Estimates of growth from direct ageing and mark-recapture data for Pacific bluefin tuna

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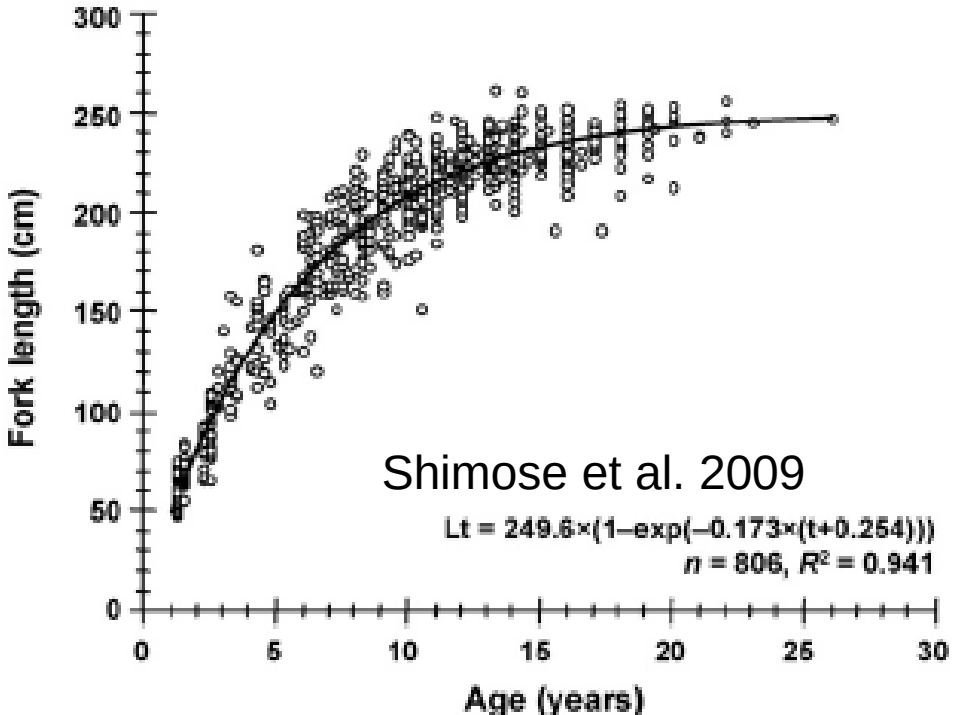
Pacific bluefin tuna growth study

- Only the otolith annual rings has been used.
- Lack of information about Age-0 growth.
- Extrapolated length < Observed length



CAA (2009-2011)

Fast growth at the early life stage

- Generally the growth@early life stage is fast in Scombroid fishes

PBF; 17 days post hatching (approx. 2 cm)

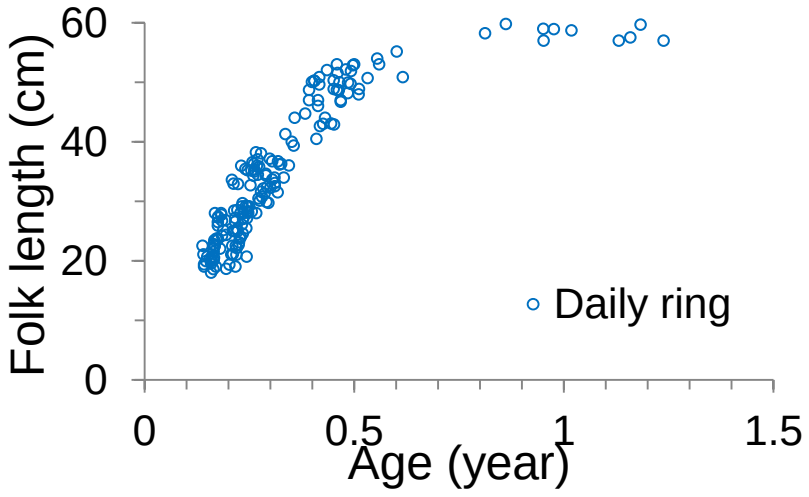
PBF; 40 days post hatching (approx. 8 cm)

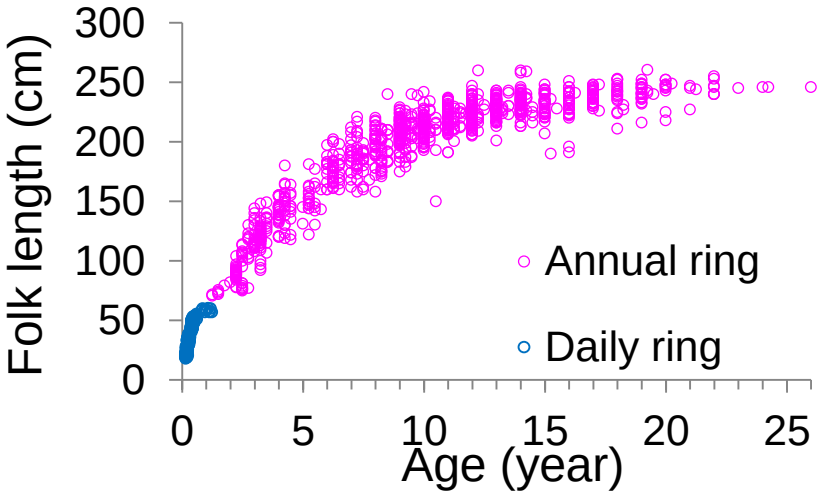
Objective of this study

- To depict the growth of PBF including age 0.
- Using several data source.
  - Direct readings of Otolith annual rings.
  - ◇ Daily rings.
  - Mark-recapture experiment.
- To consider seasonal & two-stanza growth.

Data -Otolith daily / annual rings-

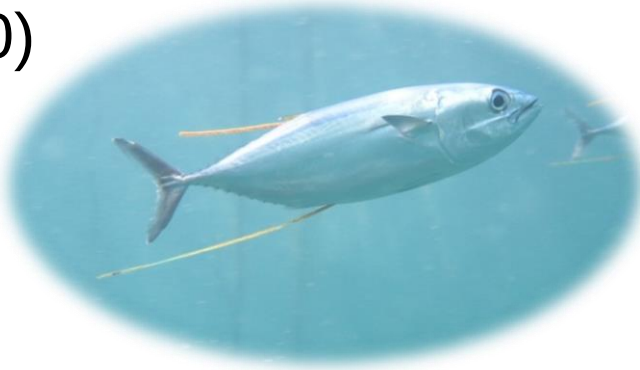
- Annual rings & Fork length
  - ✓ age 1 to 26 (70.5 to 260.5 cm FL, n=976)
- Daily rings & Fork Length
  - ✓ 51 to 453 days post hatching (18 to 60.1 cm FL, n=175)

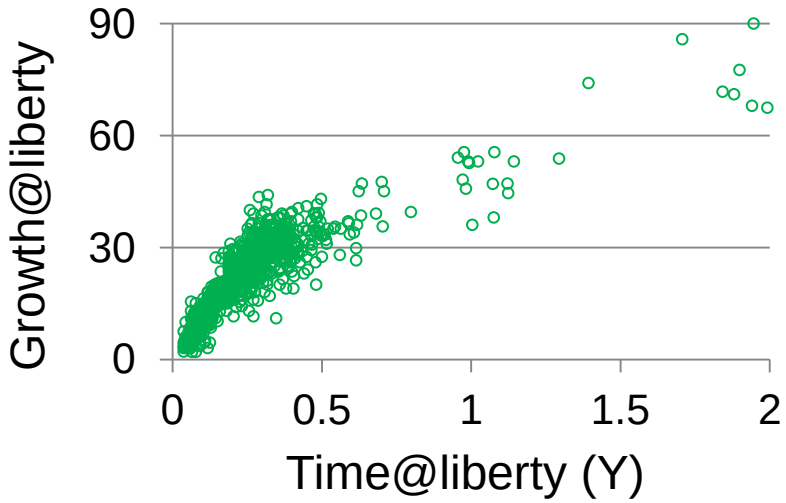


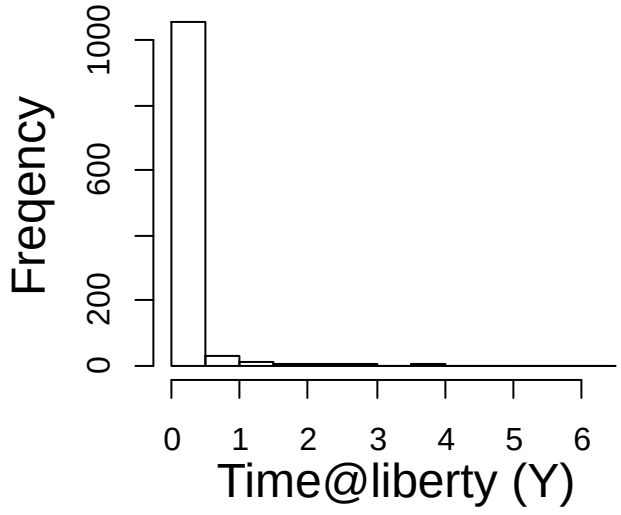


Data -Mark recapture experiment-

- Release; late July to early Sep., 1996-2013
  @Pacific side of Japan (Tosa-bay, Kochi)
- Length@release;16.5-34 cm FL (age-0)
  (more than 10,000 fish)
- Recapture data (n); 1,113 fish
- Time@liberty;14 to 2,218 days.







Growth functions

- Otolith Daily / Annual rings data (VBGF)

$$L(a) = L_\infty(1 - e^{-K(a-t_0)})$$

a; observed age

- M-R experiment data (Febens GF)

$$\Delta L(\delta T) = (L_\infty - L_{rel})(1 - e^{K\delta T})$$

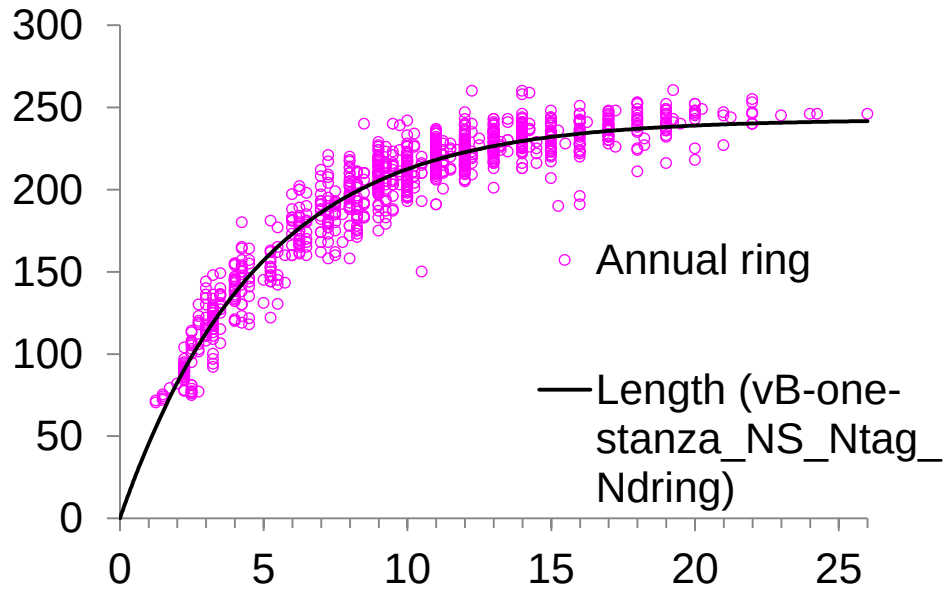
L_{rel}; Length@release δT; Time at liberty

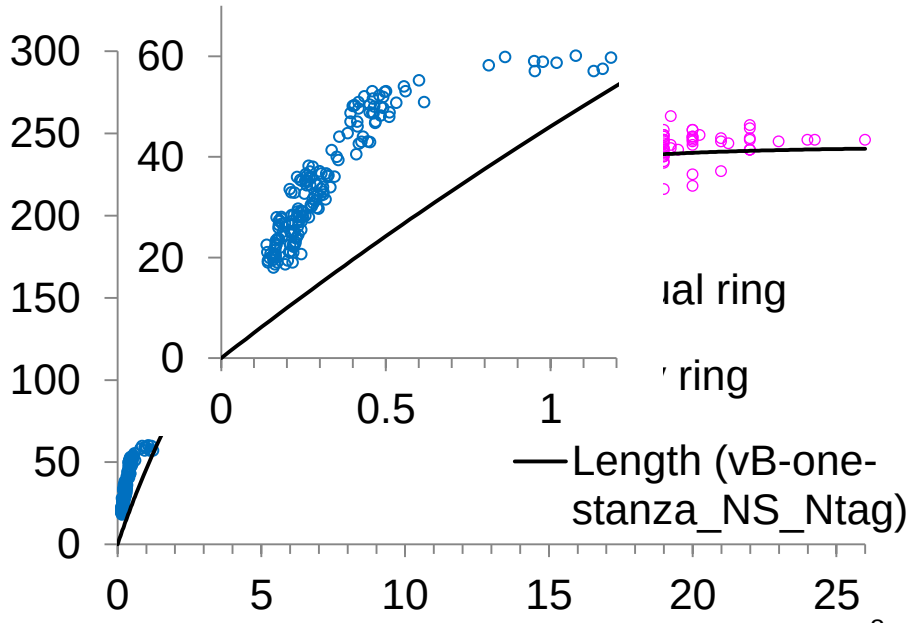
- LL was calculated for each 3 component (Otolith Daily/annual rings and M-R) and maximized with assuming log-normal error distributions.

Results (Annual rings only / Annual &Daily rings)

- There was not much difference between two growth curve.
- A curve did not fit to the daily rings data (estimate < observe).

	Linf	K1	T0
1−Stanza_NS_annual rings	243	0.208	0.0
1−Stanza_NS_anual & daily rings	242	0.211	0.0

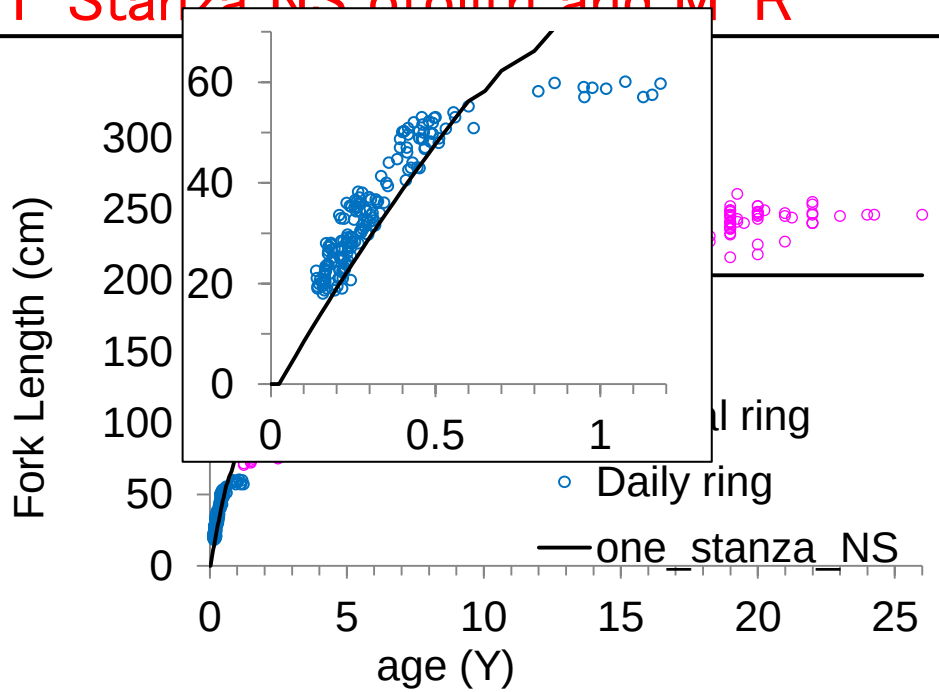


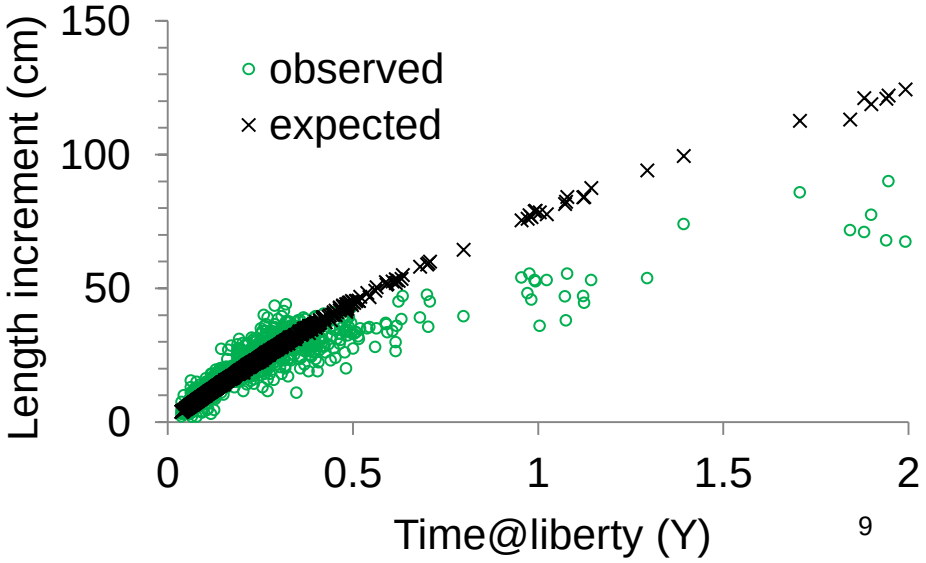


Results (Otolith and Mark-recapture data)

- Larger K and smaller L_∞ than those from otolith data only.
- A curve fit to the young stage but not to the age after 1.

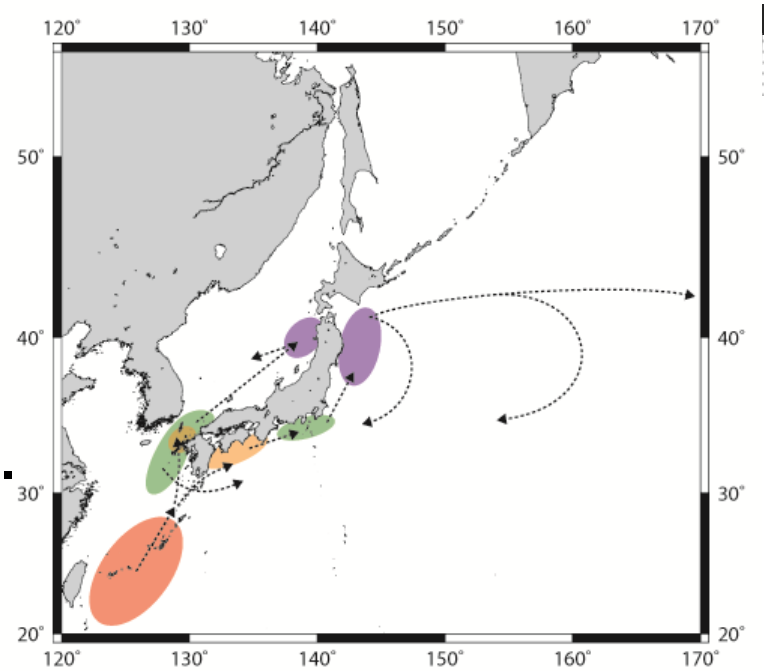
	Linf	K	T0
1−Stanza_NS_annual rings only	243	0.208	0.0
1−Stanza_NS_annual & daily rings	242	0.211	0.0
1−Stanza_NS_otolith and M−R	204	0.562	0.0





The effect of temperature on growth of PBF

- PBF experience big change in Temperature during migration.
- Seasonality and/or 2-stanza.



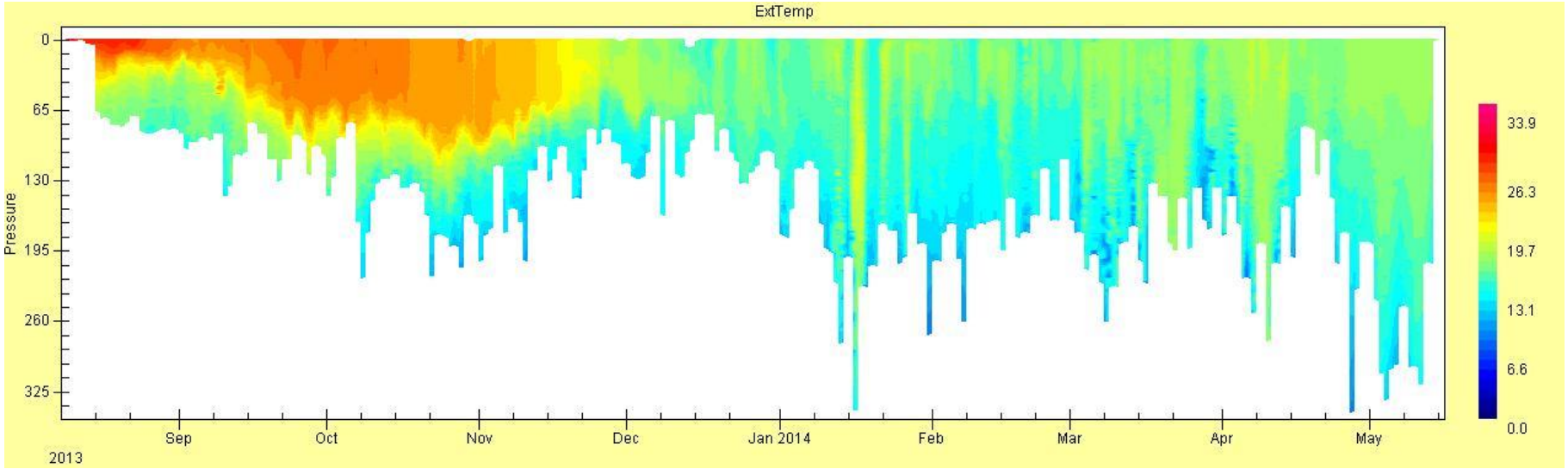


Fig. experienced temperature of age-0 PBF

Growth model

- 2-stanza growth

$$L_a = \begin{cases} L_\infty(1 - e^{-K_1(a-t_0)}) & (a < t_1) \\ L_\infty(1 - e^{-K_1(t1-t_0)-K_2(a-t_1)}) & (a \geq t_1) \end{cases}$$

- Seasonal growth

  Seasonality is assumed to be appeared on age/time.

  – Otolith data

$$a_{otolith\_s} = a + \frac{\alpha e^{-DDa}}{2\pi}\sin(2\pi(a - t_0))$$

  – M-R experiment data

$$\delta T_{tag\_s} = \delta T + \frac{\alpha e^{-DD\delta T}}{2\pi}\sin(2\pi\delta T)$$

α ;amplitude

a ;observed age

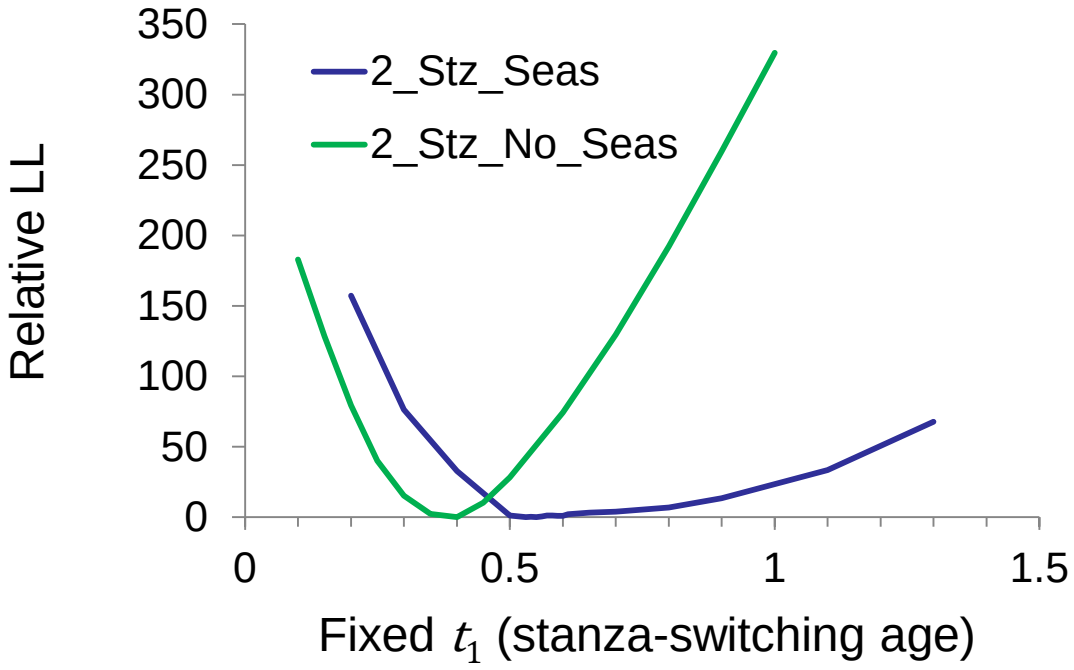
δT;Time@liberty

DD;Descending rate

Likelihood profile for t_1

- In both models, an age which is switching stanza is at young stage ($t_1 < 1$).

$$L_a = \begin{cases} L_\infty(1 - e^{-K_1(a-t_0)}) & (a < t_1) \\ L_\infty(1 - e^{-K_1(t1-t_0)-K_2(a-t_1)}) & (a \geq t_1) \end{cases}$$



Model selection

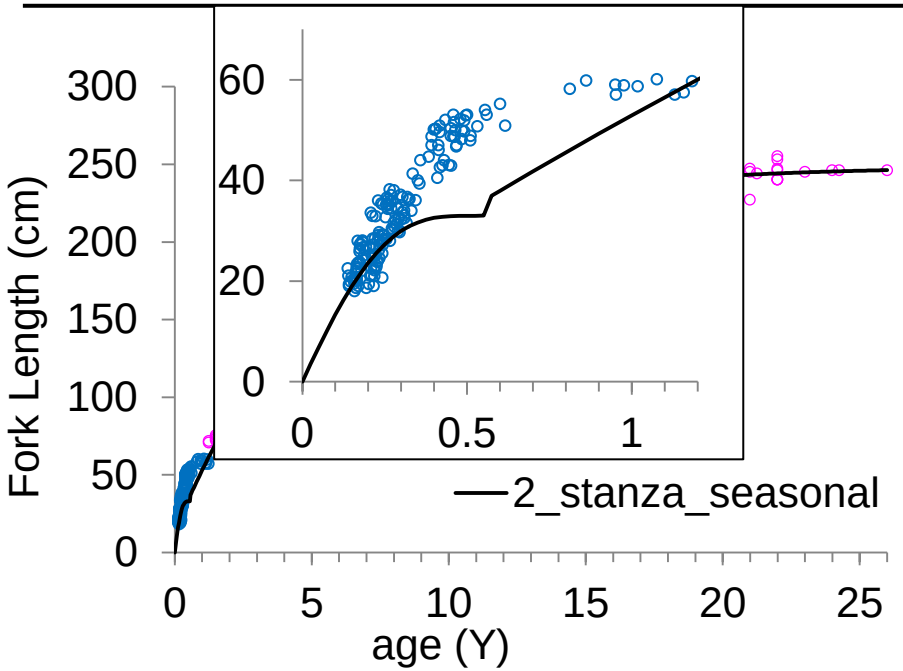
- 2 stanza models were better than 1 stanza model
- Seasonal growth model shows smaller AIC, than non-seasonal model.
- In a VBGF part, 2-stanza_non seasonal model showed a better fit to the data.

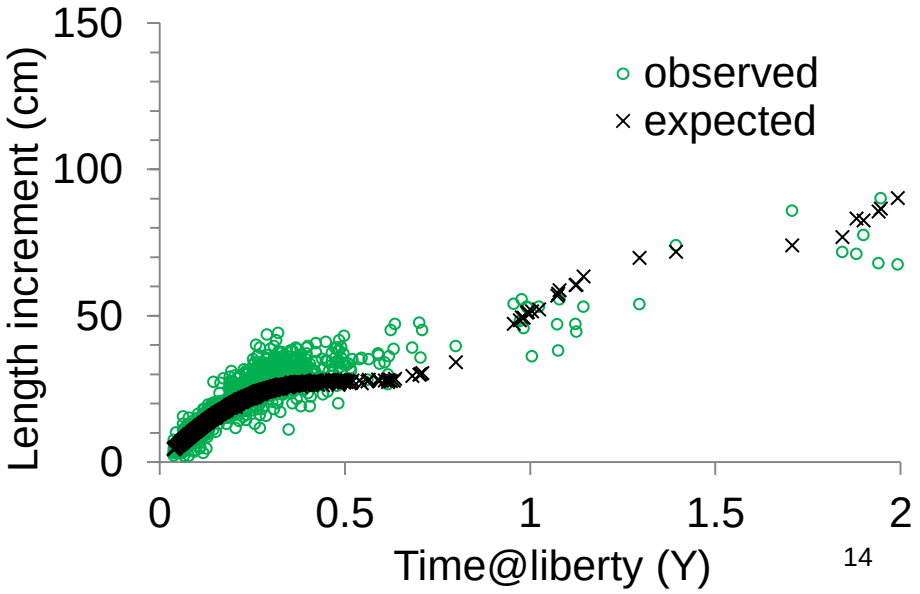
	Linf	K1	K2	T0	alpha	DD	SD1; D_ring	SD2; A_ring	SD3; M-R	AIC
1-Stanza_NS	204	0.562	-	0.0	-	-	0.19	0.20	0.25	-399
1-Stanza_Seas	225	0.290	-	0.0	1.0	0.0	0.30	0.11	0.23	-1601
2-Stanza_NS	254	0.455	0.162	0.0			0.15	0.07	0.26	-2403
2-Stanza_Seas	248	0.285	0.185	0.0	1.0	0.0	0.23	0.07	0.23	-2577

Results (Two-stanza_seasonal model)

- Fit well to both the M-R data and otolith annual rings data.
- Fit to the daily rings data remains as an issue.

	Linf	K1	K2	T0	alpha	DD	AIC
2-Stanza_seas	248	0.285	0.185	0.0	1.0	0.0	-2577

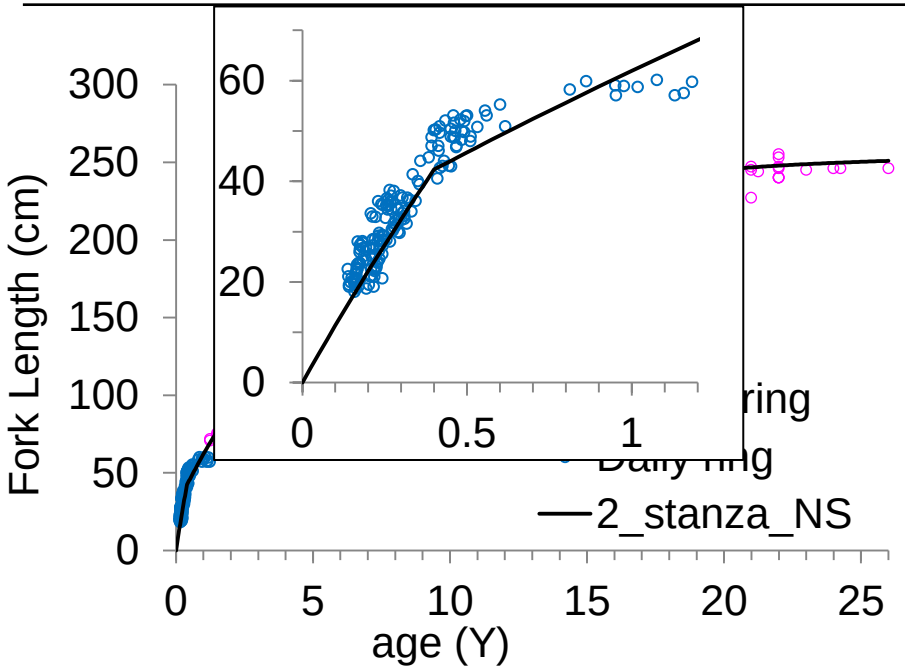


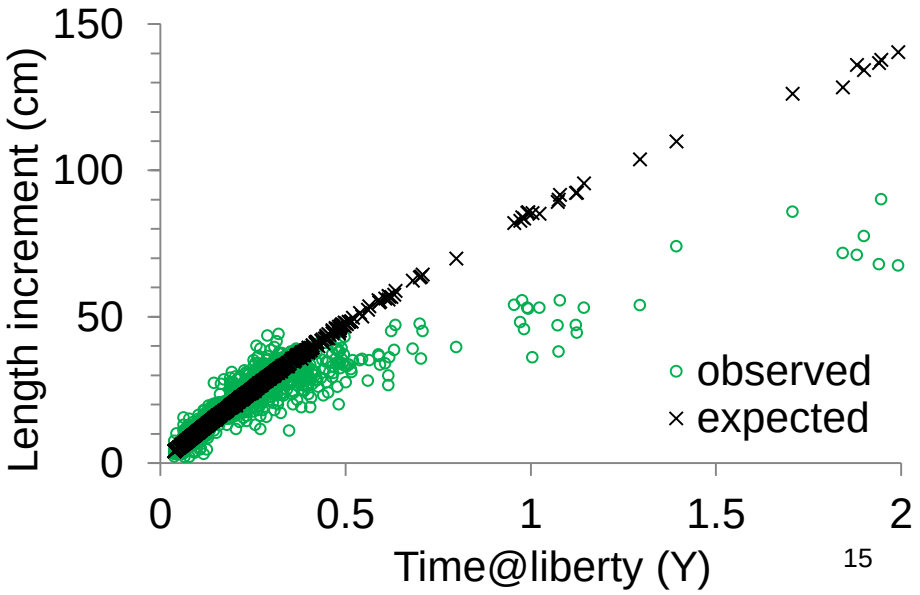


Results (Two-stanza_non_seasonal model)

- Bad fit to the M-R data but a better fit to the VBGF part than that of the seasonal model.
- Fit to the daily rings data were better than seasonal model.

	Linf	K1	K2	T0	alpha	DD	AIC
2-Stanza_NS	254	0.455	0.162	0.0	-	-	-2403





Summary

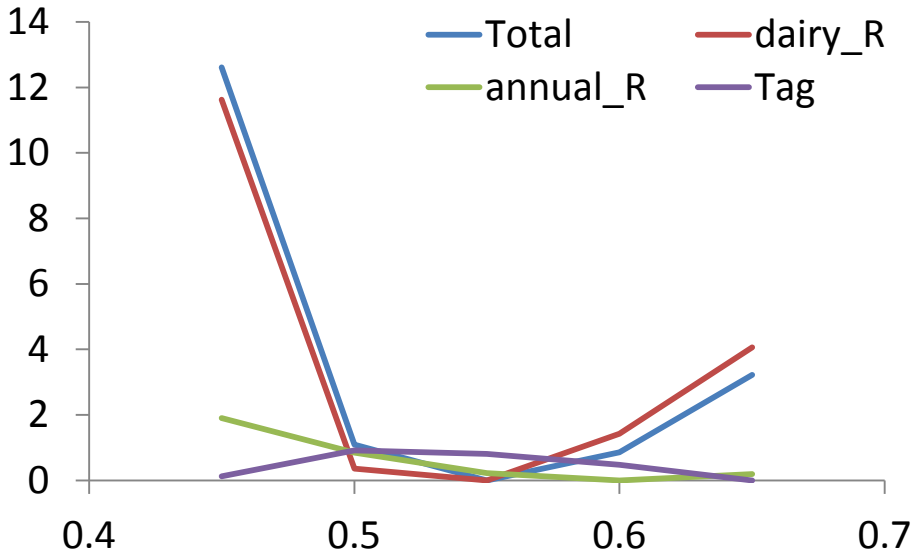
- A simple VBGF (1-stanza_No seas) could not depict growth of PBF especially the fast growth in a young age.
- Otolith daily rings and tag data showed tendency of a seasonal growth.
- 2-stanza growth model showed a better result.
- 2-stanza-non seasonal model fits well to the Otolith daily and Annual rings data.

❖ Next step

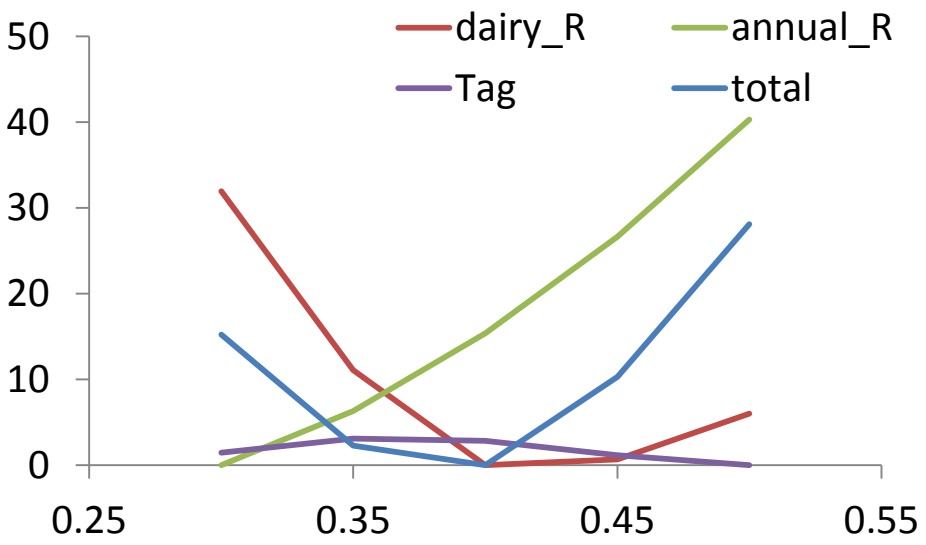
- ✓ Develop a seasonal growth modeling.
- ✓ Try an age-specific-K option in SS for PBF stock assessment model.

Thank you for your attention

2-Stanza seasonal model



2-Stanza non seasonal model



Thermal physiology

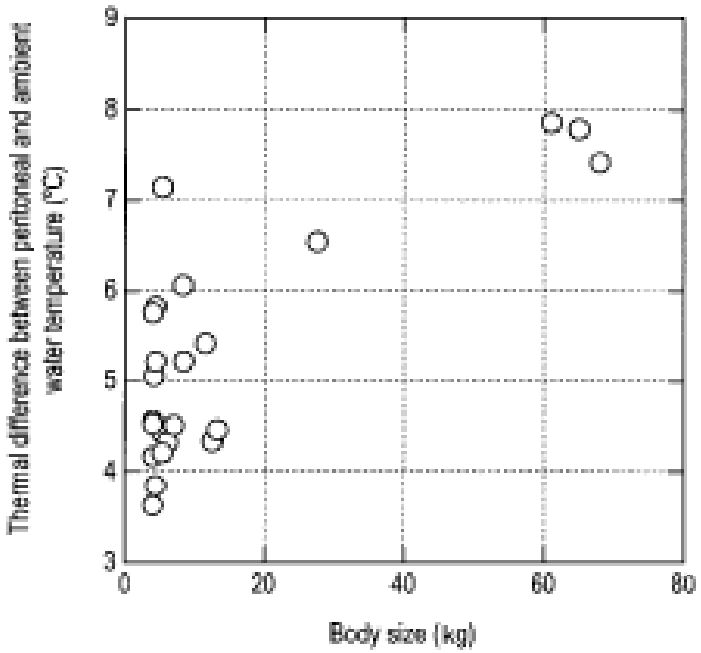


Fig. 4. Relationship between body size (kg) of bluefin tuna at the time of recapture and the mean thermal difference of peritoneal cavity temperature from the ambient water temperature recorded during about an hour from noon.

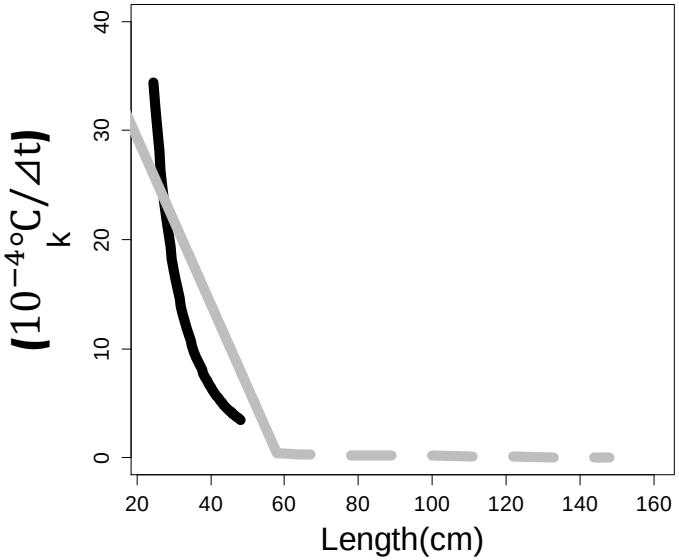
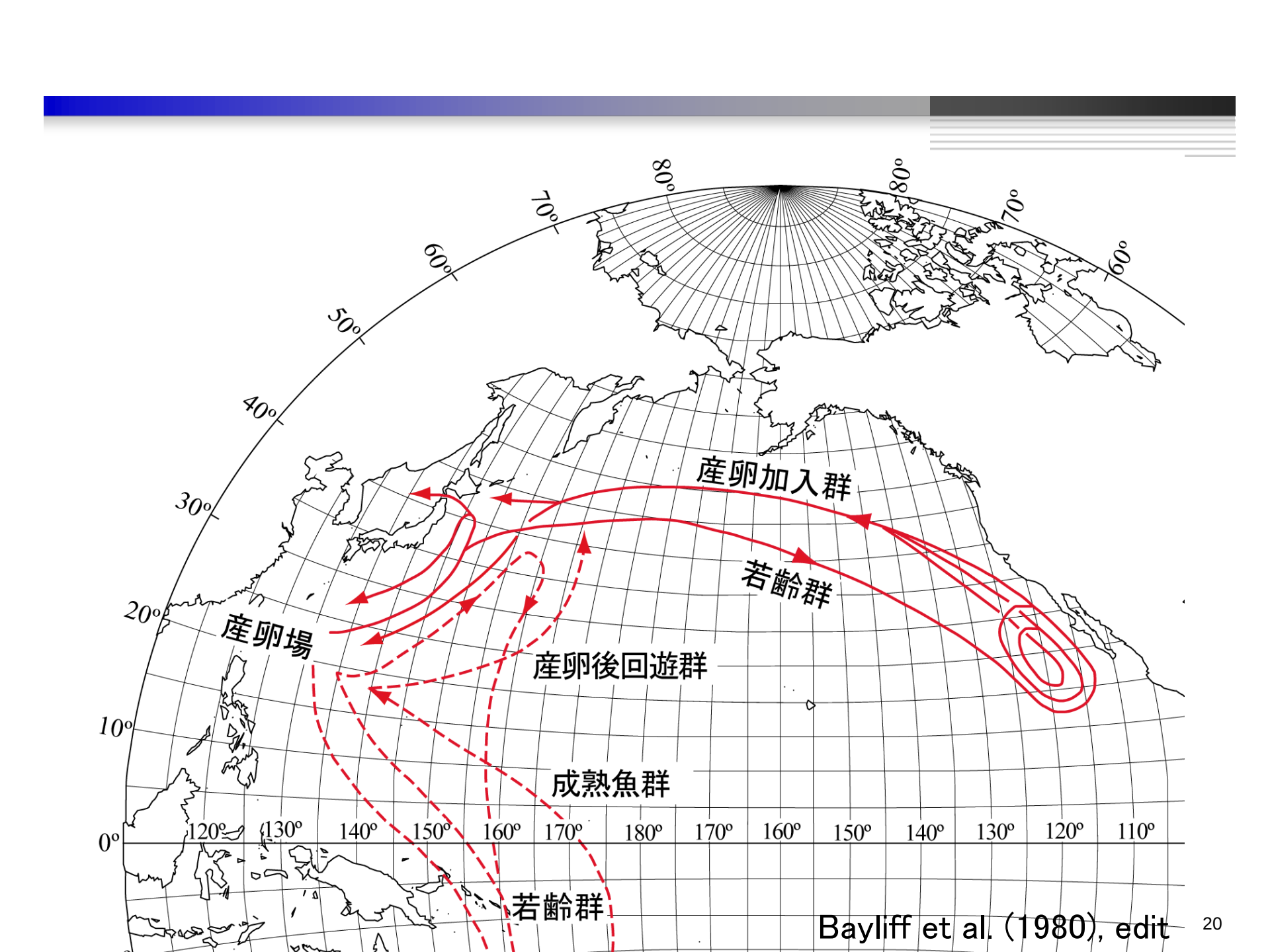
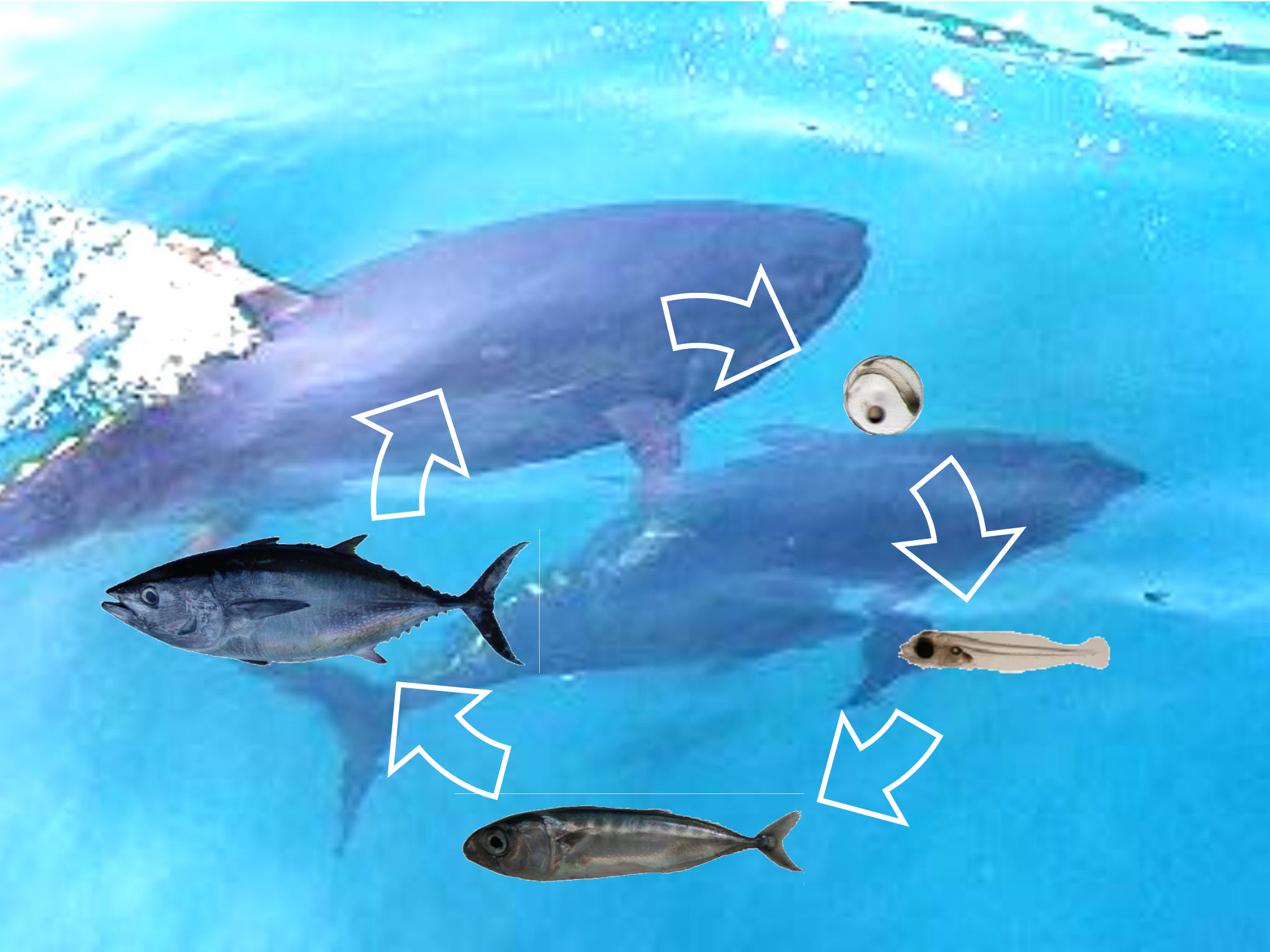


Fig. Heat exchange rate of young PBF.



Bayliff et al. (1980), edit



Results (One-stanza_seasonal model)