Navigating Changes in Small Pelagic Fish and Forage Communities: Climate, Ecosystems, and Sustainable Fisheries
May 4 – 8, 2026 | La Paz, Mexico

W7: Operationalizing Ecosystem-Based Management of Forage Species using Management Strategy Evaluation

From Climate Forcing to Fisheries Management:
Integrating Environmental Variability into MSE Frameworks

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FISH and FISHERIES

Management strategy evaluation: best practices

André E Punt[1,2], *Doug S Butterworth*[3], *Carryn L de Moor*[3], *José A A De Oliveira*[4] & *Malcolm Haddon*[2]

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- Test each plausible source of uncertainty, unless there is clear evidence it is irrelevant.
- Consider spatial structure, multiple stocks, predator–prey interactions and environmental drivers.
- Environmental effects can often be explored **by imposing trends on operating-model parameters**.

FISH and FISHERIES

Management strategy evaluation: best practices

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Selection of uncertainties (Punt et al. 2014)

1. By representing the effects of environmental variability as trends or variation in operating-model parameters, the environment is treated implicitly rather than as an explicit driver.

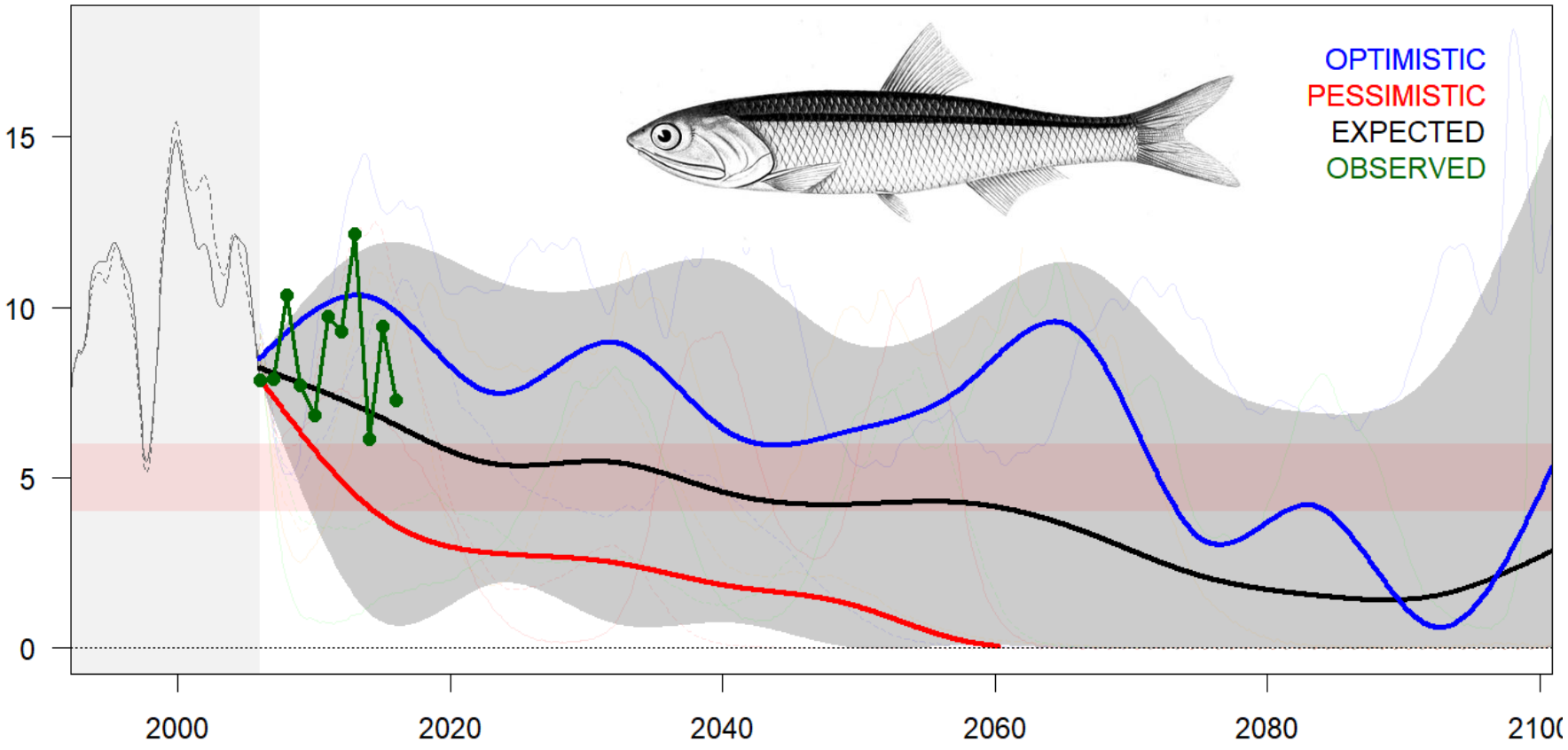
- Environmental effects can often be explored **by imposing trends on operating-model parameters**.

2. However, many applications require explicit environmental forcing, because the source, timing, persistence and predictability of environmental variability can affect both stock projections and the performance of harvest strategies.

Climate Change

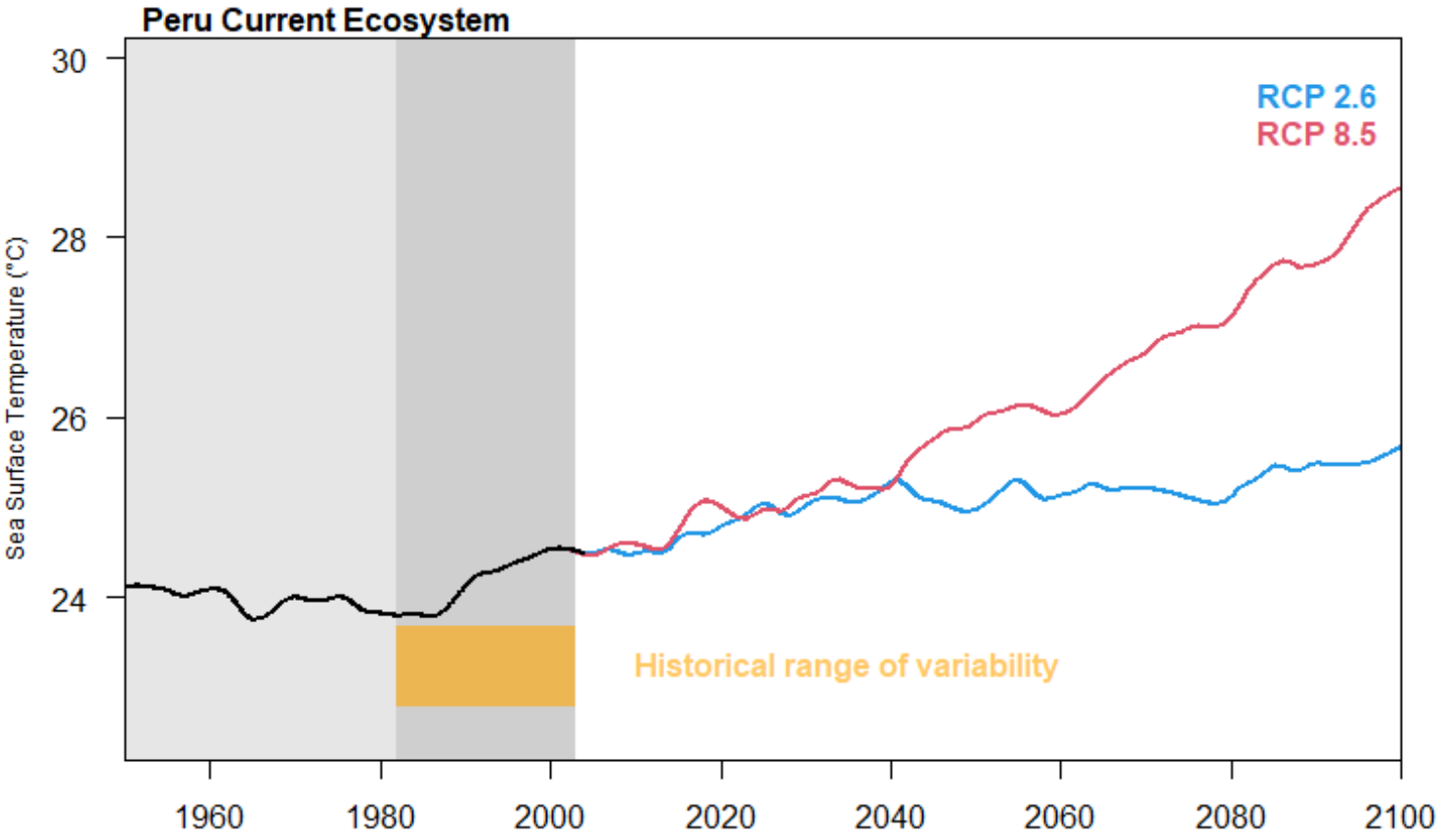
- This has become increasingly more important globally: as climate change affects fish populations and fisheries, management needs more reliable stock projections and harvest strategies that remain robust under shifting production regimes and environmental extremes.
- Long-term scenarios of changes in drivers and their ecosystem impacts

Anchovy biomass (M tons)

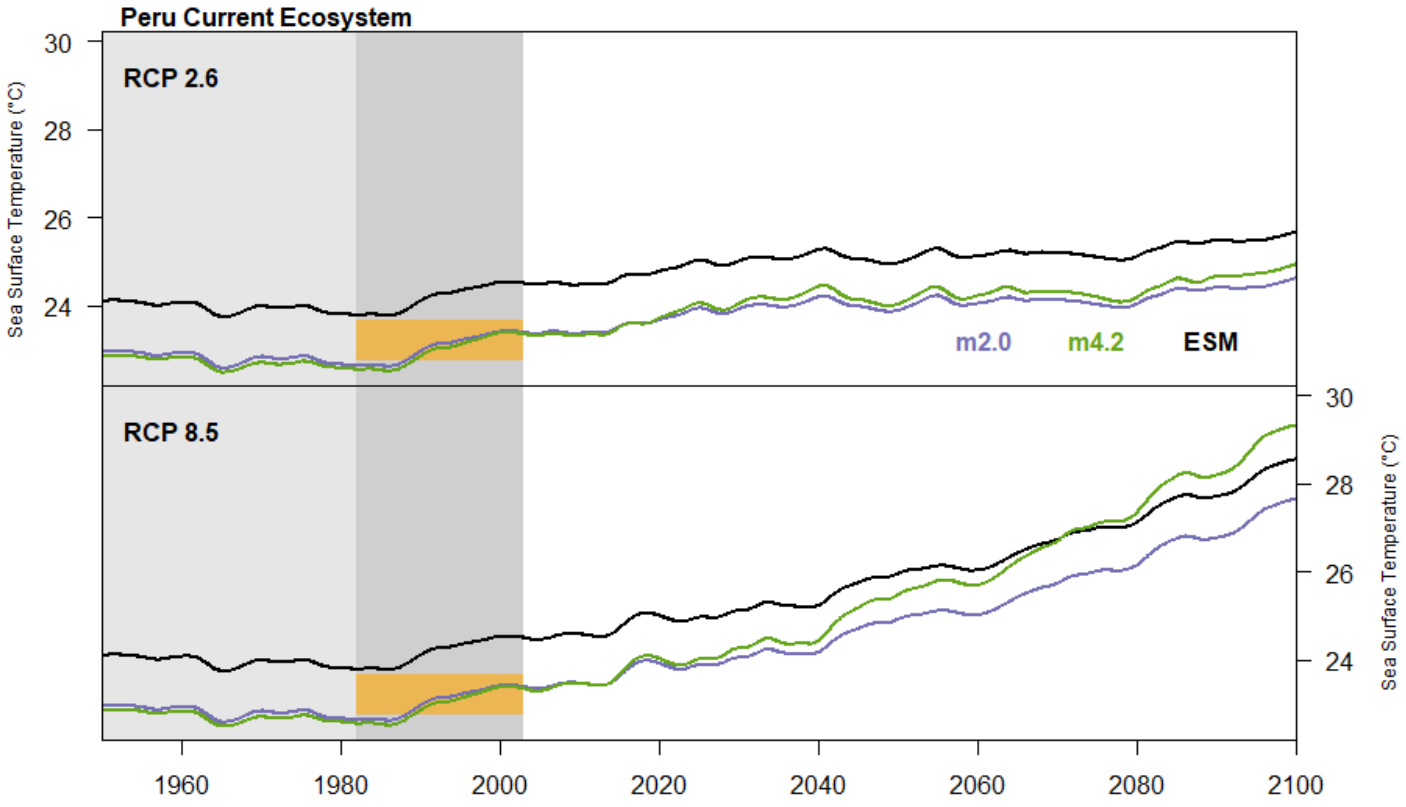


Biomass Limit Reference Point

Oliveros-Ramos et al. 2018


Peru Current Ecosystem
Sea Surface Temperature (°C)
30
28
26
24
1960
1980
2000
2020
2040
2060
2080
2100
RCP 2.6
RCP 8.5
Historical range of variability

Statistical downscaling and bias-correction



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Original Article

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Multi-model approach for statistical downscaling and bias correction of Earth system model outputs for marine ecosystem impact applications

Ricardo Oliveros-Ramos [1,2,*], Yunne-Jai Shin [1], Dimitri Gutierrez [2], Verena M. Trenkel [3]

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[2]Instituto del Mar del Perú (IMARPE), Callao 07021, Perú
[3]DECOD, IFREMER, INRAE, Institut Agro, Agrocampus Ouest, Nantes, France
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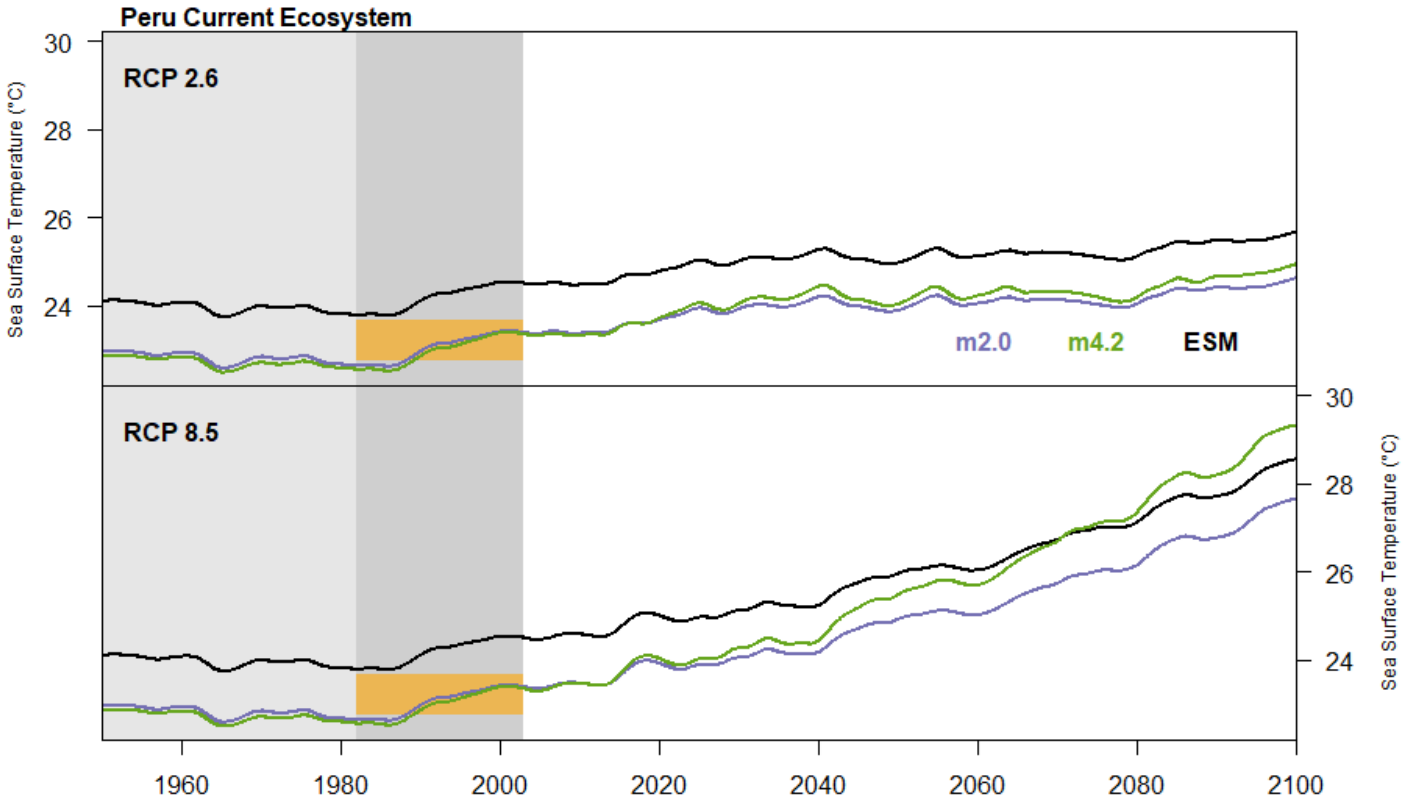
Abstract

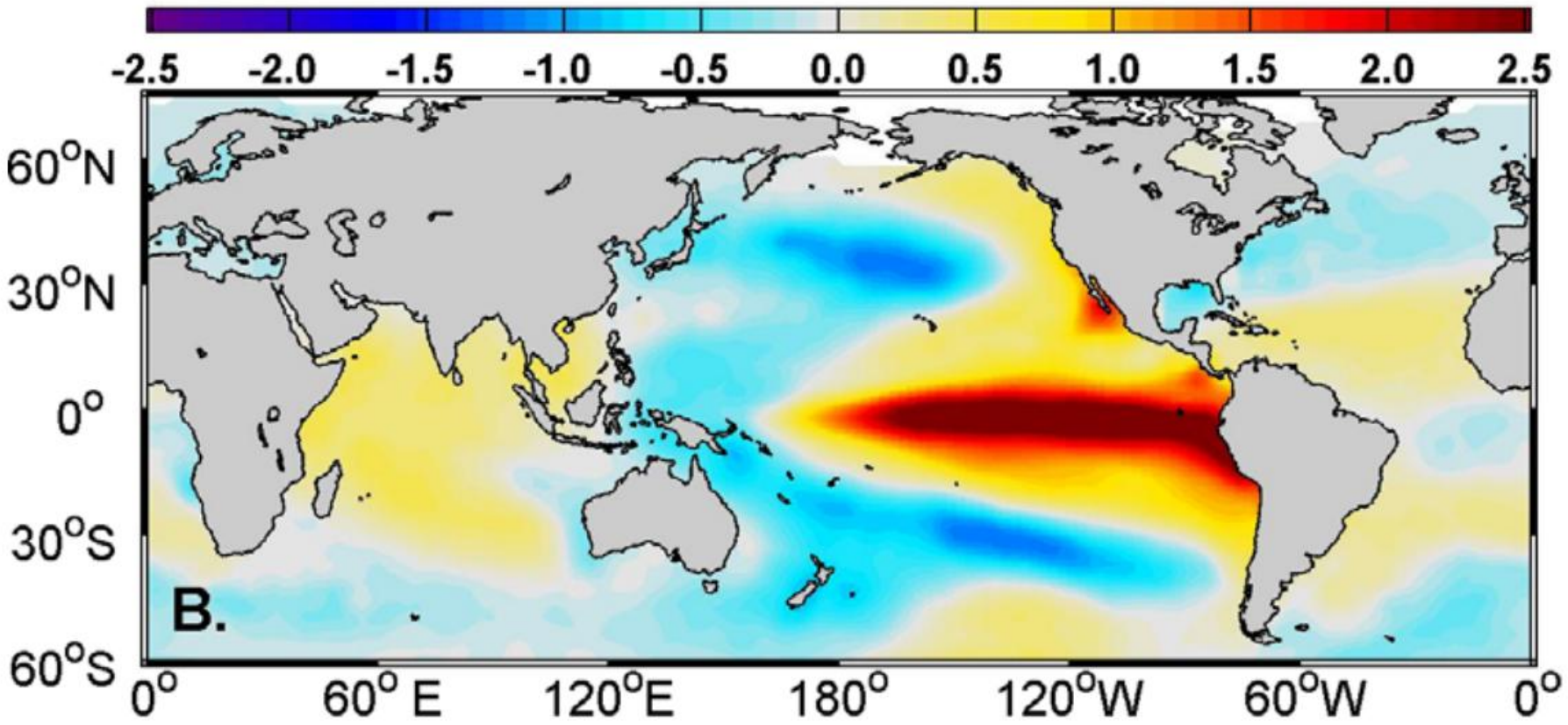
Earth system models (ESMs) are the main tool for understanding the impacts of global change and are regularly updated to provide more reliable scenarios of the future. However, their confrontation with observations reveals biases that need to be corrected, especially for impact applications where the absolute scale of the environmental variable is relevant. In addition, marine regional impact studies require fine-scale projections for strategic planning and management actions. Statistical downscaling provides a fast way to produce regional forcings from ESMs and can additionally produce bias-corrected outputs necessary for marine impact applications driven by or fitted to observed data. Statistical downscaling can use different parametric distributions depending on the variables used, and generalised regression can provide a flexible approach for this purpose. We propose a multi-model approach based on non-parametric generalised regression and a set of indicators to select a robust statistical downscaling model that can be used to project future scenarios for marine ecosystems. The empirical cumulative distribution of the variables to be downscaled is modelled, ensuring that not only the mean but also the variance and quantiles (including minima and maxima) are properly represented, improving the prediction of extreme events and taking into account spatial autocorrelation. We incorporated future bias indicators alongside traditional evaluation metrics for model selection to identify and mitigate potential extrapolation errors in future scenario projections, ensuring more robust and plausible downscaled climate outputs. The approach presented here is applied to two contrasted regional case studies, the Bay of Biscay-Celtic Sea ecosystem and the Northern Peru Current ecosystem, using sea surface temperature from the IPSL-CM5A-LR ESM. The results show that a multi-model selection approach is appropriate, as individual model performance is case-specific.

Keywords: statistical downscaling; bias correction; regional climate impacts; climate change; marine impact assessment

Statistical downscaling and bias-correction

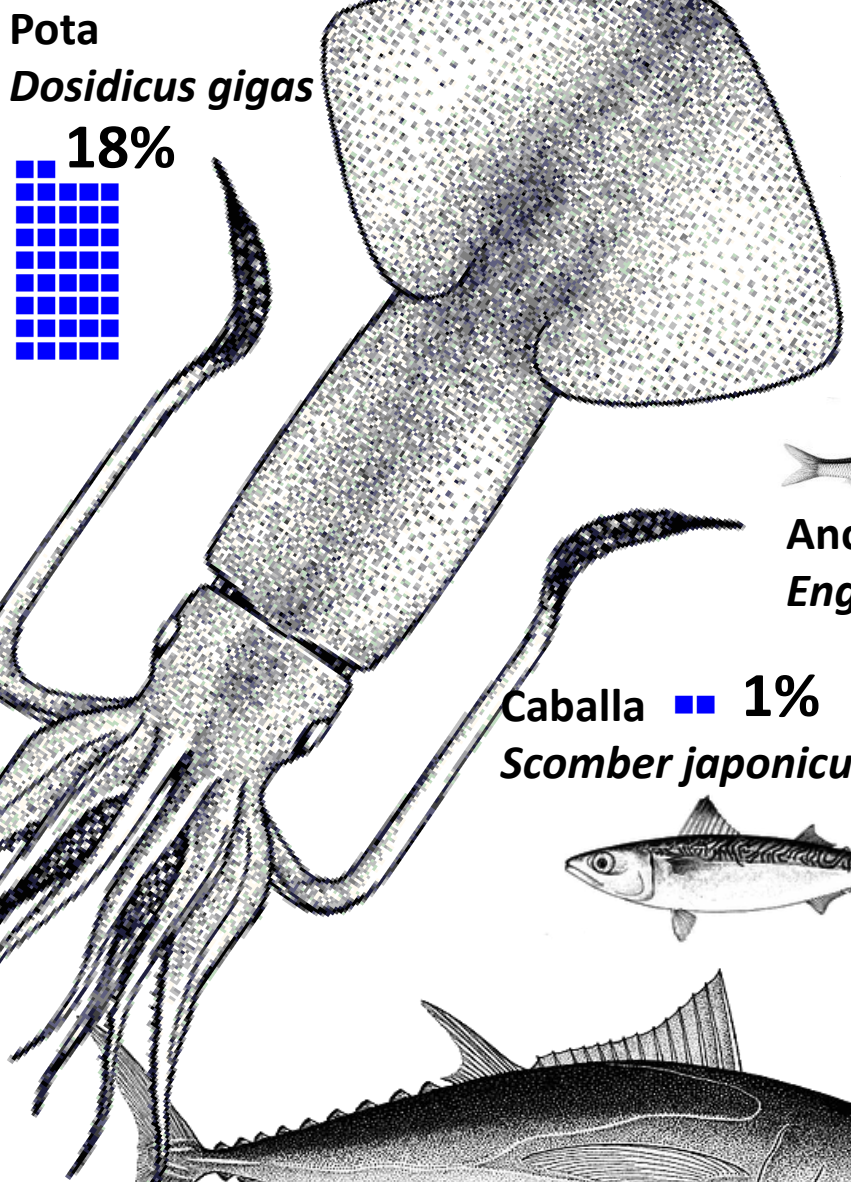


What about short-term environmental variability?

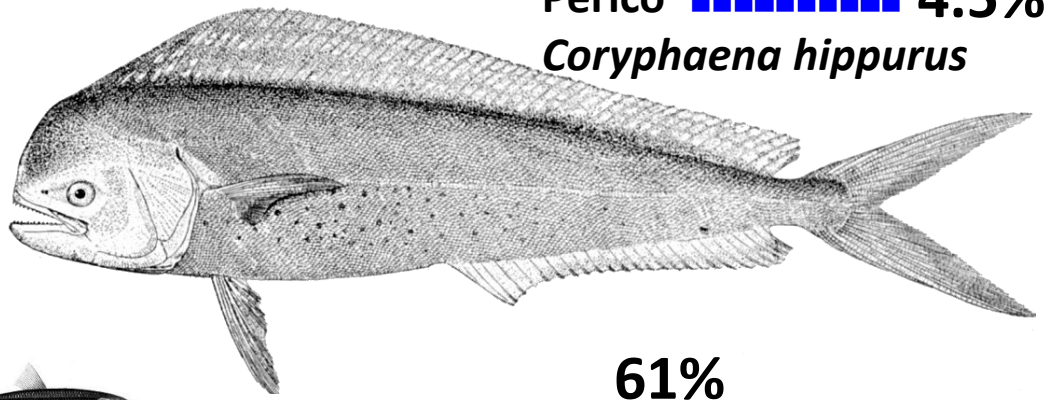


Chavez et al, 2008: spatial pattern of the EOF of SST (2°x2° from 1875 to 2007) with the northern HCS showing the highest variance relative to any coastal area of the world ocean

Pota
Dosidicus gigas
18%



Perico 4.5%
Coryphaena hippurus



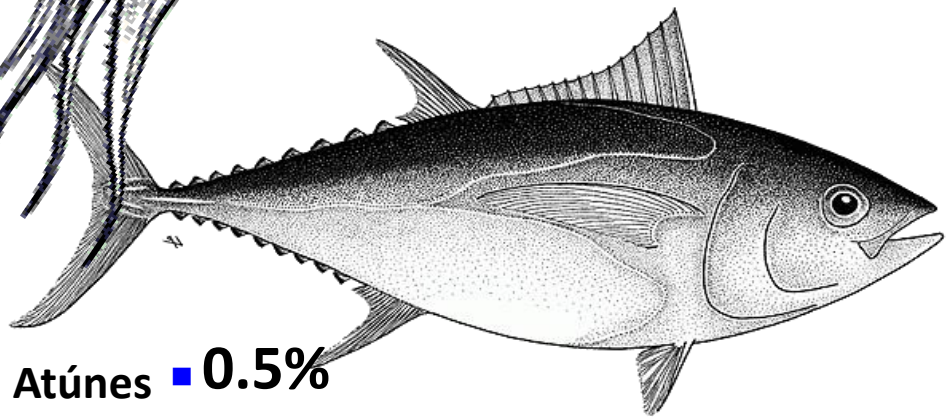
61%

Anchoveta
Engraulis ringens

Caballa 1%
Scomber japonicus

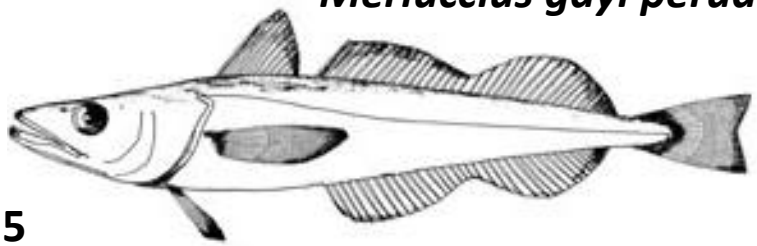
Jurel 1%
Trachurus murphyi

OTHER
12%



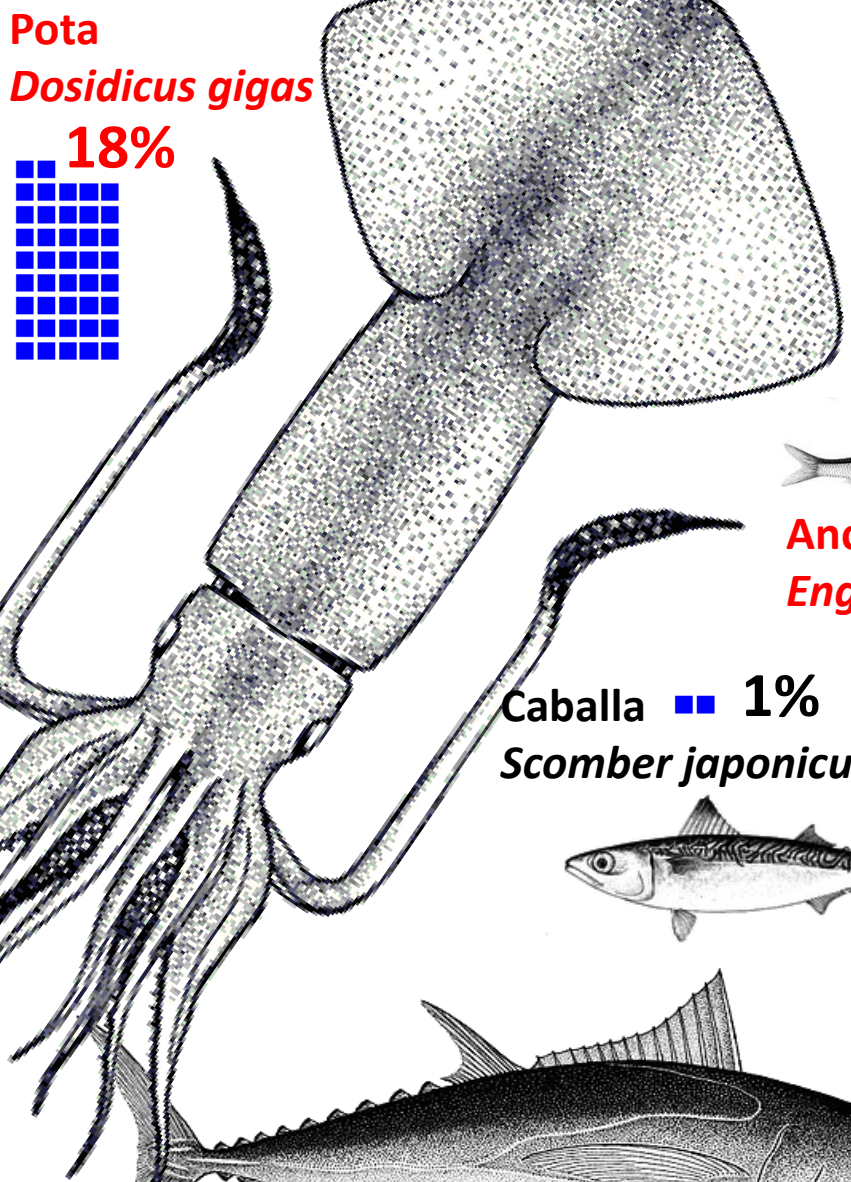
Atúnes 0.5%
Thunnus sp.

Merluza 2%
Merluccius gayi peruanus

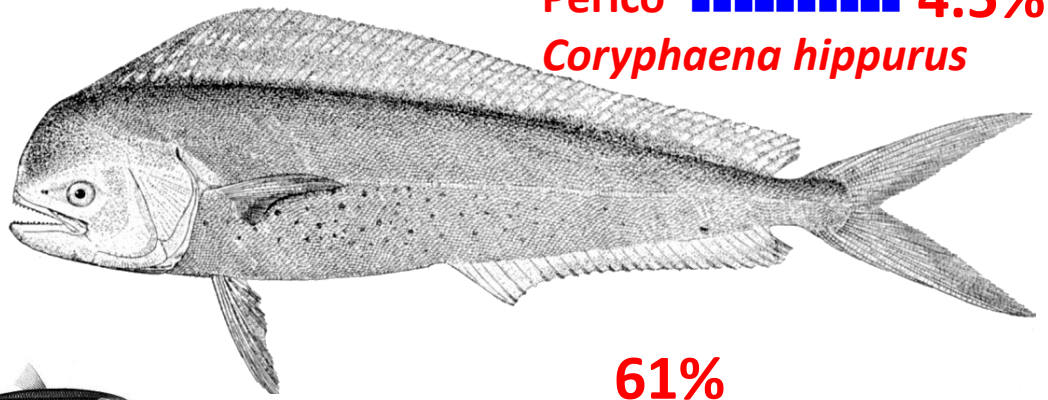


Perú: 2006-2015

Pota
Dosidicus gigas
18%



Perico 4.5%
Coryphaena hippurus



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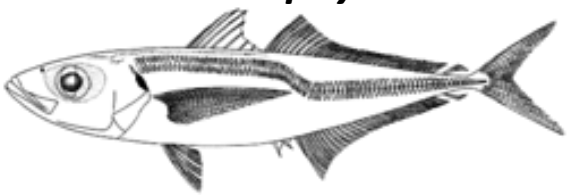

OTHER
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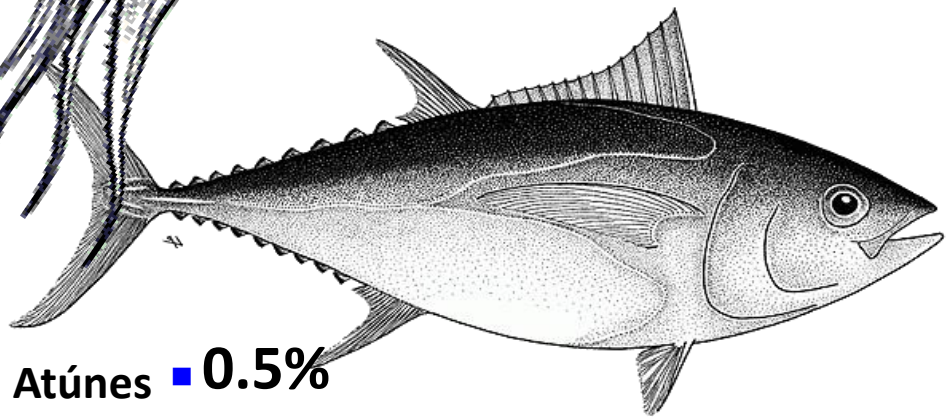

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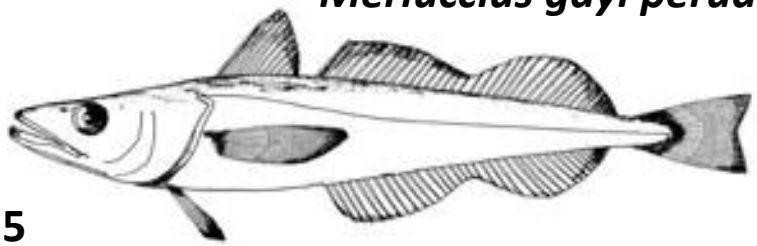
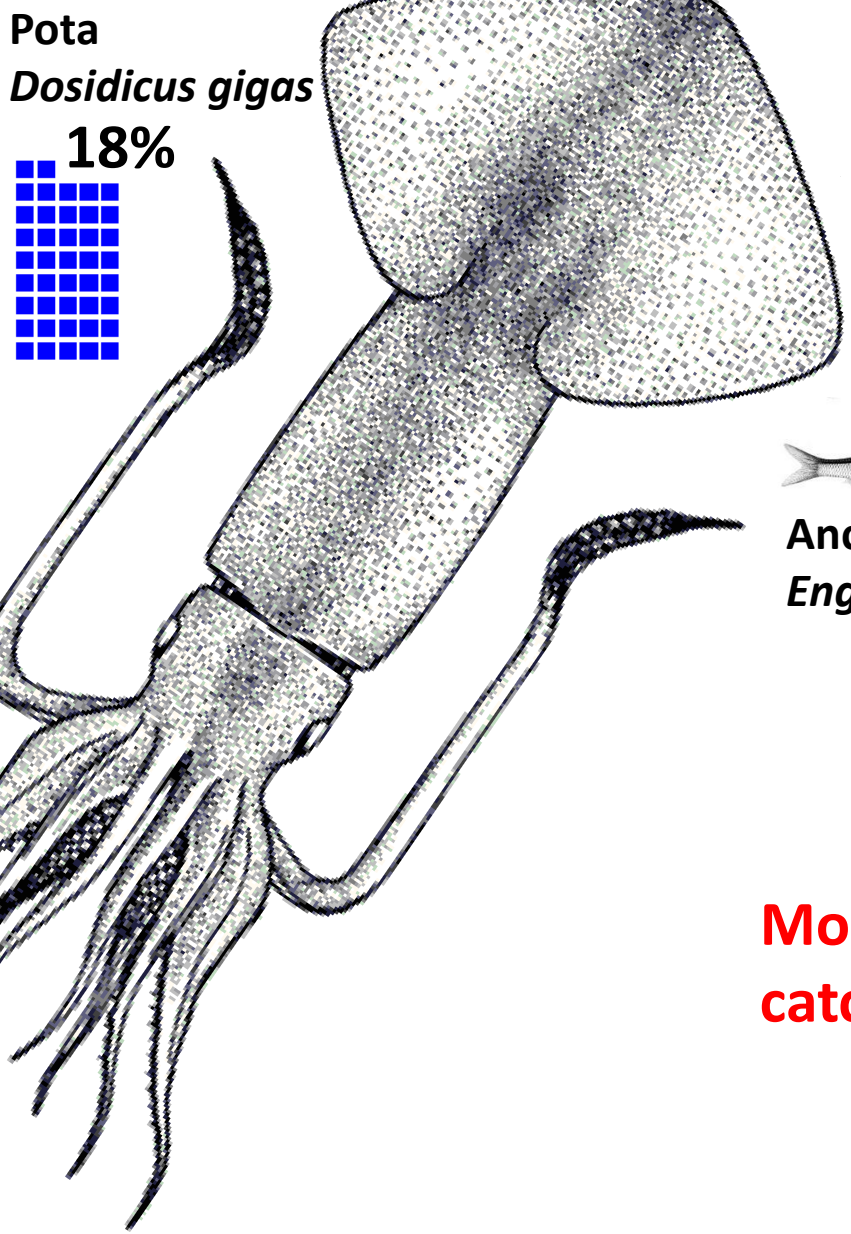


Atúnes 0.5%
Thunnus sp.

Perú: 2006-2015

Pota
Dosidicus gigas
18%



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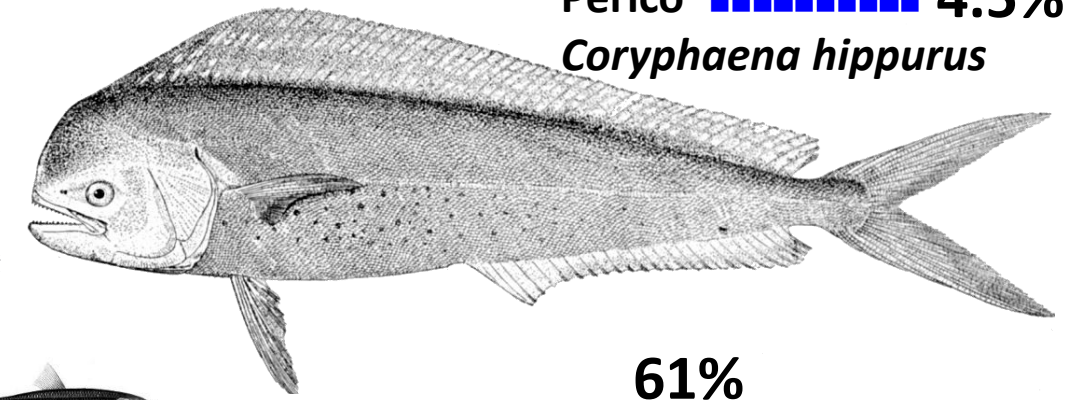


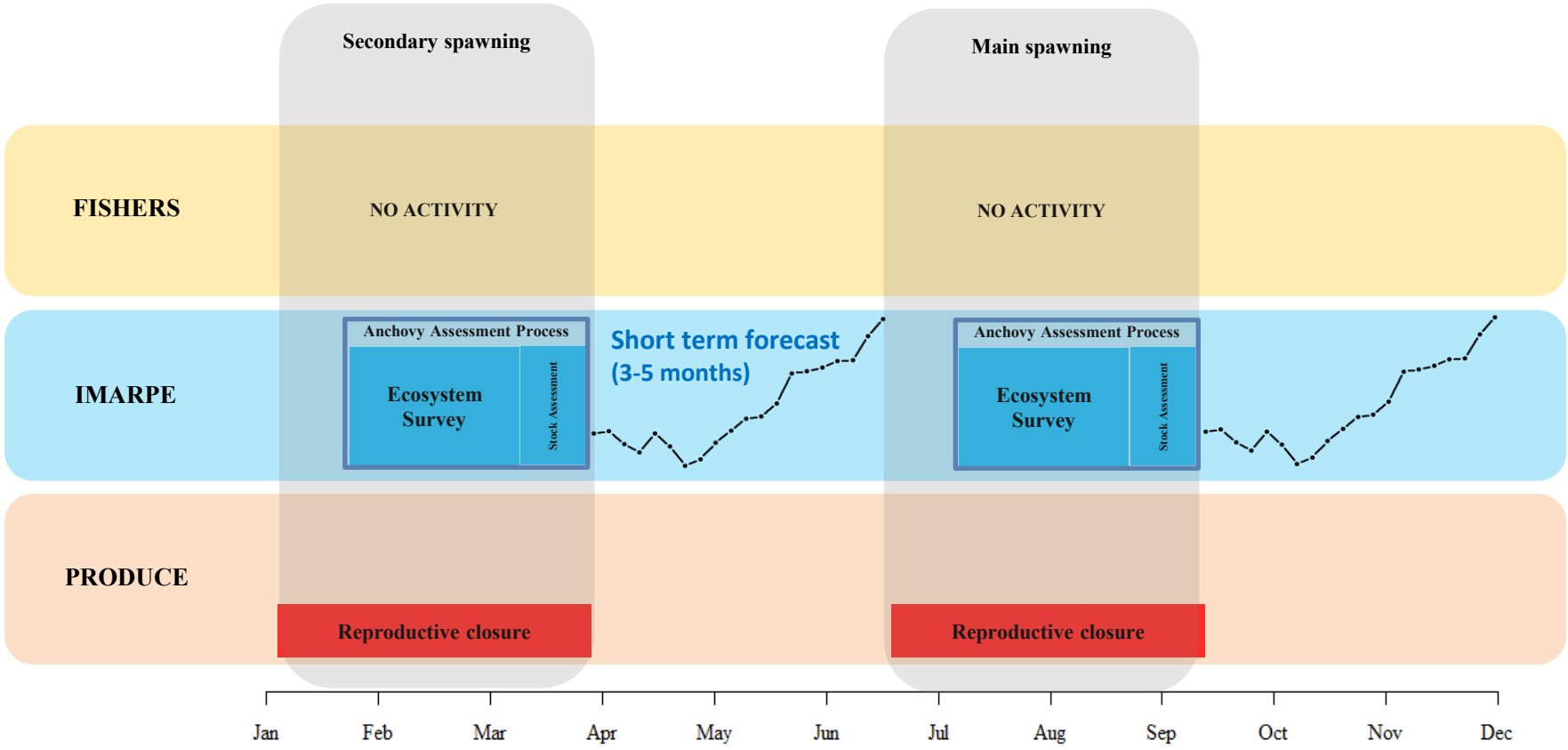
61%

Anchoveta
Engraulis ringens

More than 83% of commercial catches come from short-lived species.

Perú: 2006-2015

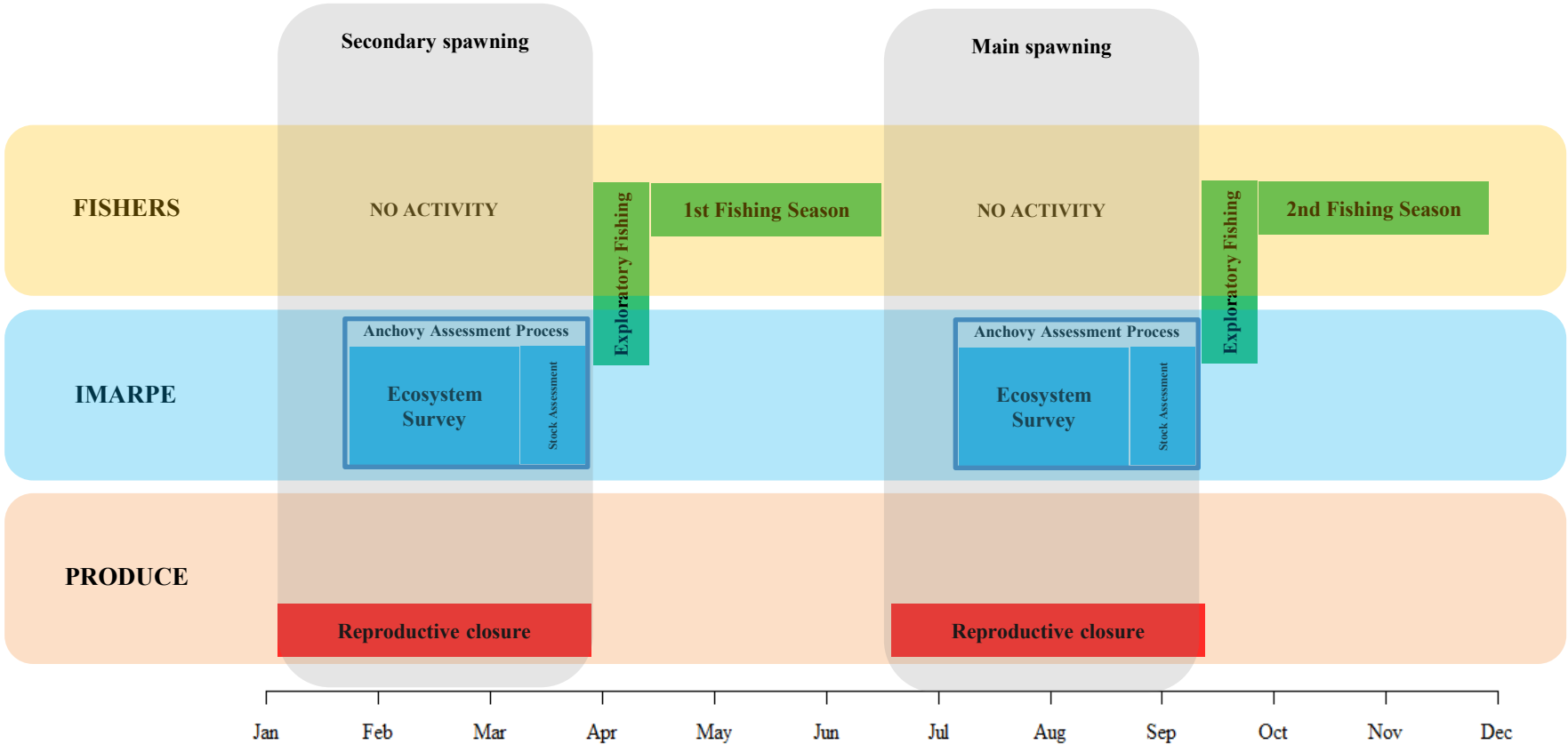
Peruvian Anchoveta Fisheries Management



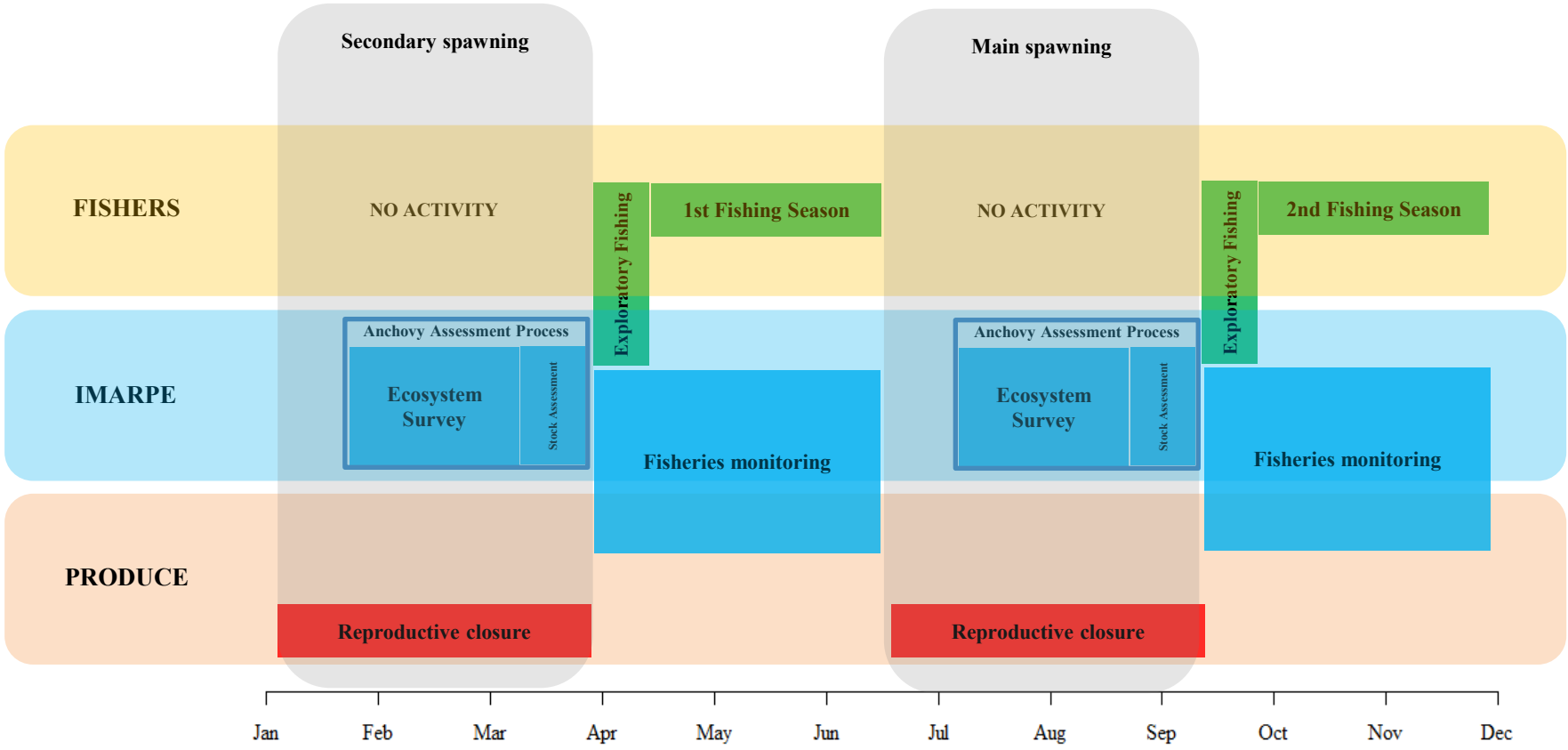
Short term forecast:

- Explicit consideration of environmental variability and uncertainty (ENFEN)
- Transparent estimation of risks associated to management decisions

Peruvian Anchoveta Fisheries Management

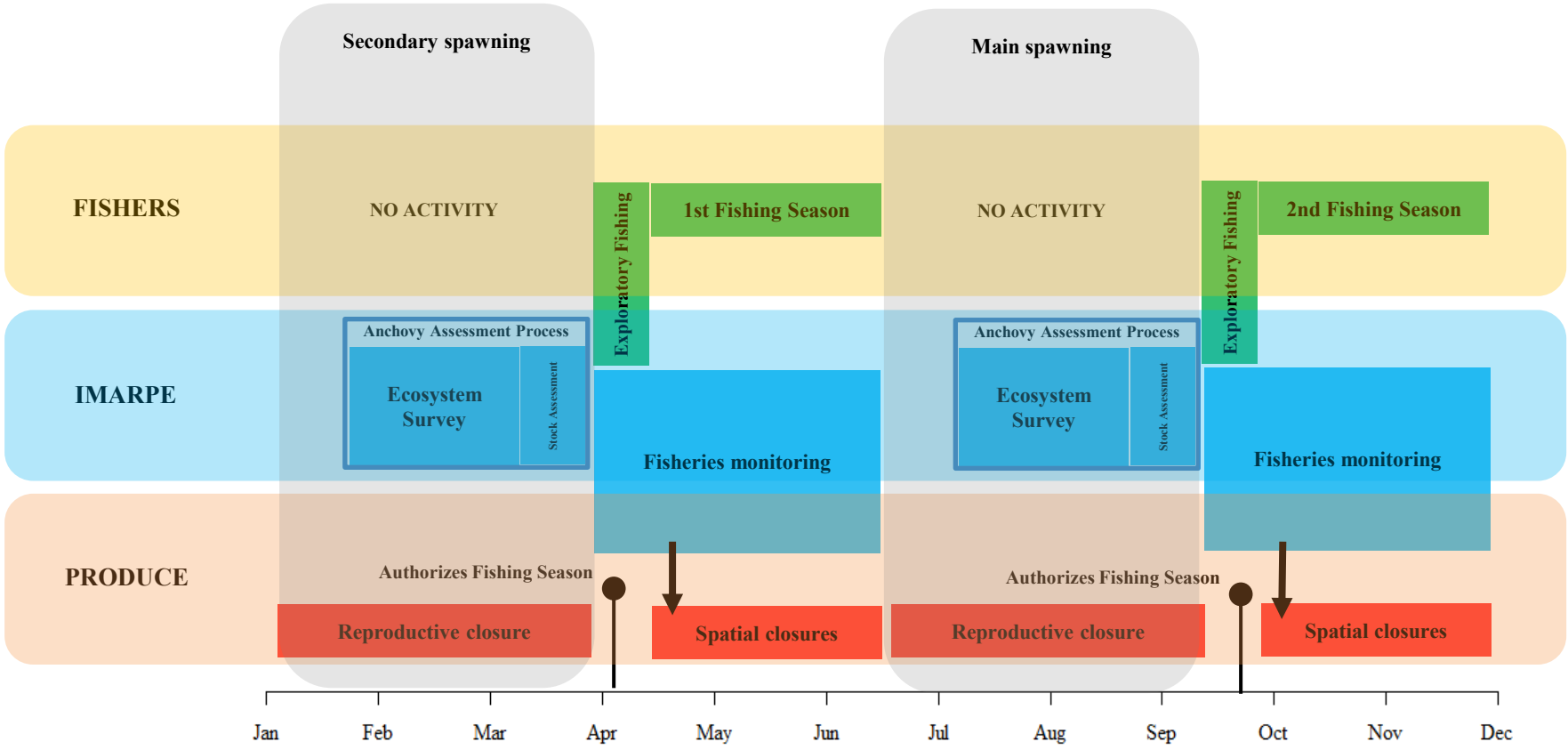


Peruvian Anchoveta Fisheries Management



<u>Intense fisheries monitoring</u>: 24/7, near 100% coverage.

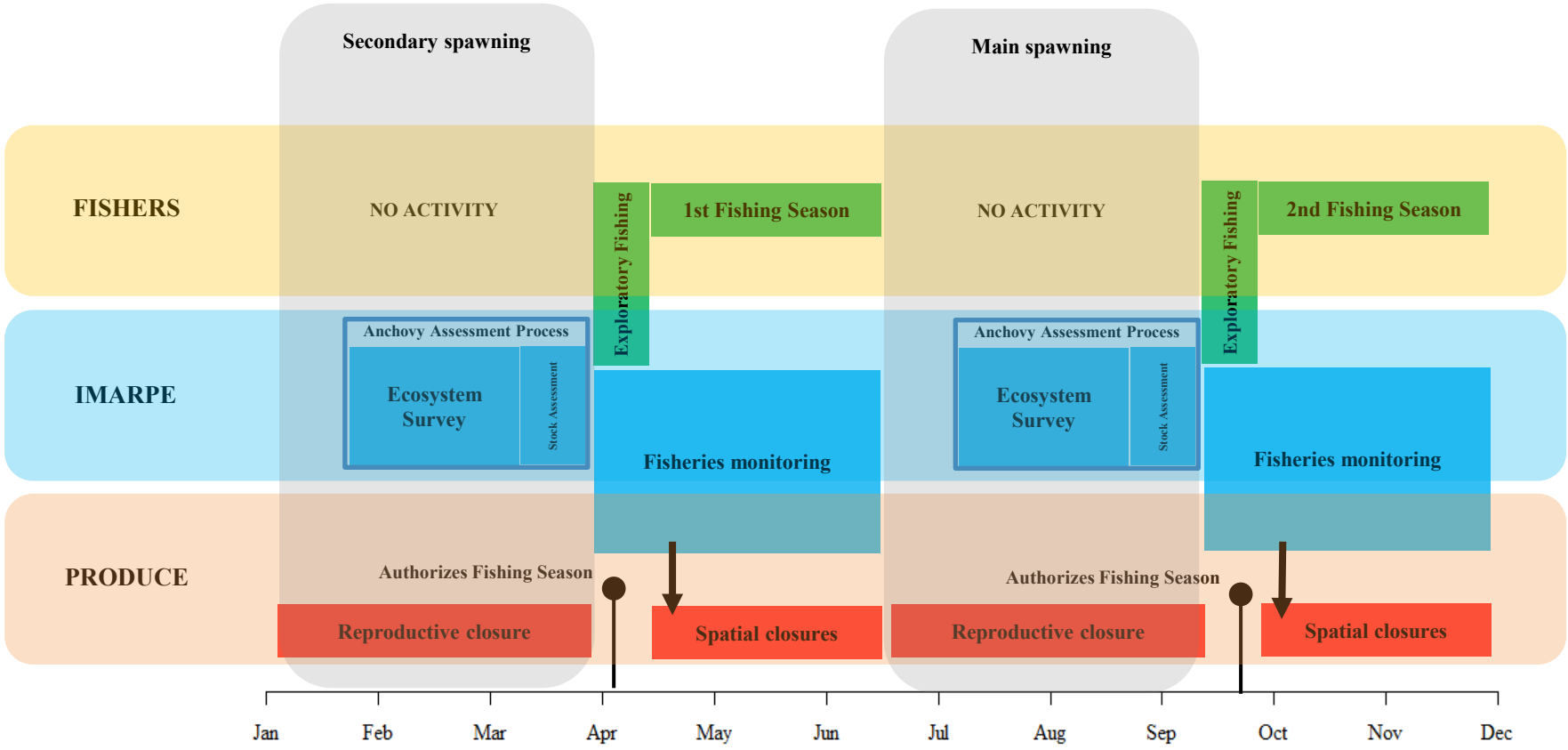
Peruvian Anchoveta Fisheries Management



<u>Near real-time management actions</u>: temporal spatial closures for protection of juveniles

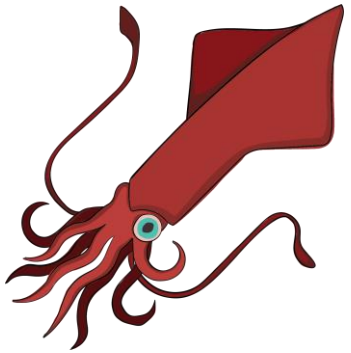
Juveniles TAC

Peruvian Anchoveta Fisheries Management



Quick Adaptive Response to short-term ENVIRONMENTAL uncertainty

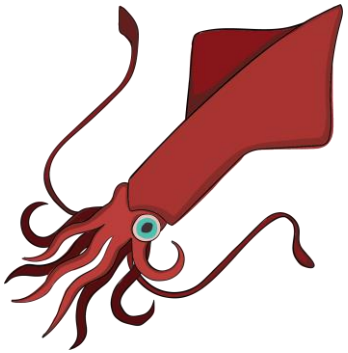
Jumbo Flying Squid



- **Biology**
  - Short lifespan, rapid growth, high natural mortality
  - Semelparous life cycle, with high mortality after spawning
  - Strong phenotypic plasticity: small, medium and large morphotypes
  - Morphotypes differ in growth, size at maturity and spatial distribution

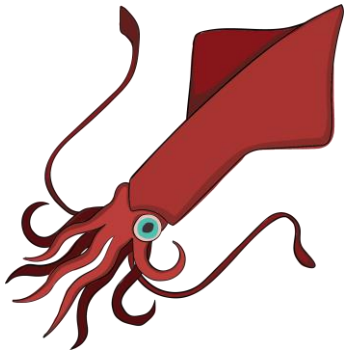
Jumbo Flying Squid

- **Ecology**
  - Ontogenetic migrations and shifting spatial distributions
  - Strong cannibalism
  - Environmental forcing, especially ENSO, affects growth, mortality, maturity, availability and recruitment



Jumbo Flying Squid

- **Assessment implications**
  - A single-stock model with fixed growth, maturity and mortality may miss the main dynamics
  - Management procedures need to be robust to shifting productivity regimes, spatial redistribution and uncertain population structure

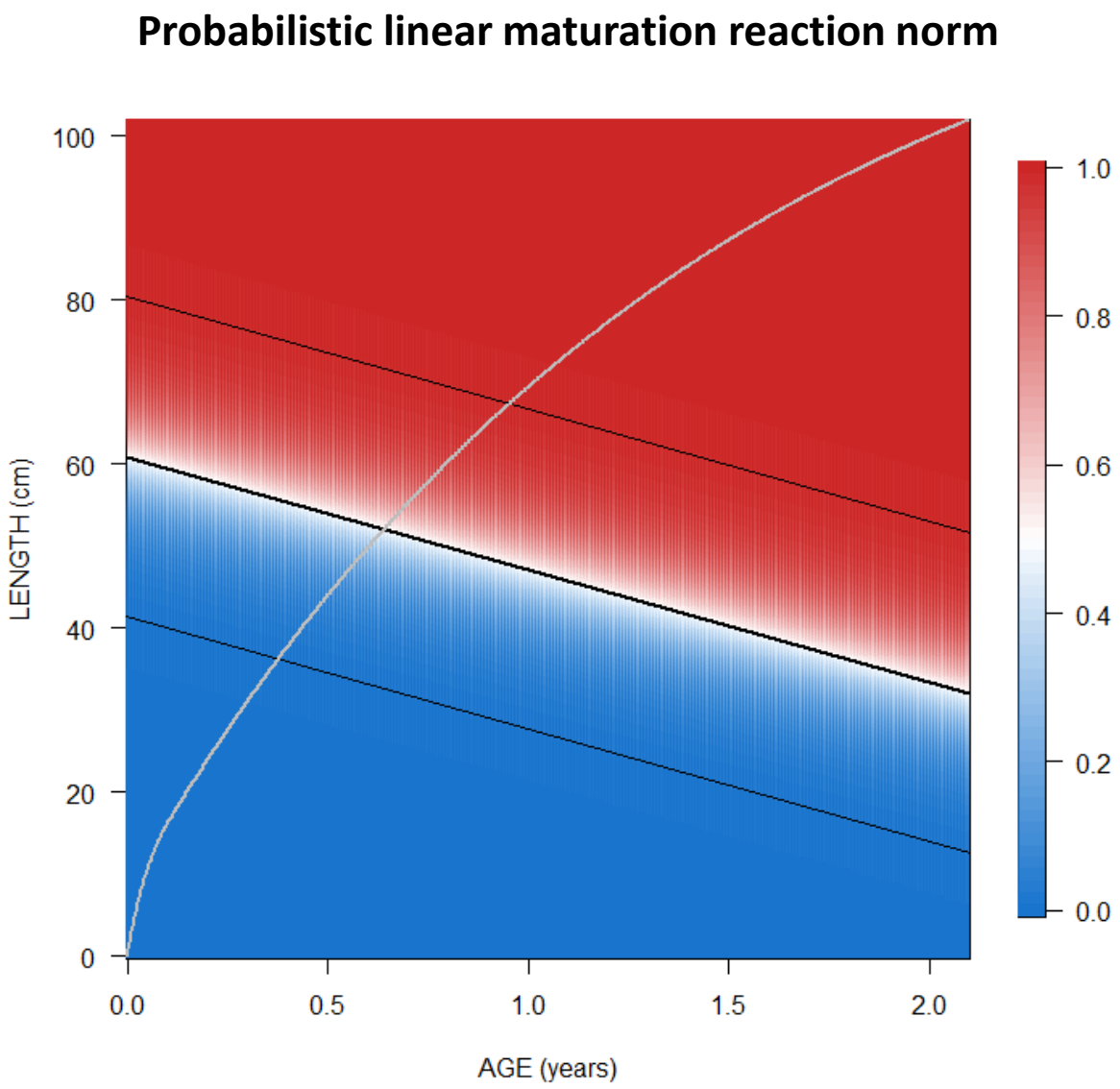


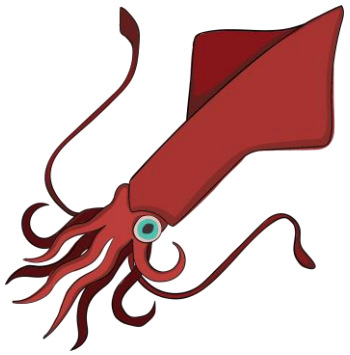
the mobility and spatial extent of the squid make intensive monitoring infeasible

OMs for Jumbo Flying Squid

- **These features raise the bar for MSE operating models**
- They must be realistic enough to test management procedures against:
  - Dynamic interannual changes in productivity;
  - spatial redistribution;
  - uncertain stock and population structure;
  - environmentally driven variability in growth, maturity and natural mortality

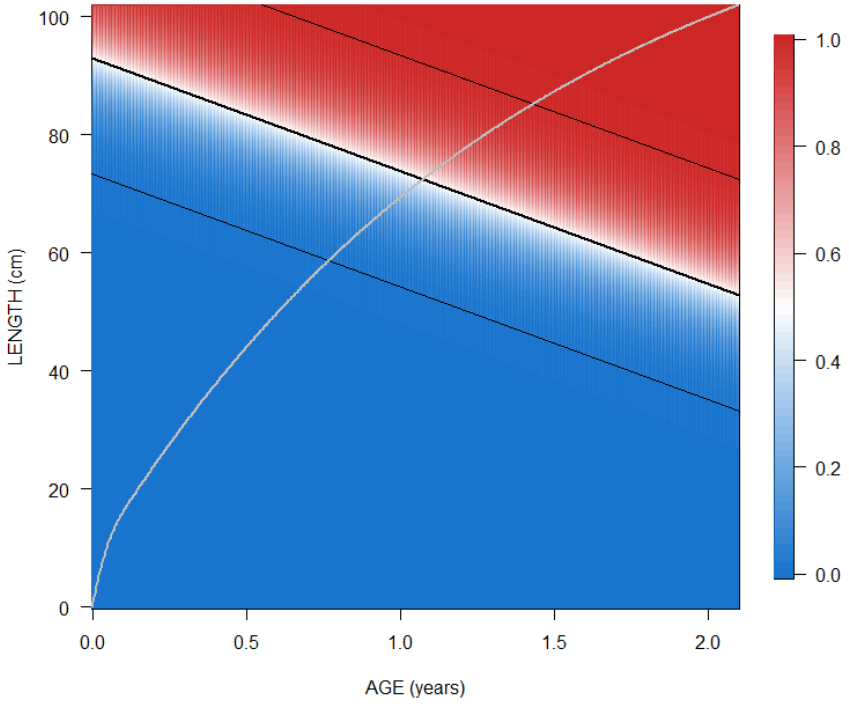
Maturation Reaction norms (MRN)



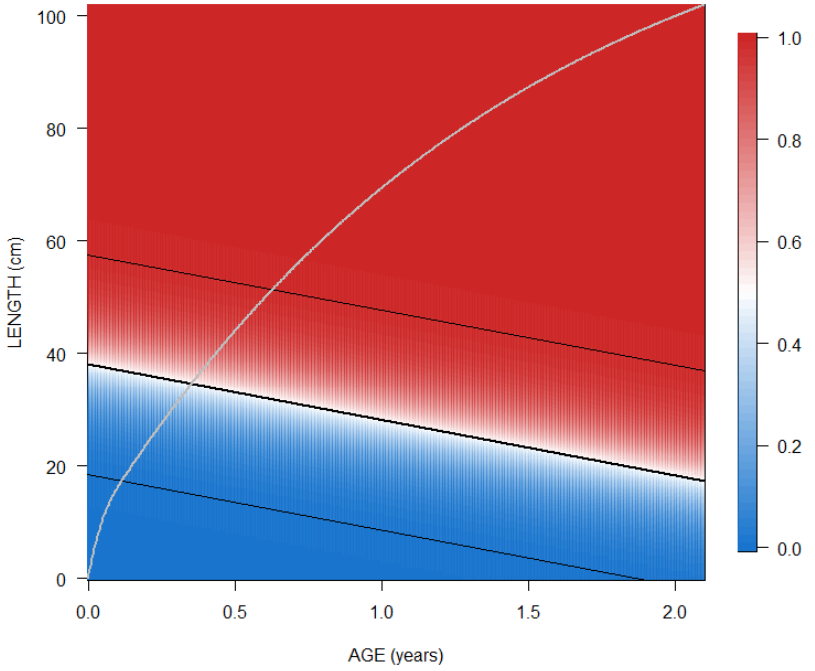


Maturation Reaction norms (MRN)

T = 13°C

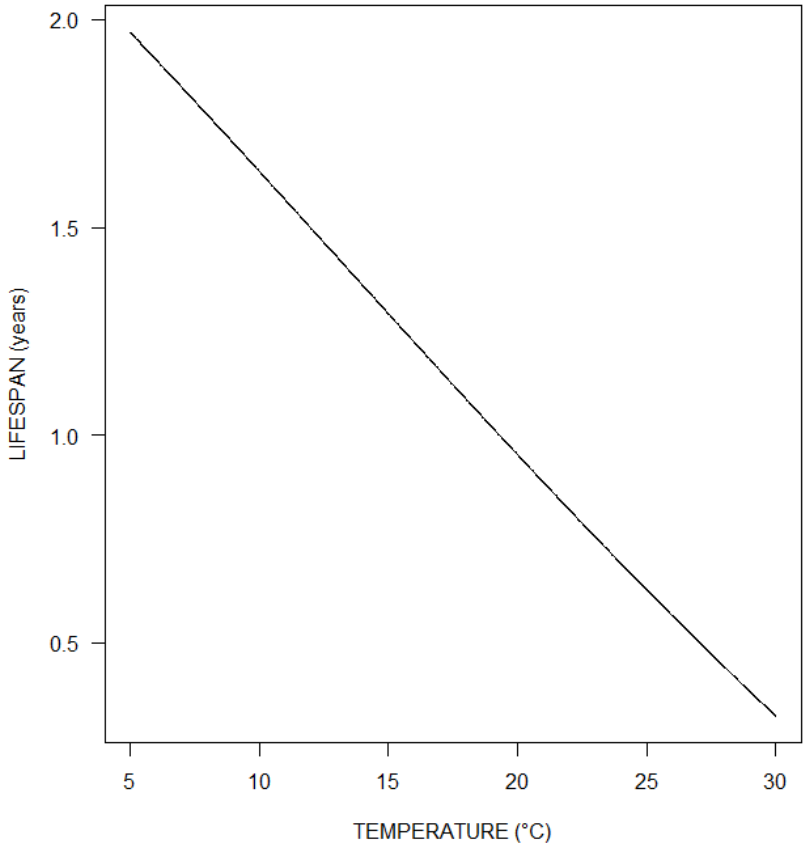


T = 25°C

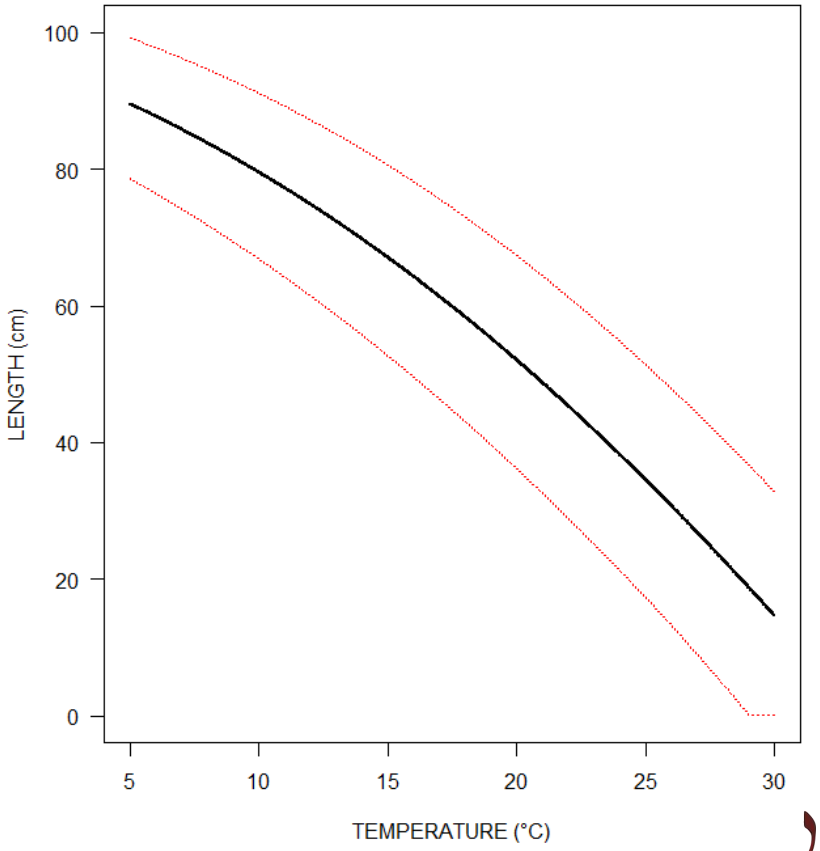


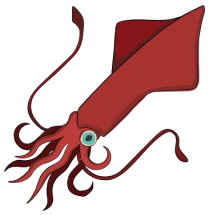
Maturation Reaction norms (MRN)

Lifespan

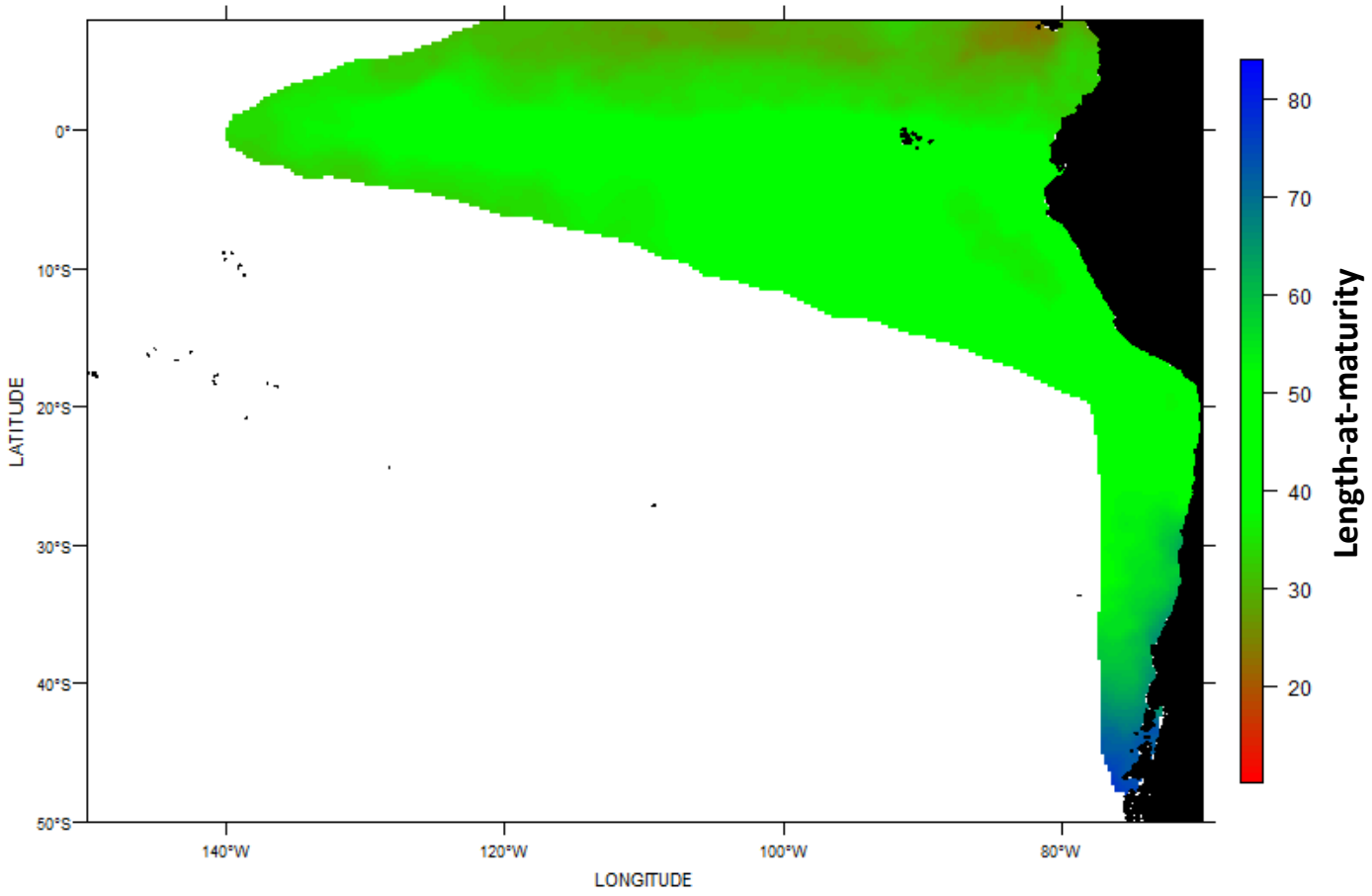


Length-at-maturity (L50)





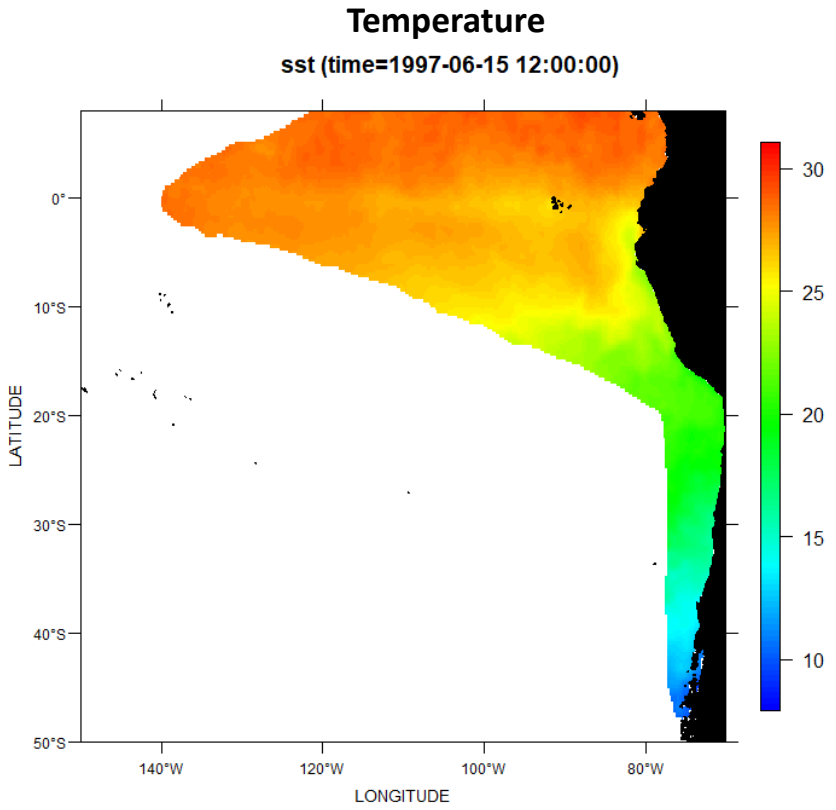
Proof of concept for *D. gigas*

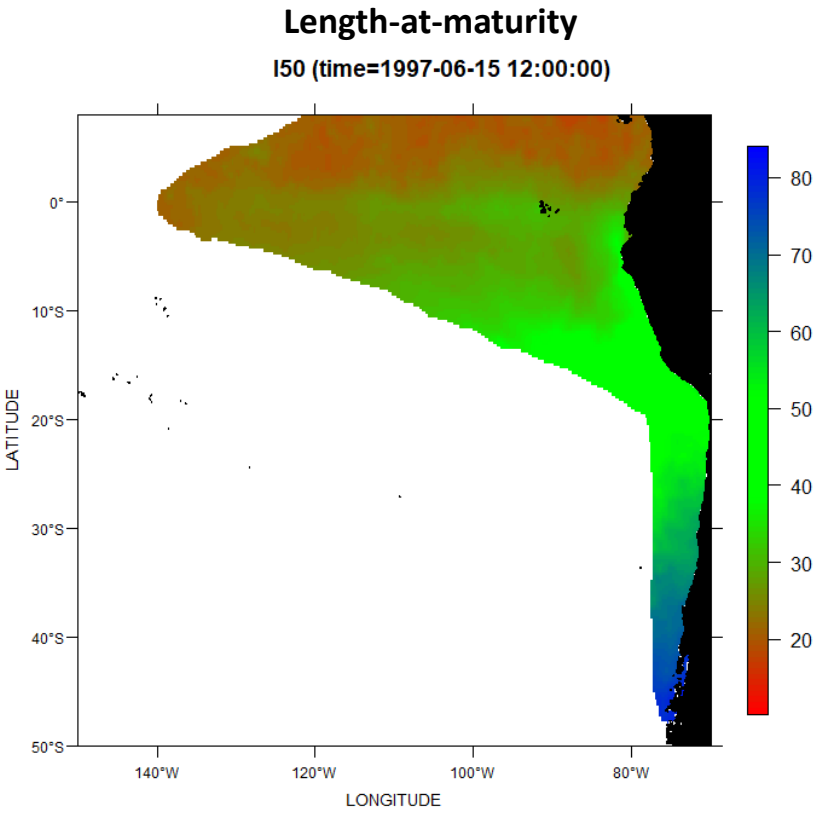


This are the predictions of the model for the ORIGIN of the phenotype due to temperature-dependent plasticity in the maturation.

This is NOT modelling migration (yet).

Proof of concept for *D. gigas*



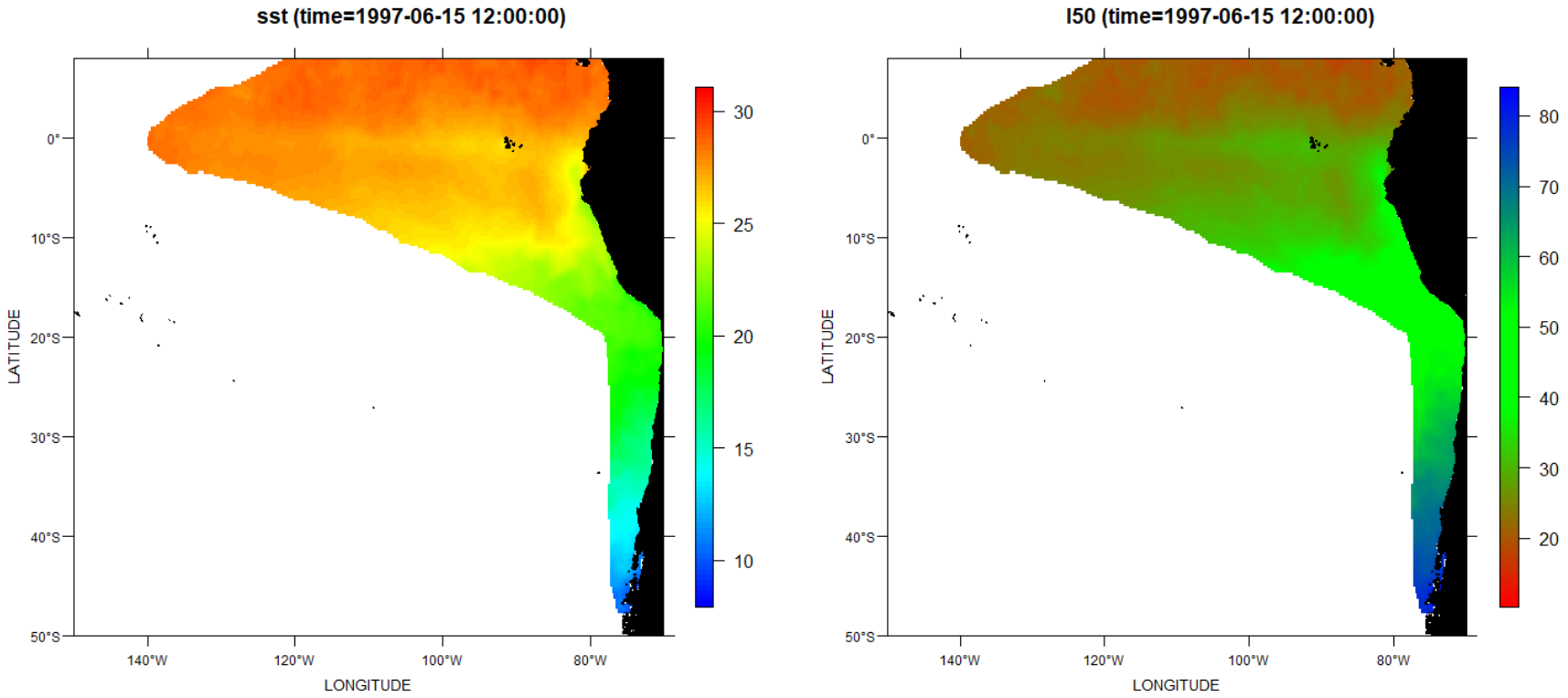


What is the "temperature" that signal the plasticity effect in the jumbo flying squid?

Can we use catch-at-length data to estimate biological and ecological parameters for the jumbo squid?

YES

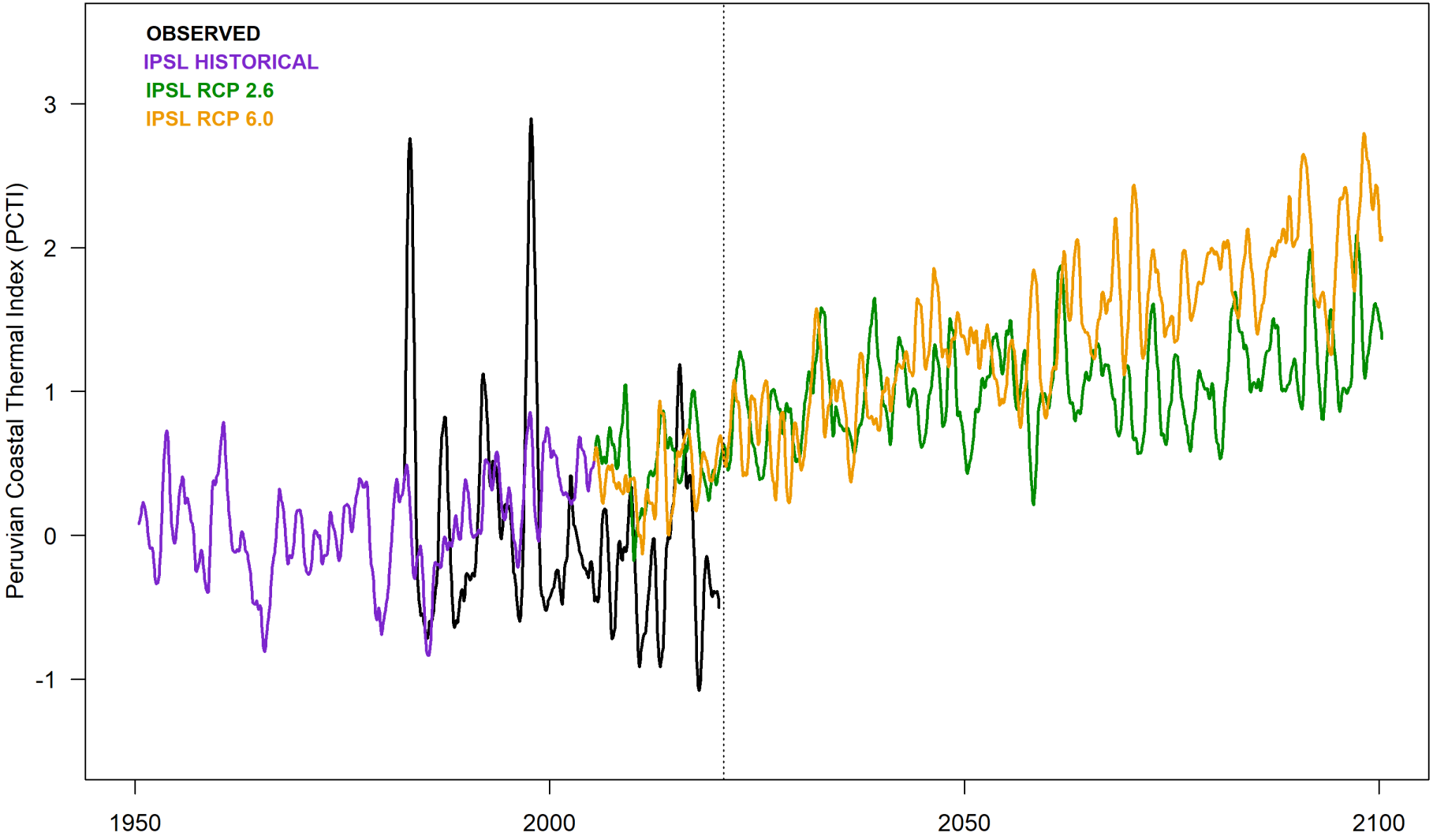
Proof of concept for *D. gigas*



<u>Under the assumption of temperature-dependent plasticity in the maturation reaction norm:</u>

- Observed variability in size-at-maturity and longevity emerge from the spatial distribution of temperature: no need of “morphotypes”
- Open the possibility to an integrated estimation of growth and maturation from all data (aging, catch-at-length).

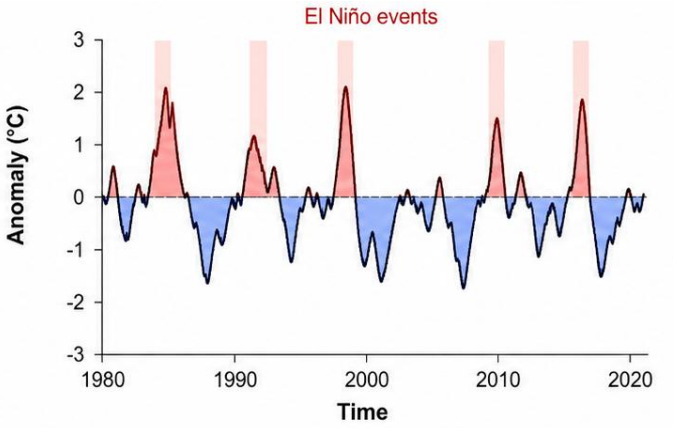
El Niño and the Southern Oscillation



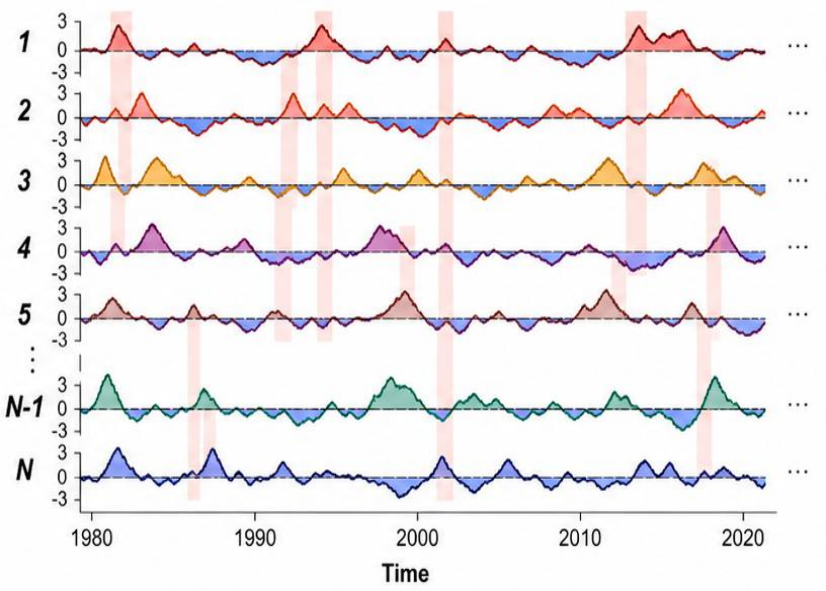
Short-term environmental variability as (another) uncertainty layer

- Downscaling and bias correction make climate forcing usable, but MSE also needs plausible sequences of short-term variability.
- Why it matters for short-lived species:
  - Trends alone miss the timing, persistence and intensity of events.
  - El Niño-like events can quickly reshape productivity, distribution and availability.
  - One climate trajectory is not enough: OMs need many stochastic environmental realisations to incorporate environmental variability.

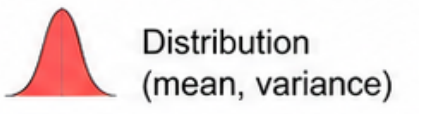
Weather generators

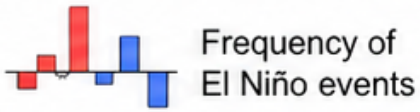


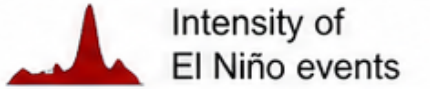
Weather Generator

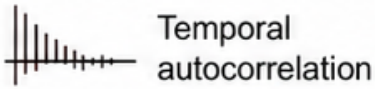


Key statistical properties reproduced



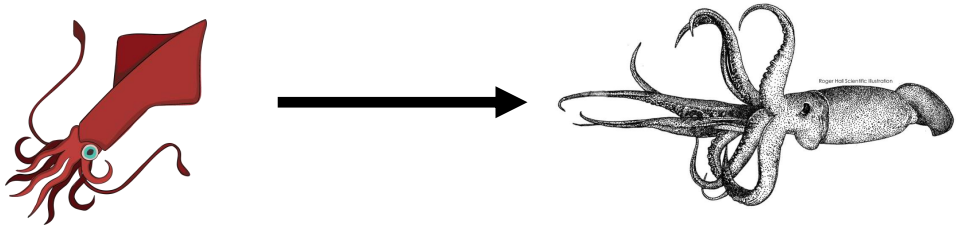




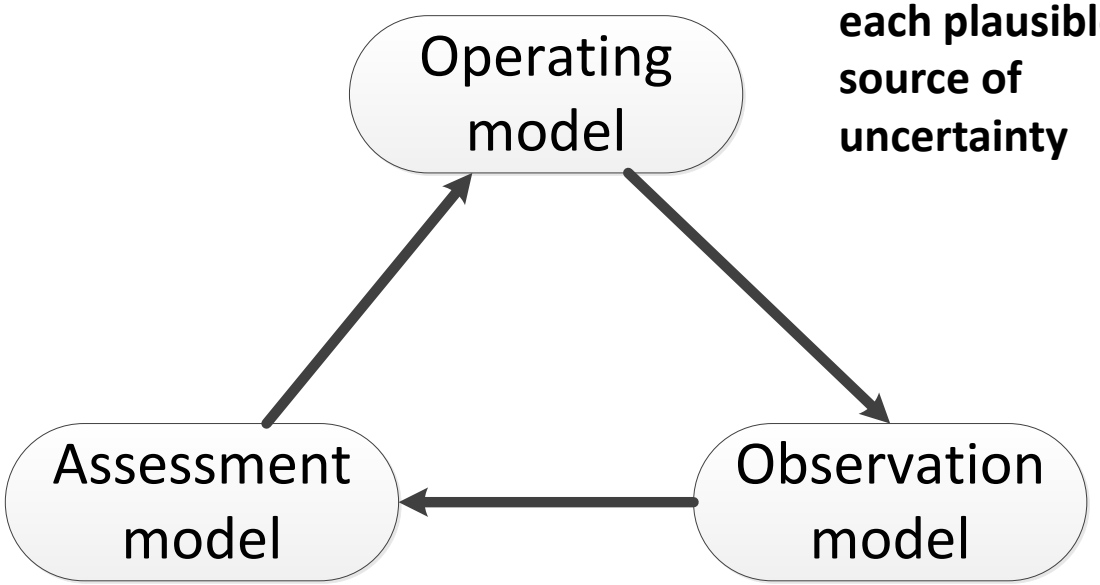


Weather generators provide many plausible, event-rich environmental sequences that represent an additional source of uncertainty for MSE and allow stress-testing of management procedures under short-term climate variability.

MSE for Jumbo Flying Squid



each plausible source of uncertainty



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W7: Operationalizing Ecosystem-Based Management of Forage Species using Management Strategy Evaluation

Ricardo Oliveros Ramos

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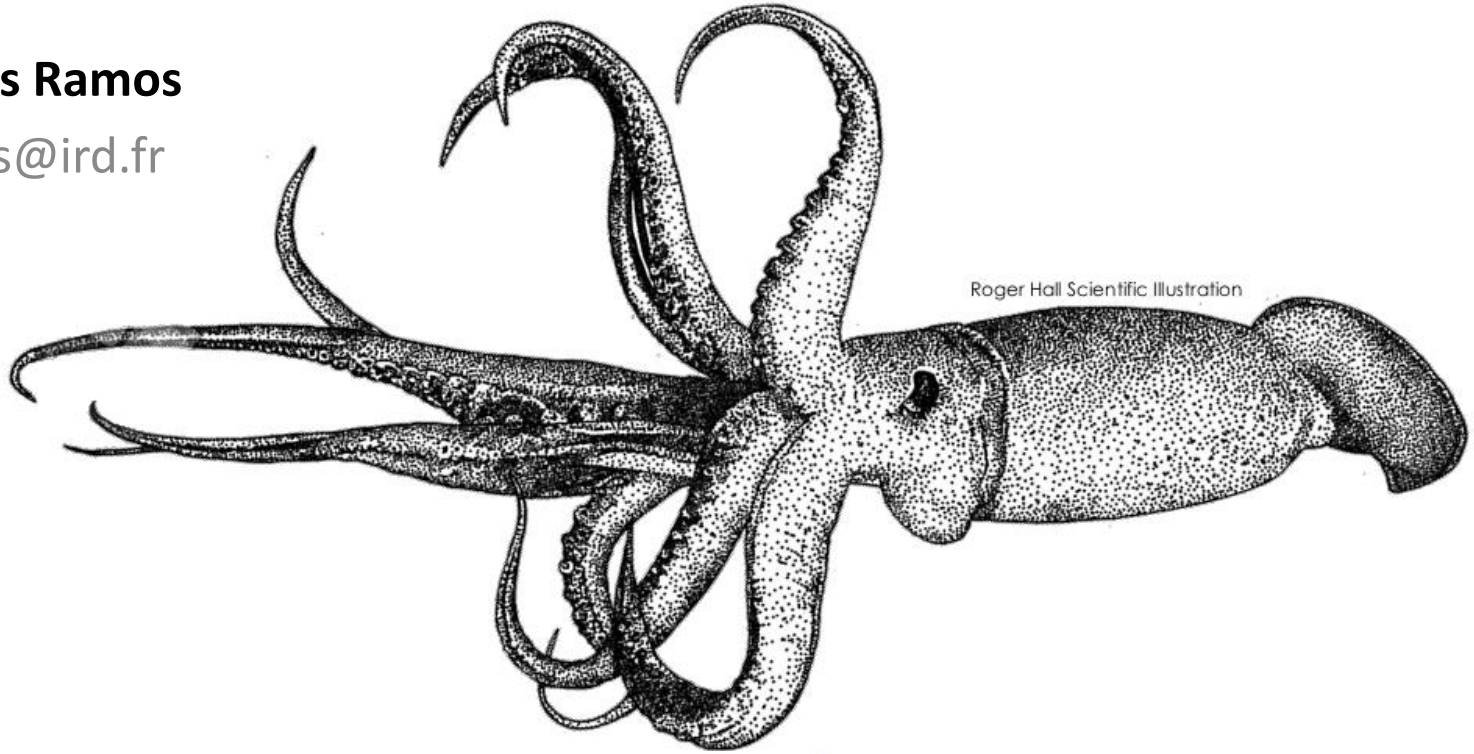

¡GRACIAS!

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