ESTIMATION OF GROWTH IN FARMED SALMON (*Salmon salar L.*) BASED ON DYNAMIC ENERGY BUDGET MODEL (DEB) AND KALMAN FILTERING

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EXACTUS

Havbruk 2012

INTRODUCTION

This poster presents preliminary results from an ongoing work on developing better tools for estimating the growth and development of salmon biomass in sea cages.

An approach to continuously estimate the weight of farmed salmon using the dynamic energy budget (DEB) theory [1] of fish growth dynamics is presented. This model is used in a continuous-discrete formulation of the extended Kalman filter (CD-EKF) [2]. The CD-EKF provides an estimate of the salmon weight. The model itself and the CD-EKF are tested against data from [3]. The data is collected during growth experiments where the fish were fed and observed for a period of 12 weeks in four different tanks with water temperature of 6, 10, 14, and 18°C. Each tank contained 23 salmon and no mortality was observed.

The DEB model parameters are scaled for the Atlantic salmon (*Salmo salar*) species in accordance to [1]. However, the maximum assimilation coefficient is chosen to be larger than in [1] due to the fact that farmed salmon are "engineered" for faster growth. See [4] for example.

Acknowledgement: we would like to thank the authors of [3] for supplying the actual raw data.

METHODS

The DEB theory describes the metabolic organization of organisms. It formalizes the uptake and the use of substrates (food, nutrients, light) for maintenance, growth, maturation and propagation. Figure 1 describes the complete metabolic organization of a DEB individual.

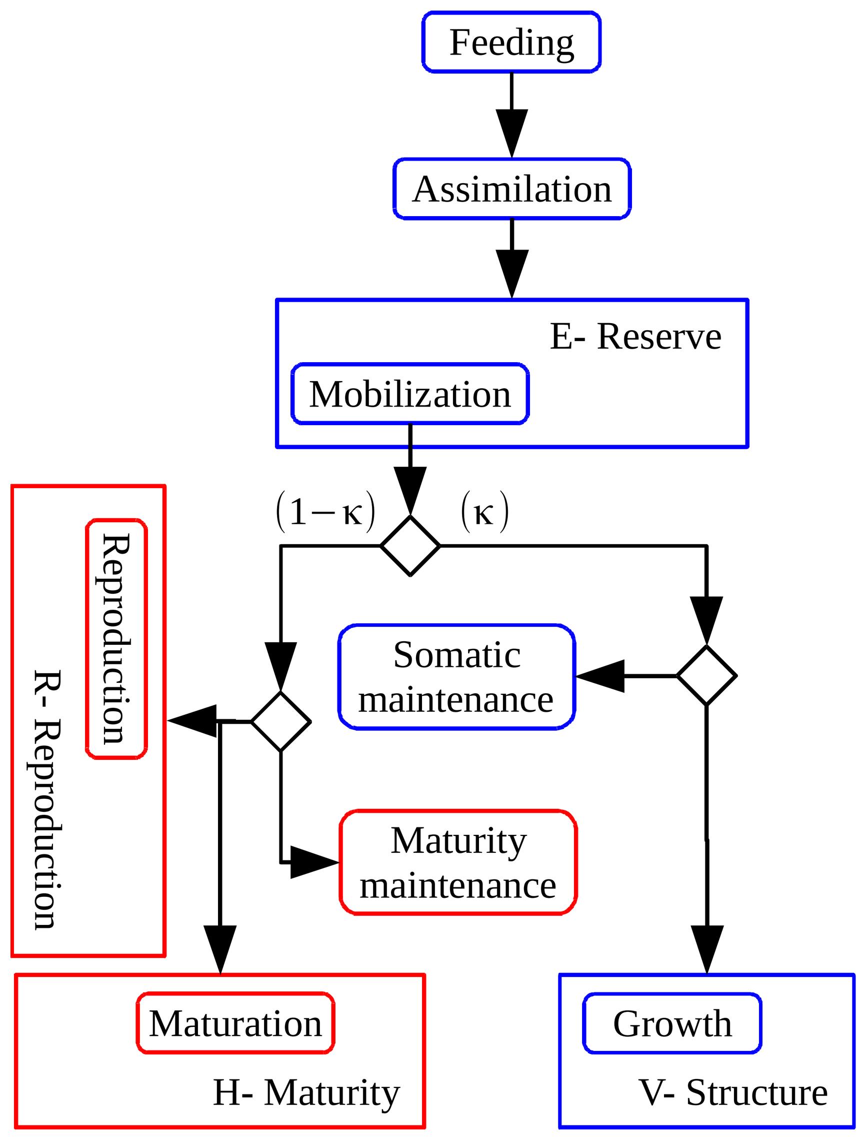

Fig.1 – **Dynamic Energy Budget metabolic organization.** Rounded boxes define sources and sinks, squared boxes define pools, and arrows represent energy fluxes. The blue color indicates the dynamics considered for modeling juvenile salmon.

The juvenile life-stage of farmed salmon needs to be described, thus only the reserve (E) and structure (V) dynamics in Figure 1 are modeled.

The Kalman filter is a well know estimation technique which has been applied in process, automotive, and other industries for decades, where the problem of estimating unknown variables is successfully solved. There are several variants of Kalman filters. A continuous-discrete type of the EKF is implemented to deal with nonlinear models and measurement rates slower than the needed estimation rate.

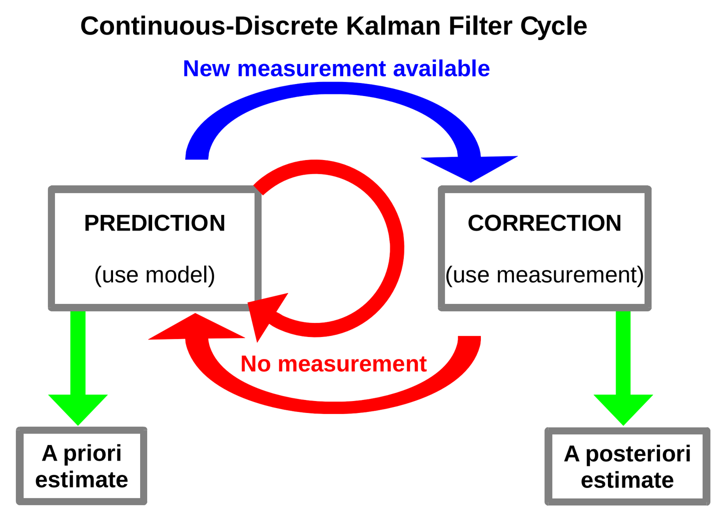

Fig.2 – **CD-EKF filter operation mode.**

Figure 2 describes the CD-EKF mode of operation. The filter integrates the dynamical model when no measurements are available. When a measurement arrives (weight in this case), the new information is used by the filter to improve the current estimate, therefore reducing weight and length uncertainties.

RESULTS

Several simulation scenarios are run in MATLAB to test the DEB model and the CD-EKF. Finally, both approaches are compared with data collected from a small-scale growth experiment [3]. Figure 1 presents the feed intake measured in four different tanks at water temperature of 6, 10, 14, and 18°C respectively. The feed intake is used as input to the model and CD-EKF. The model parameters are adjusted with the water temperature as described in [1].

Figures 4 and 5 compare the weight and length obtained from the DEB model and the CD-EKF, with the actual measured weight and length in [3]. The maximum model error is 47% for the weight, and 16% for the length. The maximum CD-EKF error is 24% for the weight, and 9% for the length. Moreover the CD-EKF is able to give an estimate of its accuracy (standard deviation of the mean) for the weight.

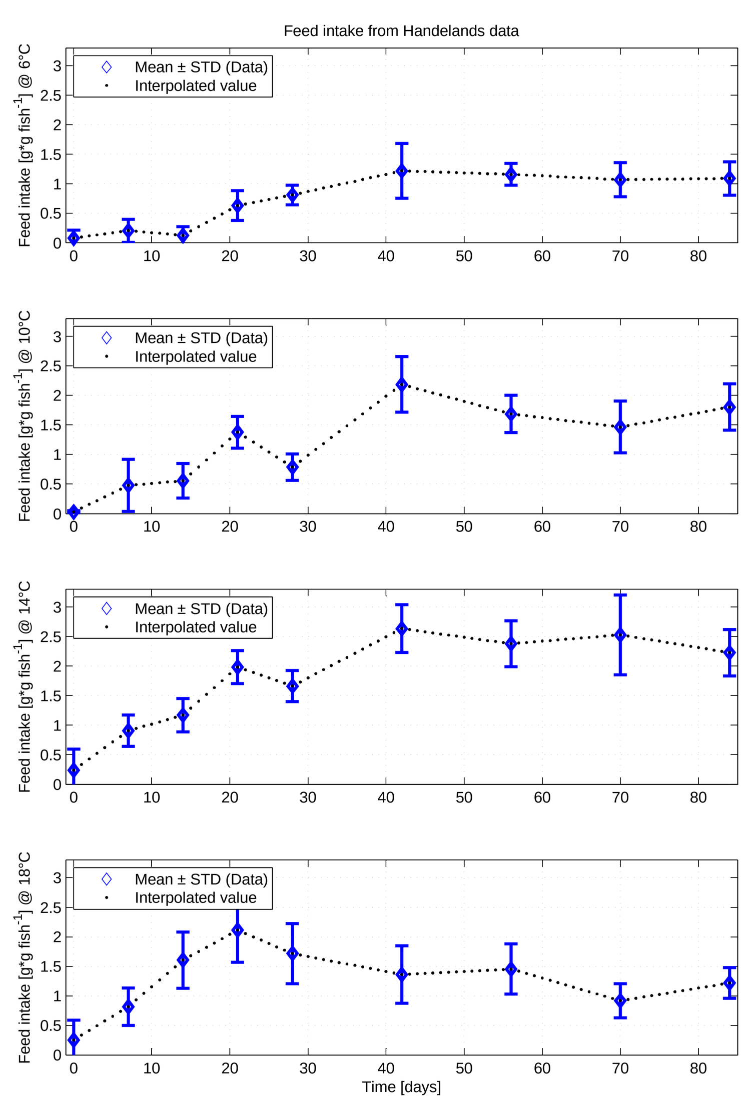

Fig.3 – **Feed intake from data in [3]**

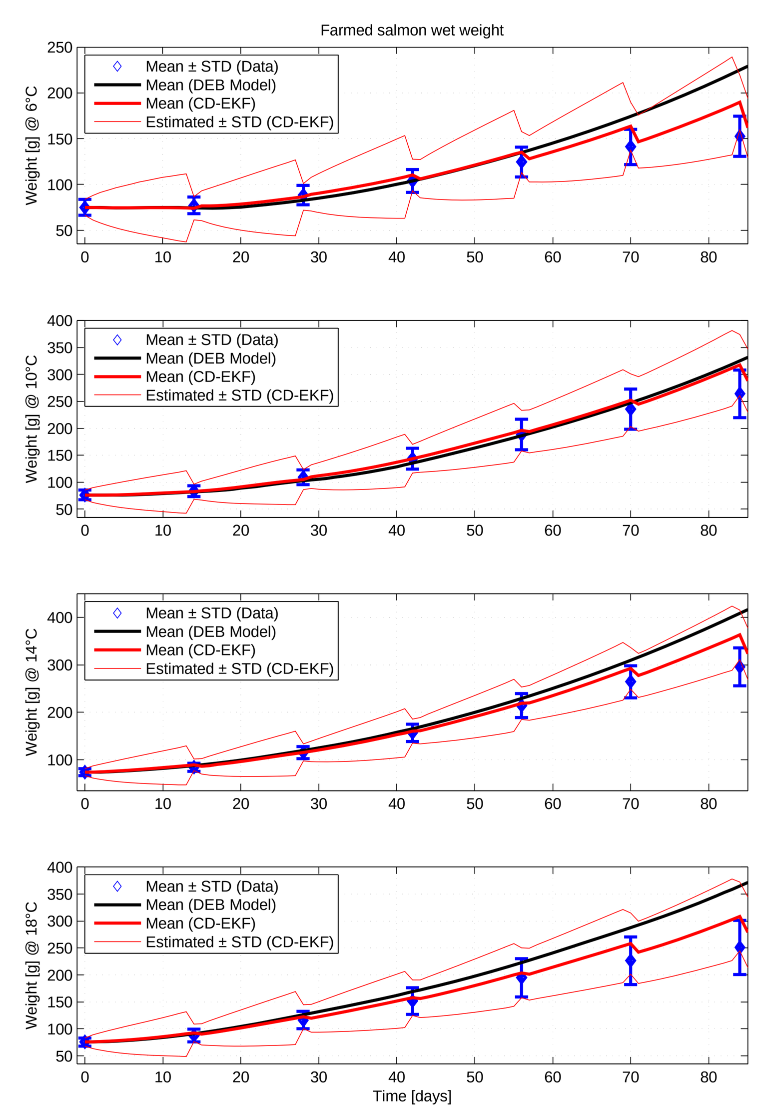

Fig.4 – **Wet weight comparison**

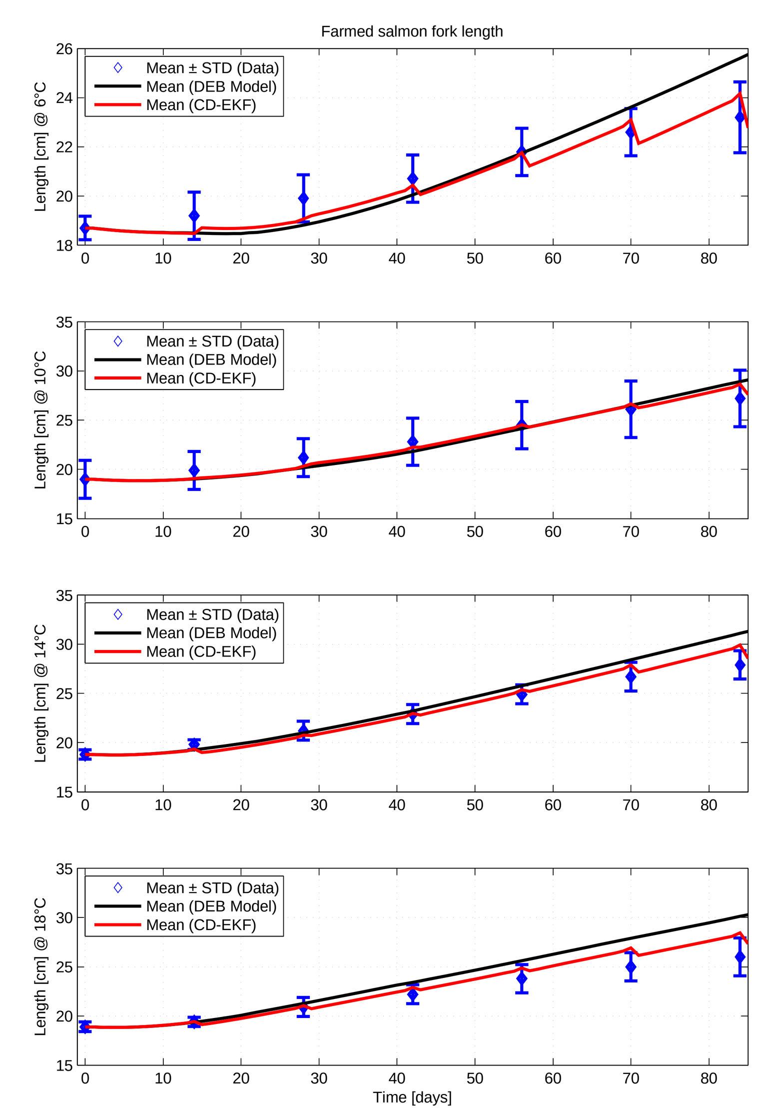

Fig.5 – **Fork length comparison**

CONCLUSION

A growth model for farmed salmon is designed by specializing the general DEB model [1]. The model together with the weight measurements are used in a CD-EKF [2] to reduce uncertainties in the growth dynamics. This is achieved by using information contained in the data [3] to correct the weight/length estimates. This is a common approach in many industrial areas and salmon farming (aquaculture in general) could benefit by applying this techniques.

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PROJECT

EXACTUS is supported by the Aquaculture program at the Norwegian Research Council 2010–2012 (project number 199788) and by industrial partners.