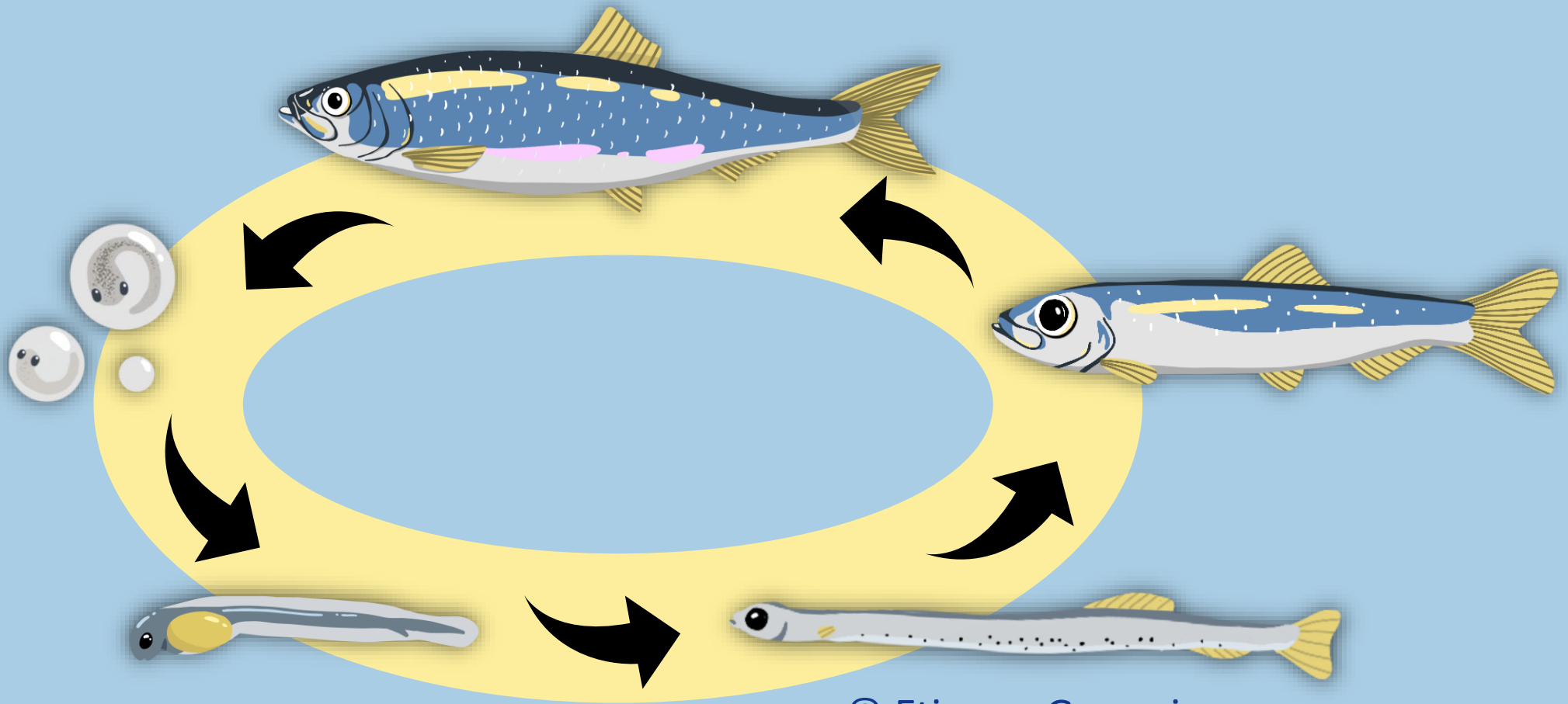


Some implications of life  
history variation across  
ontogeny, space and time  
on survival to recruitment  
in small pelagic fishes

Dominique Robert



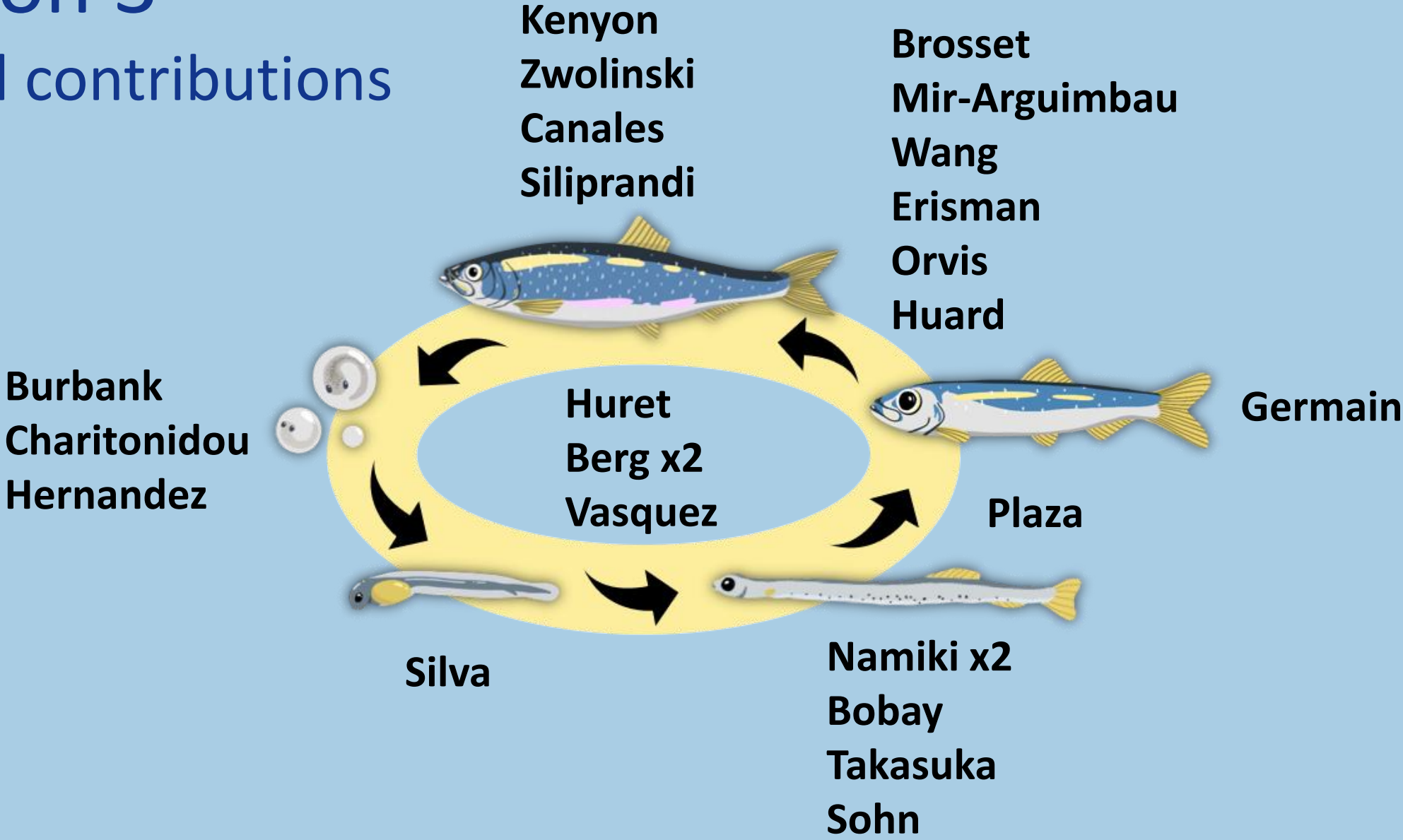
# Session 3: Life History Variation Across Space, Time, and Ontogeny: Implications for Populations, Ecosystems, and Fisheries



© Etienne Germain

# Session 3

33 oral contributions



Kenyon  
Zwolinski  
Canales  
Siliprandi

Brosset  
Mir-Arguimbau  
Wang  
Erisman  
Orvis  
Huard

Burbank  
Charitonidou  
Hernandez

Huret  
Berg x2  
Vasquez

Germain

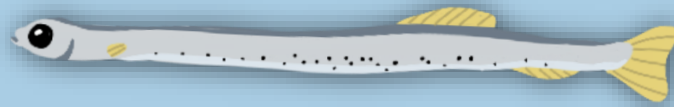
Plaza

Silva

Namiki x2  
Bobay  
Takasuka  
Sohn

# Focus for this presentation: Growth-survival paradigm

Link between larval survival and recruitment strength














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DOI: 10.1111/faf.12774

ORIGINAL ARTICLE

FISH and FISHERIES WILEY

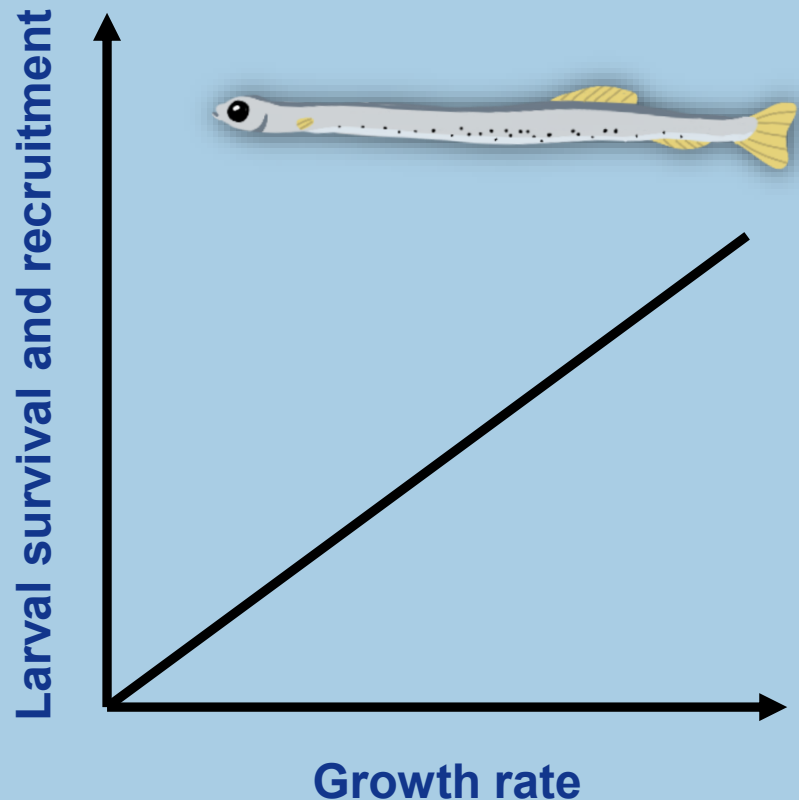
## Life in the fast lane: Revisiting the fast growth—High survival paradigm during the early life stages of fishes

Dominique Robert<sup>1</sup>  | Jun Shoji<sup>2</sup>  | Pascal Sirois<sup>3</sup>  | Akinori Takasuka<sup>4,5</sup>  |  
Ignacio A. Catalán<sup>6</sup>  | Arild Folkvord<sup>7,8</sup>  | Stuart A. Ludsin<sup>9</sup>  | Myron A. Peck<sup>10</sup>  |  
Su Sponaugle<sup>11</sup>  | Patricia M. Ayón<sup>12</sup> | Richard D. Brodeur<sup>13</sup> | Emily Y. Campbell<sup>14</sup> |  
Evan K. D'Alessandro<sup>15</sup> | John F. Dower<sup>16</sup>  | Louis Fortier<sup>17†</sup> | Alberto G. García<sup>18</sup> |  
Klaus B. Huebert<sup>19</sup> | Marc Hufnagl<sup>20</sup> | Shin-ichi Ito<sup>21</sup> | Mikimasa Joh<sup>22</sup> |  
Francis Juanes<sup>16</sup>  | Mitsuo Nyuji<sup>4,23</sup> | Yoshioki Oozeki<sup>24</sup> | Guido Plaza<sup>25</sup> |  
Motomitsu Takahashi<sup>26</sup> | Yosuke Tanaka<sup>27</sup> | Naoki Tojo<sup>28</sup> | Shingo Watari<sup>4,27</sup> |  
Naotaka Yasue<sup>29</sup> | Pierre Pepin<sup>30</sup> 

# Growth-Survival Paradigm

(Cushing 1975, Anderson 1988, Houde 2016)

The “Growth-Survival Paradigm” originates from the “Growth-Mortality hypothesis” (Houde 1987, Anderson 1988) and predicts a positive relationship between year-class strength and growth during the larval stage:



Three complementary mechanisms explain the success of fast-growing individuals:

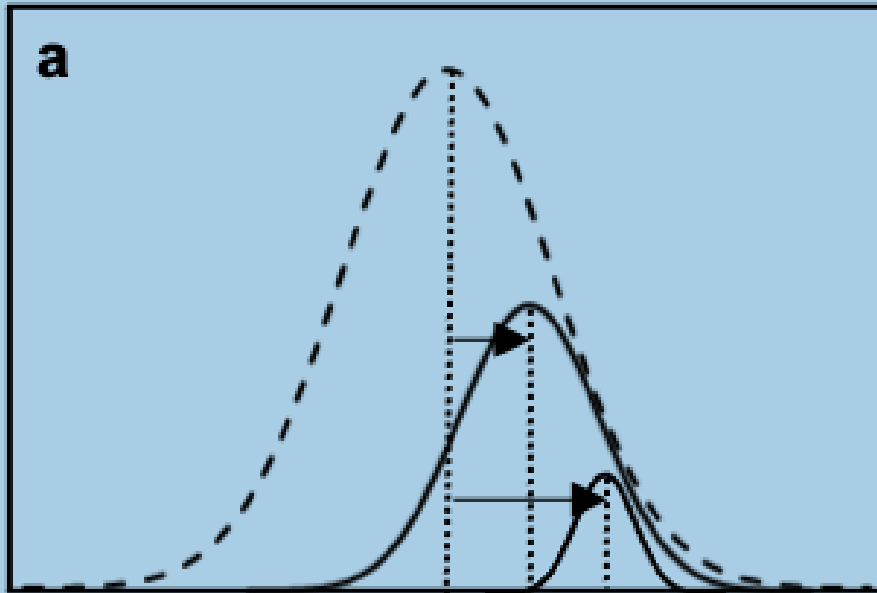
1. Bigger is better (e.g. Miller *et al.* 1988)
2. Stage duration (e.g. Chambers & Leggett 1987)
3. Growth-selective predation (e.g. Takasuka *et al.* 2003, 2007)

# Growth-Survival Paradigm

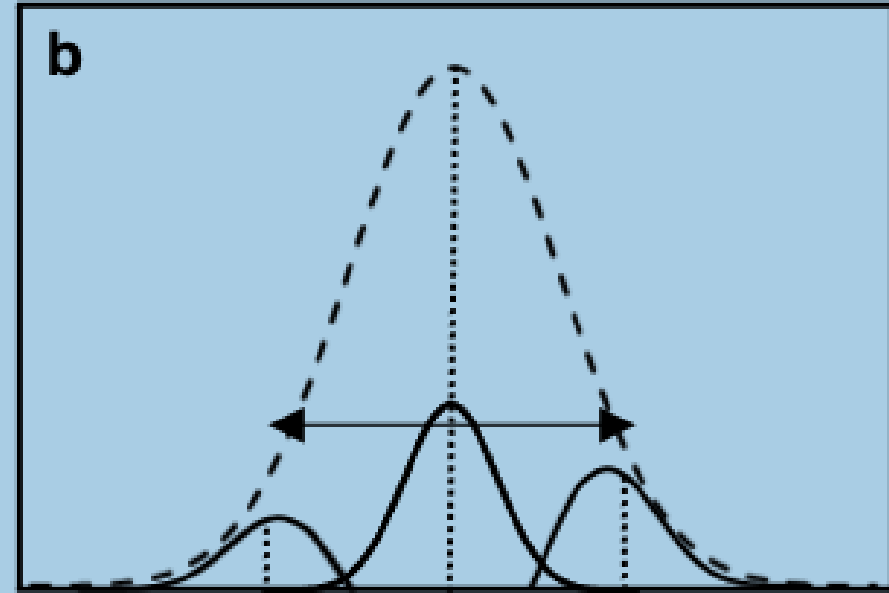
(Cushing 1975, Anderson 1988, Houde 2016)

The paradigm has often been tested by comparing the growth rate frequency distribution between the original larval population and that of survivors back-calculated to the same life stage based on the otolith growth trajectory. Increasingly high mortality is reflected by an increasing shift of the distribution towards fast growth rates.

## Conceptual Framework



## The Reality



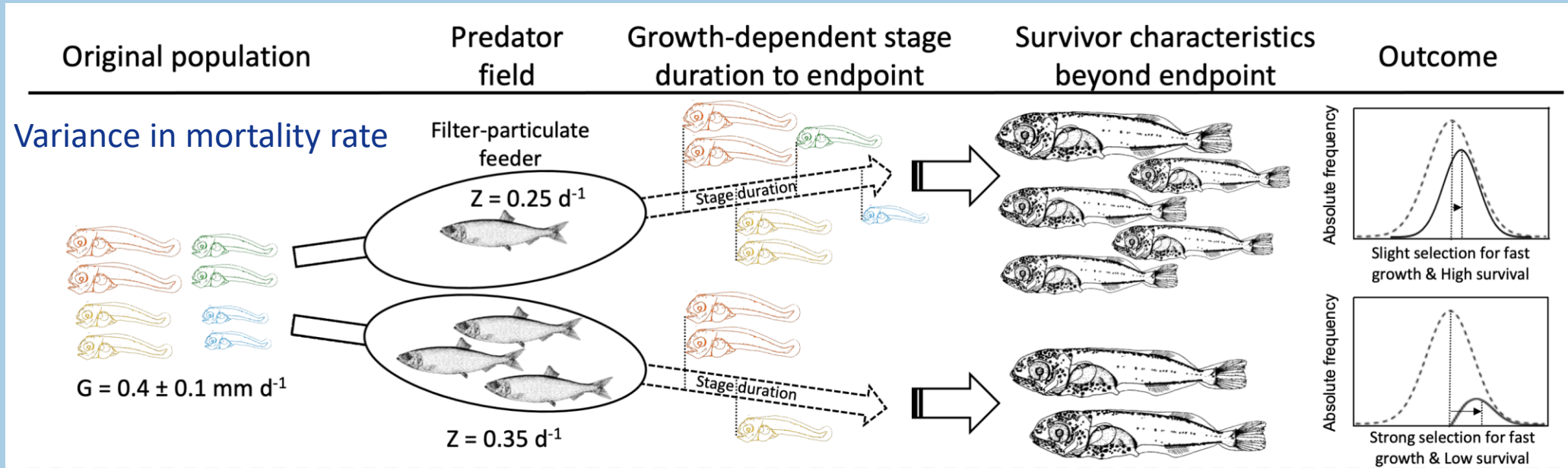
# Testing components of the paradigm

(Robert *et al.*, 2023)

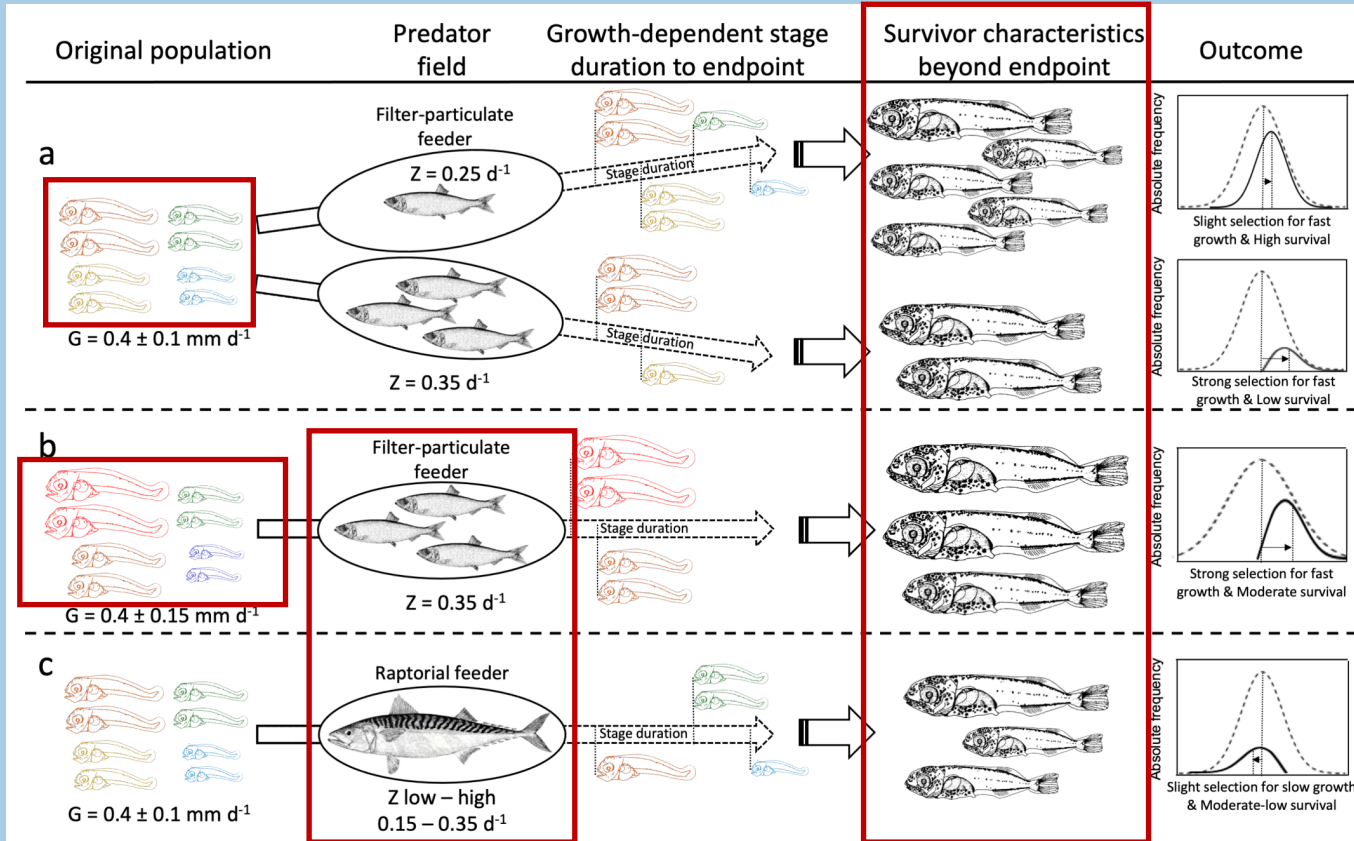
Through a simple IBM, we tested how the characteristics of individuals surviving from hatch to metamorphosis would vary with:

1. **Changes in mean mortality rate:  $0.15 - 0.35 (\pm 0.2) \text{ d}^{-1}$  (Pepin 2016)**
2. **Changes in mean growth rate:  $0.3 - 0.5 \text{ mm d}^{-1}$  (Pepin et al. 2015)**
3. **Variance in growth rate: SD:  $0.05 - 0.15 \text{ mm d}^{-1}$  (Pepin et al. 2015)**
4. **The level of autocorrelation in growth: use average individual growth experienced during first 9 d; 5 d; 2 d**
5. **The level of growth-dependent mortality: use scenarios of differential mortality rates between slow-growing and fast-growing individuals**

# Synthesis of results (Robert *et al.*, 2023)



# Research recommendations (Robert et al., 2023)



- **Predation:** Field studies generally do not quantify predation or even identify the predator field. Additional knowledge on the characteristics of the main larval fish predators is necessary to understand how mortality operates.
- **Intrinsic factors:** Revealing the effects from physiological, inherited, and behavioural traits on a larva's probability of encountering, being attacked and escaping a predator, is essential to determine how these traits may affect mortality and recruitment.

- **Variance in growth:** Consideration of spatio-temporal variability in individual growth rates and the effect of growth autocorrelation is required beyond the traditional consideration of mean growth.
- **Endpoint:** The timing during ontogeny when variability in survival drops and year-class strength is set needs to be determined in the population of interest to avoid making mistakes in the choice of the survivor stage.

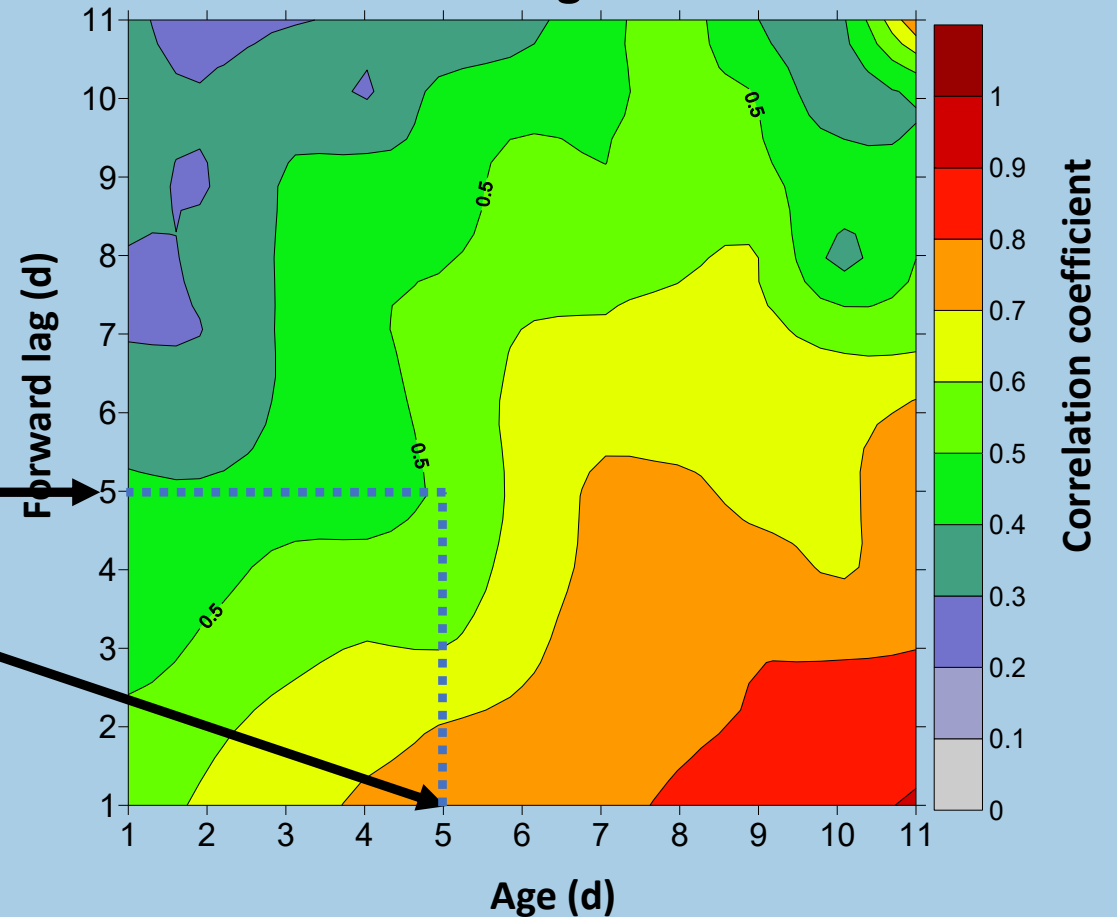
# Age-dependent Growth Autocorrelation

Example of Atlantic mackerel (Robert et al., 2014)

Individual growth trajectory



Correlogram



# Multi-species analysis of growth autocorrelation

Pepin et al. (2015) ; Tanaka et al. (2023) ; Quintanilla et al. (2026)



## Demersal and large pelagic species

*Arctogadus glacialis* (ice cod)

*Chrysophrys auratus* (pink snapper)

*Gadus morhua* (Atlantic cod)

*Istiophorus platypterus* (sailfish)

*Limanda ferruginea* (yellowtail flounder)

*Makaira nigricans* (blue marlin)

*Thalassoma bifasciatum* (bluehead wrasse)

*Ulvaria subbifurcata* (radiated shanny)

*Thunnus thynnus* (Atlantic bluefin tuna)

## Small pelagic species

*Boreogadus saida* (Polar cod)

*Perca flavescens* (yellow perch)

*Scomber scombrus* (Atlantic mackerel)

*Engraulis japonicus* (Japanese anchovy)

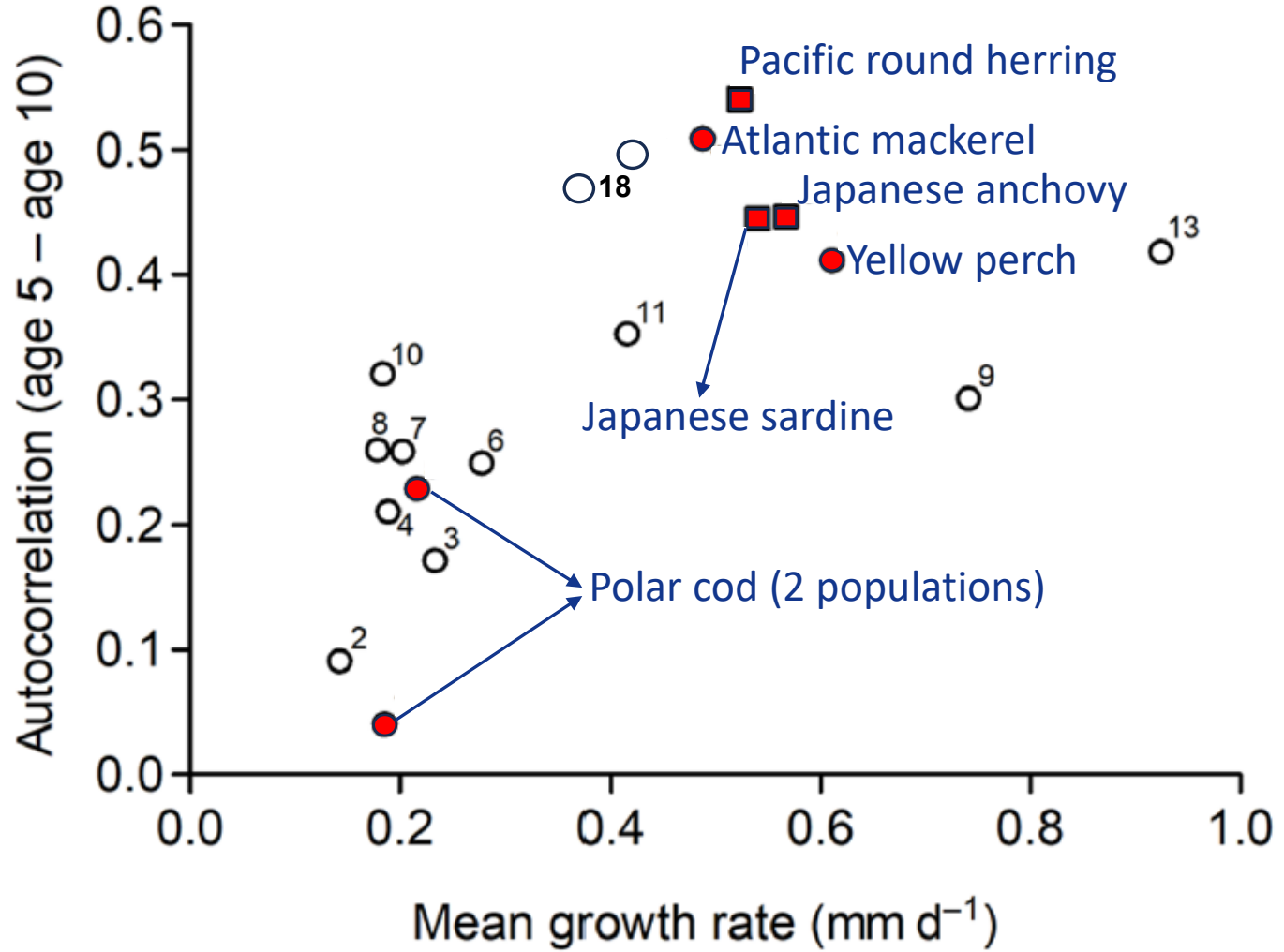
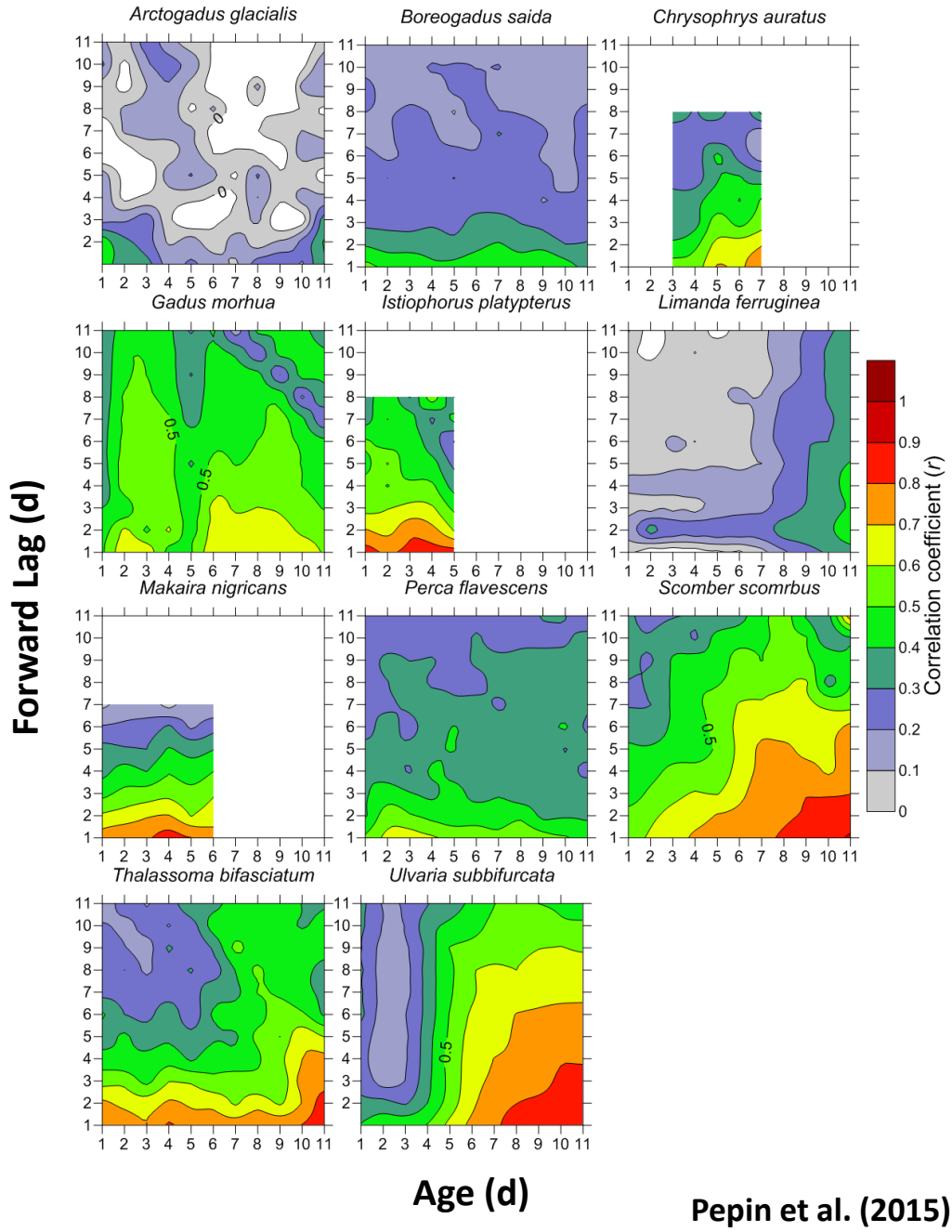
*Sardinops melanostictus* (Japanese sardine)

*Etrumeus micropus* (Pacific round herring)



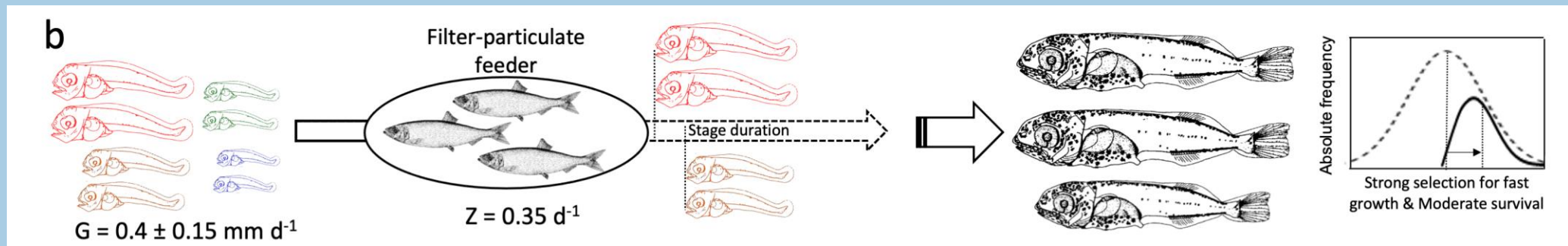
# Growth Autocorrelation Vs. mean growth rate

Adapted from Pepin et al. (2015), Tanaka et al. (2023), Quintanilla et al. (2026)



# Implications of Growth Autocorrelation

- With the exception of Polar cod, boreal and temperate small pelagic fish species investigated so far presented fast early growth combined to strong growth autocorrelation.
- Strong growth autocorrelation results in high variance in early growth and may lead to the situation where high observed growth-selective mortality does not correspond to the expected low overall survival.



- This trait found in small pelagic fishes implies that maternal effects (large size and high condition at hatching) can have a strong influence on the survival probability of larvae.

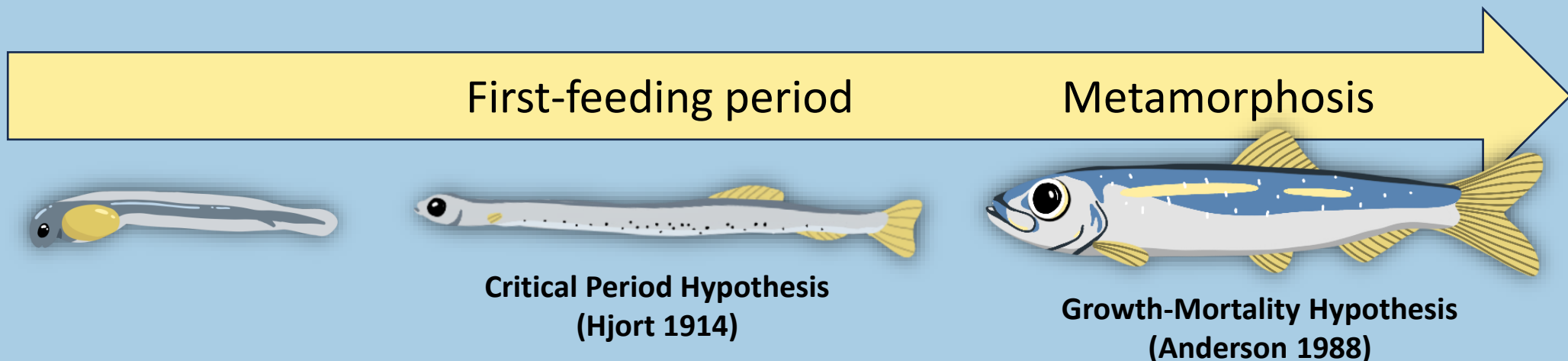
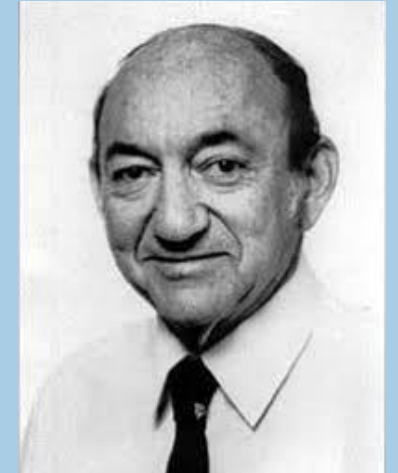
# Researching the timing of the “Recruitment Endpoint”

*The answer to the question "what limits clupeoids?" seems to be "almost everything". More realistically, the question should be phrased "what limits clupeoids mostly?"*

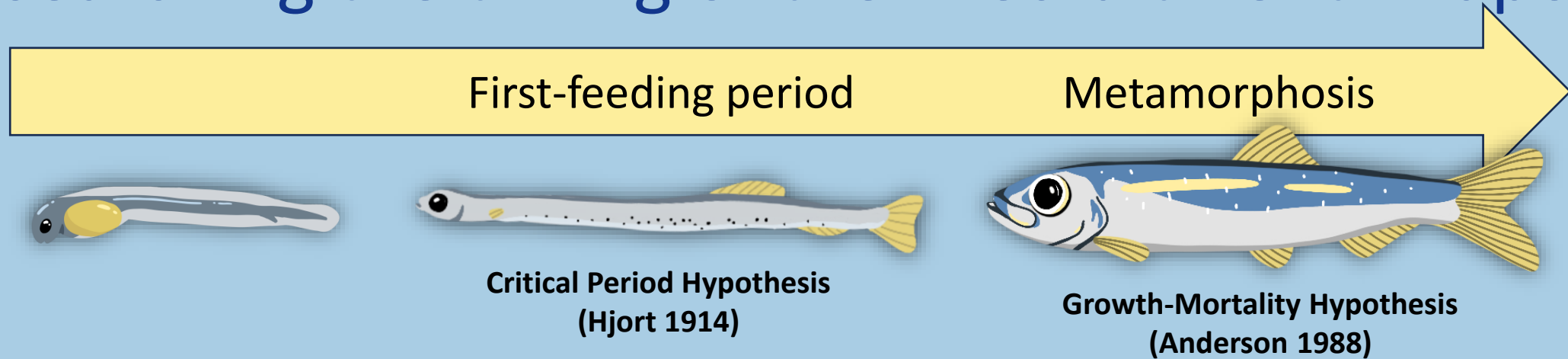
*Other questions follow this one: When, in the life cycle, does this occur?*

– Reuben Lasker (1985)

Proceedings of the 1983 International Herring Symposium in Nanaimo



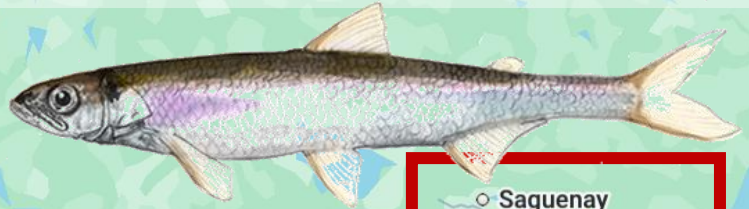
# Researching the timing of the “Recruitment Endpoint”



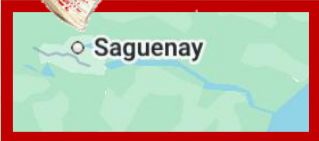
- The potential importance of mortality beyond metamorphosis in relation to recruitment control was highlighted by Sissenwine (1984), Sogard (1997), Hurst (2008), etc.
- However, studies actually investigating growth and survival beyond metamorphosis remain rare, even precluding us from measuring juvenile habitat quality (Ciotti et al., 2025)
- Why has so little work been conducted on juvenile growth and survival ?

**The difficulty of obtaining representative samples of early juvenile stages**

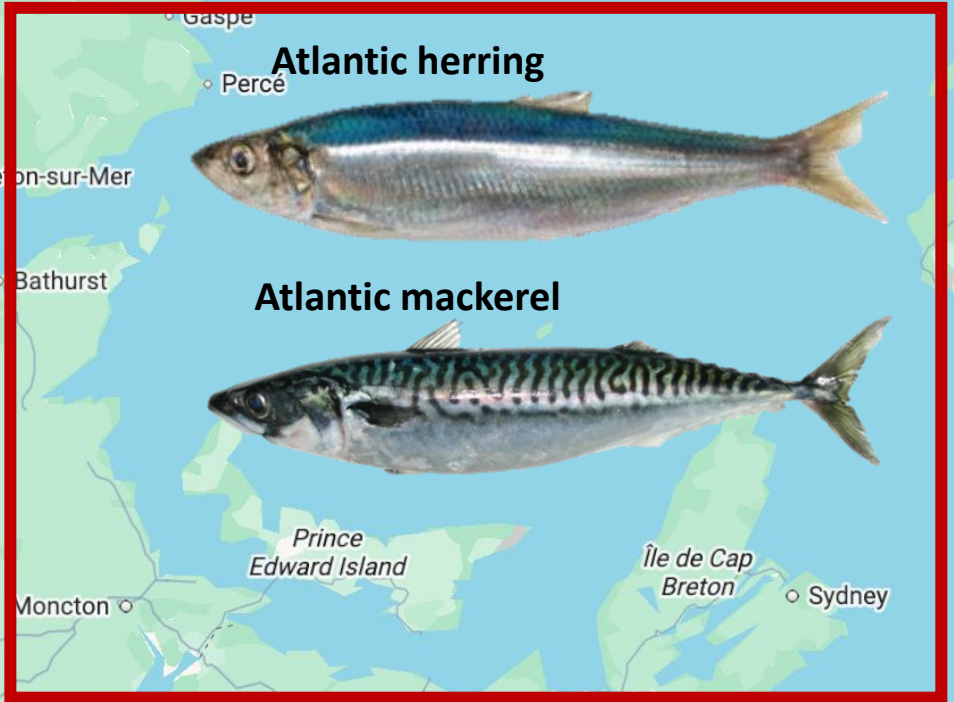
# Digging into the “endpoint” of forage fishes from the St. Lawrence system



**Rainbow smelt**



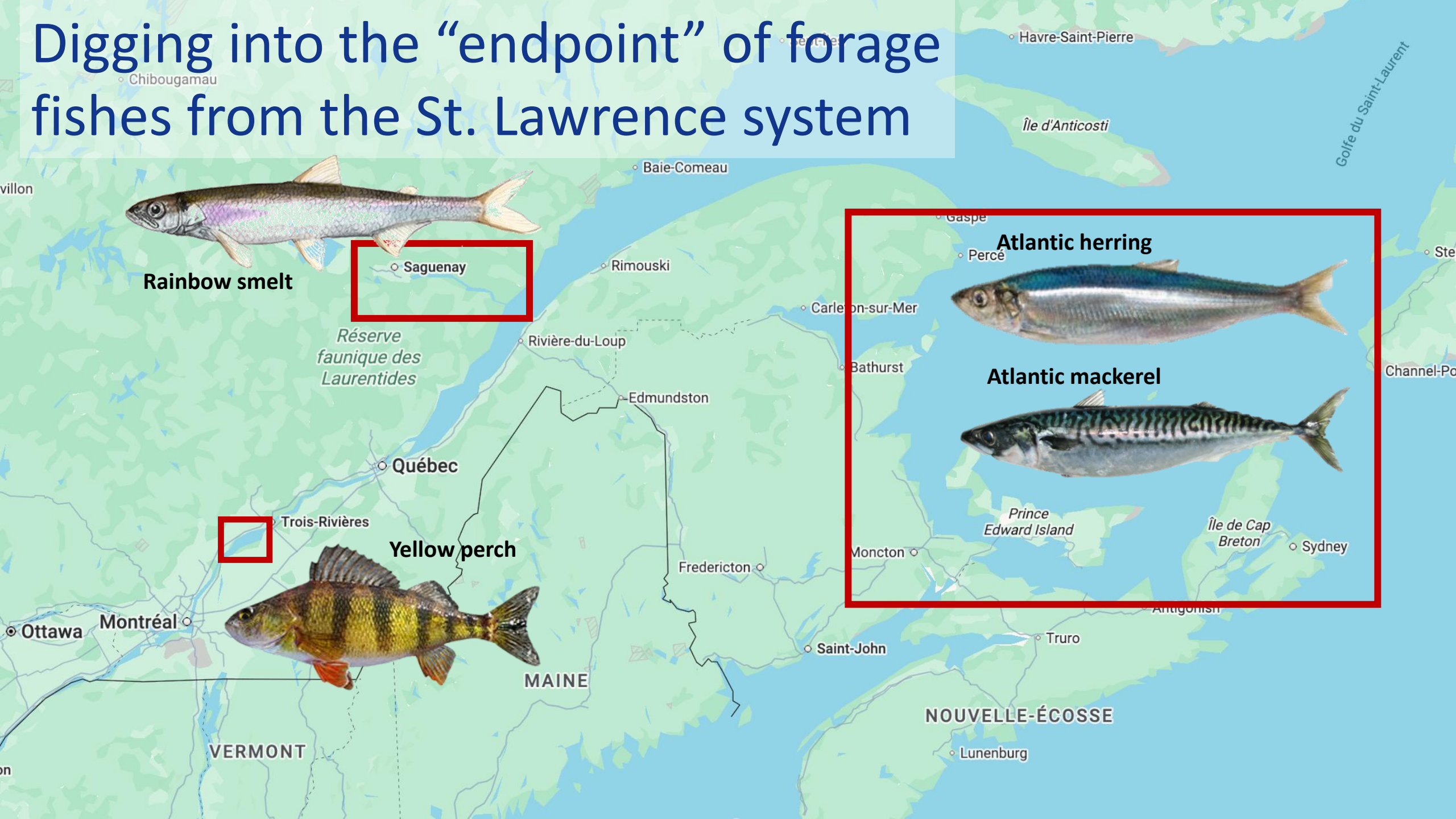
**Yellow perch**



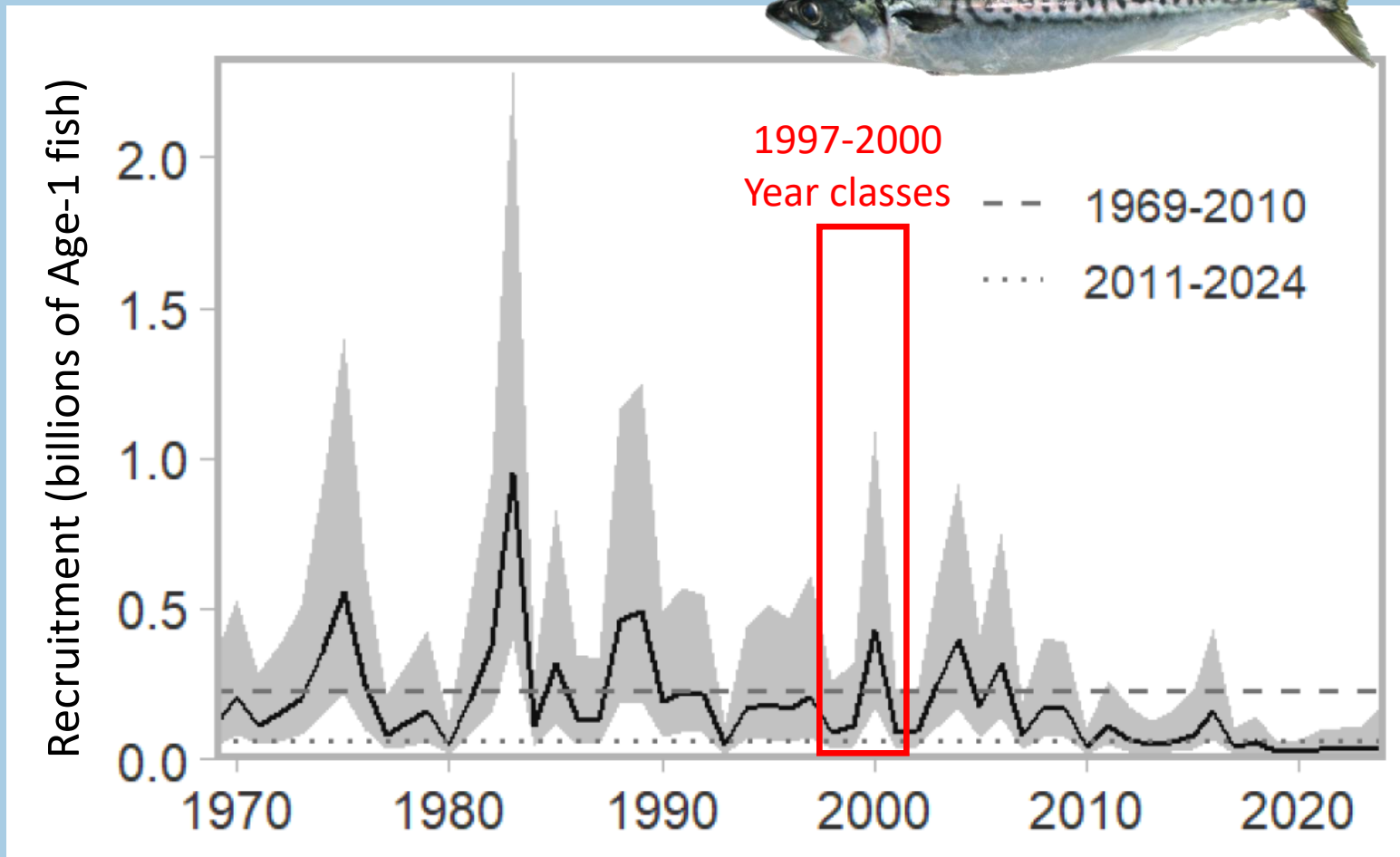
**Atlantic herring**



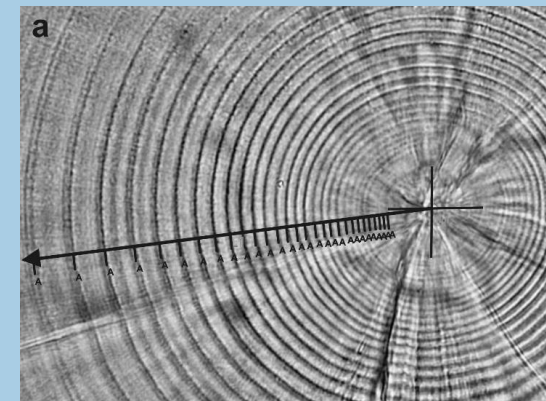
**Atlantic mackerel**



# Atlantic mackerel recruitment variability



The role of early growth on recruitment variability was first assessed by contrasting the early growth trajectory of larvae to that of 1-year-old juvenile survivors captured by the fishery, based on 4 year classes (Robert et al., 2007).

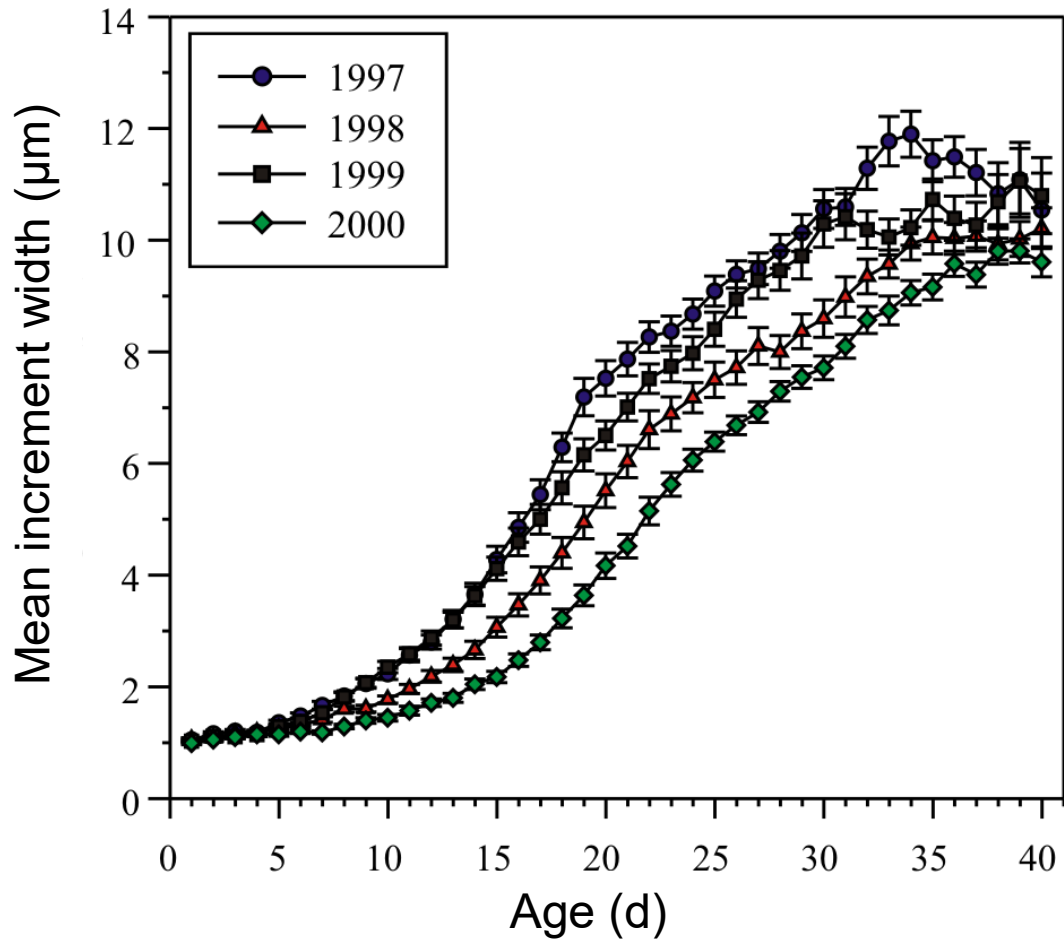


# Comparison of early growth trajectories

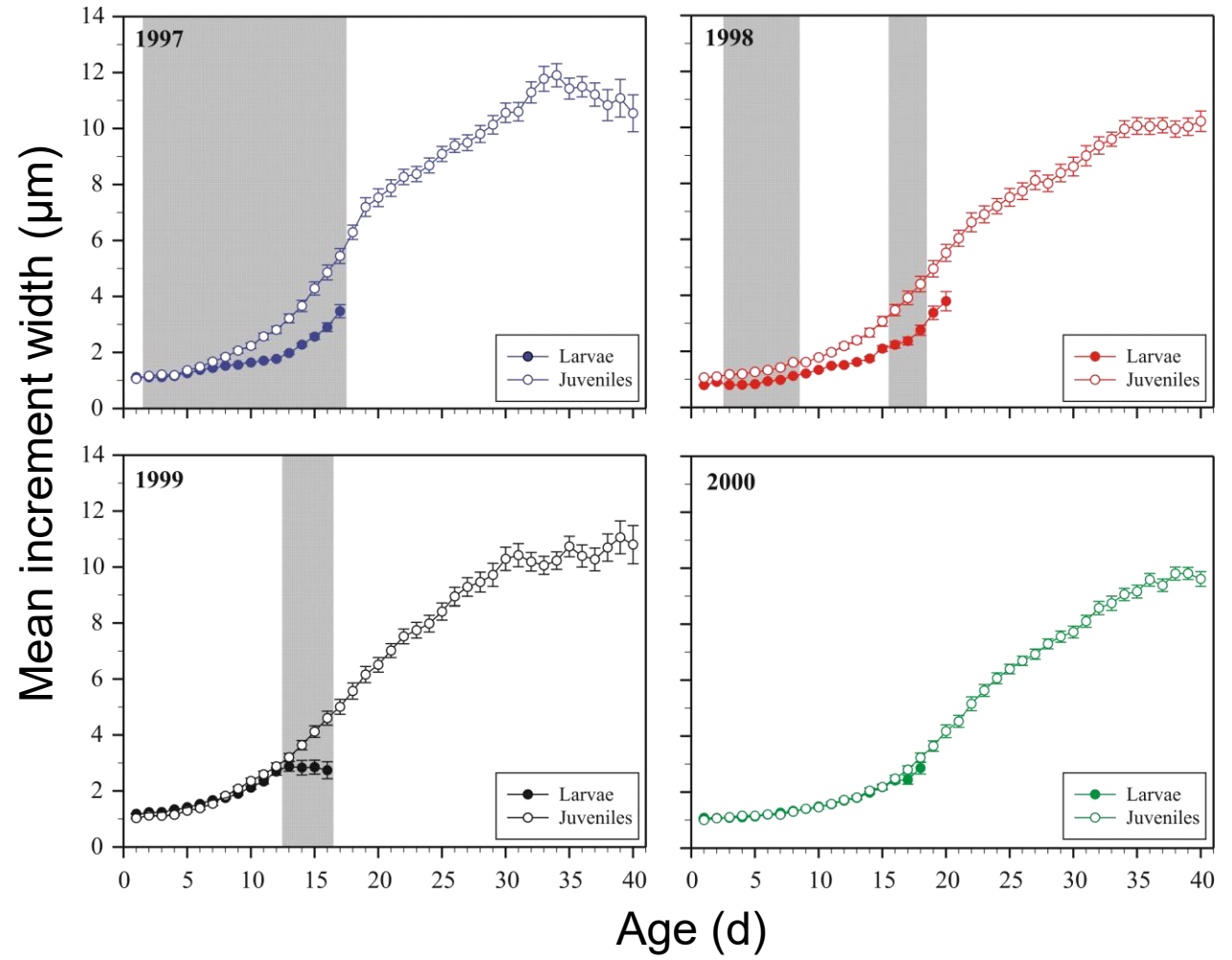
Robert et al., 2007



## Larval growth trajectory of 1-year-old juveniles



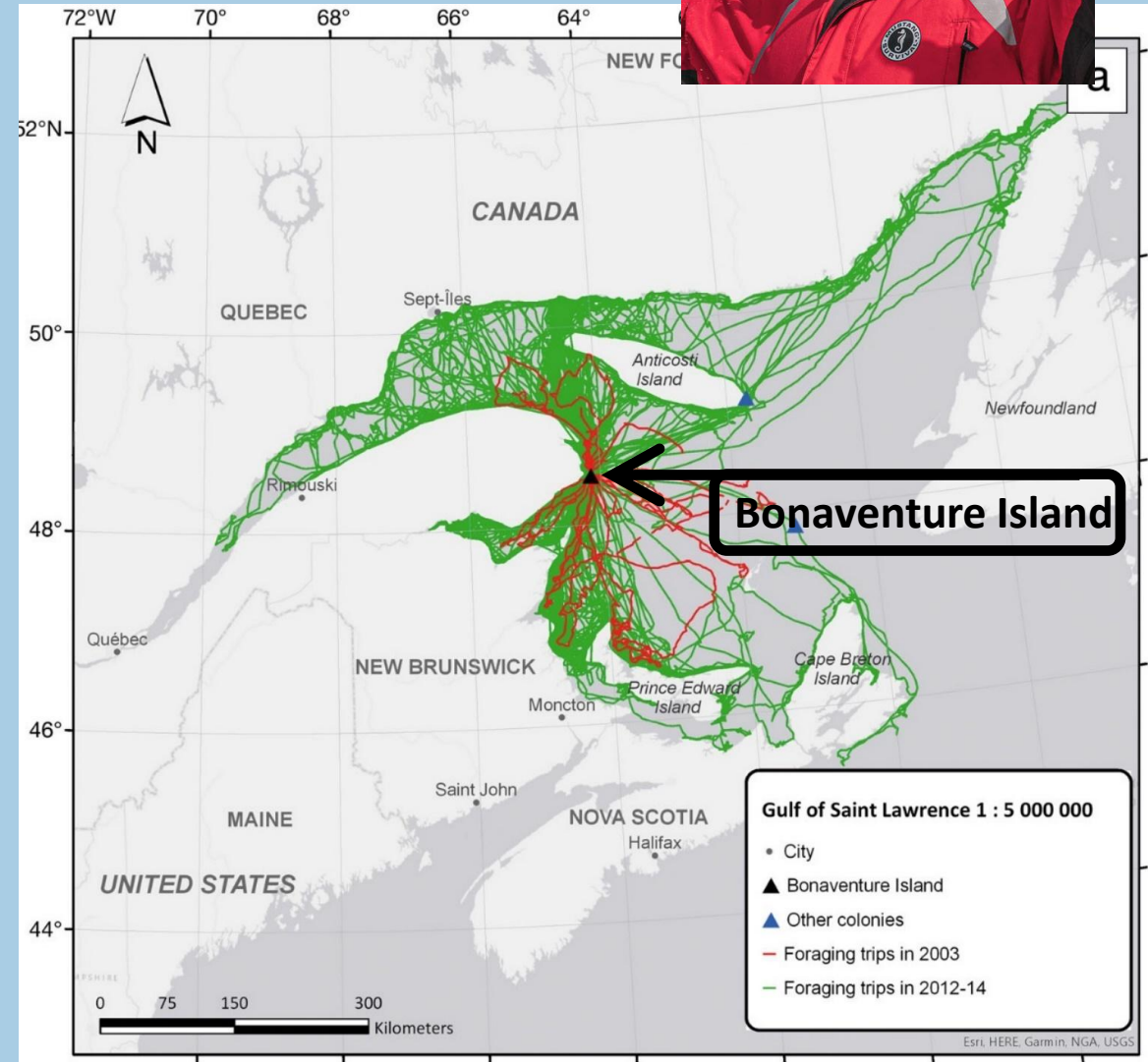
## 1-year-old juveniles Vs. their original larval population



# How to obtain Young-of-the-year mackerel ?

Northern gannet is recognized as the main predator (50,000 breeding pairs).

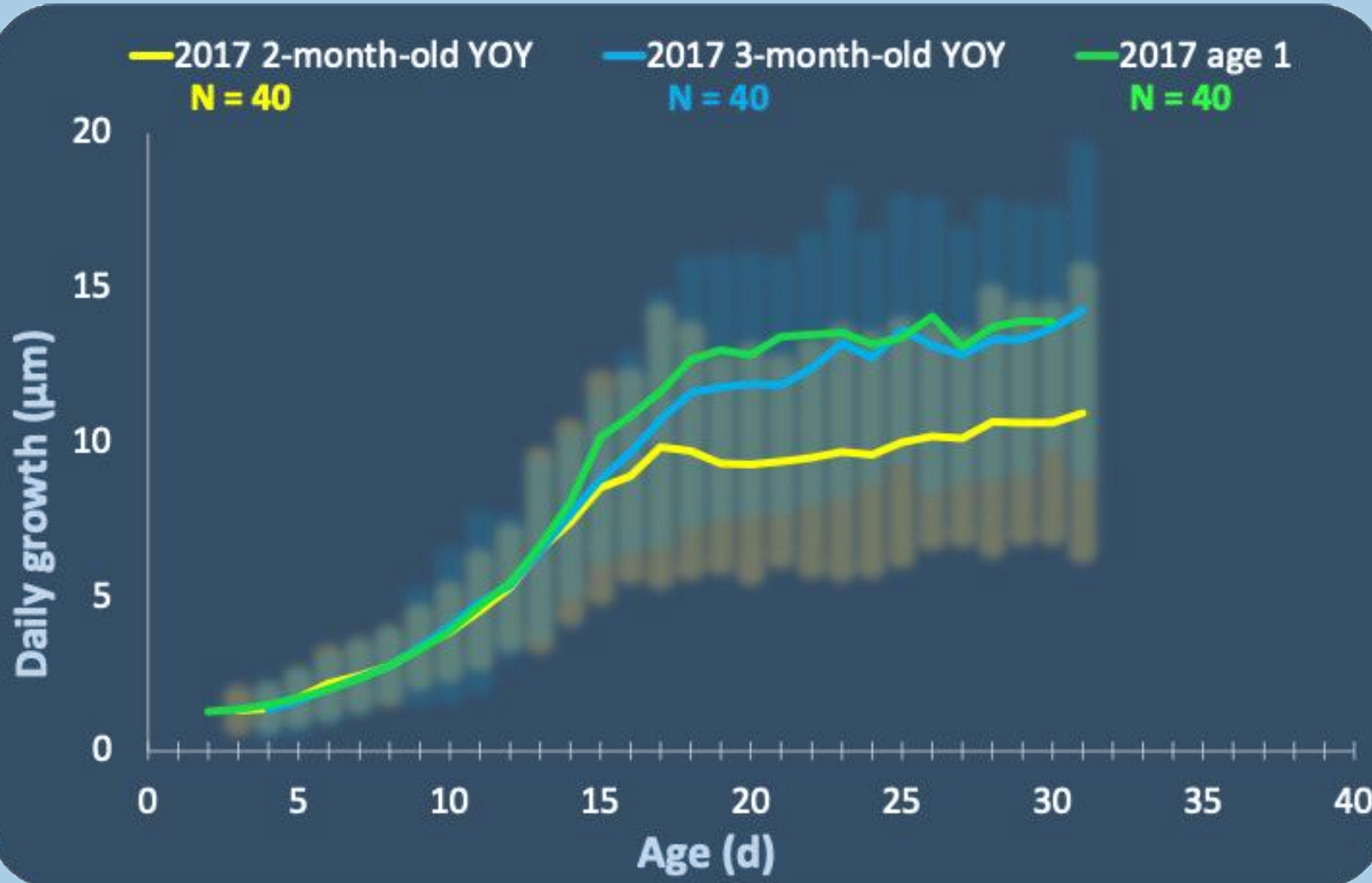
Their foraging trips cover the entire Gulf (Guillemette et al., 2018).



# The Northern Gannet as juvenile mackerel sampler

# Growth-selective mortality extends beyond larval life

Khamassi et al. (2020)

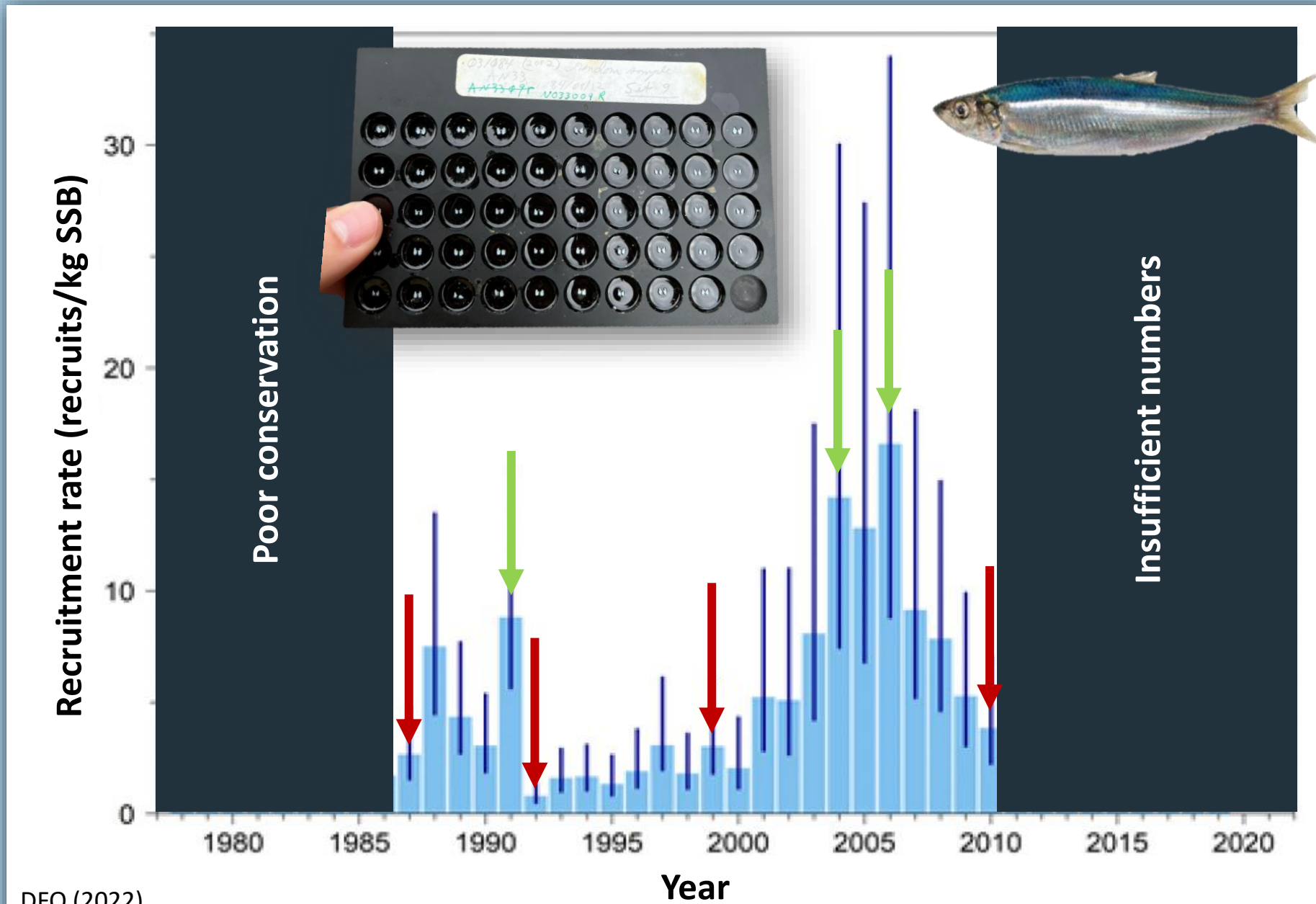


Strong difference in growth trajectory between 2-month-old and 3-month-old juveniles.

No significant difference between 3-month-old and 1-year-old juveniles

The assumption that the bulk of growth-selective mortality occurs during the larval stage was wrong!

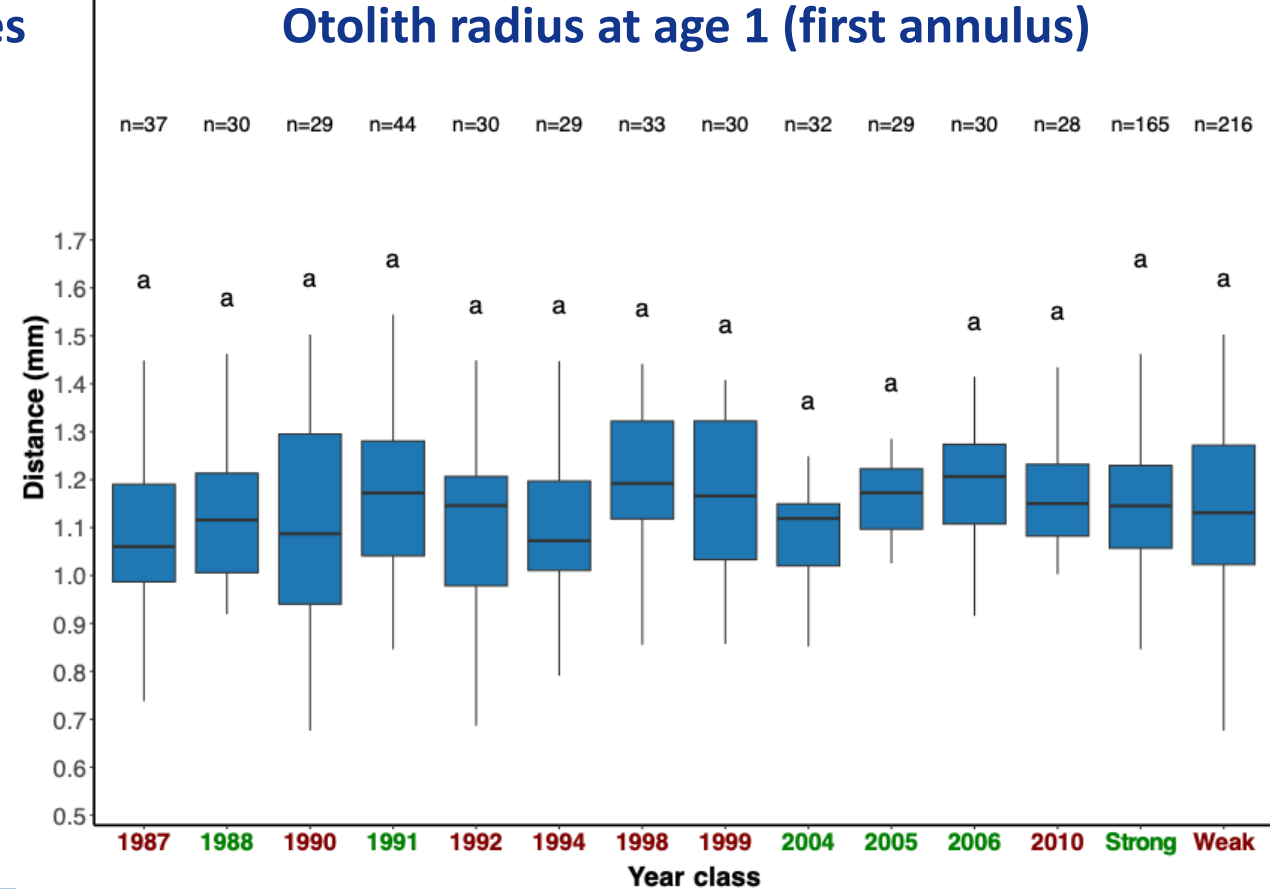
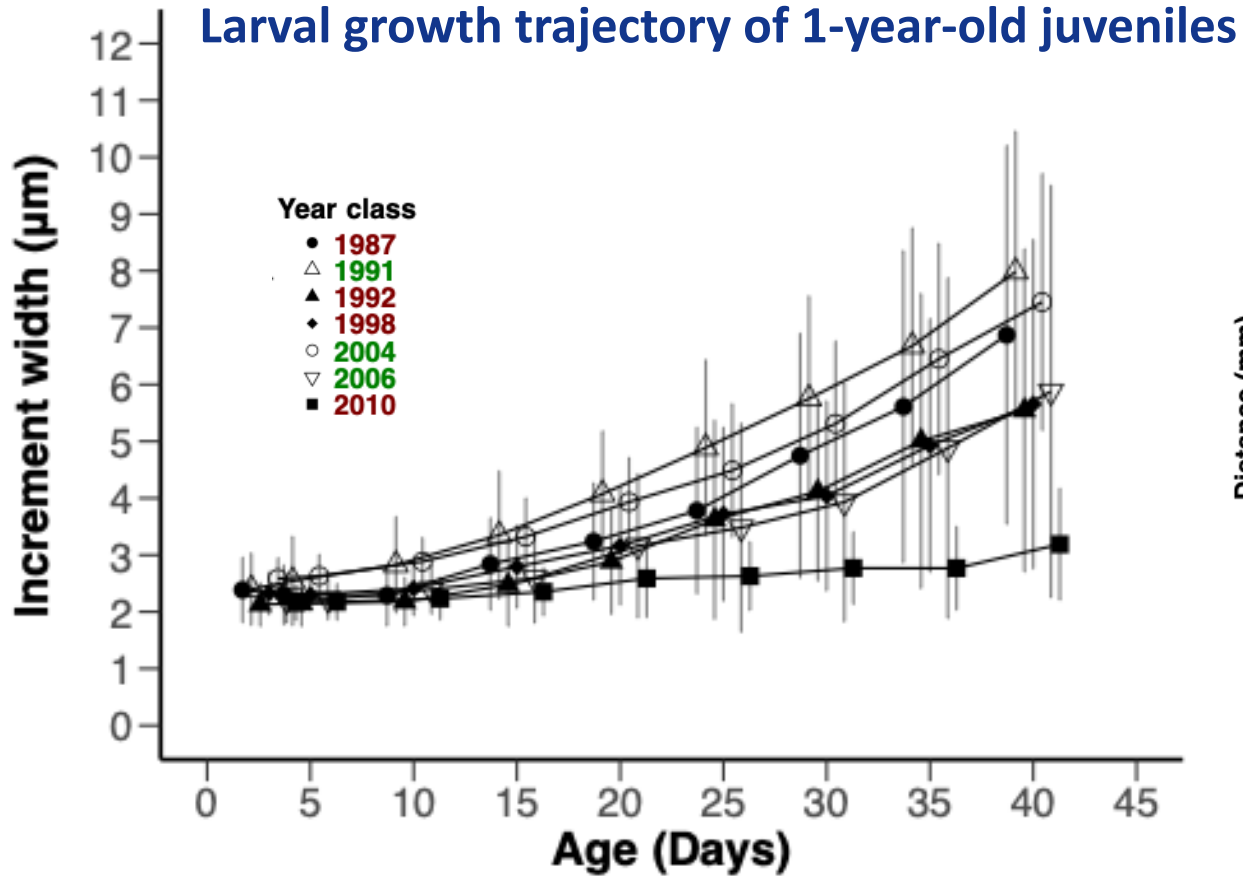
# Southern Gulf of St. Lawrence spring-spawning herring



DFO (2022)



# Comparison of early growth trajectories



- Despite the variance among years in the larval growth trajectory, with strong year-classes associated to fast growth, there was no difference in overall growth achieved by Age 1.

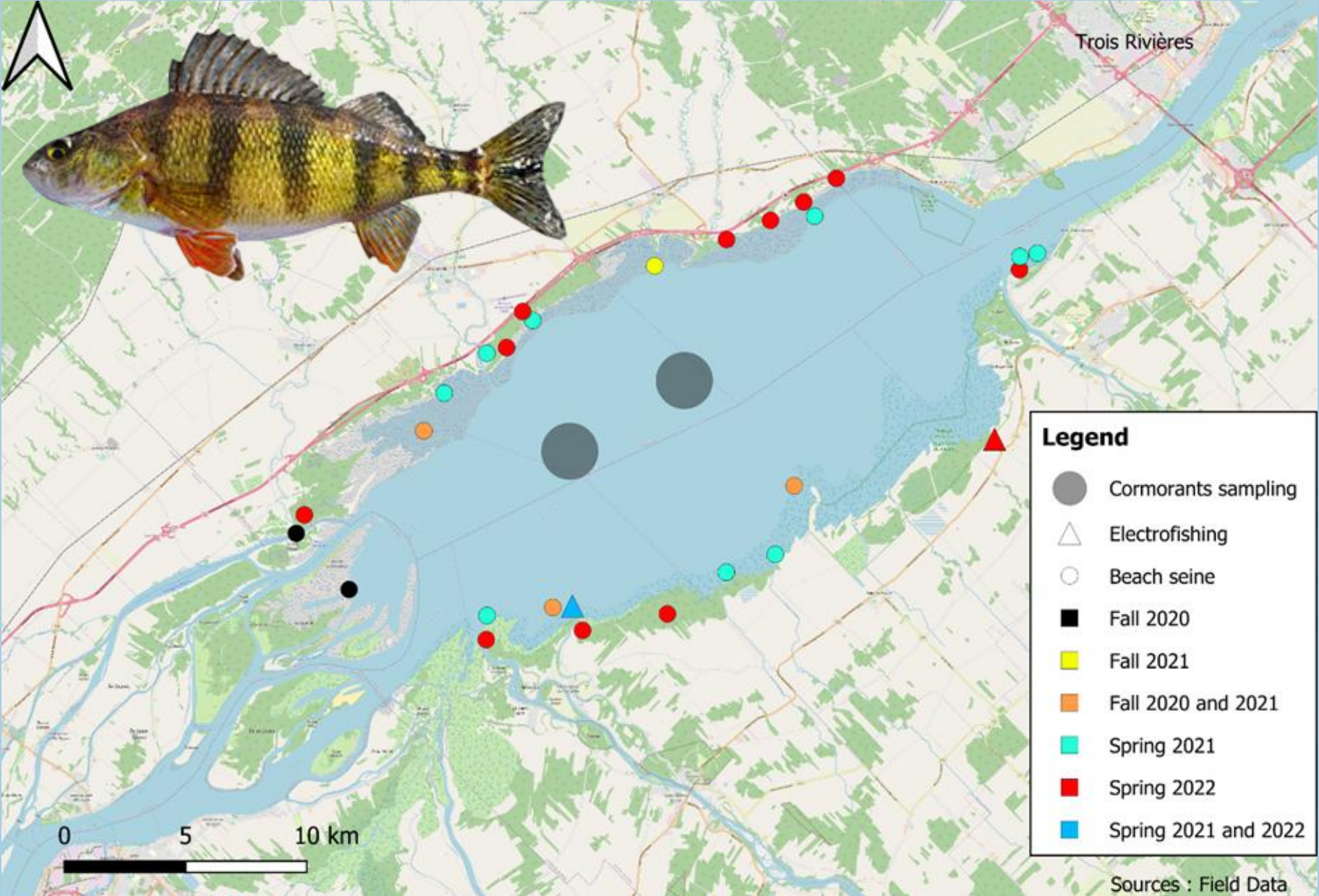
Presentation by Etienne Germain tomorrow at 9:45 AM

# Obtaining earlier life stages to narrow down the Endpoint

- 1-year-old and Young-of-the-year individuals are captured in large numbers as bycatch of a beam-trawl lobster recruitment survey
- From this summer, larvae will be sampled through a dedicated larval survey run in collaboration between university, government and industry.



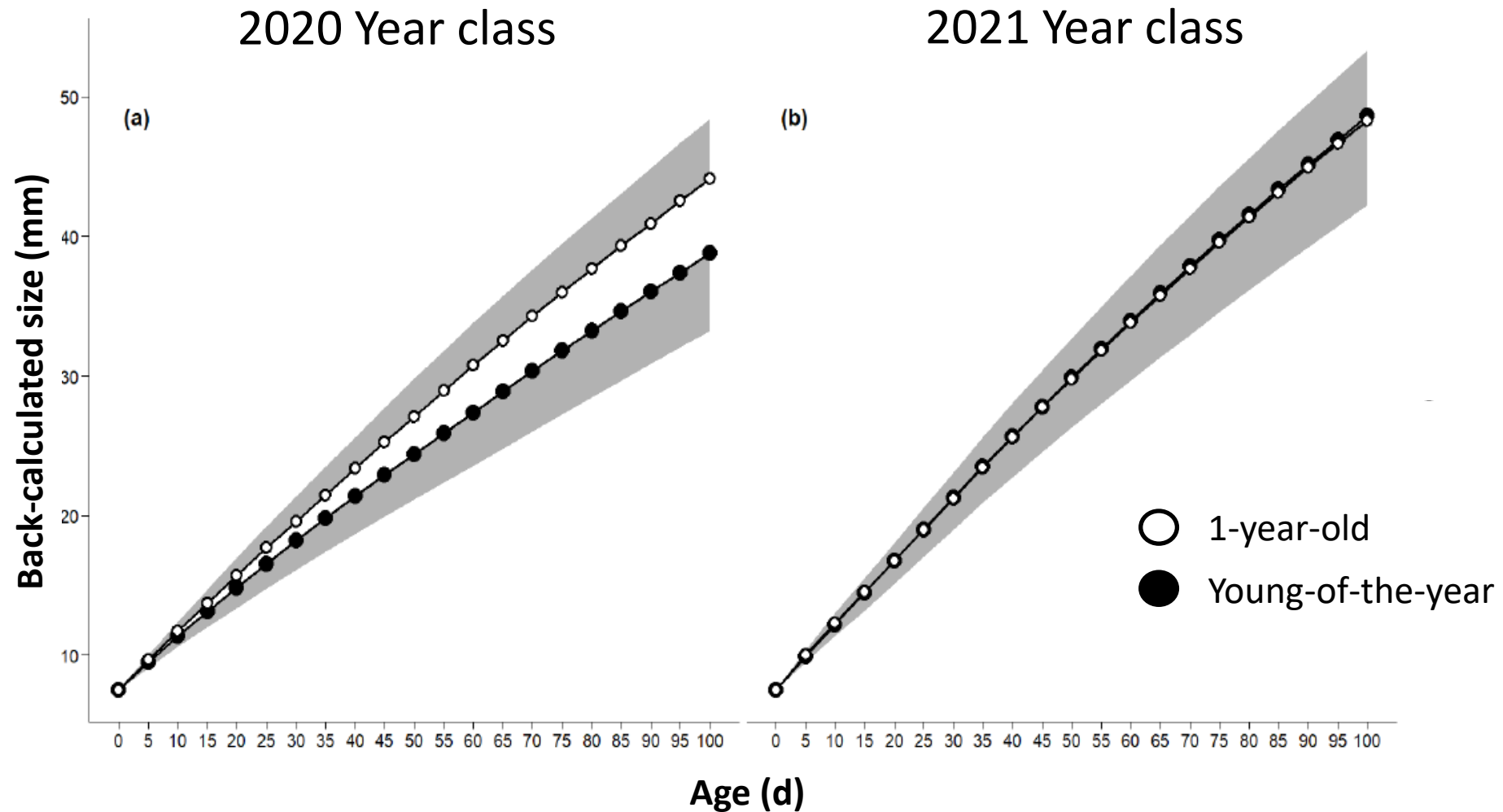
# Yellow perch in lake St. Pierre (Boussion 2025)



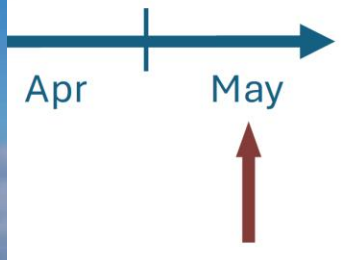
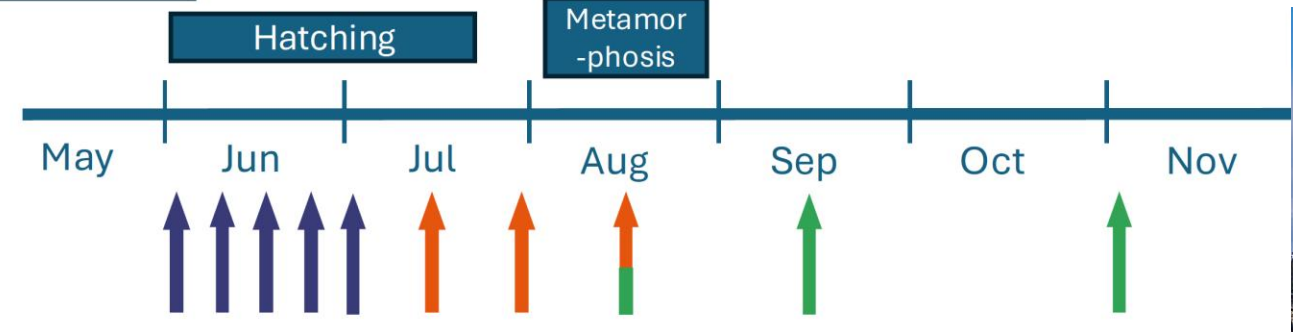
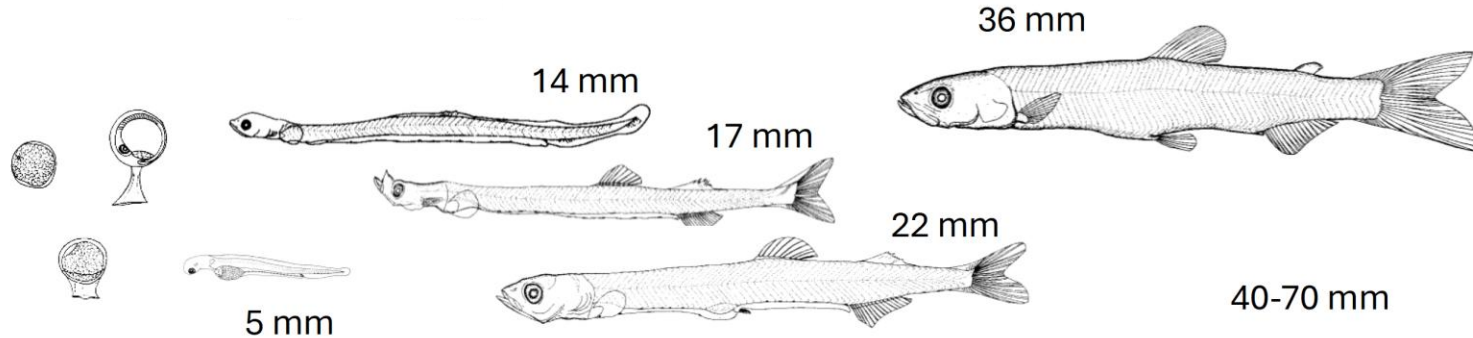
# Yellow perch in lake St. Pierre (Boussion 2025)



# Variable selection for growth during the juvenile stage



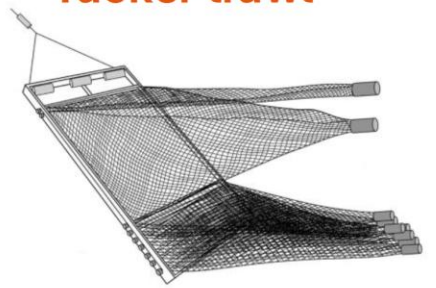
# Towards the precise estimation of the Endpoint: Saguenay Fjord rainbow smelt



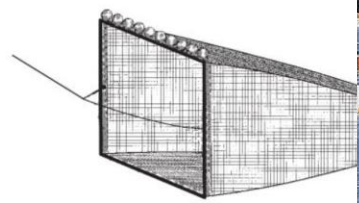
Plankton net



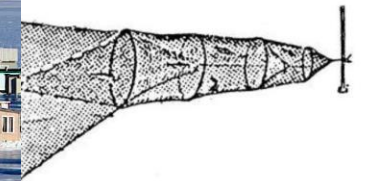
Tucker trawl



Midwater trawl



Fyke net



# A few takeaways

- Larvae of small pelagic fish are fast-growing and characterised by strong growth autocorrelation : initial growth performance is likely more important than the average species to influence year-class strength;
- This trait could make these species particularly sensitive to environmental variations post hatch, as well as maternal effects;
- We should not consider that year-class strength is set after metamorphosis;
- The endpoint at which recruitment is set often extends into the juvenile stage and should be investigated on a population basis.

# Acknowledgements

**Environnement,  
Lutte contre  
les changements  
climatiques,  
Faunes et Parcs**

**Québec** 



*Ressources  
Aquatiques  
Québec* | **RAQ** |



**NSERC  
CRSNG**



**Pêches et Océans  
Canada**



**Sépaq**

**ISMER**   
UQAR