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Exploring Relationships Between Bottom Temperatures and Spatial and Temporal Patterns in the Canadian Fishery for Yellowtail Flounder on the Grand Bank

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Abstract

Temperature data from data storage tags on yellowtail flounder and an oceanographic mooring site in NAFO Division 3N were analyzed for the period, June 2003 to November 2004 for seasonal trends. Seasonal trends in the Canadian fishery for yellowtail flounder were also examined for the same time period. An overlay of temperatures and catch rates (CPUE) suggests a temperature trend in catch rates.

Introduction

The current Canadian fishery for yellowtail flounder (Fig. 1) on the Grand Bank, NAFO Div. 3LNO, is mainly prosecuted by one company which is traditionally allocated 90% of the Canadian quota (14 135 t for 2003-2004). This otter trawl fishery has 100% observer coverage until mid-2004 and is conducted during each month with the exception of spawning time: mid-June to the end of July. Much information is collected from each fishing haul including date, position, catch, effort and depth. Catches of 1 t/hr are not uncommon and average haul duration is around 2.5 hrs (13.9 km) (Brodie and Kulka, 2004). Although fishery data are often considered biased, they may be a source of information on population densities and habitat whose location may vary in time and space in response to environmental variables (see for example Miyahara *et al.*, 2005; Igashov *et al*., 2005).

In 2000 the Department of Fisheries and Oceans, Northwest Atlantic Fisheries Centre in St. John's in cooperation with a local fish company, Fishery Products International Ltd, began a 5 year tagging program using Peterson discs (2000-2004) and electronic (archival) data storage tags (DSTs) (2001-2003) (see Walsh and Morgan, 2004; Walsh *et al*., 2006). The DSTs were used to monitor natural behaviour of adult yellowtail flounder (*Limanda ferruginea*) in relation to depth, temperature, time of day and season. Over a three year period, a total of 932 fish tagged with DSTs were released during June. Using data from 29 tags from the 2001-2002 tagging period Walsh and Morgan (2004) reported that yellowtail flounder exhibit diel and seasonal variations in depth and temperature and for the first time in this species, showed that during various times of the year, yellowtail flounder make extensive off-bottom movements at night and can remain off-bottom for several hours. Since then additional tags have been returned.

Traditionally the only source of annual data on temperature and depth distribution of yellowtail flounder on the Grand Bank has been derived from annual spring and fall Canadian bottom trawl surveys (see for example Simpson and Walsh, 2004 and Colbourne and Walsh, 2006). In this paper we explore a variety of sources of temperature data to see if we could relate temporal and spatial shifts in the fishery pattern data with temperature. The objective in using catch statistics from the fishery is to try to understand spatial changes in the population in other non-survey time period.

Materials and Methods

We investigated whether seasonal changes in habitat of yellowtail flounder could be detected using: 1) the NAFC fishery observer database and 2) bottom temperatures from three different sources: a) archival electronic data storage tags (DSTs) (June 2003-October 2004) attached to yellowtail flounder, b) DST s attached to an oceanographic mooring (deployed in Div. 3N from November 2003-November 2004, and c) the 2003 and 2004 spring (May and June) and fall (October and November) NAFC bottom trawl surveys.

Star Oddi DST milli tags, capable of recording depth and temperature, were attached to 389 yellowtail flounder in June 2003 (Fig. 2) of which 15/38 returns were at liberty longer than 6 months (see Walsh *et al.*, 2006, for details). Details on deployment, rigging (Fig. 3) and retrieval of the bottom oceanographic mooring site in Div. 3N can be found in Han *et al.* (2006). Six Star Oddi DST milli tags were also attached to the mooring to estimate their accuracy when compared to other temperature recording devices on the mooring. The mooring location in Div. 3N is seen in Fig. 1.

Results and Discussion

Fishery

Most of the catches taken in the study period, May[1] 2003-November 2004 were found mainly in the southern Grand Bank, Div. 3NO. High catches came from the Southeast Shoal area and an area on the Div. 3LN border north of the Mooring site (Fig. 1). The monthly catch and effort is shown for the time period to give a overview of trends in the fishery with both catch and effort highest in the fall of 2003 decreasing through the winter of 2004 and higher in the spring of 2004 (Fig. 4).

Trends in depth and the fishery

The June 2003-November 2004 fishery occurred at bottom depths ranging from 40- 86 m. There was an apparent seasonal shift in the average depths fished becoming shallower over time from summer of 2003 (66 m) to winter of 2004 (46 m) before again increasing to a high (65-72 m) in early summer–fall period (Fig. 5). Catch rates (CPUE) peaked January 2004 and remained fairly stable thereafter till June when the fishery was mainly in shallow depths (<55 m) with a slight downward trend in the fall of both 2003 and 2004 when the fishery was in relatively deeper waters.

Trends in temperature and the fishery

Survey temperatures

Fishery catches overlaid on survey bottom temperatures for both the spring and fall of 2003 and 2004 showed that the highest catches were taken mainly in the warmer areas of the southern Grand Bank where bottom temperatures were generally between 2-3.5°C (Fig. 6). Yellowtail catches were lower in colder (<0°C) temperature areas. This agrees with the findings of Colbourne and Walsh (2006) for survey yellowtail flounder CPUE which indicated that although yellowtail flounder can occupy a wide range of temperatures, they may have a preferred range of temperatures.

DST Temperatures

The 10 release sites and 15 recapture sites for the 15 DSTs associated with the study period are plotted in Fig. 7. Figure 7 shows that 4/10 release sites were north of 45°, 3 /10 on the Southeast Shoal and 3/10 adjacent to the shoal. With the exception of 1/15 tags, the rest of the DSTs were returned from the fishery on or adjacent to the Southeast Shoal.

[1] May 2003 fishery is added to data here because the fishery generally ceases mid June and it is meant to add information to the spatial pattern, with the exception of Fig. 1 and 6, it does not enter into any other analyses.

Mooring DST data

Temperature data from one of the DST tags attached to the oceanographic mooring show wide fluctuations in daily bottom temperatures at the mooring site during its deployment, November 2003 to November 2004 (Fig. 8). High temperatures (~2.5^{0}C) were recorded during December of 2003 which decreased gradually during the winter of 2004, peaked again to 2.7^{0}C during June and, with some variation, showed a decreasing trend to October when temperatures were below -0.5^{0}C and then increased upward in November. This time series agrees with the temperature profile given by the CTD sensor attached to the mooring and highlights some of the episodic events in temperature in that area of the bank (Han et al. 2006).

The Mooring DSTs showed that average temperatures peaked in December 2003 (1.64°C) and decreased to a low of 0.95°C in March 2004 followed by the highest peak in the series at 2.38°C in May (Fig. 9). From June to November there was a steady decline in average bottom temperatures to a low of -0.31°C in October. Analysis of the CPUE and temperature data showed that, with the exception of May, from November 2003 to April 2004 and August to November, 2004 there appears to be a trend for catch rates to fluctuate in the same direction as temperature.

Fish DST data

Monthly trends in the average depth and temperature occupied by the 15 yellowtail flounder with DSTs returned in the fishery are presented in Fig. 10. No attempt has been made to remove the off-bottom signal in both depth and temperature that characterize some of these fish at various times of the year (Walsh *et al*., 2006). Here the time series is longer than the Mooring data and covers the entire study period June 2003 to October 2004. After the initial decline in average bottom depth from June to October 2003, there was little variability from November 2003 to October 2004. Depths less than 55 m would indicate residence on the Southeast Shoal. Average temperatures steadily increased from September 2003 to a peak of 4.89°C in December, decreasing during the winter-spring months to around 2.3°C but gradually increasing to a peak of 5.15°C in October 2004.

The relationship between the DST Fish data and the fishery indicates that a similar pattern of temperature and CPUE fluctuate in the same direction from June 2003 to March 2004 (Fig. 11). However from April to October there is a tendency for the trend to be the inverse of that seen earlier.

Noteworthy is that the Fish DST temperatures and the Mooring DST temperatures show a similar trend from November 2003 to May 2004 but from June to October both temperature series show an opposite trend (Fig. 12). The spatial pattern in the fishery during the fall of 2004 showed fishery catches at that time were southeast of the mooring site where bottom temperatures were in the 1-3.5°C range (see Fig. 6). The area of cold bottom (<0°C) temperatures where the mooring was located is evident in October-November survey temperature overlay and although there was some indication of a small amount of survey catches in this cold water in November of 2004 (Colbourne and Walsh, 2006) no fishing effort was directed in that area at the time. The mooring temperature data is probably a reflection of the oceanographic regime in that particular area of the bank while the fish are sampling temperatures over a broader area of the bank probably farther south including some off-bottom temperatures.

Trends in the spatial patterns in the fishery

The catches were distributed widely across the southern Grand Bank, mostly in NAFO Div. 3NO, during the months of May to November (Fig. 13). When the American plaice by-catch becomes a problem in the yellowtail fishery the fleet fishes further north as typical of the August 2003 pattern. During the months of December to April, the highest catches were localized mainly to Div. 3N around the Southeast Shoal area where bottom depths range from 40 to 55 m. It was during the winter time period that both catches and effort were the lowest in the time series (Fig. 4). The fishery was in shallow water (average depths <55 m; Fig. 5), but the CPUE was the highest and showed a declining trend with average bottom temperatures in both the Mooring and Fish temperature data for that time period (see Fig. 9 and 11).

Brodie and Walsh (2006) reported that between 22 to 40% of the observed aggregated catches in the 2000-2005 fishery by the Canadian fleets was localized to the western edge of the northern section of the Southeast Shoal similar to that observed in January 2004 (Fig. 13). Localization of high densities of yellowtail flounder survey catches in this area were also evident in the joint 1997 winter DFO-Industry grid survey in March (Fig. 14) where bottom temperatures were 1°C . Catch rates of yellowtail in the grid surveys during the March months of 1997-1999 were always 2 to 6 times lower than the following May surveys in the same years (Maddock-Parsons *et al*., 2000).

Summary

Several patterns emerge in the analysis of the Canadian fleet fishery for yellowtail flounder on the Grand Bank. There appears to be a seasonal trend in depths fished by the Canadian fleet in the 2003-2004 fishery, with shallower depths being fished during the winter months when compared to the rest of the year. Catch rates are highest at these shallower depths and the fishery is mainly concentrated on or adjacent to the Southeast Shoal.

There is a general temperature trend for higher yellowtail flounder fishery catches to be taken in warm rather than cold sub-Arctic waters as was evident in annual spring and fall survey catches (Colbourne and Walsh 2006). There is also an apparent temperature trend in fishery catch rates with both signals moving in the same direction in the Mooring data and to some extent in the Fish data. Colbourne and Walsh (2006) analysis of 1990-2005 spring and fall survey catch rates also found a similar signal and suggested a temperature dependent catchability as one possible conclusion.

There are three spatial patterns in the fishery. A similar spring and fall pattern of wide spread effort and catches across Div. 3NO; a summer pattern, from June to September, with the southern range of fishing protracted because of the plaice by-catch issue and more effort is seen further north; and a December to April pattern where most of the effort and catches are restricted to the area of the Southeast Shoal. The western side of the Southeast Shoal area appears to be an area providing good catches at all times of the year and possibly the only area during the winter months. The significance of the winter fishery pattern is unclear but Canadian fishing skippers have mentioned that this is the only area where any high catches are found on the bank.

This paper represents the first approach in exploring patterns in temporal and spatial shifts in the fishery and catch rates with independent measures of temperature with some encouraging results. It is noteworthy that many non-environmental factors can influence fishing patterns and catch rates including market demands, fuel costs, plaice by-catch, fish size, and experience of the fishing skippers. In addition, most of the 15 DST fish were caught in the Southeast Shoal area whose data like that of the mooring may represent only what part of the population is experiencing. Also the DST fish data is contaminated with off-bottom depths and temperatures associated with vertical movements which need to be removed and the averages re-calculated to see if the signals of temperature and catch rates are more or less aligned. Further investigations will continue.

Acknowledgements

Thanks to E. Colbourne for use of survey temperature overlays and J. Morgan for summary statistics for DST tags. The DST data used in this analysis came from a joint funded 2000-2004 DFO/Fishery Products International Ltd. Project tagging project.

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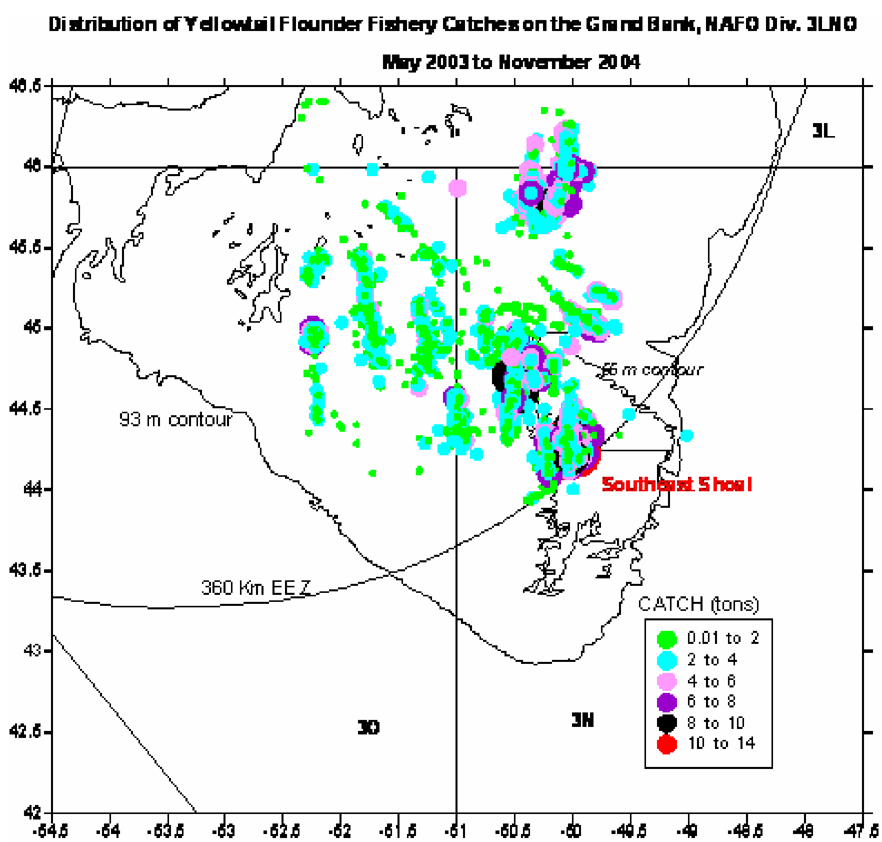

Fig. 1. Spatial pattern in catches of yellowtail in the May 2003-November 2004 fishery

Fig. 2. DST tag attachment site on yellowtail flounder along with a Peterson Disc.

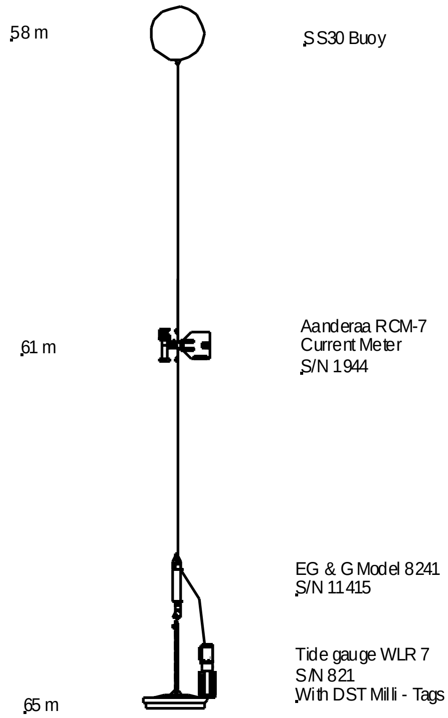

Fig. 3. Mooring layout for deployment in Division 3N showing the current meter, tidal gauge and DST tag locations relative to the bottom.

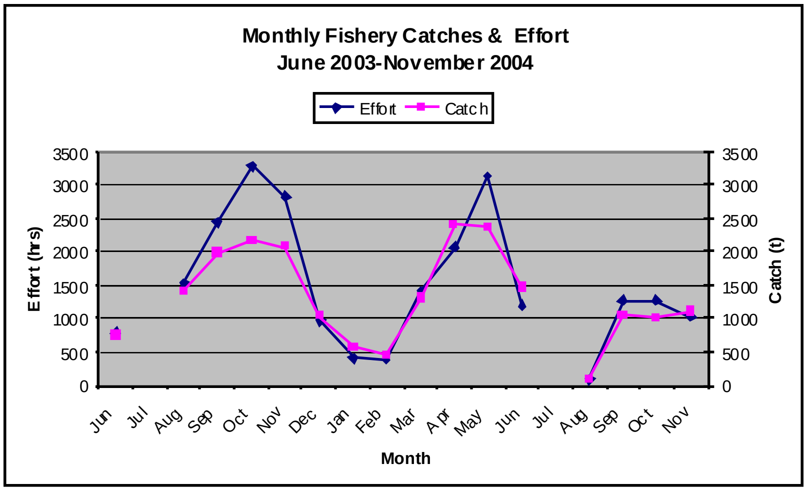

Fig 4. Temporal changes in catch and effort in the Canadian fishery for yellowtail flounder from June 2003 to November 2004.

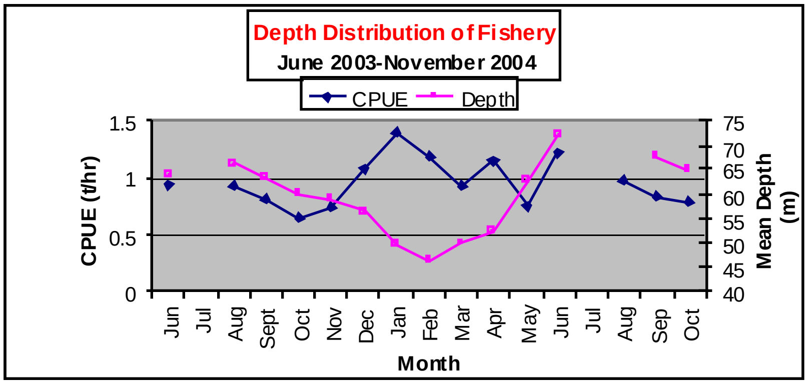

Fig 5. Temporal changes in CPUE and the depth of the fishery for yellowtail flounder during study period from June 2003 to November 2004.

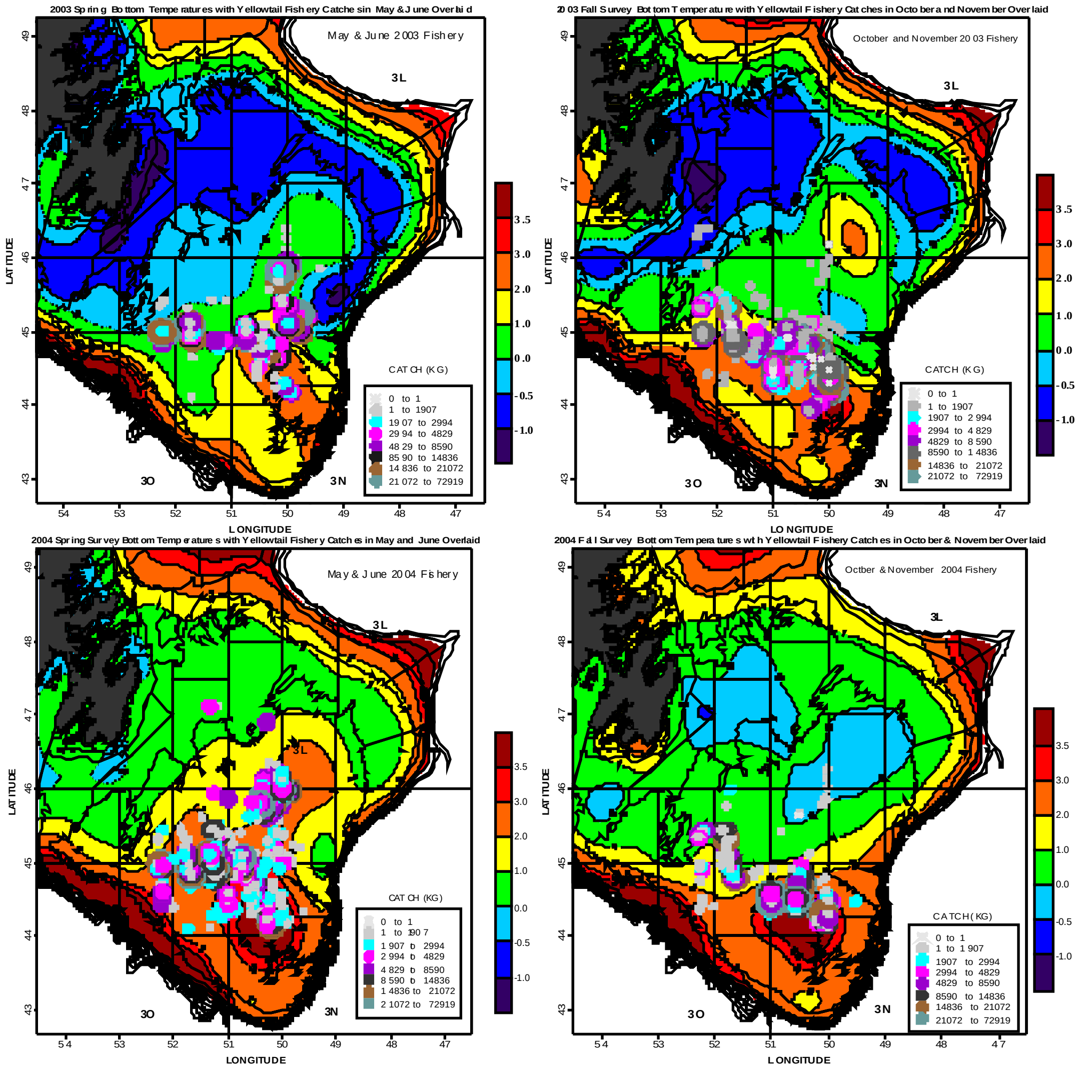

Fig. 6. Spatial pattern of the fishery and temperature field in 2003 and 2004 during the spring and fall surveys.

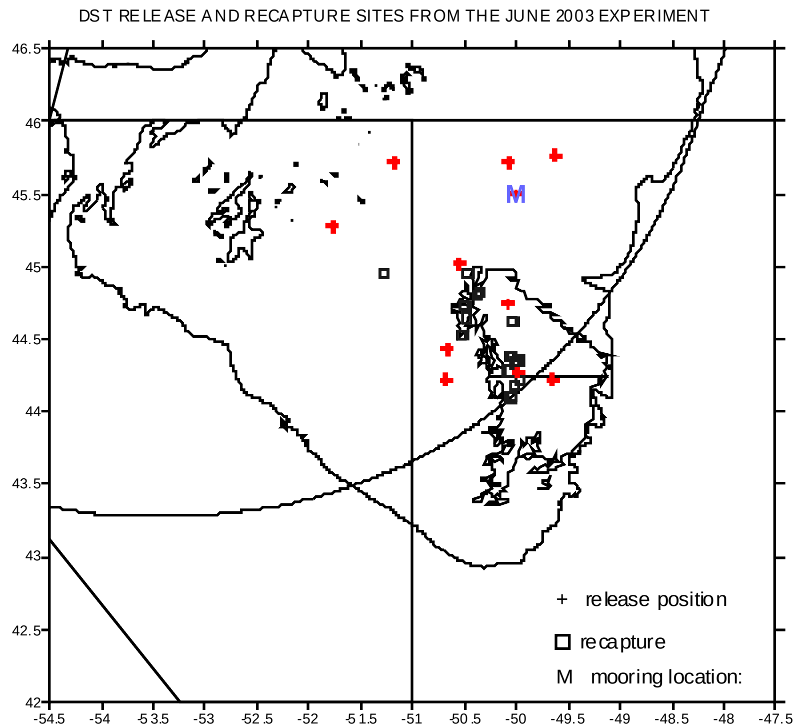

Fig. 7. Release and recapture sites for 15 data storage tags released on yellowtail flounder in June 2003, and the location of the oceanographic bottom mooring (M) in Div. 3N.

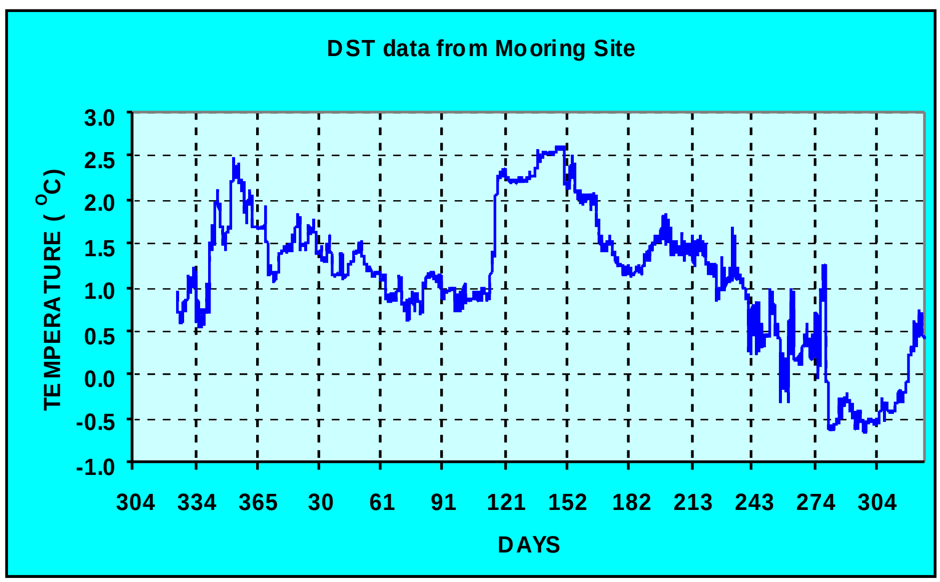

Fig. 8. Temperature data from a DST tag attached to the oceanographic mooring in Div. 3N.

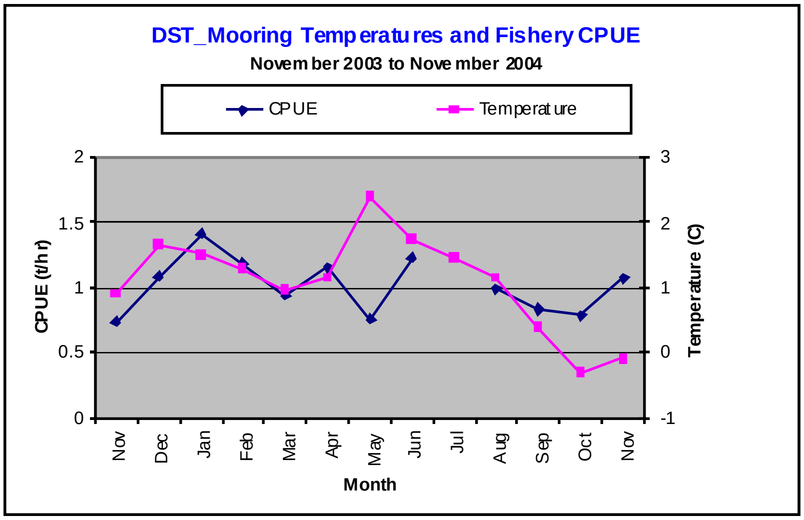

Fig. 9. Tends in the fishery catch rates (CPUE) and temperature data from the data storage tag attached to the oceanographic mooring in NAFO Division 3N.

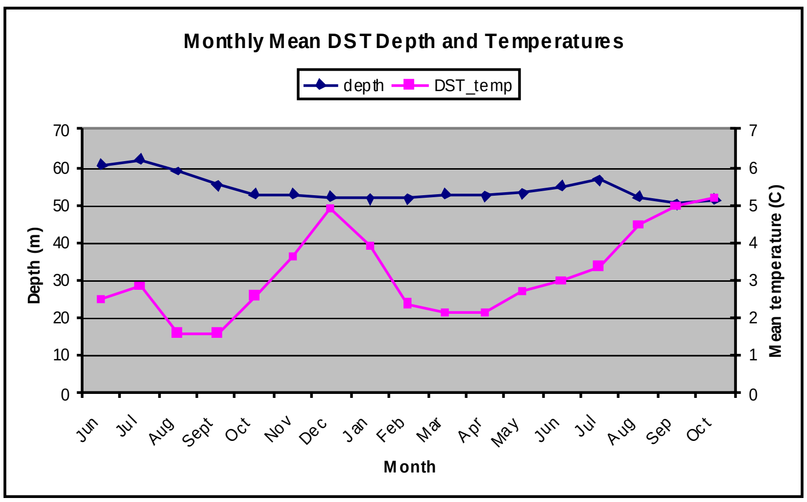

Fig 10. Monthly trends in the mean depth and temperature of 15 DST tagged fish.

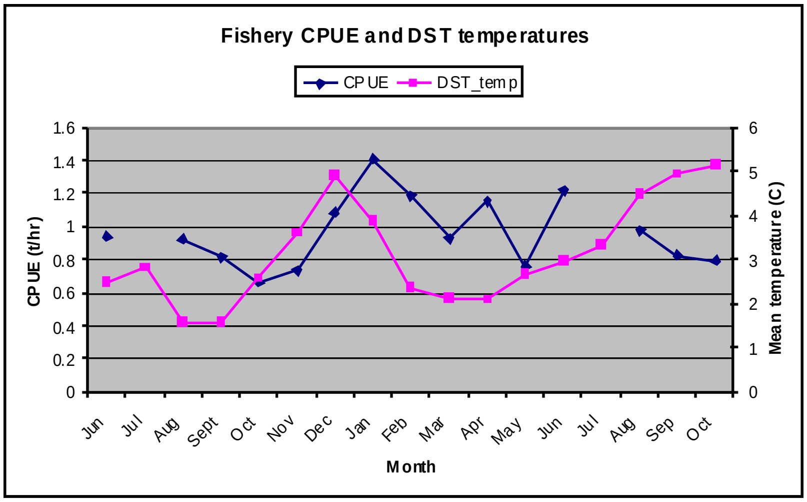

Fig. 11. Trends in fishery CPUE and average bottom temperatures from 15 DST yellowtail flounder for the period June 2003 to November 2004

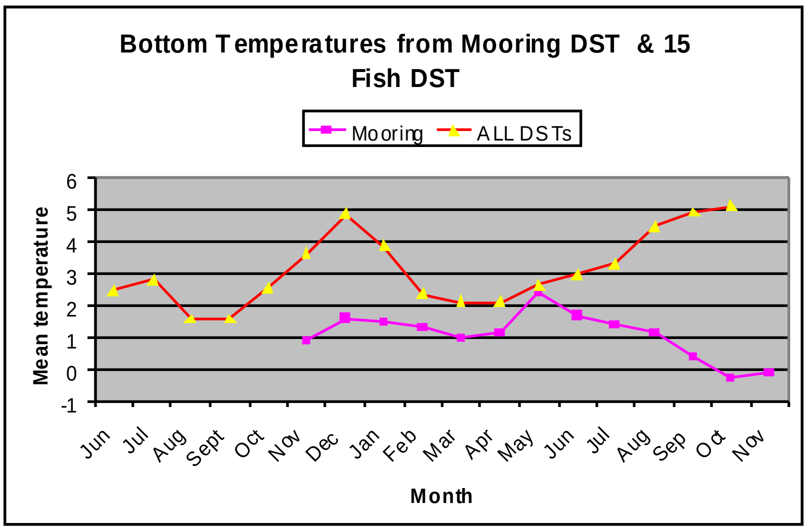

Fig. 12. Comparison of the trends in average bottom temperatures from the DST Mooring site and 15 returned DST yellowtail flounder for the period June 2003 to November 2004.

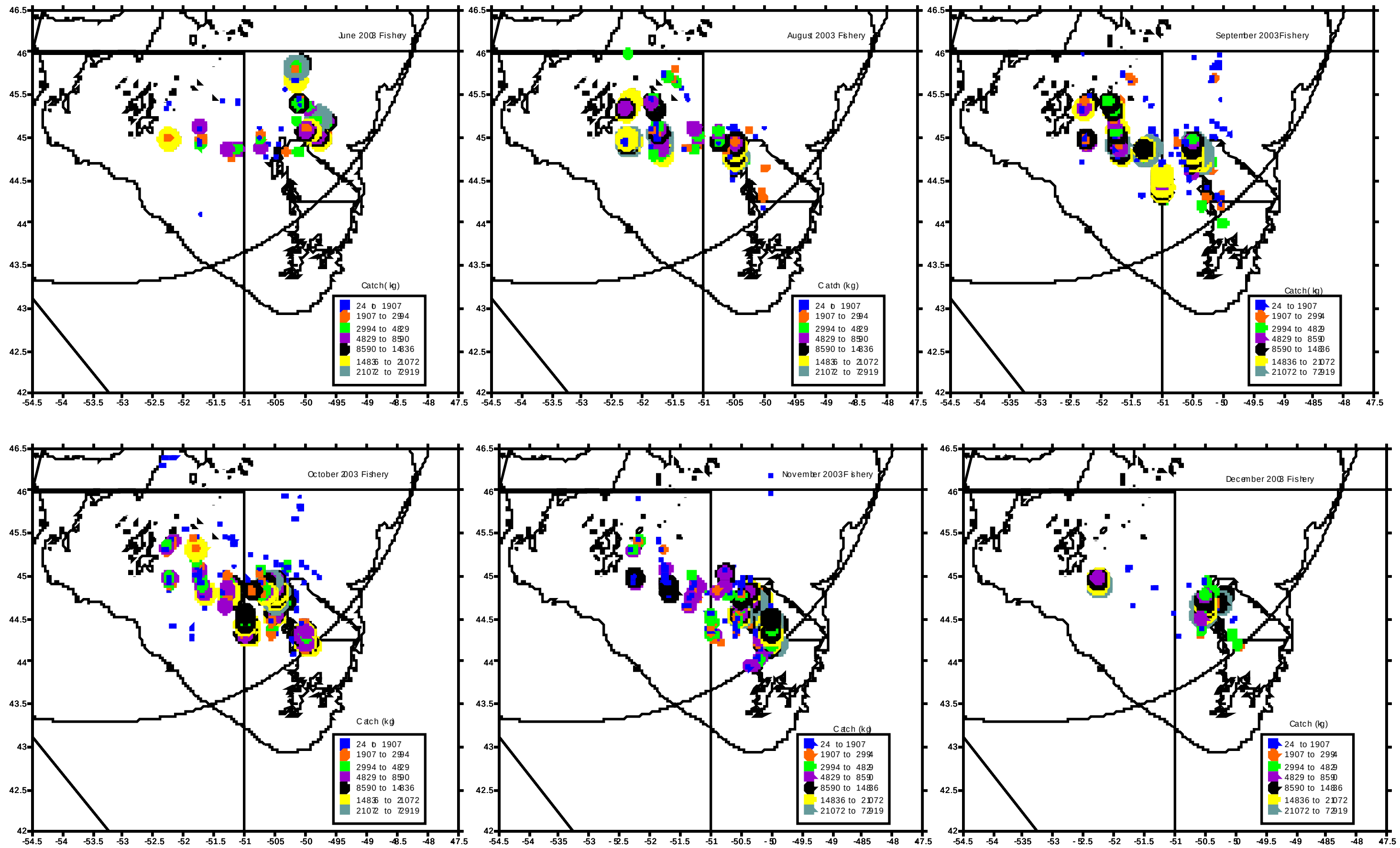

Fig. 13. Spatial pattern in the Canadian fishery catches (kg) of yellowtail flounder from June 2003 to November 2004.

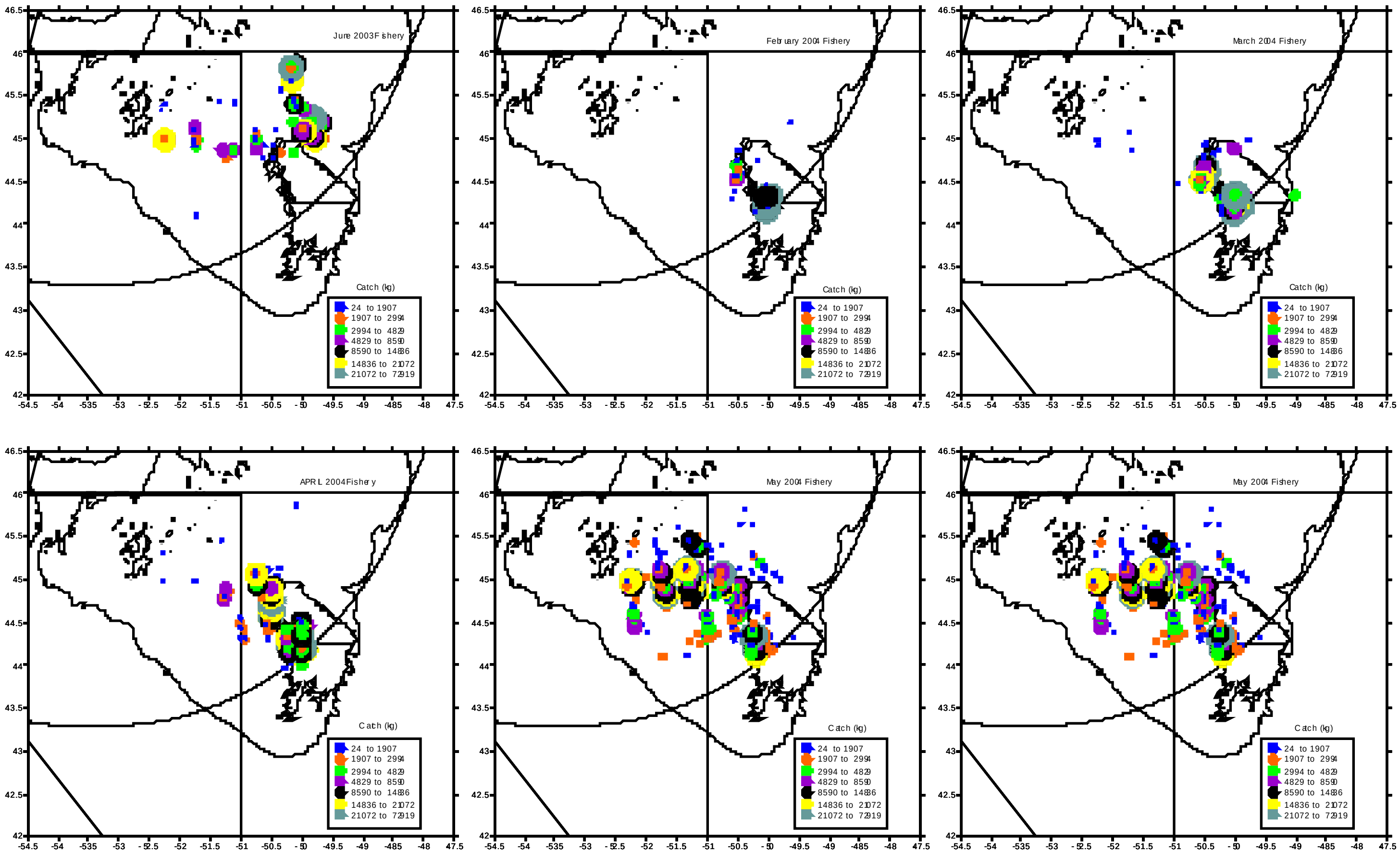

Fig. 13. (continued) Spatial pattern in the Canadian fishery catches (kg) of yellowtail flounder from June 2003 to November 2004.

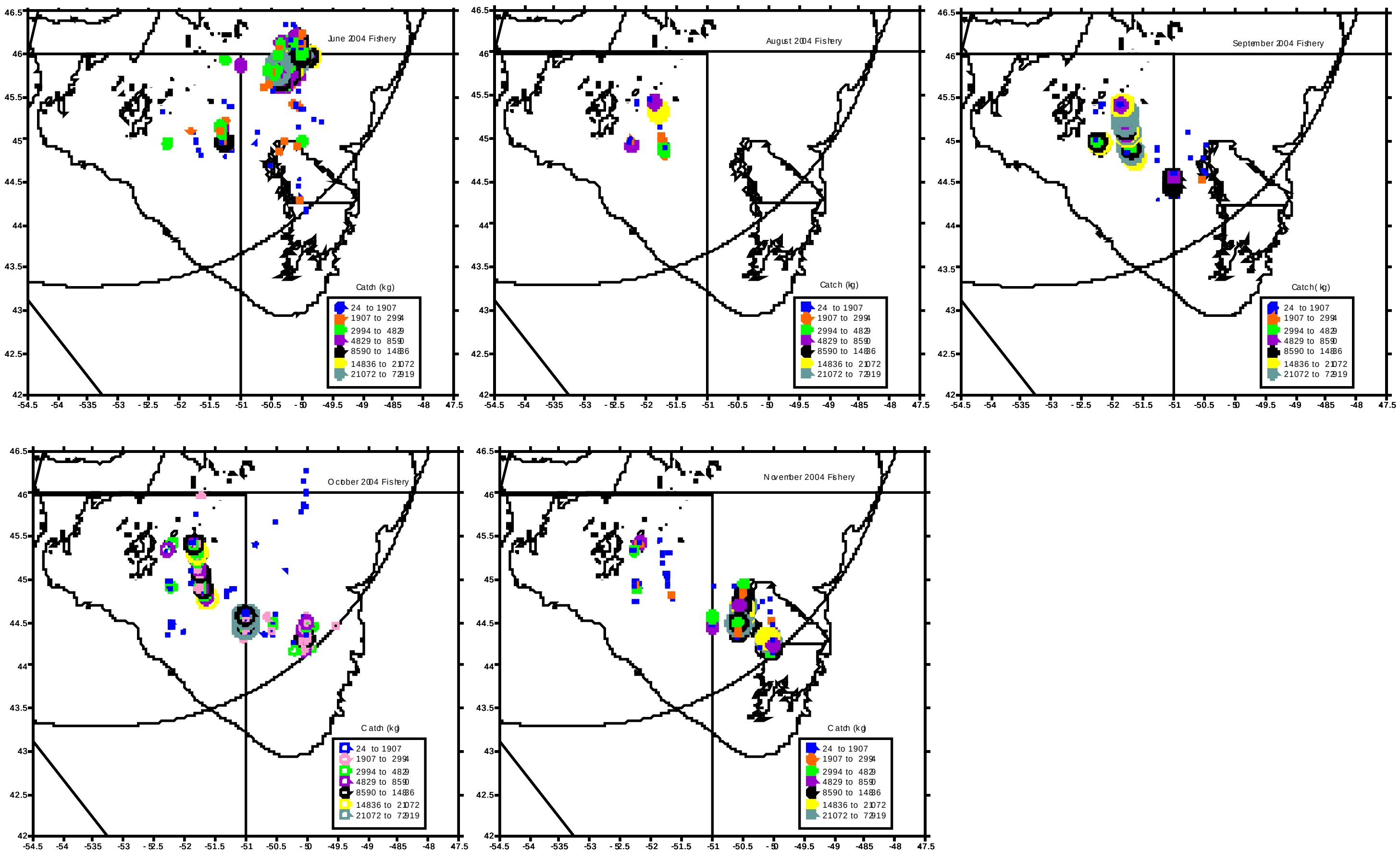

Fig. 13 (Continued) Spatial pattern in the Canadian fishery catches (kg) of yellowtail flounder from June 2003 to November 2004.

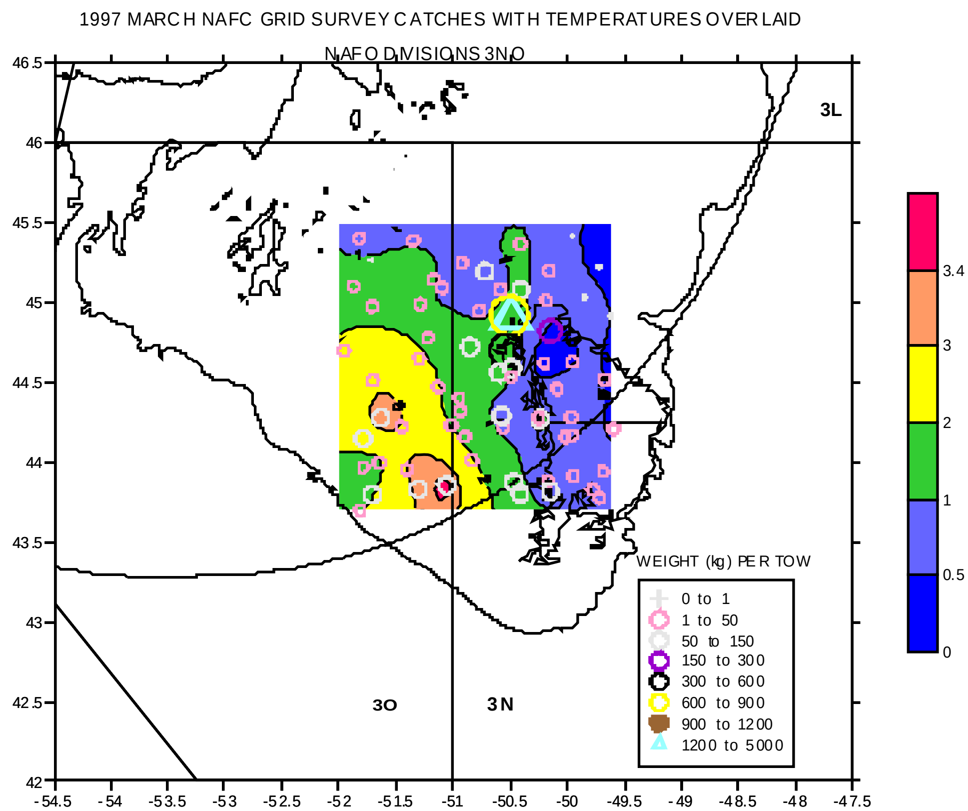

Fig. 14. Spatial pattern of standardized weight per tow of catches and bottom temperatures of yellowtail flounder during the March 1997 DFO-Industry grid survey.