The following supplement accompanies the article

Consistency in the behaviour types of the Atlantic cod *Gadus morhua*: repeatability, timing of migration and geo-location

Vilhjálmur Thorsteinsson[1], Ólafur K. Pálsson[1], Gunnar G. Tómasson[2], Ingibjörg G. Jónsdóttir[1], Christophe Pampoulie[1,*]

[1]Marine Research Institute, Skúlagata 4, 101 Reykjavík, Iceland

[2]Reykjavik University, School of Science and Engineering, Menntavegur 1, 101 Reykjavík, Iceland

*Corresponding author. Email: chrisp@hafro.is

Marine Ecology Progress Series: 462: 251–260 (2012)

Supplement 1. This supplementary material consists of a table showing details of the recaptured individuals followed by a detailed description of the tidal location model used in the study

Table S1. *Gadus morhua*. Details of individuals that were recaptured after at least 18 mo. Behaviour type: C = coastal, F = frontal. Release area: SE = southeast, SW = southwest, W = west, NE = northeast. Sex: F = female, M = male. –: no data. Dates are given in dd/mm/yy

Tag ID	Behaviour type	Release area	Release date	Recapture date	Days at liberty	Release length (cm)	Recapture length (cm)	Age at recapture (yr)	Sex
3C0306	C	W	11/04/05	29/07/07	839	102	112	12	M
2C0378	C	W	14/04/05	25/02/08	1047	77	110	9	F
1C0397	C	SE	12/04/03	26/02/06	1051	90	112	11	F
2C0404	C	W	14/04/05	28/04/07	744	101	114	7	F
1C0407	C	SE	12/04/03	29/04/07	1478	107	-	-	M
2C0417	C	SE	12/04/03	29/03/06	1082	84	104	8	M
2C0426	F	W	14/04/05	13/05/07	759	96	103	11	M
1C0431	C	SE	12/04/03	05/09/04	512	96	98	7	F
1C0444	C	SE	12/04/03	11/03/05	699	93	106	7	M
2C0444	F	W	14/04/05	16/01/07	642	81	94	-	F
1C0480	F	SE	13/04/03	02/05/05	750	89	99	8	F

Some Table S1 date formats were corrected after publication

1C0503	C	SE	14/04/03	23/11/04	589	93	103	8	F
2C0544	F	SW	17/04/03	28/03/08	1807	87	-	-	F
1C0585	F	NE	23/04/03	20/09/06	1246	99	111	10	F
1C0593	F	NE	23/04/03	06/03/05	683	78	87	10	F
1C0595	F	NE	23/04/03	11/04/05	719	73	90	9	F
1C0605	F	NE	24/04/03	05/03/05	681	78	90	9	M
1C0611	F	NE	24/04/03	22/02/06	1035	73	90	8	F
2C0641	C	W	02/04/04	13/10/05	559	77	94	6	F
2C0645	C	W	02/04/04	03/10/05	549	85	100	7	M
3C0650	C	W	02/04/04	01/09/05	517	90	105	-	F
2C0669	F	W	03/04/04	04/05/06	761	105	107	9	F
1C1146	F	SW	05/04/04	13/03/07	1072	79	98	9	M
1C1164	F	SW	06/04/04	15/04/07	1104	91	104	11	F
1C1166	C	SW	06/04/04	05/01/08	1369	77	109	9	F
1C1195	C	SW	16/04/04	24/02/06	679	91	107	10	M
1C1198	F	SW	16/04/04	23/01/06	647	102	117	12	F
1C1224	C	SE	18/04/04	04/11/05	565	65	69	6	F
1C1225	C	SE	18/04/04	02/11/06	928	87	101	7	M
1C1231	C	SE	18/04/04	07/09/05	507	70	78	5	F
1C1240	C	SE	18/04/04	17/03/06	698	101	112	10	M
1C1244	F	SE	18/04/04	24/09/05	524	84	90	7	F
1C1282	C	SE	19/04/04	10/01/06	631	103	118	8	F
1C1426	F	SE	23/04/04	07/03/06	683	98	108	-	M
1C1448	F	SE	22/04/04	03/04/06	711	98	104	12	F
1C1477	F	SE	23/04/04	12/11/06	933	75	87	-	F
1C1480	F	SE	23/04/04	19/05/07	1121	91	105	-	F
2C1489	C	W	09/04/05	10/08/07	853	100	-	-	F
2C1492	F	W	10/04/05	30/05/07	780	76	90	7	M
3C1499	F	W	10/04/05	12/08/07	854	76	-	-	M
2C1517	C	W	10/04/05	06/06/07	787	95	109	10	M

Supplement 2. Tidal location model

The first step of the tidal location model identifies possible tidal signals in the observed data storage tag (DST) patterns. This is done by sliding a 10 h window over the DST pattern and fitting a sine curve to the signal. If 3 criteria are satisfied, i.e. root mean square error, RMSE < 0.42 m; coefficient of determination, $R^2 > 0.85$; and amplitude of the fitted sine wave, A > 0.3 m, the DST pattern is identified as a potential tidal signal. The second step, applied when a fit to a sine curve is identified, consists of finding the most probable location of the fish by comparison of the amplitude and phase of the fitted sine curve with calculated tidal signals within the model domain. These steps are identical with those of Pedersen et al. (2008) (see Literature Cited in the main text), except for the criteria on minimum amplitude, which was twice as small in this study to adapt to tidal conditions in the sea around Iceland, resulting in an automatically proposed location of the fish.

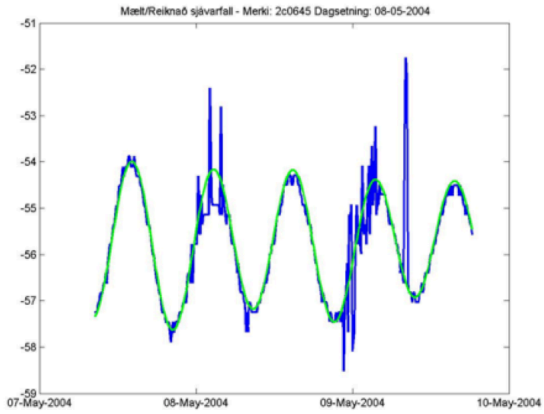
In the third step of the model, a decision is made on whether the identified potential tidal signal and the corresponding proposed location are accepted. The decision, which is partly subjective, is based on the following 3 criteria:

(1) Is the identified signal likely to be a tidal signal, and is the fit between the observed DST pattern and the calculated tidal signal convincing? Here, an evaluation of the fit outside the 10 h window applied in the calculations is added in a subjective manner. By applying a sliding window of length >10 h, the need for this step would be reduced. This would, however, result in many very convincing tidal signals being omitted because of their limited length in time. The cod may also move to a nearby location with a slightly different water depth (see example below), which makes it difficult to implement an automatic evaluation algorithm.

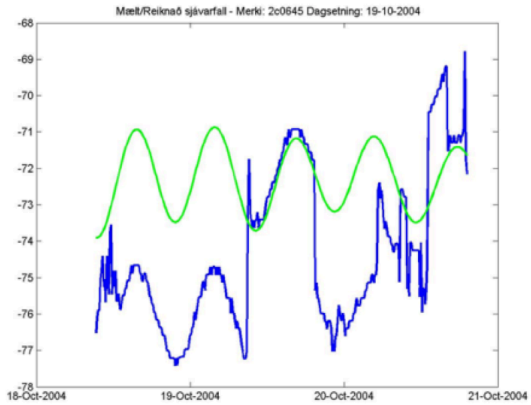
(2) Is the water depth according to the DST pattern (the cod must be at the bottom for the tidal signal to show up in the DST pattern) in reasonable agreement with the water depth taken from the tidal model at the proposed location? A difference of ~10 m is taken to be acceptable given the limited resolution of the tidal model as well as the expected accuracy of the proposed location.

(3) Is the swim speed of the cod from the last accepted location within reasonable limits? A reasonable maximum swim speed for the cod is within the range of 20 to 40 km d^{-1}, but a more relaxed criterion (~50 km d^{-1}) was applied here to reflect the expected accuracy of the method and the proposed tidal locations.

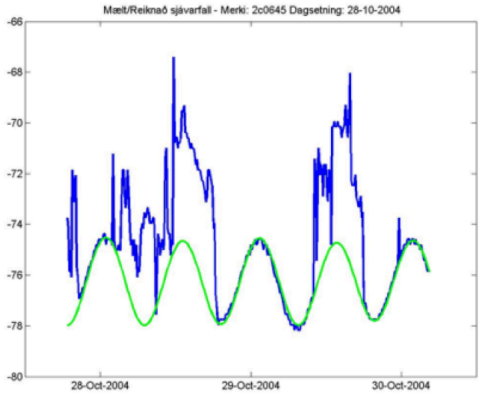
The final decision, whether a proposed location is accepted or not, is based on an evaluation of all the above criteria together. Given below are a few examples of accepted or rejected locations for cod 2C0645. In all cases, the 10 h window applied in the calculations is at the centre of the graph. For easier comparison between the DST pattern (blue curve) and the proposed tidal signal (green curve), the average of the calculated tidal signal (mean depth) has been set equal to the average depth in the DST pattern within the 10 h window (i.e. an exact match between the mean water depth as measured in the DST pattern and that from the tidal model has been assumed, cf. point 2 above).



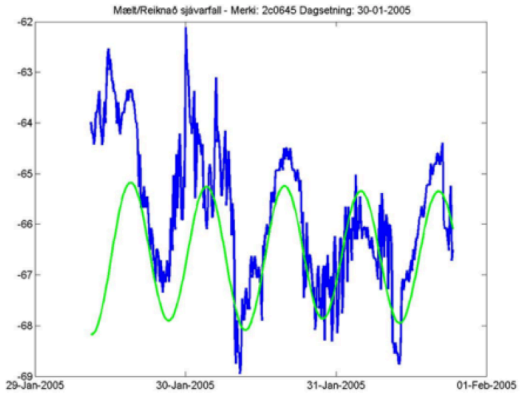
8 May 2004: Very good fit to the tidal signal, both within the 10 h window and outside it. The cod stays at the bottom for a long period. Location accepted.



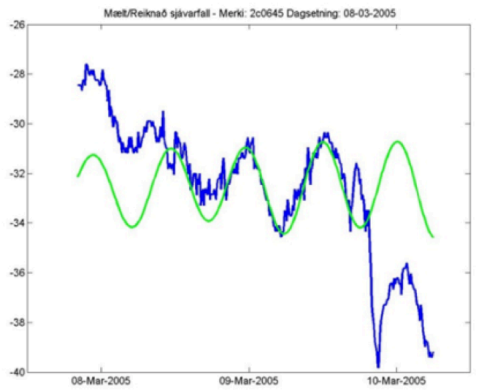
19 October 2004: Very good fit to the tidal signal within the 10 h window. Also convincing tidal signals outside the 10 h window (both forward and backward in time), although at different depths (the cod moves to a nearby location where the water depth is slightly different). Location accepted.



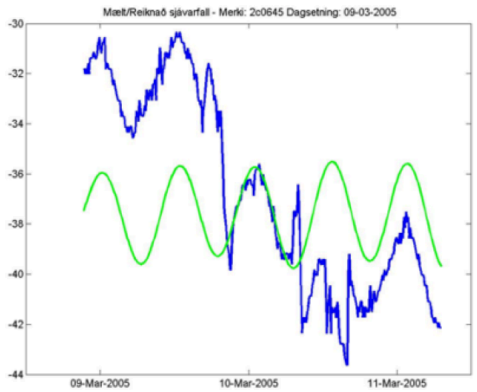
29 October 2004: Very good fit to the tidal signal, both within the 10 h window and outside it. The cod revisits the bottom repeatedly. Location accepted.



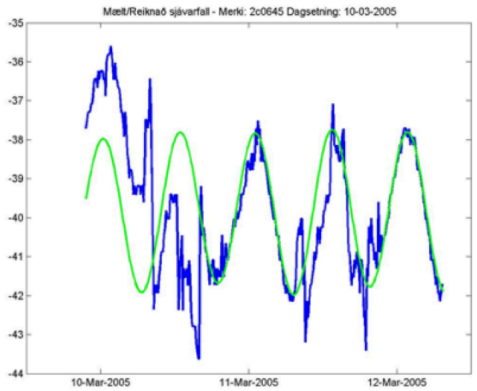
30 January 2005: There is no clear tidal signal in the DST pattern, neither within the 10 h window nor outside it. The fit within the 10 h window is not convincing. Location rejected.



8-9 March 2005: Good fit within the 10 h window as well as immediately following it. Location accepted.



9-10 March 2005: Reasonable fit within the 10 h window, but swim speed from the last accepted location (example above) too large (250 km d^{-1}). Location rejected.



10-11 March 2005: Good fit within the 10 h window as well as outside it (forward in time). Swim speed from last accepted location (2 examples above) within reasonable limits (50 km d^{-1}). Location accepted.

Supplement 3. Verification of the accuracy and reliability of the tidal location model

The accuracy and reliability of the tidal location model were verified by applying the method to time series from stationary tags (tags moored at fixed locations, Fig. S1). The results are given in the table below. The location predicted by the tidal location model is referred to as the 'calculated location'. Note that locations are given in degrees longitude and latitude, whereas the difference between calculated and actual location is given in km.

In general, the accuracy of the method is very good, giving a calculated location within 10 to 20 km of the actual location. The only exceptions to this occurred at 3 locations along the northern coast of Iceland, in Húnaflói (tag ID 1C2702 and 3C2703), at Tjörnes (tag ID 1M8714 and 1M8715) and for 1 tag in Þistilfjörður (tag ID 1C2719; the other tag in Þistilfjörður, ID 1C2708, gave a much better result). The difference in Þistilfjörður may be due to problems with the measurements, as 1 tag gave a very good result whereas the calculated location of the other tag was less accurate. For Húnaflói and Tjörnes, the discrepancies are believed to be due to localized inaccuracies in the tidal model. These inaccuracies were later reduced by re-calibration of the tidal model, but that work was done after the analysis presented in the current paper was finished. The effect of these inaccuracies should be minimal in the present study, as no locations were detected near the Húnaflói area for any of the 41 tagged cod analysed in this paper, and only a handful of locations (4 to 5 altogether) where detected near the Tjörnes area.

Table S2. Comparison of actual and calculated locations for stationary tags

Tag ID	Location			Calculated location		Difference (km)		
	Name	Long.	Lat.	Long.	Lat.	Long.	Lat.	Total
1C2718	Breiðafjörður	-23.243	65.238	-23.004	65.203	-11.15	3.88	11.81
1C2715	Faxaflói	-22.704	64.214	-22.759	64.111	2.70	11.40	11.72
1M8722	Hornbanki	-21.583	66.824	-21.522	66.787	-2.67	4.14	4.93
1M8723	Hornbanki	-21.583	66.824	-21.351	66.784	-10.15	4.44	11.09
2C2702	Húnaflói	-21.000	65.686	-20.749	65.799	-11.46	-12.60	17.03
1C2702	Húnaflói	-21.348	65.673	-21.250	66.187	-4.49	-57.14	57.32
3C2703	Húnaflói	-21.000	65.686	-21.265	66.186	11.91	-55.66	56.92
1C2713	SE af Hrolllaugseyjum	-15.838	63.943	-15.756	63.799	-4.02	15.95	16.45
1C2705	Selvogsbanki	-21.394	63.557	-21.397	63.564	0.14	-0.85	0.86
1C2704	Skaftárós	-17.633	63.666	-17.256	63.691	-18.57	-2.87	18.79
3M8994	Snæfellsnes	-24.134	64.831	-23.960	64.720	-8.04	12.92	15.22
2C2718	SSE Stokksnesi	-14.822	64.135	-14.750	64.135	-3.47	4.09	5.36
2C2719	SSE Stokksnesi	-14.822	64.135	-14.761	64.102	-2.97	3.64	4.70
2C2705	Straumnes	-23.301	66.506	-23.270	66.532	-1.40	-2.81	3.13
1M8714	Tjörnes	-17.477	66.154	-18.257	66.210	34.98	-6.20	35.52
1M8715	Tjörnes	-17.477	66.154	-18.431	66.225	42.76	-7.92	43.49
1C2703	Út af Alviðru	-18.425	63.394	-18.510	63.301	4.24	10.35	11.18
1C2708	Þistilfjörður	-15.384	66.278	-15.252	66.298	-5.92	-2.22	6.32
1C2719	Þistilfjörður	-15.720	66.540	-15.503	66.310	-9.70	25.62	27.40

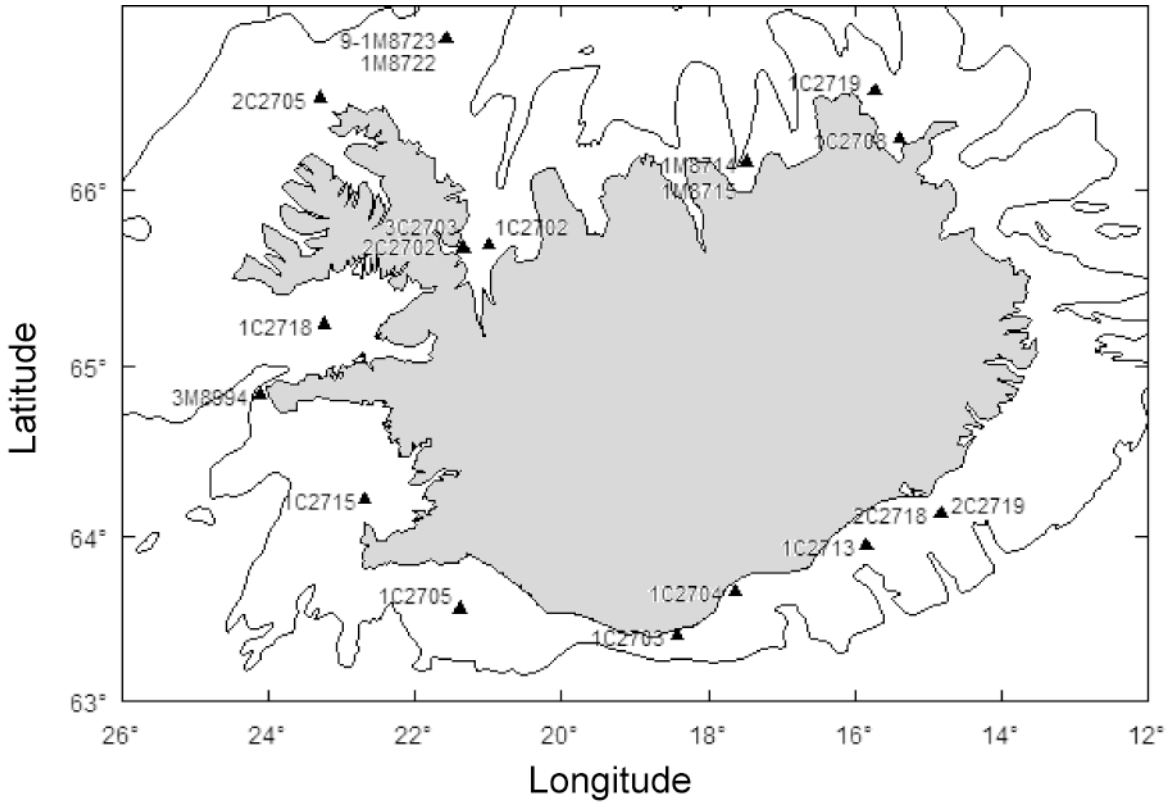


Fig. S1. Locations and identification numbers of stationary tags for a verification of the tidal location model. The 200 m depth contour is indicated.