

Testing the growth-mortality hypothesis in the anchoveta (*Engraulis ringens*) in the Humboldt Current system using otolith microstructure analysis



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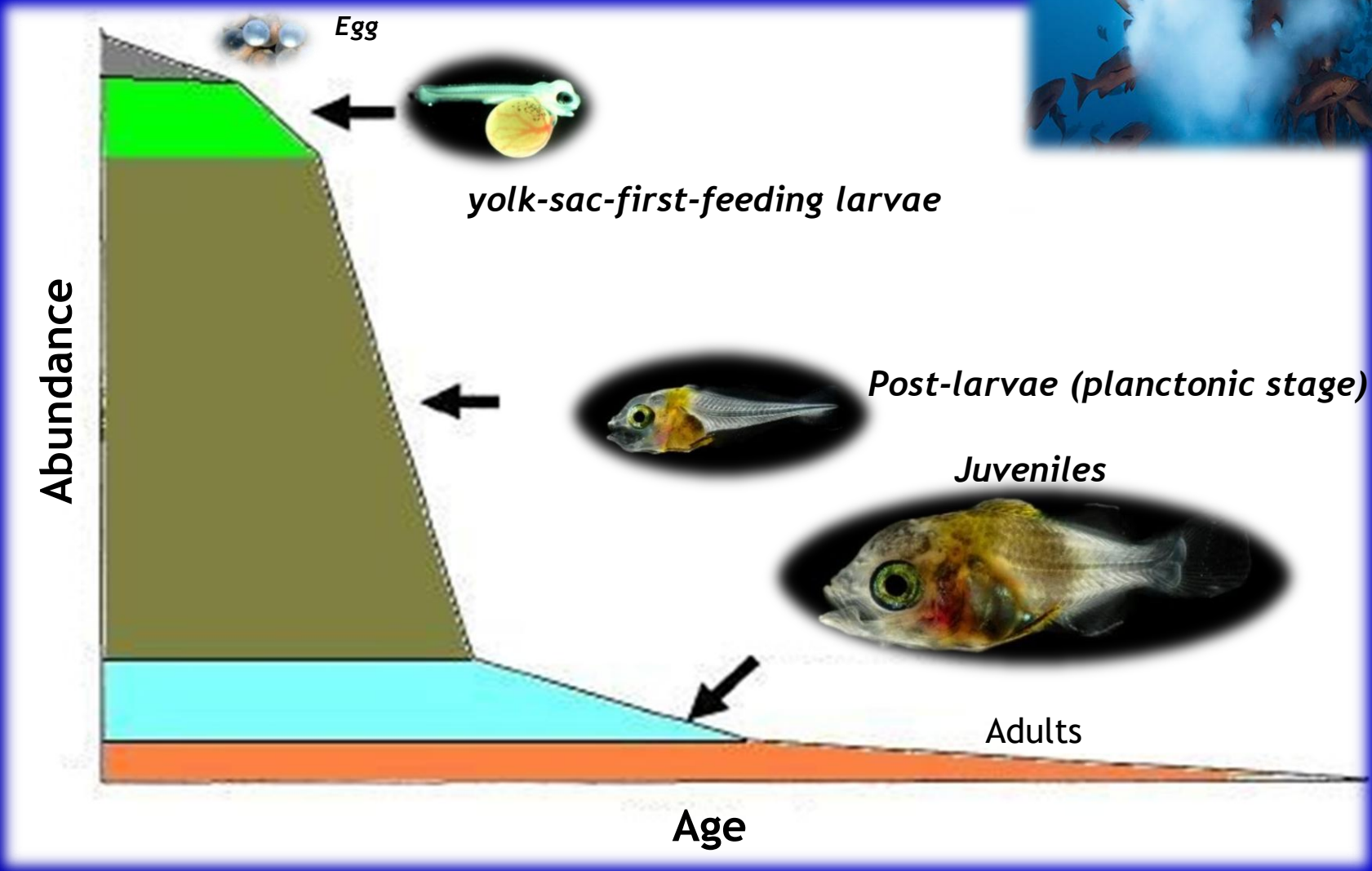
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Survival through the life stages of fishes

Broadcast spawning

Natural Mortality is extremely high (99%)



Hypothesis associated to the early stages of fishes

Critical-Period
(Hjort, 1914)

Match-mismatch
(Cushing 1982)

Stable-Ocean
(Lasker 1975)

Larval-dispersal
(Parrish 1976)

Optimal-window
(Cury & Roy 1989)

**Growth
Mortality**

Anderson 1988)

Environment (main driven force)



Yolk-sac stage

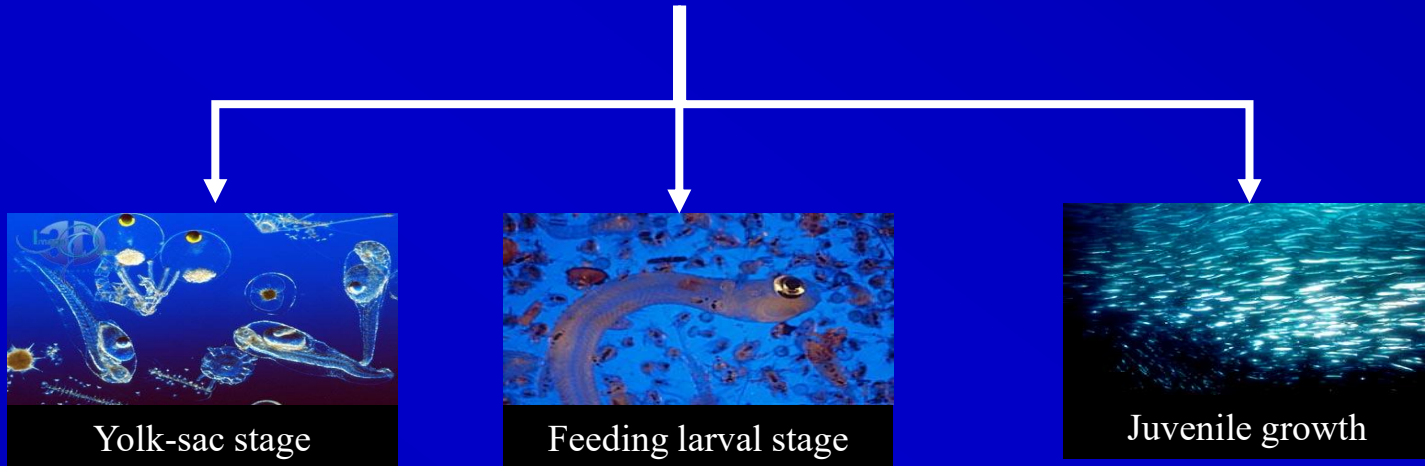


- ❑ Period after absorption of yolk sac is critical for fish survival
- ❑ Larvae that are unable to their first feeding should die due to starvation
- ❑ During this critical period more than 99% of the offspring will die

Growth-mortality hypothesis

(Anderson 1988)

“Larger and/or faster growing individuals are more likely to survive than smaller and/or slower growing conspecifics”



Non-mutually exclusive mechanisms

- ❖ **The bigger-is better** (Miller *et al.* 1988; Legget & DeBlois 1994)
- ❖ **Growth rate** (Miller *et al.* 1988; Legget & DeBlois 1994)
- ❖ **Stage duration** (Chambers and Leggett 1987, Houde 1987)
- ❖ **Growth-selective predation** (Takasuka *et al.* 2003)

Growth-mortality hypothesis

FRAMEWORK: GROWTH SURVIVAL PARADIGM (GPS)

ORIGINAL ARTICLE



WILEY

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

Robert et al (2023)

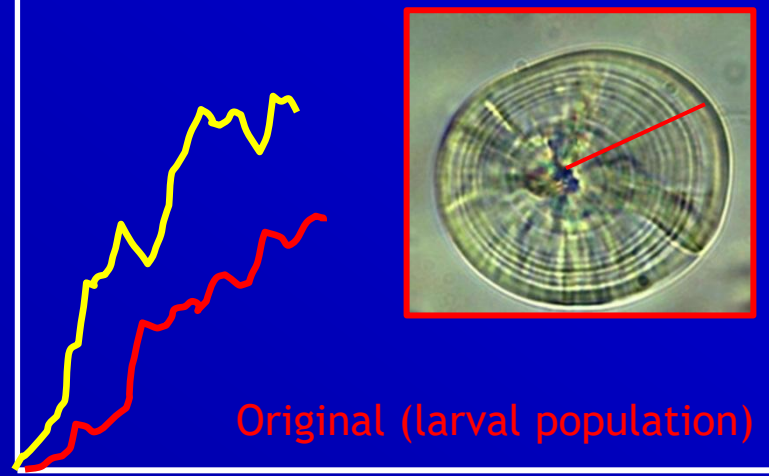
Otolith micro-structure analysis have demonstrated to be is a cost-effective tools to test growth-mortality relationships

Traditional Approach

Sobrevivientes (collected later)



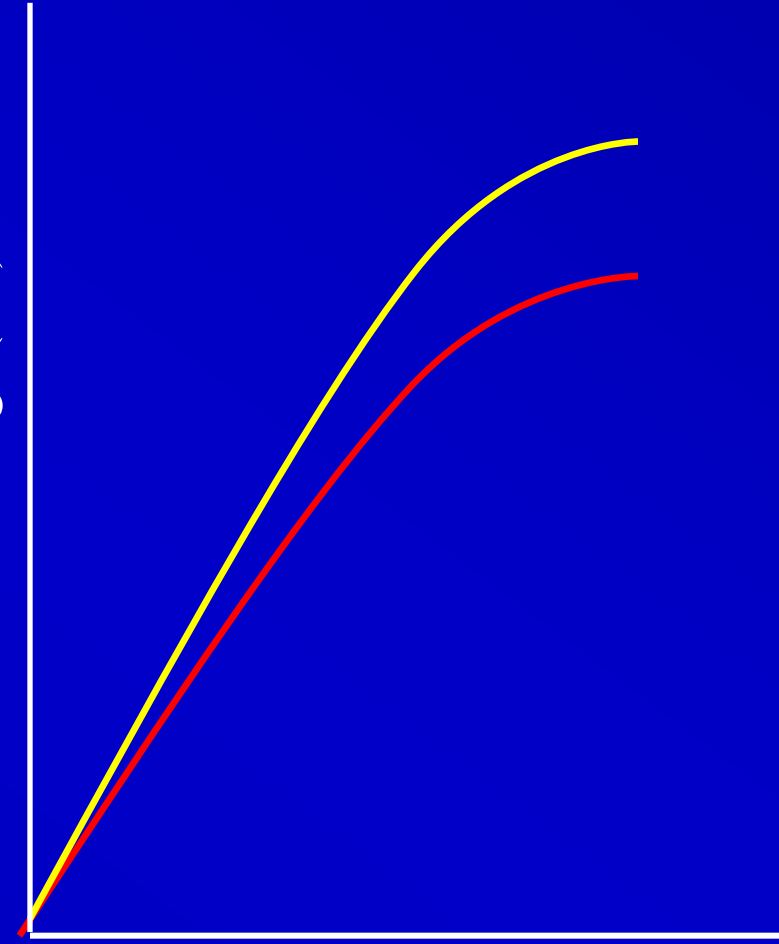
Increment width (um)



Age

B-I-B

Radii-at-age (um)



Age

Hypothesis and objective

Hypothesis

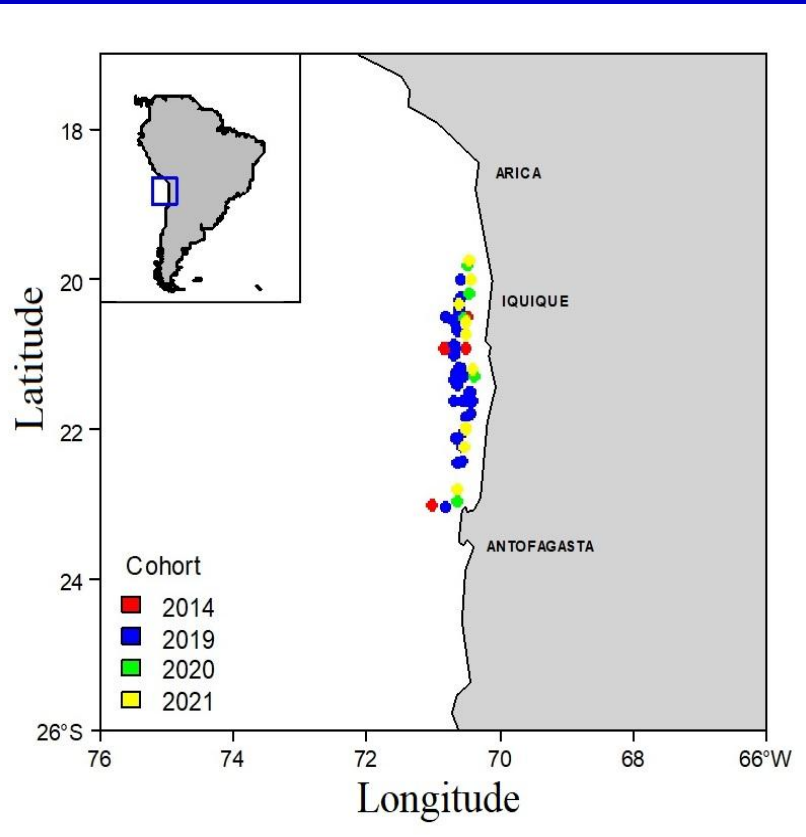
Larger and older survivors of anchoveta were always those that grew faster when they were larvae in the Humboldt Current System in northern Chile

Objective

Test the growth mortality hypothesis in the anchoveta in northern Chile, by comparing the otolith radius and increment width at daily age, between members of the original larval population and survivors

Methods

Study Area in Northern Chile Hydroacoustic surveys (IFOP)

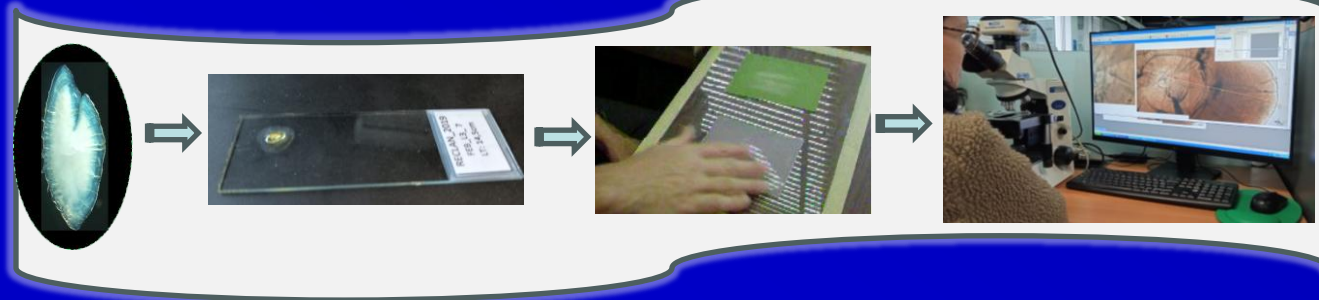


Basic statistics of total length (mm) and number of sagittal otoliths of spring cohorts.

Ontogenetic stage	Length of fish (mm)		Number of otolith by cohort				
	Mean±sd	Range	2014	2019	2020	2021	Total
Larvae	7.3±3.4	2.0-16.3	106	56			162
Pre-recruit	43.4±6.4	30.0-55.0		119	81	52	252
Recruit	96.9±17.2	60.0-120.0	95	98	75	82	350
Total by year			201	273	156	134	764

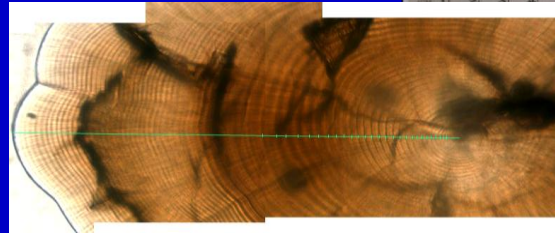
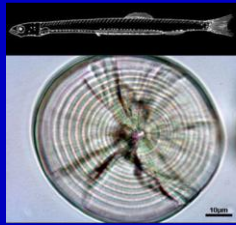
METHODS

Otoliths



Otolith constitutes a permanent record of growth

Original Population



Survivors

Statistical analysis
Linear mixed-effect models

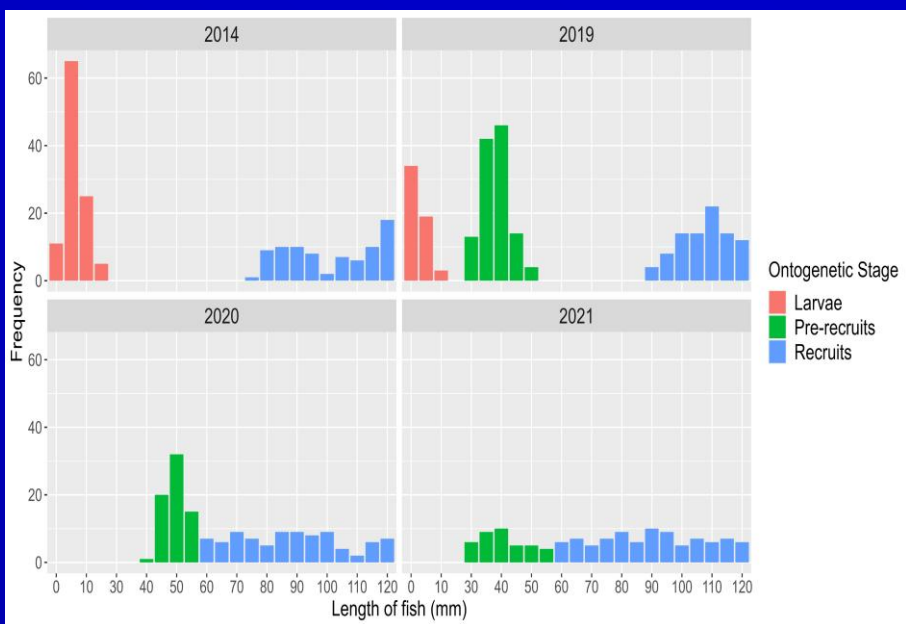
- ❖ Normality
- ❖ Homogeneity of variance

$$\sqrt[4]{RAI_{ijk}} = \alpha_0 + \beta \sqrt{A_{ijk}} OS_{ijk} + (\beta \sqrt{A_{ijk}}) |Y_{ij}/IDfish) + \varepsilon_{ijk}$$

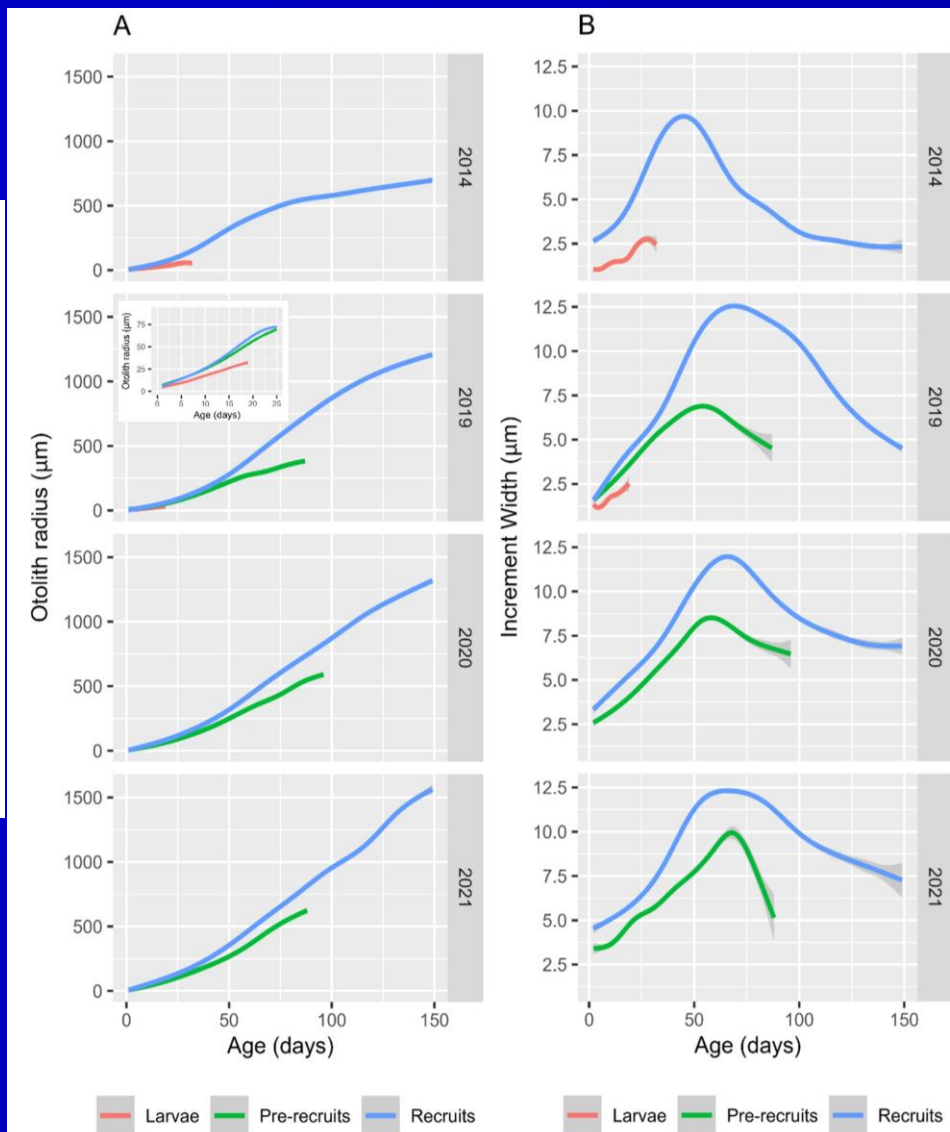
$$\log IW_{ijk} = \alpha_0 + \beta \log(A_{ijk}) * OS_{ijk} + (\beta \log(A_{ijk}) |Y_{ij}/IDfish) + \varepsilon_{ijk}$$

RESULTS

Frequency distribution of TL across cohorts



GAM smoothed profiles of mean otolith radii-at-age (A) and width-at-age (B)



RESULTS

Summary from a Lineal Mixed Effect Model to test for significant differences for radii at-age for the first 20 days of fish life

Random effects:					
Groups	Name	Variance	Std.Dev.	Corr	
IDFish:Year	Intercept	0.01348	0.11608		
	sqrt(age)	0.00216	0.04652	0.51	
Year	Intercept	0.01017	0.10083		
	sqrt(age)	0.00107	0.03263	0.89	
Residual		0.00106	0.03254		
Number of observations: 12,640, groups: ID:Year birth, 735; Year_ birth, 4					
Fixed effects					
	Estimate	Std. Error	df	t value	Pvalue
Intercept	2.37888	0.05080	4.04	46.83	1.11e-06
sqrt(age)	0.41143	0.01651	4.06	24.92	1.37e-05
Pre-recruits	-0.09544	0.01049	724.06	-9.10	< 2e-16
Larvae	-0.34068	0.01328	852.80	-25.65	< 2e-16
sqrt(age)*Pre-recruits	-0.04679	0.00426	662.45	-10.98	< 2e-16
sqrt(age)*Larvae	-0.17220	0.00575	907.35	-29.96	< 2e-16

RESULTS

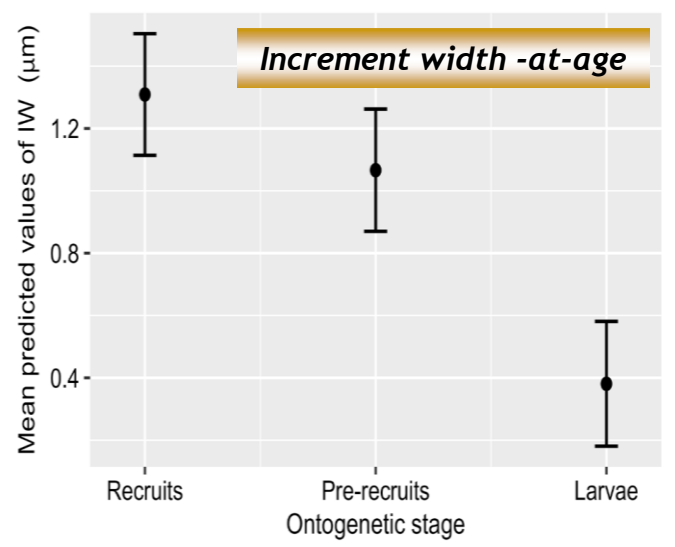
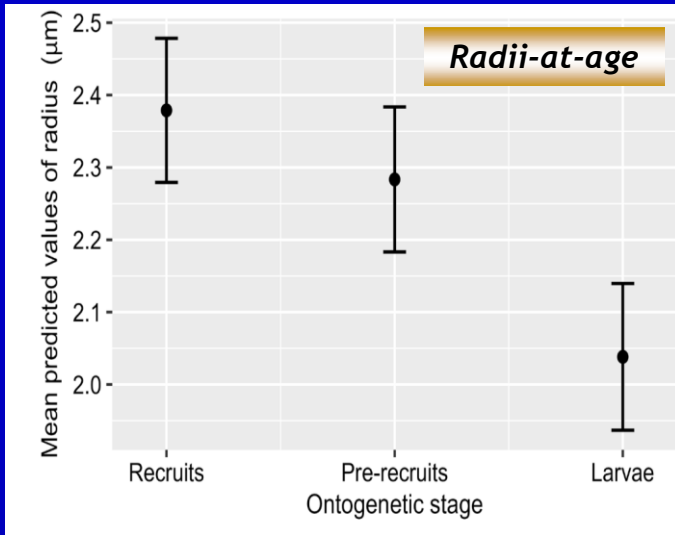
Summary from a Lineal Mixed Effect Model to test for significant differences for increment with-at-age for the first 20 days of fish life

Random effects:				
Groups	Name	Variance	Std.Dev.	Corr
IDFish:Year	Intercept	0.05141	0.2267	
	log(age)	0.01715	0.1310	0.21
Year	Intercept	0.03900	0.1975	
	log(age)	0.00996	0.0998	-1.00
Residual		0.04249	0.2061	

Number of observations: 12,443, groups: ID:Year birth, 733; Year birth, 4

Fixed effects	Estimate	Std. Error	df	t value	Pvalue
Intercept	1.30889	0.09953	4.05	13.15	0.00018
log(age)	0.26820	0.05054	4.08	5.31	0.00574
Pre-recruits	-0.24279	0.02036	693.73	-11.92	< 2e-16
Larvae	-0.92784	0.02885	1.189.20	-32.17	< 2e-16
log(age)*Pre-recruits	0.01163	0.01297	646.96	0.90	0.37008
log(age)*Larvae	-0.25587	0.02062	1.459.03	-12.41	< 2e-16

RESULTS

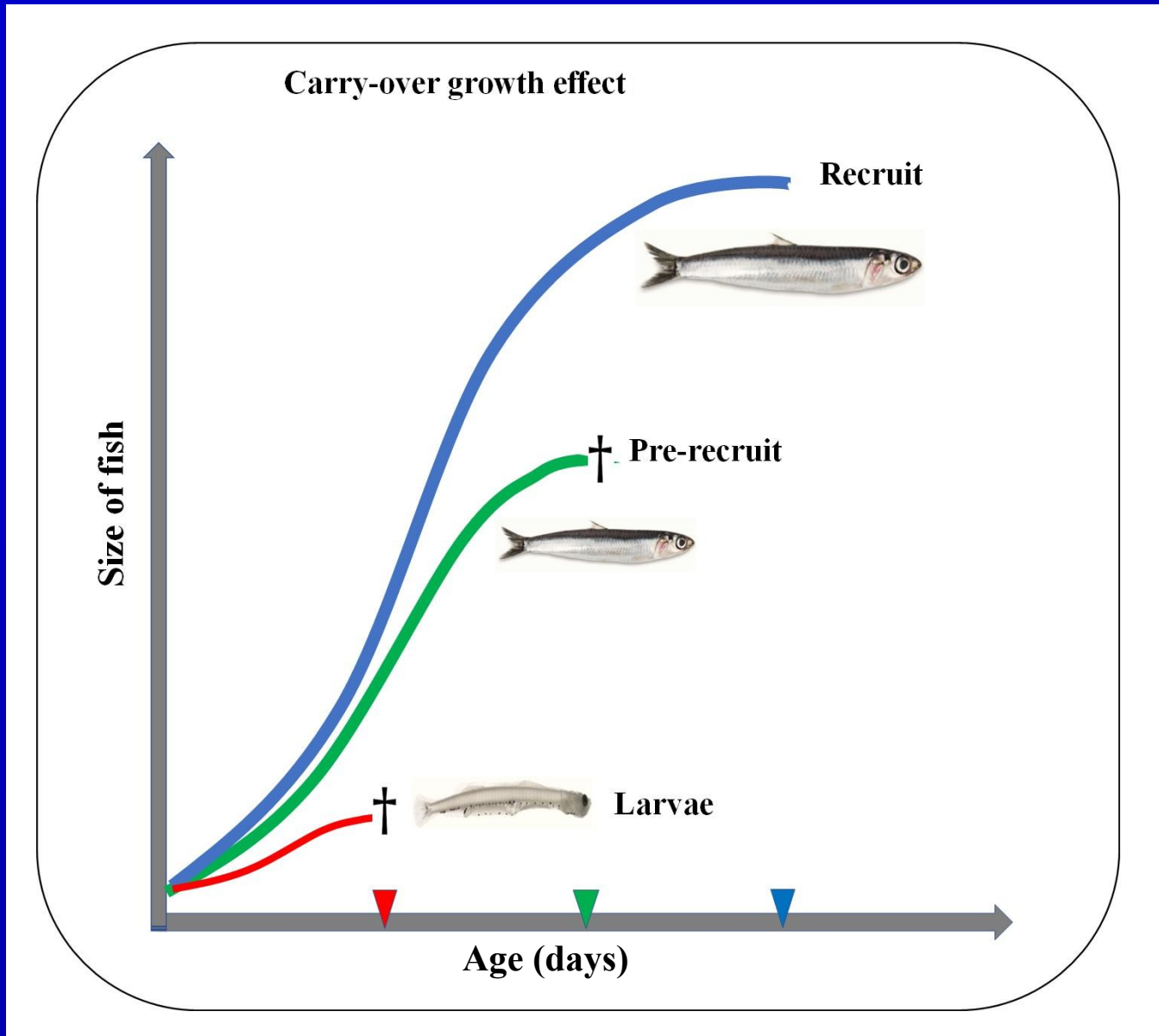


Multiple comparison mean otolith radius and daily increment width from linear mixed-effects model

	Ontogenetic stages	Estimate	Std. Error	z value	Pvalue
Radius	Pre-recruits – Recruits == 0	-0.1792	0,0177	-10.02	<2e-16
	Larvae – Recruits == 0	-1.3139	0,0272	-48.31	<2e-16
	Larvae – Pre-recruits == 0	-1.1367	0,0300	-37.89	<2e-16
Increment Width	Pre-recruits – Recruits == 0	-0.2501	0.0191	-13.08	<2e-16
	Larvae – Recruits == 0	-1.3279	0.0352	-37.68	<2e-16
	Larvae – Pre-recruits == 0	-1.0778	0.0378	-28.49	<2e-16

Conceptual model

Conceptual model illustrating a “carry-over effect” in survivor selection



Conclusions

- ❖ *Results show evidence in favor of the growth-mortality hypothesis for anchoveta, because survivors were always larger and grew faster than members of the original population.*
- ❖ *Late juveniles (recruits) were always larger and grew faster than early juveniles, which could be indicative of the occurrence of a carry-over effect on survival selection.*
- ❖ *These findings become an early evidence that growth-mortality relationship could be a key mechanism to contribute to understand the existence of survival fluctuations of anchoveta in northern Chile*



Thank you!
And now what?

