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Vertical migrations of saithe (*Pollachius virens*) in Icelandic waters: diel and seasonal differences, extent and duration of directed runs.

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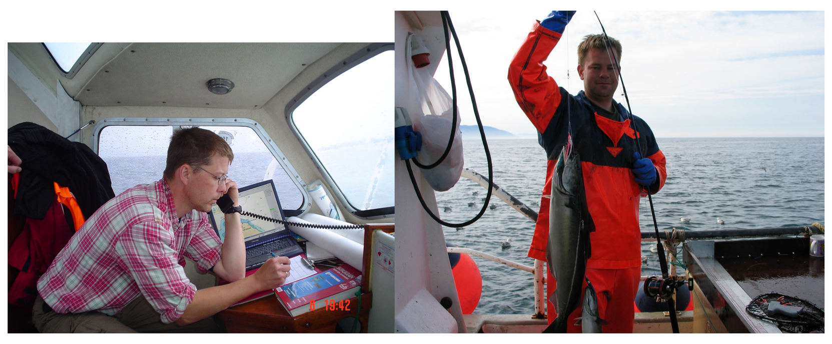

'MRI Department of saithe tagging'

Abstract

Data storage tags (DSTs) implanted in saithe (*Pollachius virens*, NW-Atlantic pollock) in Icelandic waters have revealed diel and seasonal differences in vertical migrations which influence catchability and have implications when saithe are studied as acoustic objects. The poster presents results based on a data set of hourly recordings of depth and temperature from 32 saithe and compares them with commercial logbook data. Measurements at 1 minute intervals were made for a subset of the series and have been retrieved from 14 recaptures. The data are analysed with respect to diel and seasonal differences in saithe vertical movement at hourly intervals. Duration and vertical extent of upwards and downwards directed runs are analysed with one minute resolution. The results may help elucidate saithe swimming behaviour and possibly contribute to an understanding of tilt angle distributions, which in turn influence saithe acoustic backscatter strength/area.

Material and methods

Data for this study are recordings of depth from recaptures of saithe tagged intra-peritoneally with DST–milli tags on jigger–surveys in shallow waters around Iceland. The tags recorded for a variable duration in the period July 2002 to June 2005.

We use changes in depth (Δz) within the depth range 10–250m at hourly intervals from 32 saithe DST recaptures (mean length 56cm). Data from the first 2 weeks at liberty were omitted. Number of fish at liberty, with live tags, was in the range of 10–28 and number of days of recordings in the range of 126–636, each month. For comparison, we study logbook data on the proportion of saithe in commercial bottom trawl catches, in hauls where saithe were recorded. Hourly depth change and proportion of saithe in catches were averaged by month and 2 hour intervals for presentation as 'image plots'. Note that for longitudes in Icelandic waters the sun is in its highest position from approx. 1300–1400 hours on a time axis given in GMT. We have readings at 1 minute intervals from 14 recaptured saithe (mean length 59cm), for a total of 78 days in September–October 2003 and 2004 and January 2005. The September/October series started 2 months after tagging and the January series 5 months after tagging. Length at tagging was in the range of 42–79cm

The tags measure pressure with an accuracy of approx. 0.4% and a resolution of 0.03% of the selected pressure and depth range (`www.star-oddi.com` for further 'tech specs'). In this pilot DST study, tags were calibrated for different depth ranges, with an upper limit of 1–10m and a lower limit of 250, 400 and 760m. Corresponding accuracies in depth reading are approx. 1, 2.5 and 3m. Assuming two depth measurements are normally and independently distributed $z_1 \sim N(\mu_1, \sigma)$ and $z_2 \sim N(\mu_2, \sigma)$, the difference between the two is $\Delta z \sim N(\mu_2 - \mu_1, \sqrt{2}\sigma)$, i.e. a given reading accuracy multiplied by $\sqrt{2}$ should be the accuracy in the difference in two consecutive readings. However, short term changes are likely to be measured more accurately, possibly close to the specified resolution, which is an order of magnitude smaller than the accuracy. This is due to differencing which will remove reasonably well behaved tag bias and possible drift over time of the pressure sensor.

As the accuracies of the DSTs varied we chose the value of 3m, *ad hoc*, as criterion for picking out directed runs, putting emphasis on 'considerable' depth changes. Thus, a run was defined as a series of consecutive measurements, which had $|\Delta z| >$ 3m and were either all increasing or all decreasing in depth. We also express Δz as a 1min average vertical speed in units of body lengths at tagging ($BL@Ts^{-1}$). As the data series are mostly from 2 months after tagging (4 days after 5 months) the fish have had limited scope for growth.

Results

Results on diel depth changes are shown in Figure 1 by time of day and month, pooled over years. Average hourly Δz was highest during daylight hours, and nocturnal activity much reduced in winter. The tagged fish were on average in deeper waters during winter with a greater scope for vertical movement (see ICES CM2006/Q:21), explaining the maxima observed in daytime in winter. These results correspond well with proportion of saithe in trawler catches by season and time of day (Figure 2) as evidenced by the reciprocal pattern in Figures 1 and 2.

The maximum Δz for run lengths from 1–8 minutes for each of the 14 tags is given in Table 2. Runs of more than 8 min duration did not meet the criteria we set. The maximum vertical extent of directed runs for different run lengths indicates that each saithe is capable of depth changes in less than a minute of the same order as the maximum achieved in runs of longer duration. This suggests each fish has an 'operating range', probably determined by its swimming capabilities and location (shallow/deep).

One minute average vertical velocity in body lengths at tagging per second was greater than $0.1BL@Ts^{-1}$ for almost 20% of depth changes (Figure 3). Given speed over ground of either 1 or $0.5BLs^{-1}$, this would correspond to an average velocity angle from the horizontal close to $6\deg$ and $11\deg$, respectively. Time spent moving up or down by more than 3m/min was on average close to 20% and ranges up to 33% for one saithe (Figure 4).

A preliminary analysis of results with the same temporal resolution from 8 similar sized cod DST showed considerably less vertical activity. For the pooled cod data, less than 5% of movements up or down were more than 3m/min, while approx. 20% of were of more than 1m/min (MRI unpublished data, pers. comm. Bjorn Bjornsson and Vilhjalmur Thorsteinsson).

Conclusions

DST-results on saithe show diel and seasonal patterns in hourly depth changes, indicating reduced activity during nighttime and in winter, which is also reflected in logbook data on saithe catches.

First results with depth registrations at 1 min intervals show the saithe in this study changing depth on average by more than 3 meters almost 20% of the time while the early returns of cod DSTs with same time resolution showed considerably smaller changes, or by 1 meter for the same proportion of recordings. It must be noted that the cod data were collected in connection with a feeding experiment in shallow fjord in NW-Iceland, which may have reduced cod activity somewhat. Further comparisons are planned for the data sets for the two species.

Studies of rapid depth changes, and differences between consecutive depth changes, which could shed light on changes in tilt angle, with DSTs should continue. As measurement frequency increases so does the need for more accurate depth readings from the DSTs. The resolution of measurement error between components of drift over time (bias) and noise (random error) in the tags has to be considered.

Table 1. Maximum extent of directed runs up and down with $|\Delta z| > 3m$ between 1 minute depth measurements for each DST by length of run. Given as range: max(Δz_{down}) – max(Δz_{up}) in m, $\emptyset$ indicates no run in that direction, empty cells no runs at all.

		Run length (min)							
DST nr	Length at tagging (cm)	1	2	3	4	5	6	7	8
715	62	-31.4 – 35.5	-32.0 – 33.7	-33.2 – 28.8	-38.5 – 32.2				
723	42	-23.3 – 25.1	-31.5 – 37.8	-32.5 – 23.7	-22.1 – 25.3	-20.0 – $\emptyset$			
725	57	-18.2 – 20.7	-22.9 – 23.8	-21.4 – 21.0	-28.9 – 20.6	-26.2 – $\emptyset$			
727	68	-21.7 – 15.9	-27.8 – 22.8	-36.9 – 21.9	-47.9 – 21.4				
734	50	-22.3 – 15.6	-34.2 – 26.4	-46.9 – 38.2	-55.6 – 48.4	-26.9 – 47.2	-63.0 – $\emptyset$		
737	49	-34.3 – 29	-43.8 – 32.3	-28.2 – 39.5	-36.2 – 32.1	$\emptyset$ – 30.3			
908	49	-27.7 – 17.8	-26.5 – 23.6	-29.6 – 26.6	-16.5 – $\emptyset$				
914	49	-8.9 – 7.7	-9.8 – 10.5						
918	50	-86.1 – 69.4	-76.2 – 83.9	-68.2 – 86.9	-72.3 – 87.3	-40.4 – 75.2	-26.2 – 52.4		
919	58	-51.2 – 40.5	-35.3 – 32.3	-42 – 38.7	-43.9 – 68.7	-54.1 – 46.9	-62.2 – 43.9	-61.3 – 48.7	-54.5 – $\emptyset$
6002	77	-30.6 – 17.4	-36.5 – 35.7	-39.2 – 45.5	-44 – 42.4	-45.5 – 46.6	-48.5 – 43.3		
6009	57	-16.7 – 20.9	-26.7 – 26.8	-38.3 – 58.9	-37.8 – 37.5	-75.5 – 51.6	$\emptyset$ – 88.2		-110.9 – $\emptyset$
6012	78	-7.6 – 6.6							
6017	79	-28.8 – 18.3	-31.6 – 23.4	-32.8 – 27.8	-29.9 – 32.1	-29.4 – $\emptyset$			

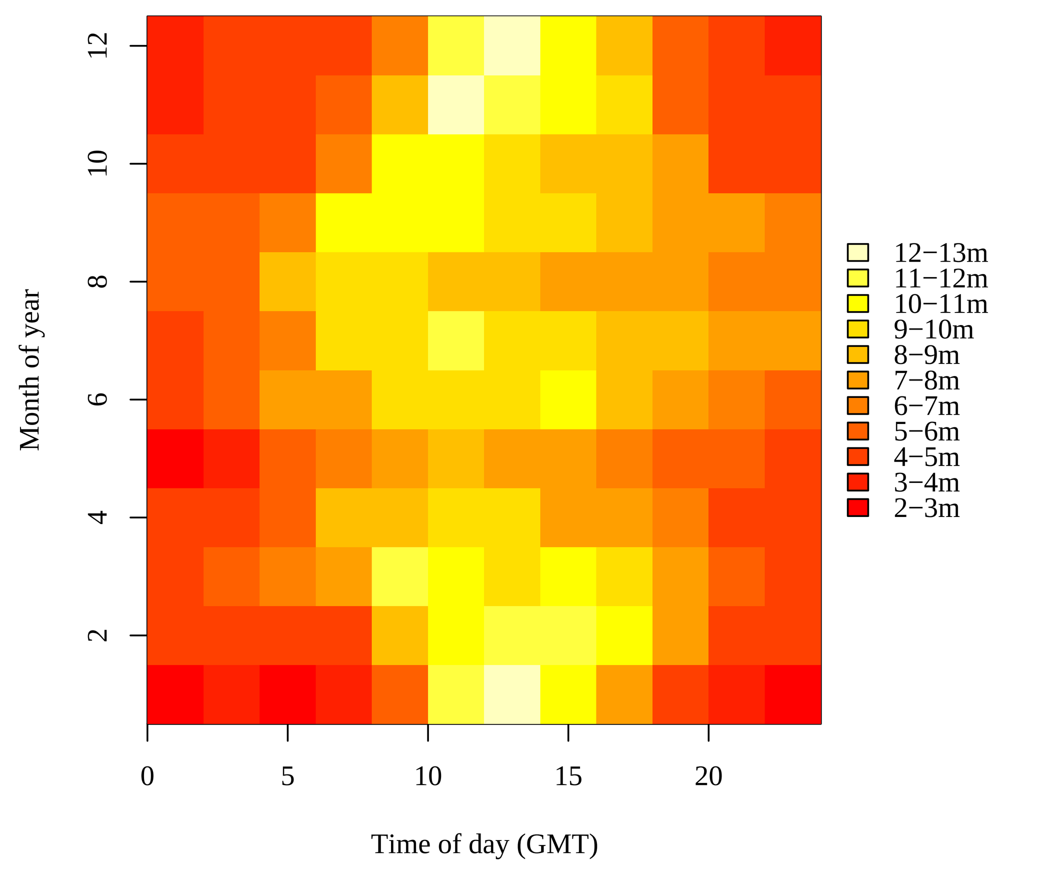

Figure 1. 'Activity pattern' of saithe by time of day and month. Mean of absolute hourly depth change ($|\Delta z|$) is shown.

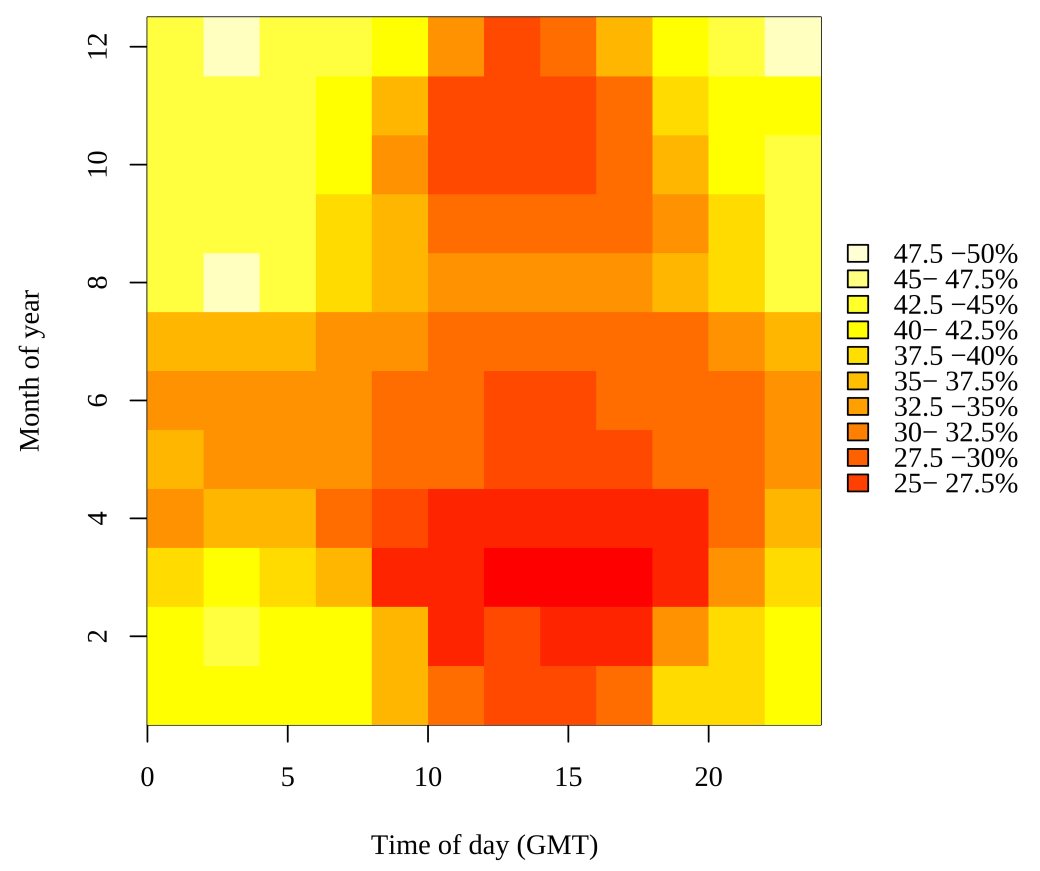

Figure 2. Mean proportion of saithe in reported catches (1991–2005) by month of year and time of day

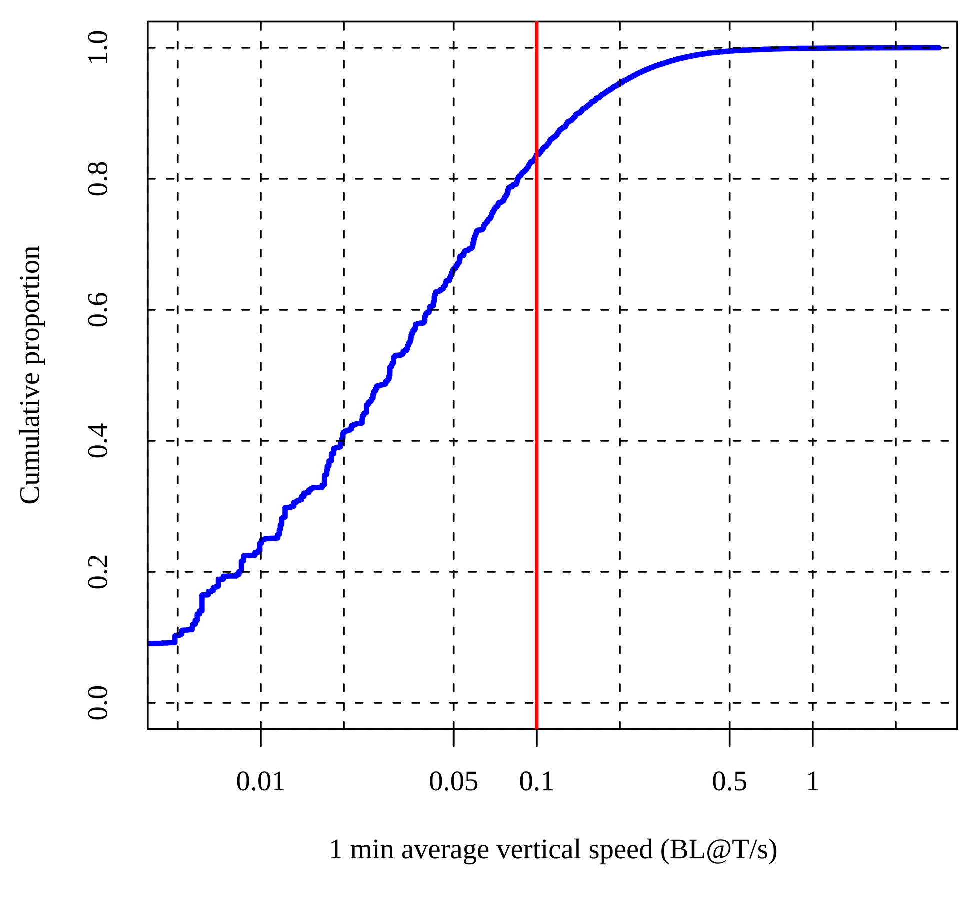

Figure 3. Cumulative distribution of $|\Delta z|$ for one minute intervals, given as average vertical speed standardized as $BL@Ts^{-1}$. Note log–scale on X–axis, the vertical line at $0.1BL@Ts^{-1}$ indicates a tilt angle of $5.7\deg$ for a fish swimming straight with horizontal speed of $1BLs^{-1}$.

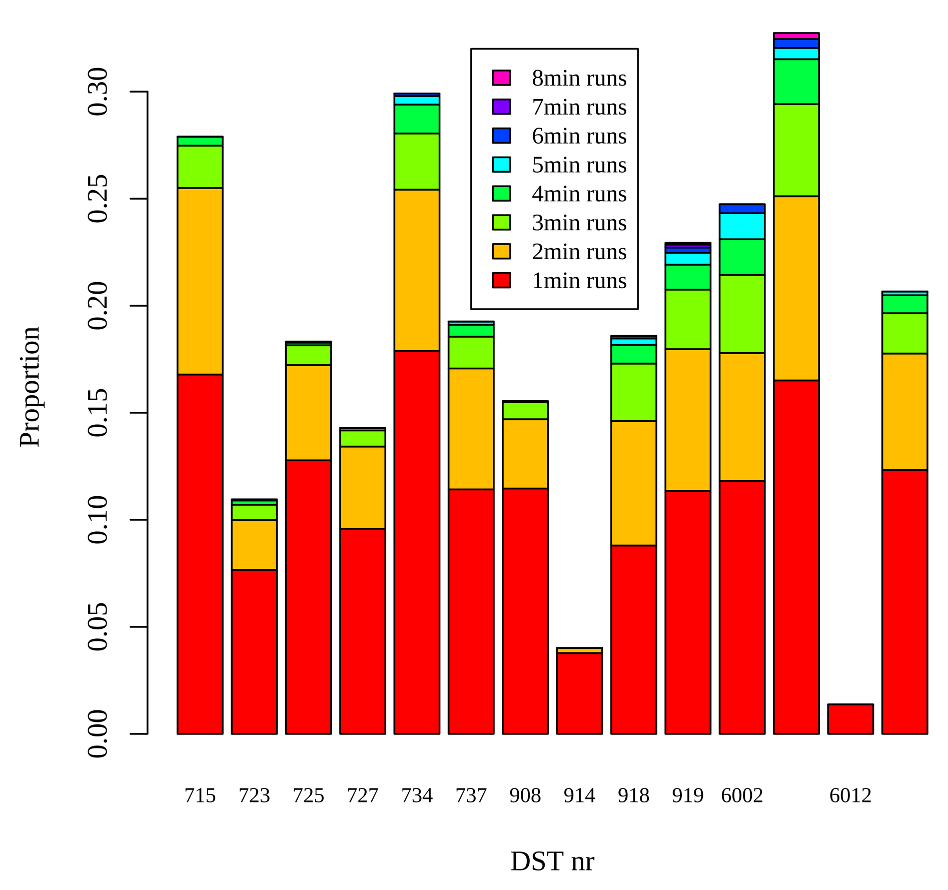

Figure 4. Proportion of time devoted to runs ($|\Delta z| > 3m$ for each one minute) of different duration by individual tagged fish. No directed runs longer than 8 min, which met our criteria, were observed.