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Spatial patterns in the retained catch composition of Irish demersal otter trawlers: High-resolution fisheries data as a management tool

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ABSTRACT

High-resolution fisheries data from integrated logbook and Vessel Monitoring Systems (VMS) records have revealed a detailed spatial structure in the species composition of the retained catches of the Irish demersal otter trawl fleets. Hierarchical cluster analysis was used to define 8 clusters with relatively homogenous species compositions. These clusters formed 34 distinct spatial regions in the waters around Ireland. Identification of these regions can be useful for a number applications, including spatial stratification of commercial or survey data, defining and characterising fishing grounds for marine spatial planning, evaluation of closed areas and prediction of how fishing effort might be re-allocated following a closure. A case-study is presented that explores options to reduce cod (*Gadus morhua*) catches by implementing seasonal closures in two of the 34 regions. Cod are caught by demersal trawlers in a mixed fishery and the catches often exceed the quota, resulting in discarding of marketable fish. Two regions were identified that had relatively low effort and high cod landings. The effects of closing these regions during the first quarter of the year were explored. Cod catches were likely to be reduced by 8–22% while only 3–9% of the annual demersal otter trawl effort would be displaced. Whiting catches were also likely to be reduced, the change in catches of some other species depended on the assumed effort displacement.

1. Introduction

Many aspects of the marine environment are highly heterogeneous in space. The distribution of demersal species can depend on variables like depth, bottom type, hydrological conditions and interactions with fishers, predators and, prey and competitors (e.g. Planque et al., 2011). Historically, fisheries management has not taken account of this fine-scale spatial structure because most data were only available at broad spatial scales. However, in recent years policy developments such as the ecosystem approach to fisheries management (FAO, 2008) and the Marine Strategy Framework Directive (EU, 2008) have driven a demand for fisheries data at a high spatial resolution. These data are also required to evaluate and monitor spatial management measures like marine protected areas or marine reserves (Eastwood et al., 2008; Hillborn et al., 2004) or fine-scale real-time fishing closures (e.g. Dunn et al., 2011; Holmes et al., 2011; Needle and Catarino, 2011). Spatially resolved fisheries data are also required to address the growing extent and diversity of ocean uses beside fisheries, many of which are incompatible with each other (e.g. recreation, wind and wave power, minerals extraction, aquaculture, shipping, conservation). These ocean uses are increasingly managed by prohibiting or permitting them in specific areas.

Effective spatial management requires appropriate boundaries to be drawn around the areas that are to be managed as mismatches between the scale of the resources and of their assessment and management can be a cause of management failure in fisheries (Lorenzen et al., 2010). In practice, however, management areas are often drawn along straight lines of latitude and longitude at scales of thousands of square nautical miles, for example stock assessment areas (ICES, 2011a), Total Allowable Catch (TAC) management areas (EC, 2011) or seasonal closures (e.g. the Trevose closure: Annex III section 6.2 of EC, 2009) although some closed areas follow more natural boundaries (e.g. the Porcupine Bank closure: Article 13 of EC 2011).

Fisheries management is often further complicated by the fact that many stocks have overlapping spatial distributions and are caught together in mixed fisheries. In Europe, fish stocks have traditionally been assessed and managed on a single-species basis. However, single-species quota tend to lead to sub-optimal use of fisheries resources (Rätz et al., 2007; Ulrich et al., 2011) because when quota for one or more species are exhausted, fishing may

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continue and this will lead to discarding of over-quota catches and fishing mortalities that are above management targets. Alternatively, if the fishery would be closed once the landings of the first species have reached their quota, then the fishing mortality of the other species in the same fishery will be below target, leading to loss of potential revenue.

Ulrich et al. (2011) have developed a tool, Fcube, which is currently used in the ICES Working Group on mixed-fisheries advice for the North Sea (ICES, 2010, 2011b). Fcube can estimate what the likely catches of the various species in the mixed assemblage will be under a variety of management scenarios and assumptions about fishers' behaviour in relation to set quotas. The approach accounts for differences in catchabilities between métiers (types of activity) within fleets (groups of vessels) and the single-species TAC settings. Fcube does not explicitly take the spatial element of catch composition into account.

Another way of managing mixed fisheries is through taxes on over-quota landings (Holland, 2003; Marchal et al., 2009) or by varying the cost of fishing by area, depending on the expected catch or landings per unit effort (cpue/lpue) (Kraak et al., 2012). These approaches allow fishers to optimise their profits by avoiding or minimising taxes or costs of fishing. If the scheme is well-designed, this behaviour should result in fishing mortalities that are closer to management targets than a TAC system alone.

The approach proposed by Kraak et al. explicitly takes the spatial and temporal variation in lpue of fish species into account. This kind of fisheries data has become available at fine spatial scales since the introduction of Vessel Monitoring Systems (VMS) which automatically collect positional data from fishing vessels. These positional data can be linked to national logbook landings data (e.g. Gerritsen and Lordan, 2011) to obtain spatially resolved fisheries data. These data can be an important tool for understanding and managing mixed fisheries if they can be presented in a usable form.

One of the problems that occurs when dealing with spatially resolved data is the large numbers of variables involved (location, time, species composition, fishing effort, gear parameters). One way of reducing the complexity of the dataset is by finding regions with similar properties that are stable over time. In the current paper we propose a method of defining regions with homogenous species compositions in the retained catches.[1] Such regions will be useful for a large number of applications, including: (1) stratification for sampling of commercial landings or other surveys; (2) stratification of commercial lpue data so these data become less sensitive to changes in the spatial distribution of the fleet; (3) defining and characterising fishing grounds for example for the purpose of marine spatial planning; (4) providing natural boundaries for closed areas or effort management areas; and (5) predicting how changes in spatial distribution of the fleet might affect the composition of the landings and/or discards. We will illustrate the latter two applications in a case study. The other applications will be considered in more detail in the discussion section.

In our case study we will investigate a situation where fisheries managers impose a seasonal closure in two regions with high cod cpue in order to reduce cod (*Gadus morhua*) catches in the Celtic Sea (the region to the south of Ireland and north of Biscay). These cod are caught as part of a mixed fishery and there is currently little or no incentive to avoid over-quota catches of cod, resulting in discarding of marketable fish. We will investigate a number of scenarios of effort displacement following this hypothetical closure. By applying the changes in effort to cpue estimates in each region we estimate the changes in catches and landings of cod and other species caught by the Irish demersal otter trawl fleet. We do not expect to precisely predict the actual effort displacement but by examining a range of possibilities, we can quantify how sensitive the results are to the various effort displacement assumptions.

2. Methods

Since 2005, all European Community (EC) fishing vessels of ≥15 m in overall length have to be fitted with VMS transponders which transmit their position at least every 2 h whilst at sea (EC, 2003). Skippers of EC vessels of ≥10 m in overall length are also required to record their retained catches on a daily basis in standard logbooks (EEC, 1983). VMS and logbook data are available to the Marine Institute for the period 2006–2009. Gerritsen and Lordan (2011) have described a method to integrate VMS data with the retained catch data recorded the logbooks. Discard data are available for the period 1995–2010; however, only around 1% of all fishing trips had discard observers on board (Anon, 2011; Lordan et al., 2011).

Following the method described by Gerritsen and Lordan (2011), each VMS location of Irish demersal otter trawlers was allocated an effort value, which is the time since the previous VMS record (generally 2 h). The VMS data were filtered for vessel speeds between 1.5 and 4.5 knots in order to select records corresponding to fishing activity. In a small proportion of cases (<3%) the vessel speed was not transmitted, for these records the vessel speed was estimated from the distance and time interval since the previous record. Gerritsen and Lordan (2011) have shown that vessel speed can distinguish fishing activity with an accuracy of 88% and most errors (both false-positive and false-negative) occurred around the start and end of fishing operations. The daily retained catch data were allocated equally to the 'fishing' VMS records for each vessel and date. The resulting retained catch and effort data were aggregated to the grid of 0.10° longitude × 0.05° latitude. This grid size was chosen as a compromise between spatial resolution and the number of data points per grid cell. Any grid cells with fewer than 5 VMS 'fishing' records or less than 100 kg total retained catch were omitted from the analysis. Data from all available years (2006–2009) were combined for the initial analysis.

A hierarchical cluster analysis was performed on the gridded data to identify areas with similar species compositions. The 10 most abundant species and species categories in the landings were included in the cluster analysis (Table 1). Some of these were grouped at a higher taxonomical level (rays/skates and deepwater species). These 10 species categories accounted for 90% of the total demersal landings, all other species were grouped in an 11th category ('other'). The retained catch weights by species category in each grid cell were converted to proportions. Next, a dissimilarity matrix was constructed by calculating the Euclidian distance between the cells using the proportions of the 11 species categories to define their location in 11-dimensional Euclidian space. A hierarchical cluster analysis, using Ward's minimum variance clustering algorithm (Gordon, 1987) was then applied to this matrix. The spatial distance between the grid cells was not taken into account in the cluster analysis, so any spatial patterns that emerge from the analysis are the result of similarities in the retained catch composition of neighbouring cells.

The most appropriate number of clusters was chosen using expert knowledge: if the number of clusters is too low, then species that occur in distinct habitats will be grouped together but if the number of clusters is too high, then similar fisheries will be assigned to different clusters. After deciding on an appropriate number of clusters, the spatial distribution of these clusters was mapped and

[1] Throughout this document the terms 'retained catch' and 'landings' are used interchangeably. The term 'landings' can be confusing when discussed in a spatial or temporal sense as the landings generally take place in port at the end of a trip while the catches take place at sea throughout the trip. Only the retained catches are landed but most catches also have a discarded component.