combination of the three targets).

The value of the explanation level (EL) must be chosen to provide thresholds (EQLs) which assure an effective discrimination between trips, and a great amount of target species in the landings of the métiers directed to them.

The choice of the retained métiers together with an eventual combination of target species remains quite subjective but is driven by the overall purpose, i.e., to obtain directed CPUEs for assessed stocks.

2.2. Directed CPUEs, VPA and predictions

Using two sets of explanatory qualification thresholds (75 and 90 % EQLs), production by species and fishing effort were split into the different métiers over the whole period. For each target, there is one 'pure' métier and some 'mixed' métiers, parts of landings of a target species are generally shared among the pure and some mixed métiers, the sum of which gives the percentage corresponding to the applied explanation level. Directed CPUEs are calculated within the relevant 'pure' métier only.

A tuned VPA is carried out for two species : Whiting (*Merlangius merlangus*) in the Celtic Sea and Saithe (*Pollachius virens*) from the Northern fishery. Using catch and effort data from directed trips, new tuning files were created from annual catch at age data for the French tuning fleets as used in the relevant ICES working groups (WG). These were derived by applying the ratio of weights landed by the two series (Directed / WG). This method would not be accurate if the 'old' tuning data had been constructed on a quarterly basis. It is also assumed that age compositions of the new tuning fleets are similar to old ones.

The extended survivors analysis (XSA) tuning process [8, 22] was conducted with the same parameters used in the ICES working groups (which may not be completely relevant since a change in the tuning fleets may cause changes for some options). As in the ICES working groups, short term predictions are carried out using average recruitments (geometric mean over the period), catch numbers at age for the last assessed year (1995) and average fishing pattern (over the three last years) scaled to the last mean fishing mortality F (1995).

3. RESULTS

3.1. Status of a species from its relative contribution in the catch of each trip

Figure 2 shows the most illustrative of the cumulative relative French landings ($P_{j,s}$) for some of the main species caught during 1983-1994. *Figure 3* presents the cumulative relative French fishing effort related to the percentages of each species in catches. Thus, for a given species, setting a qualification level (X-axis), the contribution to the total landings (or effort) of trips for which this qualification level is not reached is easily found on the Y-axis. On the other hand, given an explanation level (EL) on the Y-axis, the corresponding 'explanatory qualification level' (EQL) is given on the X-axis. This latter is the threshold required to assure that the qualified trips at least contribute to the given explanation level for the total landings of the species.

3.1.1. The cumulative relative landings curves

Among the main species caught in the Celtic Sea and off the west coast of Scotland, three types of cumulative relative landings curves could be identified with some intermediate states, leading to four categories of species.

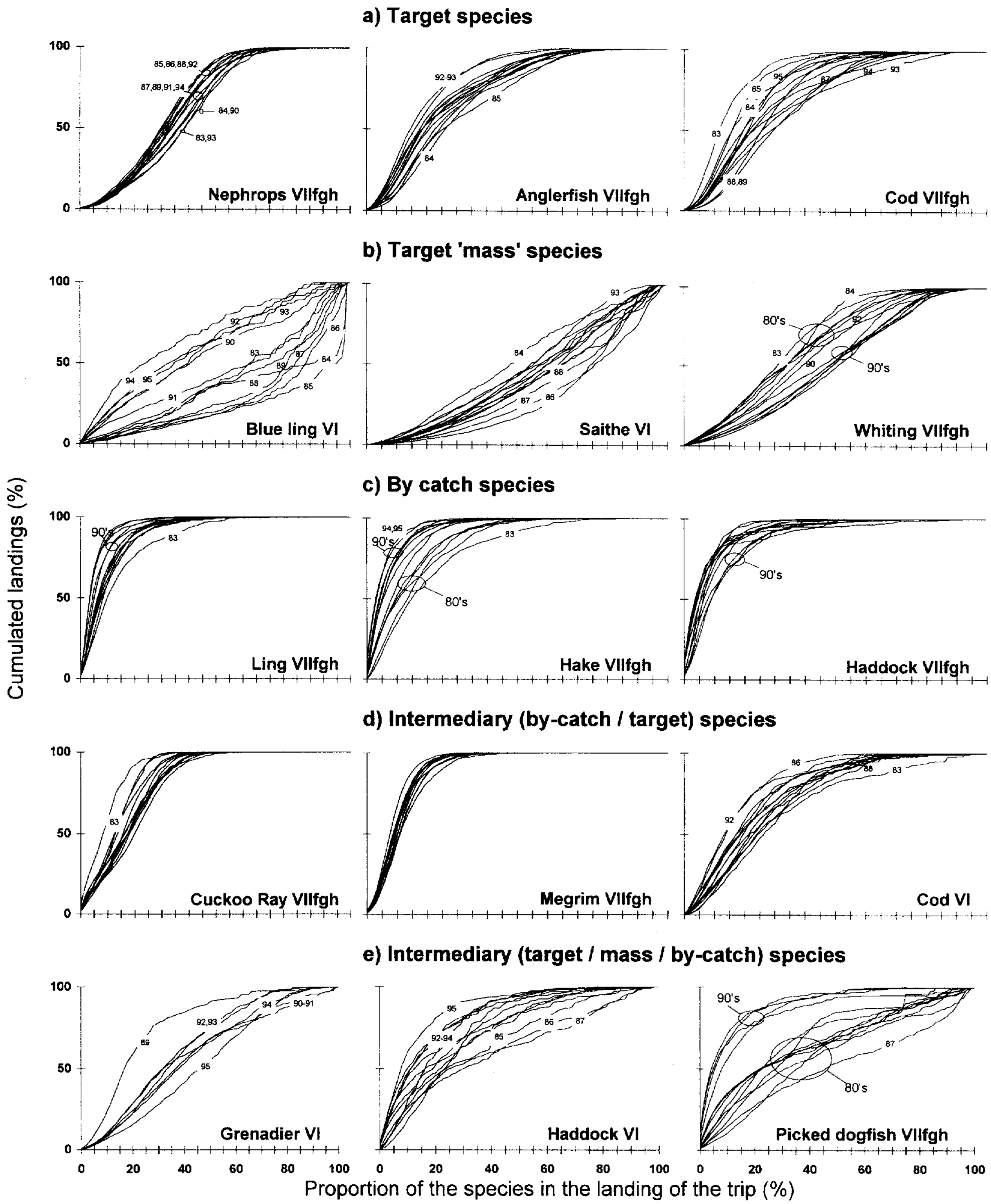

Figure 2. Cumulative relative landings of the French demersal fishery off the west coast of Scotland (ICES sub-area VI) and in the Celtic Sea (ICES divisions VIIfgh) for some (a) Target species, (b) Target 'mass' species, (c) By-catch species, (d) and (e) Intermediary species. X-axis is the percentage of each species (in weight) in the landings of each fishing trip (truncated value). Y-axis is the cumulated percentage of landings for trips for which the species represents less than the given (in abcissa) in the fishing trip landings.

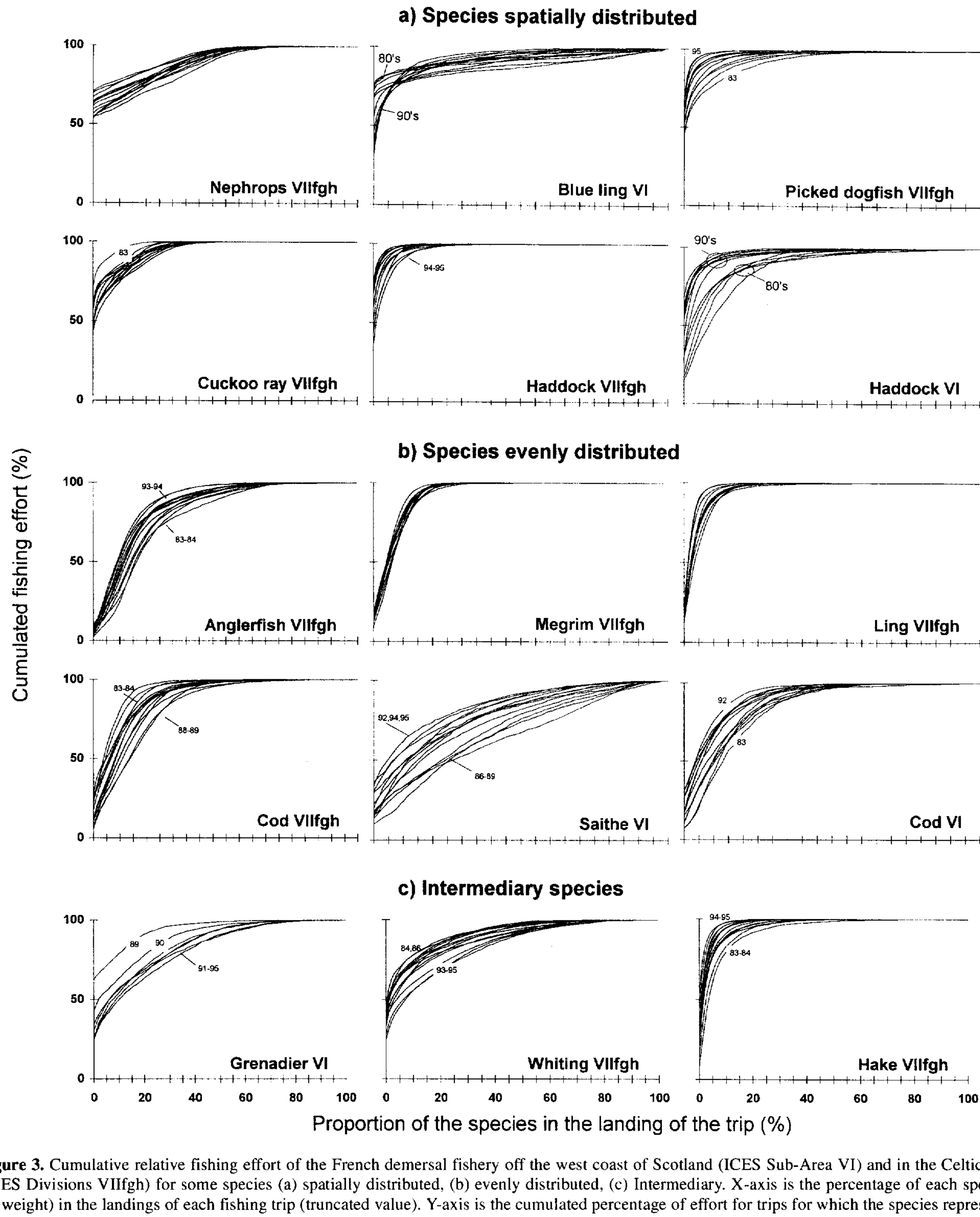

Figure 3. Cumulative relative fishing effort of the French demersal fishery off the west coast of Scotland (ICES Sub-Area VI) and in the Celtic Sea (ICES Divisions VIIfgh) for some species (a) spatially distributed, (b) evenly distributed, (c) Intermediary. X-axis is the percentage of each species (in weight) in the landings of each fishing trip (truncated value). Y-axis is the cumulated percentage of effort for trips for which the species represents less than the given (in abcissa) in the fishing trip landings.

Target species: The most important part of these species' landings comes from trips for which the proportion of these species in the landing are medium size (10–50 %) with a small amount from trips with very high or very low proportions (> 60 %, < 5 %). As shown in *figure* 2a, the shape of the curve is sigmoid-like. In the Celtic Sea, this was the case for Norway lobster (*Nephrops norvegicus*) (over 60 % of landings from trips where Norway lobster contributes between 20 and 50 %), anglerfish (*Lophius piscatorius* + *Lophius budegassa*) (more than 50 % of trips with qualification levels between 0.10 and 0.30) and cod (*Gadus morhua*).

Target 'mass' species: Some species can be called 'mass species' due to their schooling behaviour. When mass species are targeted a large part of their landings (> 40 %) comes from trips in which the relative contribution of these species to the landing is very high (> 70 %), whilst very little (< 10 %) comes from trips in which these species make up only a small part (< 20 %) of the landing. This is shown by the shape of the cumulative relative landings curve which is very concave (exponential) (*figure* 2b) and causes high 'explanatory qualification levels' (EQLs greater than 0.30 for a 90 % EL). Blue ling (*Molva dypterygia*) (during 1983-1989) and saithe (*Pollachius virens*) in the Northern fishery and whiting (*Merlangius merlangus*)in the Celtic Sea could all be considered 'mass' species.

By-catch species: Almost all the landings for these species come from trips with only small proportions in catches. For instance, ling (*Molva molva*), hake (*Merluccius merluccius*), and haddock (*Melanogrammus aeglefinus*) are by-catch in the Celtic Sea French fishery (*figure* 2c).

Intermediary species: A special mention should be made for megrim (*Lepidorhombus whiffiagonis*) and cuckoo-ray (*Raja naevus*) in the Celtic Sea fishery and cod (*Gadus morhua*) in sub-area VI which are more than simple by-catch species as shown by the slight sigmoid shape of their curves (*figure* 2d) but as yet are not actually target species.

Finally, some species such as haddock in the west of Scotland fishery could be considered as a target species in some years but not others (*figure* 2e). This is also the case of deep sea fish which appeared to be by-catch in the first year of their catches and target or mass species in recent years. *Figure* 2e shows the case of roundnose grenadier (*Coryphaenoides rupestris*) since 1989, but it is the same for black scabbard fish (*Aphanopus carbo*) since 1990 and orange roughy (*Hoplostethus atlanticus*) in 1990. Picked dogfish (*Squalus acanthias*) in the Celtic Sea fishery, however, was a target mass species in the 80's but has become a by-catch since.

3.1.2. The cumulative relative fishing effort curves

The curves for effort (*figure 3*) show the fraction of the fishing activity devoted to some species. The amount of the relative contribution of directed fishing effort provides an indication of the status of the species, even if the main information concerns their spatial distribution and/or their collective behaviour.

Species spatially located: These species have a high percentage of hours spent fishing but constitute less than 1 % of the catch as shown in *figure 3*a for blue ling (68–76 % in 1983-1989) in the west of Scotland fishery, Norway lobster (54–70 %), picked dogfish (45–70 %), haddock (36–76 %) and cuckoo ray (42–71 %) in the Celtic Sea fishery.

Species evenly distributed: These species are fished by all vessels everywhere (*figure 3*b): anglerfish (2–10 % of hours spent fishing without any in the catch), megrim (9–19 %), ling(11–22 %) and cod (6–27 %) in the Celtic Sea, saithe (10–36 %) and cod (7–31 %) in Sub-area VI.

Intermediate state: The sigmoid shape of the curve for anglerfish and cod in some years indicates a special status for these species, since although they are caught everywhere by everybody, a large part of the total fishing time is devoted to trips in which these species have a relatively high contribution to the landing. In the Celtic Sea (*figure 3*c), whiting (24–47 %) is more evenly distributed than Norway lobster but the shape of their curves are very similar, indicating that whiting can be considered as a target species. The same applies to roundnose grenadier (24–34 %). Hake in the Celtic Sea could have been considered evenly distributed at the beginning of the period studied with few trips (8–13 %) not catching any. In recent years, however, it appears to have been more spatially distributed since about 50 % of the total fishing time was devoted to trips in which hake did not contribute to landings.

3.1.3. Conclusion on the status of the species

As a result of this study of landings, trip by trip and species by species, we can conclude that a target species is well defined by the following criteria: (i) very few landings come from trips for which the species accounts for a small part of the total catch; a large part of the landings of the species comes from trips for which its relative contribution to the catch is very high for 'mass species', or simply medium for others; (ii) a significant amount of fishing effort is devoted to trips for which this species is not caught, or is caught but contributes very little (< 1 %) to the landings of the trip; (iii) for both landing and effort, 50 % or 75 % EQLs have relatively high values; (iv) the shape of the curve (cumulative landings vs. percentage of the species) provides a visual indication of the status of the species, i.e., concave curve (exponential) for mass target species, sigmoid curve for 'simple' target species and asymptotic curve for by-catch species.

The nature and the strength of the relationship between CPUE and catch proportions can also be looked at (*figure 4*), but provides information mainly on the gregarious behaviour, or otherwise, of the species. The actual amount of landings must be kept in mind to avoid speculation about the status of species with low catches when defining the main métiers within a fishery.

3.2. Choice of the métiers and selection of the fishing trips based on target species thresholds

Using the single-species approach some target species can be identified. In the west of Scotland, saithe

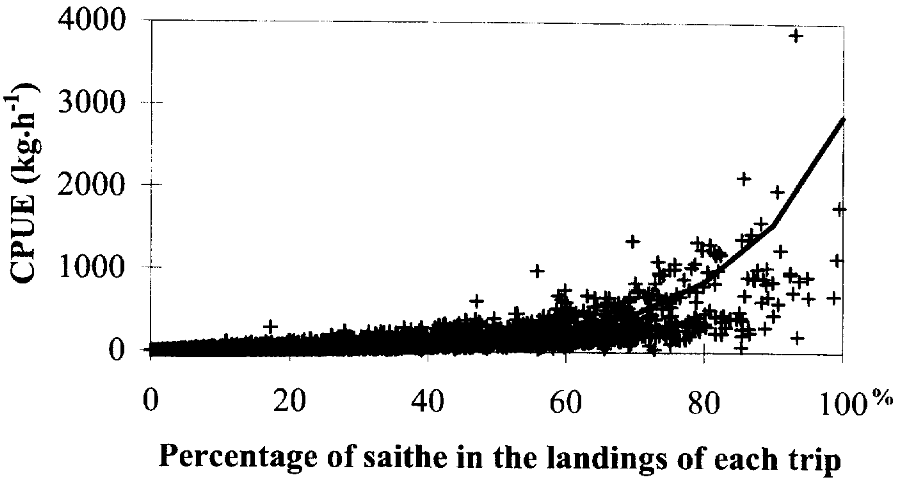

Figure 4. Saithe (west coast of Scotland): Observed CPUE related to saithe contributions in the landings of the trips and regressed: y = exp(0.06x + 1.92), $R^2 = 0.70$.

and blue ling have already been mentioned as target species [2]. Since then, a new deep sea fishery was developed, dedicated to roundnose grenadier. In the Celtic Sea, it is known [7] that the French trawler fleet divides its activities in three main métiers: Norway lobster, Gadoids (mainly cod and whiting) and so-called Benthics (anglerfish, rays and megrim). In this paper, four species have been identified as target species in this area: Norway lobster, anglerfish, cod and whiting.

In order to limit the number of métiers due to all possible combinations of targets, only three target species or group of species for each area are considered. For the study of the Celtic Sea fishery, cod along with whiting make up the target for the demersal métier, while anglerfish and cuckoo ray define the benthic one. Megrim was rejected from the definition of this last métier since a large part of this species is taken together with Norway lobster which itself constitutes the third target species. In Sub-area VI, the first two métiers contain saithe and blue ling. The third, the deep sea fish métier, is defined by the association of grenadier, black scabbard and orange roughy.

After the identification of the target(s), the qualification thresholds (EQLs) are set for each year at values corresponding to the chosen explanation level (EL). Then, by definition and as explained above, a percentage – equal to EL – of the landings of the considered species (or group of species) comes from so-called directed trips on a single-species base. Therefore, these trips are considered to be dedicated to the relevant pure and mixed métiers. *Table II* shows the values of the

Table II. Values of explanatory qualification thresholds (EQLs) for the identified target species or group of species as used to build the métiers in the west of Scotland and in the Celtic Sea, for two explanation levels (EL = 90 and 75 %).

Target species	Percentage of landings explained (EL)	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
West coast of Scotland														
Saithe	90 %	21	16	20	38	33	27	27	24	21	17	22	24	16
	75 %	40	28	37	60	54	47	43	43	38	33	37	41	34
Blue ling	90 %	19	21	31	25	29	23	16	7	8	6	5	4	5
	75 %	39	39	65	62	60	53	37	18	28	17	14	9	13
Grenadier + Scabbard	90 %							6	12	15	21	16	16	20
+ Orange roughy	75 %							11	22	28	34	28	31	37
Celtic Sea														
Nephrops	90 %	13	15	13	11	13	13	13	14	14	14	13	14	12
	75 %	23	26	21	20	22	21	22	26	23	21	23	23	21
Cod + Whithing	90 %	13	14	15	16	18	21	22	17	19	20	25	24	25
	75 %	23	27	26	33	34	35	40	36	42	35	42	44	41
Anglerfish + Cuckoo ray	90 %	9	11	12	11	8	7	7	9	9	7	6	8	9
	75%	16	19	18	19	15	14	14	16	16	12	11	14	15

explanatory qualification thresholds for the species or groups of species used to build the métiers for two levels of explanation (EL = 75 and 90 %). Since thresholds are lower for a 90 % EL, the relative amount of mixed métiers is higher than when using a 75 % EL, and the part of the métier 'Other' is much lower. Therefore, both are useful to interpret variations in allocation of fishing activity among the métiers. Only the results of the allocation of effort are presented here.

Figure 5 shows the trends of the relative contributions of each métier to the total fishing effort for two sets of explanatory qualification levels for the French demersal fishery off the west coast of Scotland. Over the 1983-1988 period, the 'pure' saithe métier accounted for 25 %, or 40 %, of the total French activity in this area with 75 % and 90 % EQLs respectively. Since 1990, the relative amount of this métier has decreased to values below 20 % – continuously with 75 % EQL, or 25 % – after a sharp drop reported in 1989-1990 with 90 % EQL. The blue ling 'pure' métier represents around 10 % of the total French activity in this area whatever the ELs considered. This means that this métier is very specialised. The deep sea fish métier, appearing in 1989, has accounted for 20–25 % (depending on the levels of the thresholds) of the total activity in this area since 1991. Finally, mixed métiers represent only a negligible part of the activity for both explanatory qualification levels, with the exception of mixed métier 'blue ling + deep sea fish' which amounts to about 15 % of the total with 90 % EQL. Other results show that the métier 'Other' contributes about two thirds to the total landings of non-target gadoids and benthic species. Because the fishery is seen through three targets only, the métier 'Other' accounts for a large part of the activity as the activity based on other gadoids and benthic species is not described.

Figure 6 shows the trends of the relative contributions of each métier to the total fishing effort for 75 and 90 % EQLs for the Celtic Sea fishery. No trends by

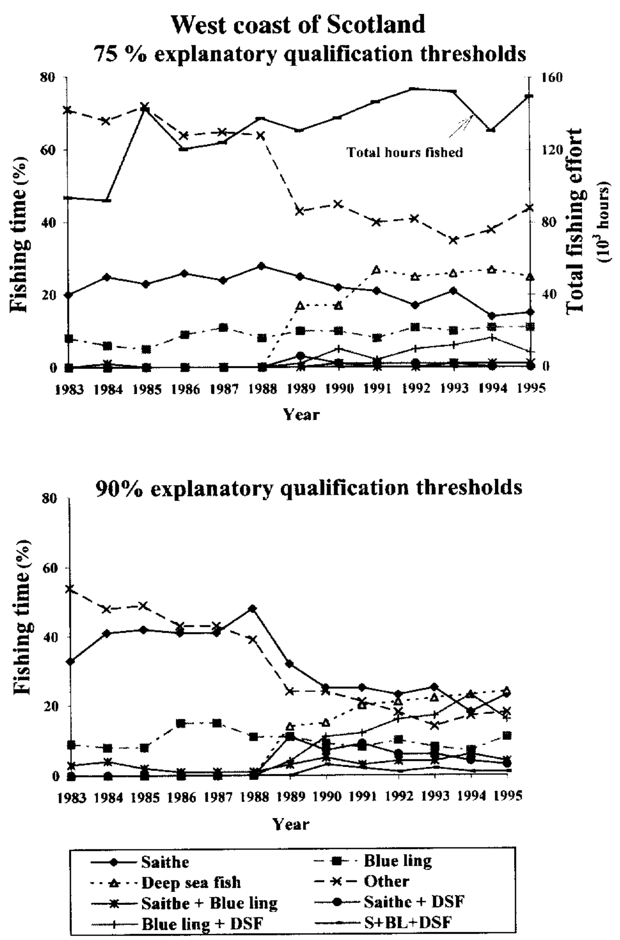

Figure 5. French demersal fishery off the west coast of Scotland: Relative contribution of each métier to the total French fishing effort for 75 and 90 % explanatory qualification levels. S: saithe; DSF : deep sea fish; BL : blue ling.

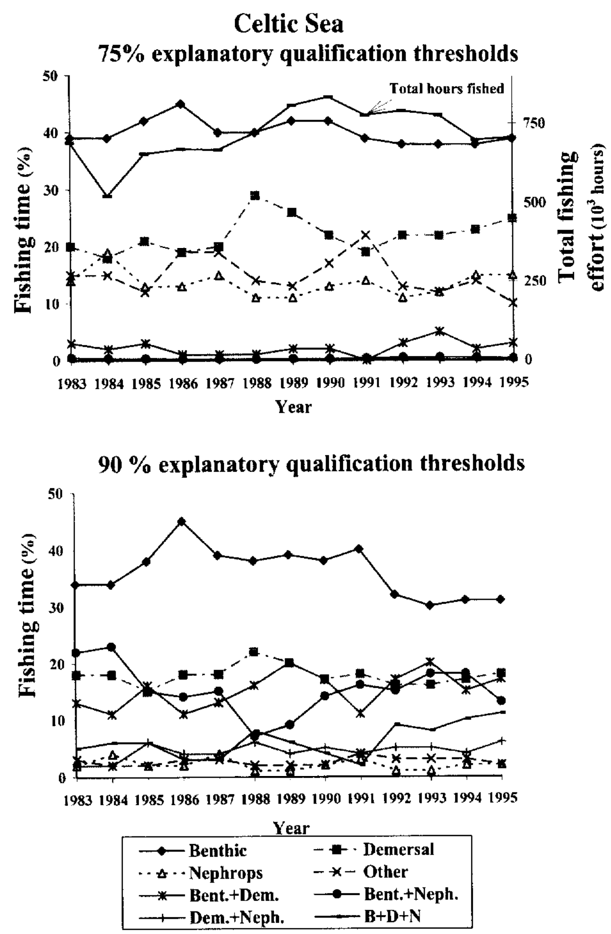

Figure 6. French demersal fishery in the Celtic Sea: Relative contribution of each métier to the total French fishing effort for 75 and 90 % explanatory qualification levels. B: benthic species; D: demersal species; N: *Nephrapas norvegicus*.

métier are obvious except a slight decrease in the contribution of the benthic métier since 1986, a peak in the demersal métier in 1988-1989 and an increase of mixed métiers in recent years. On average over the period studied, at a 75 % EL, the contribution of the three 'pure' métiers – benthic, demersal and Norway lobster – to the total activity are 40, 22 and 14 % respectively, while unclassified trips represent about 15 %, and mixed métiers less than 10 %. Setting the qualification levels in order to explain 90 % of the landings of each species (or group of species) leads to benthic and demersal métiers with almost unchanged contributions (36 and 18 % respectively), to a very poorly represented 'pure' Norway lobster métier (2 %) and to very few unclassified trips, i.e., métier 'Other' (3 %). On the other hand, mixed métiers such as 'benthic + Norway lobster' or 'benthic + demersal' contribute significant amounts (15 % each) to the total activity of the French demersal fleets operating in the Celtic Sea. This is not surprising since we know that Norway lobster trawlers target this species during daylight only and shift their effort to gadoids at night. Furthermore, they also catch some benthic species while targeting Norway lobster. Since the qualification levels for benthic and demersal target species are very low to cover 90 % of their landings, most of the 'Norway lobster' trips are classified as mixed métiers.

3.3. Directed CPUEs, stock assessment and predictions

Figures 7–9 show, for some species – saithe and blue ling off the west coast of Scotland, and Celtic Sea whiting – the values and trends of directed CPUEs

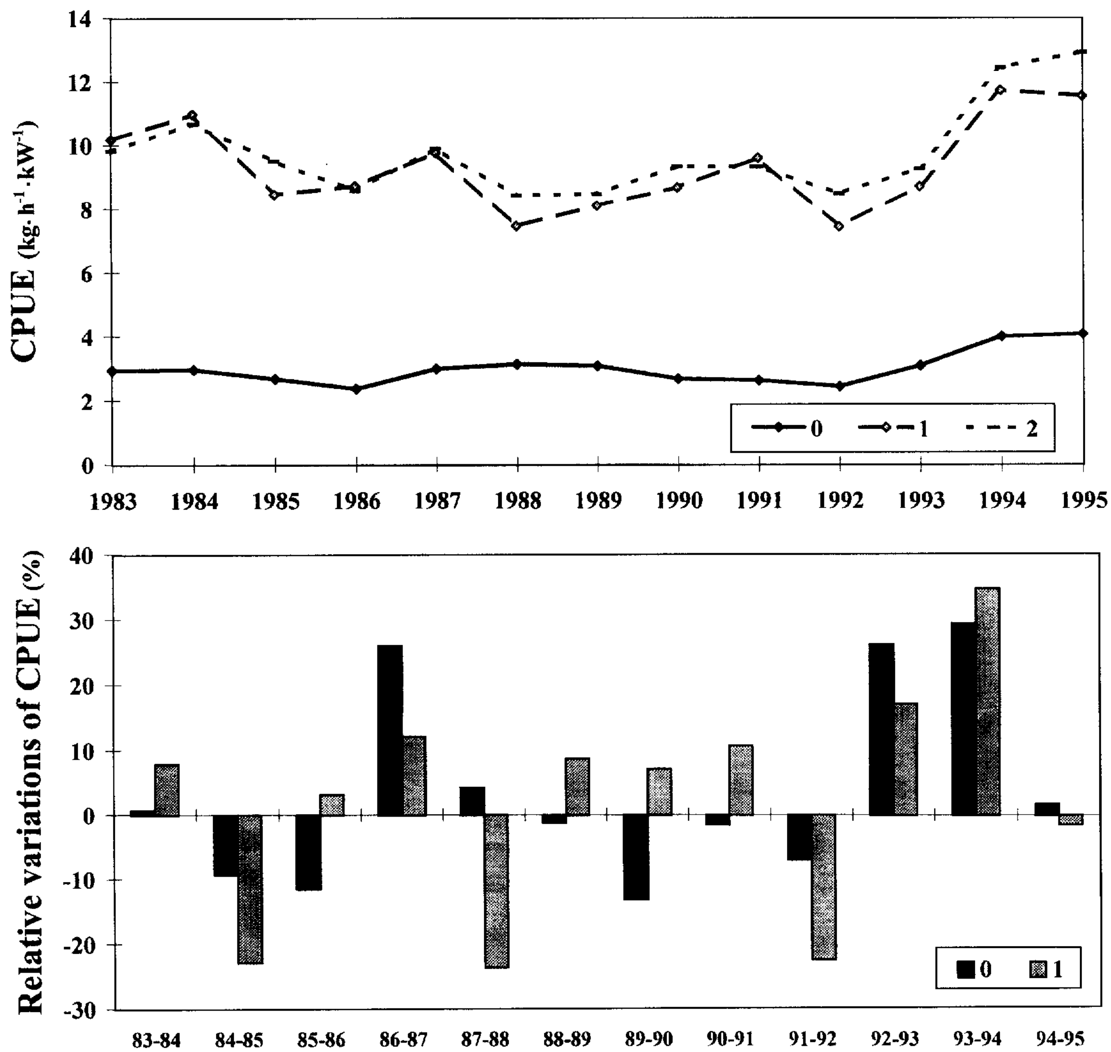

Figure 7. Whiting (Celtic Sea). Trends of French CPUE and relative variations for global and directed series: 0 = Global CPUE, i.e., Total landings / Total effort in sub-area VI (fishing time); 1 = demersal métier (pure métier defined from 75 % EQL); 2 = demersal métier (pure métier defined from 90 % EQL).

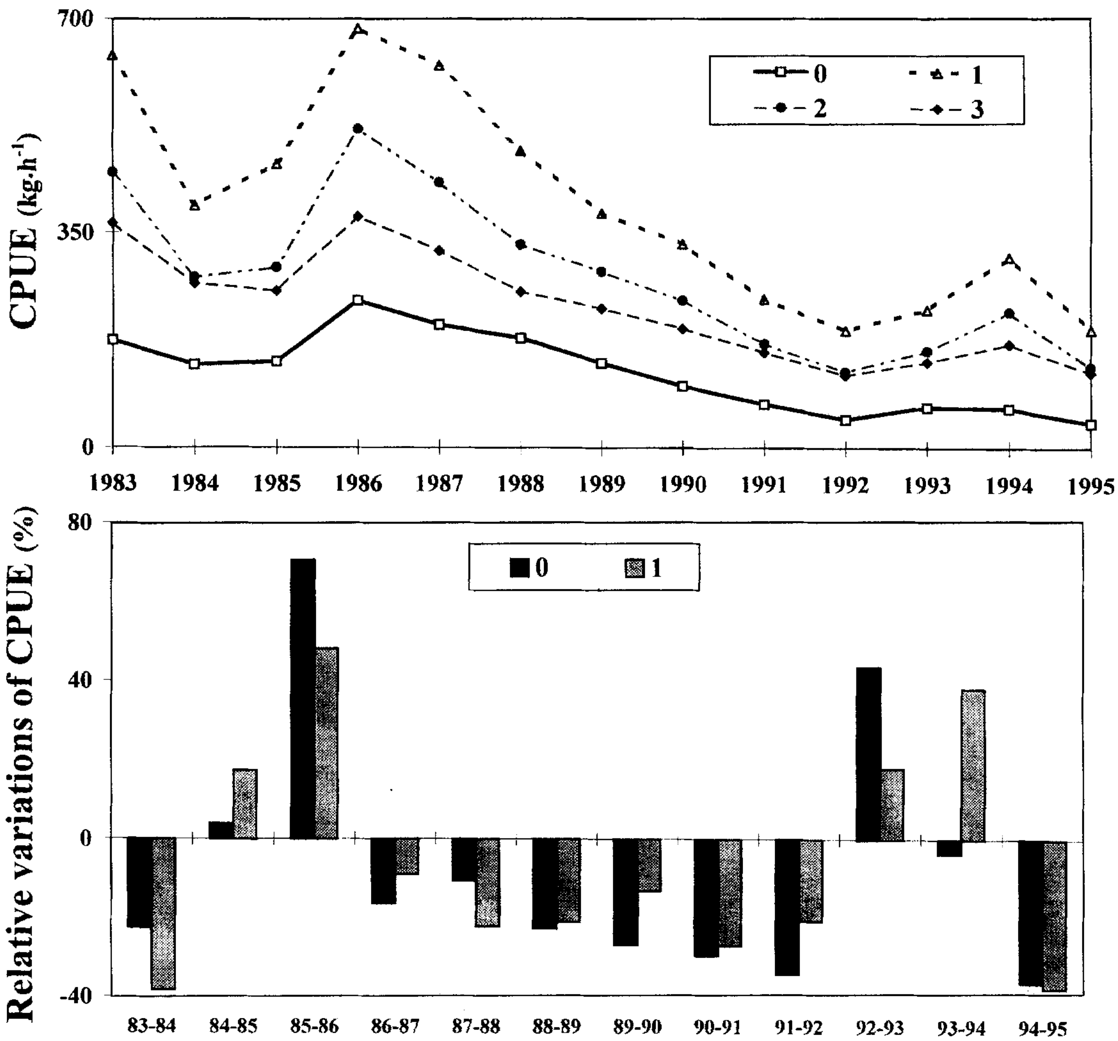

Figure 8. Saithe (west coast of Scotland). Trends of French CPUE and relative variations for global and directed series: 0 = Global CPUE, i.e., Total landings / Total effort in sub-area VI (fishing time); 1 = demersal métier (pure métier defined from 75 % EQL); 2 = demersal métier (pure métier defined from 90 % EQL); 3 = as used by the ICES working group in 1995.

compared to global CPUEs (total landings / total effort for the whole area), and their relative variations from one year to the next. For information and when available, the French CPUE values used to tune the VPAs in the relevant ICES working groups [11, 12] are also plotted.

CPUEs values obviously vary depending on the way they are calculated: for instance, in 1994, CPUE values for saithe vary from 65 $kg{\cdot}h^{-1}$ for total effort to 223 $kg{\cdot}h^{-1}$ for 'pure' trips defined with 90 % EQL, and to 314 $kg{\cdot}h^{-1}$ with 75 % EQL.

However the main result is that, from one series to another, either trends or amplitude may differ consistently. For Celtic Sea whiting, all the CPUE have fluctuated without trend since 1983, with the exception of a slight increase since 1992, but the variations from year to year can vary from one series to another: global CPUE values for instance have increased between 1987 and 1988 whilst they have decreased for directed trips. The opposite was observed between 1989 and 1990.

All CPUE series for saithe in Division VI show an overall decreasing trend since 1986 (about –70 % from 1986 to 1992). In recent years (1993 and 1994) a slight increase occurred mostly for directed series. The amount of the between-years variations depends on the considered CPUE and varies within a range from 1 to 3–4. In some years, 1984-1985 and 1993-1994, the variations are of opposite sign. Since, on the one hand, the fishing time for the saithe métier estimated with 90 % EQL shows a drop in 1989 and 1990 as mentioned above, and on the other hand, a declining CPUE is observed, the same drop occurred in the relative contribution of this métier to the landings of saithe, similar to that observed with 75 % EQL. This means that until

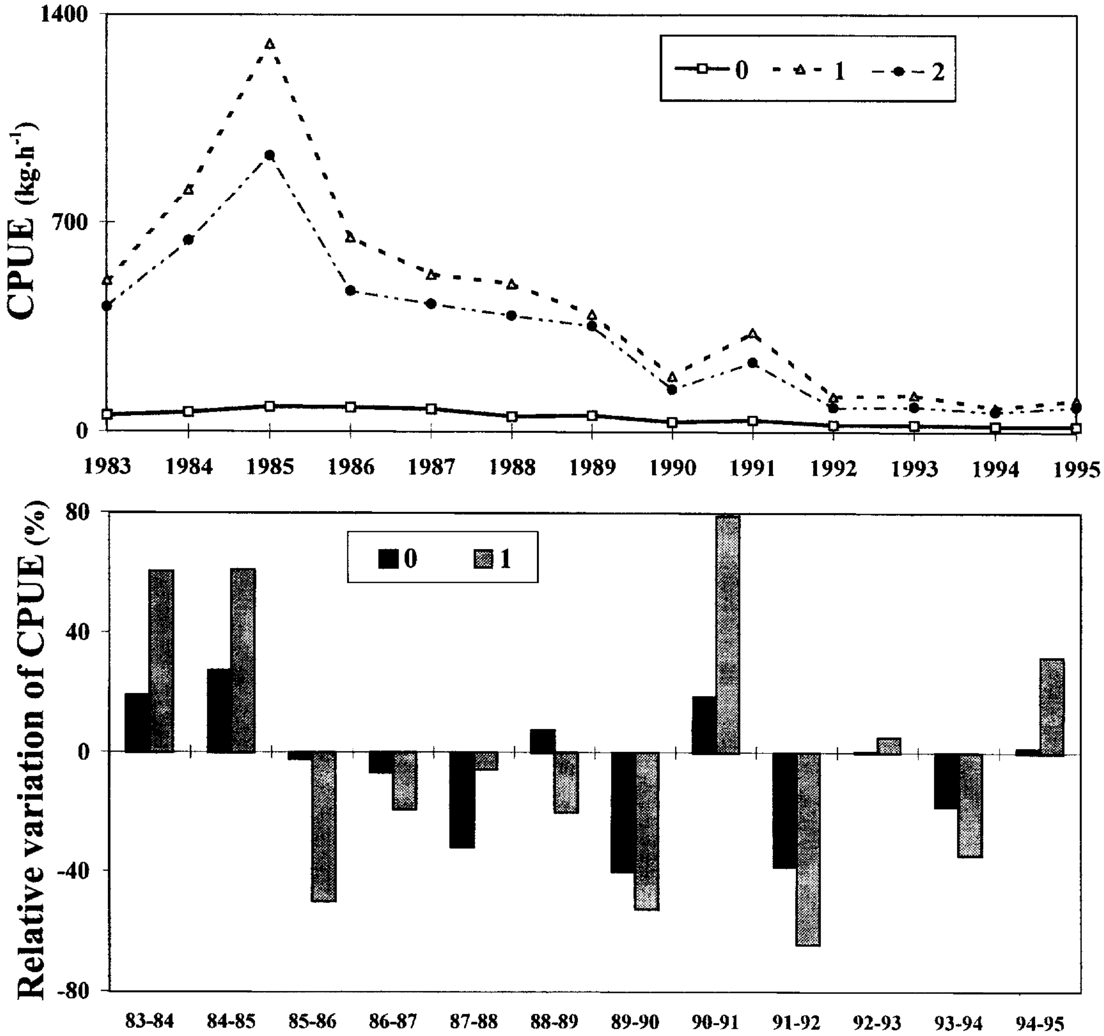

Figure 9. Blue ling (west coast of Scotland). Trends of French CPUE and relative variations for global and directed series: 0 = Global CPUE, i.e., Total landings / Total effort in sub-area VI (fishing time); 1 = blue ling métier (pure métier defined from 75 % EQL); 2 = blue ling métier (pure métier defined from 90 % EQL).

1988 saithe was caught mainly during very specialised trips but since then it has, in part, come from mixed trips.

As blue ling was caught in very few trips, it is not surprising to see very low CPUE when using the overall landings and effort data compared to those obtained from the trips in Division VI directed at blue ling. Except for 1988-1989, all the variations from year to year are in the same direction. The rate of variations quite differs among the series: between 1990 and 1991, the 75 % EQL's CPUE decreased by 80 % whilst the overall CPUE only decreased by 20 %. As mentioned above, 1989 and 1990, the beginning of deep sea fishery, must be considered as a turning point in the fishing activity in this area. Thus a mixed métier 'blue ling + deep sea fish' appeared in 1989 leading to a decrease of the relative amount of blue ling caught by the pure blue ling métier. As for saithe, this decrease is quite obvious when using 90 % EQL. This means that even though the blue ling pure métier represents a constant part of the total activity, denoting a rather constant specialisation, the amount of trips with very high catch rates have fallen dramatically.

The variations between the series are of considerable importance because their trends are used to tune the VPA. Therefore, the results of the assessment would be greatly dependent on the series used in function of the stock, as it is shown in the two following examples.

3.3.1. Assessment of whiting in the Celtic Sea (ICES Div. VIIfgh)

Two assessments tuned with a single fleet were conducted: the first one using global French CPUE values, and the second one CPUE from demersal French trips only. As the ICES working group VPA is tuned with

Table III. Whiting (Celtic Sea). Variations of the Virtual Population Analysis (VPA) results for global and directed CPUE series: (a) Global CPUE. (total landings / total time fishing) vs. demersal French CPUE (pure métier defined from 75 % EQL); (b) Global CPUE for two fleets as used in the ICES working group in 1995 vs. CPUE from directed trips of these two fleets. $\bar{F}_{2-5}$: Mean fishing mortality, age groups 2 to 5.

	WITHING (Celtic Sea)							
	Recruits		Biomass		SSB		$\bar{F}_{2-5}$	
	a	b	a	b	a	b	a	b
1982	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	1	1
1987	0	0	0	0	0	0	1	2
1988	0	0	0	0	0	0	0	2
1989	0	0	0	0	0	0	–1	1
1990	0	0	0	0	0	0	0	0
1991	0	–1	0	0	0	0	–1	0
1992	0	–1	0	–1	0	–1	–1	0
1993	0	–3	0	–2	0	–1	–1	0
1994	2	–11	0	–3	0	–2	1	3
1995	3	4	0	–5	0	–6	0	11

Table IV. Whiting (Celtic Sea). Variations in short term predictions when using the estimates obtained by VPAs tuned with global and directed CPUE series: (a) Global CPUE (total landings / total time fishing) vs. demersal French CPUE (pure métier defined from 75 % EQL); (b) Global CPUE for two fleets as used in the ICES working group in 1995 vs. CPUE from directed trips of these two fleets.

	WHITING		
		a	b
1996	Landings	2	–6
	SSB	3	–11
1997	Landings	1	–4
	SSB	2	–9
1998	Landings	0	–1
	SSB	2	–6

two French fleets corresponding to two different harbours, a new assessment has also been conducted using only the 'demersal' trips.

Despite different CPUE trends (in the amount and/or in the sign of variations) there is no notable improvements when using directed CPUE and, as shown in *table III*, results of the assessments do not differ by more than 10 % for estimated recruitment, fishing mortality and Spawning Stock Biomass (SSB). Subsequent predictions (*table IV*) also give very similar results (less than 10 % of variation).

3.3.2. Assessment of saithe in the west of Scotland (Sub-area VI)

In order to evaluate the impact of directed CPUEs to tune the VPA, the results obtained when using 'saithe French CPUE' series (i.e., built from a métier approach with 75 % EQL) and global CPUE are compared. In addition, the use of a directed CPUE series is also compared to the results obtained in the ICES working group in which the French CPUE came from a rough métier analysis of the French Northern fishery, using guessed and fixed thresholds. In all these cases, VPA is also tuned with a Scottish fleet.

The statistics concerning the fit of the catchability model, usually called 'tuning diagnostics', show that using global CPUE leads to the worse estimates (larger standard error on the fitted catchability, greater contribution of F shrinkage to the estimated F). Using directed CPUE gives better results than the previous method (smaller differences are found between the Scottish and the French fleet). Diagnostics and retrospective patterns are very similar whatever the level of explanation (75 or 90 %), and slightly better than those obtained with the CPUE series used in the working group.

Results of the assessments are presented in *table V*. Very different values for estimated numbers of recruits, SSB and Fs are obtained. Differences are much more important for the short term prediction results since variations could be greater than 100 % for SSB and around 10 % for predicted landings (*figure 10* and *table VI*).

4. DISCUSSION

It is commonly thought that market values of species might be better indicators than landed weights for setting thresholds. This could be the case in fisheries in which a species has a very high market value and consequently is very attractive to fishermen even if its landings are small. It could also be the case in fisheries in which a large amount of the landings is composed of low market-value by-catch species thereby leading to very poor discriminating percentages of actual target species. In those demersal multi-species fisheries which are studied here, no species is likely to hide the main signal; therefore, the results are very much alike

Table V. Saithe (west of Scotland). Variations of the Virtual Population Analysis (VPA) results for global and directed CPUE series: (a) Global CPUE (total landings / total time fishing) vs. saithe French CPUE (pure métier defined from 75 % EQL); (b) CPUE as used in the ICES working group in 1995 vs. saithe French CPUE (pure métier defined from 75 % EQL). SSB: spawning stock biomass; $\bar{F}_{3-6}$: mean fishing mortality, age groups 3 to 6.

	SAITHE (west of Scotland)							
	Recruits		Biomass		SSB		$\bar{F}_{3-6}$	
	a	b	a	b	a	b	a	b
1980	–1	1	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	–1
1982	0	0	0	0	–1	0	1	–1
1983	0	0	–1	1	–1	1	1	–1
1984	0	0	0	0	–1	1	0	–1
1985	0	0	0	0	–1	1	1	0
1986	1	0	0	0	–1	1	0	0
1987	1	0	0	1	–1	2	0	0
1988	1	0	0	0	–2	1	–1	1
1989	3	–1	1	0	0	–1	–1	0
1990	6	–1	2	–1	2	–1	–2	1
1991	0	–1	5	–1	4	–3	–6	1
1992	10	–3	8	–2	10	–3	–8	2
1993	20	–1	12	–2	12	–3	–13	3
1994	17	–5	18	–3	23	–3	–19	4
1995	10	–2	24	–4	34	–5	–31	6

Table VI. Saithe (west of Scotland). Variations in short term predictions when using the estimates obtained by VPAs tuned with global and directed CPUE series: (a) Global CPUE (total landings / total time fishing) vs. saithe French CPUE (pure métier defined from 75 % EQL); (b) CPUE as used in the ICES working group in 1995 vs. saithe French CPUE (pure métier defined from 75 % EQL).

	SAITHE		
		a	b
1996	Landings	6	–1
	SSB	75	–17
1997	Landings	9	–2
	SSB	101	–19
1998	Landings	10	–3
	SSB	126	–23

whether using values or weights to set thresholds. Furthermore, it is not always obvious whether fishermen are much more sensitive to values than weights since they are not completely driven by a profit maximisation rule. Finally, since prices fluctuate with time due to market constraints, the thresholds should also take into account these variations.

The first attempts to categorise trips on the basis of species thresholds were conducted in the early 90's. Target species and indications of the threshold levels were given by preliminary multivariate analysis of the catch composition by vessel, each resulting class of vessels being defined by percentages of the main species caught. The thresholds were set for the whole period studied. Their levels were agreed upon after some trials were conducted to assure a compromise between the effective discrimination of landings in the various métiers, and a reasonable amount of unclassifiable trips and of mixed métiers [11, 12, 13].

The use of an overall explanation level improves the method, since it allows the thresholds to vary from year to year depending on the relative abundance of the species.

The choice of an explanation level remains quite subjective but must lead to thresholds or qualification levels (EQLs) which assure an effective discrimination between trips – the complete disjunction occurring at very high thresholds. They should be neither too high in order to avoid too numerous unclassifiable trips (métier 'Others'), nor too low, to avoid too many interactions (thresholds reached together for two or more target species). Thresholds level must also give a great amount of target species in landings of the métier directed to it ('pure' métier), a few for the relevant mixed métiers and very few for the others. A large amount of landings of a given species in unclassifiable trips means that the threshold must be set lower. Low qualification levels lead to less important but purer 'pure métiers', the CPUEs for these pure métiers sometimes being calculated from only a very small part of the activity, as for Norway lobster and its métier defined by 90 % EQL. It should be kept in mind that any change in the qualification level of a species will also affect the allocation of the other target species in the métiers. Some trials may be needed to discover satisfactory thresholds levels.

One must also bear in mind that the procedure based on métiers is used to classify trips, to quantify directed fishing effort and/or to allocate the total catch of each species in the different métiers and not to describe the fishery precisely. Studying only a small number of species usually results in a large amount of unclassified fishing effort, which does not affect the purpose of this

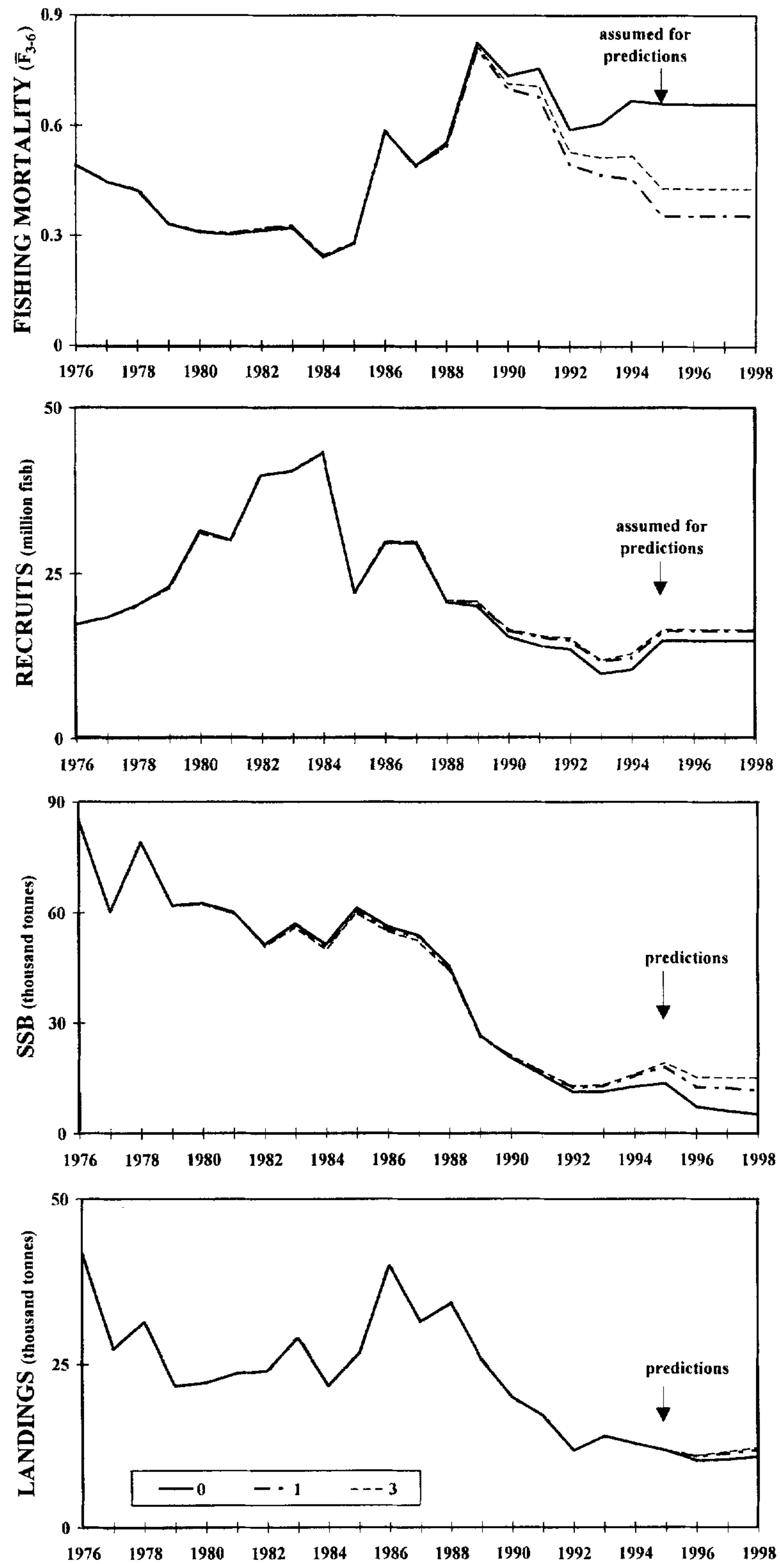

Figure 10. Saithe (west coast of Scotland). Short term predictions for landings and Spawning Stock Biomass (SSB) obtained from global and directed CPUE series: 0 = Global CPUE, i.e., Total landings / Total effort in sub-area VI (fishing time); 1 = demersal métier (pure métier defined from 75 % EQL); 3 = as used by the ICES working group in 1995.

study. More target species may be required if a proper description of the fishing effort allocation is requested. Choice of the retained métiers together with an eventual combination of target species remains quite subjective but is driven by an overall purpose, i.e., obtaining directed CPUEs for assessed stocks.

Even though CPUE calculated by way of a single-species approach may also be used to tune VPAs, a métier approach is preferred in a multi-species, multi-métiers fishery since each fleet, defined as the sum of the trips directed to a target species, represents an exclusive part of the global fishing activity. Thus, two species which are known to be caught by the same métier would have the same effort series. Furthermore, to build the métiers, the use of the 'explanatory qualification levels' – thresholds varying from year to year – provides better results since the fluctuations in relative abundance in the species are taken into account.

The procedure described above provides a new and hopefully clearer insight into directed effort analysis, even though the results may be biased:

– Firstly, bias occurs due to the possible lack of information on catch location for some species, for some trips and because of subsequent allocations based on fishing time ratios. It should also be noted that the percentage of a species in catches are calculated on landings only, whilst discarding undersizes could lead to a distorted perception of actual catch ratios. Finally, possible differences in the efficiency of the vessels (towards one or two species) are not taken into account, possibly resulting in an unclear discrimination between trips with high percentages of a particular species in their total landings.

– The second and main source of bias comes from the implicit assumption that fishermen's intentions can be revealed by the landings, i.e., fishermen always succeed when they direct their fishing effort to a particular species, or that no landings (or few) of a given species means that they did not want to catch it. If it is impossible to tell from catches how often a fisherman went out to catch a particular species and after failing was satisfied with catching other species [9], then the easiest way to deal with this problem is to assume that there is a correlation between intentions and results.

– Finally, the qualification levels are based on the relative amount of that species landed which in turn depends either on the species abundance or on the abundance of others. Thus, the use of CPUEs based on this method may introduce biases into an estimation of the trend in the abundance of a species.

This latter bias depends on the level of the thresholds used and on the degree of heterogeneity in fish distribution. The need of additional information on the distribution of fish before using CPUE as a measure of change in abundance has already been stressed [20]. For schooling species, CPUE based on data qualifying at a high threshold (i.e., measuring density of concentrations since only the successful hauls or trips are included in the estimate) would underestimate any changes [15], if the stock decline is due to fewer numbers of schools with the same density. This also implies that fishermen know where schools are. On the other hand, a low threshold of catch qualification would overestimate the decline due to changes in abundance of the species relative to that of others [14].

Despite biases, CPUEs obtained by the so-called 'thresholds method' seem more appropriate than global CPUEs for providing indices of fish abundance in a mixed-fishery. Even if the differences observed in the various CPUE trends appear relatively small, the use of directed CPUE data to tune the VPA may lead to considerable changes in stock estimates, while improving the fitness of the extended survivors analysis (XSA) catchability model. This needs to be considered in the various assessment working groups, particularly when great changes in fishing activity have occurred within the considered area.

In other respects, the use of standardised effort (with the so-called 'fishing powers') should be required to tune virtual population analysis (VPA) properly. Thus catch-per-unit effort (CPUE) series would reflect more precisely the variations in stock abundance since changes in vessels efficiency due to technological changes, learning, etc., are taken into account by fishing power-correction. For saithe, it was shown that power-corrected effort provides better results than time fishing only. This could be the case for most gadoids since fishing power for these species is strictly related to engine power [3]. For saithe, since the composition of the French fleet fishing in sub-area VI has changed over the period studied with a decrease in the number of the more powerful vessels, better results in terms of fitting are obtained when using CPUE calculated with power-correction instead of fishing time only.

Lastly, such a study can be carried out only if precise fishing statistics are available. Even if all the indications reported in the log-book are computed, such as the locations of where the main species are caught, the statistical squares are as yet not small enough, especially when there are large depth ranges, to satisfy the insatiably curious scientists. Very detailed fishing statistics are required to perform other types of fishing activity allocation based on bathymetric arrays [25] or to study the spatial structure of fish distribution [24].

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