AN ANALYSIS OF THE CHARACTERISTICS OF FISHERS AND THEIR BEHAVIOUR

STRATEGIES FOLLOWING AREA CLOSURES

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ABSTRACT

Closed areas are often used as either temporary or permanent measures to reduce fishing pressure on stocks. A major concern, however, is what happens to the effort that was previously employed in these areas. When modelling the potential impacts of the closed areas, it is necessary to model changes in fisher behaviour. However, most models have relied on assumptions based on previous behaviour that assume fishers will follow similar patterns. In 2001, an area of the North Sea was closed to fishing that had previously been heavily exploited. While most fishers reallocated effort to previously exploited grounds, a number reallocated their effort to grounds that had not been exploited in recent years, or had only been very lightly exploited. In this paper, the relationship between the characteristics of both the outré-istic and orthodox group of fishers and their behaviour are examined using a logit modelling approach in order to better understand fisher behaviour.

Keywords: Fisher behaviour; closed areas; logit model

INTRODUCTION

Considerable attention has recently been applied to modelling fisher location choice (e.g. Bockstael and Opaluch, 1983; Holland and Sutinen, 1999, 2000; Mistiaen and Strand, 2000; Curtis and McConnell, 2004). Unlike traditional modelling approaches, these studies aim to incorporate the heterogeneous nature of fishers within the analysis, capturing some of the uncertainties faced. These models have largely considered the factors that influence where fishers fish, such as costs associated with getting to the different fishing grounds, expected catch rates and catch compositions, relative prices and alternative fishing opportunities. Given such models, the impact of closing a particular area to fishing, such as in the case of a marine protected area or closure for stock or other conservation purposes, on the re-allocation of fishing effort can be estimated.

A limitation of such models is that they can only provide estimates of effort allocation to areas with known catch rates. That is, areas that have been historically fished. However, this precludes the possibility for fishers to investigate new fishing grounds (or grounds that have not been exploited in recent history) in response to the restrictions in access to their usual fishing areas. While such behaviour may be considered outré-istic (i.e. outside the bounds of what would be considered usual behaviour), such behaviour does exist. This type of behaviour is investigated by Allen and McGlade (1986), where a dynamic spatial model for Nova Scotian groundfish fisheries is developed to consider hunters (or high-risk takers) and followers (or low risk takers). They show that ignoring non-homogeneous facets of behaviour can have major consequences for ‘predictions’ of fishing effort, profits and stock levels.

Such behaviour was observed in the English beam trawl fleet operating in the North Sea following the temporary closure of an area to fishing in 2001. Although the closed area was designed to reduce the catch of cod, taken primarily by demersal trawlers, the area was closed to all fishing activity. While most
fishers (beam trawlers and demersal trawlers) re-allocated their fishing effort to areas already heavily exploited during the two months of the closure, a small number of beam trawl vessels transferred their fishing effort to areas that had either not been fished in recent history (i.e. the period over which detailed logbook records have been maintained), or had been fished very sparsely.

Such behaviour could not be predicted using standard fisher location choice models as the locations – with no known catch rates – could not be factored into the analyses. The purpose in this study is to examine the characteristics of the beam trawl fishers and estimate how these characteristics affect the decision to fish in either known or new areas. In particular, the technical efficiency and risk aversion of these fishers is considered, along with physical characteristics of the vessels. The contribution of these factors to the propensity to fish in new areas is estimated using logit regression analysis.

ECONOMIC DISINCENTIVES FOR EXPLORATORY FISHING

Exploratory fishing is a well-established phenomenon in the fishing industry. Without exploration, fisheries production would be limited to what could be taken from shore. Deep water species such as Orange roughy would be unknown.

In many cases, however, exploratory fishing is undertaken by research institutes using public funding. Lack of property rights can create a disincentive for exploration by individuals who must incur the additional risk associated with exploration, but cannot prevent other fishers from reaping the benefits if new productive fishing grounds or fisheries are discovered. This differs from many other industries, where patents and other short-term barriers to entry can enable at least quasi-rents to be generated and compensate the explorer for the higher level of risk that they undertake. For example, in the case of science, patents can be granted to new technologies that are developed providing exclusive property rights over the exploitation of the new development. For non-renewable resources such as oil and minerals, property rights can be established over new finds, providing a potential return from exploration. Studies of risk associated with ownership of the resources has found that increasing ownership risk results in slower rates of petroleum exploitation, and increased rates of exploitation of known forest resources (Boan and Deacon 1997).

In the case of fisheries, such property rights generally do not exist. Fishing a new area involves a risk of little or no return. Discovering a viable resource results in effort being applied by other fishers who did not undertake the risk, and the subsequent dissipation of any economic rents that may have been generated from the discovery. This issue has been addressed in some fisheries through the issuance of exploratory licences that allow the explorer at least some exclusive access to new areas or fishing techniques. For example, the Australian Fisheries Management Act (1991) has provisions for the granting of exploration licences to exploit previously unexploited areas.

In existing fisheries, where information on catch rates in different areas can be observed, there is little incentive to try new areas as the opportunity cost of the activity is known, while the potential gain is unknown and in any case is also only short lived. Exploratory fishing under such circumstances requires a degree of risk seeking behaviour. Dreyfus-Léon (1999) developed a neural network model of fisher search behaviour and found that fishers tend to operate in known areas close to shore when there was uncertainty about catches in other areas. Fishers also avoided areas with potentially high catches but high variability. However, poor catches in known areas that were expected to have higher catches triggered exploration into new areas, suggesting risk averse behaviour unless there was a low opportunity cost.

Studies of attitudes to risk in different fisheries have found that most fishers are risk averse and that risk preferences are generally homogeneous (e.g. Bockstael and Opaluch, 1983; Mistiaen and Strand, 2000; Eggert and Tveteras, 2004). However, even in fisheries dominated by generally risk averse behaviour,
some trips can be considered as risk seeking. Mistiaen and Strand (2000) found that about 5% of the trips they observed could be considered as risk seeking behaviour even though the fishers were generally risk averse. Strand (2004) found that fishers were generally risk averse, but this varied spatially over the fishery, with fishers from more peripheral areas exhibiting greater risk aversion than those in the main areas of the fishery.

THE NORTH SEA COD CLOSURE, 2001, AND THE ENGLISH BEAM TRAWL FLEET

Cod stocks in the North Sea, as in many other parts of the Atlantic, are at an all time low. Despite numerous calls by scientists and conservation groups to reduce cod catches in the area over much of the 1990s, managers were reluctant to implement large quota reductions when considerable uncertainty existed about stock sizes, but considerable certainty existed about the employment impacts of TAC reductions.

In 2001, in response to falling estimates of spawning stock biomass for North Sea cod and eventual recognition that the stock of cod in the North Sea was at serious risk of collapse, a cod closure area was introduced as part of a stock recovery programme (Commission Regulation (EC) No 259/2001 of 7 February 2001). The area, shown in Fig. 1, was closed to any fishing activity during this period, with the exception of purse seining and trawling for sandeels and pelagics. This temporary closed area was designed to cover the main spawning period of cod in the North Sea, and was in force throughout the period 14 February to 30 April 2001.

![Figure 1: North Sea cod closure area, 2001 (by ICES rectangle, denoted by shading)](Source: Commission Regulation (EC) No 259/2001)

While the main target species of the English beam trawl fleet are plaice and sole, cod is an important bycatch species. Recorded cod landings by the English beam trawl fleet in 2000 constituted
approximately 1.2% of the total UK cod quota for the North Sea. The beam trawl fleet operates in similar areas to the demersal trawl fleet, including the area closed to fishing in 2001. This area is considerably important to the beam trawl fishery. In 2000, almost 70% of both the total value and weight of catch of the fleet during March and April – the main period of the closure – was taken within the area (Fig. 2). The period of the closure accounted for around 16 per cent of the total value of landings over the year, with 11% taken from the area of the closure.

As would be expected, most beam trawl fishing activity reallocated onto areas traditionally fished during the period of the closure. However, 11 areas were identified which had little or no catch in 2000 but at least a 10-fold increase in catch in 2001. Four of these areas had not been previously fished.

**DATA**

The data used in the analysis was compiled from a number of sources. Detailed spatial logbook data were available for both 2000 and 2001 in order to identify the areas fished in the two years. Areas (i.e. the ICES rectangles identified in Figure 1) were considered as new areas in 2001 if they were not fished in March and April in 2000, or were very lightly fished but more intensively fished in 2001. As mentioned above, a 10-fold increase in output from the area during March and April, 2001, was considered as an indicator of effectively exploratory fishing as the areas had previously been scantily exploited. Boats were classified as exploratory (i.e. outré-istic) if they operated at some point in the new areas during the period of the closure.

Information on boat characteristics were available from the fleet register. The key characteristics initially examined were the size, engine power and age of the vessels in 2001. Estimates of technical efficiency (TE) of the individual vessels were derived from a previous study (Hutton et al 2001). Estimates of the coefficient of variation (CV) of plaice catches were derived from annual landings data over the period 1990 to 2000. As plaice is the main target species, dominating the catch in terms of both value and quantity. The data were first normalised by a stock index to remove the effects of changes in stock size on catch rates. Only boats that operated in at least 4 month a year for each year and for at least 3 years over the period 1990-2000 were considered. In addition, boats that predominantly target brown shrimp (*Crangon crangon*) but fished for plaice also were excluded. Finally, only boats that operated in 2001 were considered.
Boats were also classified on the basis of their main landing port. Five separate categories were identified: 1) Lowestoft (main UK), 2) Harlingen (main Dutch), 3) other Dutch ports, 4) other UK ports, and 5) other continental European ports. The distribution of landings to these ports in 2001 is illustrated in Fig. 3. Vessels landed into 38 different ports in 2001, although over half the landings were to the two main ports.

![Figure 3. Distribution of landings to port categories, 2001](image)

In total, information on all the key variables was available for 41 vessels. Of these, 11 boats were considered to undertake some form of exploratory fishing activity during the period of the closure. A summary of the key data is presented in Table 1. From this table, there is little apparent different between the vessels that fished in the new areas and those that fished only in traditional areas.

<table>
<thead>
<tr>
<th>Table 1. Key characteristics of vessels in the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>All boats</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>mean</td>
</tr>
<tr>
<td>CV (%)</td>
</tr>
<tr>
<td>TE (%)</td>
</tr>
<tr>
<td>Length (m)</td>
</tr>
<tr>
<td>Engine power (kW)</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
</tbody>
</table>

The coefficient of variation (CV) in the historical value of plaice catch was assumed to represent the level of risk aversion of the fisher. From the frequency distribution of the CV (Fig. 4), most vessels had a relatively low coefficient of variation, suggesting that they predominantly operate in areas where catches are relatively stable. Decreasing numbers of vessels had increase CV, suggesting that they operated in areas that produced varying catches from year to year.

Several of the variables were highly correlated. In particular, boat length was highly correlated with engine power (Table 2), so engine power was not used in the econometric analysis to avoid multicollinearity problems. The coefficient of variation was also negatively correlated with boat length, with the larger boats having a lower variance in their output.
The CV of the vessels was also negatively correlated with its technical efficiency (TE), illustrated also in Fig. 5. This apparent relationship between efficiency and CV suggests that skill may also help to reduce variability in catches, with better fishers knowing where best to fish, thereby minimising their inter-annual variations in catch. Alternatively, it could also imply that the better fishers were also the most risk averse, operating in areas where catches were more assured.

\[ y = -0.1832 \ln(x) + 0.3283 \]
\[ R^2 = 0.3505 \]
For the sub-set of boats that operated in the new areas during the period of the closure, the inverse relationship is still apparent (Fig. 6). While most boats that undertook exploration were around or above average in terms of technical efficiency, these mostly had lower than average CV. Conversely, the boats with the higher CV scores also tended to have the lower efficiency scores.

![Figure 6. Relationship between TE and CV for the outré-istic vessels](image)

**EMPIRICAL ANALYSIS**

The characteristics affecting the propensity to undertake exploratory fishing were examined using logit regression analysis. The model can be expressed as

\[
L_i = \ln \left( \frac{P_i}{1 - P_i} \right) = \beta_0 + \sum \beta_i X_i + u_i
\]  

(Eq. 1)

where \( P_i \) is the probability that a particular outcome will be achieved given the set of characteristics \( X_i \), and \( L_i \) is the log of the odds ratio, known as the logit. The model is estimated using maximum likelihood estimation.

The variables considered in the analysis were the coefficient of variation, technical efficiency, age and length of the vessel. A set of dummy variables representing the main port of landing was also included in the analysis. The dependent variable was a binary variable with the value of 1 if the boat had operated in one of the “new” areas during the period of the closure, and 0 if the boat only operated in more traditional fishing grounds during this period.

**Results**

The main regression results are presented in Table 3. In the initial model where all inputs were included, most of the estimated coefficients were not significant. This initial result was not surprising given the correlation between several of the variables. The model was restricted, with variables excluded on the basis of changes in the Akaike Information Criterion (AIC) and the Schwart Criterion (SC). Lower values in these statistics indicate a better fitting model.
### Table 3. Binary logit regression results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>All variables Standard</th>
<th>Wald</th>
<th>Restricted model Standard</th>
<th>Wald</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Error</td>
<td>χ²</td>
<td>Estimate</td>
</tr>
<tr>
<td>Intercept</td>
<td>6.0714</td>
<td>6.5569</td>
<td>0.8574</td>
<td>0.0806</td>
</tr>
<tr>
<td>CV</td>
<td>0.0615</td>
<td>0.0437</td>
<td>1.9781</td>
<td>0.0806</td>
</tr>
<tr>
<td>TE</td>
<td>-0.0401</td>
<td>0.0335</td>
<td>1.4306</td>
<td>-0.0136</td>
</tr>
<tr>
<td>Age</td>
<td>0.0509</td>
<td>0.0738</td>
<td>0.4763</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>-0.1093</td>
<td>0.1248</td>
<td>0.7658</td>
<td></td>
</tr>
<tr>
<td>Port2</td>
<td>-1.2653</td>
<td>1.7608</td>
<td>0.5164</td>
<td></td>
</tr>
<tr>
<td>Port3</td>
<td>-4.5093</td>
<td>1.6697</td>
<td>7.2933 ***</td>
<td>-3.5824</td>
</tr>
<tr>
<td>Port4</td>
<td>-9.6198</td>
<td>3.993</td>
<td>5.804  **</td>
<td>-7.1752</td>
</tr>
<tr>
<td>Port5</td>
<td>-4.6986</td>
<td>1.9923</td>
<td>5.5618 **</td>
<td>-3.102</td>
</tr>
</tbody>
</table>

Hosmer and Lemeshow Goodness-of-Fit Test
- $χ^2$: 14.3764
- Pr > $χ^2$: 0.0725
- AIC: 48.452
- SC: 63.874
- % Concordant: 88.8

In the restricted model, only CV and three of the port dummy variables were significant. TE was not significant, but excluding it from the model resulted in a higher AIC and SC, indicating a worse fit. The Hosmer and Lemeshow goodness of fit statistic is a $χ^2$ statistic. Rejection of the statistic indicates that the model is a poor fit, hence the higher the probability value the better. The unrestricted model could be rejected at the 10% level of significance, while the restricted model could not be rejected, again indicating that the model is a reasonable fit to the data. Finally, the percentage concordance is a measure of the agreement between the predicted event and the actual event. While this decreased with the restricted model, the other statistics suggest that the restricted model is the most appropriate.

The results suggest that, as expected, the likelihood of undertaking exploratory fishing increases with decreasing risk aversion (as indicated by the CV). Operating from the minor ports also greatly reduces the likelihood of undertaking exploration. The likelihood of undertaking exploration also decreases with increased efficiency of the vessel. However, as there appears to be a relationship between risk aversion and efficiency, this result is also as expected.

### Table 4. Adjusted Odds Ratios

<table>
<thead>
<tr>
<th>Effect</th>
<th>Estimate</th>
<th>95% Wald Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
<td>1.084</td>
<td>1.005</td>
</tr>
<tr>
<td>TE</td>
<td>0.986</td>
<td>0.962</td>
</tr>
<tr>
<td>Port 3</td>
<td>0.028</td>
<td>0.002</td>
</tr>
<tr>
<td>Port 4</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Port 5</td>
<td>0.045</td>
<td>0.003</td>
</tr>
</tbody>
</table>

The adjusted odds ratio (Table 4) indicate the marginal impact of an increase of one unit in a variable on the probability of undertaking exploratory fishing. From the table, an additional one percentage point increase in the coefficient of variation increases the probability of undertaking exploration by about 8.4%. In contrast, operating out of ports 3-5 (i.e. a one unit increase in the dummy variable from 0 to 1) reduce
the probability of undertaking exploration to almost zero (i.e. a decrease in the probability of between 95
and 99.9%). This is consistent with Strand (2004) who found that boats from the more spatially extreme
areas were more risk averse and less likely to undertake exploratory fishing activity.

**DISCUSSION AND CONCLUSION**

It is reasonable to assume that all fishers pursue a rational economic strategy (e.g. profit maximisation)
with respect to allocation of effort. However, following the closure of traditional fishing in the North Sea
gounds, unexpected fishing behaviour was observed by a small number of the English beam trawl fleet
that transferred their fishing efforts to areas that had not been fished in recent history. This behaviour was
not a response to the normal causes that influence production behaviour (e.g. as consumer demand, price
of output and technology were independent of area fished). Furthermore, given the existence of
alternative fishing areas with know productivity levels, the incentive to change production decision was
relatively weak. Approximately three quarters of the fleet reallocating effort to these areas.

It is well established in the literature that decision-making strategies depend on individual’s perception of
expected profit, perception of risk and attitude to risk. The results of the logit regression analysis suggests
that the likelihood of undertaking exploratory behaviour increased the higher the coefficient variation of
historical catch. Assuming that risk preferences are reflecting in historic variation in catch, then boats that
operated in the new areas most likely demonstrated risk-seeking behaviour. In comparison, the boats that
went to the previously fished areas adopted a risk adverse fishing strategy. As mentioned previous, most
previous studies found fairly homogenous risk aversion in fisheries (Mistiaen and Strand, 2000; Eggert
and Tveteras, 2004). In comparison, this study found greater apparent heterogeneity in risk attitudes, more
consistent with studies in agriculture (Binswanger, 1980; Bardlsey and Harris, 1987).

While it might be reasonable to assume that a good skipper makes good input choices, including location
choice, their choice of inputs will also be affected by their risk preferences. Kumbhakar (2002) found that
risk preferences have greater impact on input choices than technical efficiency. This is consistent with the
results of this study where apparent attitudes to risk are highly significant in determining location choice
whiles technical efficiency was not significant.

Dreyfus-Leon (1999) characterised discovery and exploitation as key elements in hunting and fishing
involving aspects such as adaptiveness and creativity. For this particular fleet, the majority of boats
engaged in a safer fishing strategy more analogous to routine factory production process moving to areas
in order to secure inputs and therefore output. However, in an open access fishery there are no known
rewards for finding a new area to fish. Therefore by avoiding risk-seeking strategy these vessels are not
excluded from exploiting any subsequent stock discoveries. The safe strategy payoff therefore is the
potential to maximising expected returns based on existing knowledge of the fishery with the potential to
benefit from the exploratory activities of others, avoiding the cost of risk seeking behaviour (e.g. zero
return on search effort).

The nature of the logit analysis is that boats need to be classified into either one category or another. In
reality, activity in the new areas was more of a continuum, starting from zero for boats that fished only in
known areas. Boats that fished in the new areas also fished in the known areas. In fact, most of their time
was employed in these areas, with less than 10 per cent of their days fished during the period of the
closure employed in the new areas. This does not necessarily negate the results. Comparing the estimated
log of the odds ratio of undertaking exploration (derived from the boat characteristics and the model
presented in Table 3) with the share of effort expended in the new areas during the period of the closure
(Fig. 7), there is still an apparent positive relationship. The boats with the greatest log odds ratio (i.e. the
boats most likely to partake exploratory activity) were also those that devoted the greatest share of their
effort to the new areas. Conversely, those boats that only marginally could be defined as exploratory (i.e. with low odds ratio values) tended to dedicate the least effort to the new areas.

\[ y = 0.0085x + 0.0153 \]
\[ R^2 = 0.4528 \]

![Graph showing the relationship between log of the odds ratio and intensity of activity in the new areas.](image)

**Figure 7. Relationship between log of the odds ratio and intensity of activity in the new areas**

A feature of the fishery observed during the analysis was an apparent inverse relationship between risk aversion and technical efficiency. This relationship has not been previously discussed in the literature on efficiency and risk preference and there is no *a priori* reason why such a relationship should exist. However, further investigation may prove interesting if similar results are also found in other fisheries.

Only eleven boats in the data set were identified as outré-istic fishers. Of these, only two boats fished in grounds with no previous history of exploitation. The data requirements of statistical techniques require more observations than this to produce any meaningful results. Hence, the broadening of the definition of exploratory fishing grounds. To examine the characteristics and behaviour of narrowly defined outré-istic fishers would therefore necessitate an alternative methodology. Using a multi-method approach, qualitative techniques could be used to explore such a sub group.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


ENDNOTES

a The propensity for exploitation of known fish stocks to increase in the absence of property rights is well established in the fisheries economics literature.

b The logic behind this assumption is that fishers who are more risk averse will fish in areas where catches are more assured, and inter-annual variations in catch (after removing the effects of changes in stock size) are likely to be relatively small. In contrast, more risk seeking fishers will operate in areas with higher variability but potentially higher yields. On this basis, fishers with relatively low observed variance in catches are most likely to be more risk averse than those with observed high variance.