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ESTIMATING FISHING EFFORT IN THE NAFO REGULATORY AREA USING VESSEL MONITORING SYSTEM DATA

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Abstract

Vessel monitoring system (VMS) data is positional and navigational data which is required to be transmitted by all fishing vessels operating in the NAFO Regulatory Area to the NAFO Secretariat, via national fisheries monitoring centers. Using speed as a proxy for fishing activity allows elucidation of spatial patterns of activity and has been useful in studying the effects of spatial management measures. It has been suggested that NAFO Scientific Council make further use of VMS data in preparation of their advice to the Fisheries Commission. This has previously been problematic due to the highly sensitive nature of the positional information contained in VMS data. In this study we present the results of work carried out by the NAFO Secretariat linking VMS data with bathymetric information for the period 2008–2012, to examine trends in effort. This presents Scientific Council with a flexible, anonymized data product containing detailed fishing effort information.

Introduction

The exploitation of fishery resources on a sustainable basis requires not only an understanding of the biological parameters of the fished population, but also of the patterns and trends in the exploitation of that resource by fishers and of the impacts that this exploitation has on the wider ecology of the whole marine ecosystem impacted by fishing. This goal of sustainable exploitation is most likely to be achieved through the development of spatially explicit models of commercially significant stocks, non-target species and habitats coupled with knowledge of the distribution of fishers' activity which take into account mortality on non-targeted species (Piet *et al.*, 2009).

Vessel monitoring system (VMS) data consists of positional and navigational (heading and speed) information, transmitted via satellite from fishing vessels to fishery monitoring centres. All vessels operating in the NAFO regulatory area have been required to submit VMS data since since the early 2000s, with a minimum polling rate which has decreased from once every six hours in 2004 to hourly, since 2011.

Due to the high level of information contained in VMS data about the commercial activities of individual fishers and concerns about the individual's right to privacy, access to raw data is tightly controlled, which makes conducting meaningful analyses in fisheries with stakeholders from multiple nations difficult.

Analyses which infer fishing behavior of vessels from VMS data use vessel speed, and in some fleets direction (e.g. Hintzen *et al.*, 2009) to differentiate trawling and steaming. These analyses assume that boats steaming will mostly follow a straight line at a high speed and boats fishing are characterized by a more erratic trajectory and a low speed. The angle and speed characterizing the different behavioural states have to be specified *a priori*. While some work has been done applying Bayesian process models (Vernard *et al.*¸2010), these have not been shown to perform better in the identification of fishing activity than the application of a simple speed rule which has been verified by

observation (Borchers and Reid, 2008). Work comparing VMS data with notes of fishery observers carrying high frequency GPS loggers in the Scottish demersal fleet found speeds between 0.5 and 5 knots to be indicative of fishing activity (Campbell, pers. obs.). VMS data at speeds greater than 8 knots tended to correlate with steaming, while polls at intermediate speeds represent various activities, including the shooting of nets, downtime overnight, dodging weather and slow transits between grounds (fig. 1).

A wide range of approaches have been applied to the analysis of VMS data. Deng *et al.*, (2005) found that at a high polling frequency of 20 minutes, it was possible to assess trends in catch rates of the Australian Northern Prawn fishery on a 6 x 6 nautical mile grid. Lee *et al.* (2010) reviewed work to date using VMS data to estimate distribution of fishing activity and highlighted the importance of using common and open methods of analysis, for example, summation of points into standardised grids and using speed profiles to delimit fishing activity from steaming which are equivalent across fleets, in order to ensure cross-comparability of findings.

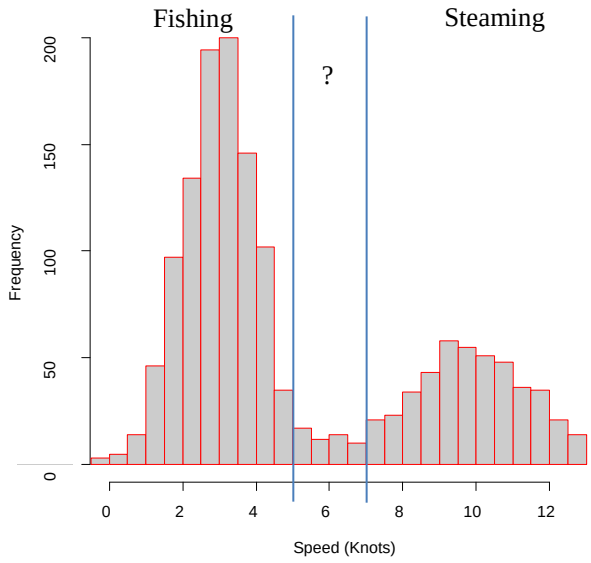

Figure 1. Hypothesised frequency histogram of speed distibtions from VMS polling data.

Methods

VMS data (position, speed and time), coupled with information on radio call sign and flag state were extracted from the NAFO Secretariat's VMS database for all fishing vessels in the NAFO regulatory area between January 1st 2008 and December 31st 2012,. Data were initially filtered to exclude all duplicate pings. Technical information detailing the type of gear used on each trip was also downloaded allowing each VMS ping to be associated with the use of a particular gear type. As VMS data is known to be a very poor indicator of effort in longline fisheries (Campbell *et al.*, 2010) the small number of vessels recorded as using this gear were excluded from further analysis.

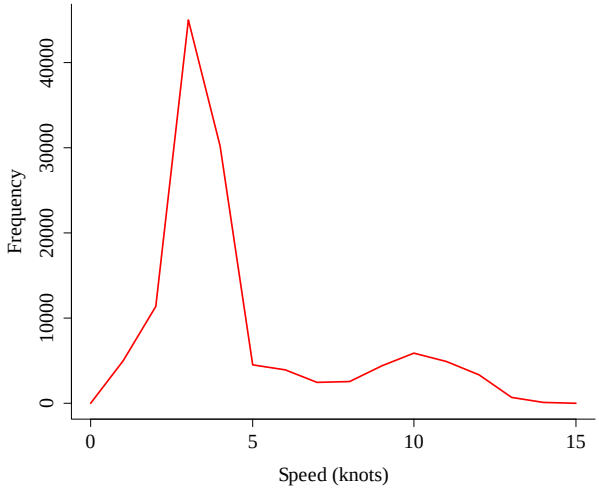

Figure 2. Frequency distribution of VMS polls from fishing vessels active in the NAFO regulatory area during 2012.

Through exploration of the data, it was determined that a speed of 5 knots represented a good proxy for fishing activity (see fig. 2). This is in line with most other studies of VMS data from otter trawlers.

Bathymetric data was extracted from the General Bathymetric Chart of the Oceans (GEBCO) 1 nautical mile data set for an area covering the extent of the NAFO Convention Area (30 – 78N, 30 – 80W) (IOC, 2003). To improve processing efficiency, all positive values (i.e. "land") were dropped from the data. Coordinates of the polygons bounding NAFO divisions were taken from the NAFO Conservation and Enforcement Measures (fig. 3).

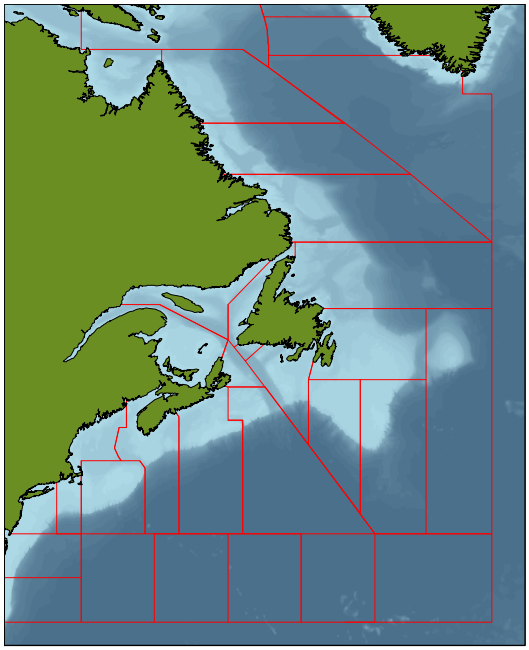

Figure 3. GEBCO bathymetry data for the northwest Atlantic Ocean.

VMS pings were assigned to into a 1' latitude by 1' longitude grid in R (v. 2.14.0) using the *sp* library (Bivand *et al.*, 2008) and the corresponding depth for this trapezoid in the GEBCO data was assigned to this set of points. The *sp* library was also used to assign VMS data to NAFO Divisions. The requirement for VMS equipment is a position accurate to ±500m; assigning fishing VMS pings to grid cells at this scale in theory approaches the technical specification of the data currently available, however in practice, modern GPS equipment is much more precise than this.

The time between consecutive pings from a vessel was calculated. While this is most often around 1 hour in more recent years, prior to 2011 the interval was around 2 hours, but this rate of reporting varied widely. Figure 4 shows the distribution of time between consecutive pings in 2008. As there is no association between the onset of fishing activity and the transmission of a VMS ping, it can be reasoned that the time between pings at fishing speeds can be equated to time spent fishing.

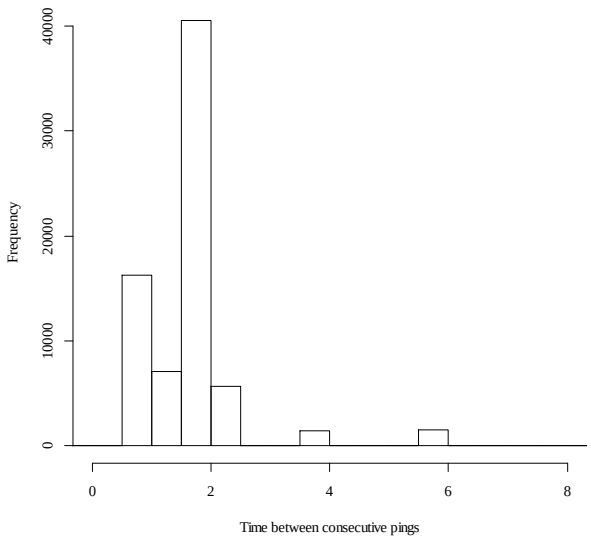

Figure 4. Histogram of time (hours) between consecutive pings from all vessels active in 2008.

Results

Visual examination of effort distribution provided by this method is in line with what is known of fisheries in the NAFO regulatory area, and shows little variation in spatial distribution from year to year (figs. 5a-e).

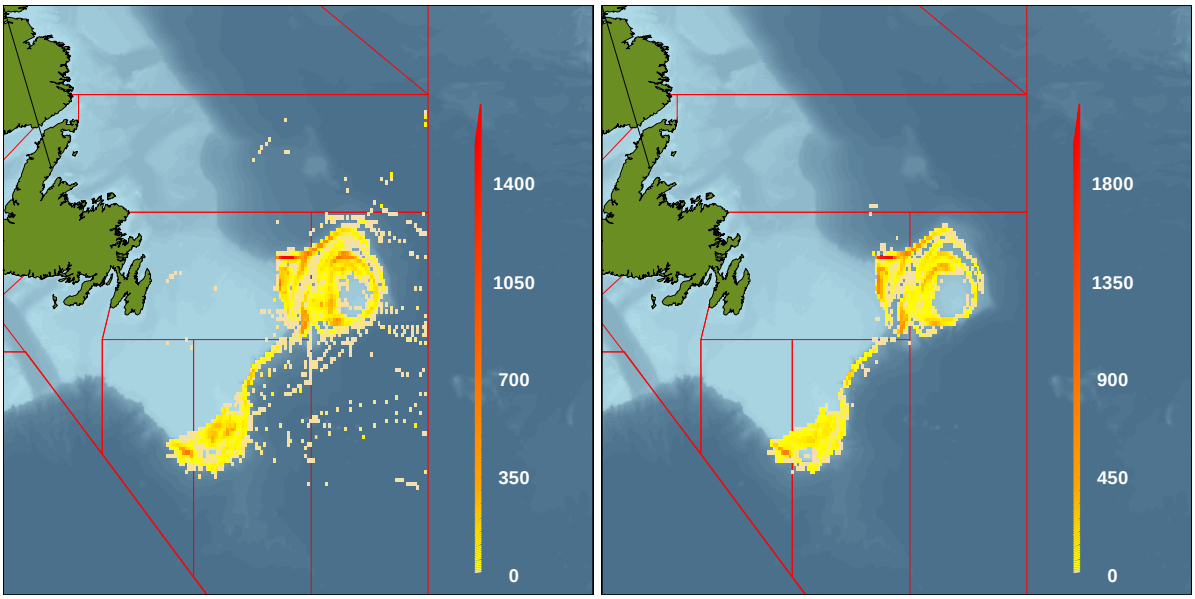

Figure 5a (left) and 5b (right). Distribution of fishing activity from VMS data for 2008 (left) and 2009 (right).

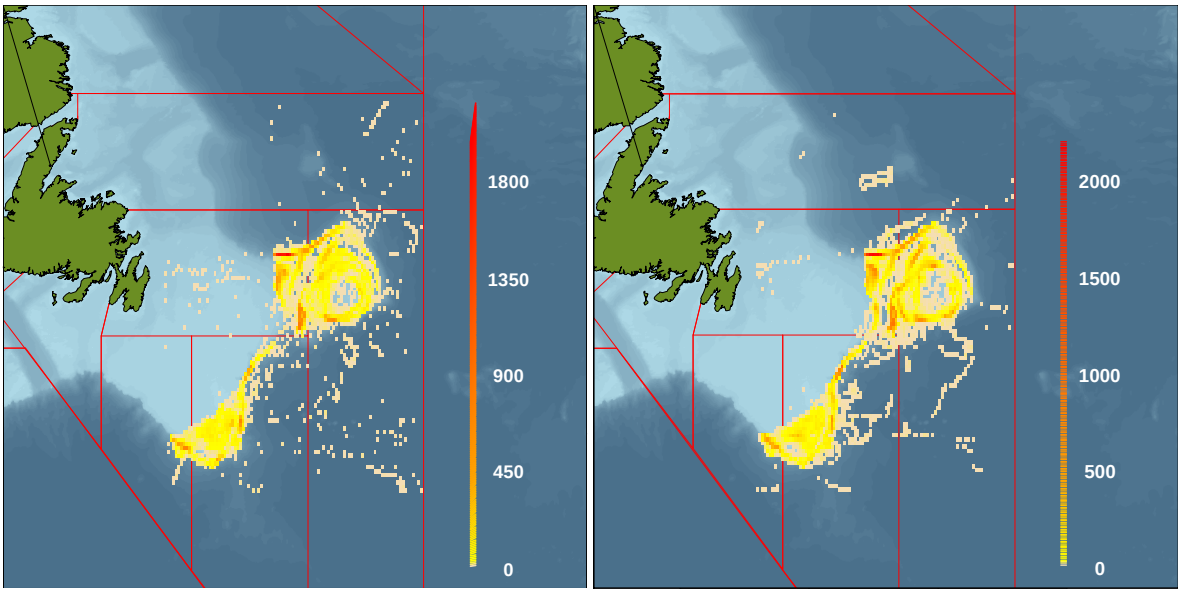

Figure 5c (left) and 5d (right). Distribution of fishing activity from VMS data for 2010 (left) and 2011 (right).

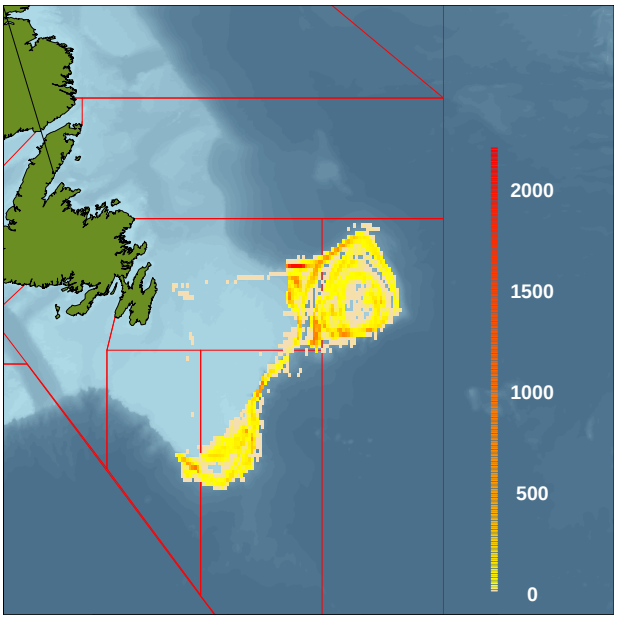

Figure 5e. Distribution of fishing activity from VMS data for 2012.

To validate these results against existing data, hours fished estimated from VMS data by contracting party, by division were compared against equivalent submissions from the Statlant 21B data set. This revealed a reasonable correlation, with a few areas of divergence between data sets (fig. 6).

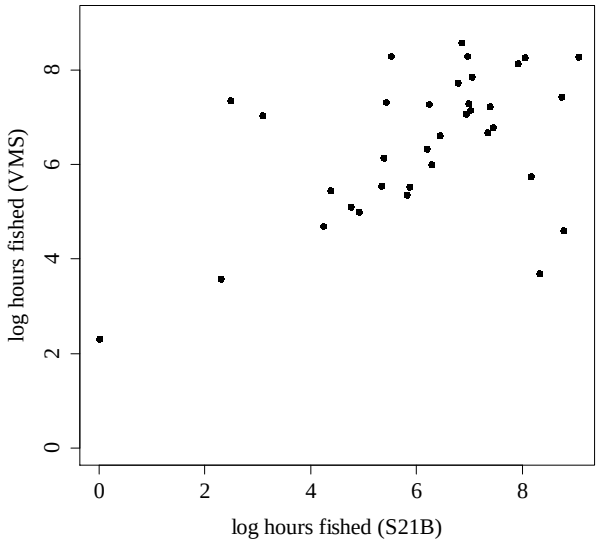

Figure 6. Effort from VMS and STATLANT 21B submissions, for those contracting parties who submit this data.

A number of example time series of effort are presented below for vessels targeting fish at depths shallower than 200m in Div. 3LNO (fig. 7), vessels fishing between 7 – 1600m in Div. 2J and Divs. 3KLMNO (fig. 8), and vessels targeting shrimp in Div. 3M and Divs. 3LN (figs. 9, 10)

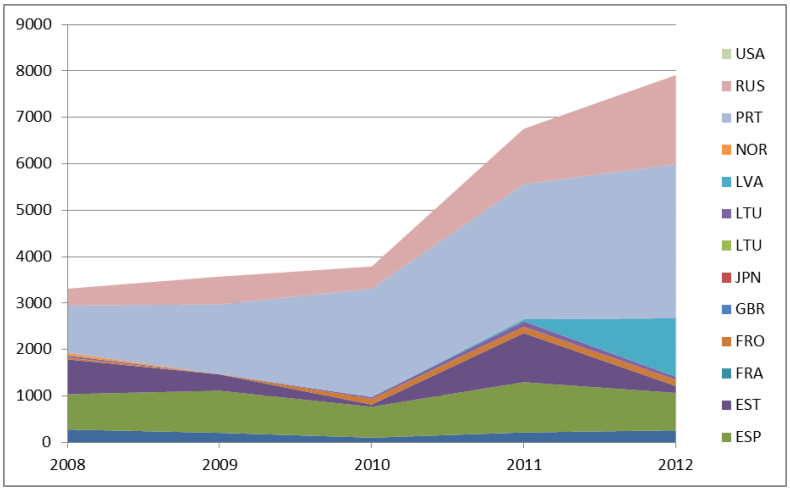

Figure 7. Effort (hours fished), by flag state, at depths shallower than 200m in Div. 3LNO, 2008 – 2012 (excluding shrimp fishers).

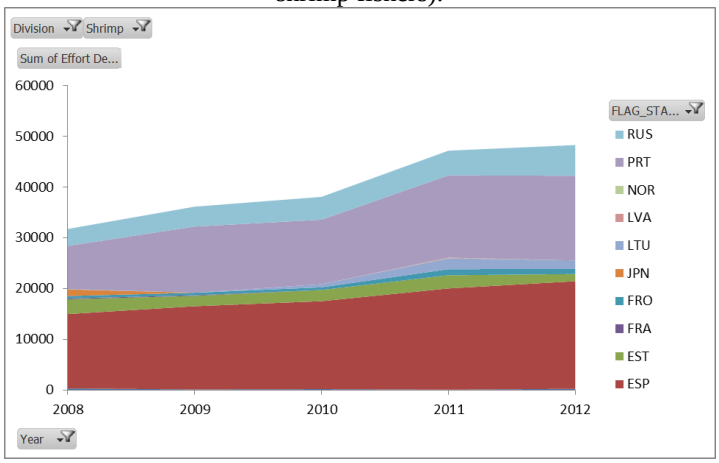

Figure 8. Effort (hours fished) by flag state at depths between 2J3KLMNO, 700 - 1600m, 2008 – 2012 (excluding shrimp fishers).

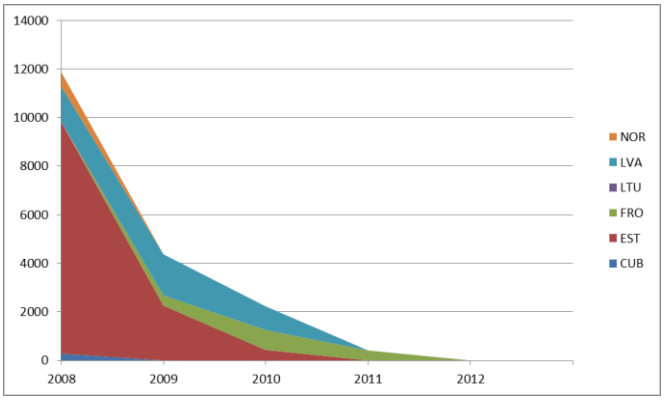

Figure 9. Effort (hours fished) by vessels targetting shrimp in Div. 3M

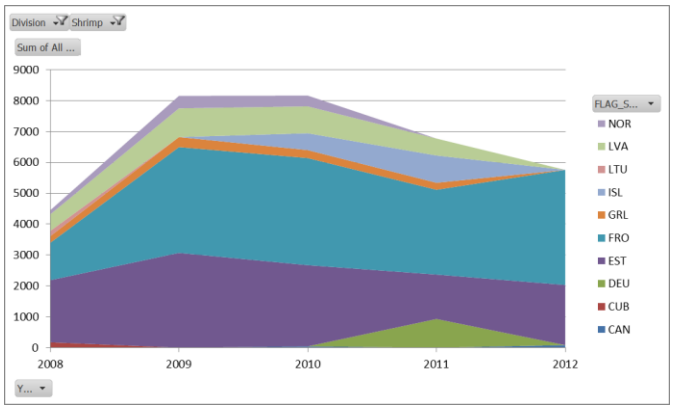

Figure 10. Effort (hours fished) by vessels targetting shrimp in Div. 3LN.

Discussion

This work presents Scientific Council with a flexible tool which can be used to assess trends in fishing effort against which variations in catches and stock abundance can be compared. Scientific Council is invited to explore this data and make recommendations to the Secretariat as to how its presentation can be improved to better suit their needs.

There are a number of caveats which need to be borne in mind when interpreting this data. Foremost is the fact that NAFO receives no VMS data from with the EEZs of Coastal States (other than from vessels steaming from the NAFO regulatory area to and from ports), therefore this method does not provide a complete picture of fisheries with a significant Canadian involvement.

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