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A method to address the non-random spatial distribution of on-board observer data to map landings and discards

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ABSTRACT

The Landing Obligation is legislation meant to gradually reduce discards in European fisheries from 2015. Identifying spatial patterns of landings and discards is an important element in mitigating the effects of this legislation on fishing activity. On-board observer data have already been used to address this issue based on models involving statistical assumptions in relation to the non-random spatial distribution of data, which may cause errors in the parameters of interest. An alternative non-model-based mapping method using nested grids is applied to explore the spatial distribution of landings and discards for two French fishing métiers in the Celtic Sea and western English Channel from 2011 to 2016. The grid fineness and the estimate precision are found to depend mainly on the density and variability of on-board observer data. Moreover, an extensive coverage of fishing activity in space and time, and of all fishing vessels, is required to produce meaningful maps.

1. Introduction

Discards are defined as unwanted fish retained by a fishing gear, which have been brought on board a fishing vessel and are returned into the sea (European Commission, 2002). In 2013, the Common Fisheries Policy introduced the Landing Obligation (LO) to eliminate discards in European fisheries (European Commission, 2013). Since 2015, fishers have to gradually retain onboard, register and land all catches of species subject to quotas. To mitigate the effects of this legislation, fishers are encouraged to avoid areas with high abundance of unwanted fish (Bellido et al., 2011; FAO, 2010). Knowing spatial patterns of landings and discards could help to identify fishing zones to be avoided (i.e., high discards) or to be exploited (i.e., low discards and medium/high landings).

The French on-board observer programme (Obsmer) has collected data on fisheries landings and discards under the European Union (EU) data collection regulation (2002–2008) and the subsequent data collection framework (EC, 2008). Based on a sampling programme, its main purpose is to quantify discards, identify what is discarded, when and by whom (Cornou et al., 2017). As fishers target particular fish species at places where they know fish are, fishing activity is non-randomly spatially distributed (Augustin et al., 2013; Pennino et al., 2014; Poos et al., 2013; Sims et al., 2008). Previous studies have explored the spatial distribution of landings and discards using on-board observer data (Lewison et al., 2009; Paradinas et al., 2016; Pennino et al., 2014; Sims et al., 2008; Viana et al., 2013), based on models involving statistical assumptions in relation to the non-random spatial distribution of data, which may cause errors in the parameters of interest. An alternative non-model-based mapping method using nested grids (Gerritsen et al., 2013) is applied in this study. The method addresses the spatial non-randomness of data by adjusting the size of each grid cell as a function of the number of observations therein (i.e., small cell sizes are used in areas with many observations, and vice versa). This approach produces a number of cells with a sufficient number of observations to make precise estimates.

A fishing métier is defined as "a group of fishing operations targeting a given species or group of species, using a given gear, during a defined period of the year and/or within a defined area, and which are characterized by a similar exploitation pattern" (EC, 2008). Two French fishing métiers with high discard proportions of species subject to quotas (Cornou et al., 2017) were selected to illustrate the advantages and disadvantages of the method: the trawling métier targeting demersal species in the eastern Celtic Sea and the western English Channel, and the netting métier targeting demersal species, cephalopod

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and crustaceans in the western English Channel and West of Brittany; hereafter referred to as trawlers and netters respectively.

The mapping method is expected to address the non-random spatial distribution of the data, and the Obsmer samples are expected to be representative of fishing activity in space and time, and of all fishing vessels. These criteria are assessed using quantitative and qualitative indicators.

The potential of the nested grid method is established by exploring the spatial distribution of landings and discards for the two fishing métiers over the period 2011–2016. The following is a description of the data, case studies and mapping process, i.e., what are the grid parameters? How to create the nested grids from a division-based procedure? How to estimate landings and discards in each cell? Finally, quantitative and qualitative indicators are used to evaluate the resulting maps.

2. Material and methods

2.1. Data

The Obsmer data were collected by at-sea observers who were placed on fishing vessels for the duration of a fishing trip to sample catches during fishing operations (FOs), i.e., from the time of launching the fishing gear to when it is hauled aboard. Within a trip, a random sample of FOs, ranging from one-third to half, was observed during which the retained and non-retained portions of the catch were observed separately by identifying, weighing and measuring all species. For the non-observed FOs, landings were only weighed and counted (Cornou et al., 2017). Data also included the characteristics of fishing trips (duration, landing port, etc.) and FOs (gear type, fishing effort, geographical coordinates, etc.). The observed and non-observed FOs were combined to create the nested grid, but only the observed FOs were used to estimate landings and discards, and evaluate the resulting maps.

Fisheries statistics based on logbooks, sales, and fishing effort data from the Vessel Monitoring System were also used to estimate landings and discards, and evaluate the resulting maps. Logbooks included data on the quantity of fish retained on-board by individual vessel, fishing sequence (i.e., a combination of day, gear, and 60′ latitude x 30′ longitude rectangle – the size of the ICES statistical rectangles) and species. Fish auction sales included data on vessel ID, date of sale, volume and landed value per species. To address potential discrepancies between these sources of data, a tool aiming at cross-checking them was applied (Demaneche et al., 2010). The most likely estimates of total landings and fishing effort were provided by individual vessel, fishing sequence and species.

Vessel characteristics including length, identification code, name, and harbour were also available for the whole fleet.

2.2. Case studies

The trawling métier, targeting demersal fish species with the use of single or twin-rig otter trawls in the eastern Celtic Sea and the western English Channel, is carried out by vessels larger than 18 m. Fishing activities remain relatively unchanged over the year. Fishing trips last on average 7 days. From 2011–2016, average annual discarded proportions varied between 20.1 and 32.3% (Fig. 1). The most important target and non-target species subject to quotas were haddock, whiting, European hake, cod, megrim, boarfish, anglerfish, cuckoo ray, pollack, and common cuttlefish. One to two percent of days-at-sea were observed (Fig. 2b), resulting in a total of 2,260 days-at-sea (Fig. 2a) and 7152 FOs sampled for this métier.

The netting métier, targeting demersal fish species, cephalopods and crustaceans with the use of gill or trammel nets in the western English Channel and the West of Brittany, is carried out by vessels less than 15 m. Fishing trips last on average 1–l2 days. Average discarded

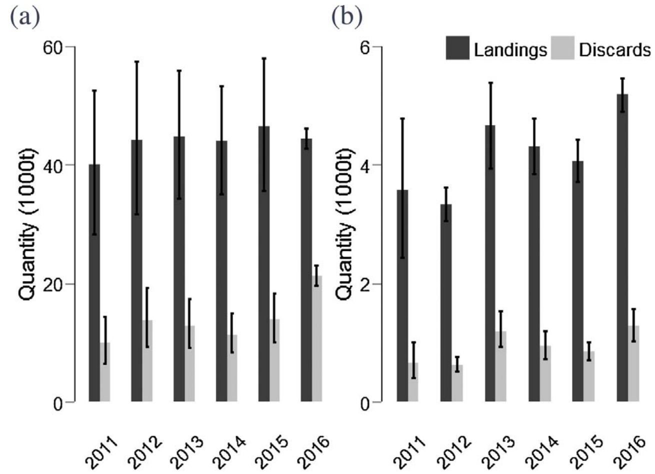

Fig. 1. Annual estimates of total landings and discards (in 1000 t) of all species, for (a) trawlers and (b) netters from 2011 to 2016 (Cornou et al., 2013, 2014, 2015, 2016, 2017; Dubé et al., 2012). Bars indicate sampling error calculated by bootstrap methods (Cornou et al., 2017). Note that the two y-axis differ by a factor of 10.

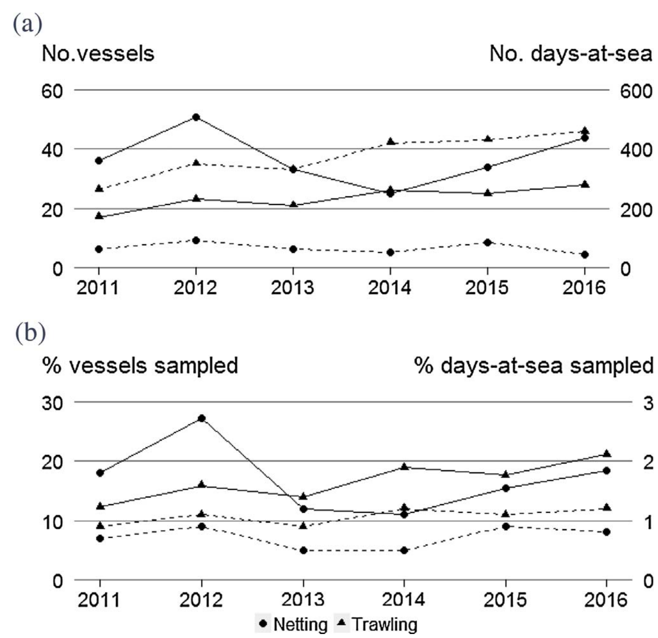

Fig. 2. Sampling effort for trawlers (triangles) and netters (diamonds) from 2011 to 2016 (Cornou et al., 2017, 2016, 2015, 2014, 2013; Dubé et al., 2012). The left y axis indicates the (a) number and (b) proportion of vessels sampled (solid lines). The right y axis indicates the (a) number and (b) proportion of days-at-sea sampled (dashed lines).

proportions varied between 12.9 and 20.5% from 2011 to 2016 (Fig. 1). The most important target and non-target species subject to quotas were angler fish, pollack, European hake, whiting, and common sole. A lower amount of FOs (1902) was available for this métier, owing to the smaller size of the fleet (Fig. 2).

The next sections describe the processes of creating the nested grids, estimating landings and discards, and evaluating the resulting maps.

2.3. Creating the nested grids

From the average geographical coordinates of each FO (i.e., midpoint from a straight line between the beginning and the end of a FO), the nested grids were constructed for each métier based on an iterative process of cell division. Starting with a coarse regular grid, each cell was divided one or several times according to the number of FOs therein (N). The division-based procedure required maximum $Nmax_i$