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SPF S2: *Life Cycle Closure: Advances in Process Understanding*

# Growth autocorrelation in small pelagic fish larvae in the Kuroshio Current system: Do early growth rates influence later growth rates?

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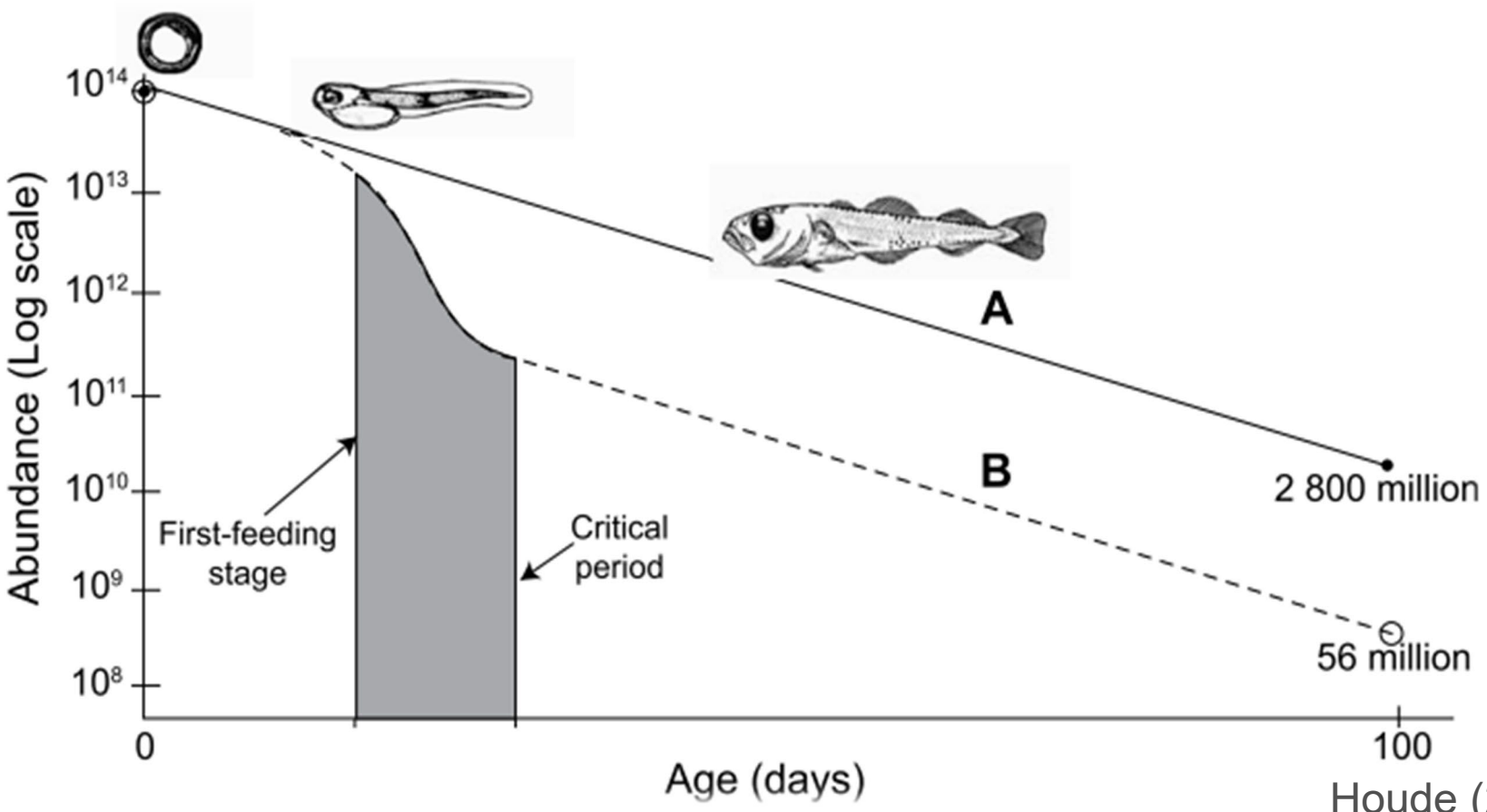
# Johan Hjort's "critical period" hypothesis
(Hjort, 1914, 1926)

- Year-class strength is determined in the short period after first feeding.
- Larvae that fail to feed during this period die of starvation.




Houde (2008)

# Is the “critical period” hypothesis supported?

Variability in recruitment is determined not only by the first-feeding period.

(Leggett & Deblois, 1994; Houde, 2008)

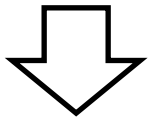
## The current understanding extended from the “critical period”

- Recruitment is determined by cumulative mortality sources experienced throughout the larval stage.

  (Leggett & Deblois, 1994; Houde, 2008)

- Larger and/or faster growing individuals will have a higher probability of survival (“growth–survival” paradigm).

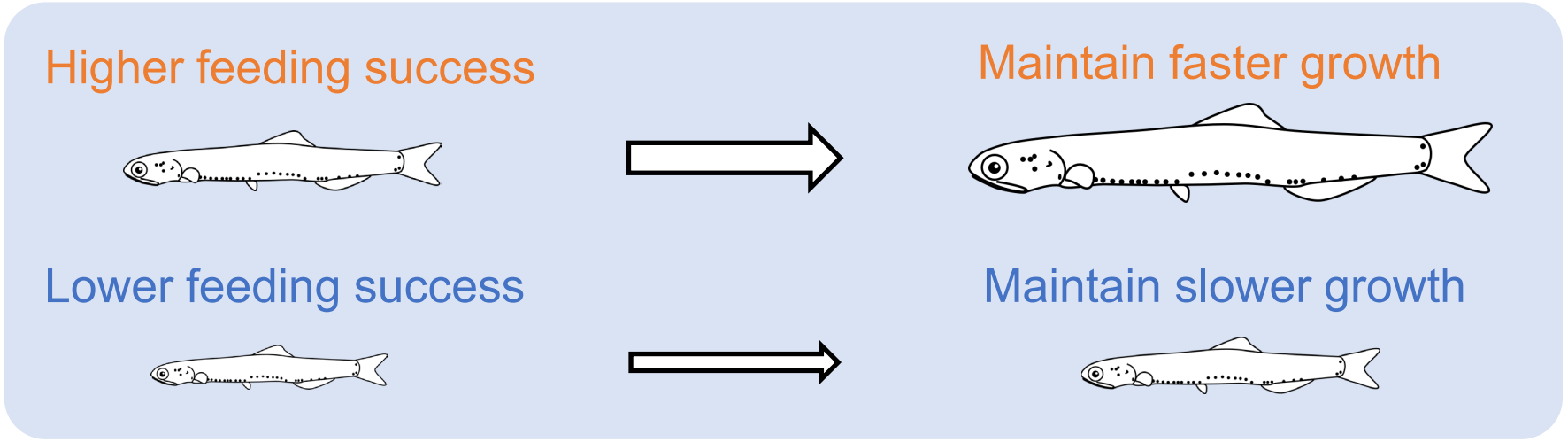
  (Anderson, 1988; Takasuka et al. 2003)



**The growth rate throughout the larval stage can potentially influence survival potential and drive subsequent recruitment.**

# Effect of early growth rates on later growth rates

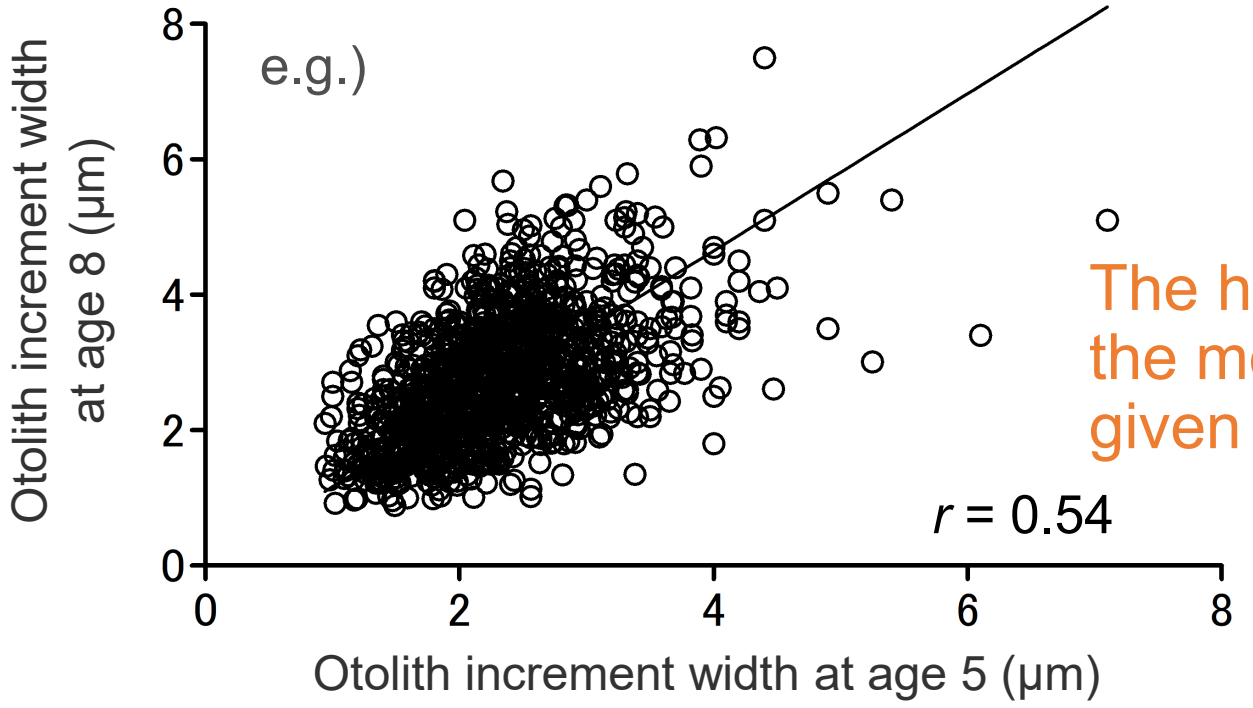
- Larvae achieving high feeding success and growth rates are likely to maintain faster growth rates thereafter. (Anderson, 1988)




**Do early growth rates influence later growth rates and survival potential throughout the larval stage?**

# Growth autocorrelation

- Recent studies analyzed growth autocorrelation based on otolith daily increment width to test the effect of early growth on later growth.
  (Robert et al., 2014; Pepin et al., 2015; Burns et al., 2021)
- Growth autocorrelation is expressed as Pearson's *r* value between otolith increment widths at a certain age and any later age.




The higher the autocorrelation value is, the more strongly growth achieved on a given day is affected by past growth.

# Reported nature of growth autocorrelation (Pepin et al., 2015)

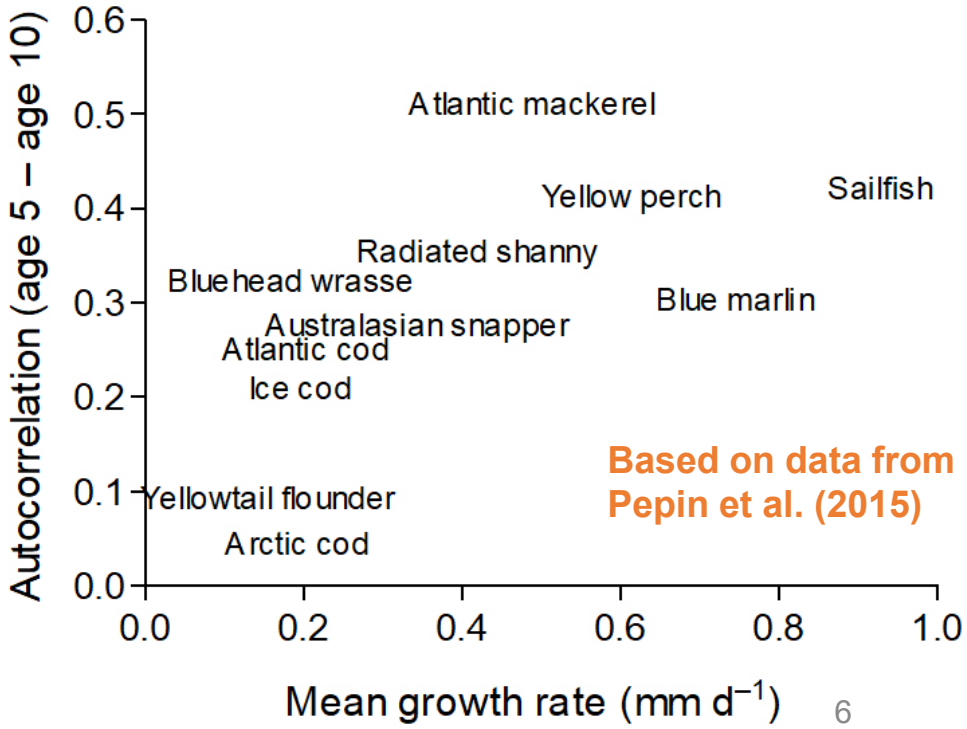
- Pepin et al (2015) examined growth autocorrelation for 11 fish species from various environments.

- Species with higher growth rates tend to have stronger autocorrelation values.

## Limitations of that study

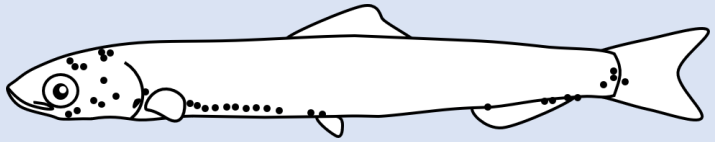
- Limited taxonomy of target species **(not in SPF, except for Atlantic mackerel)**

- Only young individuals were examined. (first 12 days of life)

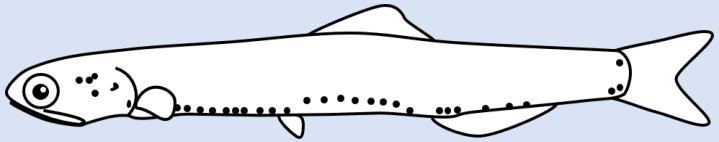


# SPF species considered in this study

**Japanese sardine**
*Sardinops melanostictus*



**Japanese anchovy**
*Engraulis japonicus*



- Rich data sets available over wide spatial and temporal scale
- Consist mainly of late larvae, allowing us to examine the effects of early growth rates throughout the entire larval period.

# Objectives

1. Do the early growth rates influence later growth rates in sardine and anchovy?

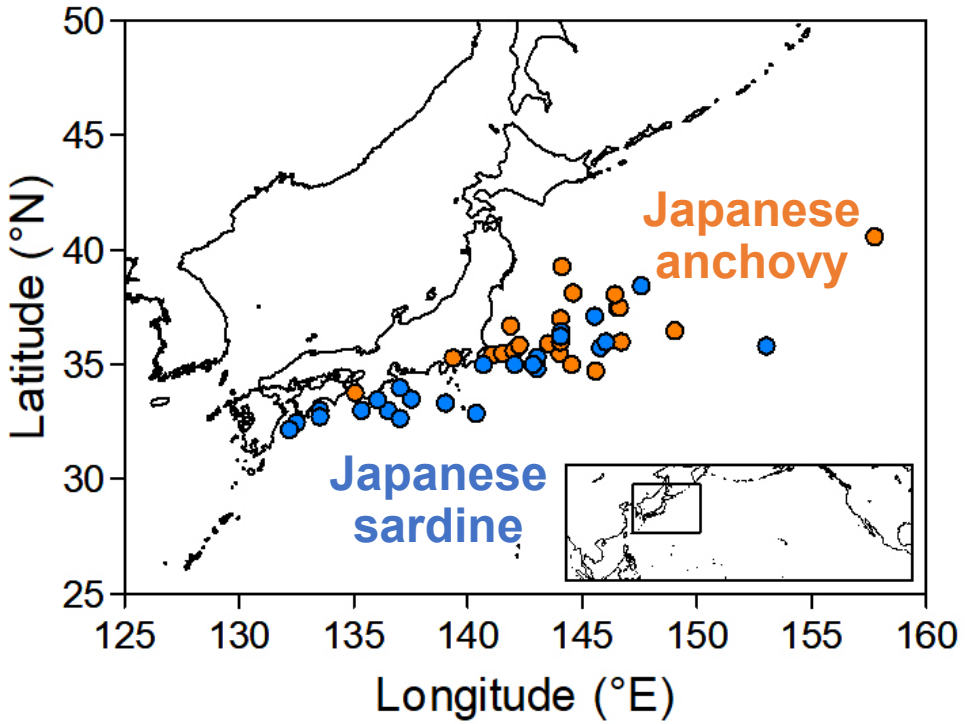
2. Do early growth characteristics differ between the two species?

- Growth autocorrelation is analyzed by pooling individuals over various environments based on the published data sets.

- Testing growth autocorrelation with the samples of sardine and anchovy larvae collected simultaneously

# Published data sets (wide spatiotemporal scale)

| Data source | Year | Net tow | N |
|---|---|---|---|
| **Japanese sardine** Takasuka et al. (2007) | 1990–2004 | 30 | 766 |
| Yasue et al. (2011) | 2006–2008 | 19 | 360 |
| **Japanese anchovy** Takasuka et al. (2007) | 1996–2003 | 30 | 1,985 |
| Yasue & Takasuka (2009) | 2006–2007 | 33 | 1,009 |
| Yasue et al. (2011) | 2007–2008 | 22 | 430 |

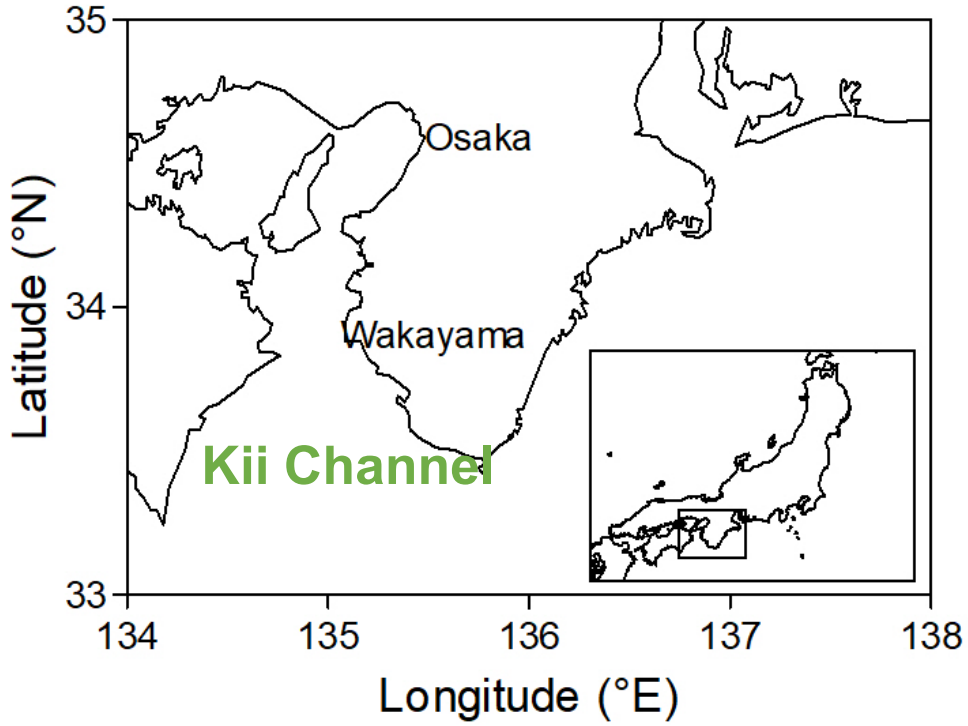



Data include samples from a wide range of environmental conditions.

# Samples of sardine and anchovy collected simultaneously

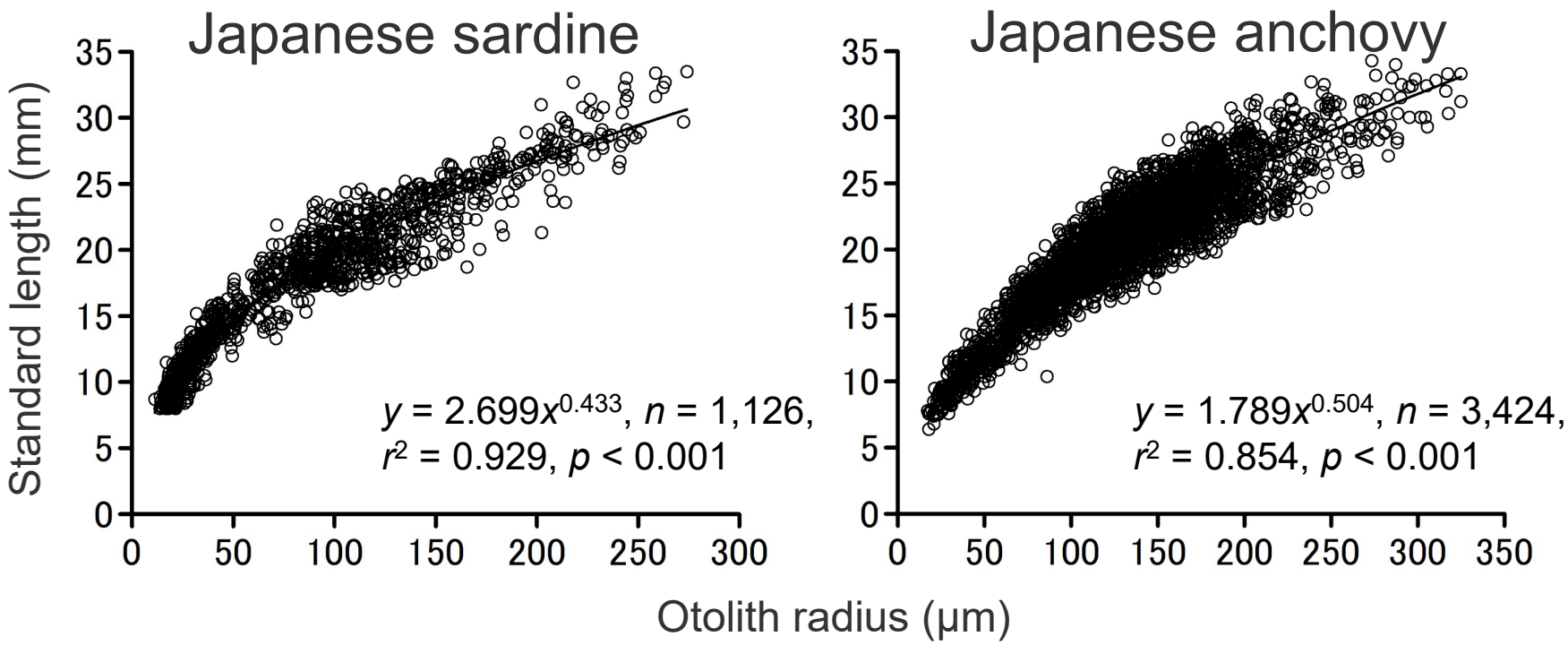
- Kii Channel, 20 April 2021
- Collected by a commercial “shirasu” trawl in coastal fishing grounds

| | | |
|---|---|---|
| Japanese sardine | : | 214 ind. |
| Japanese anchovy | : | 423 ind. |

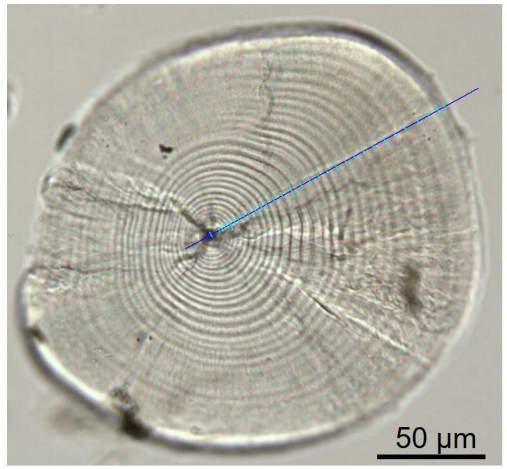



“shirasu” means commercially-harvested pelagic fish larvae in Japanese.

# Otolith incremental width




Japanese sardine otolith




- Strong relationships between otolith and somatic sizes
- Daily increment formation has been verified.
  (Hayashi et al., 1989; Tsuji & Aoyama, 1984)

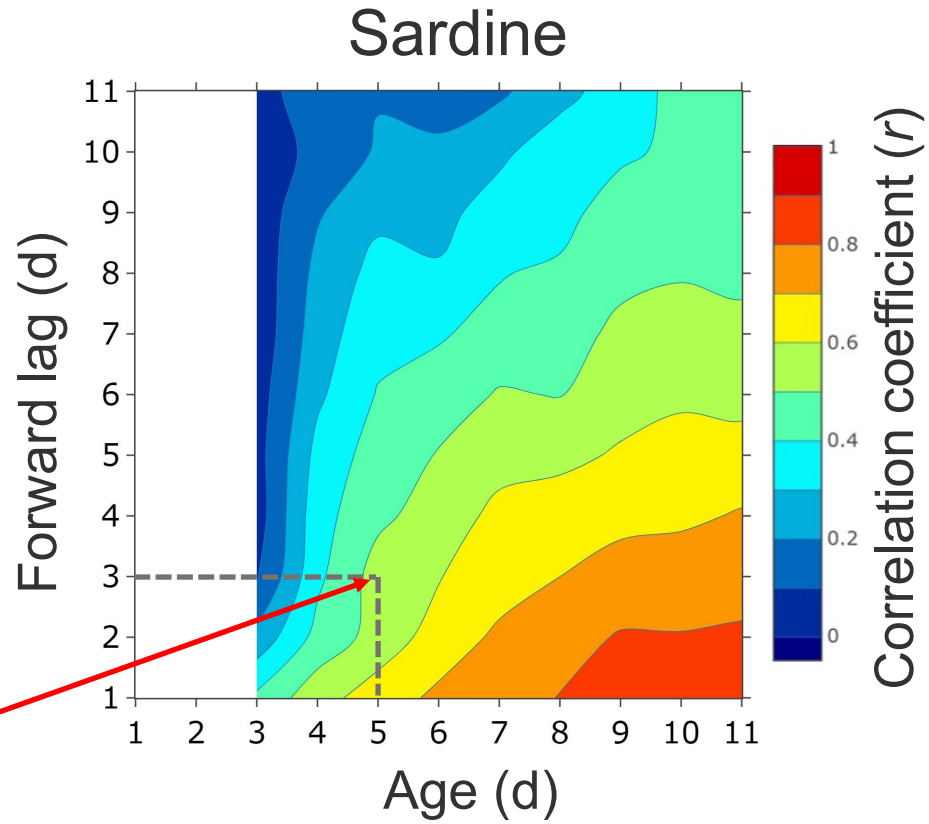
⇨ Otolith increment width used as a proxy for somatic growth rate

# Growth autocorrelation analysis

| ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 7.93 | 4.34 | 3.22 | 4.73 | 3.91 | 4.81 | 3.9 |
| 2 | 0.99 | 1.76 | 3.68 | 1.68 | 2.17 | 1.3 | 1.43 |
| 3 | 1.43 | 2.07 | 2.41 | 1.77 | 2.61 | 1 | 1.81 |
| 4 | 0.99 | 1.76 | 1.95 | 1.48 | 2.93 | 1.4 | 2.19 |
| 5 | 1.87 | 1.55 | 1.03 | 1.28 | 3.8 | 2 | 1.52 |
| 6 | 1.76 | 1.34 | 1.26 | 1.97 | 1.74 | 1.7 | 1.71 |
| 7 | 2.2 | 1.34 | 1.38 | 1.77 | 2.61 | 2.8 | 2.38 |
| 8 | 2.53 | 2.38 | 2.53 | 2.66 | | 2.9 | 2.67 |
| 9 | 1.98 | 2.89 | 2.87 | 3.15 | | 3.5 | 1.9 |
| 10 | | | | | | | |
| 11 | | | | | | | |

| | FORWARD LAG | | | | | |
|---|---|---|---|---|---|---|
| RING | R+1 | R+2 | R+3 | R+4 | R+5 | R+6 |
| 1 | -0.24782 | 0.08067 | 0.23375 | 0.3804 | 0.37007 | 0.3 |
| 2 | 0.42223 | 0.23049 | 0.08008 | 0.04966 | 0.05942 | 0.0 |
| 3 | 0.55987 | 0.43269 | 0.37776 | 0.36075 | 0.33139 | 0.2 |
| 4 | 0.65161 | 0.5377 | 0.54243 | 0.47899 | 0.44522 | 0.4 |
| 5 | 0.72056 | 0.64548 | 0.59464 | 0.5433 | 0.50693 | 0.4 |
| 6 | 0.76163 | 0.71822 | 0.6566 | 0.62813 | 0.56256 | 0.5 |
| 7 | 0.80322 | 0.76105 | 0.69985 | 0.63026 | 0.58526 | 0.4 |

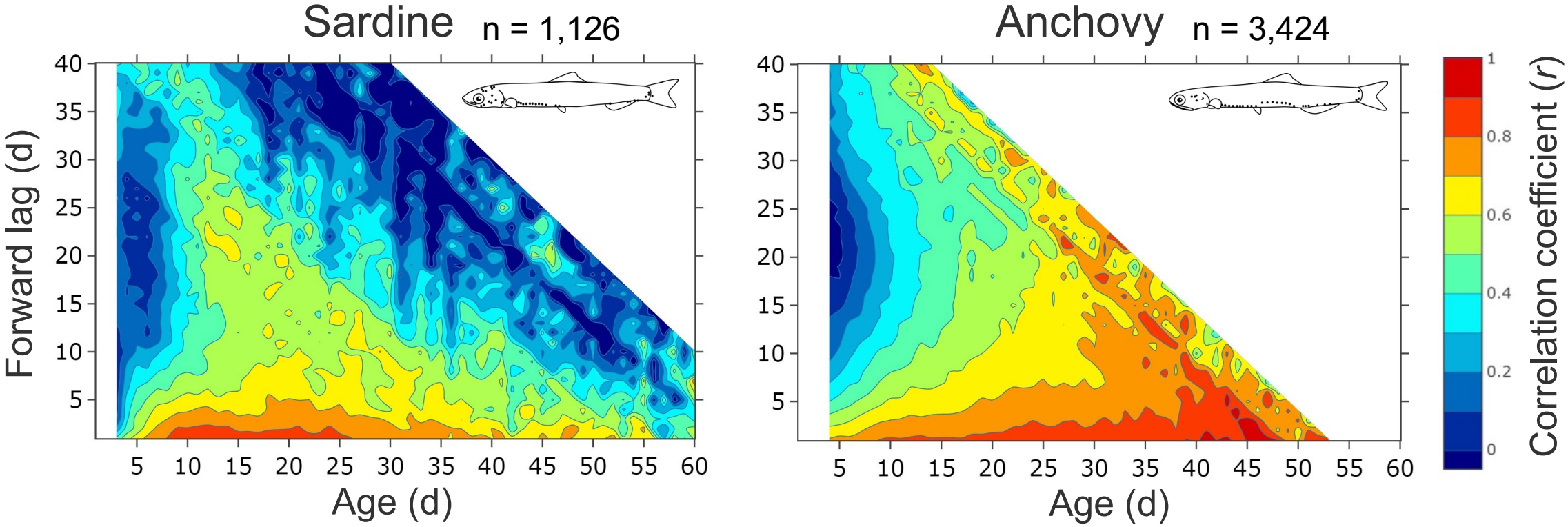
Pearson's *r* correlation coefficient




※ Sardine +2 (Hayashi et al., 1989)
Anchovy +3 (Tsuji & Aoyama, 1984)

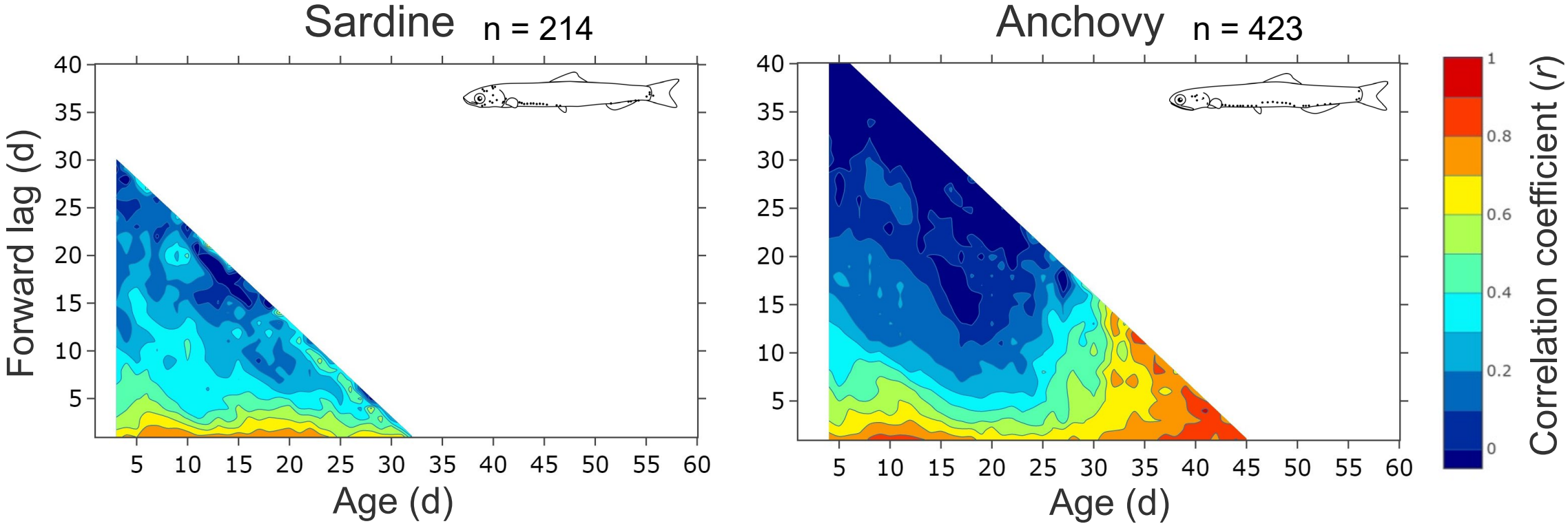
Correlation coefficients were calculated for all combinations of ages, as far as available for ≥20 individuals.

# Data pooled over wide spatiotemporal scales




- Strong autocorrelation (>0.7) was observed at almost all ages.
- Autocorrelation of sardine decreased with age after age 15.
- Autocorrelation of anchovy continued to increase with age.

# Data from samples collected simultaneously

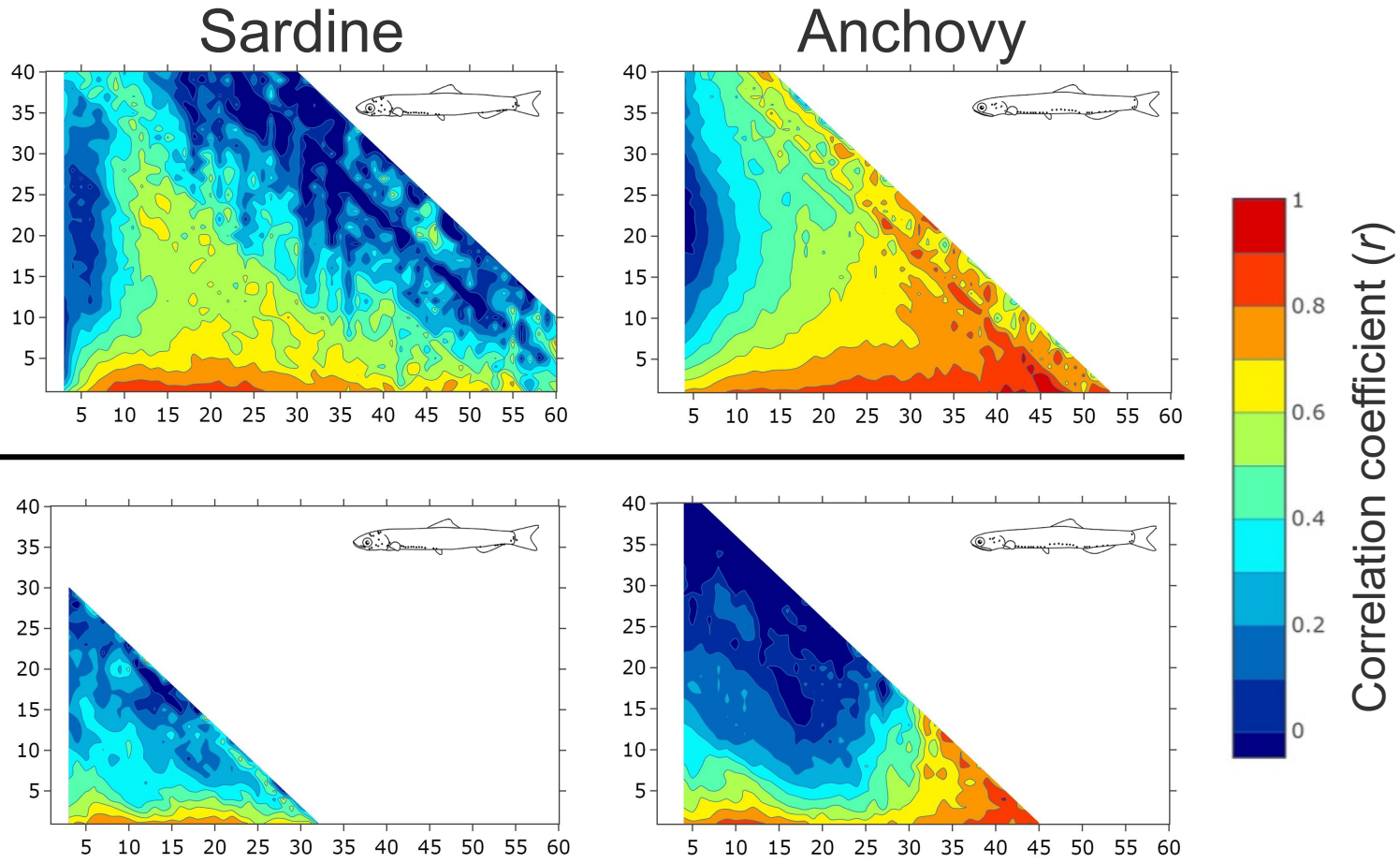



- Strong autocorrelation (>0.7) was observed at almost all ages.
- Autocorrelation of sardine was mostly constant.
- Autocorrelation of anchovy increased rapidly after age 25.

# Species-specific autocorrelation trend

Wide spatial and temporal scale

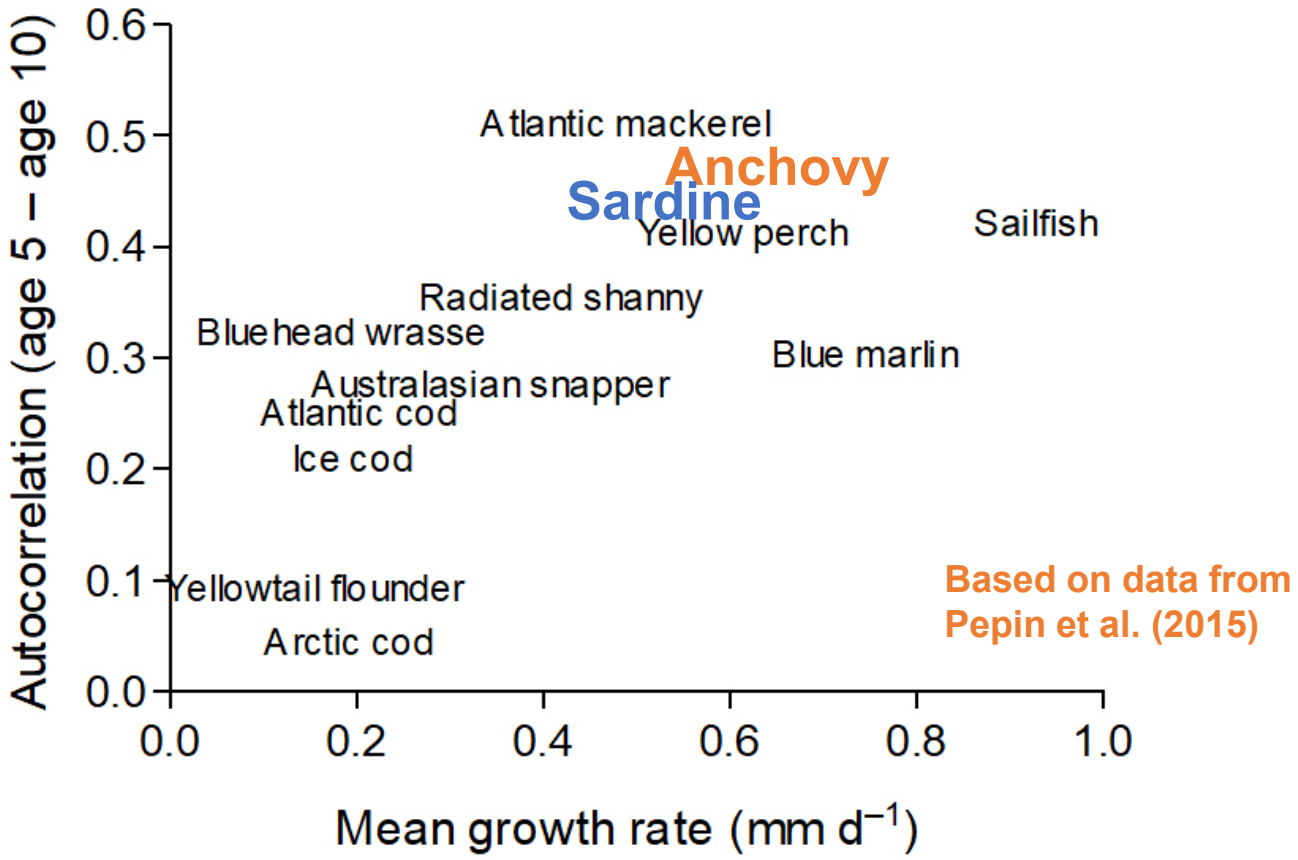
Sample collected simultaneously




The trend was similar even under the same environmental conditions.

The observed trends reflect species-specific patterns, rather than differences in the experienced environment.

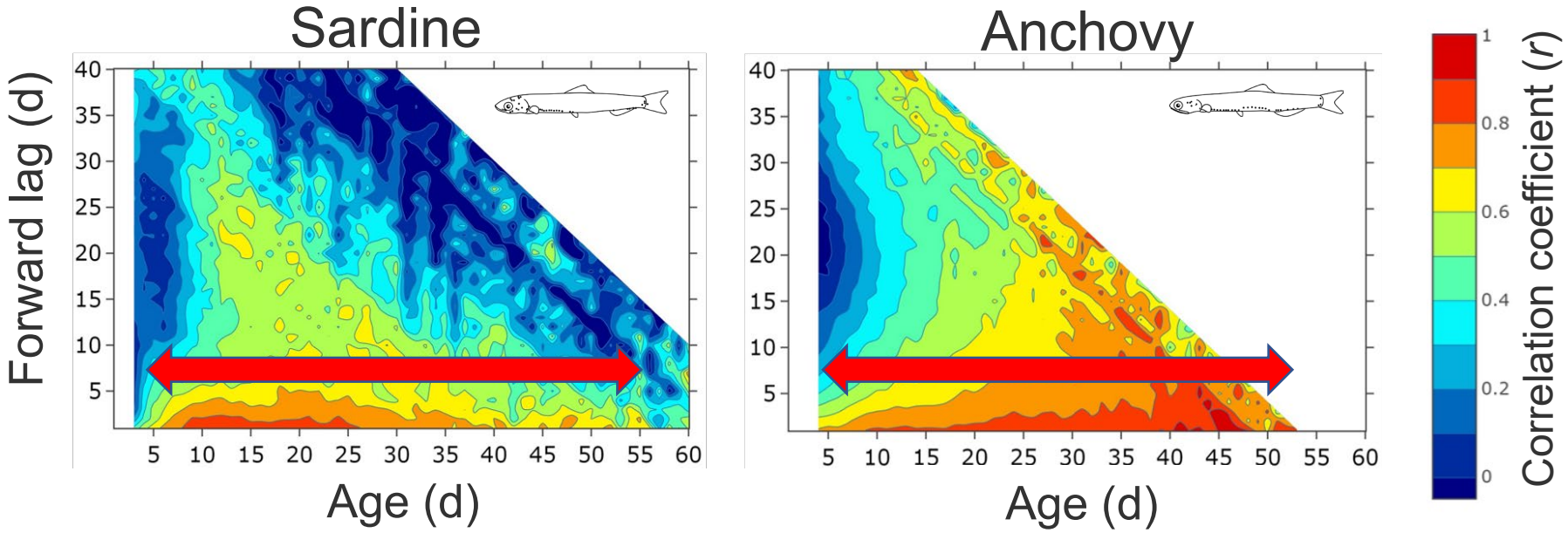
# Comparison to other species in Pepin et al. (2015)




- Two clupeoid species show highly autocorrelated growth history.
- Out results are consistent with the relationship between growth rates and autocorrelation in Pepin et al. (2015).

# Effect of early growth rates on later growth rates

- Strong autocorrelation was detected from young age.
- Strong autocorrelation was detected throughout the larval stage.



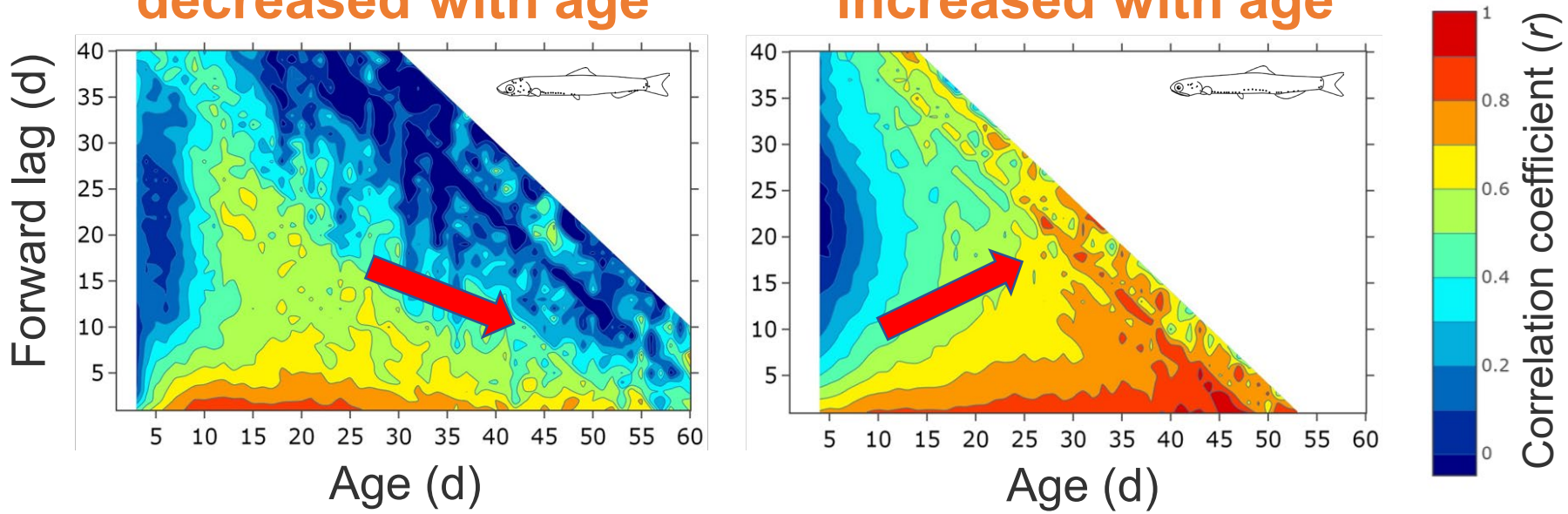

Early growth influence later growth throughout the larval stage in the two SPF

# Difference between two species

At older ages, the duration of forward lag with strong autocorrelation was….

Sardine
**decreased with age**

Anchovy
**increased with age**




Growth of sardine seemed to become less dependent on past growth at some point in the late larval stage.

# Differences in sensitivity to environmental variability

## Greater sensitivity to environmental variability in sardine relative to anchovy

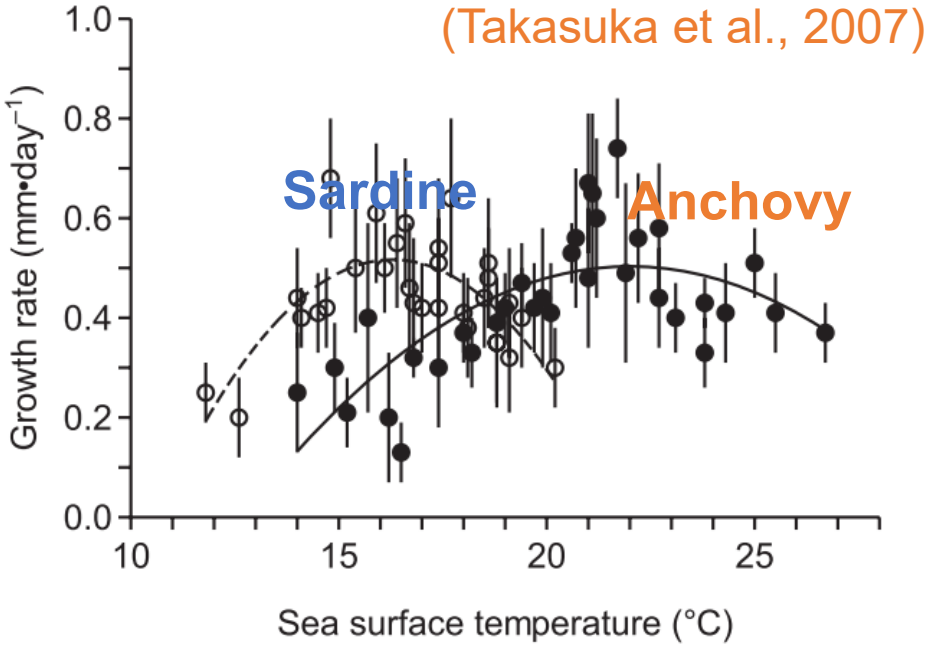
- The sensitivity of growth rates with temperature fluctuations is greater for sardine than for anchovy.

  (Takasuka et al., 2007)

- The relationship between prey density and growth rate is stronger for sardine than for anchovy.

  (Takahashi et al., 2009)

(Takasuka et al., 2007)




Differences in sensitivity to environmental variability could be responsible for interspecific differences in autocorrelation at older ages.

# Conclusion

- Strong autocorrelation was detected throughout the larval stage.
  →Early growth influence later growth throughout the larval stage.

- These trends were confirmed to be similar even under the same environmental conditions.
  →The results of growth autocorrelation reflect species-specific patterns.

- Difference in autocorrelation between sardine and anchovy at older ages
  →This interspecific difference could be attributed to differences in sensitivity to environmental variability.

# Perspective

Year-class strength is determined by….

(Hjort, 1914, 1926)

**short “critical period”**

**after the first-feeding**

VS

(Leggett & Deblois, 1994; Houde, 2008)

**cumulative mortality**

**throughout early life**

- Our results showed that early growth could drive later growth and survival potential to recruitment.

From this view point, the present findings could reconcile the classic and current hypotheses of recruitment mechanisms.