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The Geographical Distribution of the High-Seas Commercial Greenland Halibut Fishery in the Northwest Atlantic

by

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Abstract

An analysis of the Greenland halibut fishery in the NAFO Regulatory Area (NRA) was undertaken using data provided through the Vessel Monitoring System (VMS). The fishery occupies distinct regions on the slopes of the nose and tail of the Grand Bank, with little indication of consistent spatial changes in the pattern of fishing among quarters or years. There is evidence that the effort has been reducing fairly steadily from 2003 to 2007. This is in line with the observed reduction in TAC.

Introduction

Recent developments using Vessel Monitoring Systems (VMS) allow for the improved monitoring of vessel activity in time and space. The potential uses of this geographical information for stock assessment and management are only just being realized. Information coming from the VMS data falls somewhat in between the traditional commercial catch (landings) sampling that has formed the basis of stock assessment for over 40 years, and the more modern approaches of co-management where stakeholders (Government, scientists, industry, conservationists, local community and fishers) share responsibilities.

The VMS data for vessels fishing in the NAFO Regulator Area (NRA) is held by the NFAO Secretariat, Dartmouth, Nova Scotia, Canada. Recent advances have allowed the NAFO Scientific Council to access summary VMS data in order to answer questions that will assist in the management of the fishery.

This paper details the seasonal fishing patterns of commercial fishing vessels targeting Greenland halibut in the NRA. The basic data is derived from locations transmitted by fishing vessels as part of the monitoring and surveillance protocols that have been in place since 2003. Using certain assumptions, it is possible to quantify when and where vessels are fishing, and to observe seasonal patterns and annual changes.

Materials and methods

The VMS data

Vessels within the NRA are required to automatically transmit their position at regular intervals since 2003. In January 2004, the reporting interval changed from every six hours to every two hours and has remained since at this interval. Manual transmissions every six hours are required in the event of a failure of the automatic transmission. A sudden and unexpected change to the transmission protocol occurred in the beginning of 2005 when the normal two hourly automatic transmissions failed and were replaced by six manual hourly transmission. This reduced both the quantity and quality of the information and took several months to fully rectify. For this reason, effort data for the first quarter of 2005, and perhaps the second quarter of 2005, may be both low and unreliable. VMS data for the final quarter of 2007 is not included in this report, as it was not available at the start of this analysis.

Each transmission contains the vessel call sign, latitude, longitude, and time, as well as certain other information not used in this analysis. This information is stored in a database held at the NAFO Secretariat. Vessel speed and direction are not forwarded to the NAFO Secretariat.

Data analysis

Transmission pair. It was necessary to work with successive pairs of transmission positions in order to calculate both vessel speed (to determine fishing activity) and transmission interval (to determine fishing effort).

Filtering criteria. Data was excluded from the analysis for the following reasons:

(1) transmissions had to satisfy the *a priori* condition of being consistent with the know depth range of the Greenland halibut fishery which is between 700 and 2000 m.

(2) Data was excluded from the analysis if the time between successive transmission, Δt_{2-1}, was <1 h and ≥7 h.

Fishing positions and time. The first of the pair of transmissions, satisfying the filtering criteria, was used as the vessel position and time of fishing.

Fishing depth. The General Bathymetric Chart of the Oceans (GEBCO) ocean floor provides depth data in a 1 minute latitude and 1 minute longitude grid (http://www.ngdc.noaa.gov/mgg/gebco/). The GEBCO depth nearest to a transmitted position was used to assign bottom depths to transmitted vessel locations.

Transmission interval. The time between two successive transmissions satisfying the filtering criteria, was called the transmission interval, $\Delta t_{2-1,n}$.

Speed. The start and end positions and transmission interval of the transmission pair were used to calculate average vessel speed between two successive transmission, s_{2-1}, from position and time information by triangulation using algorithms given in Williams (2008).

Vessel activity. A vessel was deemed to by fishing if its calculated speed was between 1.0 and 5.9 knots. The vessel was determined to be steaming when the speed was 6.0 knots and above. Speeds less than 1.0 knots can occur for a variety of reasons and the vessel was assumed to be inactive. Hence:

$$\begin{cases} s_{2-1}<1 & \text{vessel inactive,} \\ 1\leq s_{2-1}<6 & \text{vessel fishing,} \\ s_{2-1}\geq 6 & \text{vessel steaming.} \end{cases}$$

Unit area. The NRA was divided into squares of 1 minute latitude × 1 minute longitude. A vessel was deemed to be fishing in the 'unit area' when the fishing position fell within the boundaries of the unit area. At these latitudes, the area of the 'unit area' can be taken as 0.67 nm^2 (2.30 km^2).

Fishing effort. Effort was measured in two ways. *Days fished* was assessed by counting the number of days a vessel was in a particular area, with a day being identified as the occurrence of a single transmission pair in an area within a 24 hour period. This method is acceptable for large areas when vessels do not regularly cross the area boundaries. However, it can not be used for small areas owing to the large number of double counting that occurs.

For small areas, such as the minute squares, it is preferable to use the *number of hours* in the area. In some years, particularly 2003, transmission were often sent in manually at around six hourly intervals. And sometimes, transmission were made more frequently than the required two hour interval. The measure of effort used in each unit area was the summation of the time between successive transmission that satisfied the filtering criteria over some time period (year, quarter , *etc*.) is

$$T = \sum_{\text{all } n} \Delta t_{2-1,n}$$

where T is the total time in hours within an area, $\Delta t_{2-1,n}$ is the transmission interval in hours, and the subscript n refers to a transmission pair satisfying the filtering criteria. The number of points in each unit area is the total number of transmission pairs but is not a good estimator of effort, or even relative effort, because of differences in the transmission intervals.

Results

TAC and the number of vessels

The Greenland halibut TAC in Div 3klmno has been reduced from 31 122 t in 2003 to 11 856 t in 2007. This is part of the Greenland halibut rebuilding plan and aims to rebuild the stock. The number of vessels fishing for Greenland halibut in the NRA decreased from 80 in 2003 to 68 in 2004 following a 52% reduction in the TAC from 2003 to 2004. The number of vessels has been declining steadily since and is now around 47 (Table 1).

	2003	2004	2005	2006	2007
Number of vessels	80	68	58	49	47
TAC (NRA portion of 3klmno only)	31 122	14 820	14 079	13 709	11 856

Table 1. Number of vessels fishing in the NRA and allocated Total Allowable Catches (TAC) for 2003–2007.

The number of transmissions per unit area

The number of transmission pairs, *i.e.* the number of fishing positions, per unit area, is highly over-dispersed, with most of areas having little or no fishing (Fig. 1). The maximum number of positions in a 1 minute square in one quarter was 67. Fifty percent of the unit areas had only one fishing position, eighty percent had 5 or less fishing positions, and 90% had less than 10 fishing positions. Because of the over-dispersed nature, a few of the unit areas were very important, with 50% of the fishing positions occurring in only 9% of the unit areas, which was those unit areas having 10 or more fishing positions.

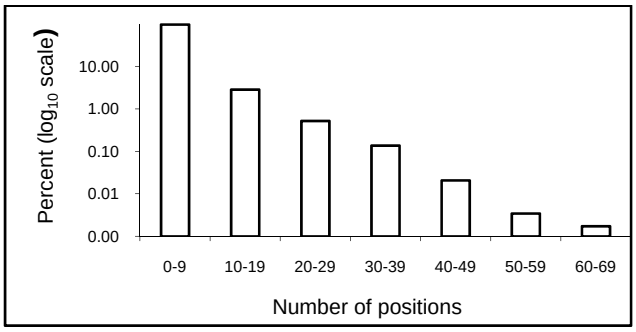

Fig. 1. Histogram of number of fishing locations per minute square showing $\log_{10}$ percent data.

Fishing depth

Fishing depths, or at least the depth of water at an identified fishing position, shows a bimodal distribution with median values in the 400–499 (Fig. 2, open bars) and 110-1 199 m (Fig. 2, closed bars) depth ranges. There is a marked trough between the two peaks at around 700 m, and this indicates that there is the potential to apportion the fishery to a shallow water fishery (0–700 m) and a deepwater fishery (700–2 000 m). The significance of the increased percentage fishing in the 100–199 depth range is not known and not relevant to this paper. The depth range of the deepwater fishery coincides with the known depth at which the Greenland halibut fishery operates and is the reason for the use of the 700–2 000 m depth range (W. Brodie, pers. comm.).

Spatial and temporal distribution of the deepwater fishery

The hours fished in each minute square ranged from zero to a maximum of 132 h (Fig. 3). Some 45% of all minute squares was 2 h, which arises because of the high number of squares with only one transmission pair and the 2 h

nominal transmission interval. A total of 12% of squares showed more than that 10 h fishing and only 1.4% had more than 30 h fishing.

Spatial and temporal trends are shown in Fig. 4. There is a clear high concentration of effort on the northeast side of the Grand Bank, with lesser concentrations at the southern end of the Flemish Pass and around the tail of the Grand Bank. There is a widespread background of fishing effort at around two h per square representing approximately one valid transmission

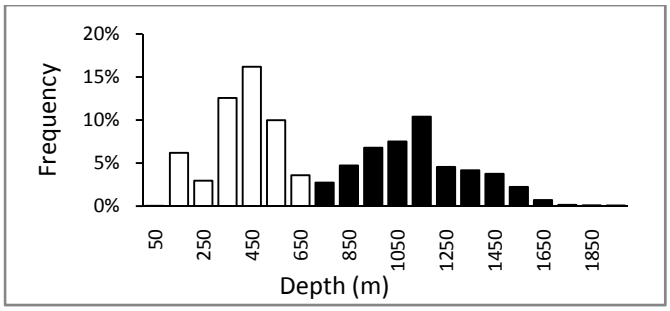

Fig. 2. Percentage of fishing activity by depth in the deepwater fishery in the NRA.

pair. It is difficult to judge the significance of these low level efforts. No clear trend could be identified in the spatial distribution of fishing effort. It would appear that there is less effort in the third quarter and that there has been a general decline in effort over the five years of VMS data.

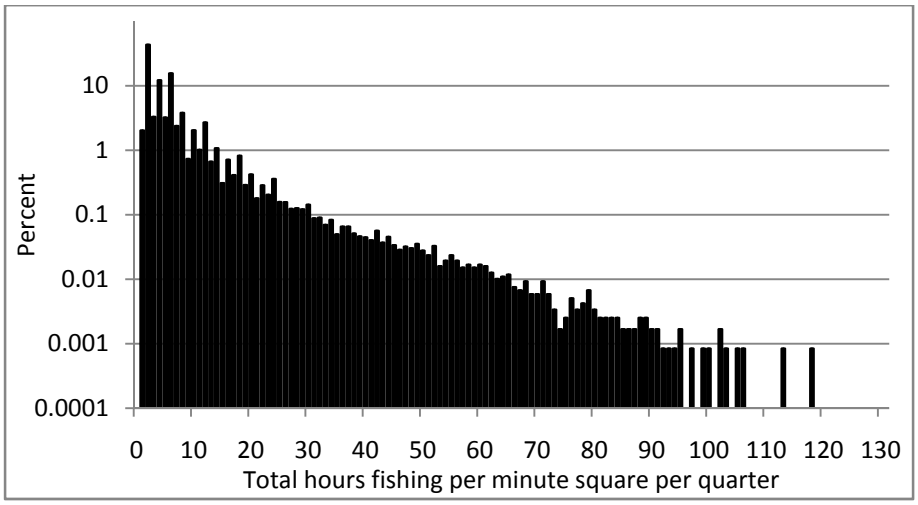

Fig. 3. Percent of allocation of fishing effort by quarter among the minute squares in the NRA.

Effort

Using the VMS transmission data, the total fishing days in the regulatory area ranged from 489 in the second quarter of 2005 up to 2 445 for the last quarter of 2003 (Table 2). The visual impression of a reduction of effort in the third quarter is partially confirmed, and the trend of a reduction in overall effort from 2003 to 2007 is clear. The total number of days fished in 2003 and 2004 was high at 8 118 and 7 072, respectively, and then it approximately halved in 2006 and 2007. The sudden drop in 2005 may have been exaggerated by a sudden and forced change in the reporting protocols.

Table 2. Fishing days in the NRA in the 700–2 000 m depth range by quarter in 2003–2007.

Year	Q1	Q2	Q3	Q4
2003	1954	1985	1734	2445
2004	2302	1967	1390	1413
2005	624	489	790	638
2006	1219	831	778	819
2007	993	844	415	

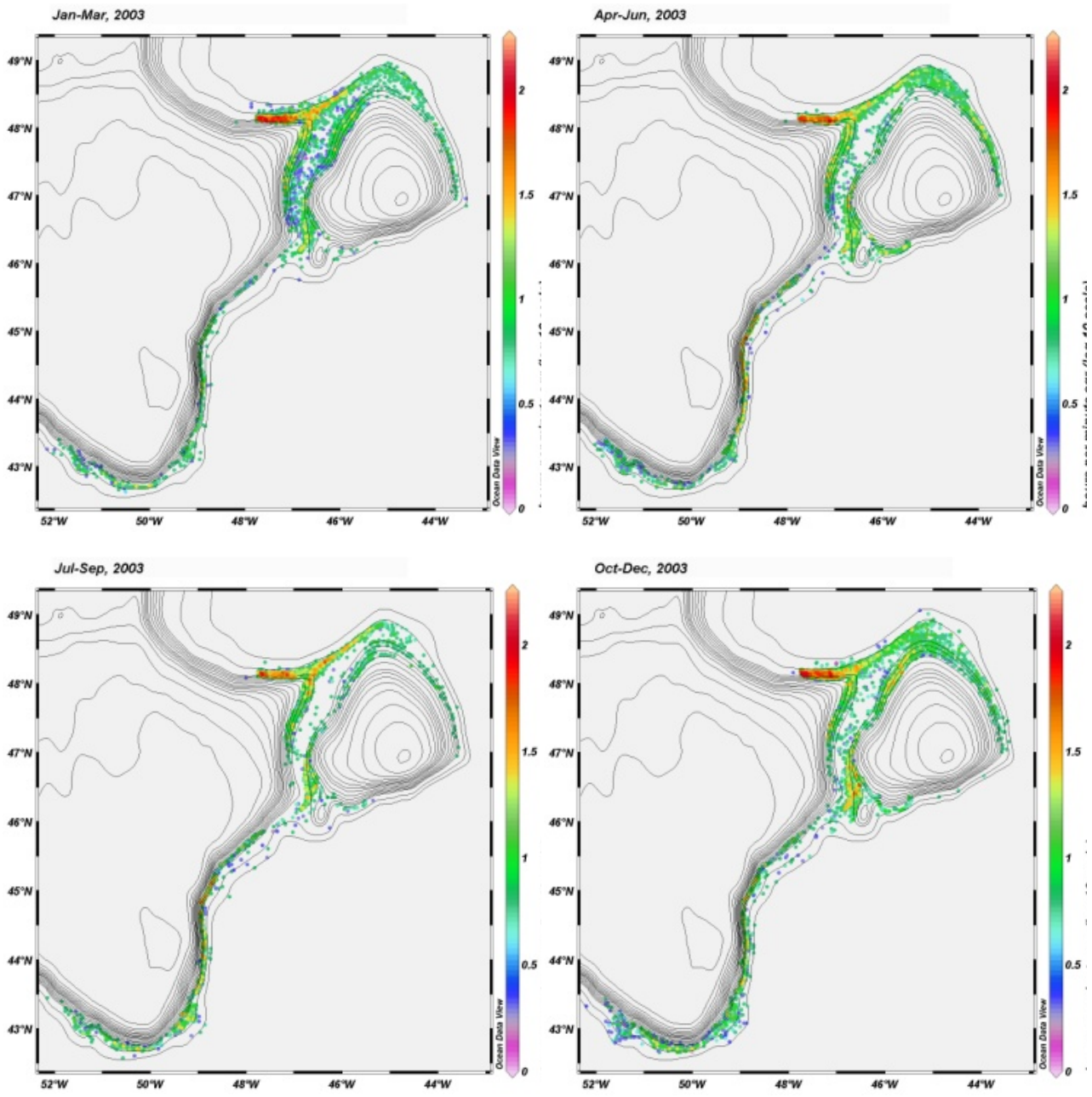

Fig. 4. (2003) Spatial distribution of fishing effort in the 700–2000 m depth zone in the NRA from 2003–2007. The scale represents the logarithm of the number of hours fished per minute square per quarter.

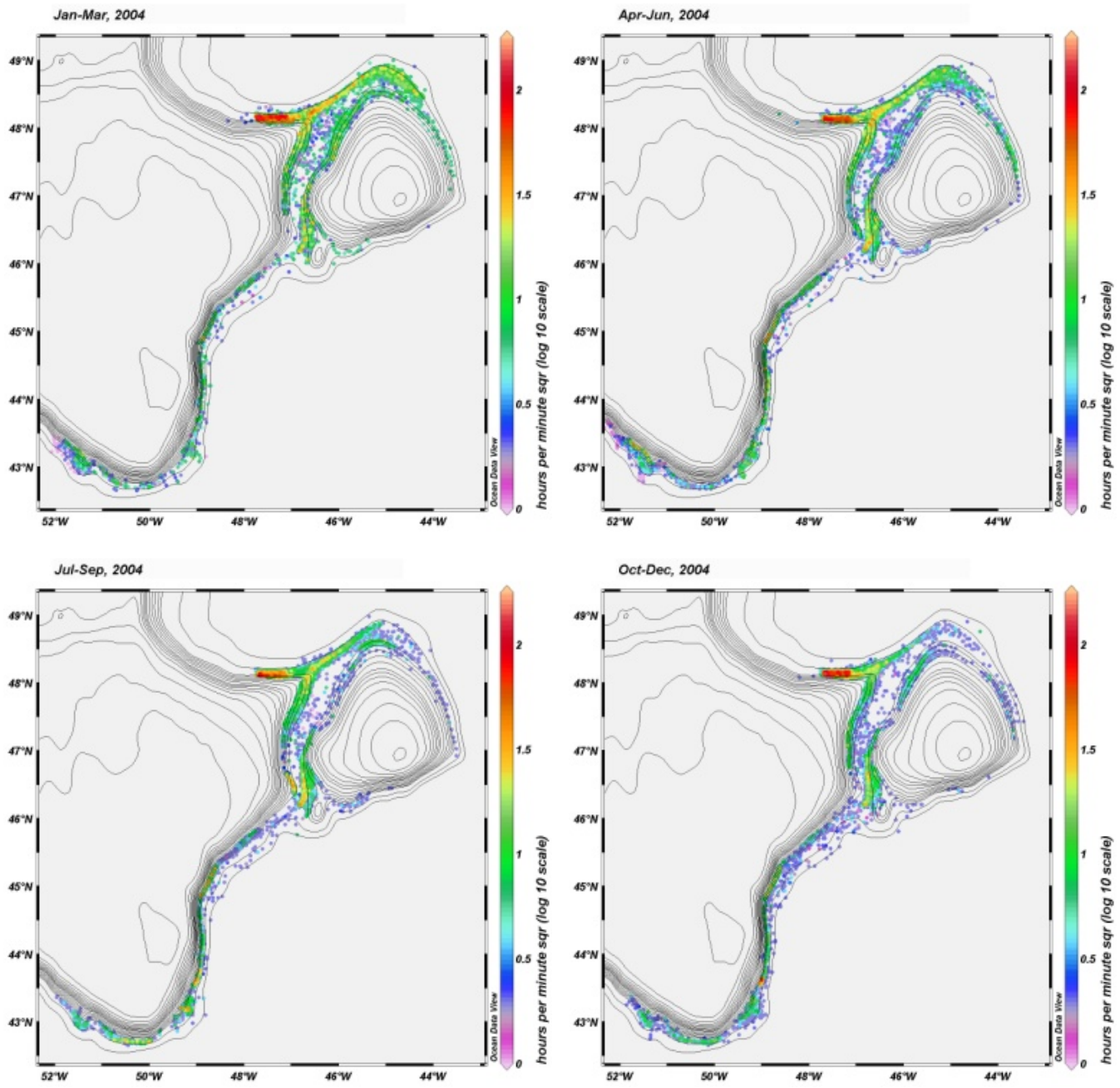
Jan-Mar, 2004
Apr-Jun, 2004
Jul-Sep, 2004
Oct-Dec, 2004
49°N
48°N
47°N
46°N
45°N
44°N
43°N
52°W
50°W
48°W
46°W
44°W
2
1.5
1
0.5
0
hours per minute sqr (log 10 scale)
Ocean Data View

Fig. 4. 2004.

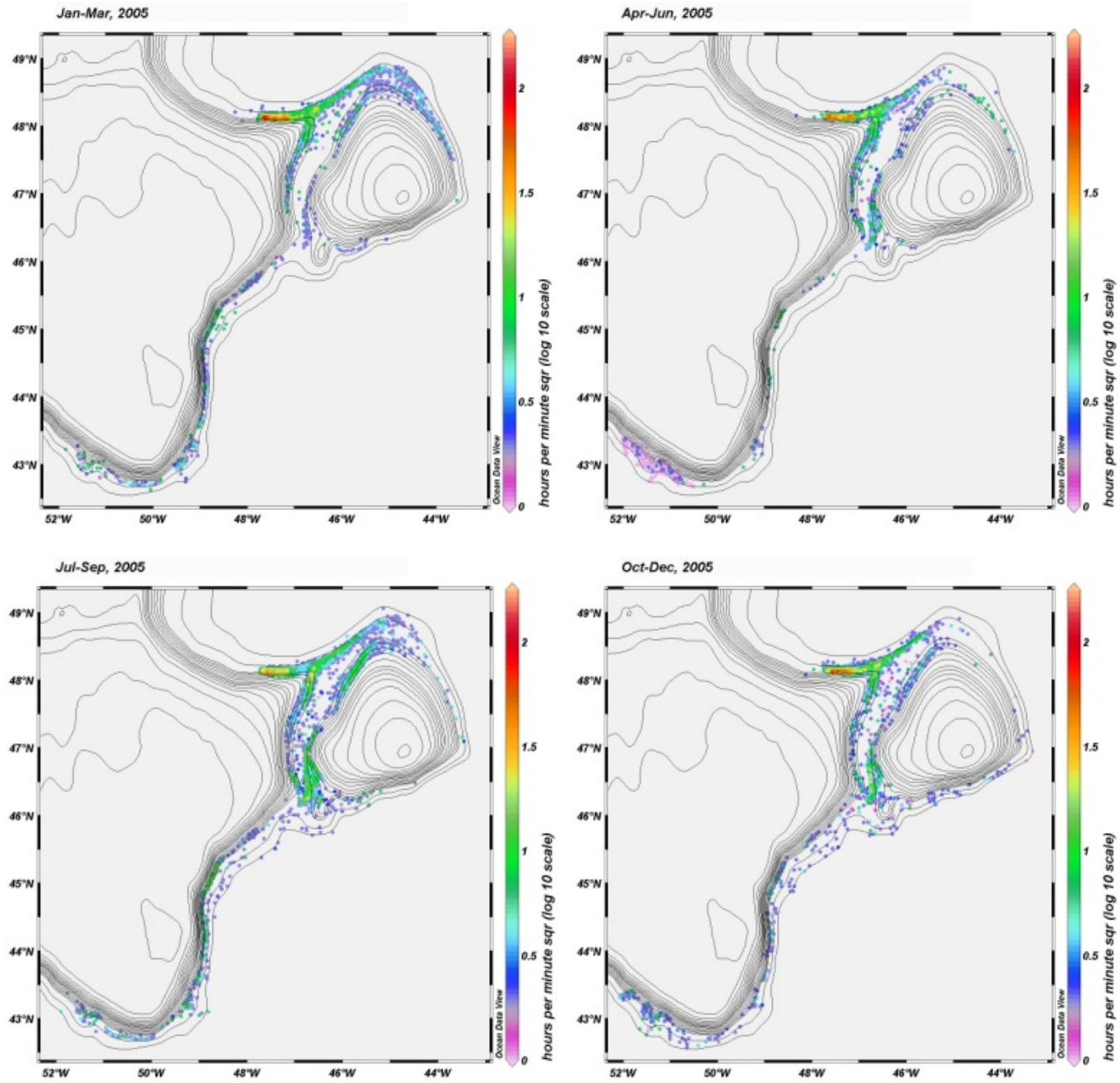
Jan-Mar, 2005
Apr-Jun, 2005
Jul-Sep, 2005
Oct-Dec, 2005
49°N
48°N
47°N
46°N
45°N
44°N
43°N
52°W
50°W
48°W
46°W
44°W
2
1.5
1
0.5
0
hours per minute sqr (log 10 scale)
Ocean Data View

Fig. 4. 2005.

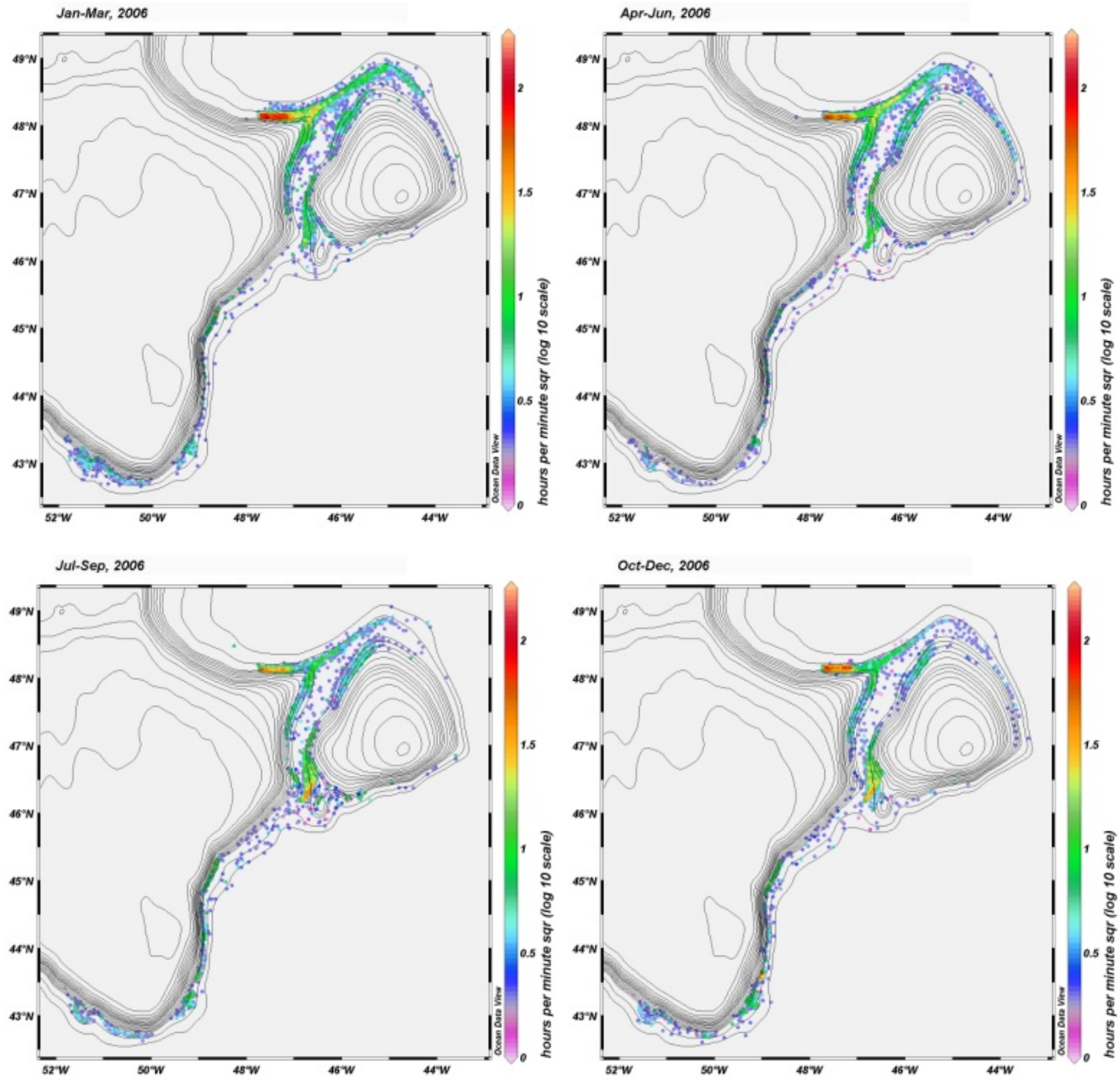
Jan-Mar, 2006
Apr-Jun, 2006
Jul-Sep, 2006
Oct-Dec, 2006
49°N
48°N
47°N
46°N
45°N
44°N
43°N
52°W
50°W
48°W
46°W
44°W
2
1.5
1
0.5
0
hours per minute sqr (log 10 scale)
Ocean Data View

Fig. 4. 2006.

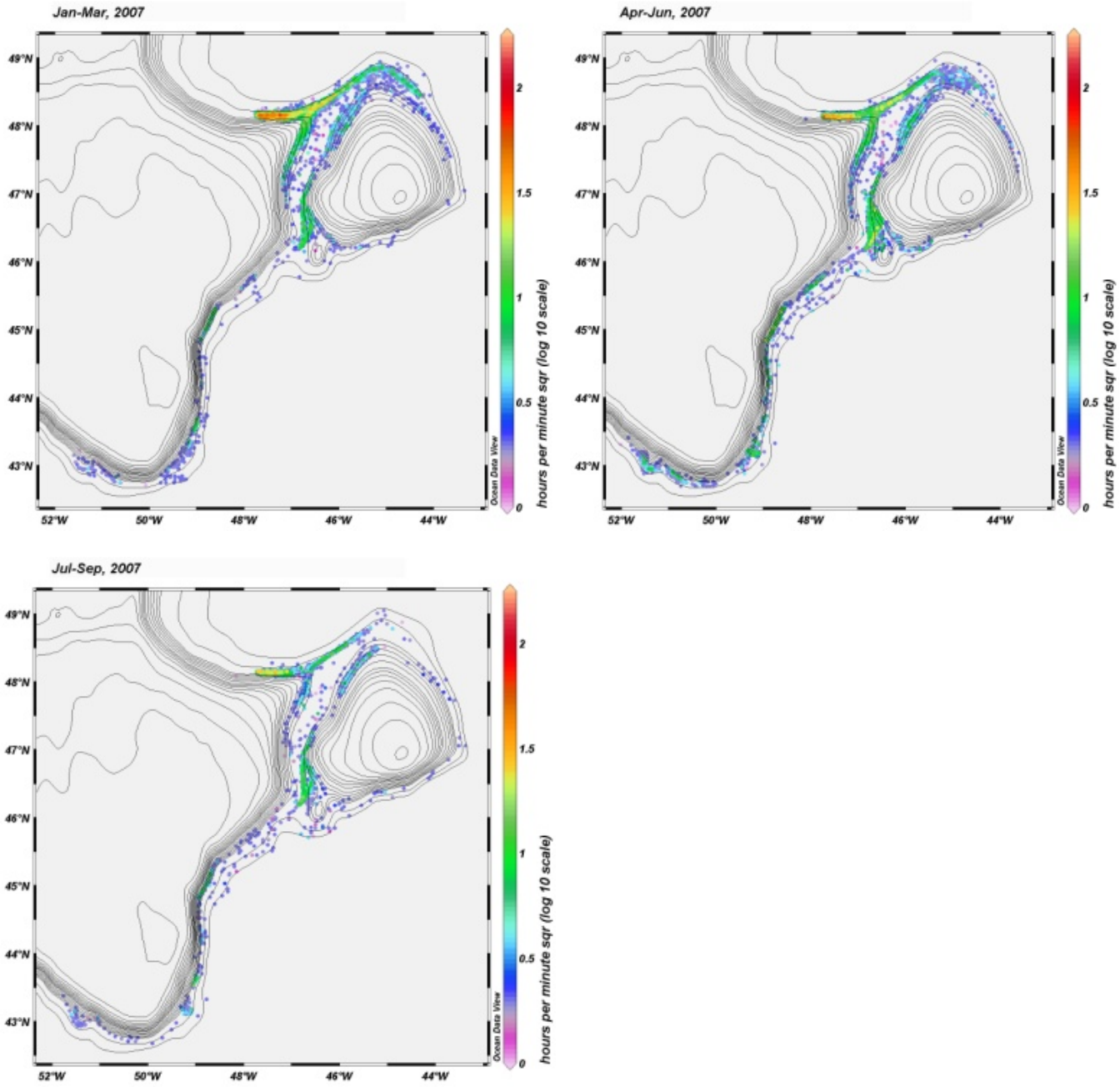
Jan-Mar, 2007
Apr-Jun, 2007
Jul-Sep, 2007
49°N
48°N
47°N
46°N
45°N
44°N
43°N
52°W
50°W
48°W
46°W
44°W
2
1.5
1
0.5
0
hours per minute sqr (log 10 scale)
Ocean Data View

Fig. 4. 2007.

An estimation of the total hours fished in the NRA, using the summed transmission intervals, shows very similar trends to that seen for days fished. In general, the hours fished is 60–80% of the days fished value (assuming we can multiply the days fished by 24 to get hours). The main reasons for the discrepancy is that many transmissions fail to satisfy the filtering criteria because vessels are constantly moving in and out of the 700-2000 m depth zone (Table 3).

Table 3. Hours fished in the NRA in the 700–2 000 m depth range by quarter in 2003–2007.

Year	Q1	Q2	Q3	Q4
2003	31316	31081	26199	38705
2004	38821	34129	25700	24614
2005	11218	8556	12884	9465
2006	21596	16033	12665	14748
2007	16784	14574	6118	

Discussion

This paper presented information derived from VMS transmissions in the NRA. It is generally assumed that the deepwater fishery mainly centers around Greenland halibut, with the other deepwater fisheries, *e.g.* for grenadiers, being relatively minor. At present, it is not easily feasible to directly analyze the VMS data by target fishery. This could be undertaken, to some extent, using observer, COE/COX and port inspection reports.

A comparison with the STATLANT 21B database has not been presented here owing to issues arising from the identification and reporting of target species. Effort is reported by target species, and target species is defined in the CEM as the species comprising over 50% of the catch. Almost half of the landed Greenland halibut reported in STATLANT 21B came from reports that identified the target species as something other than Greenland halibut. This procedure follows the reporting guidelines, but means that an analysis of Greenland halibut effort is not easy to obtain *via* STATLANT 21B, because effort for Greenland halibut is only reported against Greenland halibut identified as the target species. This was not investigated further in this paper, as an analysis of STATLANT falls outside of the intention of the paper.

References

Williams, E. 2008. Aviation formulary V1.43. http://williams.best.vwh.net/avform.htm#Example. Viewed 16 January 2008.