Reproduction Short-term Vertical Movements of Chum Salmon *(Oncorhynchus keta)* Using a Simple Model

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Introduction

Vertical movements pattern of chum salmon *(Oncorhynchus keta)* during homing migration were examined using archival tags. Vertical movements through thermocline with a periodicity of less than 1 h were observed in daytime in the North Pacific.

Objective

To examine why this high frequency vertical movement was caused, we developed a simple vertical movement model based on the heat budget model.

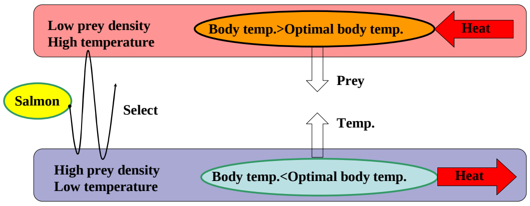
Archival tag

Sampled items：Depth, Ambient temp.,Body temp., Light intensity
Sampling interval：256 seconds (Fish #894)
512 seconds (Fish #256)
Archival tagging operations were conducted in the Bering Sea in July 1998. Archival tags (Northwest Marine Technology, Inc., U.S.) were inserted into the abdominal body cavity of chum salmon onboard the research ship. The tagged chum salmon were released in the Bering Sea and recovered along the coast of Hokkaido, Japan within 68-100 days after their release.

Vertical movement model of chum salmon and the governing equation

1.Assumption and rule of the vertical movement model

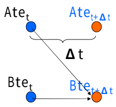
∗The vertical movement model is based on the heat budget model.
∗Ambient temperature attenuates in exponential.
∗When body temperature of chum salmon is more than an optimal body temperature, they migrate to the depth of high prey density, and when the body temperature is less than the optimal body temperature, they migrate to the sea surface. Here, the range of optimal body temperature is mean body temperature±SD during daytime.
∗Prey density of chum salmon has diel vertical movement(0m-60m), and the normal distribution vertically.



2. Heat budget model

$$Bte_{t+\Delta t} = k(Ate_t - Bte_t)\Delta t + Bte_t$$

Bte: Body temperature(ºC)
Ate: Ambient temperature(ºC)
t, Δt: Time and time step(0.1s)
k: Heat-transfer coefficient (0.0148s^{-1})



Body temperature at t+Δt is calculated from ambient (Ate) and body temperature (Bte) at t using the heat budget model.

3. Profile of water temperature

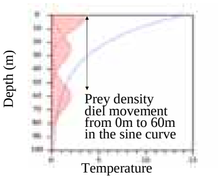
$$Ate_t = \exp(-aZ_t + b)$$

a: Attenuation coefficient of ambient temperature(0.02-0.04)
b: Constant (3.)

4. Position of fish

$$Z_t = F \times \Delta t + Z_{t-\Delta t}$$

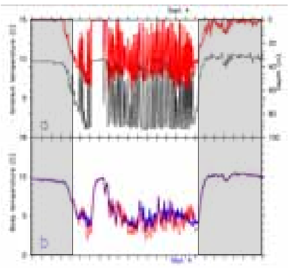
Z: Depth (m)
F: Velocity of fish(0.6m/s)



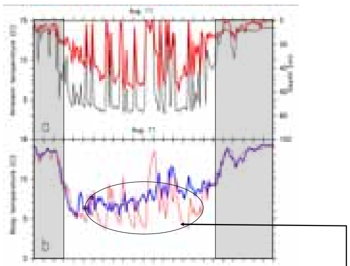
Vertical profile of temperature (blue line) and prey density (red).

Results of archival tag

Estimation of body temperature by the heat budget model.



(a) Time series of depth (red line), ambient (black line), (b)body temperature (blue line) for data from Fish #894 and calculated body temperature (red line) from the heat budget model over a 24 hours period in the case of high frequency movement pattern on 4 September. Calculated body temperature (red line) by the heat budget model is similar to observation (blue line).

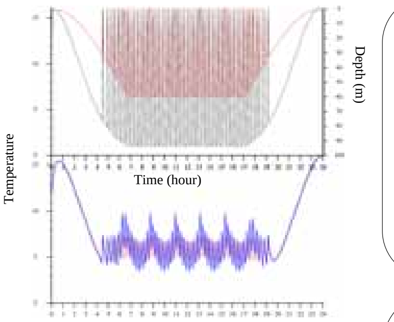


(a) Time series of depth (red line), ambient (black line), (b)body temperature (blue line) for data from Fish #256 and calculated body temperature (red line) from the heat budget model over a 24 hours period on 11 Augast.
Calculated body temperature (red line) by the heat budget model is not similar to observation (blue line).

Why cannot the body temperature (Fish #256) be reproduced by the heat budget model in the case of data by the sampling interval of 512 seconds ?

Results of the vertical movement model

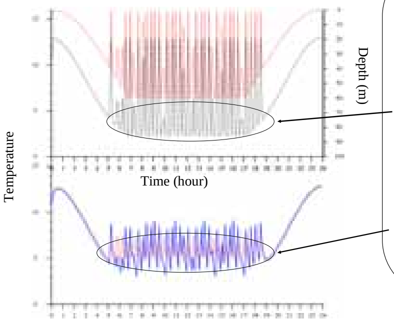
1.The model reproduced the high frequency vertical movement of chum salmon.
2.The body temperature(blue line) of Fish #256 are not reproduced by the heat budget model.



Model result for Fish # 894 (Sampling interval 256 s)

Time series of depth (red line) and ambient (black line) over a 24 hours.

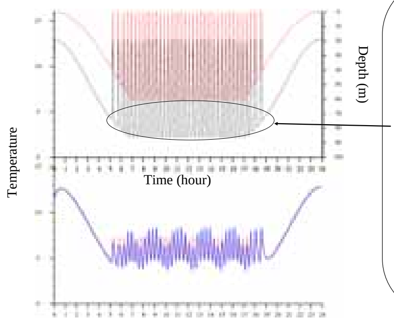
Body temperature (blue line) by the vertical movement model and calculated body temperature (red line) from the heat budget model over a 24 hours. Calculated body temperature (blue line) by the heat budget model is similar to the body temperature (red line) by the vertical movement model.



Model result for Fish #256 (Sampling interval 512 s)

Time series of depth (red line)) and ambient (black line) over a 24 hours.

Aliasing occurs, when sample frequency is not twice higher than the highest frequency in the input signal.
Body temperature (blue line) by the vertical movement model and calculated body temperature (red line) from the heat budget model over a 24 hours.
Calculated body temperature (blue line) by the heat budget model is not similar to the body temperature (red line) by the vertical movement model. Since aliasing existed in the body temperature in the case of sampling interval of 512 seconds, the body temperature is not reproduced from Bte and Ate using the heat budget model.



Model result for Fish #256 (Sampling interval 256 s)

Time series of depth (red line)) and ambient (black line) over a 24 hours.

Aliasing does not occur.

Body temperature (blue line) by the vertical movement model and calculated body temperature (red line) from the heat budget model over a 24 hours. Calculated body temperature (blue line) by the heat budget model is similar to the body temperature (red line) by the vertical movement model.
Since aliasing did not exist in the body temperature in the case of 256 seconds, the body temperature is reproduced from Bte and Ate using the heat budget model.

Conclusion

1.The vertical movement model reproduced the high frequency vertical movements such as observation. As the result of the selection of the prey or the temperature, the high frequency movement was caused.
2.The model result suggests that if the body temperature of chum salmon is in the range of the optimal body temperature, they will be able to obtain the prey in the water which is less than the optimal body temperature.
3. In the case of Fish #256, it is possible that the aliasing existed in the data due to the high frequency vertical movements.