Spawning pattern detection using PatternFinder.

Introduction

The Atlantic cod spawning season in Icelandic waters is from mid March to mid May [6]. During this time there are periods of minimal vertical movement and also spikes where the cod rises and dives. These spikes could indicate a ventral mount [1].

A ventral mount as described by Brawn (1961):
"Then if the female became stationary at the bottom of the tank it was prodded ventrally by the male, which caused it to swim upwards. At the surface the male mounted the female dorsally and then immediately slipped down one side into a ventral mount with the male inverted below the female. In this position the cod spawned while swimming in circles at the surface." [4]

This case study is based on data analysis in relation to **Lunacy in Atlantic cod: Assessing the timing of spawning in Atlantic cod using ocean models and electronic data storage tags** by Grabowski et al. [1].

The sample data is provided by the Marine Research Institute of Iceland, see figure 1. The data is from a DST Centi, manufactured by Star-Oddi. Depth samples are at 10 minute intervals for 3 years.

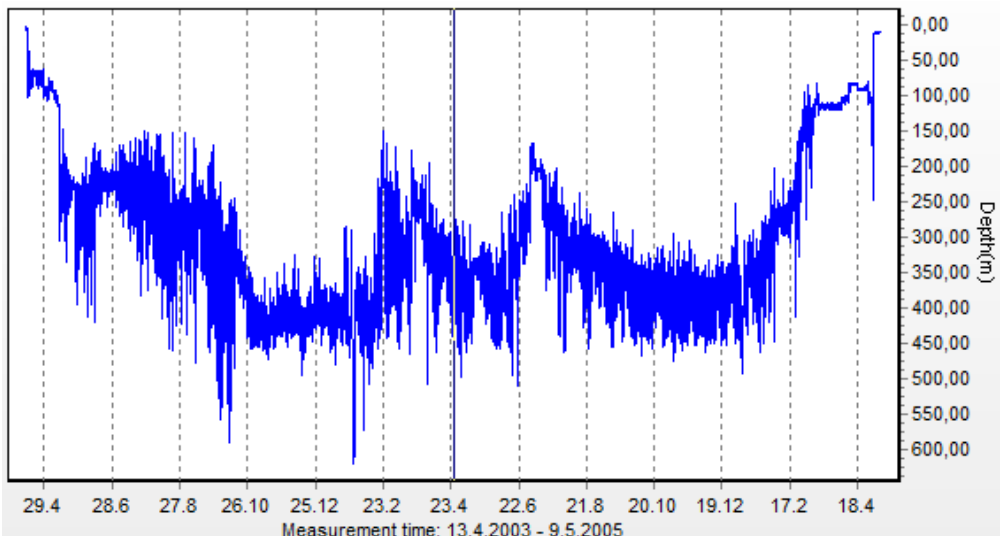

Figure 1: Sample data

Method

Candidates for spawning patterns are spikes that occur during the spawning season and where there is a clear tidal signature. They can be found by doing the following:

1. Open the data in PatternFinder by creating a single file project
2. Export the spawning season from the depth signal
3. Find clear tidal signature
4. Find ventral mounts
5. Intersect tidal signature and ventral mounts

Open the data in PatternFinder by creating a single file project

To create a new single file project go to the menu bar and select Project-SFP-New. Then browse to the location of the DAT file, see figure 2. This procedure is described in more details in the user's manual chapter **Single File Projects (SFP)** [5].

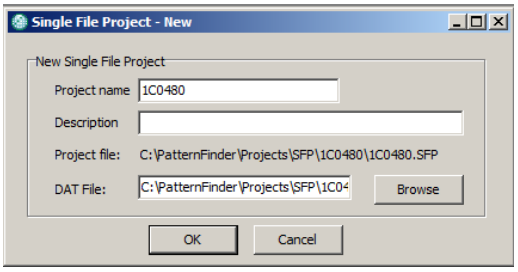

Figure 2: Create new single file project

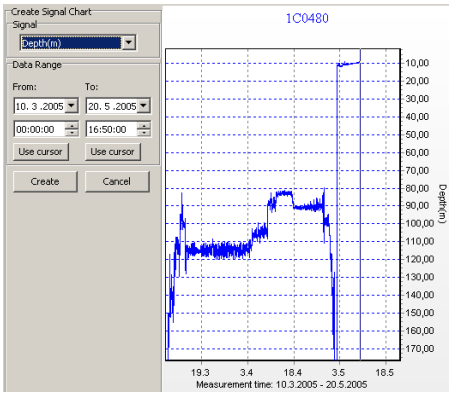

Figure 3: Export signal

Export the spawning season from the depth signal

To export the season from the DAT file first open the DAT file. Then press the operation button **Select Signal to Signal Chart.** The beginning and end of a spawning season is inputted, 10 March and the end 20 May, this is repeated for each year, see figure 3. See chapter **Charts.SDX chart** [5] for more details.

Find clear tidal signature

Studies suggest that cod courtship during spawning aggregations take place near the seabed. Because of this behaviour it is possible to search for tidal waves that indicate when the cod may be in a spawning aggregation [1].

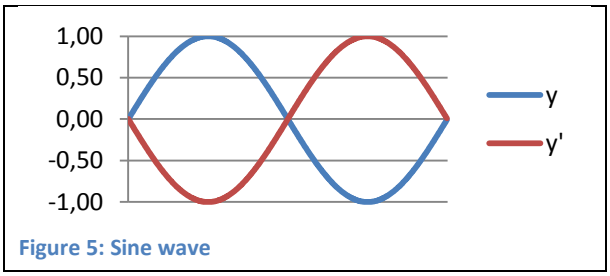

Figure 5: Sine wave

First start by creating two 12 hour sine waves, y and y', see figure 4. Although a tidal period is approximately 12 hours and 25.2 minutes a 12 hour wave is used. This is because PatternFinder doesn't allow overlapped occurrences.

In an attempt to find tidal signature in a noisy period the signal is filtered. Single spike filter is first used, 10m/10min see figure 5, then moving average, 3 measurements window and 10 iterations see figure 6, the filters are described in the user's manual chapter **Filtering and Operations**.

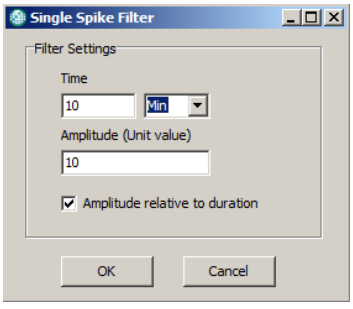

Figure 6: Single spike filter

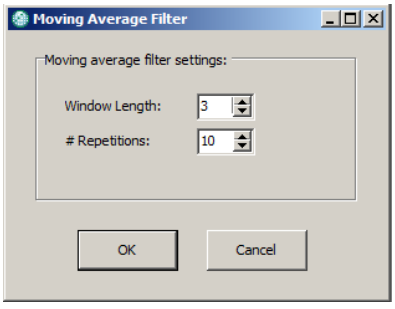

Figure 7: Moving average filter

A correlation pattern template search, with 90% threshold, is performed using the two sine waves as template, see figure 7. Then filter the patterns by amplitude, less than 5.0m. Pattern occurrences from y and y' are then combined, see figure 8 and 9. The chapter **Pattern analysis** [5] in the user's manual describes the operations in greater detail.

The pattern search for the unfiltered signal gave good results for the area we estimated to be a tidal signature. In the filtered signal we found more tides for the noisy areas.

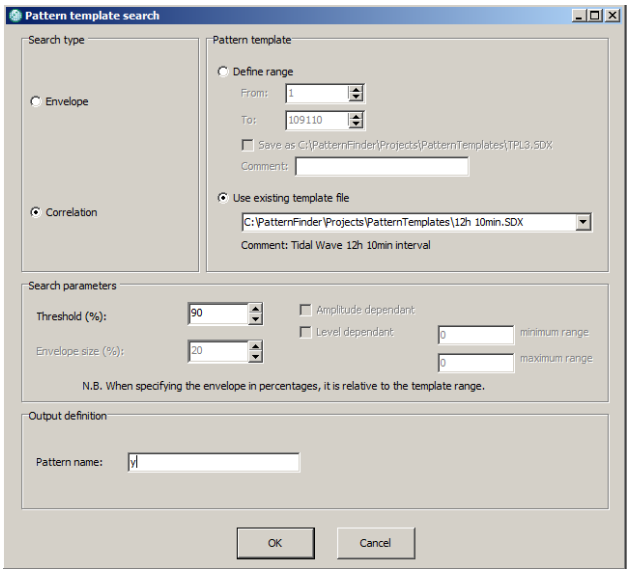

Figure 8: Pattern template search

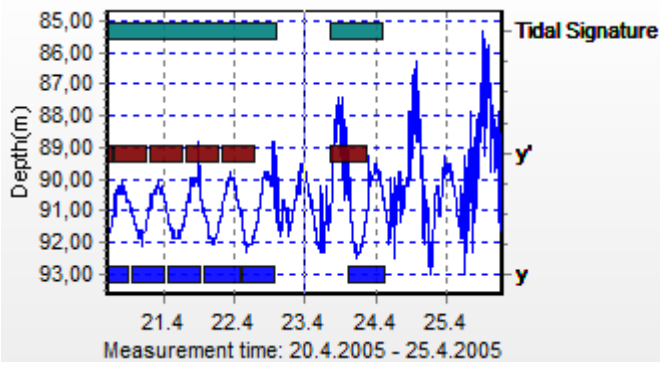

Figure 9: Tidal signature, unfiltered

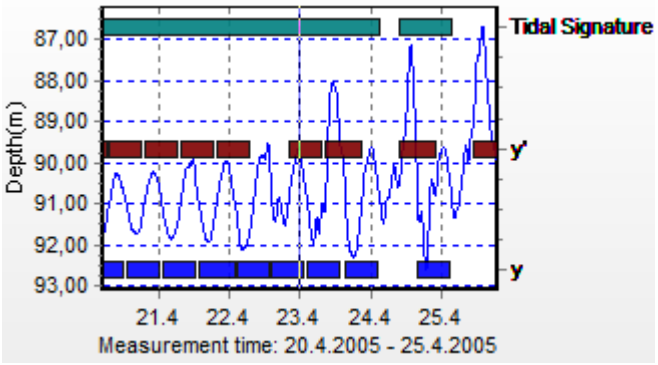

Figure 10: Tidal signature, filtered

Find ventral mounts

First a signal is created that mimics a ventral mount, see figure 10, where a cod is stationary at the seabed with a rise and dive back to the previous depth. To reduce the possibility of noise being identified as a ventral mount there must be three consecutive measurements of similar depth prior to the cod rise.

A correlation pattern template search is then performed using the ventral mount signal as template, on each spawning season. Then filter the patterns by amplitude, 1.35m-15.0m, and hit-percent, 90%-100%.

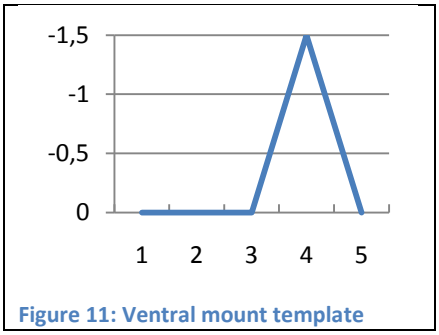

Figure 11: Ventral mount template

Intersect tidal signature and ventral mounts

The spawning pattern can then be found where there is both a tidal signature and a ventral mount.

The tidal signatures and ventral mounts are then combined into a multi pattern chart, see figure 11. Then the intersection of patterns is found.

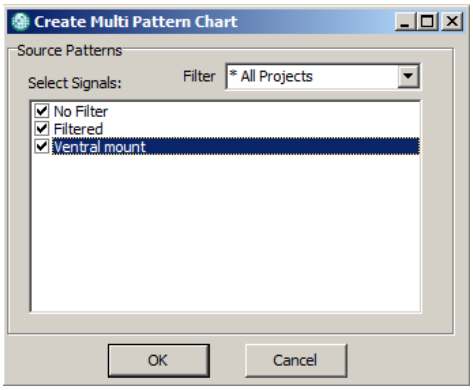

Figure 12: Create multi pattern chart

Spawning pattern A is the result of tidal signature from an unfiltered depth signal and spawning pattern B is from the filtered signal, see figure 12. Spawning pattern A had only a few occurrences and is not considered in the final result.

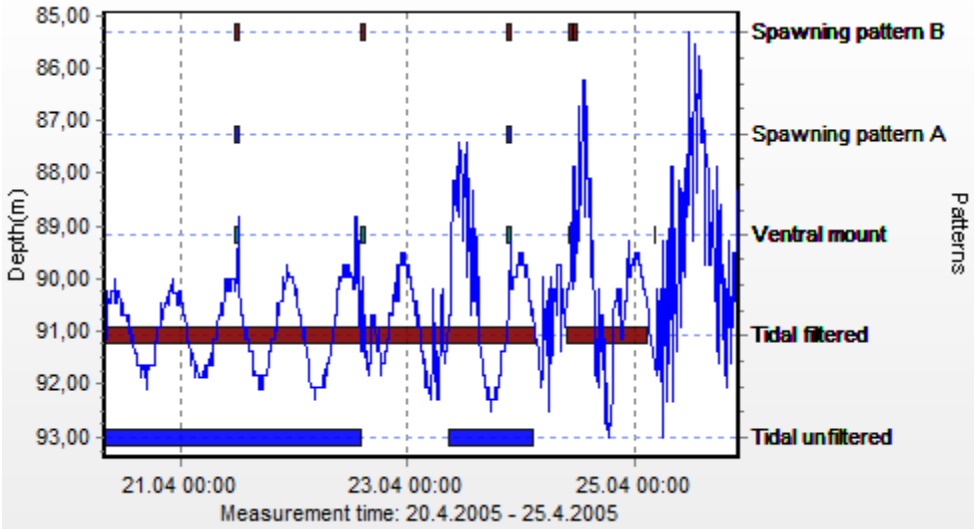

Figure 13: Spawning patterns

Result

The example data used in this case was from a female cod. The measurements were from 13.4.2003-9.5.2005. In 2005 PatternFinder found two good tidal signatures each approximately 4 days long and with different depth, possibly indicating different spawning aggregations. There were no good tidal signatures in 2003-2004 resulting in only a single spawning pattern. In 2005 there were 16 spawning patterns.

Grabowski et al. had manually observed 4 occurrences in 2003. PatternFinder did recognise 3 of them as ventral mounts but it did not find a tidal signature to identify them as spawning patterns. Grabowski et al. had also observed 8 occurrences in 2005 where PatternFinder found 16 and 5 of them matched his, see table 1.

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Occurrence	Grabowski TB	Tidal filtered	Ventral mount	Spawning pattern
15.4.2003 06:30	✓		✓	
15.4.2003 07:50	✓		✓	
15.4.2003 11:40	✓		✓	
15.4.2003 12:10	✓			
7.5.2003 15:30		✓	✓	✓
15.3.2005 08:30		✓	✓	✓
15.3.2005 12:20		✓	✓	✓
18.3.2005 03:00		✓	✓	✓
31.3.2005 00:30		✓	✓	✓
7.4.2005 12:30		✓	✓	✓
7.4.2005 19:00		✓	✓	✓
8.4.2005 09:10		✓	✓	✓
10.4.2005 11:20		✓	✓	✓
15.4.2005 00:10		✓	✓	✓
16.4.2005 15:50	✓			
21.4.2005 12:00	✓	✓	✓	✓
22.4.2005 14:40	✓	✓	✓	✓
23.4.2005 13:40	✓	✓		
23.4.2005 21:40	✓	✓	✓	✓
24.4.2005 10:50		✓	✓	✓
24.4.2005 11:40	✓	✓	✓	✓
24.4.2005 18:00	✓	✓		
26.4.2005 01:30	✓	✓	✓	✓
26.4.2005 07:00		✓	✓	✓
Total	**12**	**19**	**20**	**17**
2003 % of Grabowski's		**0%**	**75%**	**0%**
2005 % of Grabowski's		**88%**	**63%**	**63%**

Table 1: Spawning occurences 2003-2005

Further application

The tidal wave signatures can be used for other purposes such as geolocation. The tidal occurrences can be exported from PatternFinder and then imported to the application used to calculate geolocation.

References

1. Grabowski TB, BJ McAdam, K Logemann, V Thorsteinsson & G Marteinsdóttir. Lunacy in Atlantic cod: assessing the timing of spawning in Atlantic cod using ocean models and electronic data storage tags. ICES CM 2010/A11.
2. Grabowski TB, Thorsteinsson V, McAdam BJ, Marteinsdóttir G (2011) Evidence of Segregated Spawning in a Single Marine Fish Stock: Sympatric Divergence of Ecotypes in Icelandic Cod? PLoS ONE 6(3): e17528. doi:10.1371/journal.pone.0017528
3. Grabowski T.B., V. Thorsteinsson, and G. Marteinsdóttir. Assessing the lekking hypothesis for the mating system of Atlantic cod (Gadus morhua) using electronic data-storage tags. ICES CM 2009/B1.
4. Brawn VM (1961) Reproductive Behaviour of the Cod (Gadus callarias L.). Behaviour 18: 177-197.
5. Star-Oddi. PatternFinder user's manual
6. Thorsteinsson, V. and Marteinsdottir, G. 1998. Size specific time and duration of spawning of cod (Gadus morhua) in Icelandic waters. International Council for the Exploration of the Sea. C.M. 1998/DD-5. 18 p.