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DEFINING SPECIES SPECIFIC EFFORT

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ABSTRACT

Four measures of species specific effort are presented. These measures are constructed by utilising definitions of fishery zones based on a Principal Component Analysis of the English demersal catch data. The measures are compared by considering their correlation with partial fishing mortalities.

INTRODUCTION

Modern methods of fish stock assessment often use effort data to tune analyses. The measures of effort used are often derived from multidirectional fisheries and are, therefore, not fully appropriate for use with single stocks. One obvious and intuitively appealing approach to deal with this multidirectional fisheries problem is to split the total effort into effort by species. A convenient tool for studying this problem is provided by the principal component analysis (PCA). Based on the first two PC scores of the main demersal species (cod, haddock, whiting, plaice, sole and saithe) caught by the English fleet in the North Sea, we define fisheries zones for each of these species. We then use these zone definitions to split the total English demersal effort by species.

METHODS

Our approach to splitting the total demersal English fishing effort is the following:

1) Perform PCA based on correlation matrices of the percentage catch of each species. The transformation of the catch data is required due to the enormous variance of the data set.

2) Based on the clusters of the scores shown by the plot of the first two PCs and the association of these clusters with variables such as North and East coordinates, port of landing and percentage of the catch by species, we define five fisheries zones (see Figure). These fisheries zones overlap geographically - they are zones of *fishing type*.

3) Having defined fisheries zones it is desirable to investigate their robustness.Three approaches have been used. Firstly, we have used the PCs in a direct way to identify potential outliers and influential observations. Secondly, we have simulated the catch and effort data intending to reproduce the natural changes that may occur in the fisheries. Thirdly, we have used a multiple linear regression model to investigate the behaviour of the parameter estimates (PRIN1 and PRIN2) through the years. We will not

discuss these aspects further, but the investigations suggest that the zones are robust and are stable to quite large changes in catch and effort data.

4) We can now use these definitions of zones to help us to split the total demersal effort into species specific effort. Four measures of effort are described: a) proportion of the total catch by species (used in two ways) ; b) zone definitions; and c) a multiple linear model of the log transformed CPUE data. The new measures of effort are calculated as follows:

Method I - Proportion of the total catch by species times observed effort, ie.

$$E_i = \sum_{j=1}^{n} E_j * C_{ij}/C_j$$

where E_i denotes the new effort for the i^{th} species, E_j denotes the j^{th} observation of the total demersal effort, C_{ij} denotes the j^{th} observation of the catch of the i^{th} species and C_j denotes the total catch at j^{th} observation (i = 1, 2,...,6 (species) , j = 1, 2,...,n (observation)).

Method II - Proportion of the catch by species in each zone times the effort in each zone. Based on those values, the measures of effort are then estimated as:

$$E_i = \sum_{z} C_{iz}/C_z * E_z$$

where C_{iz} denotes the catch of the i^{th} species in the z^{th} zone, C_z denotes the total catch in z^{th} zone and E_z denotes the total demersal effort in z^{th} zone (z = 1, 2,...,5 (zones)).

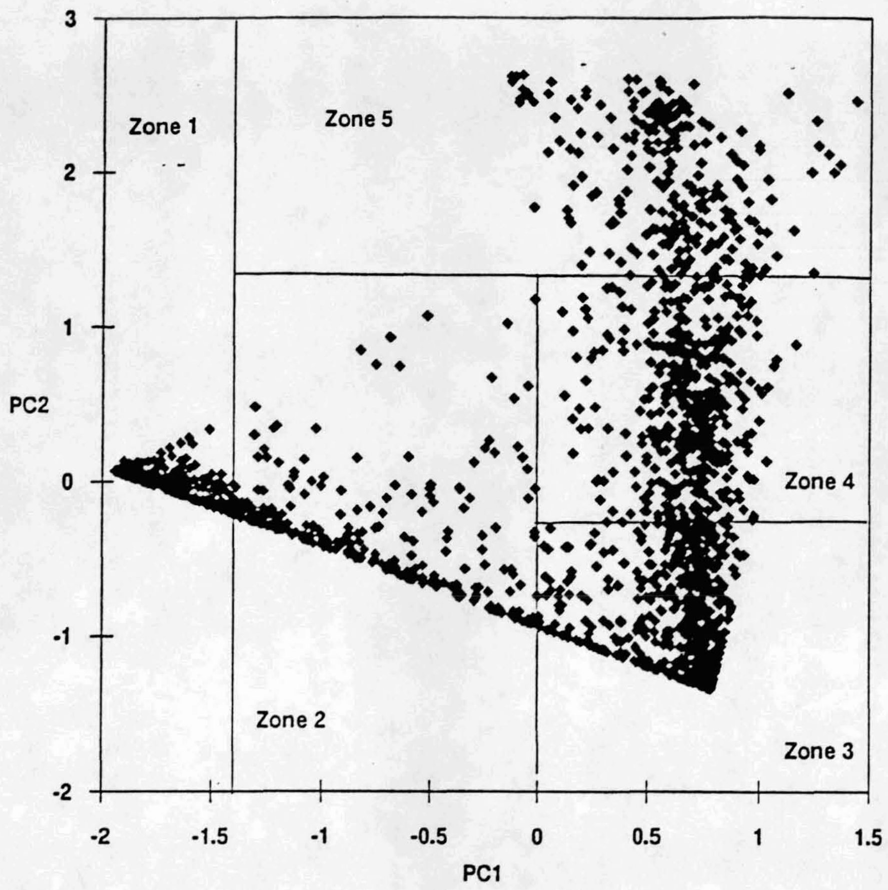
Method III - Gathering the effort of the zones. Based on the percentage of the catch by species in each zone, we choose the following distribution of species by zones:

SP.	COD	HAD	WHG	PLE	SOL	POK
ZONE	2,3,4,5	4,5	4,5	1,2	1	5

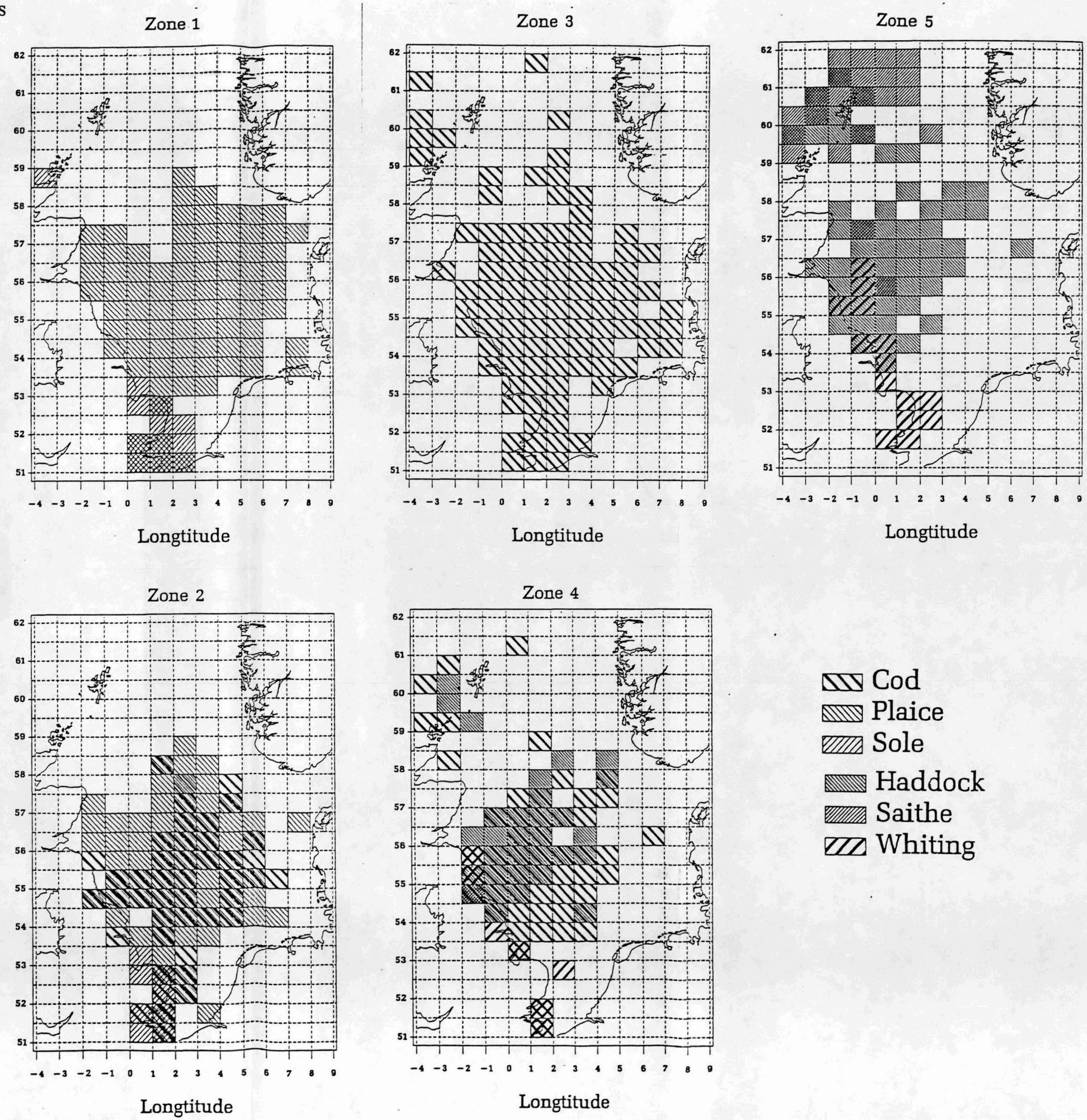
The new measure of effort is then either the observed effort in the z^{th} zone indicated above, or the sum of the observed effort in the zones indicated, ie.

$$E_i = \sum_{z} E_z$$

The plane of PC2 vs PC1 for 1987, showing the zone definitions



Interaction of the species, in each zone, as shown by PC2 X PC1. Only distribution of catch greater than 50% is shown.



Zone 1: 93% plaice and sole.
Zone 2: decreasing catch of plaice and sole (55%) and increasing catch of cod (37%).
Zone 3: 83% cod.
Zone 4: 94% cod, haddock and whiting.
Zone 5: 90% cod, haddock and whiting and also saithe.

NOTE: Percentage as the average of the period 1983/87.

where z = 2, 3, 4, and 5 for cod, 4 and 5 for haddock, 4 and 5 for whiting, 1 and 2 for plaice, 1 for sole and 5 for saithe.

Method IV - The multiple linear model of the log transformed CPUE data. The following model was fitted:

$$LCPUE_i = LLV + PRIN1 + PRIN2 + PRIN3$$

where $LCPUE_i$ = natural logarithm of the CPUE of the i^{th} species calculated using nonspecific demersal effort, LLV = natural logarithm of the length vessel; PRIN1, PRIN2 and PRIN3 are the scores of PC1, PC2, and PC3, respectively.

The new measures of effort are then estimated as

$$E_i = \sum_{j=1}^{n} (C_{ij}/CPUE_{ij})$$

Where: $CPUE_{ij}$ denotes the j^{th} CPUE estimate of the i^{th} species.

5) Having defined these new measures of species specific effort it is desirable to make objective tests to know how good they are. We have used a simple approach. Namely, the evaluation of the correlation coefficient between the various measures of species specific effort and the partial fishing mortality for the species due to UK fleets. The partial fishing mortalities are based on total fishing mortalities calculated by ICES Working Groups.

RESULTS

The methods used to split the total demersal fishing effort into species specific effort give widely different results. The table shows the R^2 values of the linear relationship between the new measures of species specific effort and the partial fishing mortality.

	OVERALL EFFORT	METHOD I	METHOD II	METHOD III	METHOD IV
COD					*
R^2	0.069	0.043	0.055	0.011	0.723
F	0.220	0.130	0.180	0.030	7.830
pr(F)	0.669	0.739	0.703	0.866	0.068
HAD		**	**	**	
R^2	0.147	0.955	0.857	0.935	0.027
F	0.520	64.610	18.010	42.850	0.080
pr(F)	0.523	0.004	0.024	0.007	0.790
WHG		**			
R^2	0.104	0.906	0.022	0.233	0.021
F	0.350	28.860	0.070	0.910	0.060
pr(F)	0.590	0.013	0.811	0.410	0.816
PLE		*	*		**
R^2	0.349	0.727	0.745	0.504	0.878
F	1.610	8.000	8.760	3.050	21.570
pr(F)	0.294	0.066	0.060	0.179	0.019
SOL		**	*		*
R^2	0.037	0.948	0.712	0.347	0.706
F	0.110	54.290	7.410	1.600	7.200
pr(F)	0.758	0.005	0.073	0.296	0.075
POK					
R^2	0.045	0.045	0.008	0.289	0.186
F	0.140	0.140	0.020	1.220	0.690
pr(F)	0.732	0.731	0.888	0.350	0.468

** pr(F) > 0.025, * pr(F) > 0.075

DISCUSSION

The R^2 values of the linear relationship between the new measures of effort and partial fishing mortality can be high for all species (apart from saithe) and vary according to the different methods used . This suggests that the new measures of species specific effort could be used to improve the *ad hoc* tuning of VPA by the ICES Working Groups. The performance of different effort measures for each species can be associated with the nature of the fisheries.

None of the methods perform well for saithe, possibly because of the following hypotheses: a) the saithe assessments are generally regarded as very poor and the F estimates can therefore be regarded as not a very useful variable for testing, b) the English statistics for saithe are not as good as for the other species because saithe is not a major target species for the English fleet and also because most of the landings are abroad and the data less reliable. In view of that, the whole data set (national and international) needs to be improved in order to provide a useful measure of effort.

Method IV is the only method that performs well for cod, with a value of R^2 equal to 0.723 whereas the overall demersal effort, used up to now for assessment purposes, has an R^2 of only 0.069 . This method also performs well for flatfish, especially plaice which has an R^2 value of 0.878 whereas the overall effort shows an R^2 value of 0.349. For sole, the R^2 value was 0.706 which compares with an R^2 of 0.948 using method I. We know from the results of the PCA, that the first PC shows a contrast between the roundfish (cod, haddock and whiting) and the flatfish (plaice and sole). Further results from this first PC should, however, be emphasised to help us to understand the R^2 values.

In the first PC, cod shows consistently high positive loading, through the years, whereas plaice shows a consistently high negative one. Haddock and sole show high opposite loadings (positive and negative, respectively) only in two of the years and whiting shows a high positive loading only in one year. The second PC shows a contrast between cod against haddock and whiting. The third PC reveals a contrast between the fishing for whiting and sole against the fishing for saithe and haddock, but the latter species shows high loadings in only two years. As the first PC accounts for the greatest proportion of the total variation of the data set (0.30 on average for the five years), it is to be expected that method IV performs well for cod and flatfish, particularly plaice, because of the consistent contrast between cod and plaice.

The lack of consistency of high loading for haddock and whiting in the first component, as well as the contrast into roundfish groups in the second component, may explain the failure of method IV for haddock and whiting.

Methods I , II and III perform very well for haddock which shows very high values of R^2 - respectively, 0.955 ; 0.857 and 0.935 . The overall demersal effort used up to now for assessment purposes, has an R^2 value of 0.147 .

Both the contrasts of the second and third principal components and the zone definitions (see Figure) reflect a concentrated northward spatial distribution of haddock (and saithe). The northward distribution may explain why these three methods perform very well for haddock. As method III is zone dependent, and haddock is a major target species for the English fleet to the north, almost all fishing effort in zones 4 and 5 relate to haddock fisheries. Similarly, methods I and II perform very well for haddock because when it is caught it is usually the target species.

Method I also shows very high values of R^2 for whiting (0.906) and sole (0.948), whereas the overall effort used up to now produces very low R^2 values: whiting (0.104) and sole (0.037). This method also performs well for plaice, but the total variation explained with method IV was higher. Unlike haddock, whiting is not a major target species for the English fleet, and it is usually caught as by-catch. Although zones 4 and 5 are the best representation of the spatial distribution of whiting, they are not good enough to provide a useful measure of effort, because whiting is caught over a wide area. The simple proportion of the catch, Method I, was excellent as a new measure of species specific effort for both whiting and sole.

Although this work is in its early stages, it does demonstrate that we can substantially improve our definitions of effort by species. This has implications for the quality of our assessments and short term *status quo* predictions.