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# Predicting fisher response to competition for space and resources in a mixed demersal fishery

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ABSTRACT

Understanding and modelling fleet dynamics and their response to spatial constraints is a prerequisite to anticipating the performance of marine ecosystem management plans. A major challenge for fisheries managers is to be able to anticipate how fishing effort is re-allocated following any permanent or seasonal closure of fishing grounds, given the competition for space with other active maritime sectors. In this study, a Random Utility Model (RUM) was applied to determine how fishing effort is allocated spatially and temporally by the French demersal mixed fleet fishing in the Eastern English Channel. The explanatory variables chosen were past effort i.e. experience or habit, previous catch to represent previous success, % of area occupied by spatial regulation, and by other competing maritime sectors. Results showed that fishers tended to adhere to past annual fishing practices, except the fleet targeting molluscs which exhibited within year behaviour influenced by seasonality. Furthermore, results indicated French and English scallop fishers share the same fishing grounds, and maritime traffic may impact on fishing decision. Finally, the model was validated by comparing predicted re-allocation of effort against observed effort, for which there was a close correlation.

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## 1. Introduction

According to the FAO (2012) most fisheries resources are already fully exploited or over-exploited due in part to excess fishing capacity and fishing power. Fishing activities can also have adverse effects on the structure and functioning of marine ecosystems (Buchen, 2009; FAO, 2012). To address that challenge, many fisheries management agencies have adopted an Ecosystem Approach to Fisheries Management (EAFM) approach (Browman and Stergiou, 2004), by implementing management plans. This approach aims at maintaining or restoring fisheries resources to sustainable levels, while mitigating the adverse ecological impacts of fishing (Pauly et al., 2002). To accurately assess and evaluate fisheries management performances, it is essential to better understand the processes driving the dynamics of the marine ecosystems and the fishing fleets that impact them (Fulton et al., 2011; van Putten et al., 2011; Wilen et al., 2002).

Understanding and predicting the complex interactions between resource users and ecosystem dynamics is essential to reduce the risk of management failure (Hilborn, 2004). A founding principle of ecosystem-based management is that humans are fully part of ecosystems (Leslie and McLeod, 2007), and one of the main challenges for decision-makers is to better understand the factors that influence human behaviour (Wilson and McCay, 2001). This is of particular importance to fisheries managers who need to better understand the mechanisms of fishing effort allocation, so to better anticipate fishers' reactions to management.

*Abbreviations:* DCF, Data Collection Framework; DPMA, Directorate for Marine Fisheries and Aquaculture; EAFM, Ecosystem Approach to Fisheries Management; IBM, Individual-Based Modelling; IFD, Ideal Free Distribution; IIA, Independence of Irrelevant Alternatives; LRI, likelihood ratio index; MSFD, Marine Strategy Framework Directive; RUMs, Random Utility Models; VSS, Vessel Separation System.

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Fishers' decision-making can be cast in terms of short-versus long-term choices (Van Putten et al., 2011). For example long-term choices include decisions about capital investment, or about whether to enter or exit a particular fishery (Nostbakken et al., 2011). Conversely short-term decisions may consist of immediate actions, such as choosing a fishing area and/or a type of fishing activity (sometimes referred to as a "métier") at the beginning of, or during a fishing trip, and also includes actions, such as discarding fish (Andersen et al., 2012; Hilborn, 1985; Hutton et al., 2004). In this study we concentrated on short-term behaviour, and in particular the factors that determined fishing effort allocation both spatially and across métiers. An increasing number of studies have investigated and modelled short-term fishers' behaviour using both conceptual and data driven approaches. Conceptual approaches include applications of the Ideal Free Distribution (IFD) theory (Gillis, 2003; Rijnsdorp et al., 2000), optimal foraging theory (Dorn, 2001), Individual-Based Modelling (IBM) (Millischer and Gascuel, 2006; Soulié and Thébaud, 2006) or vessel trajectory analysis (Bertrand et al., 2005; Vermard et al., 2010). Many data-driven approaches to fishers' behaviour modelling have built in Random Utility Models (RUMs). RUMs provide an appropriate and functional approach to describe how fishers make a choice among a panel of finite alternatives (Wilen et al., 2002). Such a discrete-choice modelling approach has been applied to analyse fishers' choice of fishing ground (Hutton et al., 2004; Wilen et al., 2002), target species (Pradhan and Leung, 2004a; Vermard et al., 2008), and gear type (Andersen et al., 2012; Holland and Sutinen, 1999; Marchal et al., 2009).

Fishers do not necessarily know all of the surrounding environmental factors and so may only have partial information about the precise position and availability of their target species. In most fleet dynamics studies, skippers have been assumed to choose their fishing ground, gear and/or target species, based on their own experience (e.g. their past choices/activity) and on their economic expectations for a given choice (e.g. past profit achieved). For example, fishers' behaviour can be influenced by fish price fluctuations, which are often seasonal and are an important factor to take into account when evaluating the expected profitability of alternative potential choices (Dupont, 1993; Loannides and Whitmarsh, 1987). Anecdotal evidence suggests that other factors which have seldom been considered in past empirical studies could determine fishers' behaviour. These factors include communication between fishers, or radar-screening of concurrent vessels which may indicate the presence of target species in a specific area. By contrast, skippers compete for space and resources, not only with other fishers, but importantly also with other sectors of activity operating in the same maritime areas. Exploitation of marine resources, for example aggregate extraction, offshore wind farms and maritime traffic can impact the choice of fishing grounds by restricting access or decreasing the availability of fish resources. In EU waters, the Marine Strategy Framework Directive (MFSD) of the European Union (EC, 2008a) requires that the different sectors of activity operating on the same maritime domain be managed jointly rather than in isolation. A key issue for fisheries managers then becomes to understand how fishers operate their activities and adjust their tactics in area-constrained environments.

To assess spatial constraint impact, this paper aimed to identify and quantify the determinants of fishing fleet dynamics in one of the most congested maritime area in the world, the Eastern English Channel (ICES Division VIId)(Fig. 1). The analysis focused on French fleets catching flatfish species, sole (*Solea solea*) and plaice (*Pleuronectes platessa*). The flatfish species represent an important source of revenue for fishers in this area, however this fishery has important impacts on the marine ecosystem (Riou et al., 2001). Random utility modelling is used to gain insights into how fishers choose a métier and/or an area, at the scale of a trip, whilst interacting with other fishing fleets, maritime activities and spatial management (regulations). Maritime traffic in the Channel is thought to interact substantially with fishing activities due to it being one of the world busiest shipping lanes encompassing a large proportion of the Channel (Figs. 1 and 2). The main form of spatial regulation for commercial fishing activities in the Channel is the coastal area within twelve nautical miles from the coastline (hereafter called the "12-mile zone") where trawling is prohibited to vessels with an engine power exceeding 221 kW or an overall length exceeding 24 m. Finally we tested the predictive capability of the model to forecast effort re-allocation one year ahead using two different predictors, and then predicted re-allocation of effort was compared against realised/observed re-allocation of effort.

## 2. Materials and methods

### 2.1. Data

#### 2.1.1. French fishing fleets

French landings (in both weight and value) and fishing effort data are collected by the French Directorate for Marine Fisheries

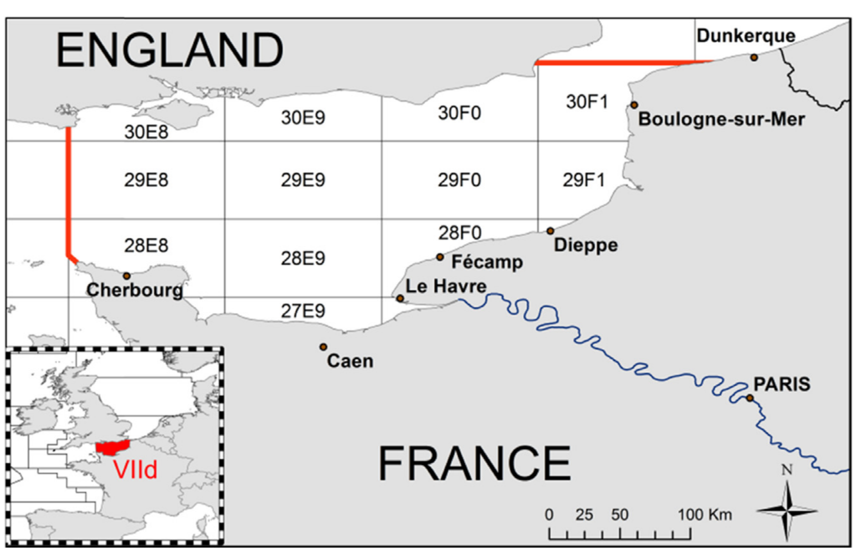


**Fig. 1.** Statistical rectangles and main fishing harbours in the Eastern English Channel (ICES Sub-Divisions VIId).

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