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Dynamics of growth autocorrelation in Japanese anchovy larvae: Influence of sea temperature and feeding conditions

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Positive effect of fast growth on survival

“Growth–survival” paradigm

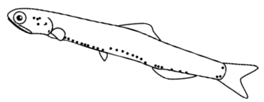
Faster-growing fish larvae have a higher survival potential.

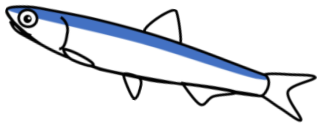
(Leggett & Frank, 2008; Takasuka et al., 2017; Robert et al., 2023)

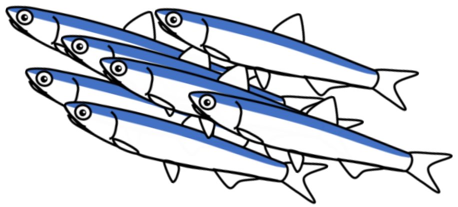
Faster growth during the larval stage ⇨

- Larger body size
- Shorter larval period
- Less vulnerability to predation

⇨ **Lower mortality rate**



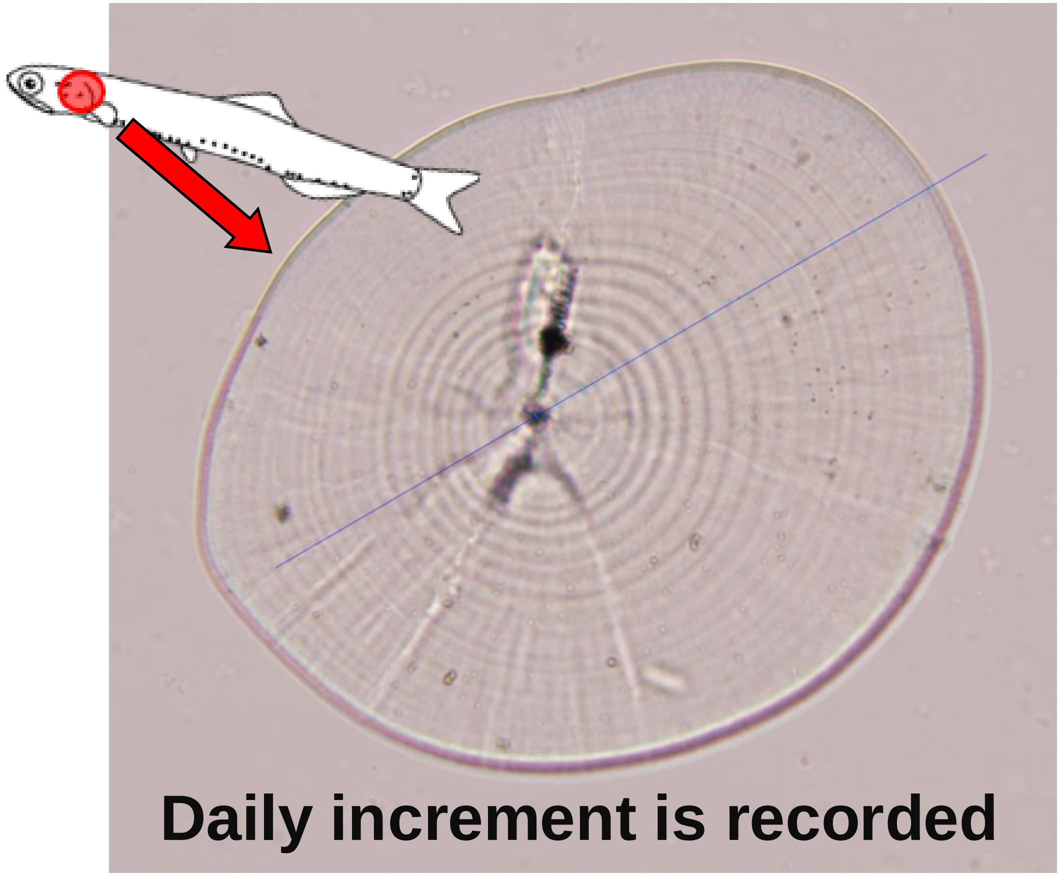


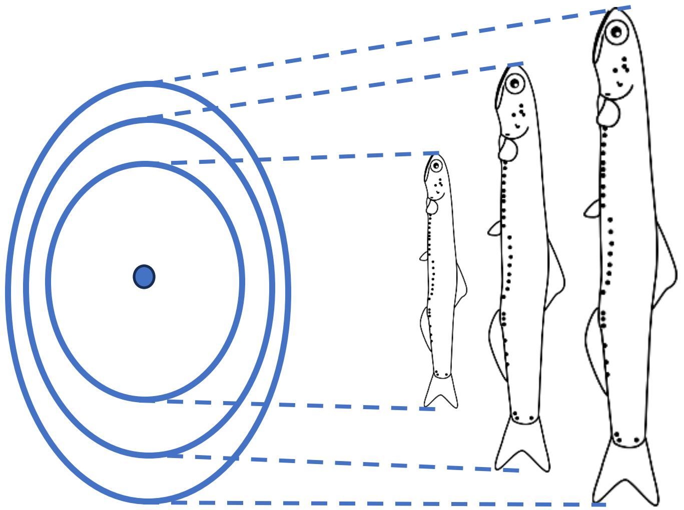


Growth history from hatching is a key determinant of survival potential.

Otolith microstructure

Growth history can be estimated based on otolith microstructure.





Each daily increment width links to daily growth rate in fish

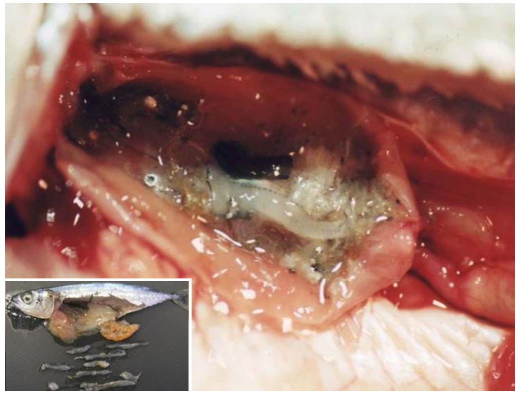
Otolith microstructure allows us to estimate daily growth history.

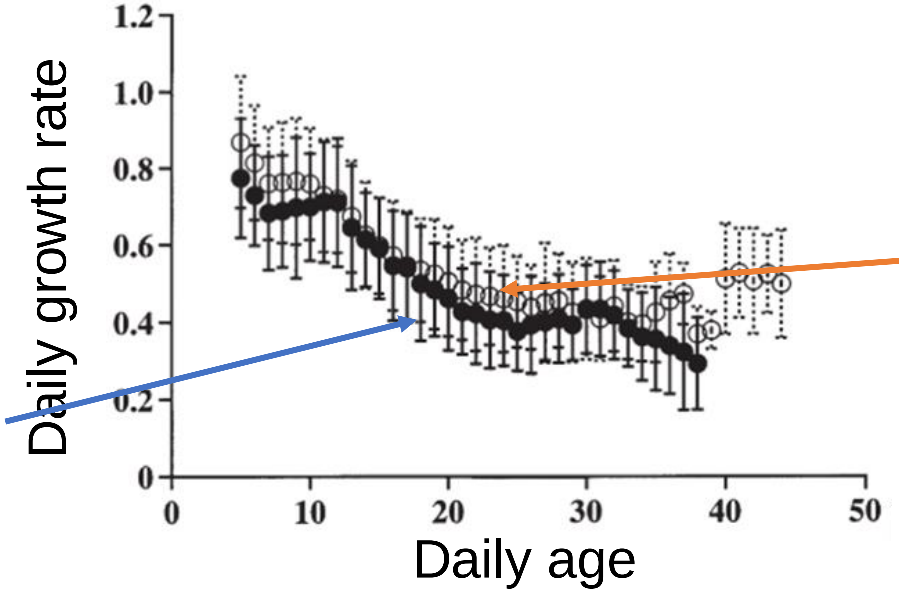
Growth history

Growth history of surviving and ingested larvae of Japanese anchovy

(Takasuka et al., 2003)

Ingested larvae





Surviving larvae

The surviving larvae were shown to have **consistently** higher growth rates than the ingested larvae in the "growth-selective mechanism" (Takasuka et al., 2003).

Early growth rates would influence later growth performance.

("growth autocorrelation")

What determines growth rates?

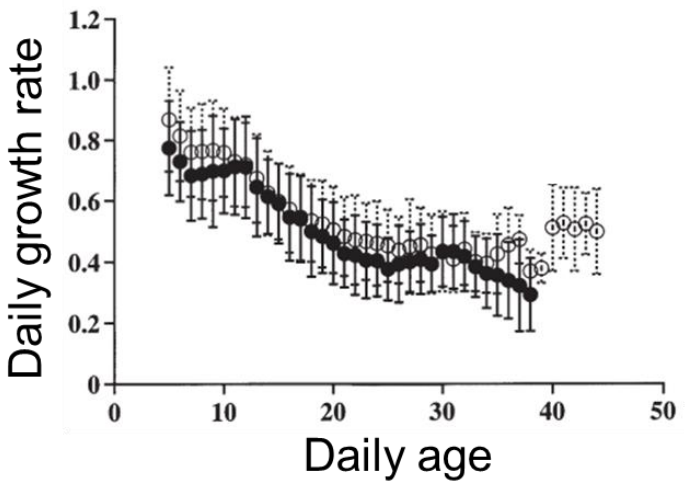
Growth rates during the early life stages are influenced by environmental factors such as prey density and temperature.

(Takasuka et al., 2006; Takahashi et al., 2010)

Growth rates during the early life stages are not fully determined by environmental factors only.

(Hannes et al., 2003; Hinrichsen et al., 2010)

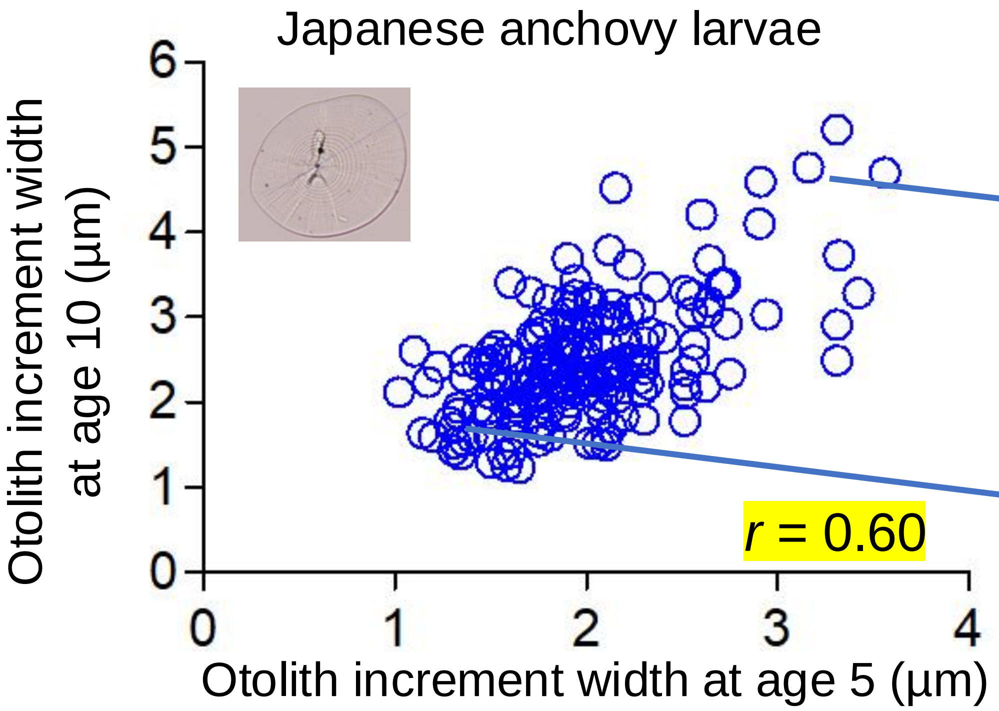
Growth autocorrelation would also influence growth rates.

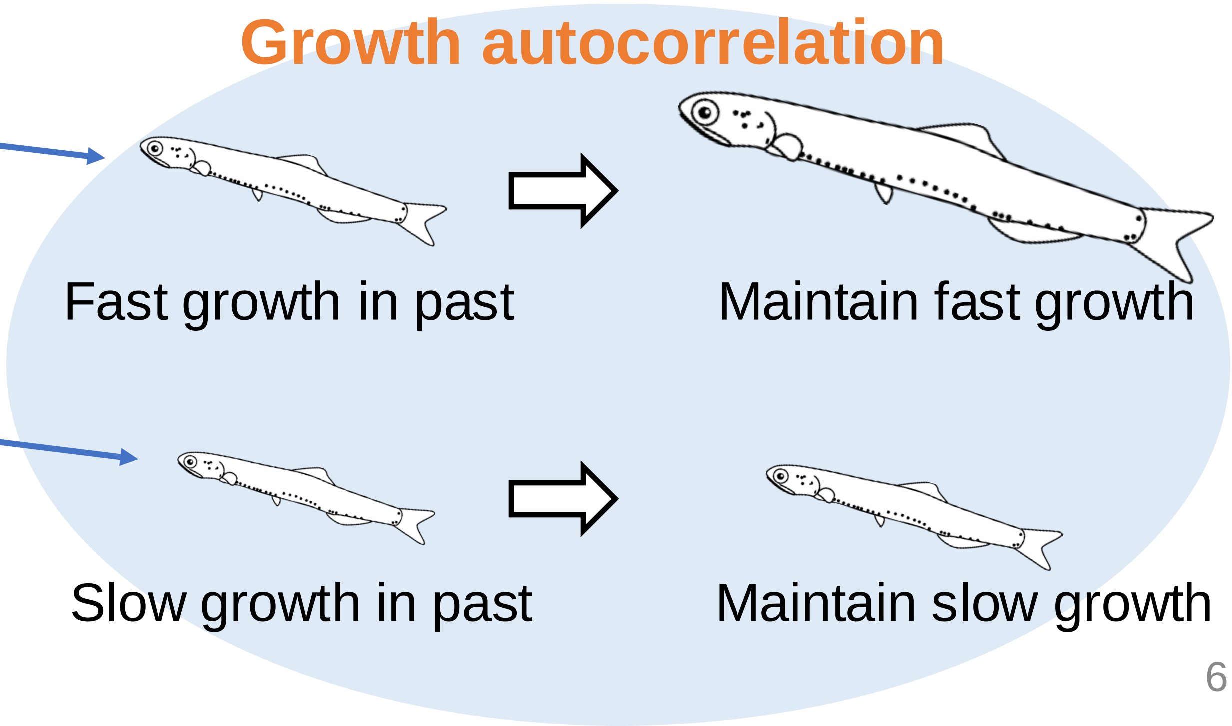


Growth autocorrelation

- "Growth autocorrelation" is estimated by calculating Pearson's *r* value between otolith increment widths at a certain age and any later age.
  (Robert et al., 2014; Tanaka et al., 2023)

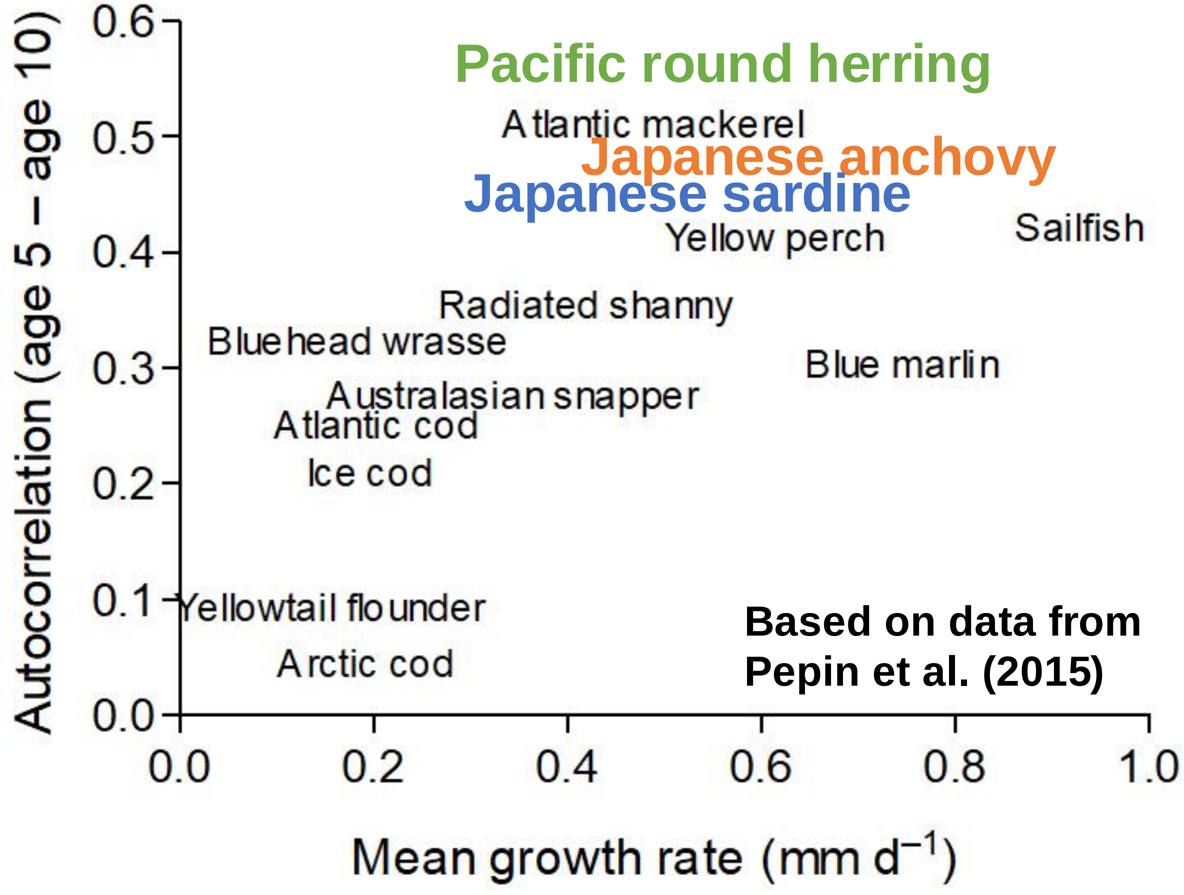
- Faster/slower-growing individuals are expected to maintain fast/slow growth.
  (Dower et al., 2009; Robert et al., 2014; Pepin et al., 2015)



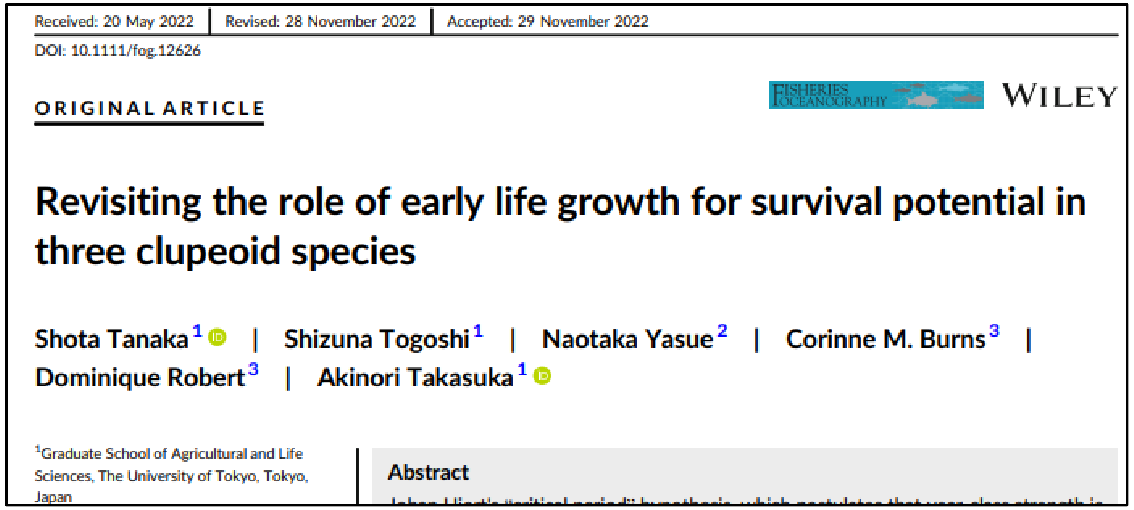


Growth autocorrelation in small pelagic fish larvae

- We examined growth autocorrelation during the larval stage of clupeoid species (Japanese anchovy, Japanese sardine, and Pacific round herring) based on published datasets.



Clupeoid species are characterized by a high growth autocorrelation.



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Revisiting the role of early life growth for survival potential in three clupeoid species

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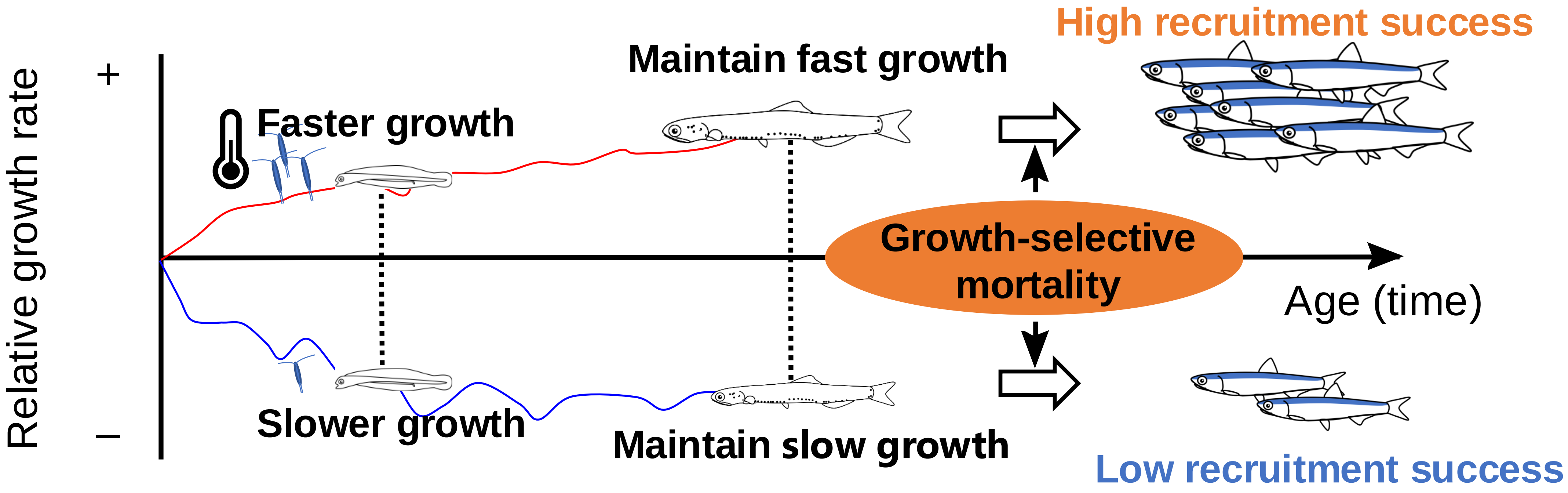
Abstract

(Tanaka et al., 2023 *FOG*)

Growth autocorrelation and recruitment

Understanding the dynamics of growth autocorrelation
would provide hints for recruitment prediction.
(Tanaka et al., 2023)

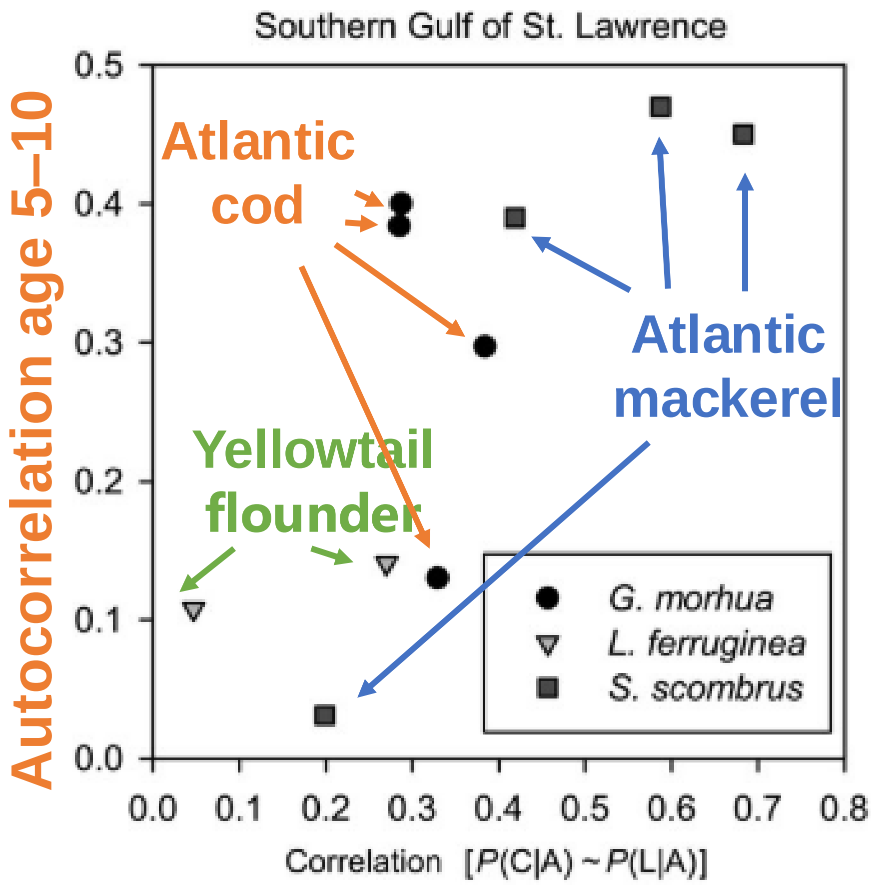


Identifying environmental factors influencing the autocorrelation would contribute to recruitment prediction based on early growth rates.

Dynamics of growth autocorrelation

- Dynamics of growth autocorrelation has not been well studied among different populations within species.

- Pepin et al. (2015) reported that the growth autocorrelation were different among different years.



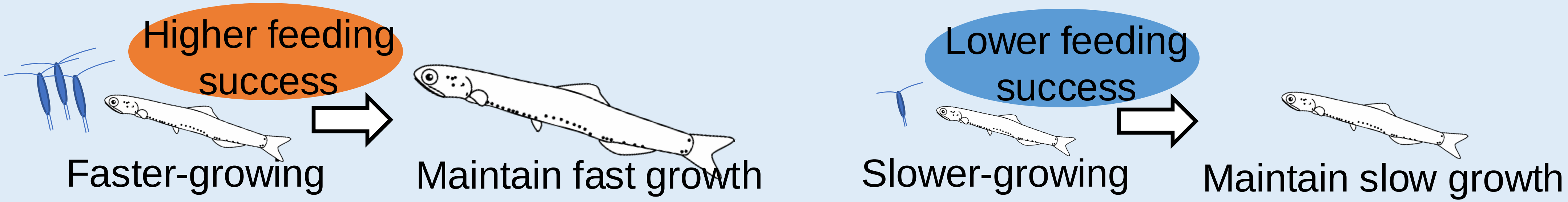
(Pepin et al., 2015)

We need to identify factors causing dynamics of growth autocorrelation.

Effects of feeding condition and temperature

Feeding condition and temperature may influence autocorrelation.

- Strong growth autocorrelation has been considered to occur through the "growth–feeding" relationship. (Robert et al., 2014; Pepin et al., 2015)



Good feeding condition would lead to high growth autocorrelation.

- Larval feeding success is influenced by temperature.

(Hunter, 1981; Dower et al., 2002; Garrido et al., 2016; Hauss et al., 2023)

Large sample sizes of larvae from different environments are required.

Shirasu fishing ground

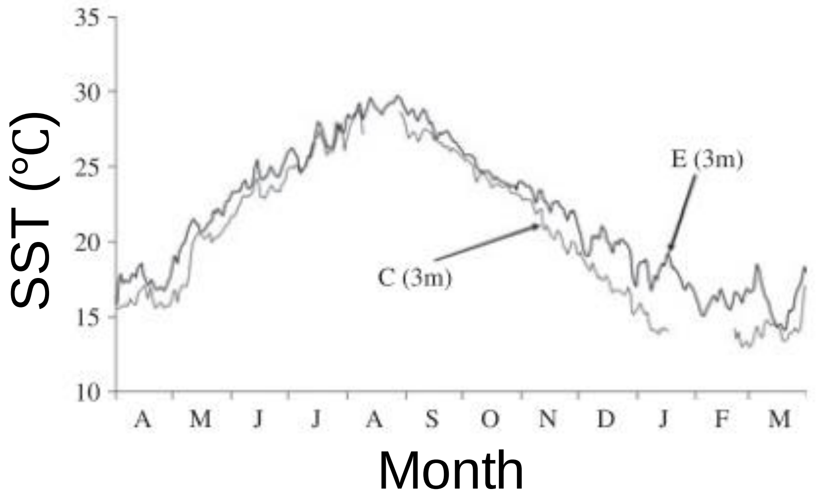
- Anchovy larvae ("*shirasu*") are commercially captured by trawlers for food resources, providing the unique opportunity to obtain large sample sizes of larvae.

- Anchovy larvae occur throughout the year, over a wide range of feeding conditions and temperatures.

(Yasue and Takasuka, 2009; Tanaka et al., 2024; Togoshi et al., 2024)

Shirasu (anchovy larvae)

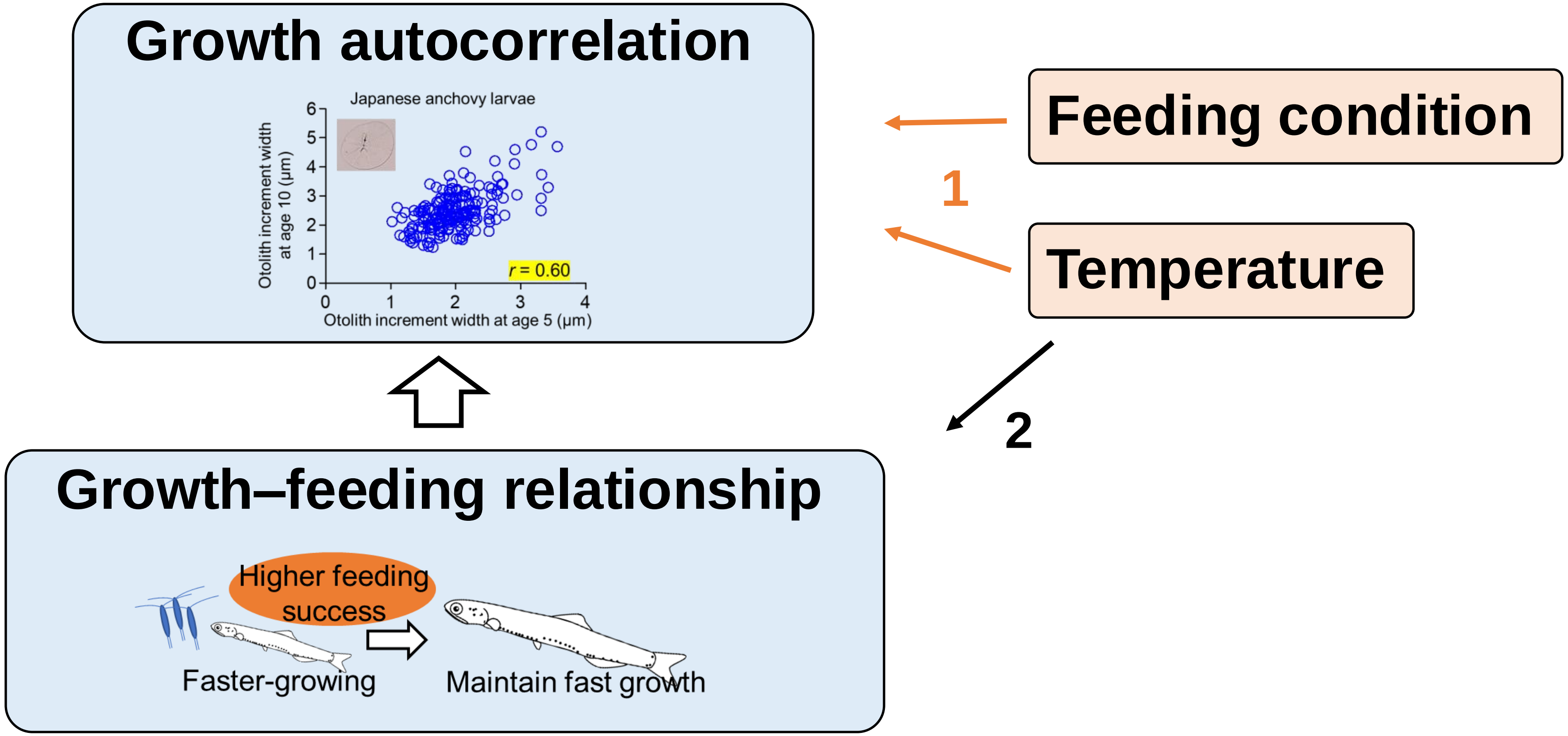
Allowing us to test the dynamics of growth autocorrelation under wide ranges of feeding condition and temperature



(Yasue and Takasuka, 2009)

Objectives

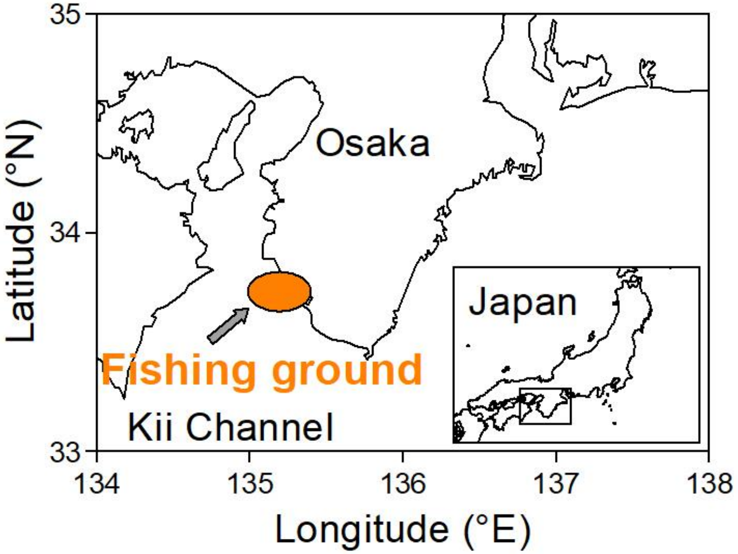
1. **To test dynamics of growth autocorrelation in relation to feeding condition and temperature**
2. To examine the effects of temperature on growth–feeding relationship



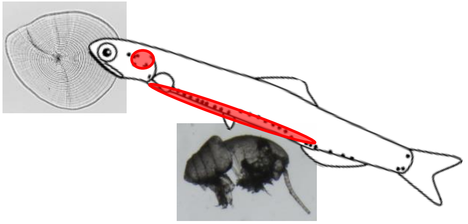
Field sampling and laboratory analyses

Japanese anchovy *Engraulis japonicus*

- The larvae were collected in the Kii Channel, Japan, from April 2021 to April 2022.



- Otolith daily increment analysis
- Gut content analysis



12 samples comprising
3,636 individuals were analyzed

Date of capture	Number
Apr 14, 2021	331
July 12, 2021	262
July 29, 2021	331
Aug 30, 2021	299
Sep 9. 2021	313
Oct 8, 2021	303
Nov 4, 2021	328
Nov 18, 2021	306
Dec 3, 2021	306
Mar 23, 2022	213
Apr 14, 2022	341
Apr 28, 2022	303

Feeding incidence and temperature

- **Feeding incidence (%)**

Percentages of feeding larvae against all larvae at the sample level

- **Temperature**

Sea temperature at 10 m depth was measured by a thermometer attached to an observation station in the Kii Channel.

Recent 5-day mean temperature was adopted for the analysis.

Sea temperature data were provided by Shirahama Oceanographic Observatory.

Growth autocorrelation analysis

- Growth autocorrelation of anchovy larvae increased with larval age.
  (Tanaka et al., 2023)

  →Correlation should be analyzed for the individuals of the same age.

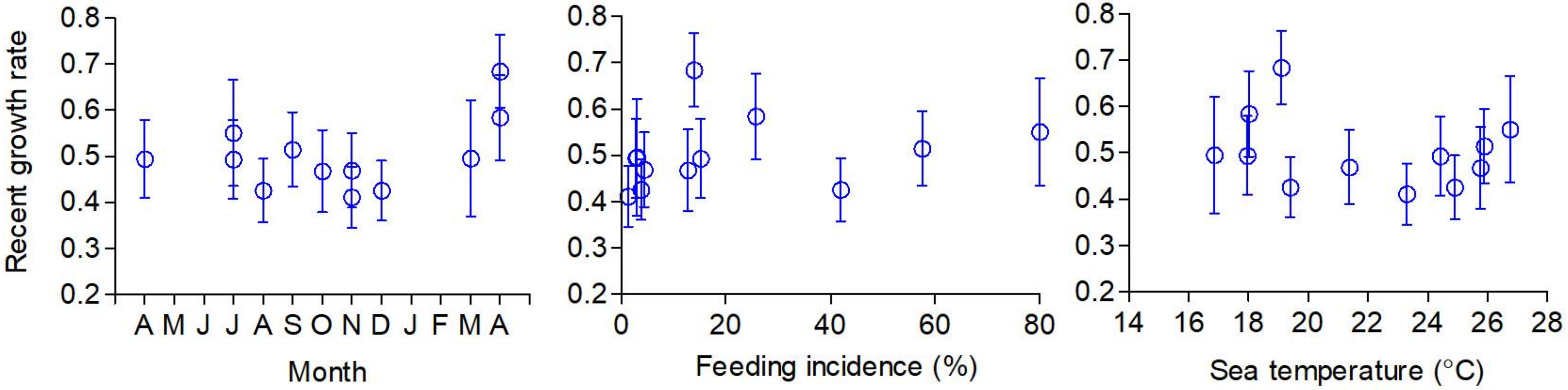
- Anchovy larvae in the Kii Channel originate from different spawning grounds.
  (Yasue et al., 2006)

  →Only recent otolith daily increment widths should be used.

⇩

For larvae of 30–40 days old, we calculated autocorrelation as a correlation coefficient between the otolith increment widths directly before capture and 5 days before capture.

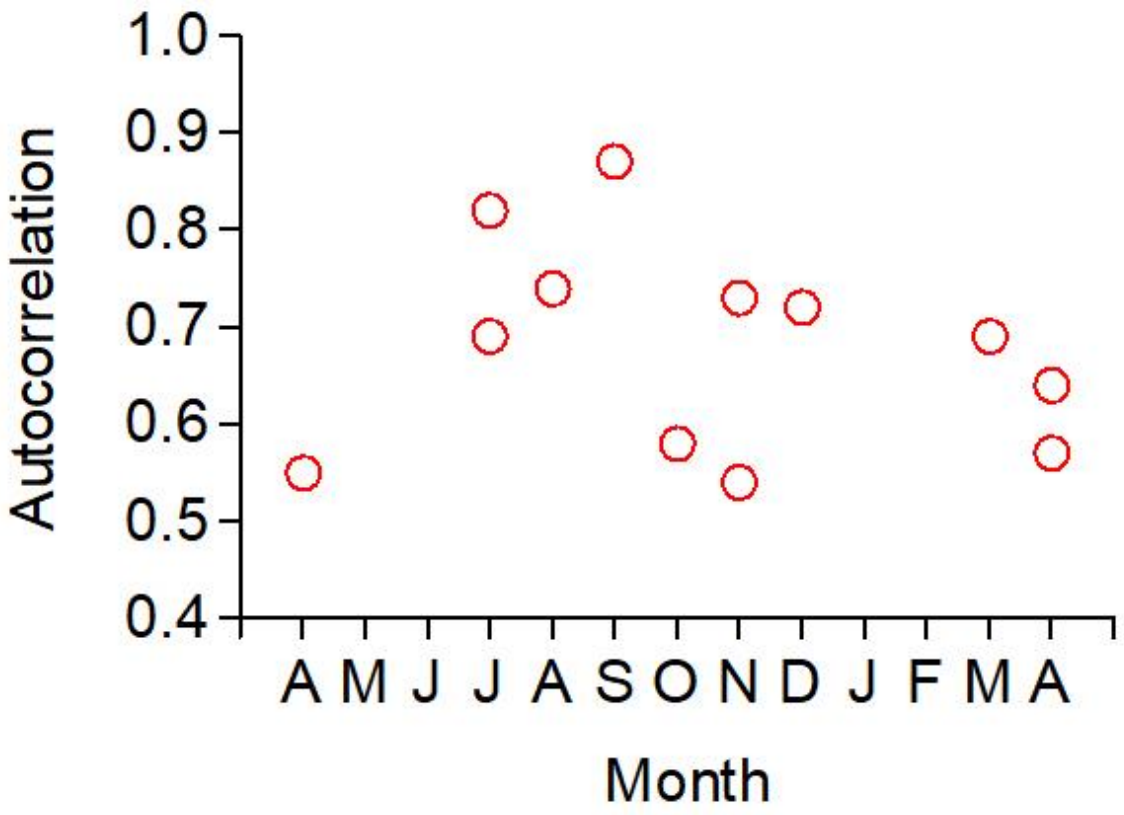
Recent growth rates



Recent growth rates were variable throughout the year.

Recent growth rates were not related to feeding incidence and temperature.

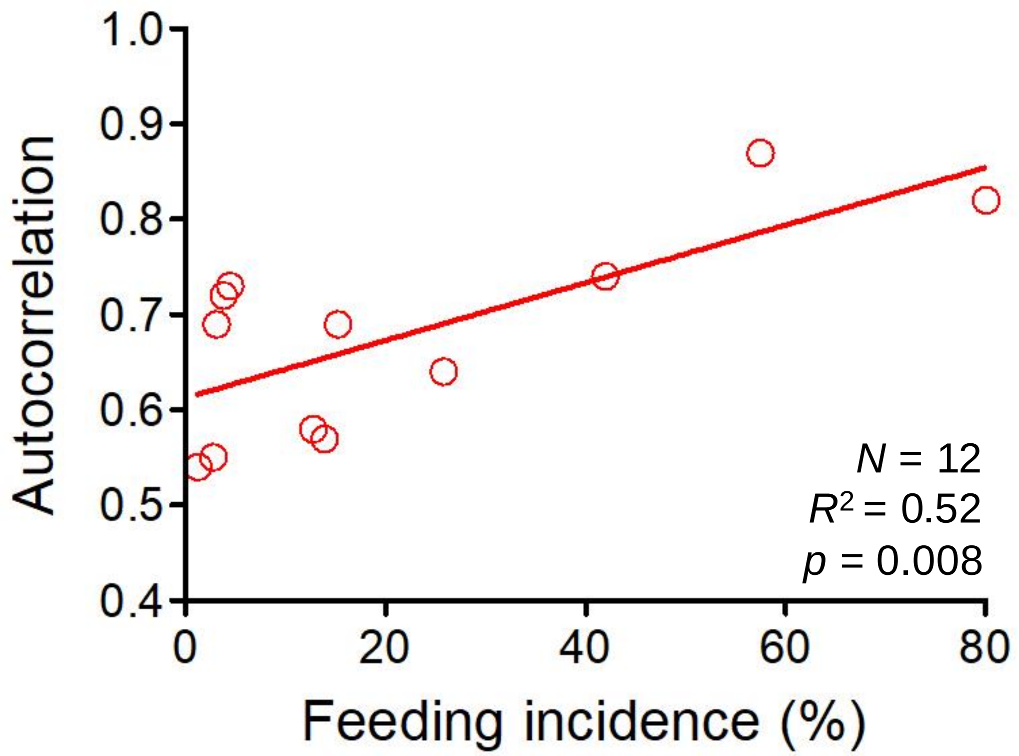
Growth autocorrelation

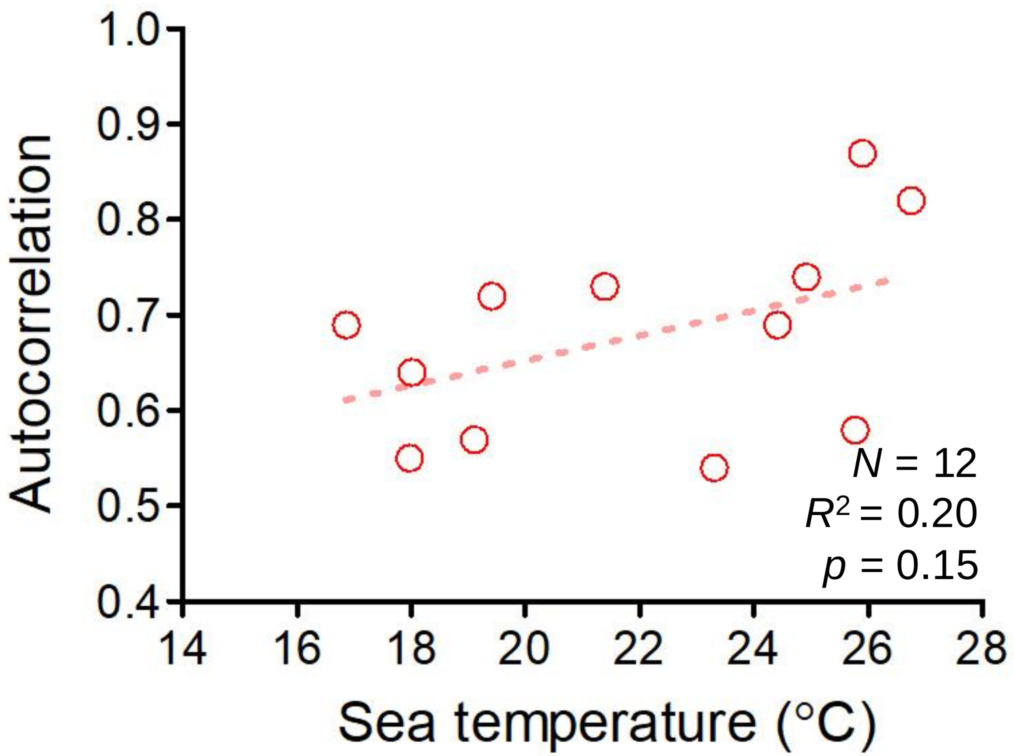


Autocorrelation showed variability in the range of 0.54–0.87.

We did not observe any seasonal trend in the level of growth autocorrelation

Effects of feeding incidence and temperature





- **Autocorrelation was strongly linked to feeding incidence.**
- Positive trend between temperature and autocorrelation (though not statistically significant)

Environmental effects on autocorrelation

Autocorrelation was strongly linked to feeding incidence.

- Growth rates fluctuated more in the lower feeding populations.

(Pepin et al., 2004)

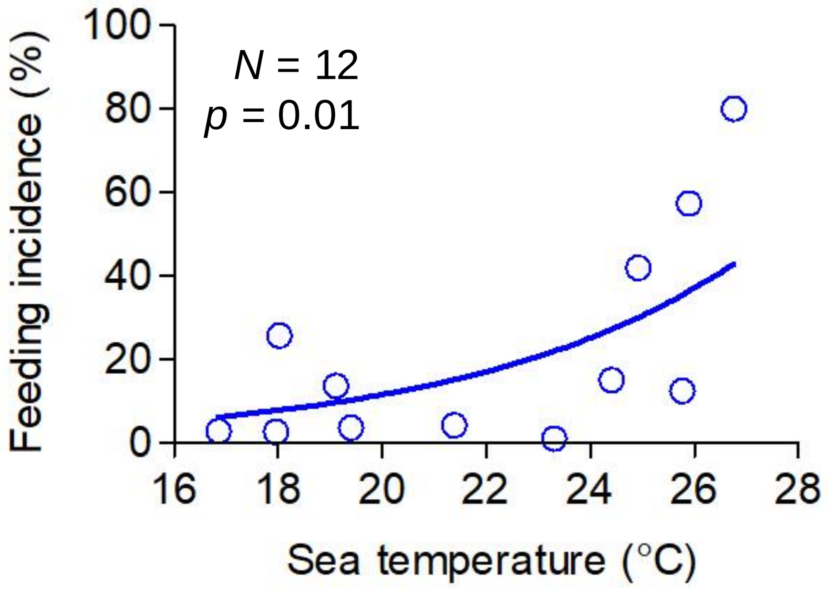
Good feeding condition would enhance growth autocorrelation.

Positive trend between temperature and autocorrelation

- High temperature enhanced feeding incidence (%).
- Temperature positively influenced larval feeding success.

(Murphy et al., 2013; Garrido et al., 2016)

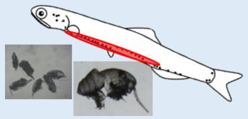
Temperature–feeding incidence



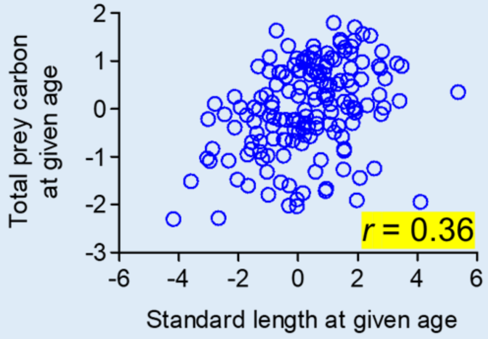
How does temperature influence the growth–feeding relationship?

Temperature effects on growth–feeding relationship

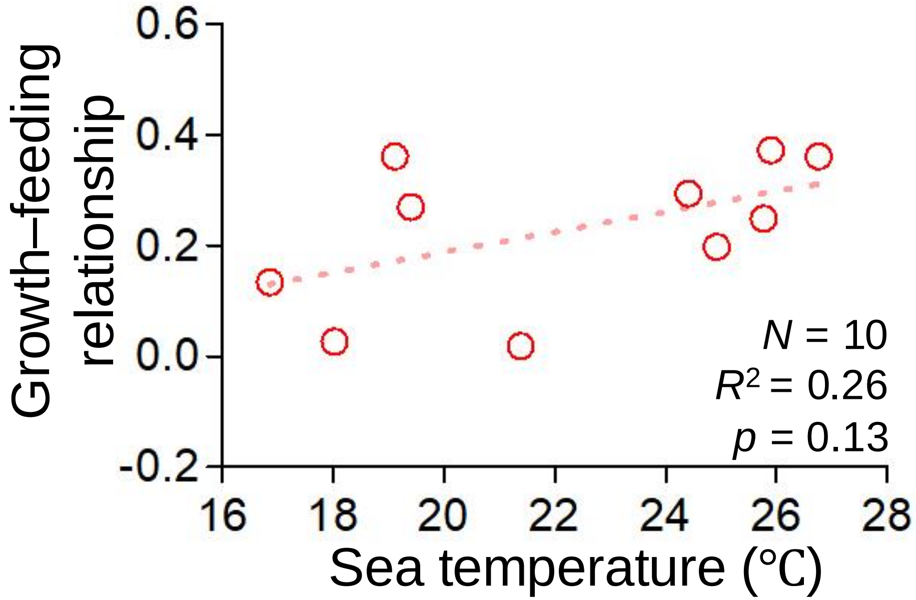
Feeding success



Growth–feeding relationship



Relationship of growth–feeding relationship to temperature



Growth–feeding relationship showed a positive trend with temperature.

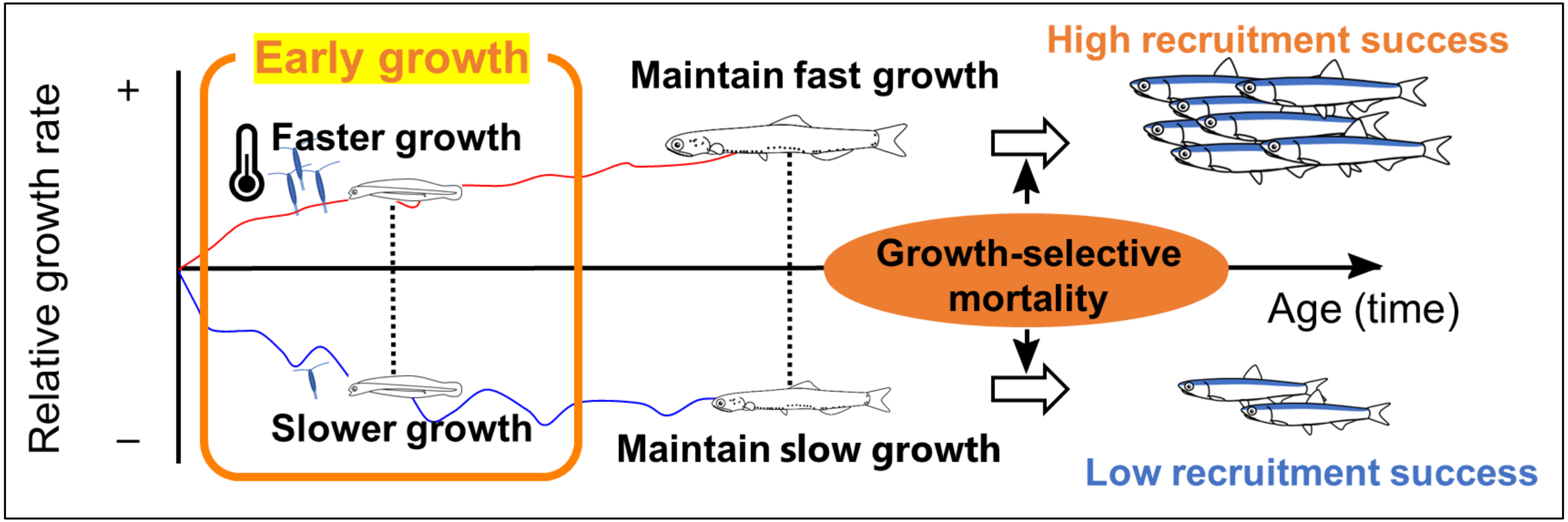
→High temperature may strengthen growth–feeding relationship.

High temperature would potentially enhance growth autocorrelation by strengthening the growth–feeding relationship.

Implications for recruitment predictions

Stronger growth autocorrelation would be observed under better feeding condition and potentially higher temperature.

In such environments,
early growth would more strongly influence future growth and recruitment.



Understanding dynamics of growth autocorrelation can contribute to predictive models for recruitment based on early growth.