Small Pelagic Fish:
New Frontiers in Science and Sustainable Management
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INSTITUTO DEL MAR DEL PERÚ
CIENCIA Y TECNOLOGÍA

Seventy years of management of the Peruvian anchoveta fishery under high environmental variability: lessons and challenges for future climate change scenarios

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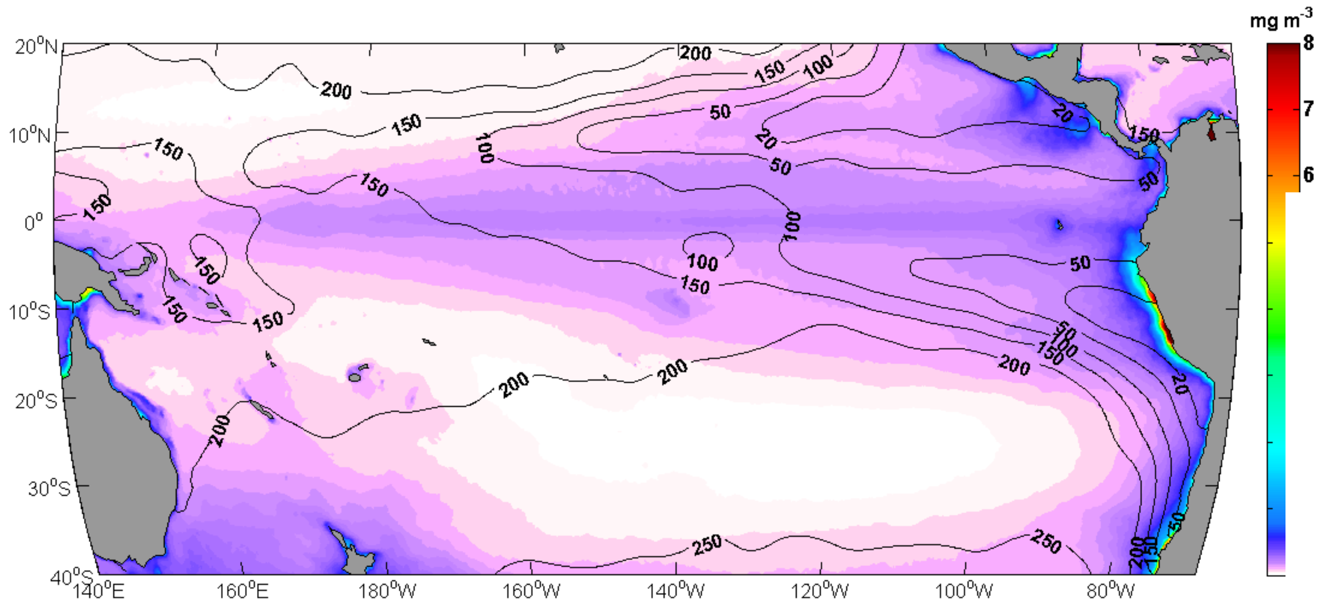
Content

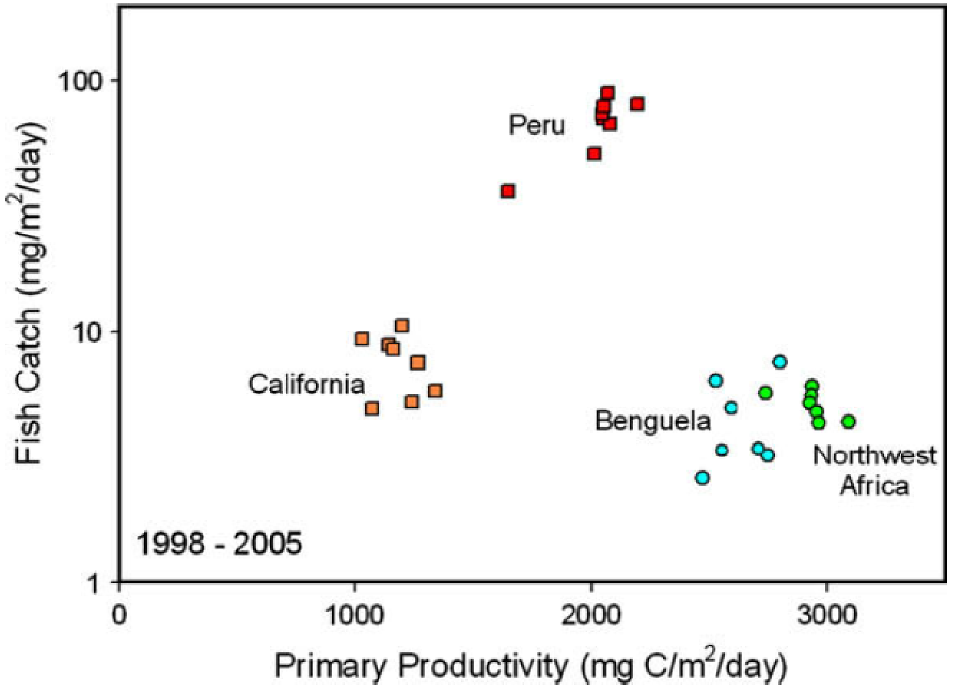
- ✓Background
  - ✓Peruvian anchoveta as the main fishing resource of the HCS
  - ✓Key anchoveta’s biological traits and environmental context
- ✓History of anchoveta management and biomass, with focus on the ‘Peruvian Northern-Central stock’
  - ✓Management principles
  - ✓From early development to the collapse of 1970s
  - ✓Current management procedures
  - ✓Biomass changes versus interannual to decadal climate variability
- ✓Challenges for future scenarios, summary and perspectives

Peruvian anchoveta is a keystone species in the HCS and sustains one of the most successful fisheries worldwide



Colors: Chlorophyll-a
Lines: Oxygen content (micromoles per L) at 100 m depth

The NHCS is the Eastern Boundary Upwelling System with the highest secondary fish production



Chavez et al., 2008, 2009

Anchoveta comprises ca. 80% of the annual landings off Peru and near 30% of those off Chile (Gutiérrez et al., 2017)

Dynamics and productivity of the HCS and Peruvian anchoveta vary at multiple time-scales driven by climate variability

- Evidences from sediment records of paleoclimatic proxies and fish bones and fish scales support glacial/interglacial, millennial, centennial and multidecadal variations of the biomass of anchovy and other fish species (e.g. sardine, jack mackerel, etc)

- Changes in 3-D habitat driven by water mass & oxygenation changes lead to variations in pelagic ecosystem functioning / prey availability and habitat suitability for the Peruvian anchoveta

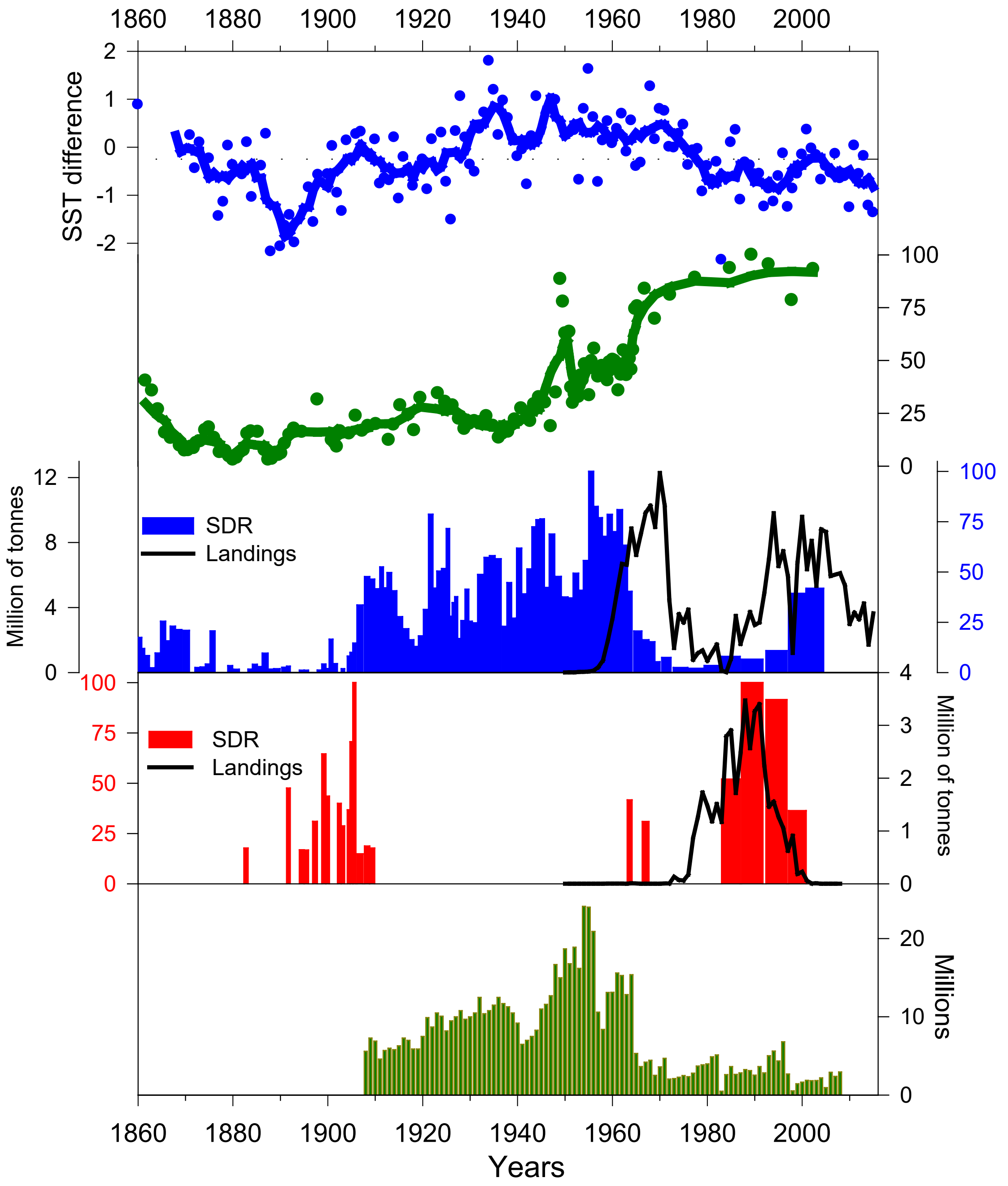
Upwelling Index (COADS)

Export production

Anchovy

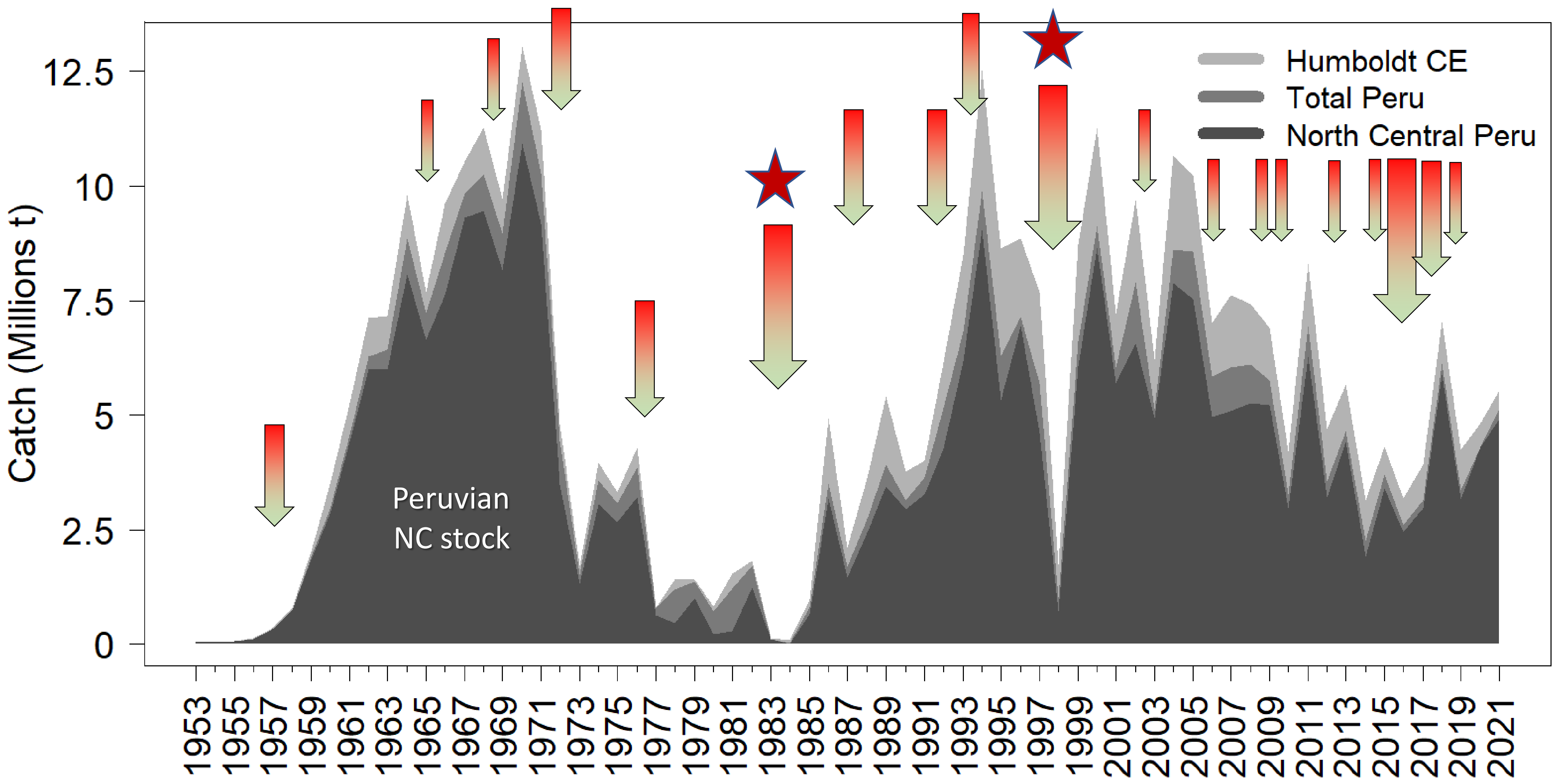
Sardine

Guano birds



Salvatteci et al., 2018 (GCB)

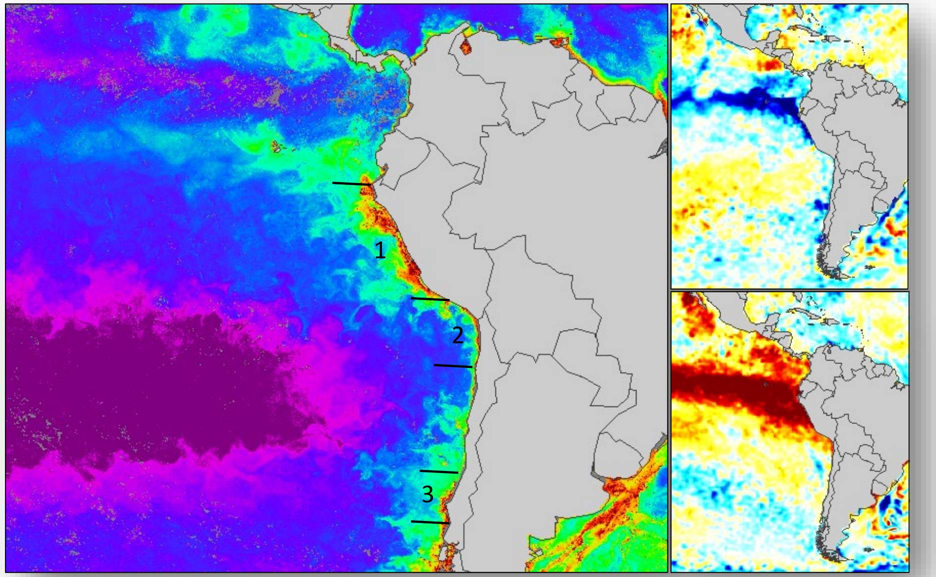
Landings of anchoveta from the Humboldt Current System and El Niño events

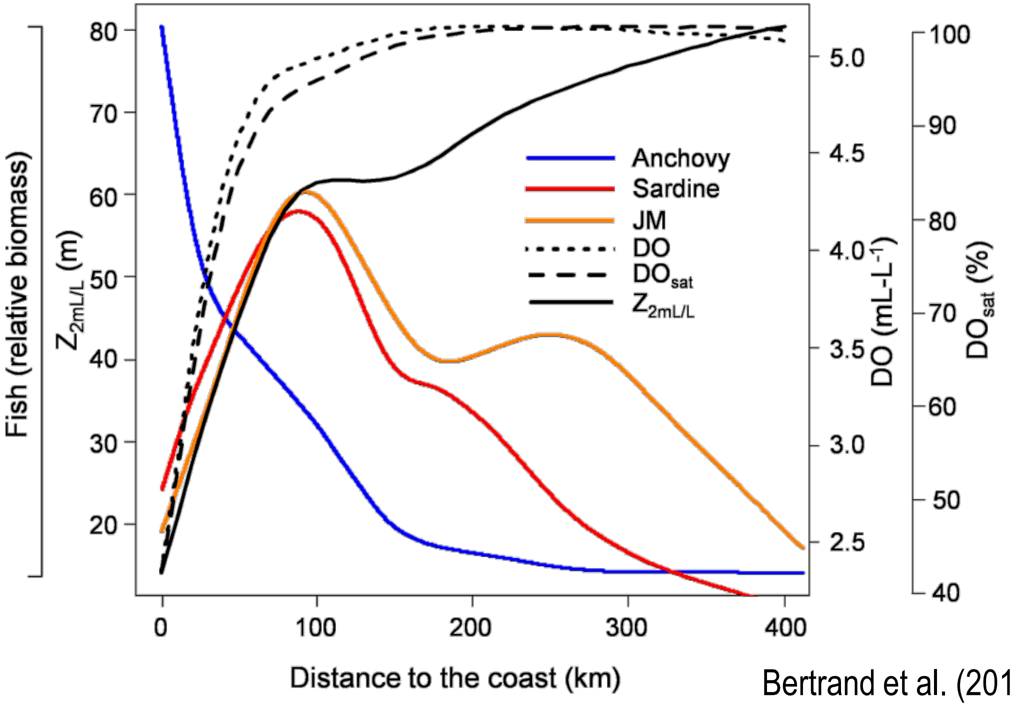


Arrows: El Niño (weak to extreme, according to anomalies in the Niño 1+2 region)

Key biological traits of Peruvian anchoveta to cope with environmental variability

- Small fish (max L ~ 20 cm). High fecundity
- Forage species (main preys euphausiiids and large copepods)
- Short life-span (~ 3 years
- Fast growth (Adult ~ 12 cm ~ 1 year)
- More tolerant to hypoxia than other pelagic species in the realm
- Able to spawn throughout the year-cycle but with two peak periods (summer & winter)
- Ontogenetic changes of its niche

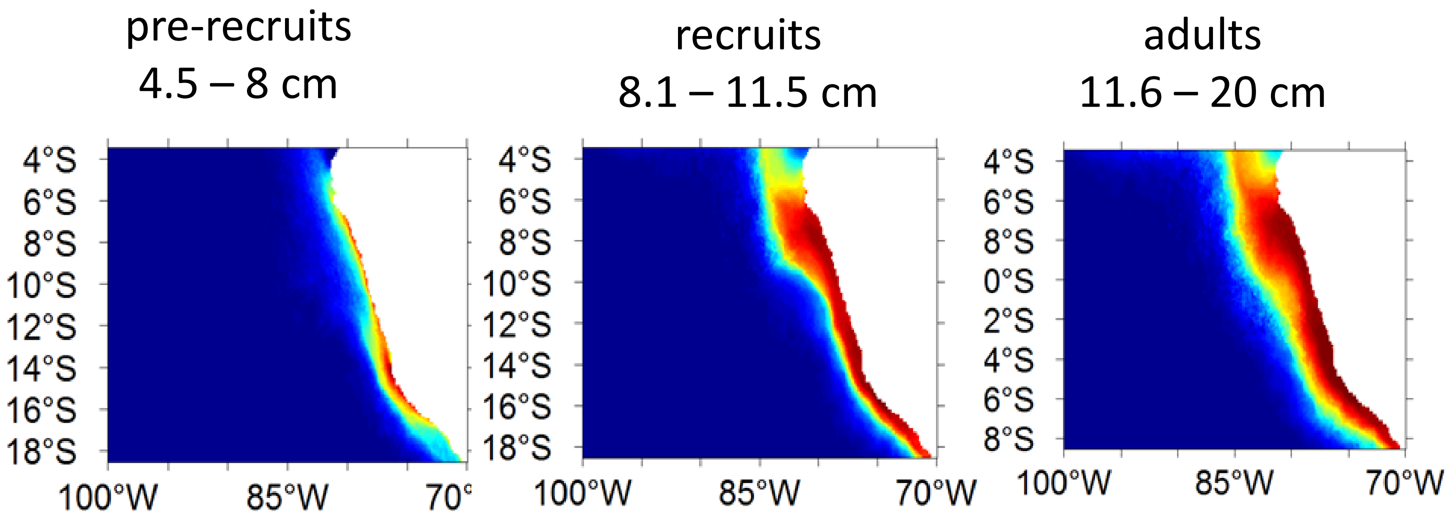




Bertrand et al. (2011, 2016)

Habitat preferences with ontogenia

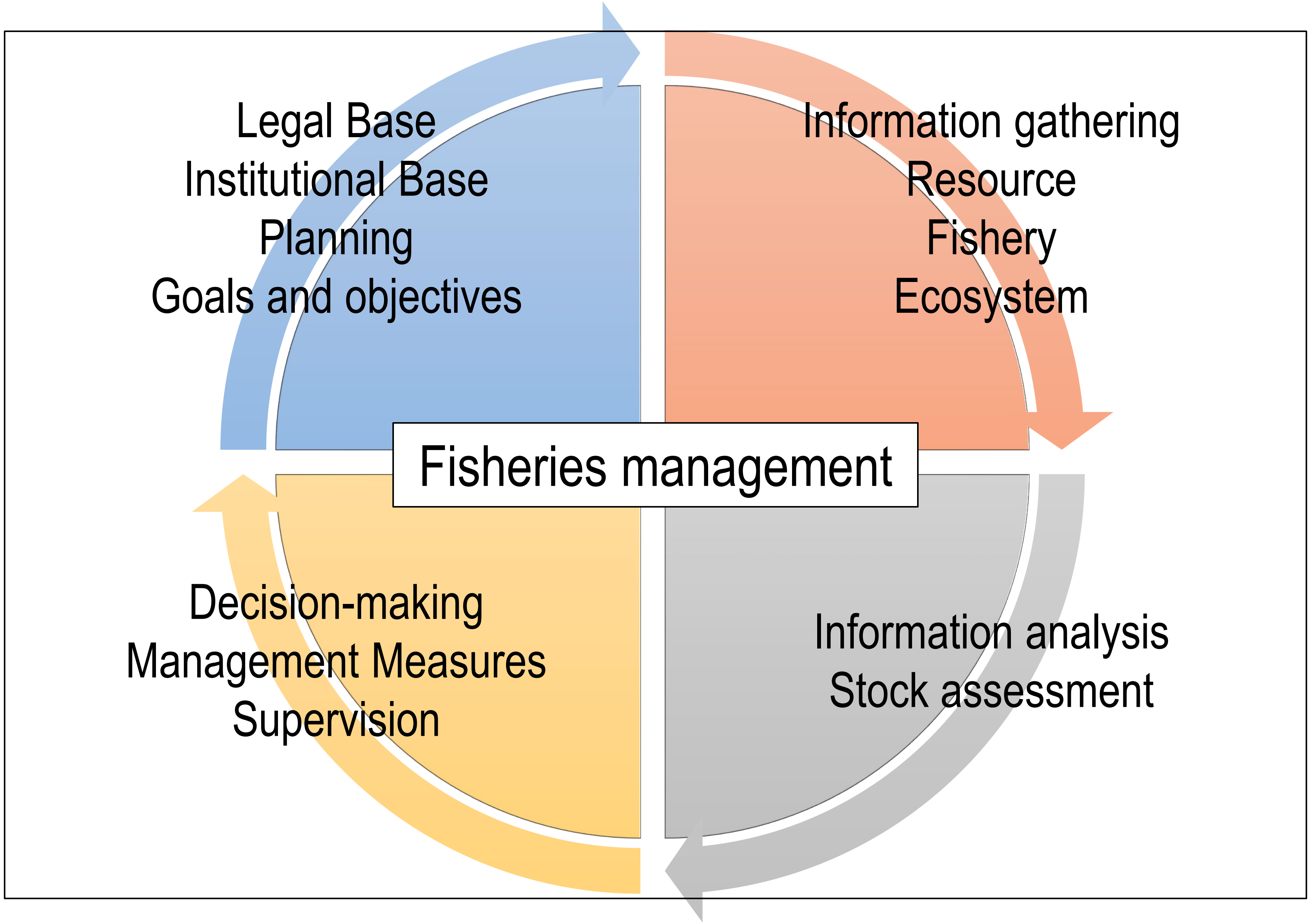
Life stage	Variable	Minimum	Maximum
Pre-recruits	SST	11,7 °C	**18,0 °C**
Adults		12,2 °C	**25,7 °C**
Pre-recruits	SSS	**34,80**	35,15
Adults		**34,50**	35,20
Pre-recruits	Chlorophyll-a	0,5 mg/L	12,9 mg/L
Adults		0,4 mg/L	28,9 mg/L
Pre-recruits	Depth of oxycline	1,2 m	**57,5 m**
Adults		1,0 m	**107,2 m**



An ecological niche model bases on presence/absence data of nearly 50 years (from fisheries and research surveys) indicate ontogenetic changes of potential habitat (Luján, 2016, 2022).

SST is the key limiting factor for pre-recruits, oxygen and SSS are the ones for recruits (not shown) and Chlorophyll-a and SSS are the key factors for adults, with spatial and seasonal patterns.

Fisheries management components



(García et al. 2003, Hindson et al. 2005, Cochrane & García 2009)

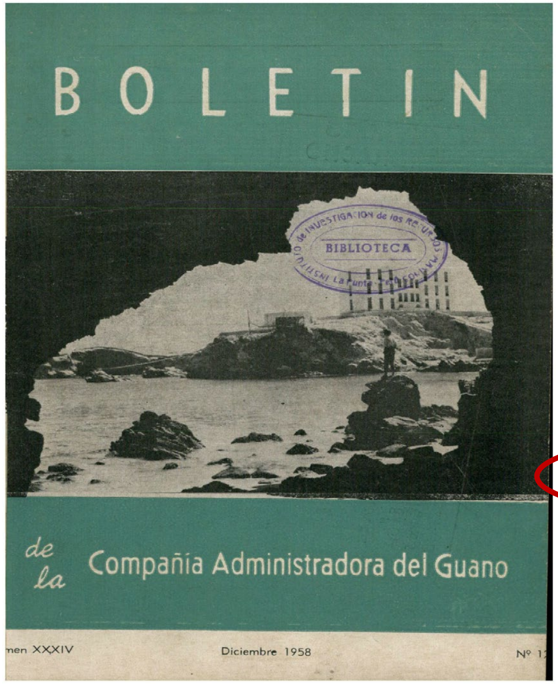
Fisheries and management milestones

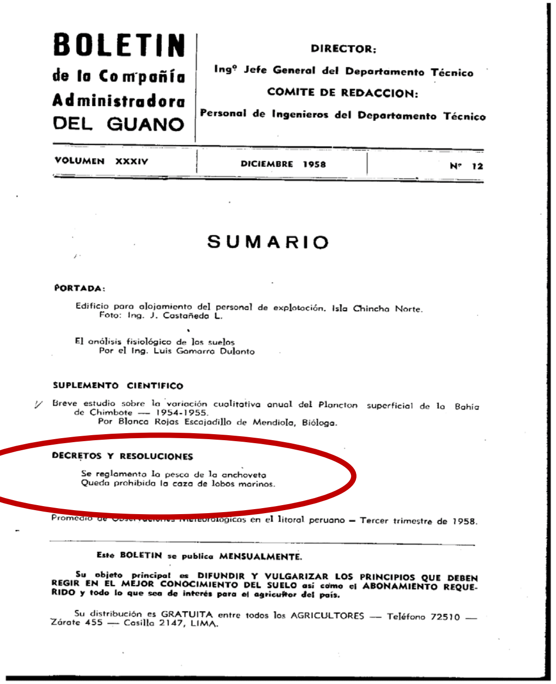
- First landings of Peruvian anchoveta reported in Peru in 1950 (500 tons) and statistics exist since then.

- First regulation measure dates back to dec-1956, in which permissions to build new fish meal factories were halted in order to protect the resource as a precautionary measure.

- A supreme decree was issued on 1958 with first regulations concerning fishing areas, mesh size, provisioing to fish meal factories, law enforcement rules, etc.

- From 1958 to 1959, landings passed from < 0.8 million tons to 2 million tons.





BOLETIN de la Compañía Administradora DEL GUANO

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PORTADA:

Edificio para alojamiento del personal de explotación. Isla Chincha Norte.
Foto: Ing. J. Castañeda L.

El análisis fisiológico de los suelos
Por el Ing. Luis Gamarra Dulanto

SUPLEMENTO CIENTIFICO

Breve estudio sobre la variación cualitativa anual del Plancton superficial de la Bahía de Chimbote — 1954-1955.
Por Blanca Rojas Escajadillo de Mendiola, Bióloga.

DECRETOS Y RESOLUCIONES

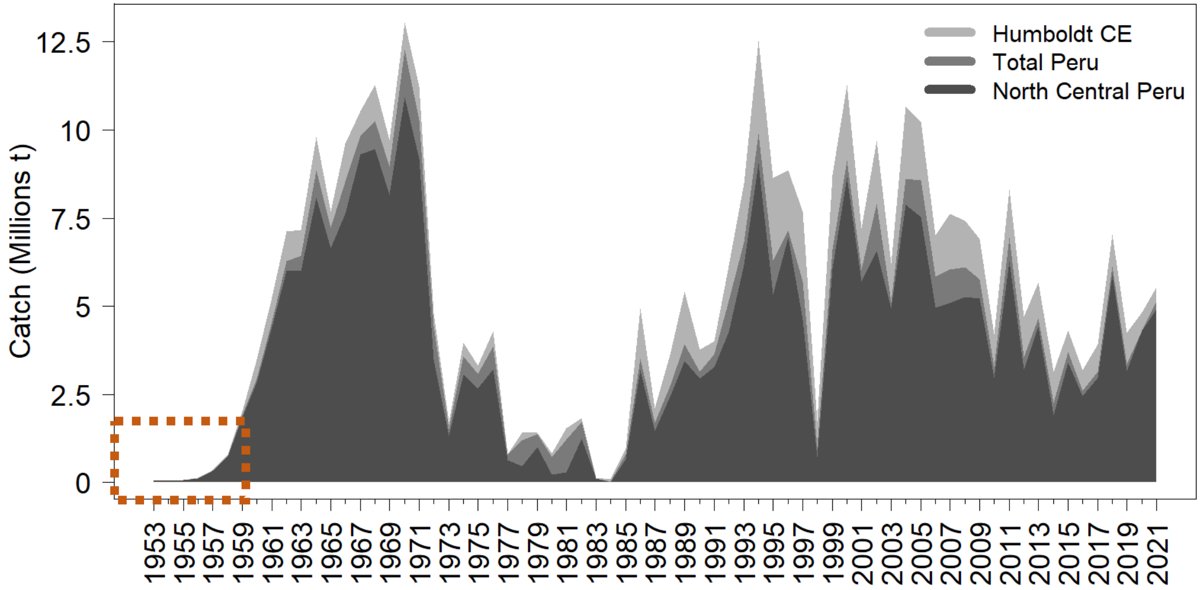
Se reglamenta la pesca de la anchoveta
Queda prohibida la caza de lobos marinos.

Promedio de Observaciones Meteorológicas en el litoral peruano — Tercer trimestre de 1958.

Este BOLETIN se publica MENSUALMENTE.

Su objeto principal es DIFUNDIR Y VULGARIZAR LOS PRINCIPIOS QUE DEBEN REGIR EN EL MEJOR CONOCIMIENTO DEL SUELO así como el ABONAMIENTO REQUERIDO y todo lo que sea de interés para el agricultor del país.

Su distribución es GRATUITA entre todos los AGRICULTORES — Teléfono 72510 — Zárate 455 — Casilla 2147, LIMA.



Primary Legislation - Fisheries Acts

1971 (Decree Law 18810)	1987 (Law 24790)	1992 (Decree Law 25977)
1. Basic norms	1. Basic norms	1. Basic rules
2. The fishing sector	2. The fishing sector	2. Fisheries management
3. The fishing process	3. Aquaculture	3. Fisheries practices
4. Fishing rights	4. Fishing practices	4. Artisanal fishing
5. Fishing incentives	5. Fishing rights	5. Aquaculture
6. Foreign capital	6. Procedures	6. Licenses
7. Fishing communities	7. Sanctions	7. Foreign Fishing
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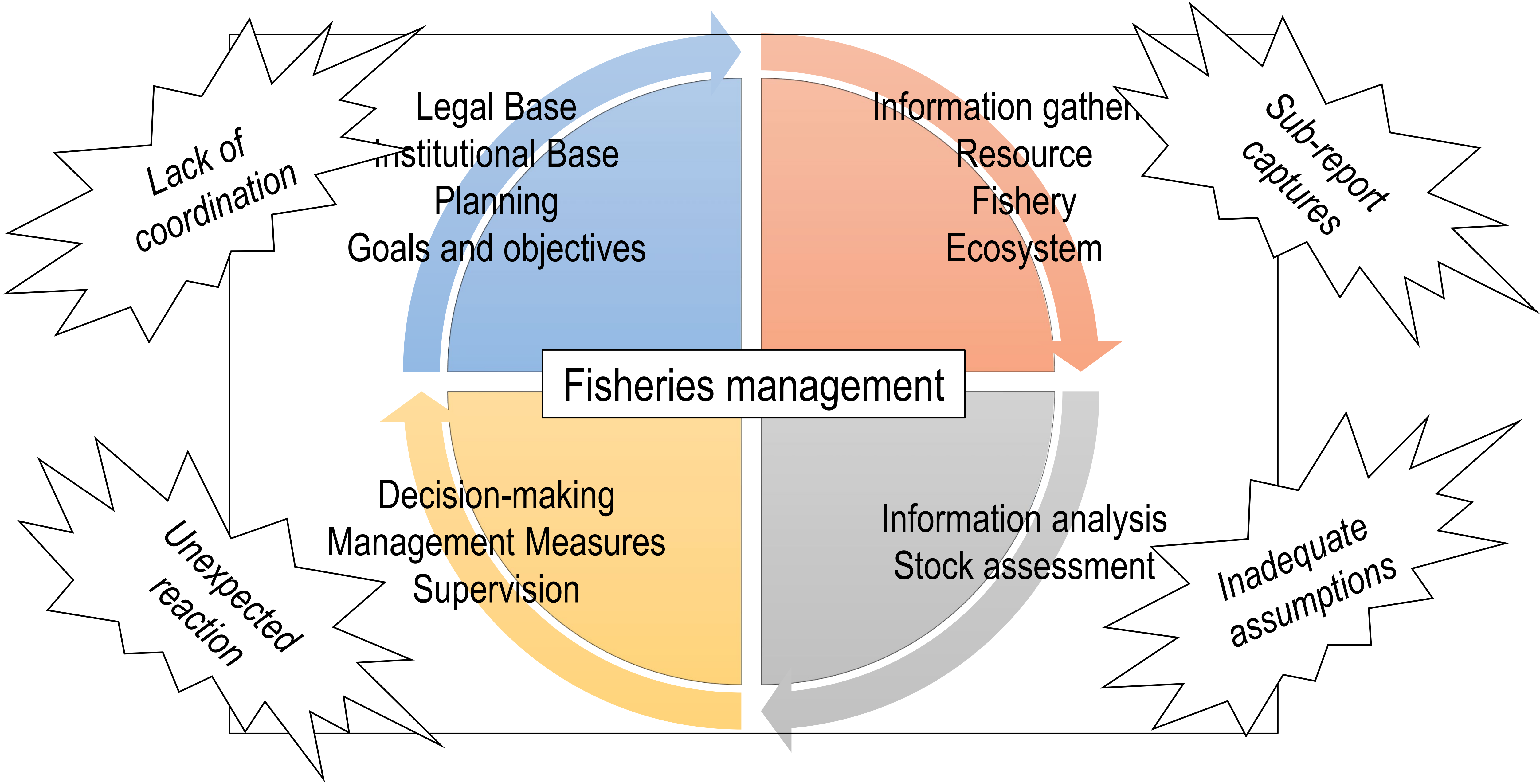
9. Sanctions	9. Incentives	9. Incentives
10. Contracts & records	10. Final provisions	10. Institutional coordination
11. Final provisions		11. Sanctions
		12. Final provisions

The Management: Institutional basis and scientific basis

Year	Institution in charge of Fisheries Management
1946	Directorate of Fisheries - Ministry of Agriculture
1949	Hunting and Fishing Directorate - Ministry of Agriculture
1961	Fisheries Service - Ministry of Agriculture
1969	Ministry of Fisheries
2002	Vice-Ministry of Fisheries - Ministry of Production

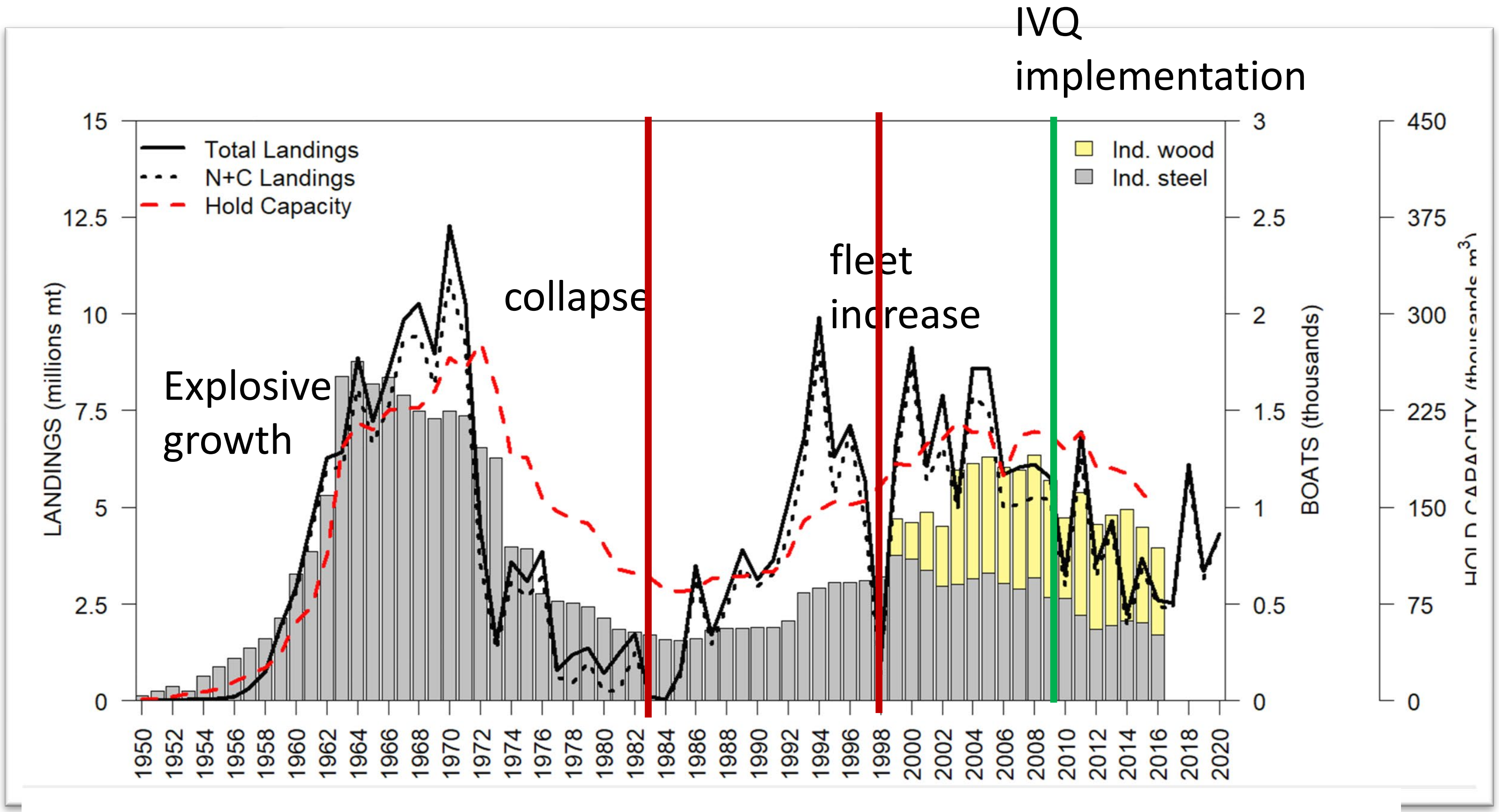
Year	Institution in charge of Scientific Research
1954	Scientific Advisory Committee of the Hydrobiological Research Council
1960	Marine Resources Research Institute (IREMAR)
1964	Marine Research Institute of Peru (IMARPE)

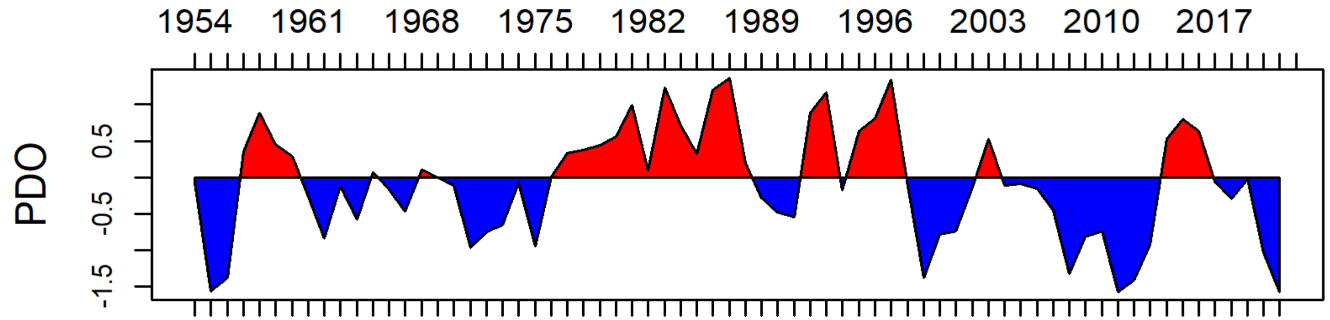
Threats and risks for the management



History of Peruvian anchoveta fishery

- Stock assessments were implemented in the 1960s, but lack of control on the fishing effort aggravated by the occurrence of an El Niño event lead to the collapse of the Peruvian stocks by 1972.
- Adverse environmental conditions contributed to a low-anchovy period that lasted 20 years.
- **Since the recovery of the resource in 1993, until present, reproductive closed seasons were applied.**
- By 2009, individual quotas were implemented to modulate the overcapacity of the fleet and the overall impact of fishing on the PA biomass.





Current management procedures

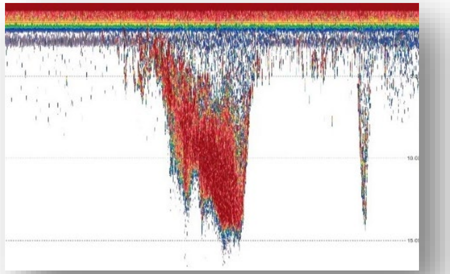
Quotas

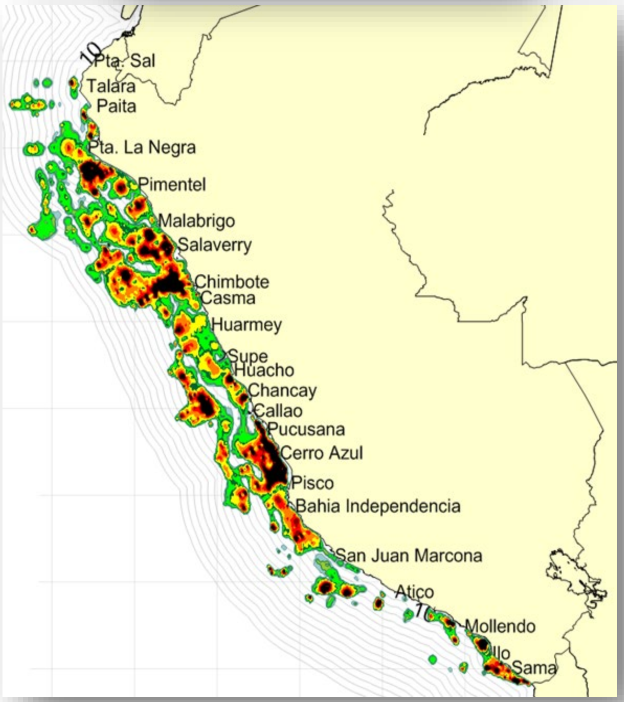
(global and Individual)

Protection of juveniles

Protection of spawning process

- Acoustic surveys, twice a year
- Estimate the biomass, age structure, reproduction, condition
- Projection of biomass under different exploitation scenarios





Other ecosystem components

Current management procedures

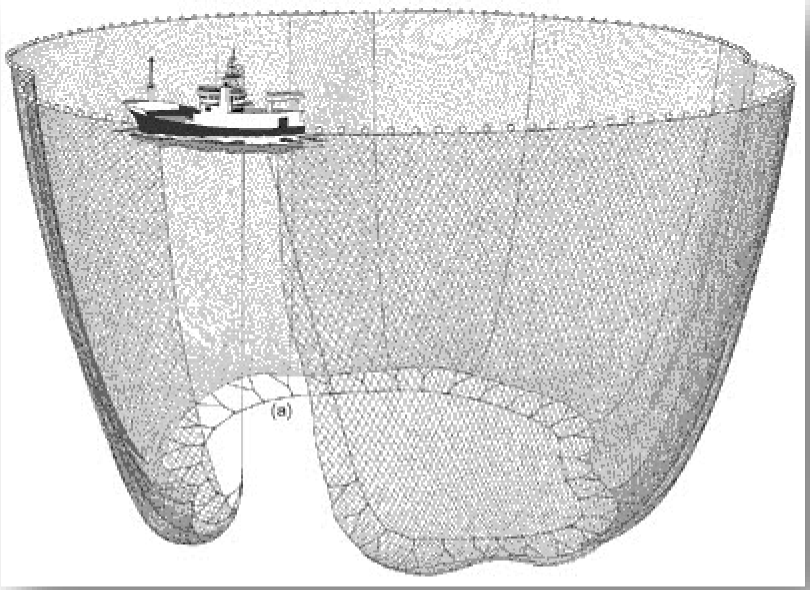
Quotas

(global and Individual)

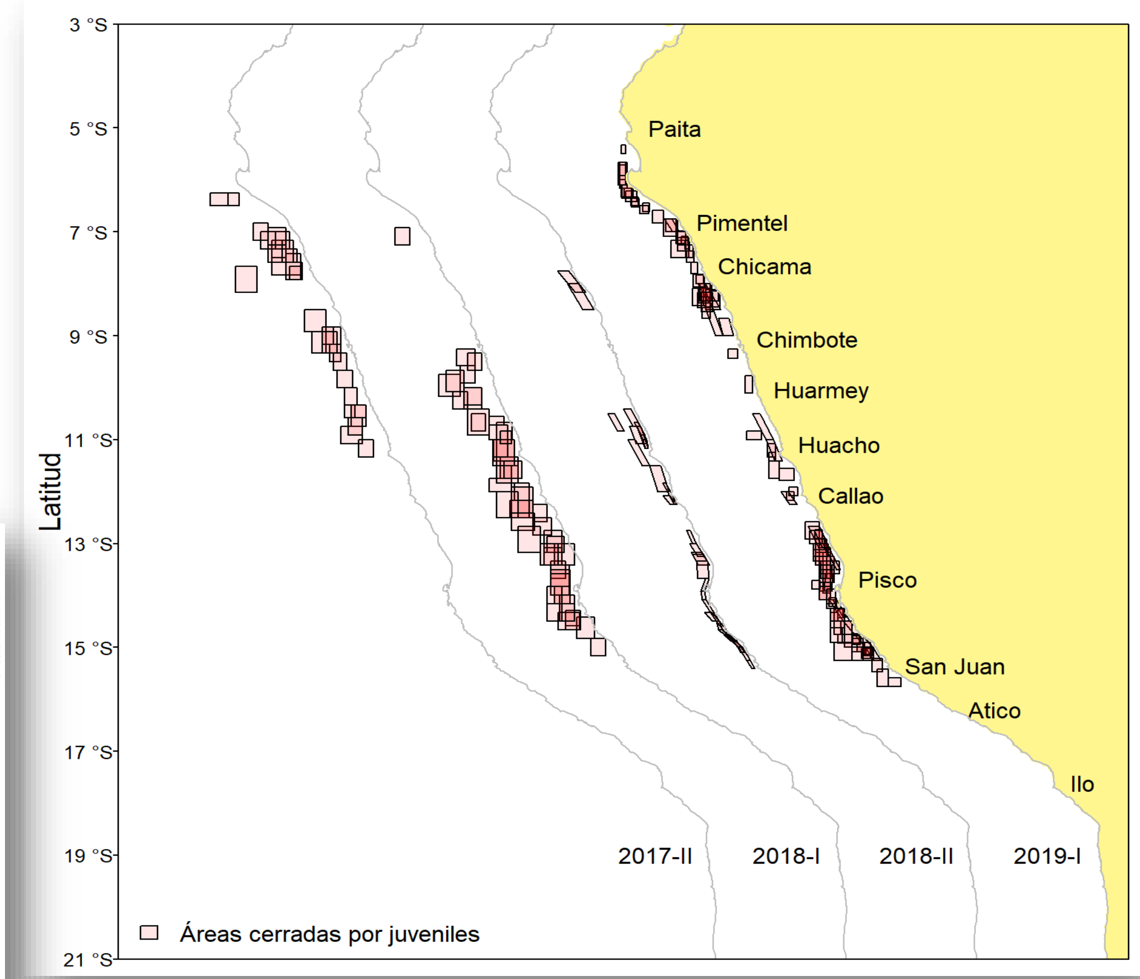
Protection of juveniles

Protection of spawning process

- Mesh size 13 mm
- Tolerance
- Space-time closures
- Quota of juveniles



In practice



Current management procedures

Quotas

(global and Individual)

Protection of

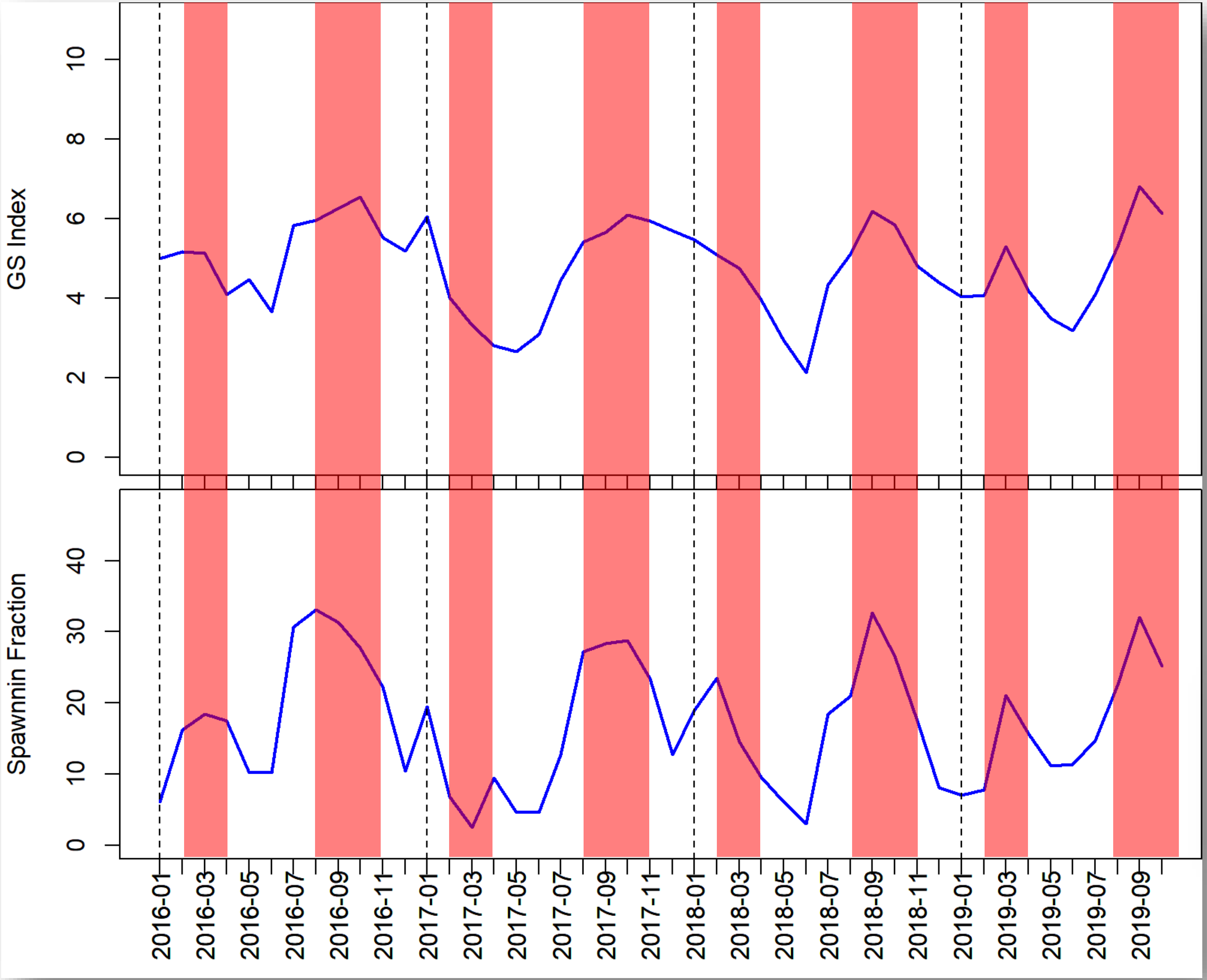
juveniles

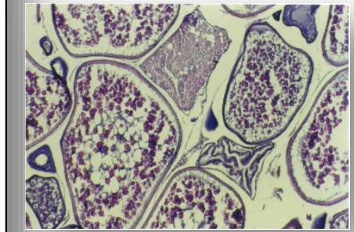
Protection of

spawning process

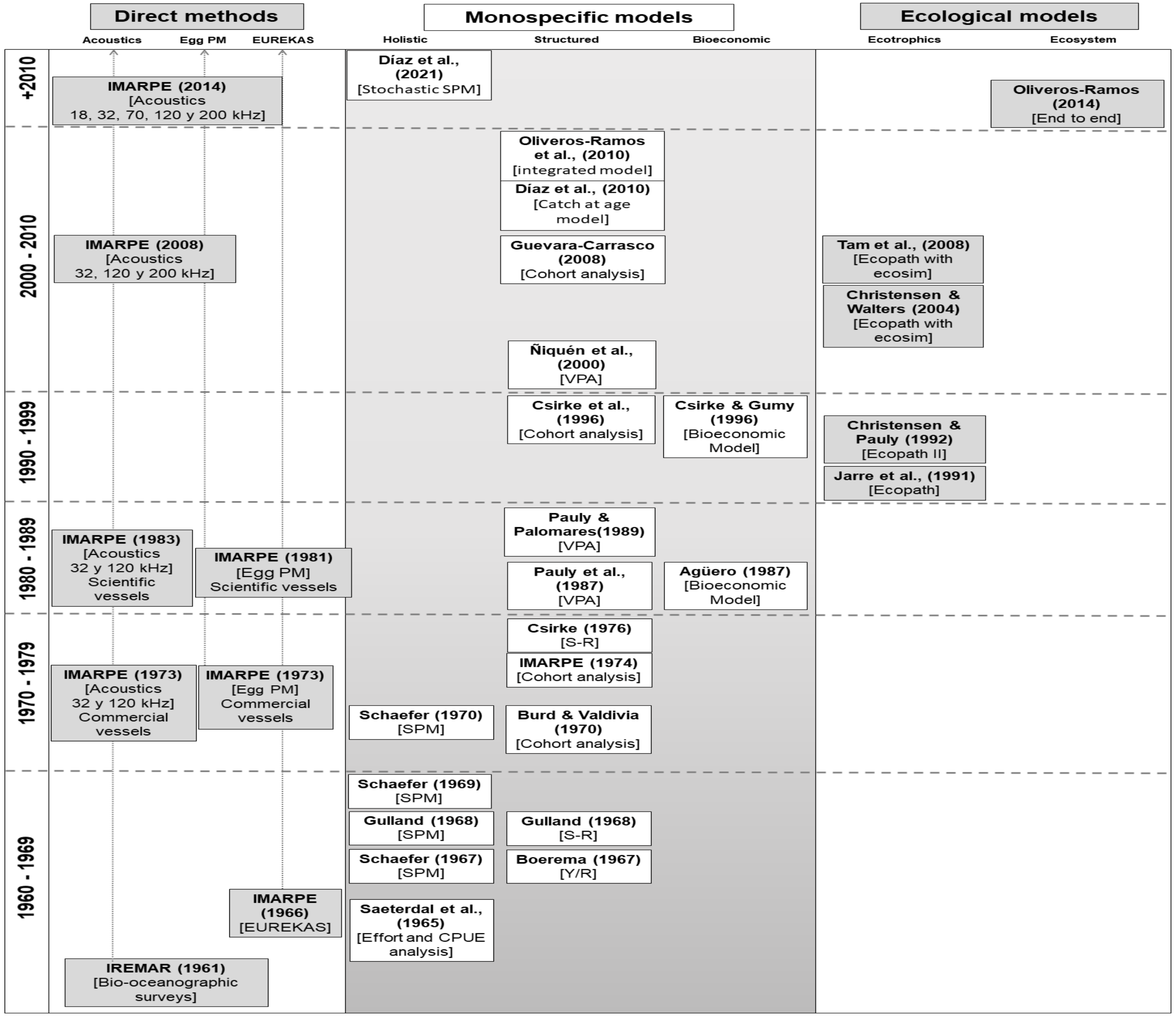
- Spawning twice a year, protected by closed seasons

In practice



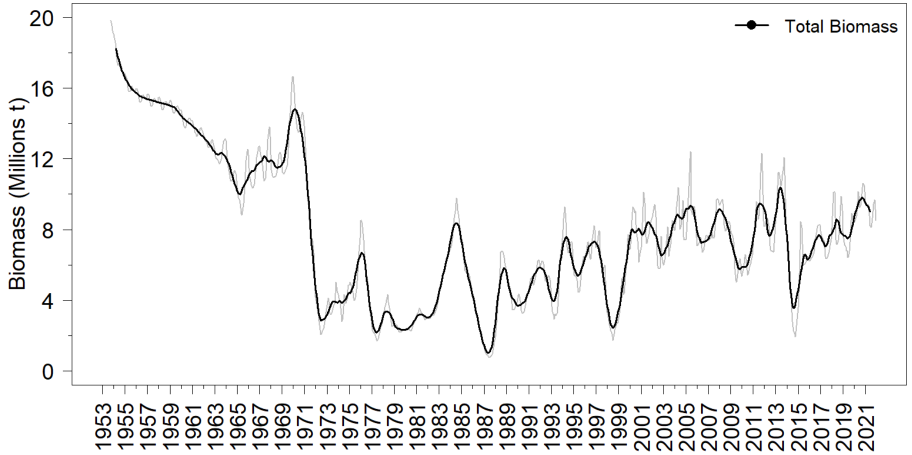


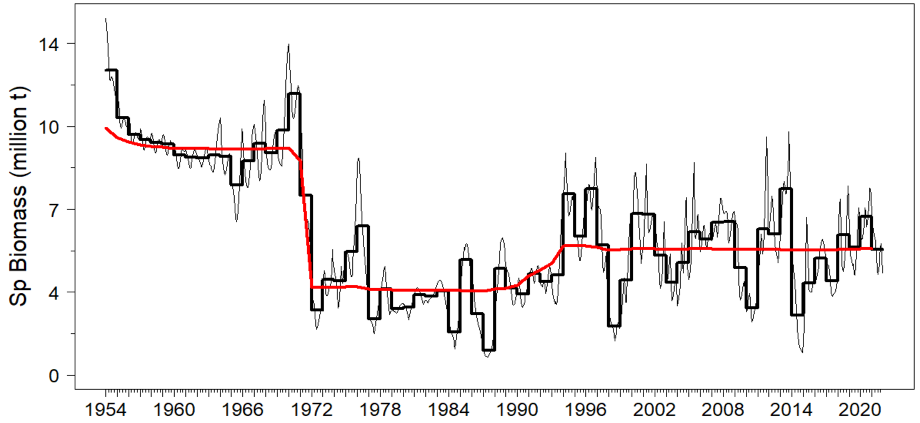
Stock assessment and ecological modelling through time

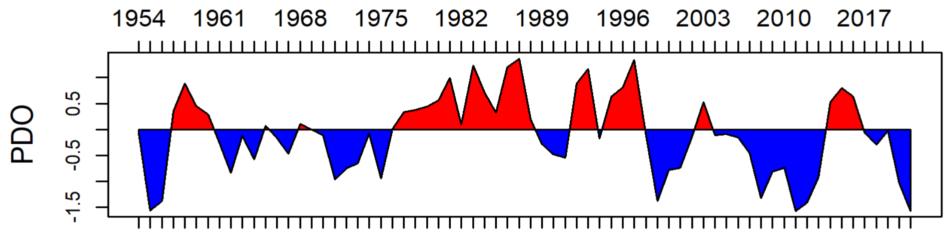


Biomass estimations (NC stock)

- Stochastic surplus production model in continuous-time (SPiCT) (Díaz, 2022; based on Pedersen and Berg 2016)
- Three periods are defined at interdecadal scales: 1953-1971 (high biomass), 1972-1993 (low biomass), 1994-2021 (medium biomass).
- Interdecadal changes of mean biomasses match with interdecadal Pacific oscillations. Warmer period was characterized by a deeper oxycline near the coast, and lower abundances of large zooplankton.
- Contrary to catches, biomass values in the latest period remain stable.

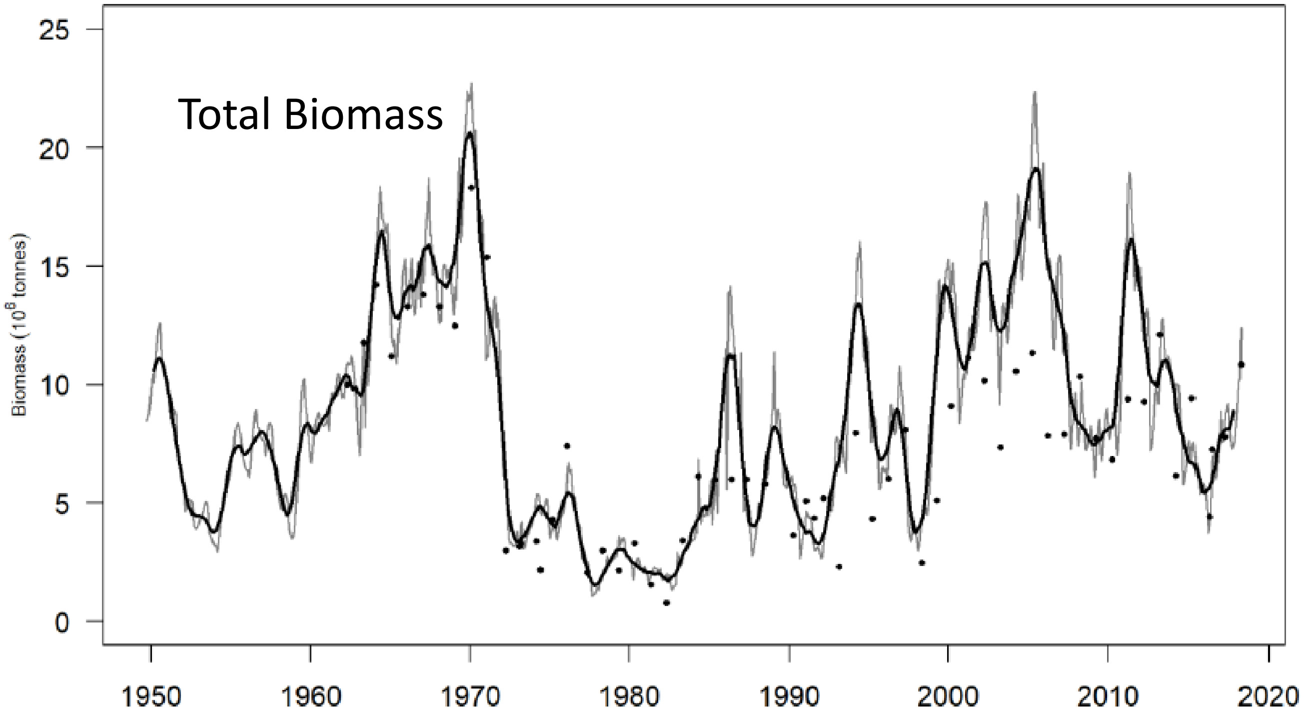




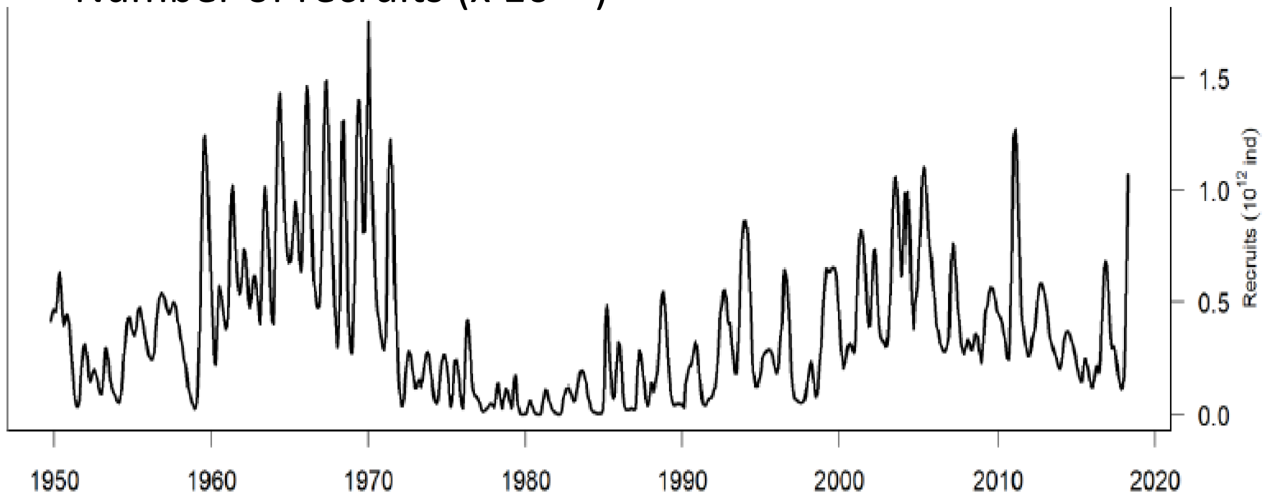


Biomass estimations (NC stock)

- A new length-based model adapted to the population dynamics of anchoveta has also been developed by Oliveros-Ramos (EBUS Conference, 2022), based on:
  - Partial spawning: time and duration of spawning peak is modeled interannually to improve the recruitment representation.
  - Environmental variability of life history: mortality (estimated), growth, condition factor (forcing)
  - Decadal variability: explicit estimation of regime shifts and its impact on population dynamics.
- The three periods are also distinguishable. First period exhibit an upward trend since the 1950s to 1970). The latest regime starts in the early 1990s as well, exhibiting intermediate recruits' numbers as compared with the two previous periods.

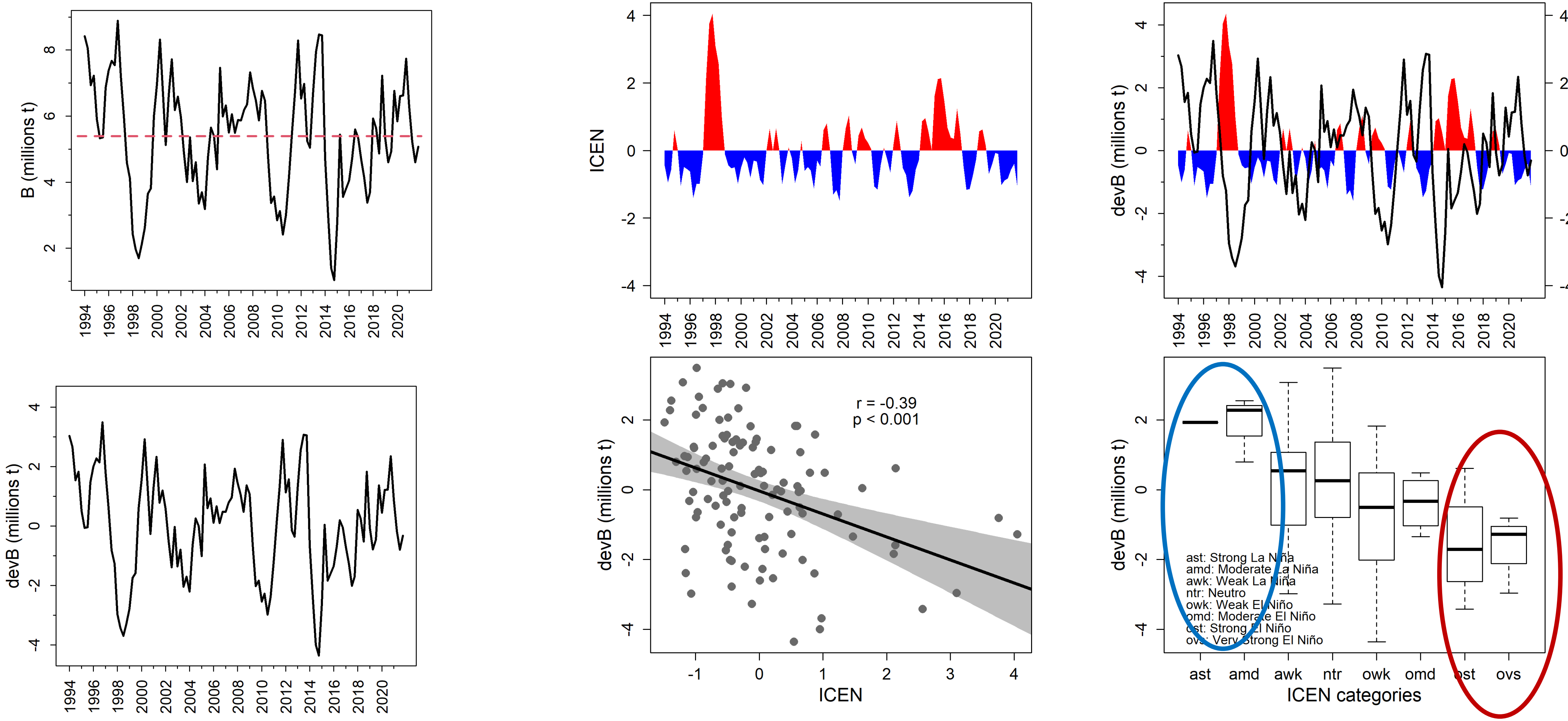


Number of recruits (x 10^{12})



ENSO vs anchoveta biomass (NC stock, 1994-2021)

Díaz, 2022



Negative correlation but with strong scattering. Clearer differences between strong/strong+ EN and LN conditions. Consistent with ENSO vs reproductive activity índices (significant positive/negative impacts with very strong LN and EN, respectively (Cubas, this meeting).

Latest developments

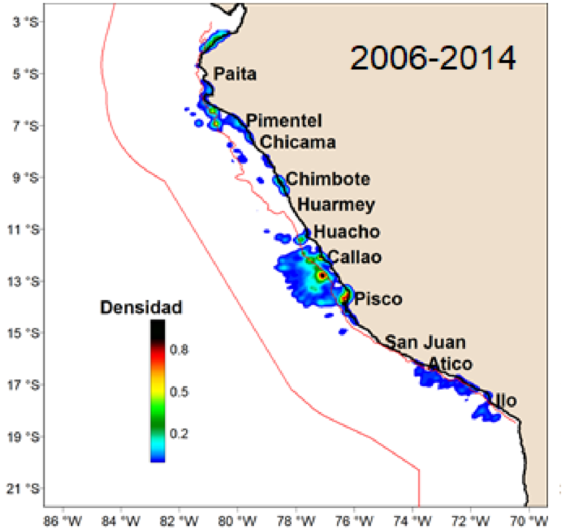
- In the last 5-7 years, an increase in the proportion of juveniles (and a diminution of adults' abundances) have been observed in the shared stock of Peruvian anchoveta between Peru and Chile.

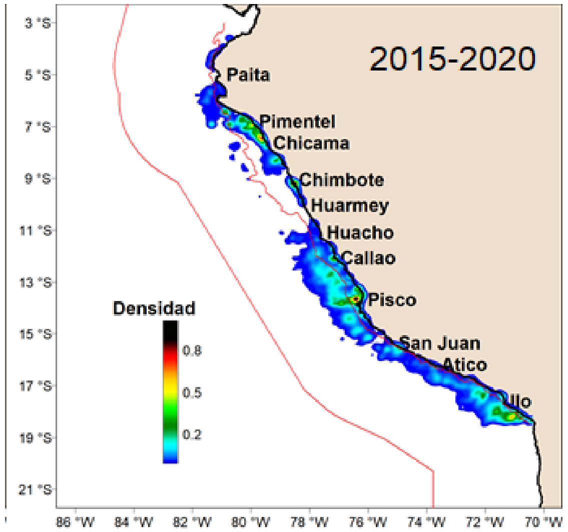
- There are evidences of demographic changes in the Chilean part (workshop IFOP-IMARPE in early 2022); not conclusive off Southern Peru.

- When present, Peruvian anchoveta juveniles off southern Peru are restricted very close to the coast.

- Fishing activity has declined since there are not sufficient adults

- Other potential explanations: good recruitments but lack of detection of adults (offshore? migration?); increased predation of adults? A natural predator of Peruvian Anchoveta has increased its abundance mainly off Southern Peru, where subtropical surface waters are closer to the coast (Marín et al., 2022 EBUS Conference).



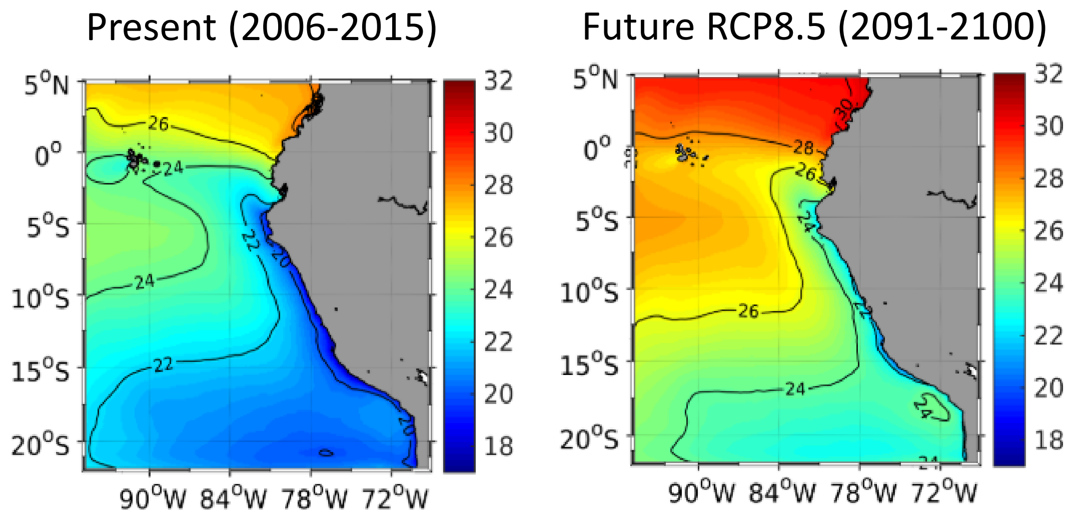


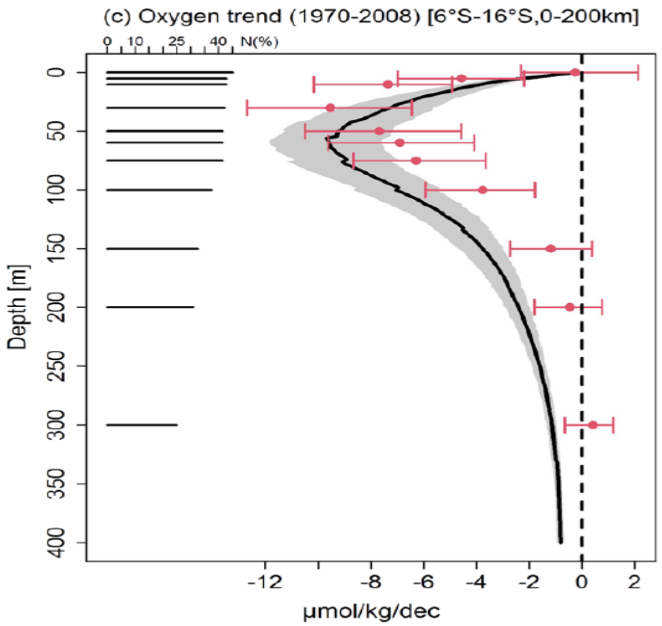
Distribution of the fishing areas obtained by the artisanal fleet aimed at capturing bonito *Sarda chiliensis chiliensis*, according to the moments of change observed in monthly landings in 2006-2014 and 2015-2020. The color densities of the fishing effort are relativized from 0 to 1 and were generated using Gaussian kernels.

Challenges under trends and future scenarios

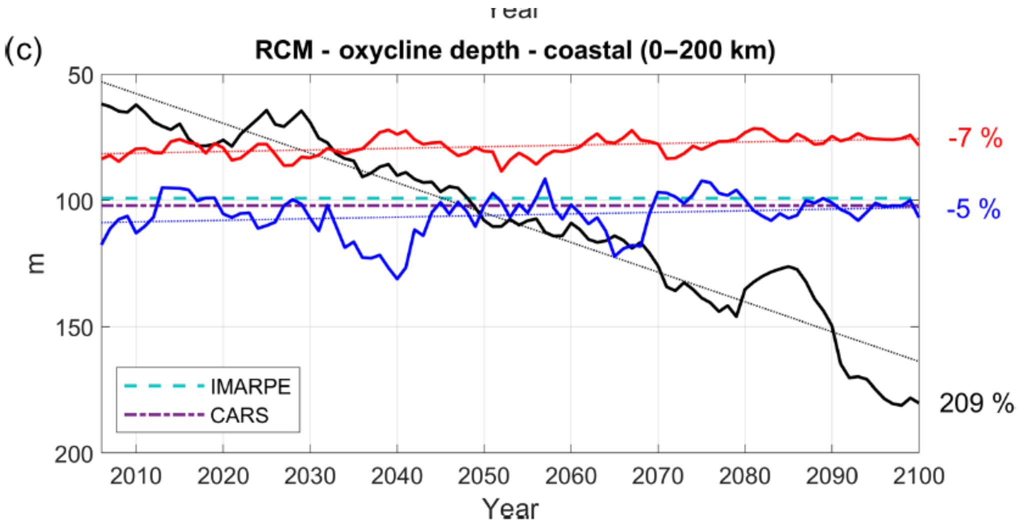
- Current projections of climate models indicate SST would increase in 2 to 4.5 C by the end of the century off Peru, accompanied by stronger stratification and less-efficient coastal upwelling (Echevin et al., 2020).

- Observed trends indicate a subsurface deoxygenation in the Peru upwelling, moving upward the oxycline, BUT… future scenarios are still uncertain (strong disagreements among models).





Espinoza-Morriberon et al, 2021



Echevin et al., 2020

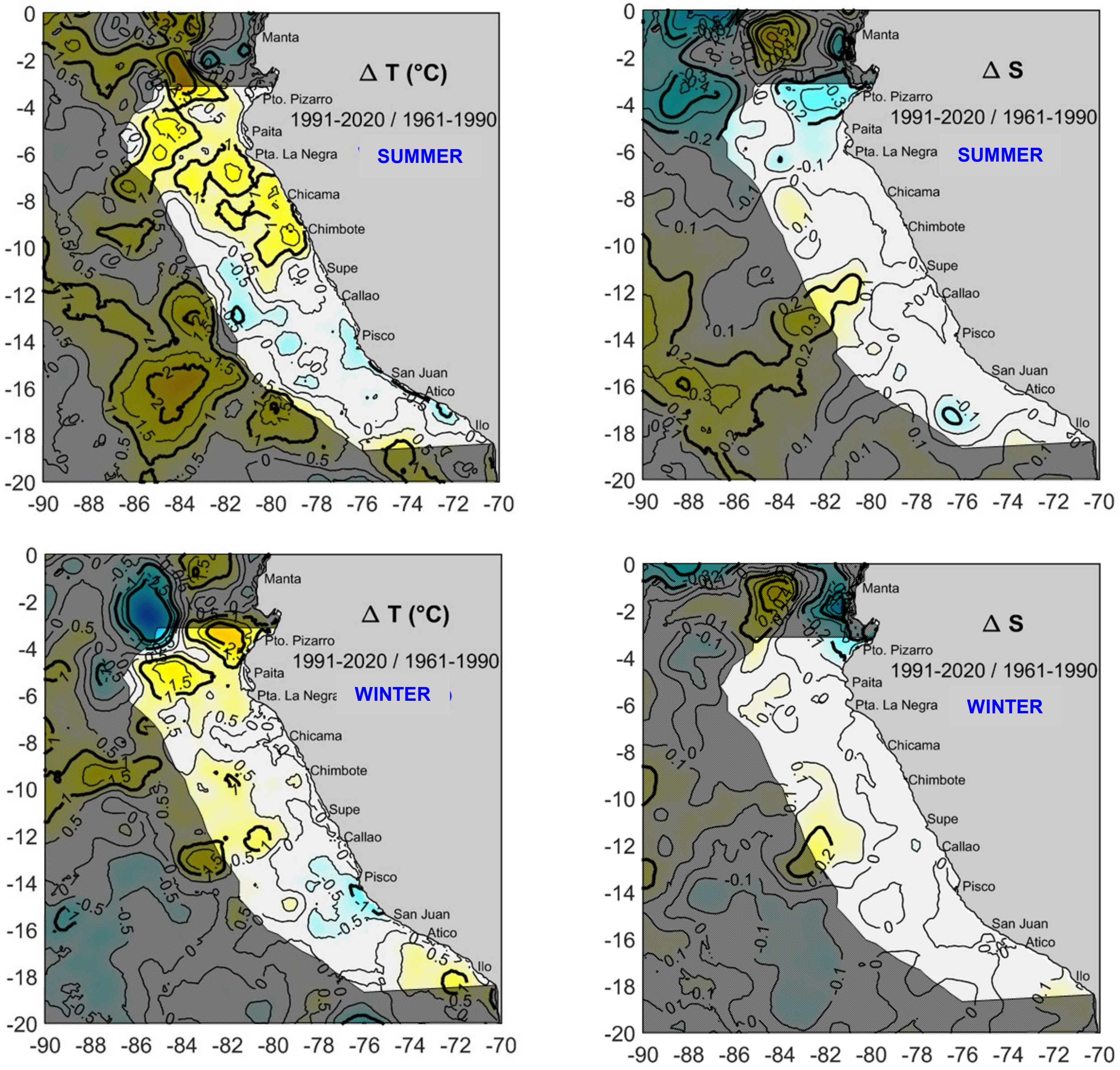
Challenges under trends and future scenarios

- Comparison between 30-year climatologies of SST and SSS off Peru (1991-2020 vs 1961-1990) indicate:

  - During summers, warmer and fresher waters off Northern Peru (increased presence of low-productive Equatorial waters). Off Central Peru, high-salinity Subtropical Surface waters (SSW) approach to the coast.

  - During winters, warming pattern off the north continues, but also off Southern Peru. SSW approach to the coast off Central and Southern Peru

- Taken together these observations (TSO) suggest a shrinking trend of the potential habitat for the Peruvian anchoveta



Summary and perspectives

- The history of the Peruvian anchoveta industrial fishery started in 1950 and its fishery management, as defined by the activities of monitoring, stock assessment and decision-making, were proggresively implemented during the development phase (1950-1963).
- The collapse of the 1970s left major lessons for the management, which led to more protective/precautionary measures that have permitted the sustainability of the industrial fishing since its recovery.
- Implementation of individual quotas have decreased the fishing pressure for the resource. Downward trends of anchoveta landings off Peru do not reflect the stability of the biomass.
- Current trends and some projections indicate a risk for the habitat suitability and hence carrying capacity of the system for anchoveta production, particularly under more pessimistic scenarios. However it is expected that climate variability (e.g. ENSO) will still be the main environmental forcing until the mid-XXI century (Gutiérrez et al., 2019).
- The new scenarios demand further adaptation measures both in the management but also from the stakeholders. These measures should aim to maximize the added value for fish production, promote the direct human consumption, and make a responsible use of the potential new fishery resources.
- Challenges are also for research in order to improve science-based decision making: ontogenia, bioenergetic modelling and genetic diversity are some of the fields that deserve stronger efforts.

Acknowledgements

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