Identification of vertical and horizontal movement patterns in cod behavior

ABSTRACT

The Atlantic cod is one of the most important commercial species known. The behavior of this species, important for fisheries, research and stock assessment, is in many ways masked by extensive horizontal and vertical dispersion in its habitat. The potential of using the Theme software in behavior studies of commercial fish stocks was tested using data from tagging experiments with adult cod in Icelandic waters. The time series were prepared for T-pattern analysis, including detection and delimitation of tidal influence in the data and event basing raw data according to predefined events. A high number of temporal patterns were detected, patterns of repeated vertical movements and speed and acceleration changes. Number of specific temporal patterns were also identified within and across vertical movements of individual cod. Future objective is to explore these patterns in relation to environmental factors and horizontal location.

Author Keywords

Cod, Gadus morhua, behaviour, DST tags, tidal wave model, T-patterns.

ACM Classification Keywords

Cod, Gadus morhua, behaviour, DST tags, tidal wave model, T-patterns.

INTRODUCTION

The Atlantic cod (Gadus morhua L.) is historically one of the most important commercial species known [2]. The behavior of this species, important for fisheries, research and stock assessment, is in many ways masked by extensive horizontal and vertical dispersion in its habitat [3]. The current study discusses a new approach to analyze behavior such as horizontal and vertical movements of tagged cod in Icelandic waters. The approach, known as T-pattern detection, has successfully been used within other research fields but never before in this particular field. The data presented show that specific temporal patterns can be identified within and across vertical movements of individual cod in relation to environmental parameters.

What Theme does

Theme (see www.patternvision.com) looks for relationships between events. It takes into account the order and relative timing (critical interval relationship). If the critical interval is less than would be expected by chance, it defines a pattern called T-pattern. Theme starts with simple patterns and gradually adds them together to form more complex patterns. Less complete patterns do not survive, longer chains are “fitter”; as the patterns recombine and grow, only the fittest survive.

METHOD

The data was collected using the Data Storage Tags (DST centi series) developed by Star-Oddi (see www.star-oddi.com). The DST centi is a small underwater data logger, available with sensors for underwater temperature and depth logging. The cod was tagged with Data Storage Tags (DSTs) with memory capacity of up to 260,000 records measuring temperature and depth at 10 minutes intervals. All measurements are time related, utilizing a real time clock inside the DST.

Each event is defined by start time and end time, and also a label indicating the meaning of the event. For example, an event may indicate that the tag was located at a certain depth level, or that temperature increased over a certain time interval. The 3 types of events used in the current study are:

- Level-based events that are based on the range of the measurement data.
- Speed-based events, which indicate changes in the data.
- Acceleration-based events, which indicate changes in speed1 over time.

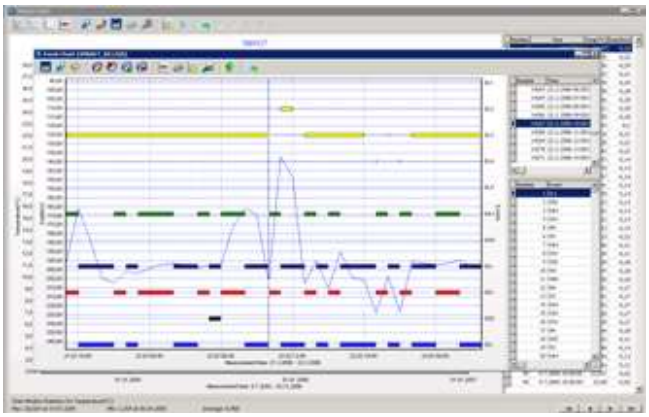

Figure 1. Event basing depth data involved partitioning time-series into defined periods/events.

Tidal wave model

A numerical model has been developed and set up to predict sea level variations and tidal currents along the Icelandic coastline, taking into account both the astronomical and meteorological forcing. The model is run on an operational basis at the Icelandic Maritime Administration to predict sea level and tidal currents in Icelandic coastal waters using a weather forecast from the European Center for Medium Range Weather Forecasts. The model is based on the two-dimensional part of the Princeton Ocean Model (POM) [4], solving the nonlinear shallow water equations numerically using a staggered finite difference scheme.

RESULTS

Tidal location of fish in the ocean around Iceland

Knowledge of the whereabouts of tagged fish between tagging and recapture is important in research on commercial fish stocks. Indirect location of fish with DST tags measuring water pressure is possible by isolating the tidal variation of sea level (pressure) from other variations of pressure, such as those due to change of depth by the fish. These, together with the tidal model, may then be used to find the location within the ocean with matching tides to those measured by the fish. Tidal location of fish has been attempted in the North Sea with good results [1].

The existence of a tidal model and in particular the existence of a database for amplitude and phase of the most important tidal components for all the ocean around Iceland make it possible to attempt tidal location of tagged fish around Iceland. Figure 2 shows results from an experimental application of this method to fish tagged in Icelandic coastal waters using the database of tidal components generated by the tidal model described here. Preliminary results show that this method can indeed be used with the current database and that the accuracy obtained in location of the fish will be acceptable. However, improvements of the database and the tidal location method being applied are planned in the near future to improve the accuracy of the predicted locations.

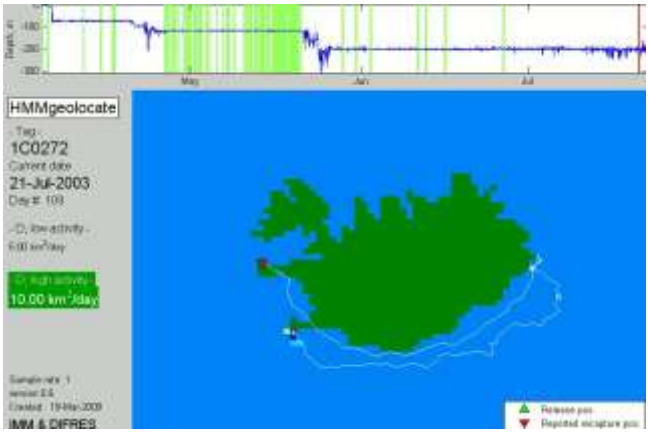

Figure 2. Example from an experimental application of this method tracing a cod tagged in Icelandic coastal waters using the database of tidal components generated by the tidal model.

Patterns of vertical movements

A high number of temporal patterns were detected in the cod DST data. These patterns were of repeated vertical movements, speed and acceleration changes as well as resting at the same defined vertical level. An example of pattern of an individual cod is displayed in Figure 3. Number of specific temporal patterns were also identified within and across individual cod vertical movements

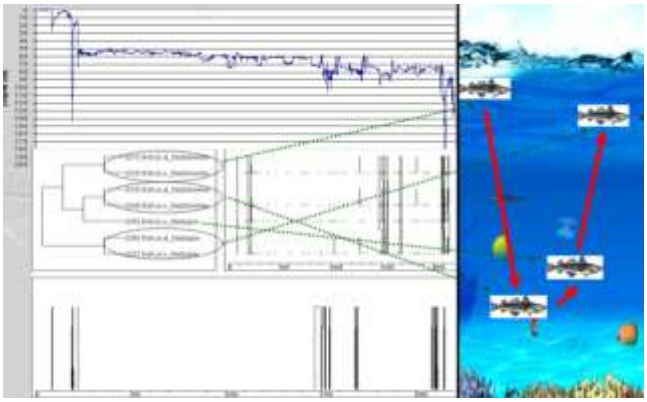

Figure 3. An example of one pattern of vertical movements found in the time series. The pattern occurs 12 time during the observation period with same order and approximately the same time interval between event types.

DISCUSSION AND CONCLUSION

Preliminary results indicate that a Theme analysis can make a significant contribution to the analysis of cod behavior, offering an increased advantage to view and understand hidden patterns within a large number of data points. A high number of temporal patterns were detected, patterns of repeated vertical movements and speed and acceleration changes. Number of specific temporal patterns were also identified within and across individual cod vertical movements. Future objective is to further search for patterns of vertical movement in relation to environmental parameters emphasizing a) behavioral patterns that are tidal-wave related, b) behavioral patterns related to temperature and depth data, c) behavioral patterns related to

observed patterns of wind speed and direction, tidal stage, lunar stage, day length, and other local oceanographic features, and d) behavioral patterns related to location of the cod in the Icelandic waters

REFERENCES

1. Hunter, E., J.N. Aldridge, J.D. Metcalfe & G.P. Arnold. 2003. Geolocation of free-ranging fish on the European continental shelf as determined from environmental variables. I. Tidal location method. Marine Biology 142: 601-609.
2. Kurlansky, M. 1997. Cod: a biography of the fish that changed the world. Walker and Company, New York. 294 pp.
3. Pálsson, Ó.K. & V. Thorsteinsson. 2003. Migration patterns, ambient temperature, and growth of Icelandic cod (Gadus morhua L.): evidence from storage tag data. Canadian Journal of Fisheries and Aquatic Sciences 60: 1409-1423.
4. Blumberg, A.F. and G.L. Mellor, 1987. A description of a three-dimensional coastal ocean circulation model. In Three-Dimensional Coastal Ocean Models, N. S. Heaps (Ed.), 1-16, American Geophysical Union, Washington, DC.