INSTITUTO DE FOMENTO PESQUERO

Environmental Forcing and Phenological Shifts in the Spawning Dynamics of Anchoveta *(Engraulis ringens)* in Northern Chile

PhD in marine sciences and applied biology

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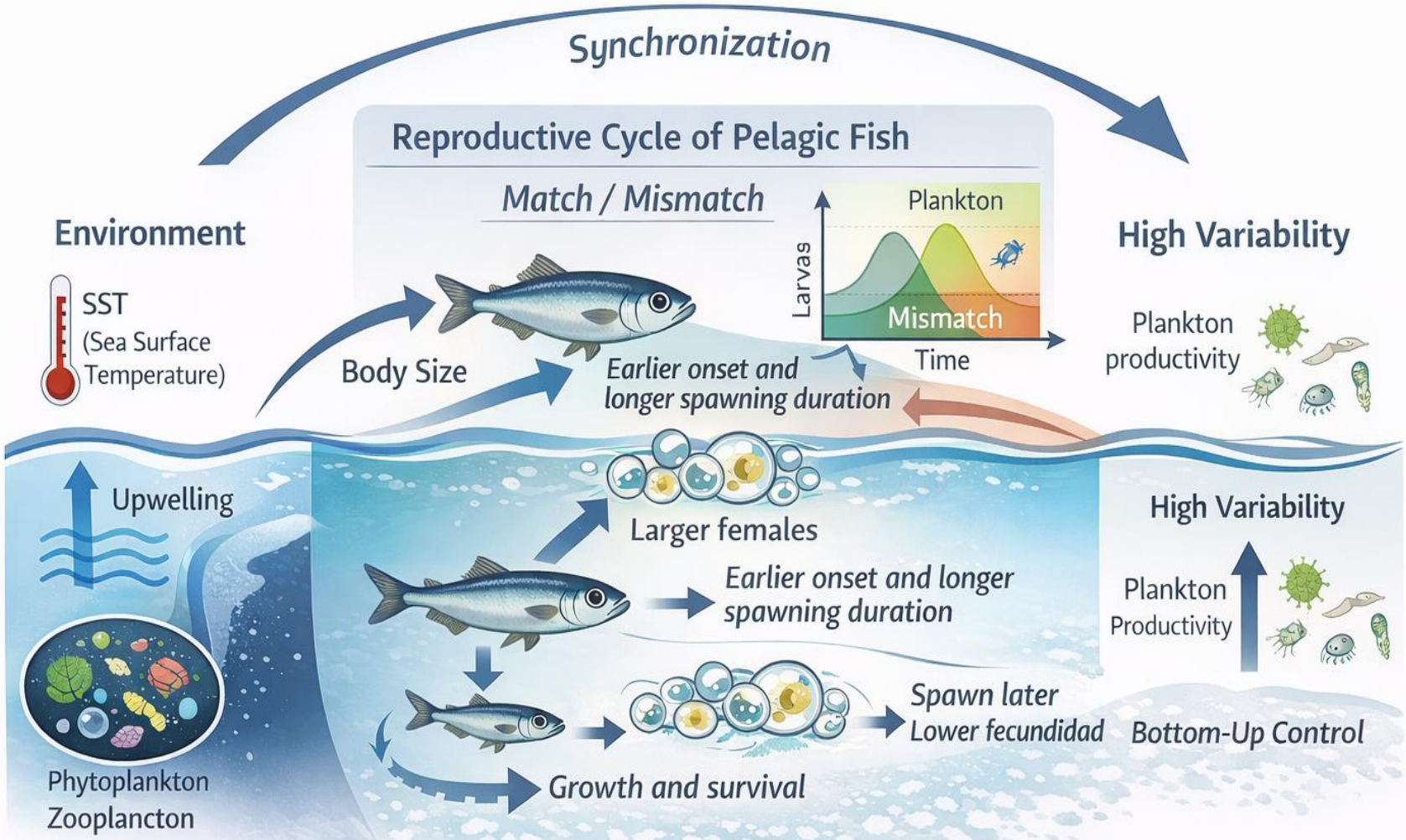

Synchronization
Reproductive Cycle of Pelagic Fish
Match / Mismatch
Environment
SST
(Sea Surface Temperature)
Body Size
Plankton
Larvas
Mismatch
Time
High Variability
Plankton productivity
Earlier onset and longer spawning duration
Upwelling
Larger females
Earlier onset and longer spawning duration
High Variability
Plankton Productivity
Spawn later
Lower fecundidad
Bottom-Up Control
Growth and survival
Phytoplankton
Zooplancton

Background

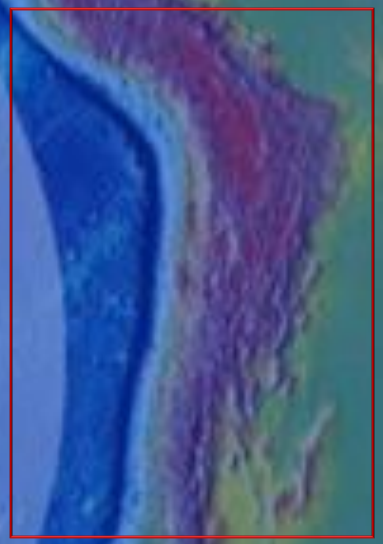
- **Case study: Anchovy (*Engraulis ringens*)**
- Humboldt Current System
- Main peak: winter–spring
- Evidence of a second peak in summer
- Period: 1997–2022
- Data source: IFOP monitoring program (industrial purse seine fleet)

Knowledge gap

Studies focused on the main peak

- Limited understanding of: Recurrence of the secondary peak
- Environmental forcing factors
- Role of size structure

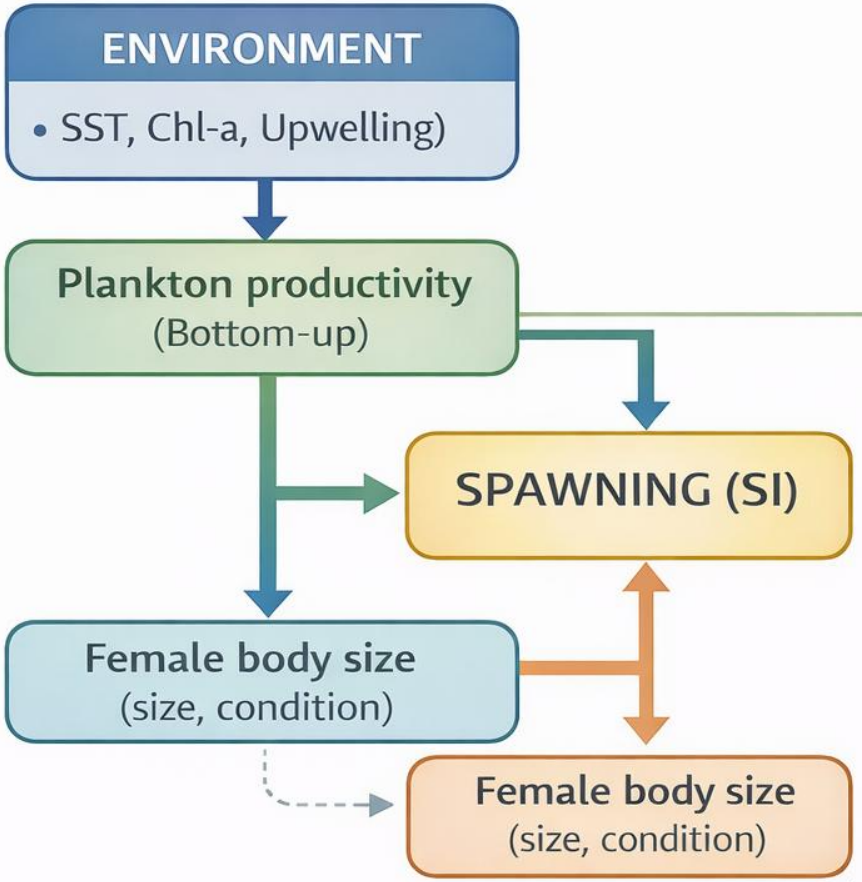
Study system



Hypothesis

We hypothesize that local environmental conditions influence the reproductive phenology anchovy, generating variable phenotypic patterns across years.

How was it analyzed?



Data analysis

Time series analysis (BFAST)

Trend, seasonality, breakpoints

Comparison across periods:

Pre/post size-structure shifts

Modeling approach

GAMs (mgcv, R)

Response: **Spawning activity (SI)**

Predictors:

SST, Chl-a

TK, PK, SEI

Female size & condition

Seasonal + interannual structure

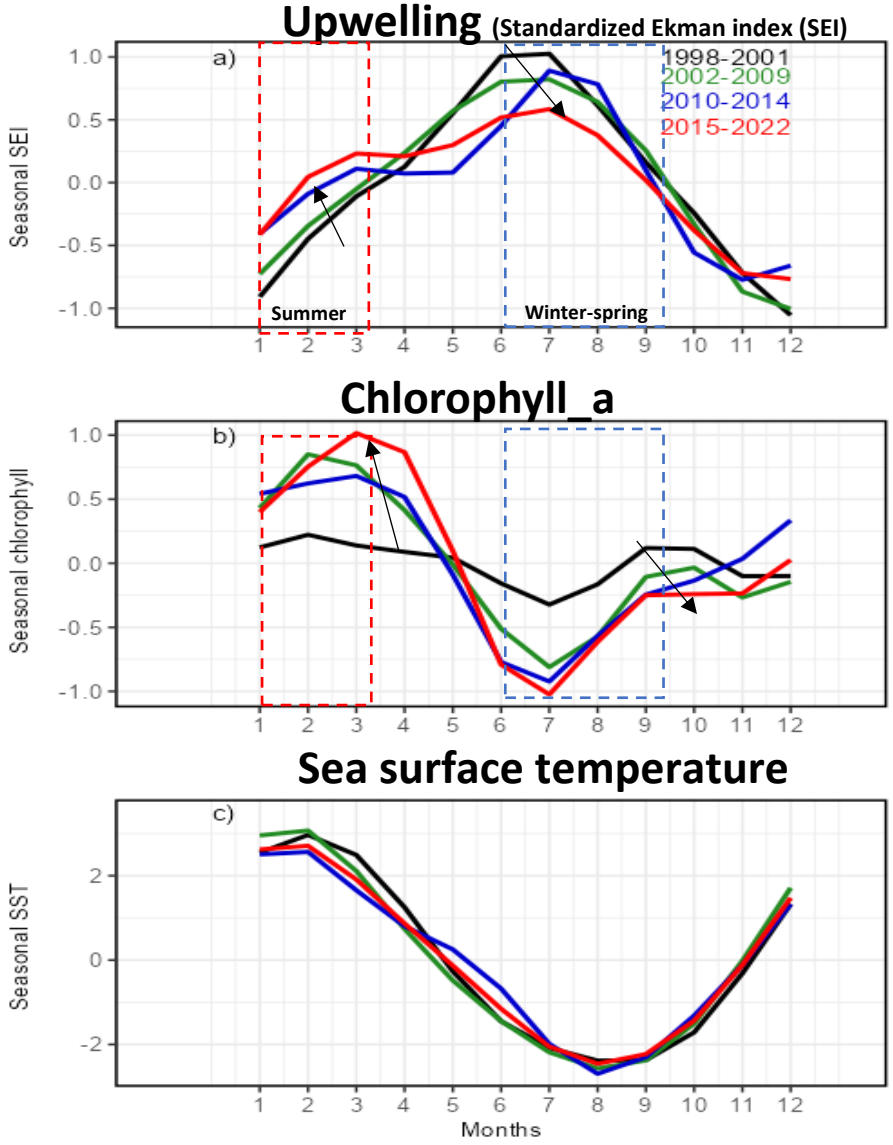
Model selection:

AIC + residual diagnostics

(i) Interannual and seasonal changes in fertilization levels

- Four environmental periods were identified.
- Decreased upwelling and chlorophyll levels in winter since the late 1990s.
- Evidence of a change in fertilization regime:
  - ❖ ↓ productivity in winter-spring
  - ❖ ↑ productivity in summer
- Relative increase in summer.
- Weak temperature changes, with slight cooling in recent summers.

Seasonality by periods



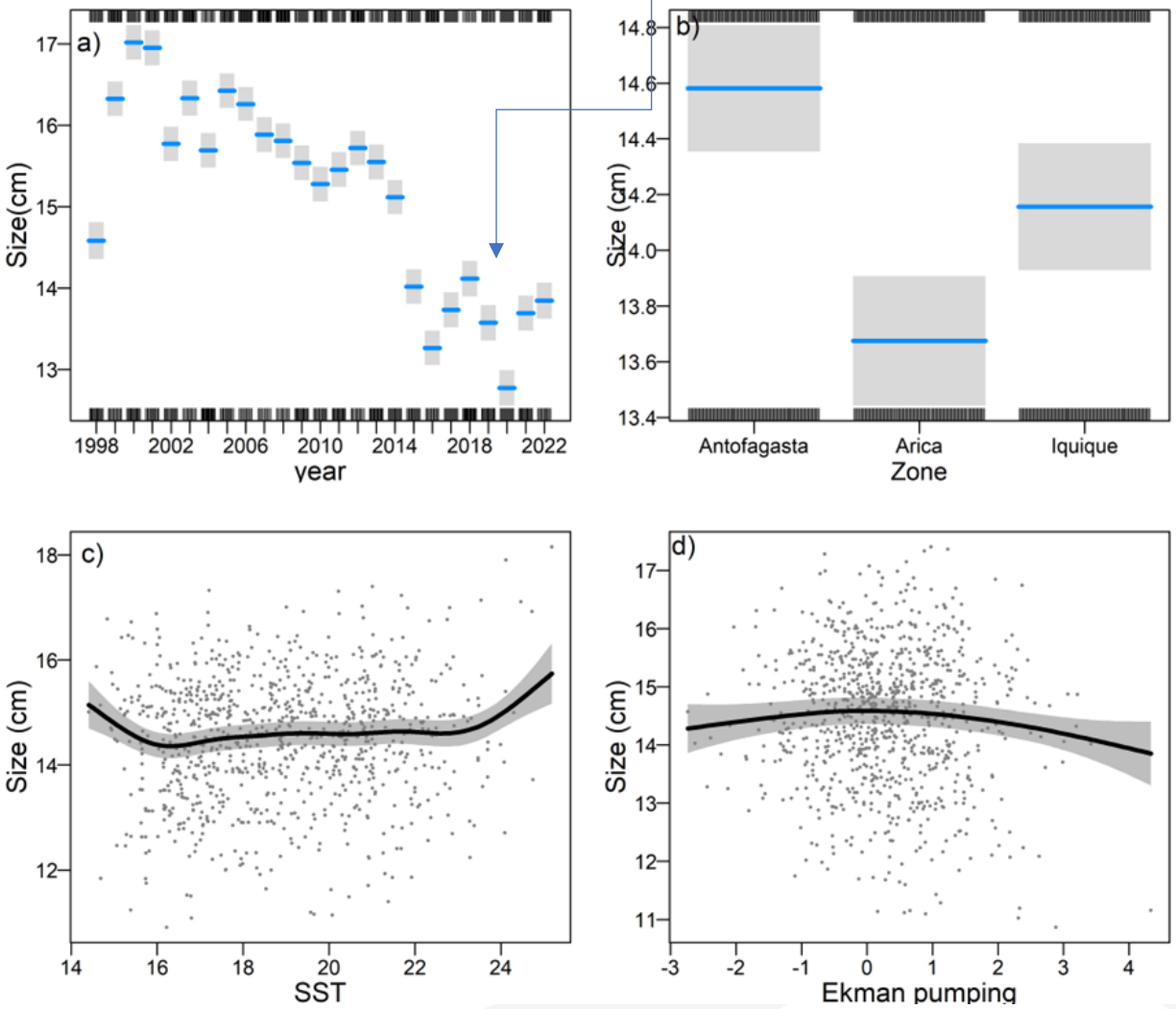
(ii) Decrease in anchovy size (1989–2024)

Progressive decline since 2002 with lower values after 2015

GAM Model

- Explanatory variables:
- Year
- Fishing zone
- Ekman pumping
- Sea surface temperature

Explain 70% of the variability.



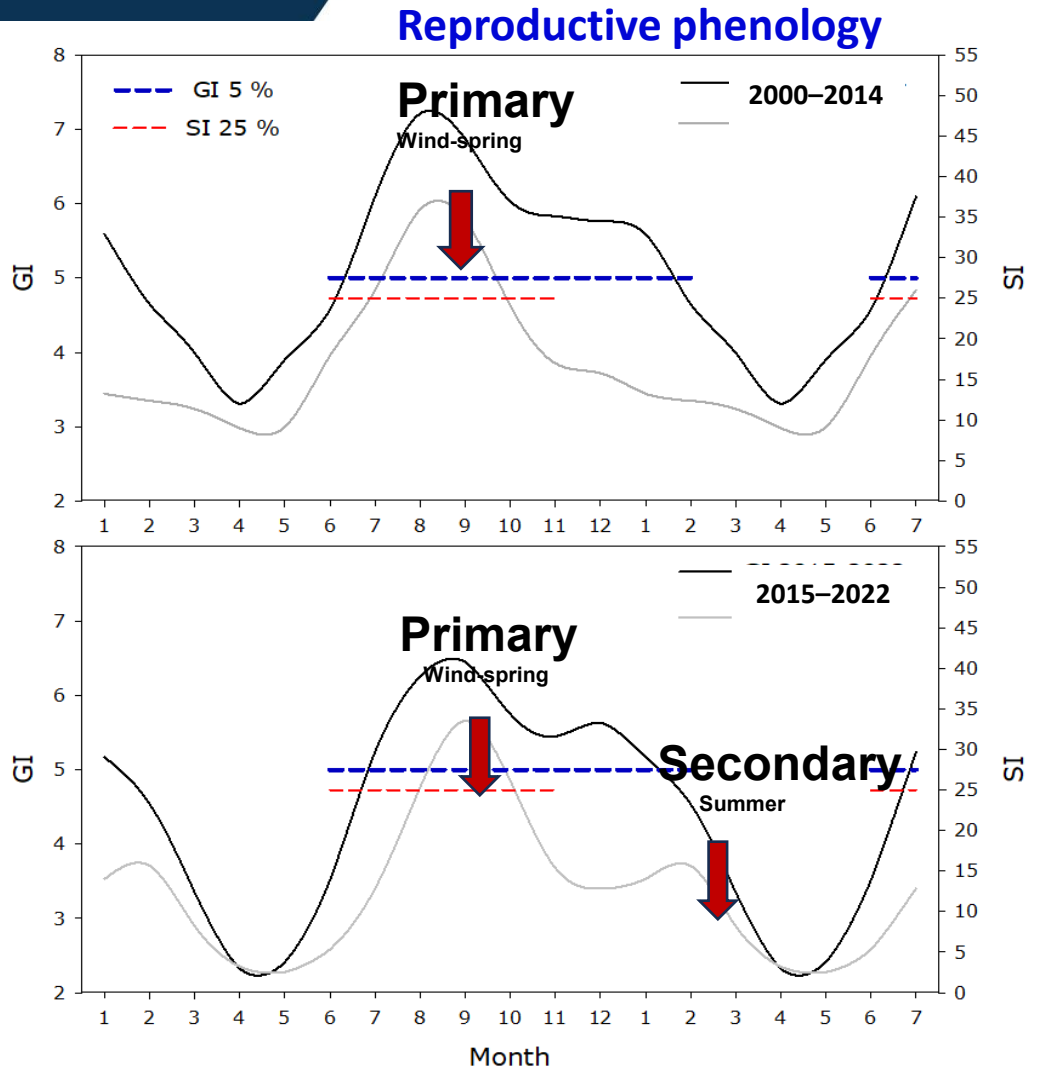
(iii) Transition from one spawning peak (winter-spring) to two peaks (winter-spring and summer)

Periods defined according to changes in size structure.

2000–2014:

A single breeding peak in winter–spring (Jul–Oct).

2015–2022:
Bimodal pattern
Primary: winter–spring
Secondary: summer (Jan–Feb)



Monthly variation of historical series GI and SI. Black and blue boxes indicate extension of the reproductive period and of greate spawning, according to GI and SI criteria, respectively.

(iv) Spawning controllers

Spawning activity (SI)

Mainly explained by:

- ❖ The model explained 52% of total variability.
- Season (50%)
- Temperature (28%)
- Period (17%)
- SEI (6%)

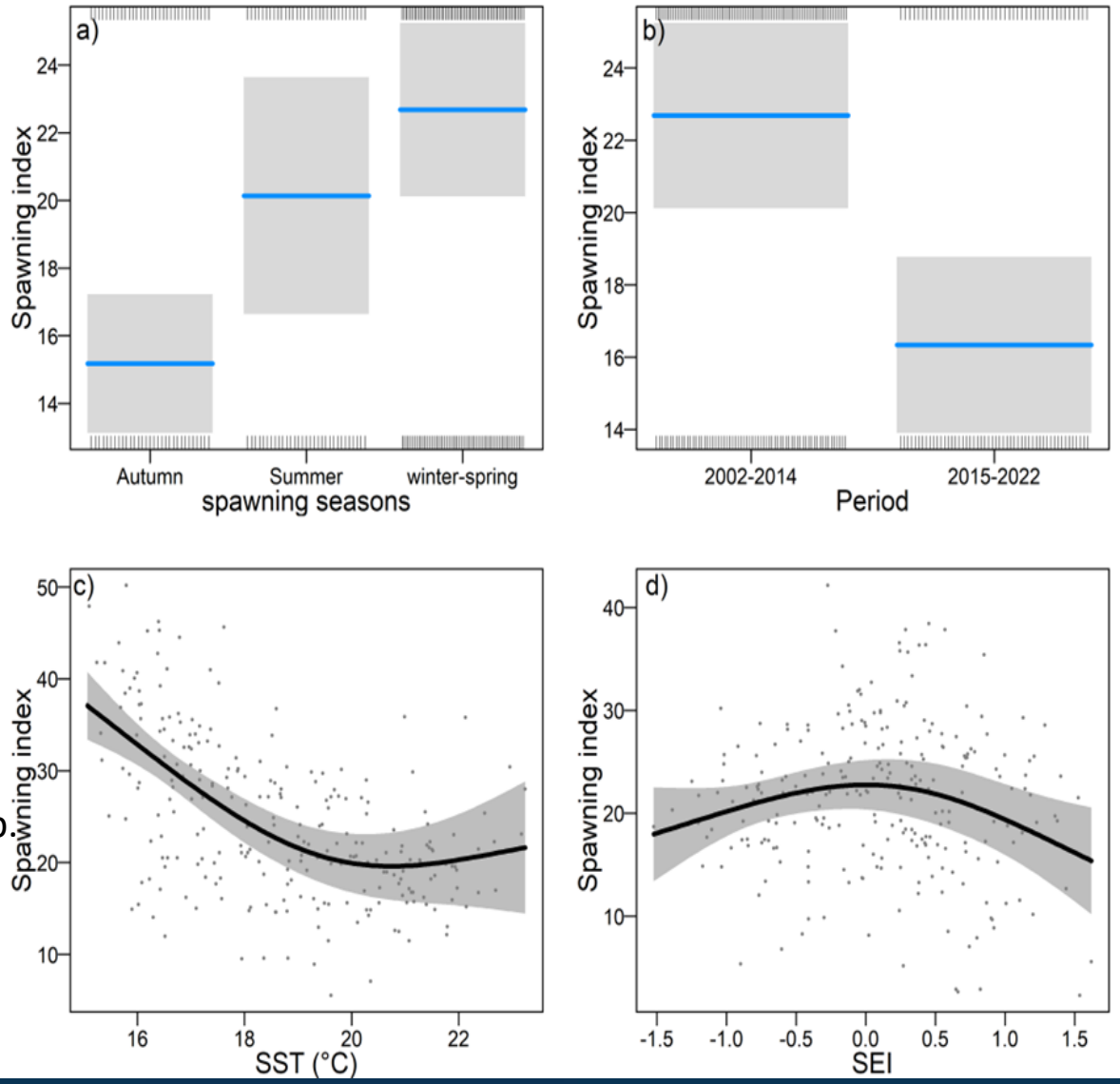
- ❖ Greater spawning occurs during winter-spring and summer.
- ❖ Significant decrease was observed between 2015 and 2022.

Environmental relations

- SST: nonlinear negative relationship.
- SEI: Weak but nonlinear effect

GAM

$$SI = \beta 0 + \beta 1 * Season + \beta 2 * Year + S1(SSTti) + S2(chl\_ati) + S3(TK\_ati) + S4(PK\_ati) + S5(Wg\_ati) + S6(Sz\_ati) + S7(Kn\_ati) + \varepsilon\_i$$



Implications & hypotheses

❓ KEY QUESTION

🐟 🥚 🥚 How do two spawning peaks coexist?

Population structure?
One unit vs 🌐 Metapopulation

🔬 HYPOTHESES

🧠 Adaptive strategy
(risk spreading)
🌐 Metapopulation structure

🌍 BROADER CONTEXT
📉 Global size decline
in pelagic species

⚙️ POTENTIAL DRIVERS
🌊 Environment
🎣 Fishing
🌀 Upwelling changes

CONCLUSIONS

🌊🌀 **Change in the environmental** → **modulates the reproduction**

↓

📅 **Phenological change** → **bimodality of spawning**

↓

📉🐟📏 ↓ reproductive intensity + ↓ body size

↓

Greater population vulnerability

- 🔹 **Implications**
- Need for:
- 🌎 Ecosystem approach
- 🛑 Precautionary measures
- 🐟🛡️ Protection of breeding stock

Take-home message

Anchovy reproductive dynamics are shifting and changing environment.

Key points

- Environmental changes → **alter fertilization regime**
- Spawning phenology → **unimodal → bimodal**
- Reduced spawning intensity → **main season**
- Declining body size → **increased vulnerability**

Implication

Need for precautionary, ecosystem-based management

Thank you