



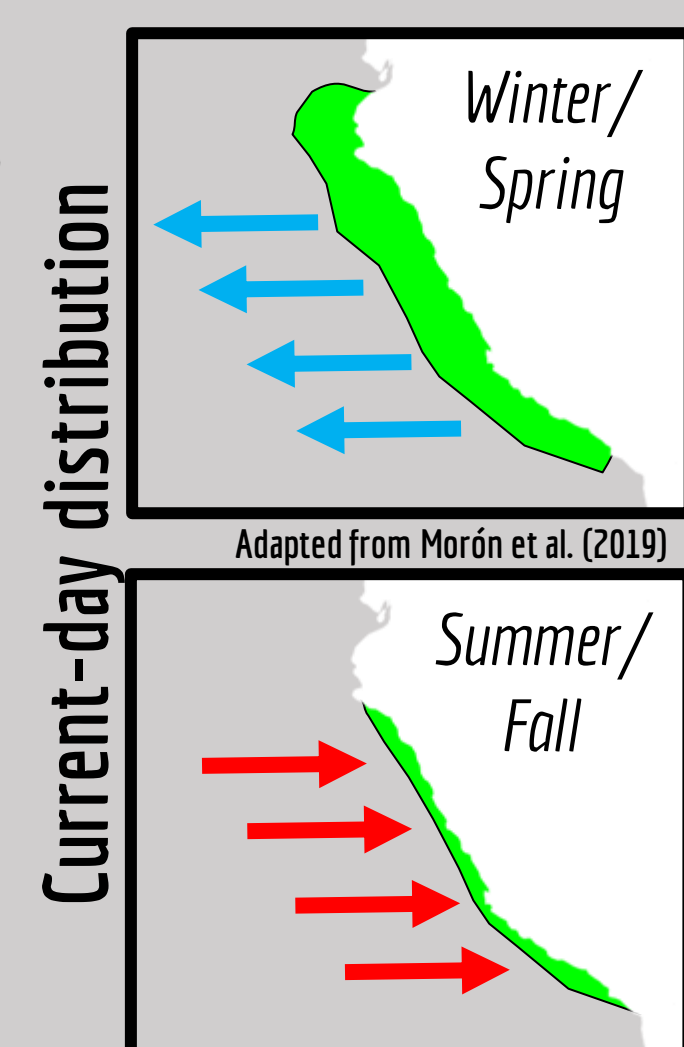
Seasonal characterization of the effect of climate change on the potential habitat of Peruvian anchovy (*Engraulis ringens*) off the coast of Peru

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Background



The Peruvian anchovy is the keystone of the Humboldt Current System (HCS) and supports one of the world's largest single-species fisheries. Its distribution is tightly coupled to the oceanographic variability, now increasingly affected by climate change...

Prior studies have not resolved the ontogenetic (juvenile vs adult), nor the seasonal (spring vs summer) dimensions of habitat, both critical for management.

Objective:

To characterize the effect of climate change on the seasonal potential habitat of juvenile and adult *Engraulis ringens* off Peru, through the rest of the 21st century

Distribution changes (summer):

- Juvenile habitat showed decline from both ends of the coastline, while adult habitat showed a southward pattern of decline. This patterns of change could not be capture by the DC and GC metrics, but where noticeable in the projection maps.
- Habitat on the northern end of the coast could be the most affected, as is the first one to manifest decline for both life stages and shows the greatest declines by the end of the century.
- A persistent belt of coastal habitat remains for both stages between Pisco Bay and Ático up to 2050-2060. Also, adult potential habitat in the Gulf of Guayaquil extends further offshore.

RCP 2.6 and 8.5 scenarios (2030-2100)

Seasonal level:

- Summer habitat shows decline with high between-scenario certainty; decline starts and show greatest changes in the near future (2030-2040) and stabilizes afterward.
- Summer habitat declines sooner or with greater magnitude, in comparison to spring habitat.
- Spring habitat response is scenario-dependent, can increase in mild warming (RCP 2.6) or decline in intense warming (RCP 8.5)

Ontogenetic level:

- Juvenile habitat shows stronger and/or sooner reductions in comparison with adult habitat, reaching declines between 62 and 72% by the en of the century

Reference Period (2010-2020)

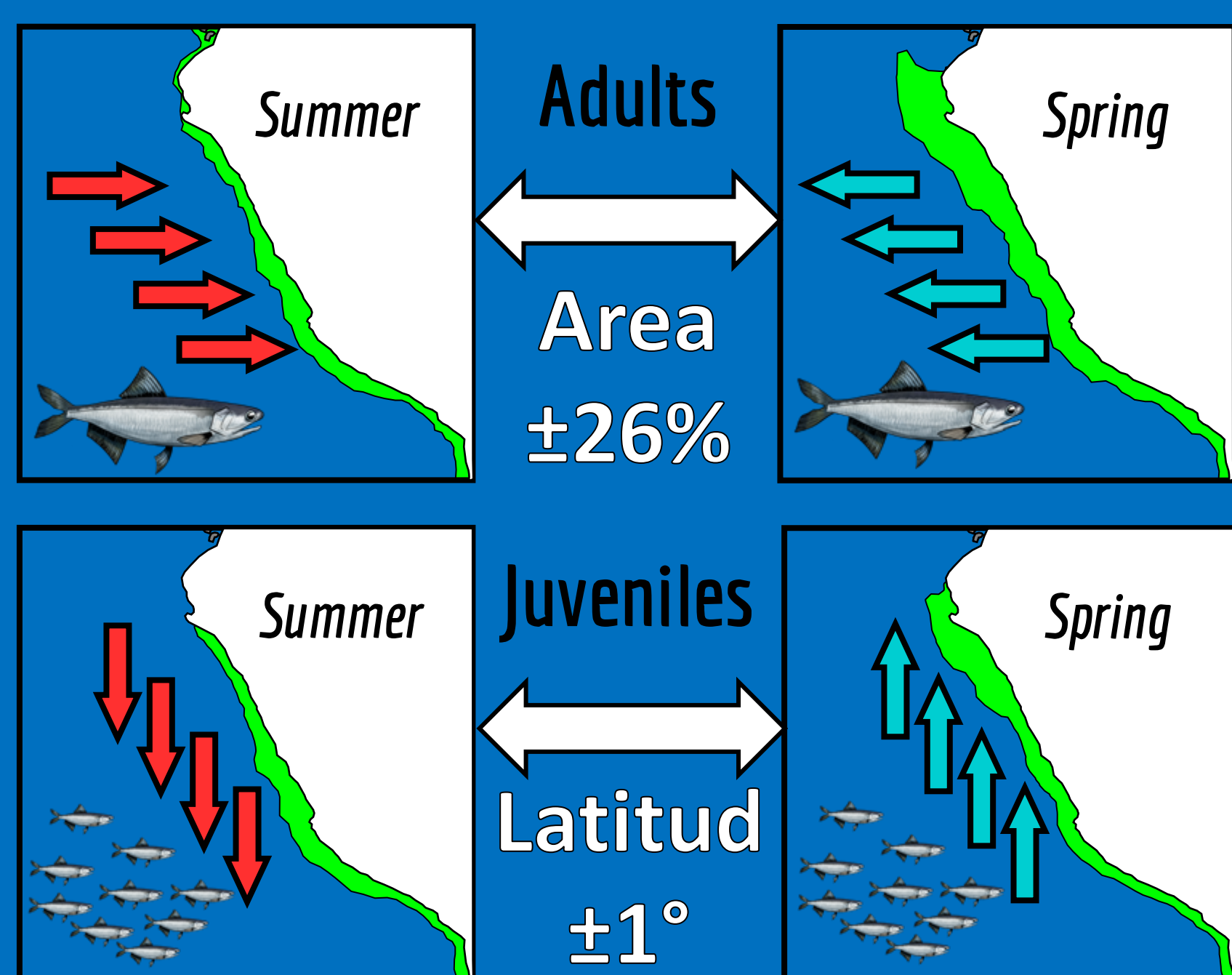
Seasonal juvenile and adult habitats were projected for the 11 years of the reference period. In each projection, total area, distance to coast (DC) and latitudinal component of the gravity center (GC) where calculated and averaged for the period:

Adult Habitat:

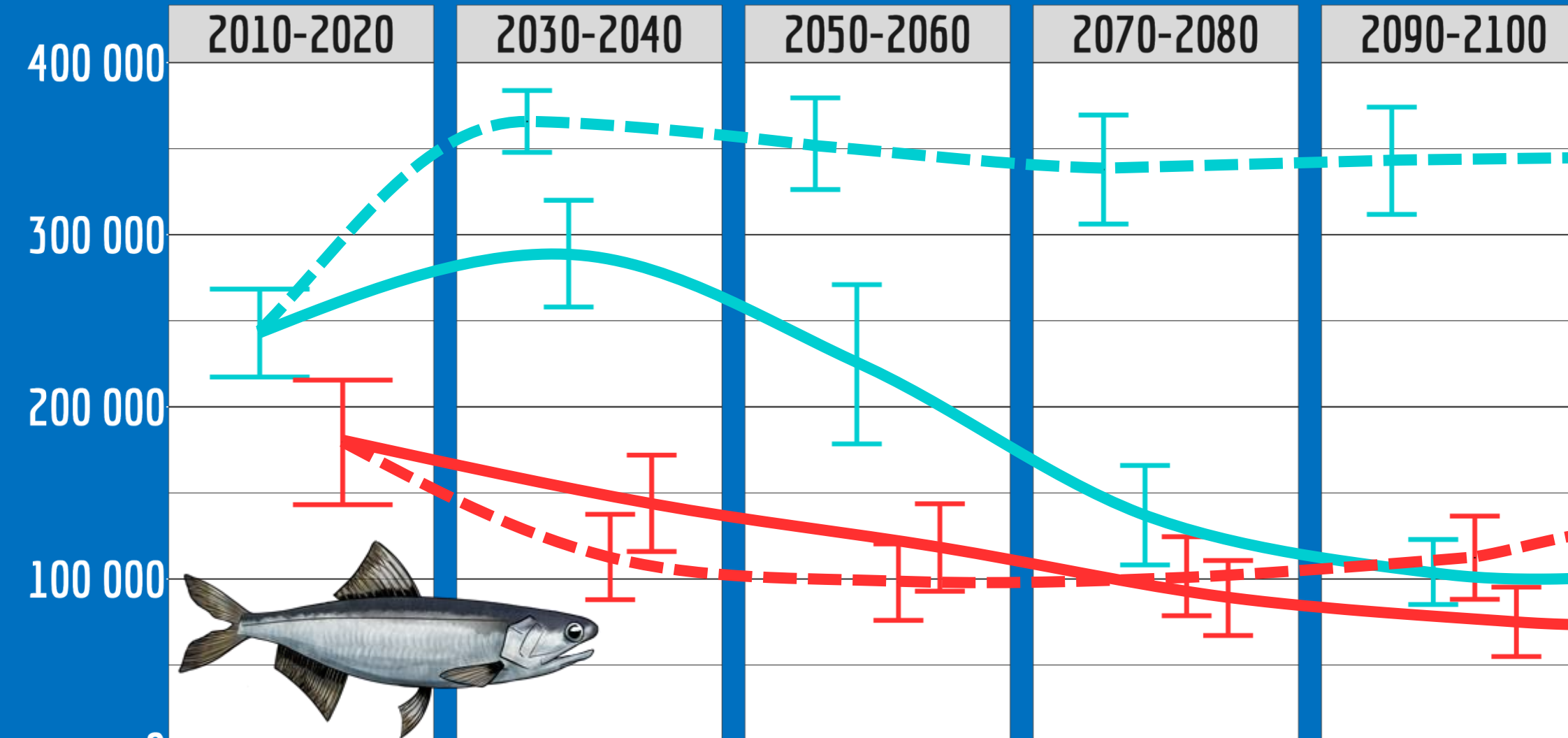
Adult habitat showed a seasonal increase in area of around ~26% during spring (from 179 320.42 to 242 858.25 km²), accompanied with an expansion further offshore of the habitat (from ~65 to 92.5 km) and no noticeable latitudinal movement. The model estimated the Gulf of Guayaquil as a potential habitat for adult anchovy.

Juvenile Habitat:

Juvenile habitat remained constant in terms of area and DC, but shifted -1° to the south during the summer, a pattern not previously documented for this life-stage

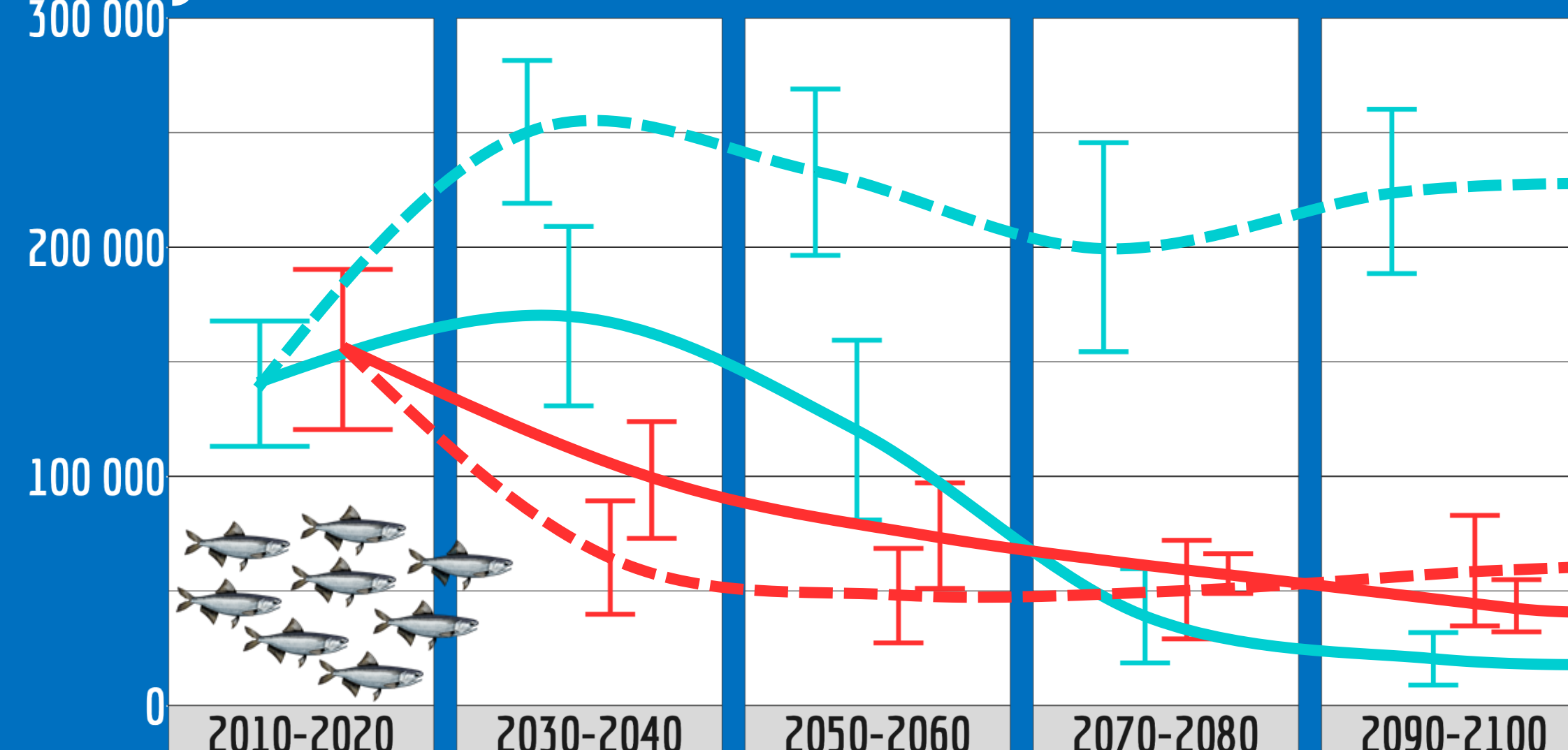


Adult habitat area (km²)



+41%
-37%
-57%
-58%

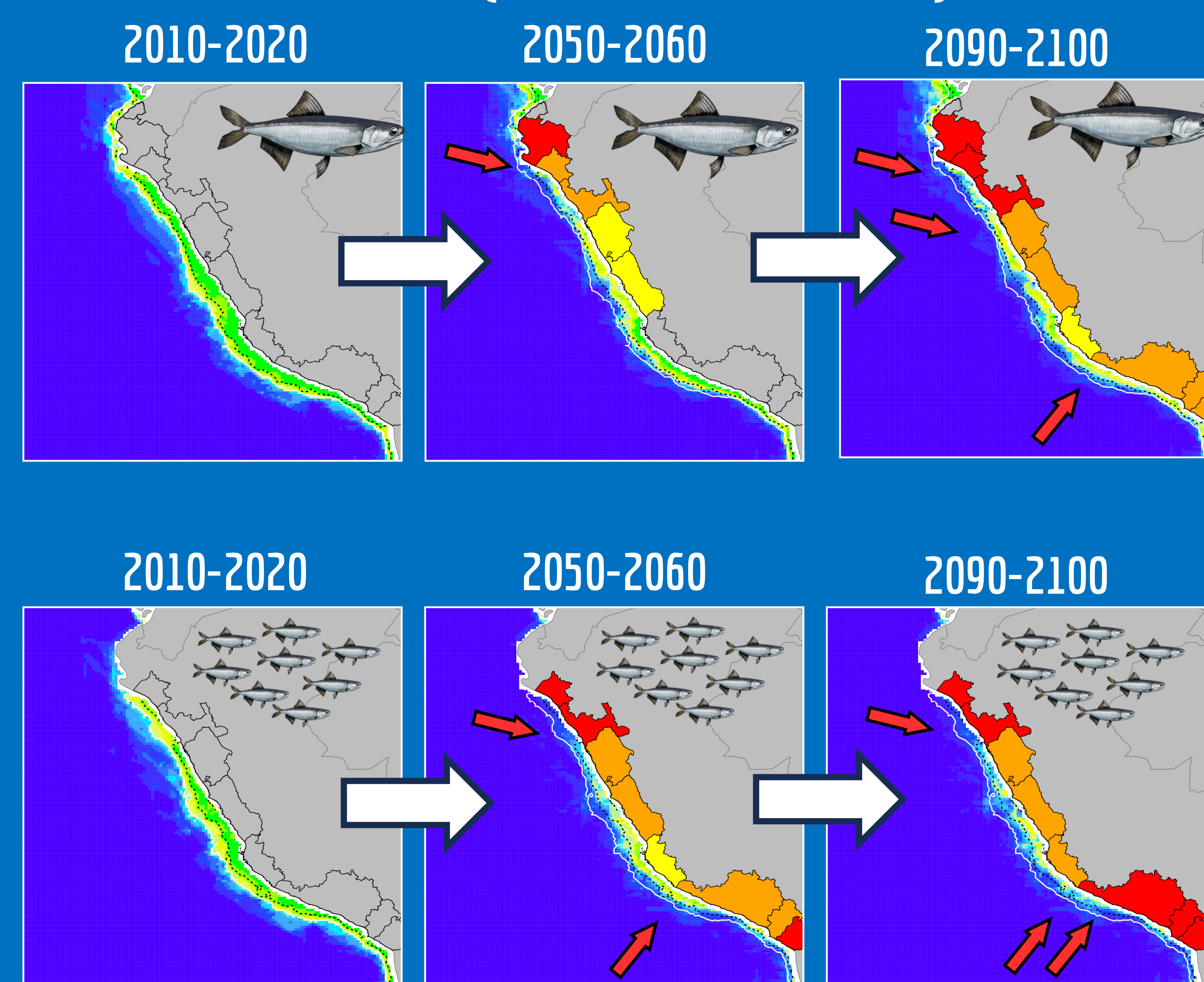
Juvenile habitat area (km²)



+60%
-62%
-72%
-85%

Spring Summer RCP 2.6 RCP 8.5

Summer (Mean RCP 2.6 and 8.5)



Methodology

Data and model:

- Anchovy data came from IMARPE's semestral hydroacoustic surveys. In total, P/A data from 5 spring and 7 summer surveys was considered⁴.
- The environmental data for the model was sourced from Mercator GLORYS12⁵. RCP scenario data was sourced from the ROMS-IPSL-MR model described in Echevin *et al.*, 2020.
- Conditional Inference Random Forest⁶ was used to model the distribution of juvenile and adult anchovy, independently.

Variable	Fuente
Presencia/ausencia anchoveta	IMARPE
TSM	Mercator GLORYS12
SSM	
EKE	
Gradiente TSM	Derivada TSM

Climate change scenarios bias correction:

- Data from the ROMS-IPSL-MR model showed some deviation with respect to the real data observed on our reference period. Delta bias correction, as described in Hawkins *et al.*, 2013, was applied.

$$X_{j/t}^{RCP\text{ corregido}} = X_{j/t}^{GLORYS} + \left(X_{j/Futuro}^{RCP} - X_{j/2010-2020}^{ROMS} \right)$$

Perspectives for fisheries Management

- The lost of habitat on the northern end of the coast could be especially important for the artisanal and low-scale fleet, as they usually operate in this area. Loss of habitat, then, could disproportionately affect different segments of the fishing fleet and special measures may be required to mitigate the socio-economic consequences this could have.
- Higher impacts on juvenile habitat are almost certain to occur. As such, there's a need to implement new management measures to mitigate the effect climate change could have on this life stage. The persistent belt between Pisco Bay and Ático up to 2050-2060 could suggest a potential climate refugium for anchovy.
- The habitat reduction and coastal compression observed could change the relationship the stock biomass and capturability, making the stock more accessible to the fishing fleet. Considering that a reduction in abundance could also happen, there could be an increase in the risk of overfishing

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HUMBOLDT TIPPING

