MODELLING SHORT-TERM CHOICE BEHAVIOUR OF DANISH FISHERMEN IN A MIXED FISHERY [1]

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ABSTRACT

Studying short term choice behaviour in commercial fisheries has mainly been an economic discipline. In this study we apply a more multidisciplinary approach to improve the understanding of how the decision of the fishermen are made on where and how to fish. Information from questionnaires with fishermen is applied to identify important factors influencing short term decision making process. We present a random utility model including the findings from the questionnaires to analyse individual Danish gillnet vessel spatial effort allocation based on information from official logbooks. The model is used to predict the reallocation of fishing effort for the Danish North Sea gillnet fleet before, under and after an area closure.

INTRODUCTION

An issue raised in fisheries science during the past years has been the low precision in predictions of the biological and economic impacts of changes in the technical measures (closed areas, mesh size regulation, etc.). In particular, the concern has been the narrow focus on only the biological analyses, disregarding the responses of the fishermen to changes in resource availability, market conditions and management regulation itself (Hilborn and Walters 1992; Wilen *et al.* 2002). The importance of including fishermen's behaviour to improve the development of efficient fisheries management has long been realized (Wilen 1979; Hilborn and Walters 1992; Charles 1995), but practical progress towards integrating the issues into the processes of stock assessment and management have been slow. The study of fishermen's behaviour is not a new discipline in fisheries sciences, however, most of these are descriptive work studies of the spatial and temporal effort allocation of selected fisheries whereas only a few studies have attempted to develop predictive models for fleet dynamics and fishermen responses to changes in external factors (see Walters and Martell 2004).

Analysing fishermen's behaviour can be structured in two levels in terms of time response scale: Long and short terms behaviour response (Hilborn 1985; Salas and Gaertner 2004). Long term behaviour (strategies) is year to year changes in the dynamics of the capacity of the fleet (fleet efficiency or number of vessels entering or leaving the fishery due to decommission, investment or attrition). Short term behaviour (tactics) are mainly made on basis of a trip and generated by the decision that fishermen make about when and where to fish (in terms of choice of fishing location, target species or type of gear/rigging) and which fish to land or discard. This paper will focus on the short term behaviour in terms of the spatial and temporal allocation of effort in a mixed fishery.

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Economic theories suggested that the distribution of fishing effort would be determined by the expected profit return for individual fishermen from fishing in alternative areas (or fisheries) (Gordon 1953). This means that the fishing effort will be distributed in such a way that the average profit rates equalizes among the alternatives (in the ecological literature this hypothesis is better known as the 'ideal free distribution' theory). This hypothesis has been successfully adopted in relatively simple case studies (one or two species, limited number of areas and homogenous vessels in terms of physical characteristics) to analyse and predict the spatial allocation of fishermen (Gillis *et al.* 1993; Hilborn and Walters 1987; Mangel and Clark 1983; Sampson 1994; Babcock and Pikitch 2000). In latter studies it is assumed that a fisherman has (in most cases perfect) knowledge of other fishermen's catch success to calculate where he can obtain the highest utility in terms of catch rate in either value or kg landed. In most European fisheries, fishermen have the option to choose among several fishing grounds, where several species can be caught with several types of gear. This complex set of choices makes it more difficult for the fishermen to gain information of his actual profit among the available alternatives at a given time. Then, adding the uncertainty of resources availability (and management regulation), it will be almost impossible for a fisherman to gain knowledge of the actually current profitability among the available alternatives. To obtain information of which alternative a fisherman has to choose to maximise his profit (or catch success) he often makes use of an array of different types of decision factors such as catch expectation, cost, available technology, fishermen past fishing pattern, tradition, availability of the stocks and management regulations (Béné and Tewfik 2001; Hilborn and Walters 1992; Salas and Gaertner 2004). The inclusion of elements from anthropological, biological and economical sciences in fishermen's short term decision process stresses the need of a more multi-disciplinary approach to improve the understanding of the complex dynamics of fishermen's short term spatial and temporal allocation of effort (Béné and Tewfik 2001; Charles 1995; Christensen and Nielsen 2005; Wilen 2004).

The main objective for this study is to construct an analytical tool to describe, analyse and model how Danish North Sea gillnetters allocate their effort among a defined number of fisheries (or tactics). First, the information from questionnaires with fishermen is applied to identify important factors influencing short term decision making process. Secondly, the obtained knowledge forms the theoretical background of modelling the behaviour based on quantitative information from commercial fishery (from logbooks, sale slips and vessel register data).

METHODS AND MATERIALS

Danish North Sea gillnet fishery

The Danish human consumption fishery in the North Sea is characterized by exploiting a wide range of fish stocks (such as cod, haddock, saithe, hake, plaice, sole, turbot and *Nephrops*) with several different types of gears and riggings. One of the larger fleet components in this mixed fishery is the Danish North Sea Gillnet fleet, which, during the last decades, have landed over 50% of the Danish cod quota yearly and contributed to around 30% of the total annual Danish landing (in value) of demersal species in the North Sea (see Table 1). The majority of the vessels in this fleet have their fishing activity in the North Sea, and during the season they shift between different types of fisheries (Ulrich and Andersen 2004).

Table 1. The average percentage of the total Danish landings for selected species categorized by major gear groups. Based on official landings statistics from 1996-2000.

	Gillnet/line	Trawl	Danish Seine	Beam trawl
Cod (kg)	59%	22%	18%	1%
Plaice (kg)	26%	25%	32%	13%
Sole (kg)	90%	3%	0%	2%
Turbot (kg)	59%	25%	3%	10%
Total landing in kg [1]	34%	33%	16%	4%
Total landing in value [1]	39%	37%	15%	4%

[1] Not included: mackerel, herring, all industrial species, mussels, prawns and shrimps.

Identification of decision factors

To identify important factors influencing on short term the decision making process information from a qualitative study derived from a larger study among all Danish demersal fishermen (Christensen and Nielsen 2005). A qualitative in-depth and semi-structured interview with sixteen fishermen (of which 5 fishermen were gillnetters in the relevant area) was conducted. These fishermen (the respondents) were strategically chosen based on the following background variables: Age, experience in the fisheries, number of days at sea per year, size of vessel, type of gear and active participation in fisheries policy-making. This method was chosen in order to get a thorough and detailed understanding of the situation of each individual fisherman, as this method allows the fishermen as well as the interviewer time to reflect and progress slowly in order to cover all relevant aspects.

In the second step a questionnaire was based on the information obtained from the interviews. The questionnaires were either sent by mail or filled out when visiting the harbours. 789 questionnaires were given/sent out; 271 (of which 44 were gillnetters with home harbours in the North Sea) or 34% of them responded. In the present study the interest was mainly on the part of the questionnaires about the importance of different factors concerning the short term behaviour. From the interview seven factors were identified: (1) the present situation (own experience from recent trips and fish prices); (2) the season/time of the year; (3) weather (wind and currents); (4) regulations; (5) limitation of by-catch; (6) fuel cost or distance; and (7) information from other fishermen. These factors were incorporated in the questionnaire to analyse the importance of the identified factors in the decision making process in terms of choice of fishing ground and choice of target species.

Data for Quantitative Analysis

Data for the quantitative analysis of fishermen's behaviour were derived from the Danish national fishery database, which was based on commercial fishermen logbooks, sale slips and vessel register data. The database contained information per vessel at trip level, including landing weights and values per species, gear, mesh size, fishing location at a resolution of ICES rectangles and vessel characteristics such as length and tonnages. Data of the North Sea gillnet fleet was extracted from the national fishery database covering the period from 1995 to 2000, where 1995 was only used as an index year to obtain information of individual fishermen past experience for 1996. The Danish demersal fishery in the North Sea is subject to common pool (open access) quota regulation. In the selected time period the TAC for most of the demersal fish species in the North Sea was relatively stable and it was assumed to have minor influence on the choice of target species.

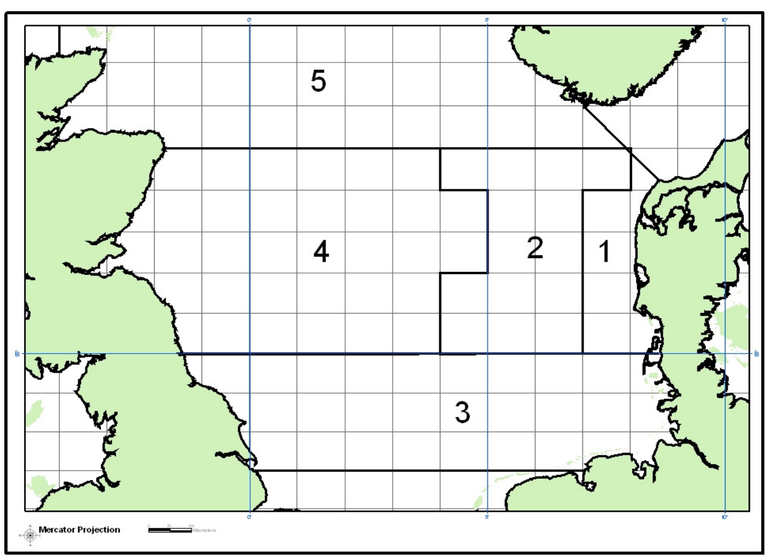

Figure 1. Map of the North Sea divided into 5 areas.

During the study period a number of vessels within the North Sea gillnet fleet were either inactive or had disappeared from the fleet due to decommission or switch to other fleet groups. Therefore the final data set was defined to contain vessels which were active during the entire study period and had annual revenue above the minimum revenue criteria that defines a fulltime fisherman set by the Danish Institute of Food Economics. The final data contained 40492 fishing trips, undertaken by 117 vessels. Summary statistics are presented in Table 2.

Table 2. Summary statistics for the Danish North Sea gillnet fleet from 1996 to 2000.

	Target species				
	Cod	Plaice	Sole	Turbot	Other
Number of trips					
1 quarter	5533	1101	110	0	192
2 quarter	3537	2462	3269	570	306
3 quarter	4056	810	1211	177	655
4 quarter	5067	233	71	0	119
Landing value per unit effort (DKK)	12898	12338	13079	10509	11074
	(10341)	(10562)	(11466)	(6938)	(8981)
Average number vessel (per year)	116	78	79	28	39
	(0.6)	(189.2)	(149.0)	(92.5)	(70.1)
Average vessel length (meter)	15.5	14.7	15.5	17.4	14.5
	(3.2)	(2.7)	(3.0)	(3.1)	(2.9)
Average vessel horse power	227.7	197.2	233.0	252.3	187.6
	(106.8)	(83.4)	(95.4)	(114.0)	(94.4)

Note: Standard deviations are given in parentheses.

In the case of complex fisheries, where the fisherman has the opportunity of exploiting different species in several fishing grounds (such as the mixed fishery in the North Sea), the analysis of a fisherman's fishing activity (on the basis of a trip) has been undertaken through defining types of fishing activities based on main characteristics such as gear used, riggings, fishing grounds and target species. Several approaches have been applied to identify a fishing activity (or fishery/tactic) in mixed fisheries, based on catch and effort data from commercial fishers (Murawski *et al.* 1983; Lewy and Vinter 1994; Pelletier and Ferraris 2000; Ulrich and Andersen 2004). In a recent study by Ulrich and Andersen (2004) fisheries for the entire Danish fleet were defined, where seven related Danish gillnet fisheries in the North Sea were identified (cod, plaice, sole, turbot and hake, long-line and 'other' fishery) based on choice of gear and target species. In the present study the long-line and the hake fishery were grouped in the 'other' fishery due to few numbers of trips within in the study period. Trips outside the North Sea were not included (<2% of the total number of trips). Based on ad hoc knowledge from historical catch information 5 areas were defined (Fig. 1). In addition, the defined areas were designed to fit the closure of a large fishing area in the North Sea in 2001 (area 2 in Fig. 1). That gave a total of 25 choices (5 target species and 5 areas), however, choices with <100 trips for the entire study period were grouped with nearby fishing areas. The final number combination of fishing area and target species was 16.

Conceptual framework of empirical model

In the case where fishermen are confronted with a finite set of alternatives, such as the choice of fishing location, gear, or fishery, a random utility methodology (also better known as RUM) has frequently been applied (e.g., Bockstael and Opaluch 1983; Holland and Sutinen 1999; Wilen, Smith, Lockwood, and Botsford 2002). The basic assumption in the random utility approach relies on the decision makers (fishermen) being assumed to choose the alternative that maximizes his utility, U_i. For a given fisherman, *n*, the probability that a particular alternative *i* is chosen can be expressed as:

(1) $$P_n(Y=i) = P_n\left(U_{ni} > U_{nj},\ \forall j \neq i\right)$$

where U represents an indirect utility for choice i for a specific fisherman. The utility is expressed by a set of explanatory variables that are summarised to form a systematic component V_{ni} (utility function which is assumed to be linear in the parameters) and a stochastic error component ε_{ni} (random part):

$$(2) \qquad U_{ni} = V_{ni} + \varepsilon_{ni} = \sum_{s=1}^{S} \beta_n \times X_{ni} + \varepsilon_{ni}$$

where S is the number of attributes. The observed utility is based on the findings from the interviews containing the identified decision factors that are involved in the Danish North Sea gillnetters' decision making process in choice of fishery (or tactic). However, these types of qualitative information are not to be found directly in the fishery database, and proxies were defined for the identified decision factors.

Two types of own experience variables were identified: (1) present knowledge/experiences; and (2) seasonal knowledge/experiences. A Danish gillnetter often makes several trips during a month where he gathers different levels of experiences/knowledge from where he has been fishing. The value of the information a fisherman collects from past knowledge/experience (in terms of catch success) tends to rapidly decline due to the high temporal and spatial availability of the fish stocks (Smith 2000). By assuming the level of recent catch success in a given choice to be proportional with recent effort allocated to that choice, we used the percentage of effort a fisherman has made in each choice during the last month ($\%EFF_{(m-1)}$) as a proxy for attractiveness of fishing in the same choice as in the previous month. The interviews indicated also that Danish gillnetters tend to follow the same fishing patterns as last year due to the seasonal availability of the individual fish stocks. As a proxy for attractiveness of fishing in the same choice as last year, we used the percentage of the effort that the fisherman made in each choice in the same month last year ($\%EFF_{(m-12)}$).

Recent information of other fishermen's catch success has been a central way to gain information of the expected profit (or revenue) (Bockstael and Opaluch 1983; Smith 2000). To estimate a fisherman's expected revenue, various types of expectation models have been applied ranging from simple approaches, such as use of total value or average value for the fleet (Bockstael and Opaluch 1983), to the more sophisticated production functions model, where different types of vessel characteristics are taken into account (Holland and Sutinen 1999; Eggert and Tveterås 2004). Similar as for own experiences, the value of catch information from other fishermen is relatively short-lived and very fast becomes unattractive (Smith 2000). In the present study we assume that a fisherman makes use of previous period catch information in terms of value per unit of effort (VPUE) and an information exchange of the average revenue rate on a monthly scale among the vessel within the gillnet fleet. The average VPUE based catch information from the previous month is standardised in terms of individual differences in catchability (or fishing power) among the vessels before it was applied as an explanatory variable in the quantitative behaviour model.

After introduction of electronic equipment it has become easy for fishermen to follow and locate other colleagues' fishing patterns and spatial aggregation of vessels. Vignaux (1996) observed that the New Zealand purse seine fleet had a tendency to move to areas where other vessels are fishing in terms of expecting higher catch success in those areas. In the present study the total effort from the previous month ($TOT\_EFF_{(m-1)}$) was used as a proxy for vessel aggregation.

From the in-depth interview the fuel cost was frequently mentioned to influence on the short term decision making process. No information of fuel consumption was available on trip level, instead distances were applied as a proxy for fuel cost. In the questionnaire fuel cost and distance were separated as two distinct decision factors; however, due to the high correlation (Christensen and Nielsen 2005) they were defined as a single factor in the quantitative behaviour analysis. Distance was calculated as the distance from departure harbour to the fishing ground (centre of the ICES rectangle, 1 unit = 30 nautical miles).

The data set was specifically selected for a time period where only moderate changes in the management regulation were enforced. Therefore management regulation was not explicitly included in the utility function. But fishermen may have been under influences of the current management regulations such as mesh size regulation and by-catch limitation. However, these effects were implicitly included in the calculation of the expected revenue rate ($VPUE_{t-1}$). Presently, no applicable proxies for weather and by-catch have yet been defined (primarily due to lack of information), and therefore not included in current version.

Behaviour model

The identified parameters in the utility function can be estimated with different classes of logit models. When the variables in the utility function are estimated they can be used to predict the relative probability of the individual fisherman's choice among the available alternatives. Assuming the random component, ε_{ij}, in equation (1) and (2) to have an independent type extreme value distribution function (McFadden 1974), the choice probability can after some algebraic manipulation be expressed as the conditional logit model:

$$(3) \qquad P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} = \frac{e^{\beta X_{ni}}}{\sum_j e^{\beta X_{nj}}}$$

The simplest way to structure a fisherman's short term decision processes is by assuming a single level decision structure (or tree). In the first test hypothesis we expect a single level decision making structure by assuming that a fisherman, before he goes fishing, chooses among the 16 choices which are defined as a combination of target species and fishing ground. To estimate the parameters in the utility function, a standard conditional logit model is applied and it takes the following form:

$$(4) \qquad U_{ni} = \beta_1 \, \%EFF_{(m-1)} + \beta_2 \, \%EFF_{(m-12)} + \beta_3 \, VPUE_{(m-1)} + \beta_4 \, TOT\_EFF_{(m-1)} + \beta_5 \, DISTANCE$$

where m is the month. One of the major restrictive assumptions for the standard logit model is the independences of irrelevant alternatives (IIA) (Train 2003), which means that a change in the attributes of one choice requires proportional changes in the probability associated with alternative choices. Wilen *et al.* (2002) pointed out that the assumption of IIA is quite often violated in the context of fishery management, as some alternatives share the same unobserved characteristics. To avoid this problem more generalized logit models can be applied to take account for heterogeneity correlation structure among choices and decision makers (Train 2003). In the fisheries literature nested logit models have mainly been used to relax the assumption of IIA for correlation among choices in modelling spatial location choice. In the nested logit models the random error component allows alternatives within a branch to be correlated. For the North Sea gillnetters the choices of target species were observed to be strongly seasonally dependent. In the second test hypothesis we assumed a two level nested logit model for choices of fisheries, where a fisherman first chooses a target species, k, and afterwards chooses a fishing area, i. The utility for a fisherman to choose a given alternative i is expressed as: $U_{ni}=W_{nk}+Y_n i+\varepsilon_{ni}$, where W_{nk} is the parameters in the first level utility function and Y_{ni} is the parameters in the second level utility function. The probability of choosing fishery i in a nested design can be expressed as the product of two standard logit models (Train 2003):

$$(5) \qquad P_{ni} = P_{ni|B_k} P_{nB_k} \quad \text{, where } i \in B_k$$

$P_{ni|B_k}$ is the conditional probability that a fisherman chooses fishery i given that an alternative i is in branch B_k, and P_{nK_k} is the probability that target species k is chosen. The $P_{ni|B_k}$ is found by using the following expression:

$$(6) \qquad P_{nB_k} = \frac{e^{W_{nk}+\lambda_k I_{nk}}}{\sum_{\ell=1}^{K} e^{W_{n\ell}+\lambda_\ell I_{n\ell}}}, \quad \text{and } I_{nK} = \ln \sum_{j \in B_k} e^{Y_{ni}}$$

where I_{nk} is the inclusive value of branch (target species) k. At level 2 the probability of choosing branch k is defined as:

$$(7) \qquad P_{ni|B_k} = \frac{e^{Y_{ni}}}{\sum_{j \in B_k} e^{Y_{nj}}}$$

where *k* is the number of branches (or target species) in the model. The observed utility function for nested logit model was divided into two levels and takes the following forms:

$$(8) \qquad U_{nk} = \%EFF_{(q-4)} \quad \text{(q=quarter)}$$

$$(9) \qquad U_{ni} = \beta_1\,\%EFF_{(m-1)} + \beta_2\,\%EFF_{(m-12)} + \beta_3\,VPUE_{(m-1)} + \beta_4\,TOT\_EFF_{(m-1)} + \beta_5\,DISTANCE$$

The utility in the first level is the percentage of effort that a given fisherman had made in each choice in the previous year in the same quarter ($\%EFF_{(q-4)}$). This explanatory variable is a proxy for the attractiveness of a fisherman choosing the same target species as last year at the same time of the season.

The statistical analyses were performed with PROC MDC in SAS (SAS Institute Inc. 1999) and the parameters for both types of models were estimated using full information maximum likelihood methods (LIML).

Both quantitative behaviour models (the standard conditional and nested logit model) operate at the level of the individual fisherman, however, we are also interested in evaluating how well the applied behaviour models predict allocation of effort among the entire North Sea gillnet fleet and how these models predict management changes such as temporal closure of a fishing area. There are several ways to represent an aggregated output (Train 2003). In the present study we have selected two ways to evaluate the predicted power of the applied behaviour models. First, by comparing the observed aggregated effort with the predicted aggregated effort, where the predicted effort was calculated by multiplying the average probability for each choice by the total observed effort for all choices for each month.

Secondly, we used the estimated parameters to evaluate how the behaviour models predicted the closure of a larger area in the North Sea in 2001[3] (from 15 February to 31 April) due to protection of the spawning cod stock. A part of the closure was placed in an area (area2 in Fig. 1) where the Danish North Sea gillnet fleet in that period normally had their main fishing activity. The estimated coefficients from the behaviour models were applied to predict/forecast the spatial allocation of effort (at a monthly timescale) for the North Sea Gillnet fleet before, under and after the closure. This closure involves all fishing activity, therefore the observed utility for those choices inside the closed area were assumed to be zero. Similar methods as used by Wilen *et al.* (2002) were applied where the utility for choices inside the closed area was set to -1000 and afterwards calculated the predicted probabilities. Due to the exponential form of the logit model the output will always turn out to be a positive number. Using a very high negative number will force the probability towards zero and in this study the probability was <0.001, which in practice meant non allocation of effort to choices inside the closed area.

RESULTS

Analysis of the questionnaire

The findings from the questionnaires indicated clearly that the present situation, season, weather and regulation were of major importance for the Danish North Sea Gillnet fleet. Whereas information from other fishermen, distance and fuel cost were less important (Fig. 2 and 3). The findings were used to define the explanatory variables expressed in the utility function of the applied quantitative behaviour models.

Quantitative analysis

The result of the estimated coefficients for both the standard logit and nested logit models is presented in Table 3. The global R^2 was 0.51 and 0.75 for the standard and nested logit model, respectively, which

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[3] The European Commission enforce an emergency closure of a large area in the North Sea to protect the spawning cod stock (see full description in the Commission regulation No 259/2001).

indicated that both models fit very well to the observed data. In the first model test: the standard logit model was tested for assumption of IIA with a Hausman test (Hausman and McFadden 1984). The choice of plaice/area1 was eliminated from the data set and re-estimated. The test statistic was $\chi^2(1) = 55.33$ and the assumption that the other 15 choices were independent of plaice/area1 was rejected. This implied that the assumption of IIA failed.

The second model test, a log-likelihood ratio test, was used to test for any model reduction in the nested logit model with the test hypothesis for equal inclusive value ($H_{02} = \tau_1 = \tau_2 = \tau_3 = \tau_4 = \tau_5$) and afterwards the inclusive value was set to 1. Both tests were rejected (H_{01}: $\chi^2(5) = 408$, $p < 0.01$; H_{02}: $\chi^2(5) = 445$, $p < 0.01$) and no model reductions were carried out.

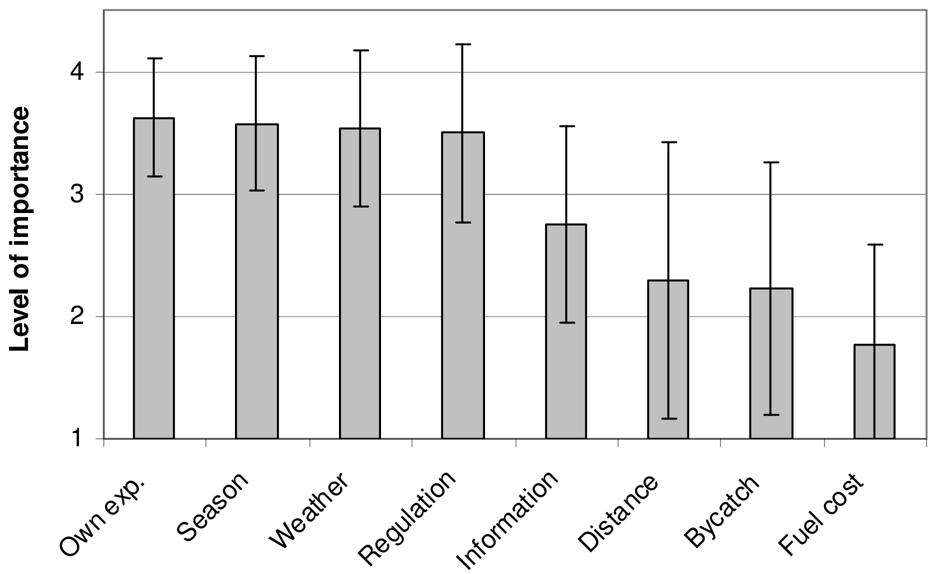

Figure 2. Choice of fishing ground: result from questionnaires: the level of importance was ranked from 1 to 4, where 1 was categorized as not important 2 as less important, 3 as important and 4 as very important.

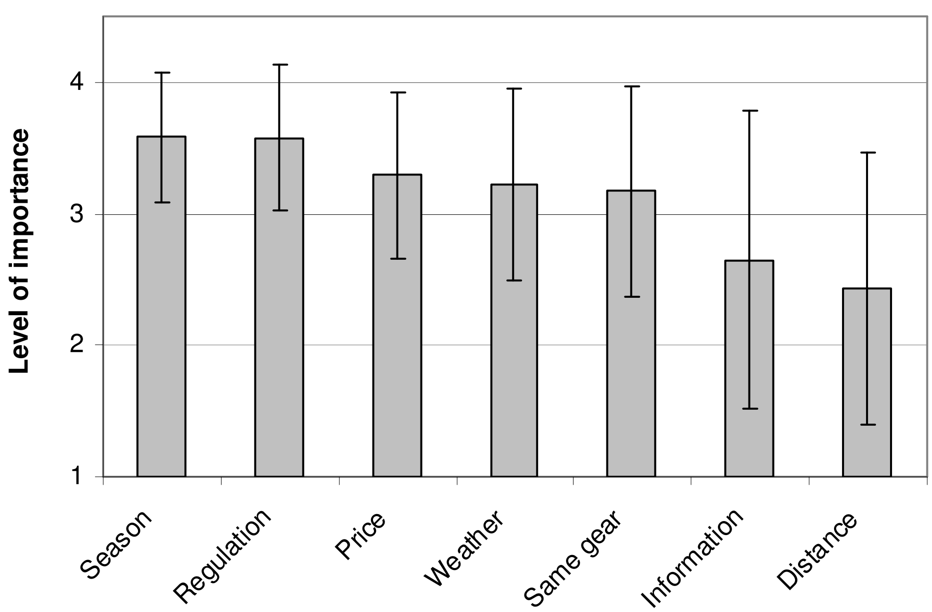

Figure 3. Choice of target species: result from questionnaires: the level of importance was ranked from 1 to 4, where 1 was categorized as not important 2 as less important, 3 as important and 4 as very important.

All the estimated coefficients within the conditional and nested logit model were tested significantly from zero at the level of 1% and no further reduction of the full model was done. Except DISTANCE, all the explanatory variables had a positive sign.

Due to differences in the structure of the utility functions in the two models, no statistical comparison was done.

Table 3. Result from standard logit and nested logit model.

		Standard logit model		Nested logit model	
	Parameter	Estimate	Error	Estimate	Error
Area parameter					
	$VPUE_{(m-1)}$ (1000 Dkr)	0.0390	0.00166	0.0387	0.00199
	Total $effort_{(m-1)}$	0.00103	0.00004	0.0009	0.00004
	Distance	-0.1798	0.00608	-0.1684	0.00661
	% $eff_{(m-12)}$	0.0198	0.00023	0.0175	0.00028
	$\%eff_{(m-1)}$	0.0236	0.00022	0.0246	0.00030
Fishery parameter					
	$\%eff_{(q-4)}$			0.0088	0.00036
Inclusive value					
Cod				0.8861	0.0140
Other				0.7172	0.0279
Plaice				0.8599	0.0169
Sole				0.8859	0.0220
Turbot				0.7515	0.0179
Log-likelihood		30995		30546	
R^2		0.49		0.75	

Model prediction

Based on the result from the statistical analysis we would have expected a better fit for the nested logit model compared to the standard logit model, but that was not the case. Both behaviour models had almost similar fit (Fig. 4). For the most abundant target species in terms of total effort, both behaviour models captured the seasonality very well. For plaice and sole both behaviour models had a tendency to respond to the observed seasonal peaks with a lag period of 1-2 months. The lagged response was expected due to high attractiveness for a fisherman to make the same choice as previous months and/or year. For the less frequently choices, in terms of effort, both behaviour models was not able to capture the seasonal dynamic; however, these choices represented only a minor part of the total effort allocated.

Before the closure both models seem to fit very well to the allocation of the observed effort; however, the cod in area 1 and 2 was slightly overestimated (Fig. 5). In the first month of the closure period both models predicted an increase in effort for cod in area 1. However, the observed effort shows that most of the vessel instead shifted to target plaice in area 1 and 3. In the second month of the closure (April) both behaviour models recaptured the "unexpected" changes in the allocation of effort. It should be mentioned that the increased effort in the sole fishery in area 1 and 2 were also observed in the previous years and both models captured this increased effort a month later.

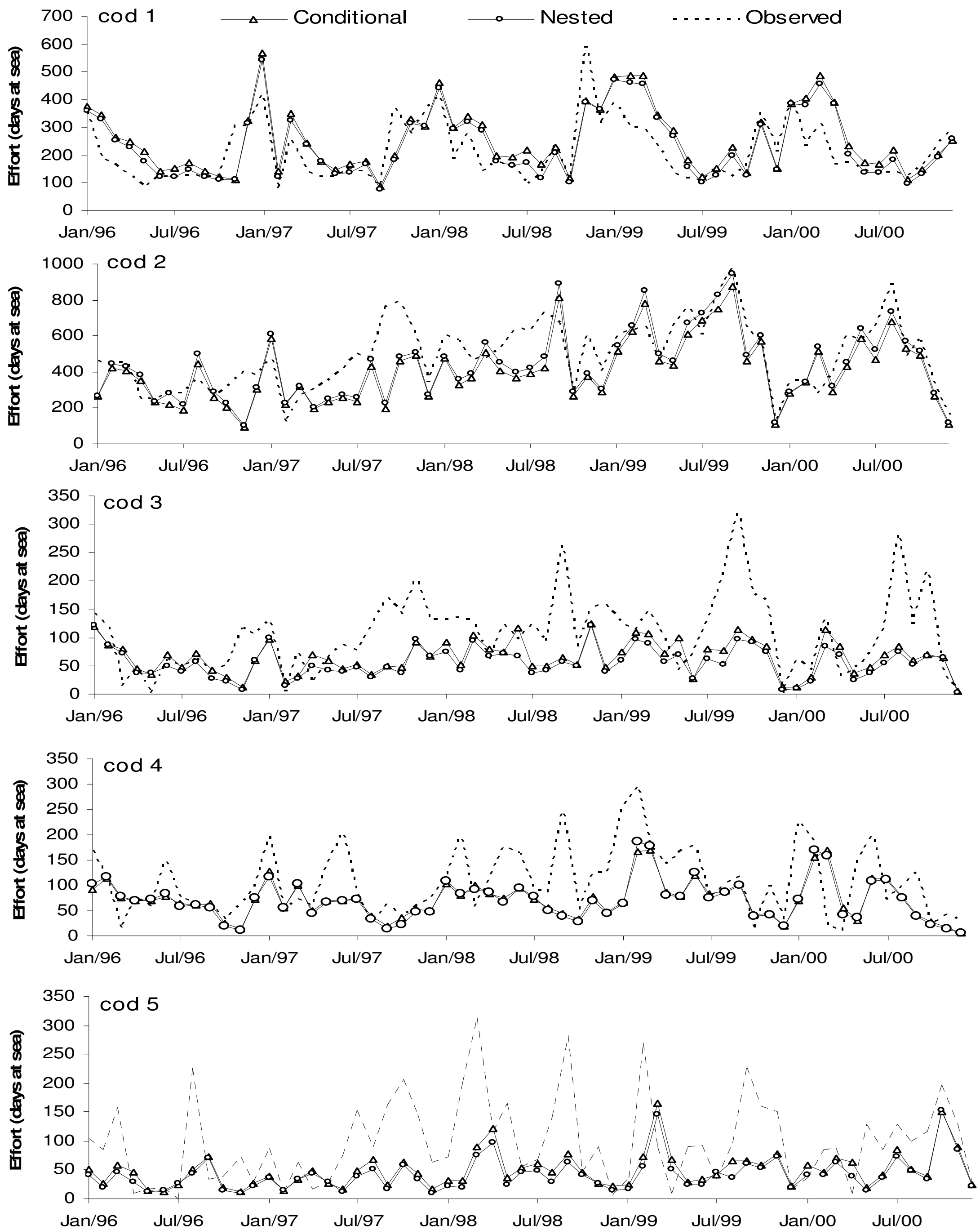

Figure 4. The temporal and spatial distribution of the observed (dotted line) and predicted (nested logit: circle symbol and conditional logit: triangle symbol) fishing effort for the North Sea gillnet fleet targeting cod in five different areas. See area definition in Figure 1.

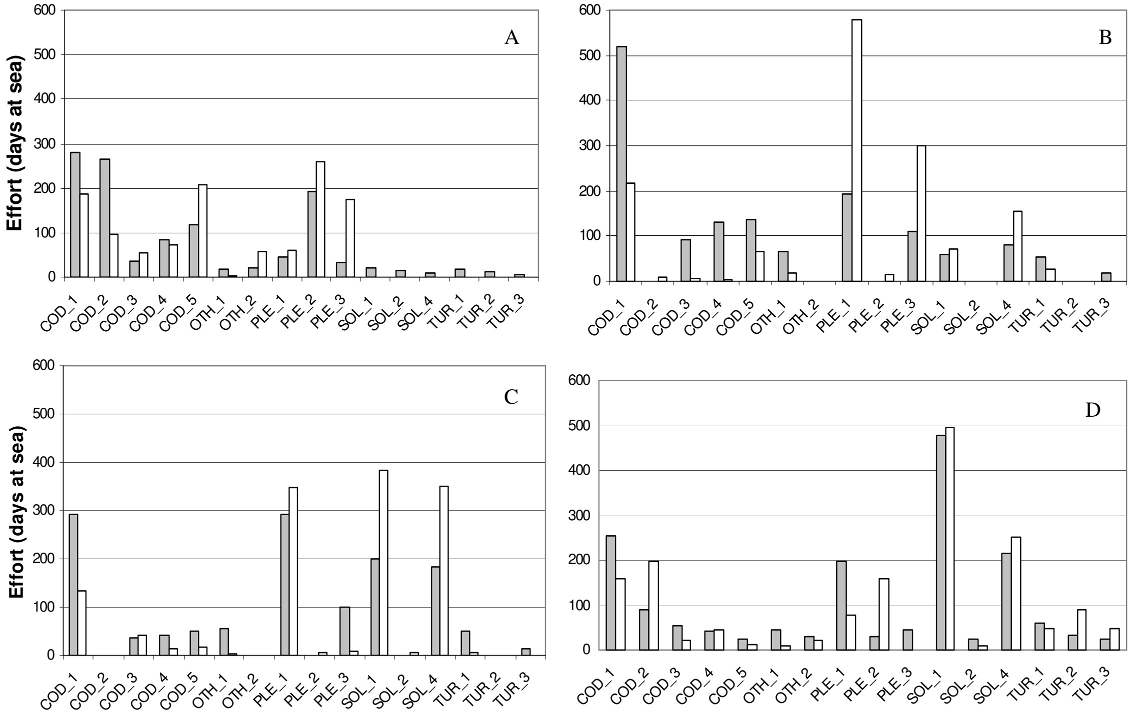

Figure 5. The spatial distribution of the observed (white bars) and predicted (grays bars) fishing effort before, under and after the closure of area 2. Before: A (February), Under: B (March) and C (April), After: D (May).

DISCUSSION AND CONCLUDING REMARKS

The transformation of the information from the questionnaire survey into a useful format for the quantitative behaviour analysis was not a straightforward process as the identified variables were not directly accessible from the fishermen's logbooks and sale slips information. Unfortunately, the questionnaires were anonymous and the linkage to the individual fishermen in the fishery data base was not possible. This anonymity was necessary to attain successfully high feedback and reliability of the answers from the questionnaires (Christensen and Nielsen 2005). In general, the problems of defining explanatory variables (or data information) that go into the utility function in discrete choice models has been given relatively little attention (Smith 2000). This study has made one step towards how to utilize information from questionnaire surveys in a more quantitative approach (based on logbooks information) to analyse fishermen's behaviour. But it also lightened the need for more interdisciplinary work to improve the fundamental understanding of which and how decision factors influence on fishermen's short decision making process.

The questionnaire survey was not only designed to identify important decision factors but also to verify the findings of the quantitative behaviour analysis. Except for distance, high similarities were found for all identified decision factors when comparing trends in the level of importance of the decision factors between the questionnaire survey and the quantitative behaviour analysis. Overall this indicated consistency in the definition of applied proxies. The distance factor was in the questionnaires weighted by the gillnetters as minor important, whereas the quantitative analysis found distance to be relatively important. The gillnet vessels were in average relatively small in size and due to unstable weather conditions in a large part of the season, they may have been physically limited to choose offshore fishing areas in the North Sea.

Own experience/knowledge was weighted as the most important decision factor whereas the expected revenue rate (or information from other fishermen) was ranked as minor important. Similar observation was found in those "RUM" studies for commercial fisheries where "own experiences" (or habit or tradition) have been included (Bockstael and Opaluch 1983; Curtis and McConnel 2004; Holland and Sutinen 1999; Hutton *et al.* 2004). Compared to the latter studies, we have modified the "own experience" proxy from a simple dummy variable to include the level of recent experiences which the individual fisherman gathered during the previous month of fishing. This has contributed to a more flexible and dynamic description and interpretation of this decision factor. However, the applied definition may only be applicable for vessels with few day trips, where for vessels in multi day trip fisheries, the updating process of own experiences and from other fishermen have been found to be of major importance (Curtis and McConnel 2004). But still the "own experiences" variable does not capture all processes involved in the decision of why a fisherman tends to choose same choice as in previous trips (or period). Bockstael and Opaluch (1983) stated that the decision making process of following same fishing pattern may be quite complex and may often be determined by a number of both economic factors (e.g., opportunity costs) and non-economic related factors (e.g., tradition and inertia).

Information from other fishermen in terms of catch rates or quantity have frequently been applied to calculate proxies for expected revenue, where positive responses have been used to confirm economic rational behaviour (Smith 2000). In the present study we found that gillnetters were positive to alternatives with higher expected revenue rates and that may imply a profit maximizing behaviour among the Danish gillnetters. However, this statement was blurred by the relatively low explanatory power of estimated coefficient compared to the estimated coefficients of own experiences ($\%EFF_{(m-1)}$ and $\%EFF_{(m-12)}$). Similar findings have been observed in other mixed fishery case studies (Holland and Sutinen 1999; Curtis and McConnel 2004). The weak response fitted to the findings in the questionnaires (information from other fishermen were in average ranked relatively low).

The findings from the interviews confirmed the complex nature of fishermen's short term decision making process of when and where to fish. This complex matter may blur the theories of economic rational behaviour but on the other hand it also indicated that more socially related factors may influence on a fisherman's short term decision process. This study was not specifically designed for testing the assumption of economic rationality, however, a growing body of literature has questioned this assumption regarding fishermen's short term behaviour in open-access fisheries (Hanna and Smith 1993; Béné and Tewfik 2001; North 1995).

The observed variability among the respondents in the questionnaires indicated some degree of heterogeneity among Danish gillnetters. This heterogeneous responsiveness may be due to differences in choice of strategy, fixed and variable costs, opportunity costs, knowledge and risk attitudes (Christensen and Nielsen 2005; Wilen 2004). This paper was not intended to study the heterogeneity of choice behaviour, however the improvement of computer power in recent years have made it possible to apply classes of discrete choices (mixed logit model) for analyses of heterogeneity among fishermen in large data set (McFadden and Train 2000; Smith 2005). Mixed logit model has in recent studies been applied in fisheries to investigate heterogeneity in risk preferences (Eggert and Tveterås 2004; Mistiaen and Strand 2000) and expected return (or information from fishermen) (Mardle and Pascoe 2004; Smith 2005).

The applied behaviour model was designed to predict the spatial effort distribution in a mixed fishery under the closure of larger area in the North Sea. Overall the model succeeded to predict the redistribution of effort among the defined fishing areas and target species under and after the closure. But the findings illustrated that the level of prediction also depended on both the temporal and spatial accuracy of interest. Modelling spatial choice behaviour in term of effort allocation based on catch and effort information from fishermen logbooks (such as in this study and many other studies of European fisheries) are restricted to spatial resolution of the size the predefined ICES statistical rectangles. As short term closures (e.g., seasonal closure, protections of aggregation of juvenile and spawning fish) are getting more frequently used as a management instrument, the demand for more spatial catch and effort information of individual fishermen are needed (such as satellite data combined with catch data).

The next step is to implement the identified short term behaviour rules into a fisheries management evaluation framework, a framework that includes both biological and economic elements to evaluate how changes in technical measures, such as closed areas, will affect both the dynamic of the fish stocks and profitability of the fleet.

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