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# Progress Toward Modeling Tagging Data to Investigate Spatial and Temporal Changes in Habitat Utilization of Yellowtail Flounder on the Grand Bank.

by

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**Abstract**

In November 2003 a bottom tending oceanographic mooring was released by NAFC on the southern Grand Bank in NAFO Division 3N. The mooring instrumentation consisted of a tidal gauge, a current meter and six electronic data storage tags and collected data for one year. In June 2003, captured yellowtail flounder where released on the Grand Bank with either Petersen disc or electronic data storage tags attached as part of a 5-year tagging project begun in 2000. The analysis of tag returns for yellowtail flounder on the Grand Bank was restricted to the period June 2003 to November 2004. The analysis of movements based on Peterson disc tags show yellowtail movements are generally southward from their release site. Seasonal analysis of movements including off-bottom vertical excursions were investigated in relation to oceanographic data. The data storage tagging data indicated that adult yellowtail flounder over the Grand Bank of Newfoundland undergo distinct off-bottom vertical migrations during the nighttime which may be associated with high tides. This paper summaries preliminary model results.

## Introduction

Mark-recapture studies can be used to estimate abundance of fish by using recaptures of the tagged fish to estimate the exploitation rate together with total landings in the fishery. These studies can also be used to estimate movements, growth, and selectivity.

Tagging yellowtail flounder with traditional techniques, i.e. Petersen discs, can provide information on movements but may underestimate their true extent. Recent electronic data storage tagging (DSTs) studies of North Sea plaice used measurements of depth and temperature to reconstruct the tracks of plaice movements (Metcalfe and Arnold, 1997). It was discovered that the rates of movements are often ten times faster and farther than those deduced from conventional mark-recapture experiments.

In the winter of 2000, the Northwest Atlantic Fisheries Centre (NAFC) and Fishery Products International Ltd, of St. John's entered into a co-operative program to begin a 5-year tagging program on Grand Bank yellowtail flounder using traditional Petersen discs in a mark-recapture study. Archival data storage tags were also used to specifically investigate vertical and horizontal movements at a finer scale of resolution. The objectives of this extensive tagging program was to estimate exploitation rates, growth rates, mortality, movements and to provide an additional estimate of population size.

In November 2003 we deployed an oceanographic mooring for one year on the Grand Bank to measure real time tidal data and oceanographic parameters such as temperature and depth (see Han *et. al*., 2006 for details) at a fixed location in Div. 3N. We also used the opportunity to compare the temperature and depth accuracy of the Star Oddi DST-Milli tags and their ability to measure tidal fluctuations. So we restrict our analyses to the time period from the tagging release (June 2003) to the time of retrieval of the mooring.

This paper summarizes progress in modelling both conventional tagging and DST data from yellowtail flounder on the Grand Bank with a focus on localized movements and the influence of oceanography.

## Materials and Methods

*Study area*

The Grand Bank is a raised submarine plateau situated southeast of Newfoundland measuring approximately 93 200 $km^2$. On this plateau, water depths range from 36.5 to 185 m, with most of the area being less than 100 m. The bank is dominated by the southward flowing cold, less saline Labrador Current concentrated along its offshore and inshore edges and the warmer Gulf Stream/North Atlantic Current flowing eastward/northeastward along the continental rise and sometimes sweeping across the southern area of the bank (Helbig *et al.*, 1992)

*Experimental design*

Fish were caught by a commercial trawling vessel using a tow duration of 10-15 minutes and a towing speed of 1.5 $ms^{-1}$. Only fish greater than 30 cm were tagged with Petersen disc and only fish greater than 40 cm were tagged with electronic data storage tags (DSTs).

<u>Peterson Disc tags</u>

The experimental design called for 210 fish to be released at each of the 31 stations on the Grand Bank, 20 high reward pink tags, 90 single red tags and 90 double red tags (see Walsh *et al.*, 2001 for details) ( Fig. 1 and 2). A total of 11 780 yellowtail were tagged and released in June 2003.

<u>DST tags</u>

Four hundred tags were available for deployment in the following sequence: ***For Div. 3L*** At each of the 6 stations tag 8 fish with DST tags coded for 32 minutes. ***For Div. 3NO*** 1) At each 25 stations release 10 fish with DSTs coded for 32 minutes and 2) Release 4 extra fish with DSTs coded for 16 minutes at every station. All fish with a DST tag were also tagged with one single Peterson disc tag placed slightly farther towards the head than the DST tag (see Fig.1). Three hundred and eighty-nine (389) electronic data storage tags were successfully released in June 2003 at 31 stations on the Grand Bank (Fig. 2).

DST Milli tags, each weigh 5 g in water (Star Oddi, Iceland) and the resolution for the depth (pressure gauge) for DST Milli tags is 0.23m (Star Oddi, Iceland). The accuracy of temperature and depth measurements were calibrated against bottom pressure gauge information from a bottom mounted oceanographic mooring on the Grand Bank and found to be very accurate (Han *et al.*, 2006).

*Analyses*

Not all DST tags included in the above statistics were used in the analyses. Those that recorded data for less than 6 months were not included as were some that had data problems. There were 4 DST tags that were recaptured after November 2004 for which data up to the end of that month were included. For each fish tag, the data was extracted and subject to minor editing to remove records that were corrupted or that were obviously erroneous and the first 24 hours from the release time were also removed. A total of 15 DST tags are used in the analysis, of which 1 DST had a faulty depth sensor after a few weeks but a workable temperature sensor. The Study Period was from June 2003 to November 2004.

*Activity levels*

Peterson Disc

The release and recapture positions of the conventional tags were used to determine relative distance traveled and the direction traveled from the release point. Data was graphically plotted in SURFER and overlaid onto maps of the Grand Bank.

DSTs

DST tags were examined for depth and temperature occupied. Simple parametric statistics were used to look at changes in depth and temperature over a 24-h period and also by month to investigate seasonal changes. Each day was divided into three periods; night, day, and crepuscular, and records from each tag were assigned to one of the three periods using the onboard clock data. Sunrise and sunset were calculated based on the method of Brock (1981) and standardized using the latitude 45°N, a position central to the release sites. The crepuscular period was defined as one-half hour before to one-half hour after sunrise and sunset. The range of depth or temperature was calculated for each fish for each period of the day on each day the fish was at liberty

## Results and Discussion

*Fishery*

We investigated whether seasonal changes in habitat of yellowtail flounder could be detected using: the DFO-NAFC fishery observer database. Most of the catches taken in the study period, May[1] 2003-November 2004 were found mainly in the southern Grand Bank, Div 3NO. Highest catches came from the Southeast Shoal area and an area on the 3LN border north of the Mooring site (Fig. 3) (see Walsh and Brodie, 2006, for details).

*Tag returns*

Peterson disc and DSTs

Fish released in June 2003 and returned end November 2004 were analysed. In total 427 of 11 780 Peterson disc tags and 38 of 389 DSTs were returned over this period (Table 1). Returns were low in July and August because of the seasonal closure of the fishery (Table 2). There was little difference in the mean length of released and returned fish for the short time period at liberty (Table 3).

Only 7 returns did not have sex recorded. Most of the returns are female because large fish were sampled. Fewer DSTs are male because the minimum and mean size of fish tagged was higher than for the discs, which means that a higher proportion of the fish were female (Table 4).

*Dispersion patterns*

Peterson Disc

Most of the tag returns come from the southern Grand Bank, NAFO Div. 3NO, in particular the Southeast Shoal area (Fig. 4) coinciding with the area of highest catches (Fig. 4) (see Walsh and Brodie, 2006).

Figure 5 shows the temporal and spatial pattern in tag returns by month for the time period June 2003 to November 2004 for those fish tagged in June 2003 and also shows average direction and distance traveled from the release sites. Distance traveled from tag release site ranged from 0 to 425 km. There does not appear to be any pattern in the distance traveled (Fig. 6; Table 5). Average distance from release sites was ~27 km. There appears to be a trend of fish being south of their release sites in an average direction of 203°SW position (Fig. 6).

[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.

*Location of spawning fish.*

Length sex and maturity data were examined for all sets from the Canadian spring RV survey from 2000 to 2005. Fish with some hydrated eggs were considered to be in spawning condition. These were MatBP, MatCP and Partly Spent in the classification of Templeman *et al.* (1978). The number of fish in these categories at each set location was summed to produce the number of fish in spawning condition at each set location.

The tag returns from the June and July spawning period were low because of the reduction/cessation of fishing by the fleet. Here in Figure 7 we showed all tag returns for the 2000-2005 overlaid on potential spawning areas on the Grand Bank. No pattern in tag returns with areas of spawning is evident. However, it should be appreciated that this is a quick analyses and the spatial pattern of spawning of yellowtail flounder on the Grand bank needs to be investigated more closely with a longer time series of data.

<u>DST</u>

The 10 release sites and 15 recapture sites for the 15 DSTs associated with the study period are plotted in Fig. 8. Figure 8 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.

*Activity pattern in yellowtail*

All DSTs analyzed showed extensive off-bottom movements and some crossing of the thermocline during the summer time (Fig. 9). There were three basic patterns in the depth data: 1) periods of very limited vertical movements, 2) periods of relatively frequent vertical movements and 3) periods of no detectable vertical movements. Figures 11 and 12 show examples of yellowtail flounder with DST tags recording data for 16 months and with both fish at liberty over the same time period. YDS4717 was tagged north of the Southeast Shoal and YDS4610 was released just to the west of the Southeast Shoal. Both were returned from the fishery on the Southeast Shoal. There were considerable variability in the depth recorded, vertical activities and temperature occupied.

<u>DSTs-Seasonal changes in depth and temperature</u>

Monthly trends in the average depth and temperature occupied by the 15 yellowtail flounder with DSTs returned in the fishery are presented in Fig. 13. 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. After the initial decline in average bottom depth from June to October 2003, there was little variability from November 2003 to October 2004. Average depths less than 55 m would indicate residence on the Southeast Shoal. After tagging fish move to shallower water overtime. 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.

Figure 14 examines average depth and temperature for seasonal trends. Average depths occupied in June, July and August are higher and appears to differ from rest of year. Average temperatures are stable from February to September (2-3°C) before starting to increase in the fall. Figure 15 shows the monthly trends in range of depths and temperatures occupied by the 15 yellowtail flounder and Fig. 16 shows the seasonal pattern in the ranges occupied. The range of mean depths occupied are higher in June, July and August when compared to other seasons coinciding with the start of an increase in the range of temperatures occupied.

<u>Diel Patterns of behaviour</u>

Each day was divided into three periods; night, day, and crepuscular, and records from each tag were assigned to one of the three periods using the onboard clock data. Figure 17 shows that average depths occupied by time of day indicated that at night depths are somewhat less than during the day or crepuscular time period especially during June to October of 2003 and July to September 2004. No trend was evident in average temperatures for each period.

Figure 18 shows the mean range in depths occupied by each individual in each month by activity period. The range in depths is highest at night when compared to day and crepuscular period for all months following their release in June 2003.

Modeling Vertical Movements

Since the tidal signal is so weak (semidiurnal tide of 1 metre amplitude of 0.005 cm/s; (Han *et al*., 2006)) in the area where the DSTs were located there was no effort to remove the tidal signal from the depth (pressure) variability.

The distribution of vertical speeds of the fish when off bottom were essentially Gaussian for all tags collectively and individually. Most observations showed speeds of less than 0.05 cm/s. This low speed was due to the episodic behaviour of the fish which was characterized by ascents, remaining in off bottom for a period of time and then descending and remaining on the bottom for a longer period.

We examined the range of vertical motion of each fish. It was noted that the large amount of time the fish spent on the bottom meant it was necessary to reduce the ensemble size to preclude these periods. This was done by including daily statistics only for days when the fish exhibited a maximum speed of greater that 0.5 cm/s. The monthly mean range was calculated by averaging the difference between the maximum and minimum depths for each day that the fish was active (maximum vertical speed >0.5 cm/s) over each month of the year. Figure 19 shows the mean range in depth occupied by each yellowtail flounder when they are off-bottom. There are differences across fish in monthly trends. Figure 20 shows the seasonal pattern in mean ranges in depth occupied when fish are off-bottom and shows there are off-bottom activity in every month. With the exception of March, there is little difference in average range of depths occupied when yellowtail are off bottom.

The relative amount of time off bottom was taken as the number of observations of fish being off-bottom multiplied by the sampling interval (16 or 32 minutes) to determine cumulative time off bottom by month. The results of seasonal analysis of range in depths occupied while off bottom, the number of observations of yellowtail flounder off-bottom and the amount of the time spent off bottom showed that July, August and September were the most active off-bottom months.

To determine what might trigger this behaviour, the speed and position of the fish was plotted along with an indication of day or night for the approximate location of the fish and the time of the year. This often showed that the fish was more active during the night period (see Fig. 23 for example) although there was some activity during the day as was evident in the diel behaviour analysis in range of depths

Oceanographic analyses

Studies on the plaice in the North Sea revealed an interesting migration mechanism by so called selective tidal stream transport (Hunter *et al*., 2004). Launch and recovery locations of tagging indicated yellowtail flounder on the Grand Bank generally move southward towards the Southeast Shoal. Based on historical moored measurements and Han's (2000) tidal model, the tidal current over the Grand Bank is significantly weaker than that in the North Sea. It's of interest to examine whether or not the flounder were taking advantage of tidal stream for their horizontal migration. As a first attempt, we have examined tidal current directions during their ascending and descending movements.

Figure 25 shows reconstructed tidal currents corresponding to the vertical migrations of a tagged fish from July to September, 2003. Red arrows are for the ascending move and the blue are for the descending move. From the release and recapture locations for this tag, we assume the dominant movement of this fish to be southward. It appears that the vertical excursions are mostly coincident with the southwest-northwest current direction. When fishes migrate horizontally from deeper to shallower waters, they are more likely to have vertical excursion during the night time when they can drift with tidal currents horizontally. However, this behavior is not evident in the same tag for the period from July to September, 2004 (Fig. 26).

## Summary

Recent data storage tagging (DST) data have indicated that adult yellowtail flounder over the Grand Bank of Newfoundland undergo distinct off-bottom vertical migrations. A preliminary examination of the potential relationship between the tide and off-bottom migration over the Grand Bank suggest the off-bottom excursion of yellow tail flounder during the nighttime may be associated with high tides (Walsh and Morgan, 2004). This vertical migration behavior was further confirmed from new tagging observations, when examined in conjunction with tidal height variation based on Han's (2000) model (Fig. 24). A possible explanation is the fish's response to the change in the hydrostatic pressure as a result of tidal rise and fall. In fact, this mechanism was discussed in juvenile plaice (e.g. Hunter *et al*., 2004).

The analysis presented here for Peterson disc tags show yellowtail movements are generally southward from their release site.

The electronic data storage tag measurement data for depth and temperature for yellowtail flounder during their period at liberty showed substantial vertical activity in all 15 DST fish. There were three basic patterns in the depth data: 1) periods of very limited vertical movements, 2) periods of relatively frequent vertical movements and 3) periods of no detectable vertical movements. Most of the vertical movements occurred at night. Night-time movements often lasted for several hours with occasional descents back to the bottom. Coincidental with some of these vertical movements was a change in recorded temperatures and it was evident that yellowtail were crossing the thermocline during the summer. These results are similar to the Walsh and Morgan (2004) analysis on yellowtail behaviour from 29 DSTs.

Seasonal examination of the number of observations and time off bottom showed that, July, August and September were the most active months. Off bottom vertical movements of yellowtail flounder are mainly nocturnal and possibly timed to high tide. There is some indication that vertical movements may be linked with southwest-northwest current direction.

Similar findings in yellowtail flounder making extensive vertical movements have also been reported on Georges Bank (Cadrin and Westwood, 2004). Passive drift in mid-water currents are thought to be the reason for yellowtail flounder in that area making extensive vertical migrations to move among fishing grounds or stock areas

Future work

- Refining models to detect seasonal trends in on and off bottom movements.
- Refining models to detect diel trends in on and off bottom movements, diurnal, semi-diurnal, daily, crespuscular.
- Refining models to detect tidal current trends in on and off bottom movements
- Refining models to detect seasonal trends in on and off bottom movements

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TABLE 1. Tag Releases 2003 with returns by end November 2004.

| | Releases | Returns |
|---|---|---|
| DST | 389 | 38 |
| High | 620 | 32 |
| Double | 2791 | 186 |
| Single | 2789 | 171 |

TABLE 2. Number of Returns by month

| | |
|---|---|
| June 2003 | 1 |
| July 2003 | 2 |
| August 2003 | 29 |
| September 2003 | 54 |
| October 2003 | 84 |
| November 2003 | 67 |
| December 2003 | 19 |
| January 2004 | 18 |
| February 2004 | 15 |
| March 2004 | 27 |
| April 2004 | 39 |
| May 2004 | 14 |
| June 2004 | 20 |
| July 2004 | 1 |
| August 2004 | 0 |
| September 2004 | 9 |
| October 2004 | 16 |
| November 2004 | 12 |
| Total | 427 |

TABLE 3. Release length (all releases 2003)

| | Mean | STD | Min | Max | CV |
|---|---|---|---|---|---|
| DST | 44.5 | 3.2 | 40 | 55 | 7.1 |
| Disc | 38.1 | 3.5 | 30 | 56 | 9.3 |

Release length (if returned)

| | Mean | STD | Min | Max | CV |
|---|---|---|---|---|---|
| DST | 45.9 | 3.7 | 40 | 55 | 8.1 |
| Disc | 38.8 | 3.3 | 30 | 51 | 8.4 |

TABLE 4. Number of returns by month sex and tag type

| | DST | | High | | Double | | Single | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| June 03 | | | | | | | | 1 |
| Jul 03 | | 1 | | | 1 | | | |
| Aug 03 | 1 | 2 | 1 | 2 | 6 | 6 | | 11 |
| Sep 03 | | 5 | 1 | 3 | 8 | 18 | 4 | 14 |
| Oct 03 | | 9 | 2 | 5 | 9 | 24 | 3 | 31 |
| Nov 03 | | 7 | 1 | 4 | 9 | 17 | 4 | 24 |
| Dec 03 | | 3 | | 1 | 2 | 9 | | 4 |
| Jan 04 | | 2 | | 1 | | 5 | 1 | 7 |
| Feb 04 | | 1 | | 1 | 2 | 4 | 3 | 4 |
| Mar 04 | | | 1 | 3 | 3 | 11 | 3 | 6 |
| Apr 04 | | 1 | | 4 | 6 | 11 | 3 | 14 |
| May 04 | | 2 | | | 1 | 4 | 1 | 4 |
| June 04 | | | | | 3 | 9 | 4 | 4 |
| July 04 | | | | | | | | 1 |
| Aug 04 | | | | | | | | |
| Sep 04 | | | | | | 3 | 2 | 4 |
| Oct 04 | | 3 | | 1 | | 5 | 2 | 5 |
| Nov 04 | | 1 | | | 2 | 5 | 1 | 3 |

TABLE 5. Distance traveled from release location was calculated for each month of recapture.

Distance traveled by recapture month

| Month | Distance | Std. Error | Minimum | Maximum |
|---|---|---|---|---|
| January | 36.3285714 | 9.2686665 | 3.7000000 | 111.9000000 |
| February | 24.6400000 | 4.1749799 | 3.3000000 | 62.3000000 |
| March | 30.7333333 | 5.1414383 | 2.1000000 | 107.4000000 |
| April | 32.7421053 | 5.6544959 | 0 | 112.500000 |
| May | 54.7000000 | 31.2340175 | 2.9000000 | 424.8000000 |
| June | 35.7000000 | 6.4741059 | 0 | 107.0000000 |
| July | 18.6666667 | 2.0851326 | 14.6000000 | 21.5000000 |
| August | 27.3857143 | 3.8103476 | 2.4000000 | 81.5000000 |
| September | 23.4403226 | 2.4055698 | 2.1000000 | 107.4000000 |
| October | 26.3030928 | 2.3627999 | 1.0000000 | 99.1000000 |
| November | 25.4015152 | 2.5503009 | 0 | 73.5000000 |
| December | 46.5083333 | 5.5835182 | 8.8000000 | 64.8000000 |

Fig. 1. DST tag attachment site on yellowtail flounder along with a Peterson Disc

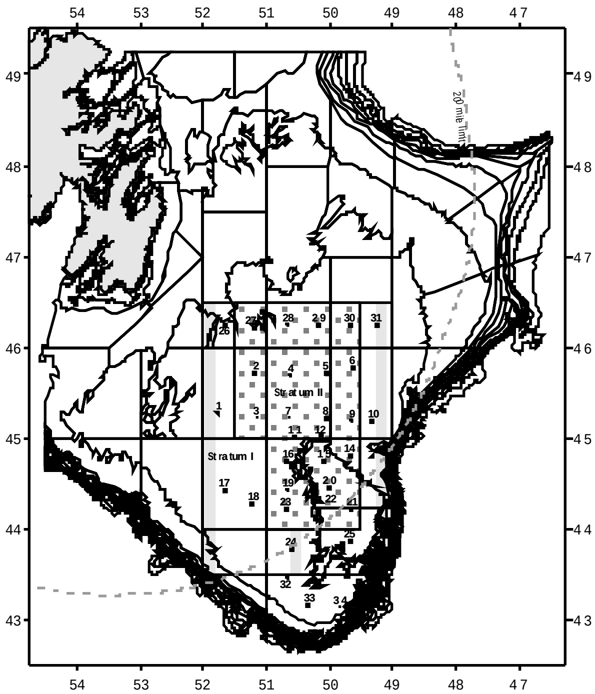



Fig. 2. Map of the study area showing release sites for the 2000-2004 yellowtail tagging program. Stratum 1 and Stratum 2 are boundaries for modeling abundance estimation.

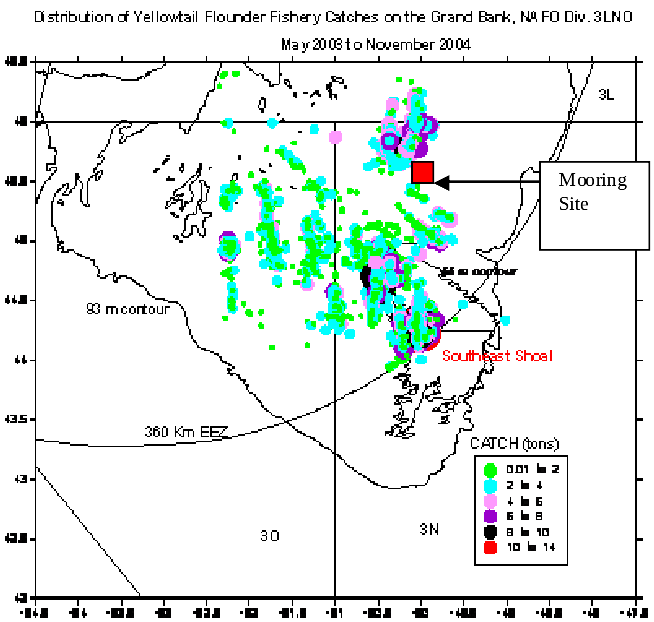



Fig. 3. Spatial pattern in catches of yellowtail in the May 2003-November 2004 fishery.

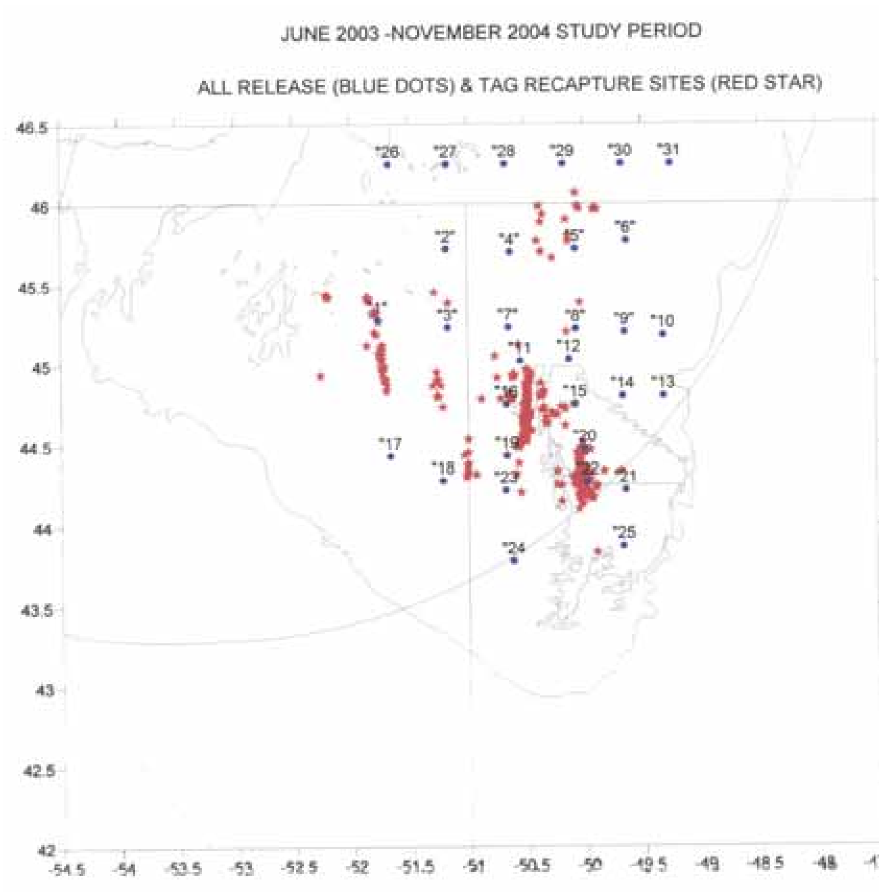



Fig. 4. Recapture positions (red star) of Peterson Disc tagged yellowtail flounder. Numbers refer to the release sites.

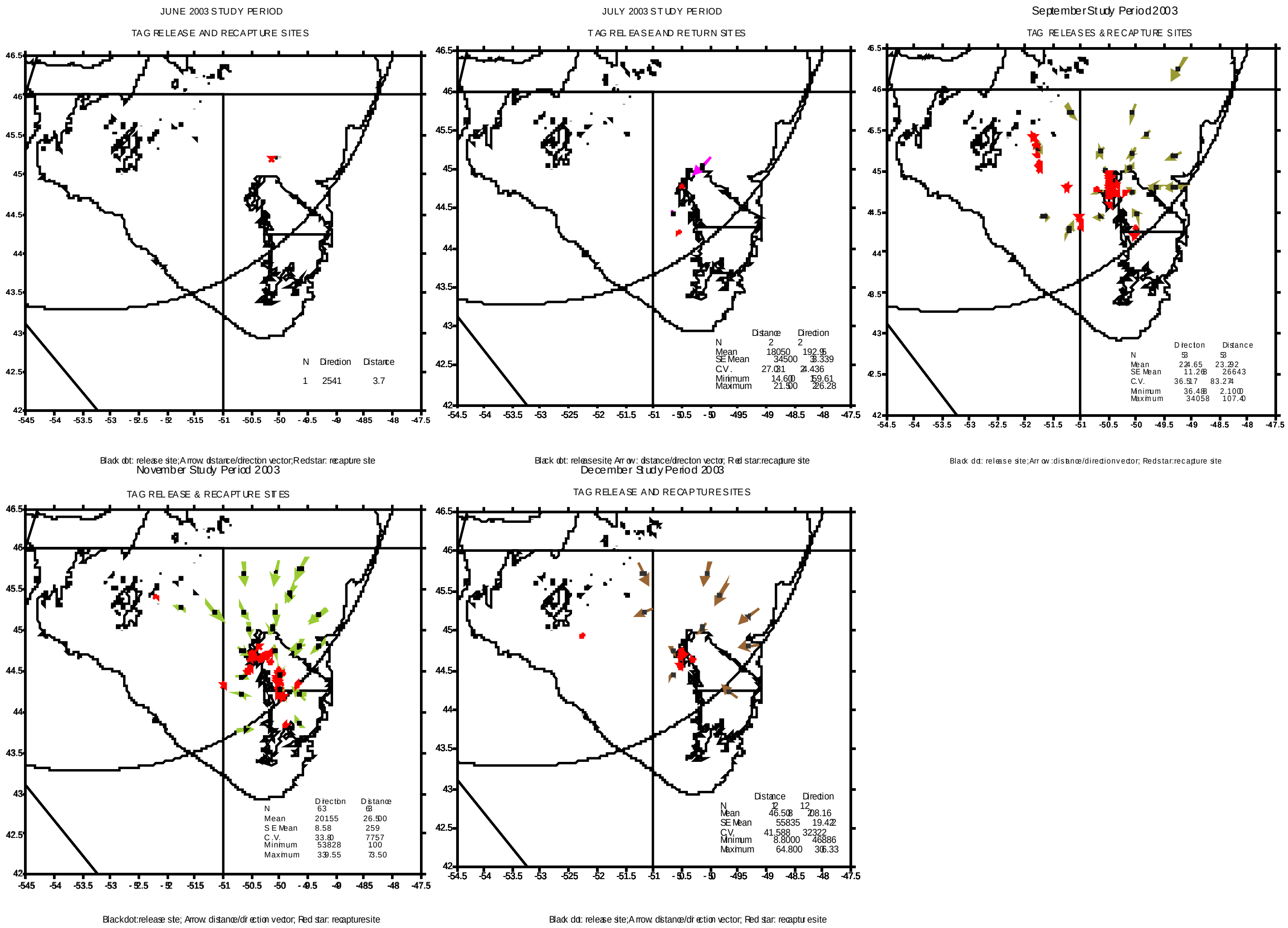



Fig. 5. Spatial plots of tags returned by month after release in June 2003. Black dot: release site; Arrow: distance/direction vector; Red star: recapture site.

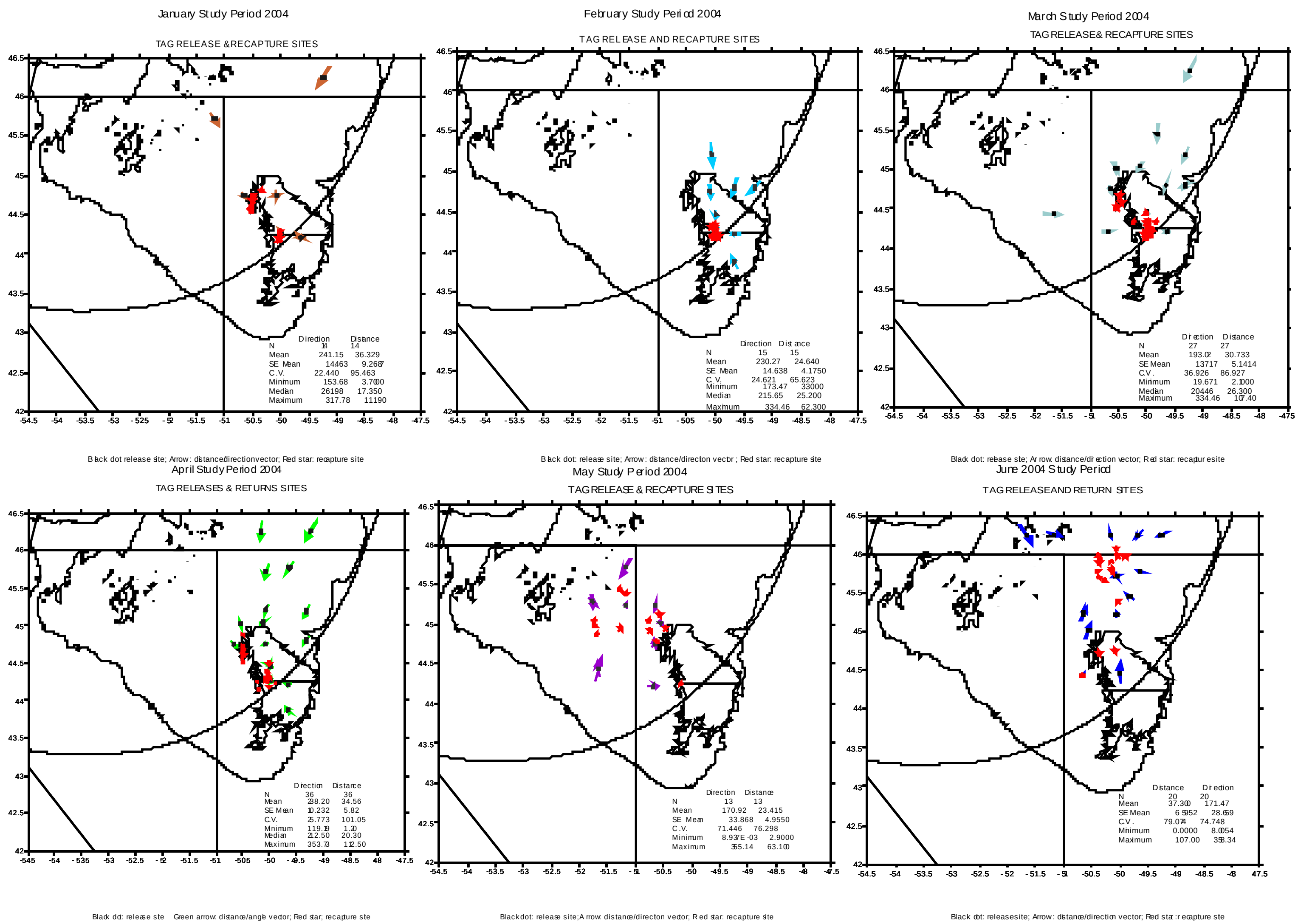
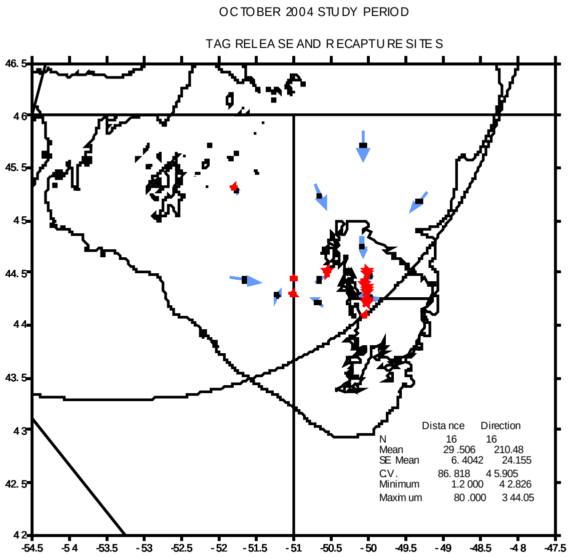
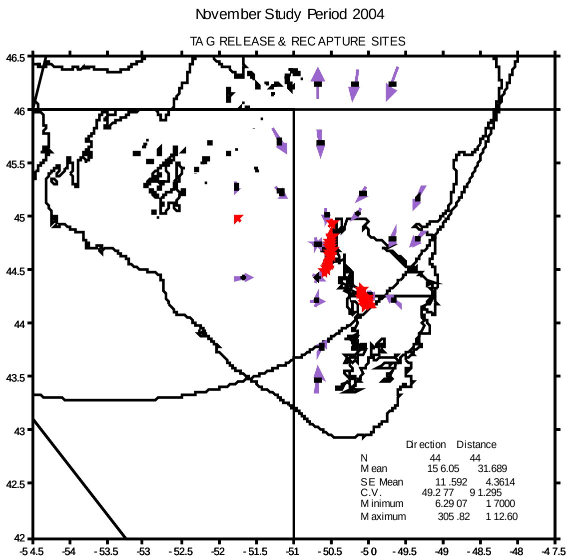



Fig. 5 continued




Black dot: release site; Arrow: distance/direction vector; Red star: recapture site




Black dot: release site; Arrow: distance/direction vector; Red star: recapture site

Fig. 5 continued

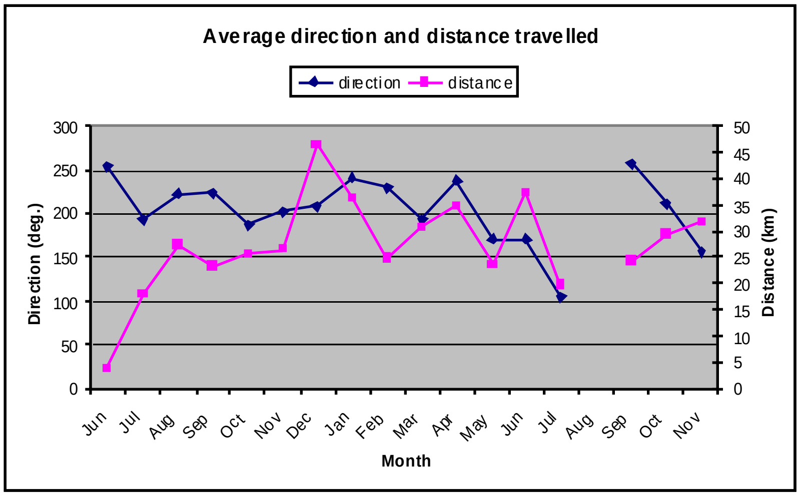



Fig 6. Average distance and direction traveled from release site by month.

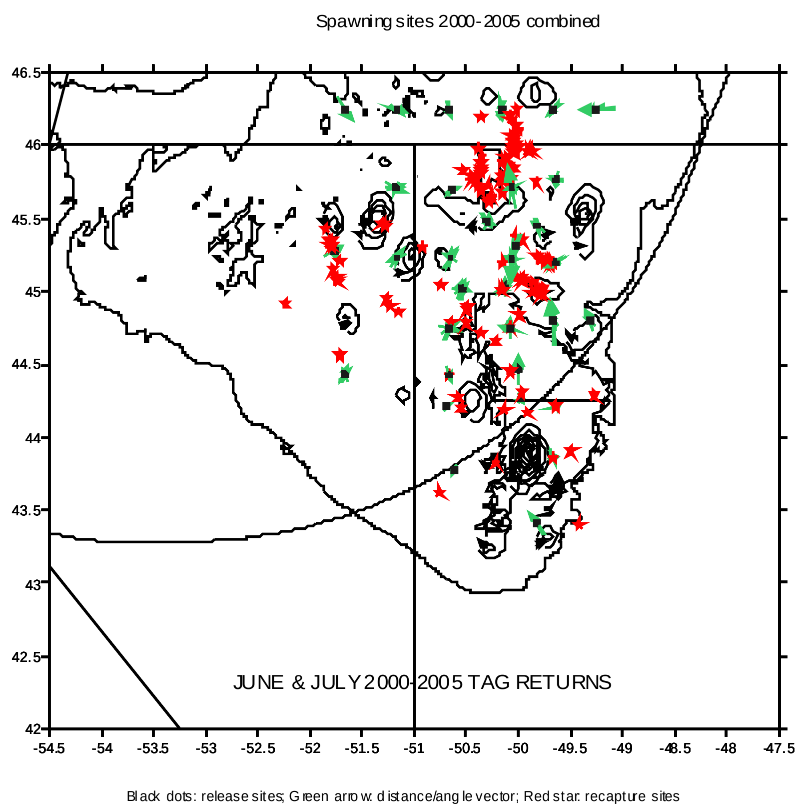



Fig 7. Pattern of returns in relation to spawning areas.

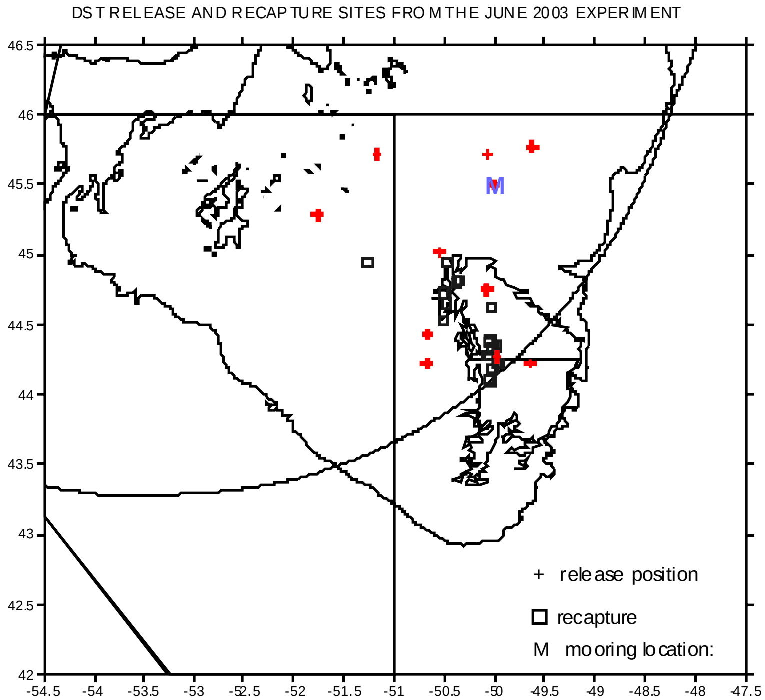



Fig. 8. Release and recapture sites for 15 data storage tags released on yellowtail flounder in June 2003, and the location of the oceanographic bottom mooring (M) in Div. 3N.

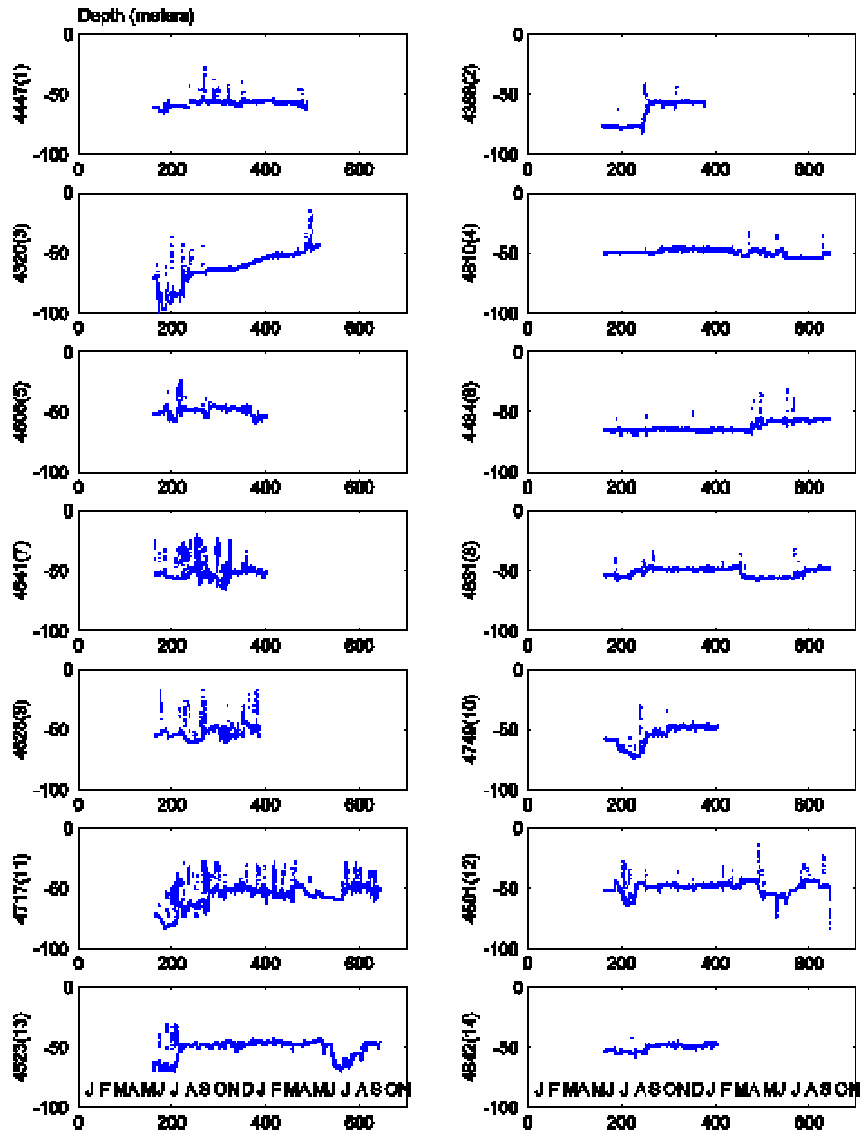



Fig. 9. Daily trends in depths occupied by 14 yellowtail flounder with DST attached. For the study period, June 2003 to November 2004.

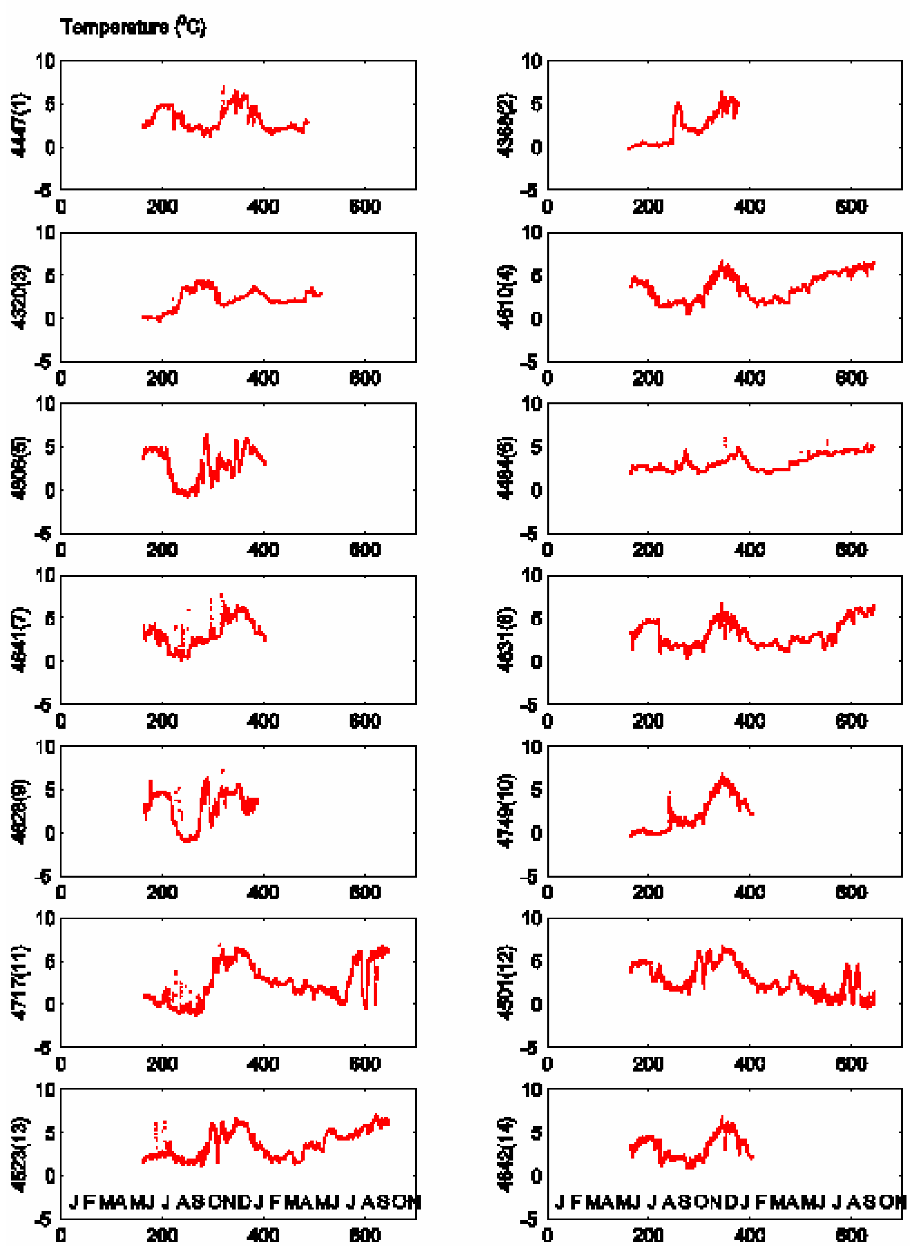



Fig. 10. Daily temperatures occupied by 15 yellowtail flounder with DST tags attached for the study period, June 2003 to November 2004.

June 12, 2003 to October 7, 2004

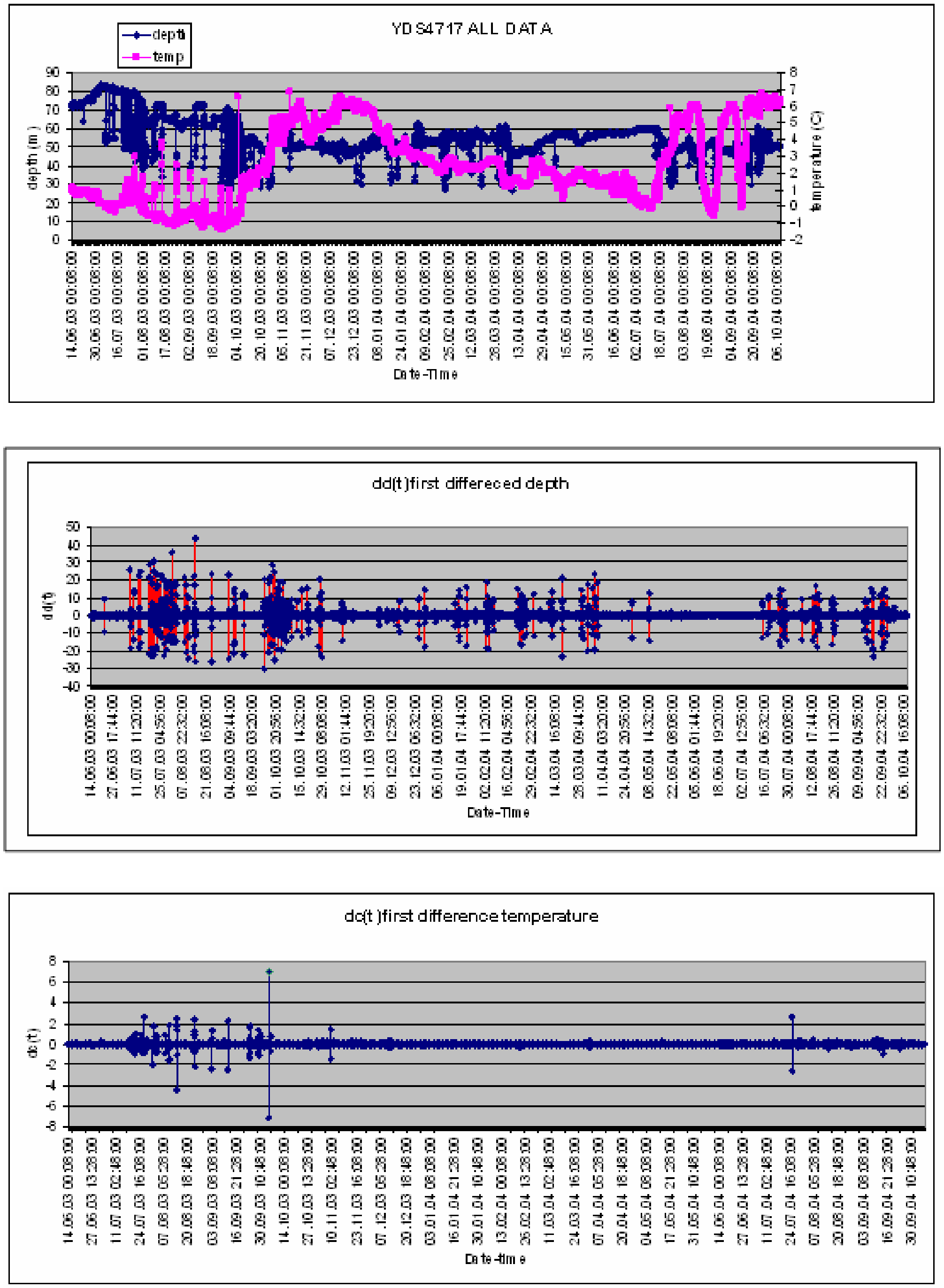
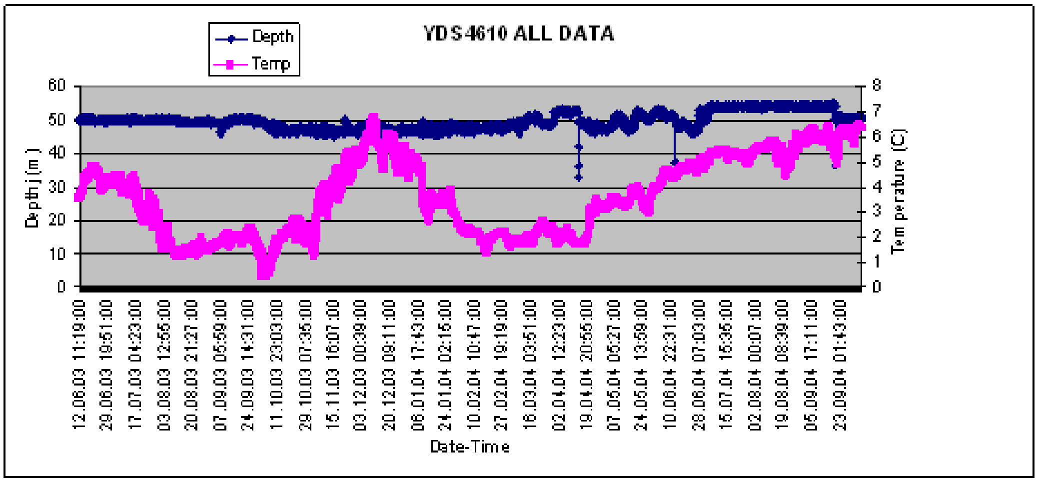



Fig. 11. Daily depth and temperature profiles for Yellowtail YDS4717. Top: all data; Middle: first differenced depth; Bottom: first differenced temperature.

June 11, 2003 to October6, 2004.



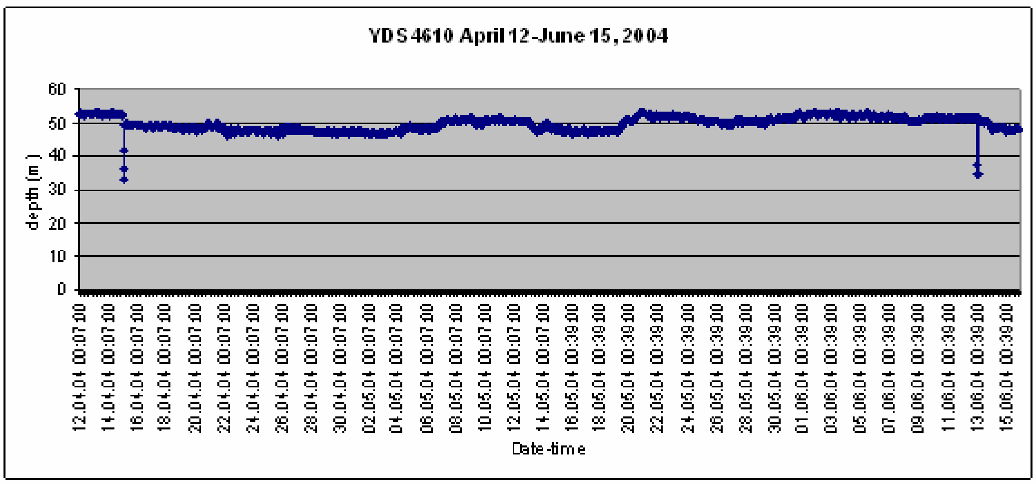
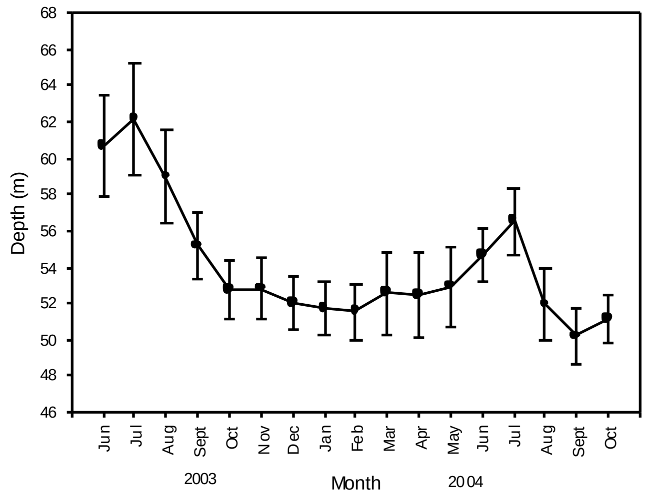




Fig. 12. Daily depth and temperature profiles for Yellowtail YDS4610. Top: all data; Bottom: On bottom activity for April 12 to June 15, 2004.



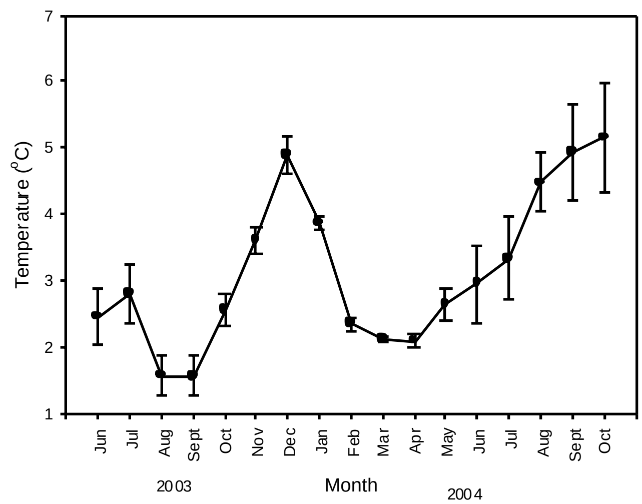




Fig. 13. Trends in the monthly mean depth and temperature (plus standard deviations) occupied by yellowtail flounder.

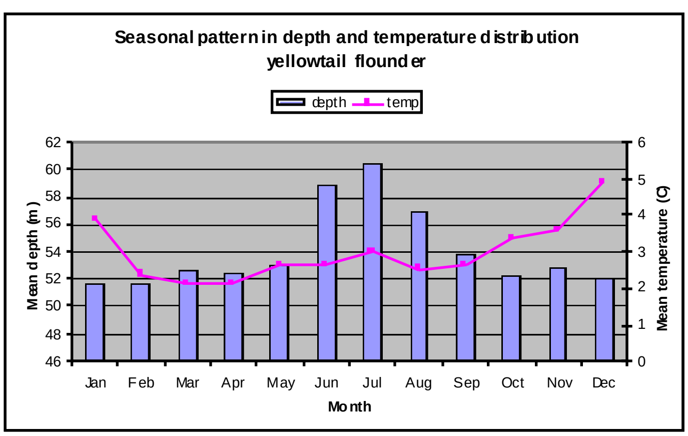



Fig. 14 Seasonal trends in mean depth and temperature.

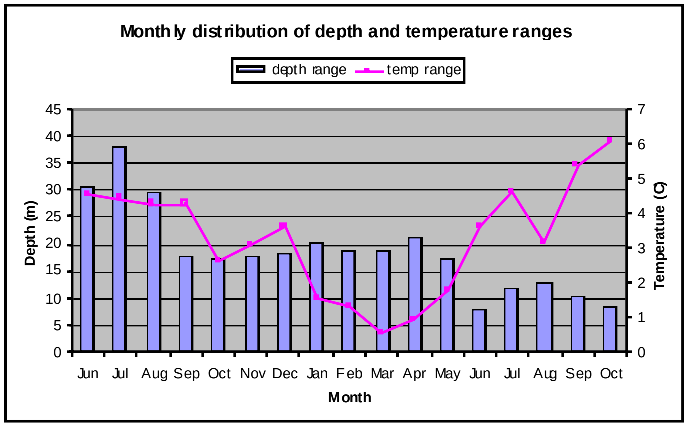



Fig. 15. Monthly trends in the ranges of depth and temperature occupied by yellowtail flounder, June 2003 to November 2004.

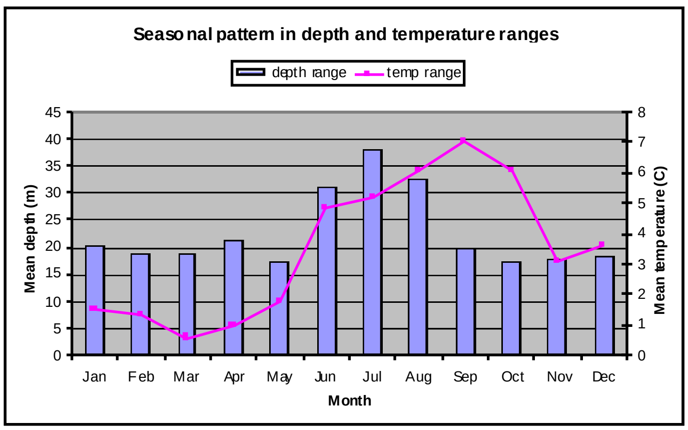



Fig. 16. Seasonal trends in depth and temperature ranges occupied by yellowtail flounder.

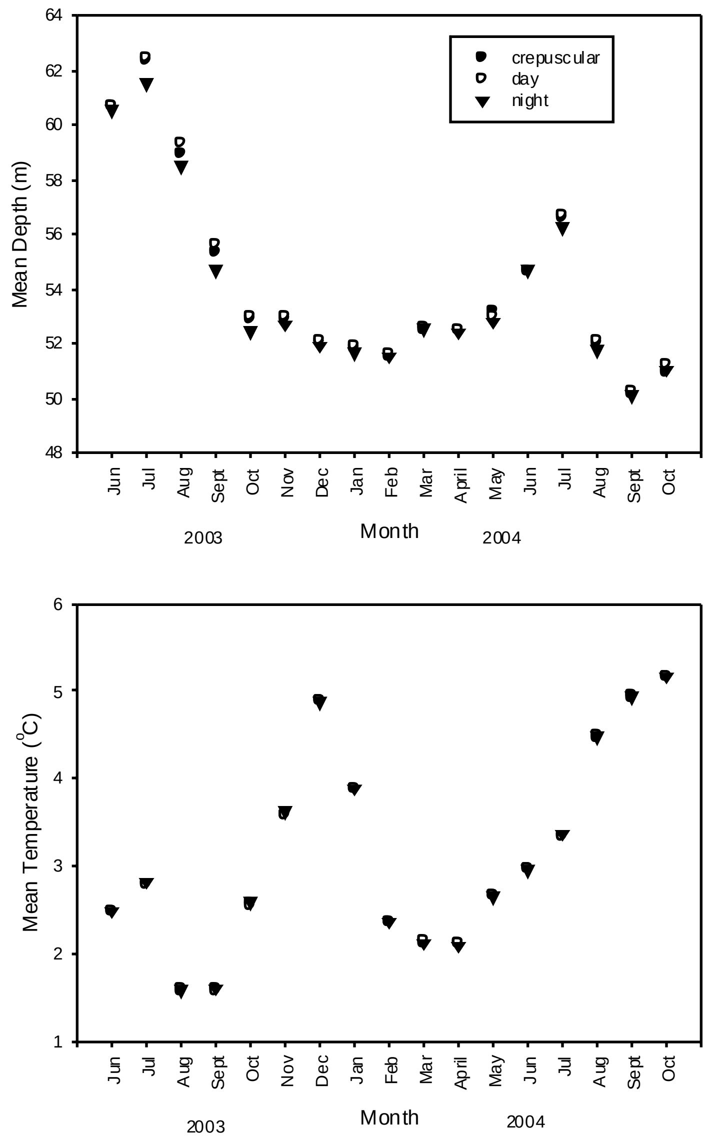



Fig. 17. Mean depth and temperatures occupied y activity period.

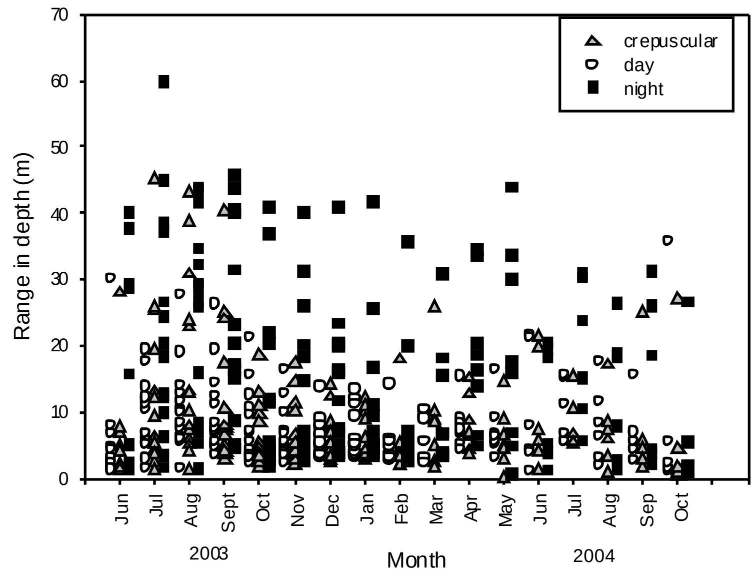



Fig. 18. Mean range in depths occupied by yellowtail flounder by activity period.

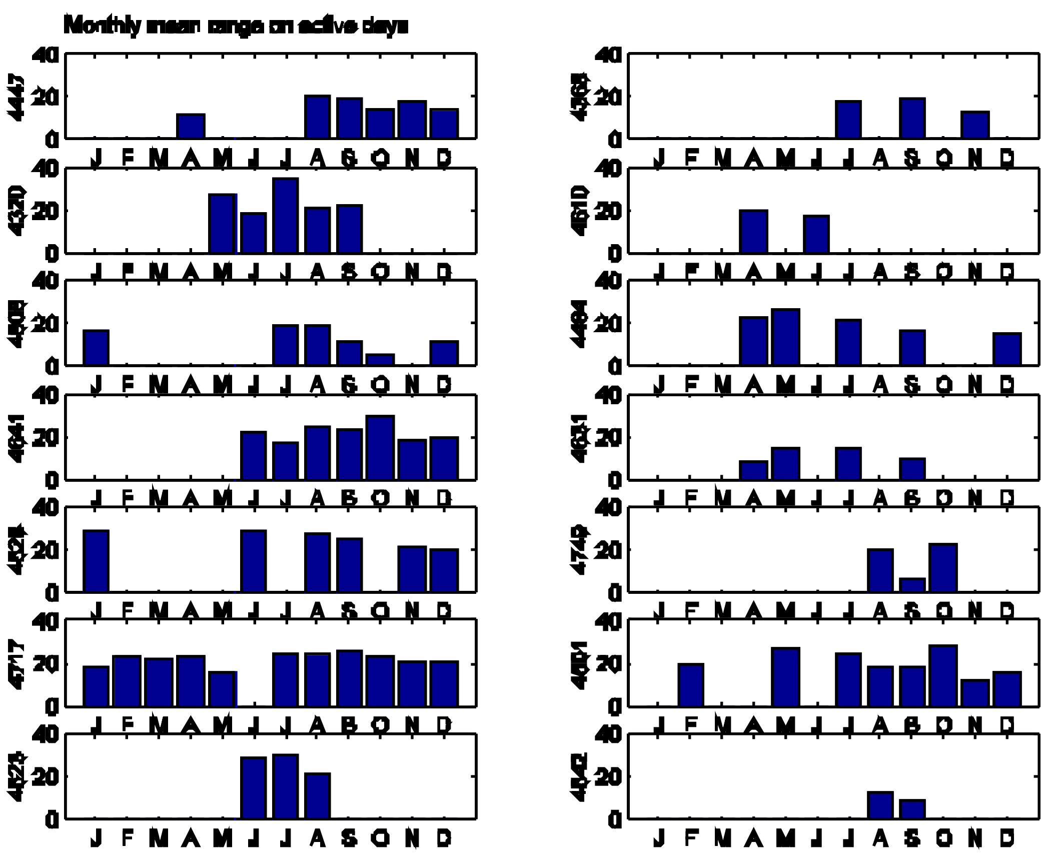



Fig. 19. Mean range in depth (m) occupied by yellowtail flounder when they are off bottom.

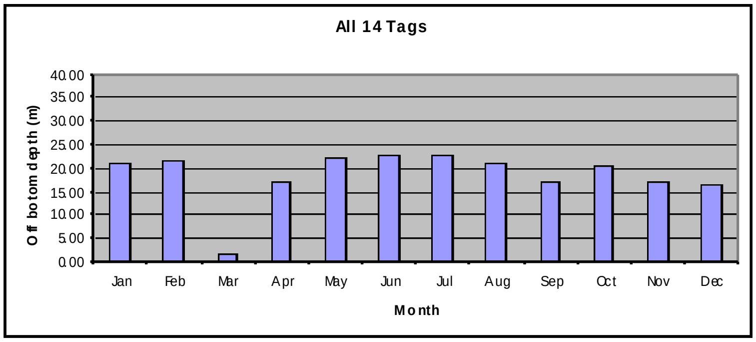



Fig. 20. Seasonal trends in mean range in depths occupied by yellowtail when off bottom.

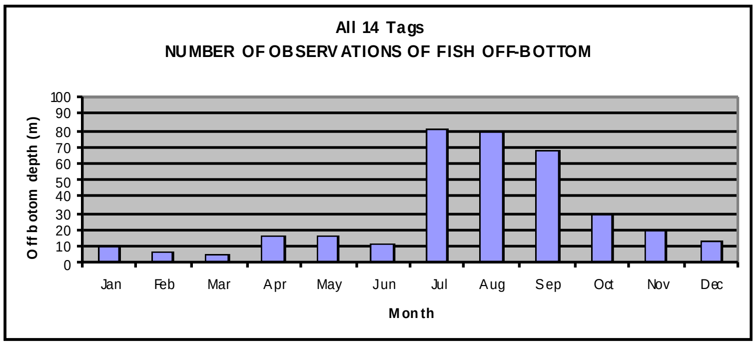



Fig. 21. Seasonal trends in the off bottom activity levels.

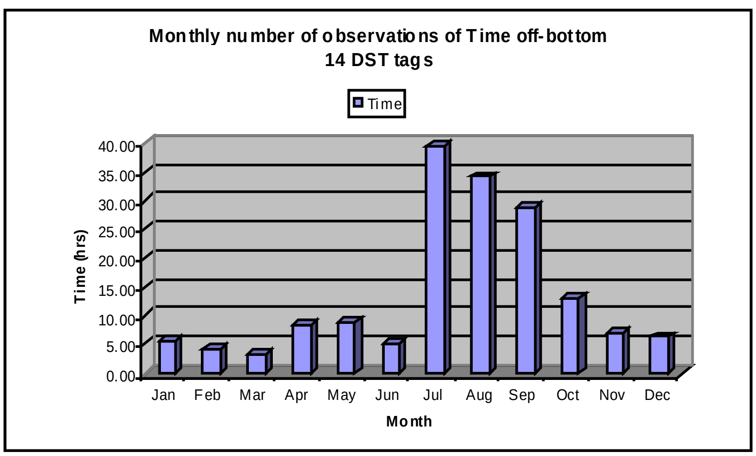



Fig. 22. Seasonal trends in the total amount of time (hrs) yellowtail are off bottom.

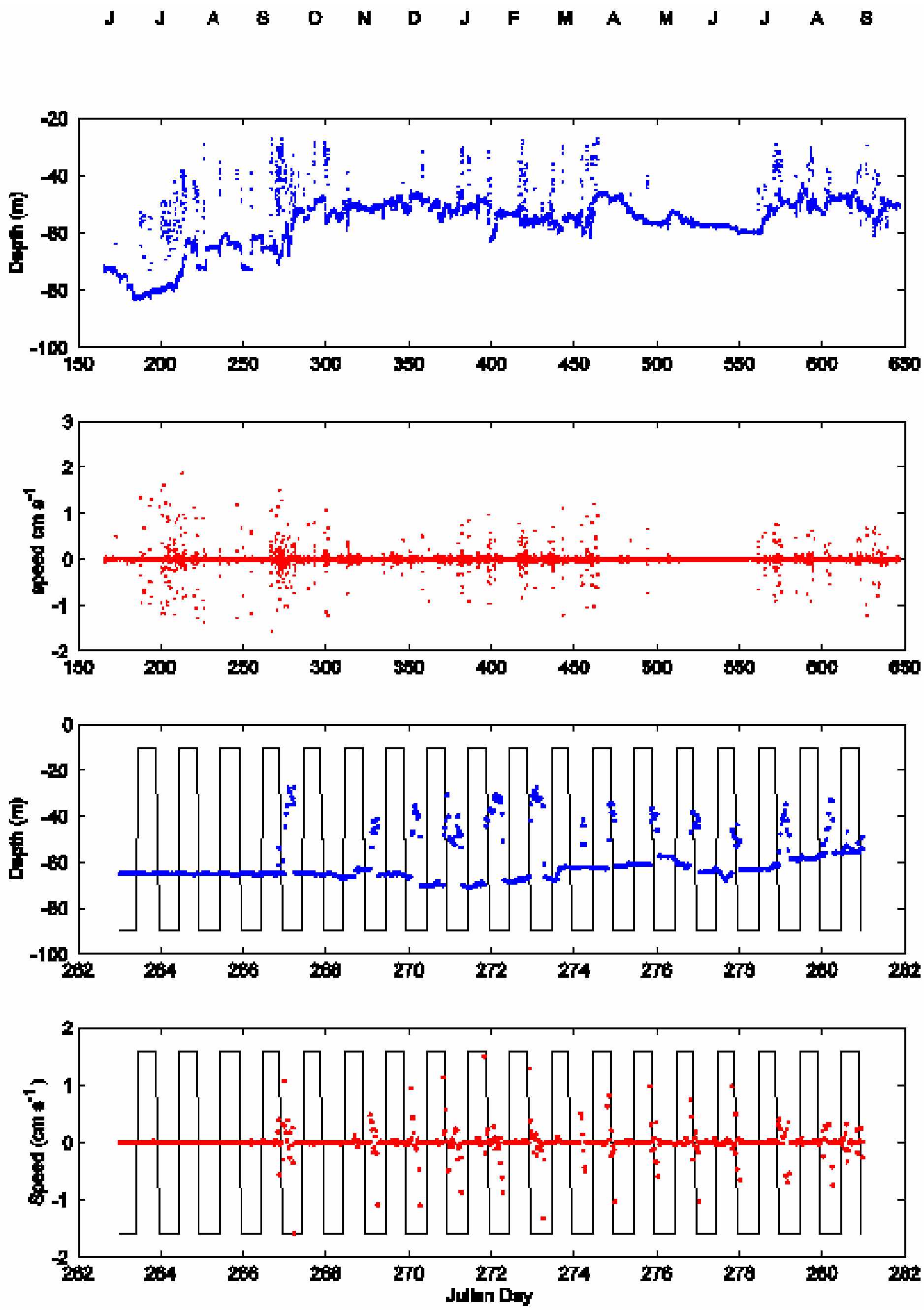



Fig. 23. Activity levels in yellowtail DST4717 in relation to depth, swimming speed and off bottom movements.

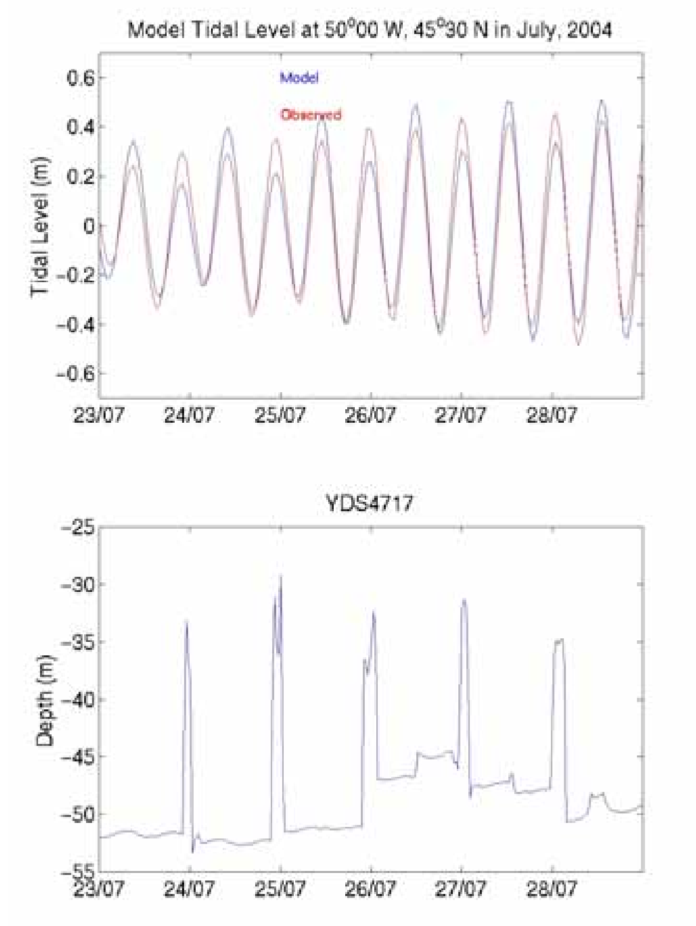



Fig. 24. Tidal rise (upper) and fish's vertical migration (lower) from 23 to 28 July, 2004.

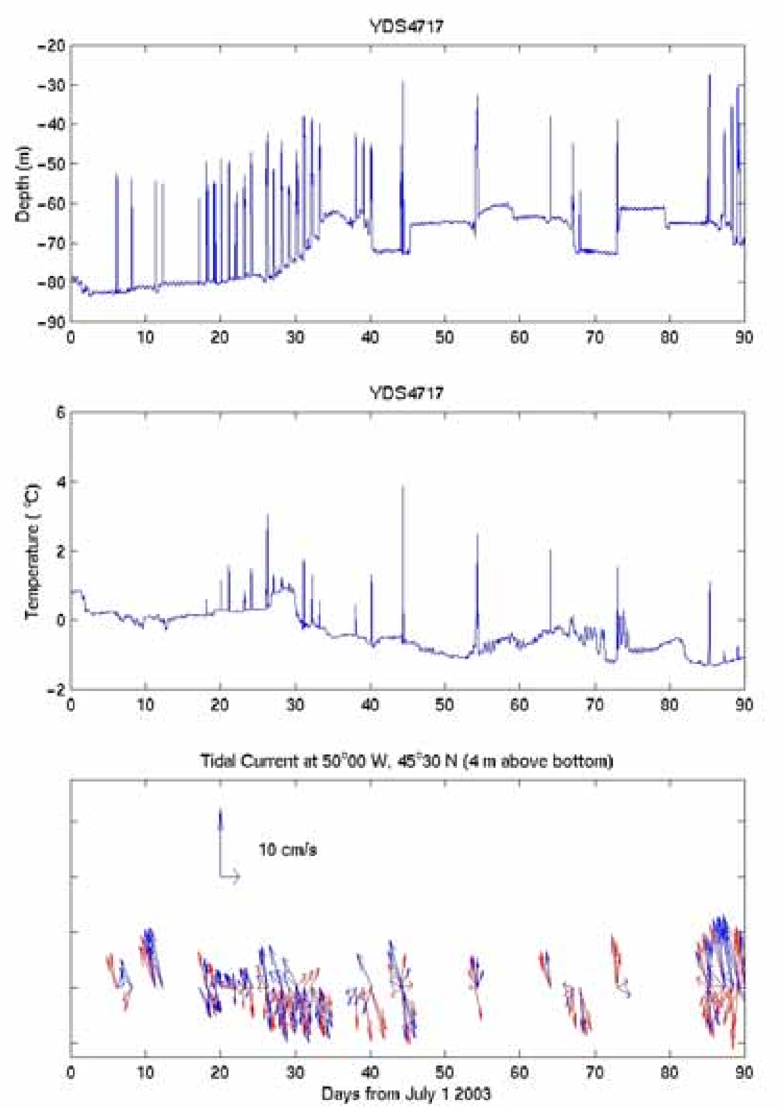



Fig. 25. Fish's vertical migration (upper), water temperature (middle) and tidal currents (lower) from July to September, 2003.

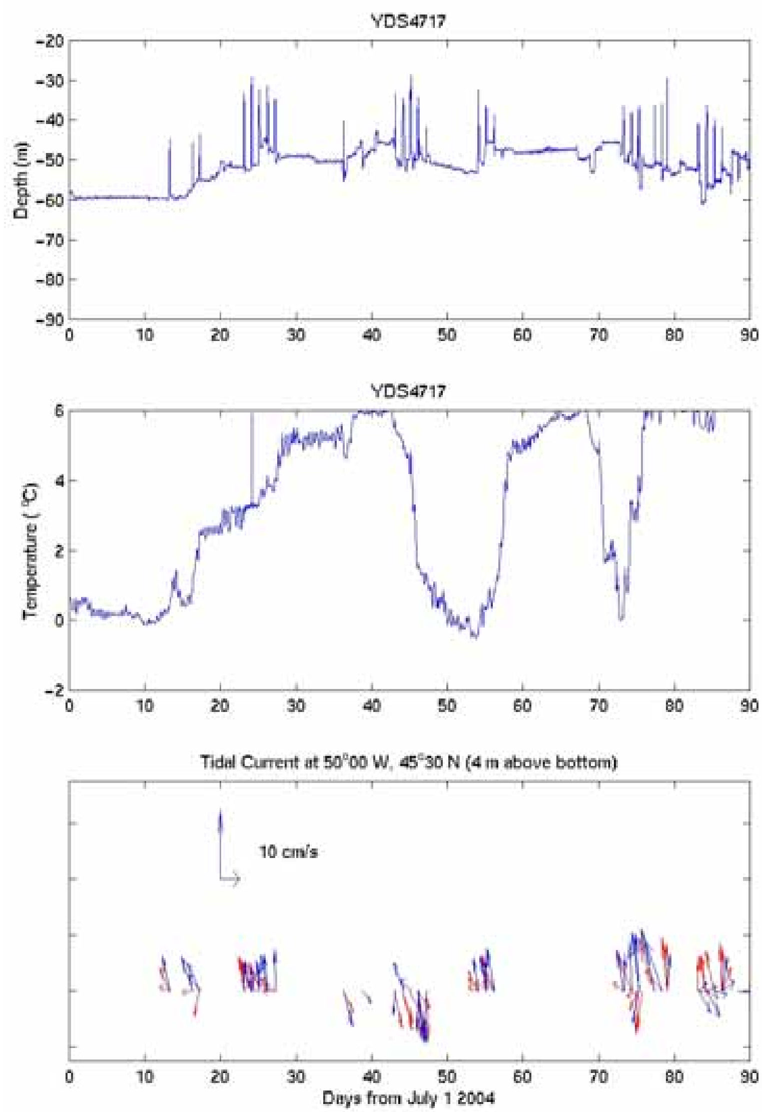



Fig. 26 Fish's vertical migration (upper), water temperature (middle) and tidal currents (lower) from July to September, 2004.

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