The Southern boundary current system: how the Climate Change impacts the atmospheric circulation, ocean, and fisheries (SW South Atlantic Ocean)

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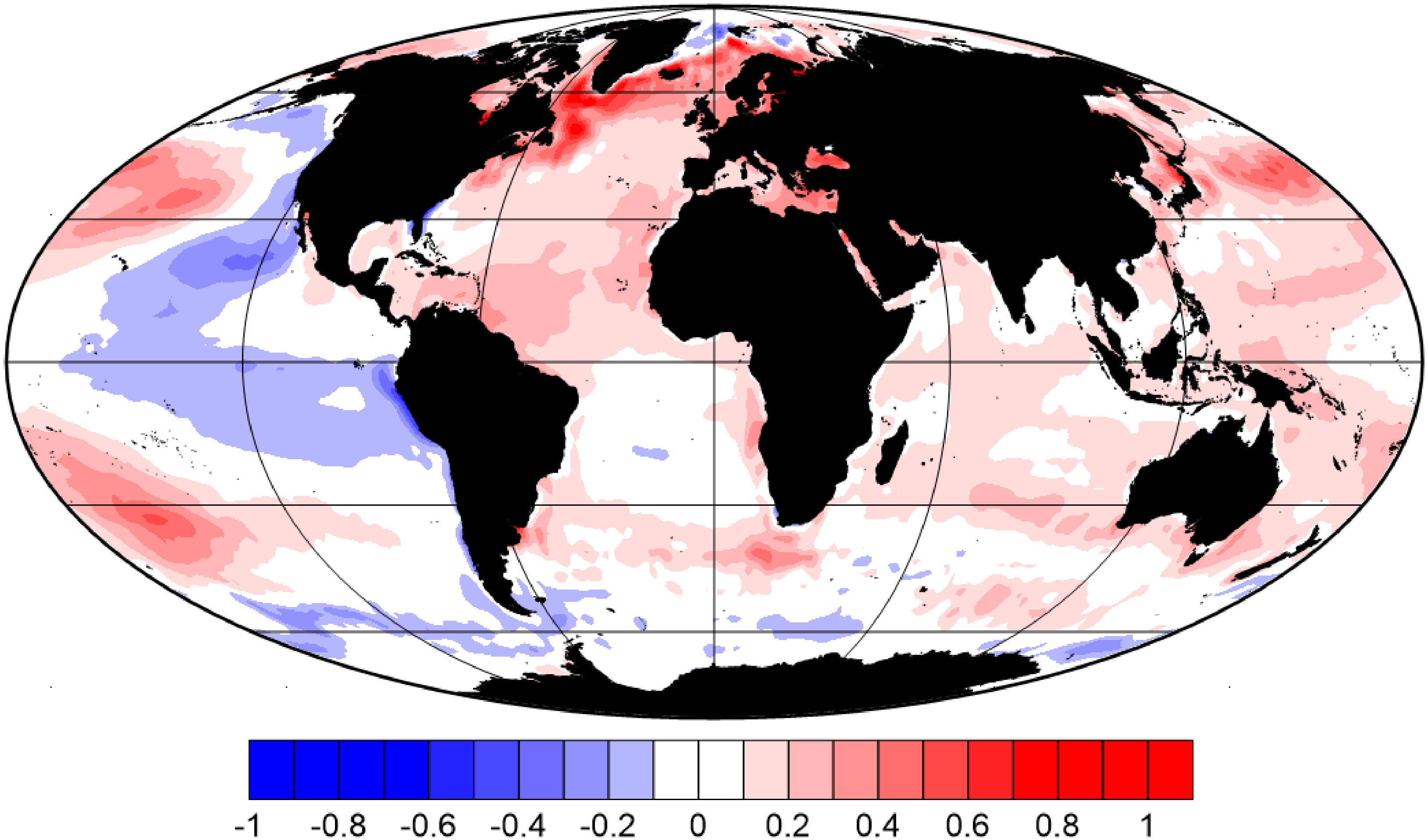
Inhomogeneous warming (global scaling)

Sea Surface Temperature **(SST)** trend (°C/decade)



Climate change and subtropical WBCs warming

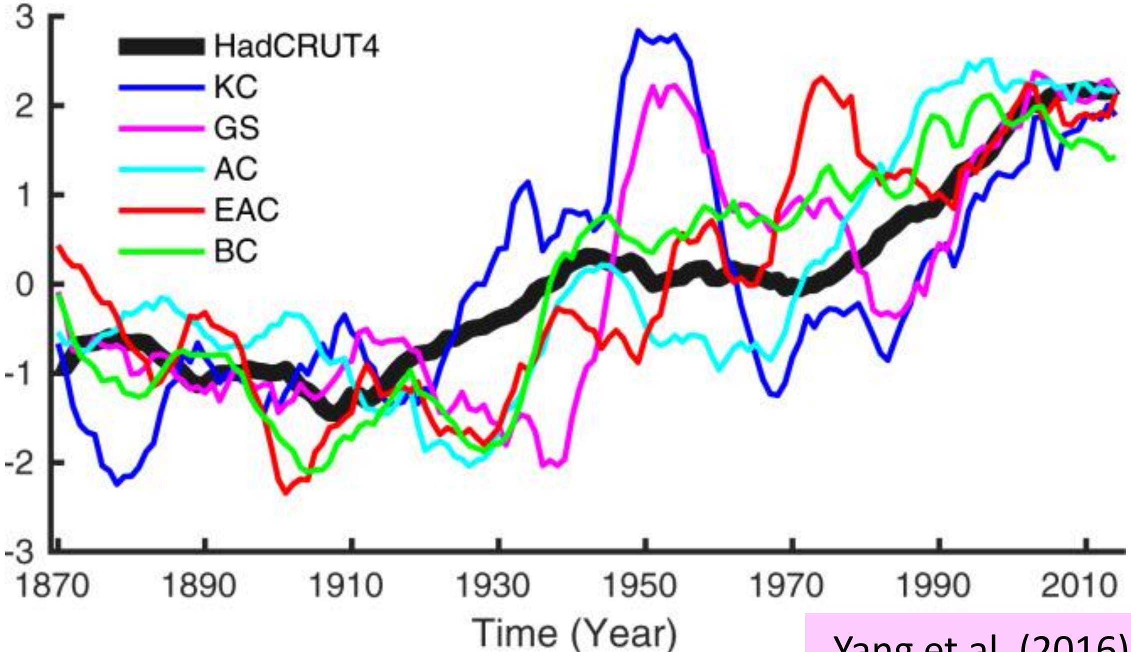
- During the past decades, a consistent **poleward shift of the major subtropical ocean gyres driven by climate change has been reported**, and a **stronger surface ocean warming trend** has occurred over the subtropical **western boundary currents of the oceans (WBCs)**.

- **Why is there a stronger surface ocean warming trend over the path of subtropical WBCs?**

- Because they are **warm, fast-flowing currents** that form on the western side of ocean basins. **They carry warm tropical water to the mid-latitudes** and vent large amounts of heat and moisture to the atmosphere along their paths.

- The accelerated warming is associated with a synchronous poleward shift and/or intensification of global subtropical **WBCs** in conjunction with a systematic change in winds over both hemispheres.

In the **South Atlantic Ocean**, a poleward displacement of the subtropical gyre at a rate of 0.11°/decade has been observed, and the **subtropical WBC** - the Brazil Current (**BC**) - has been reported as one of the most extensive and **intense surface warming hotspots in the global ocean.**

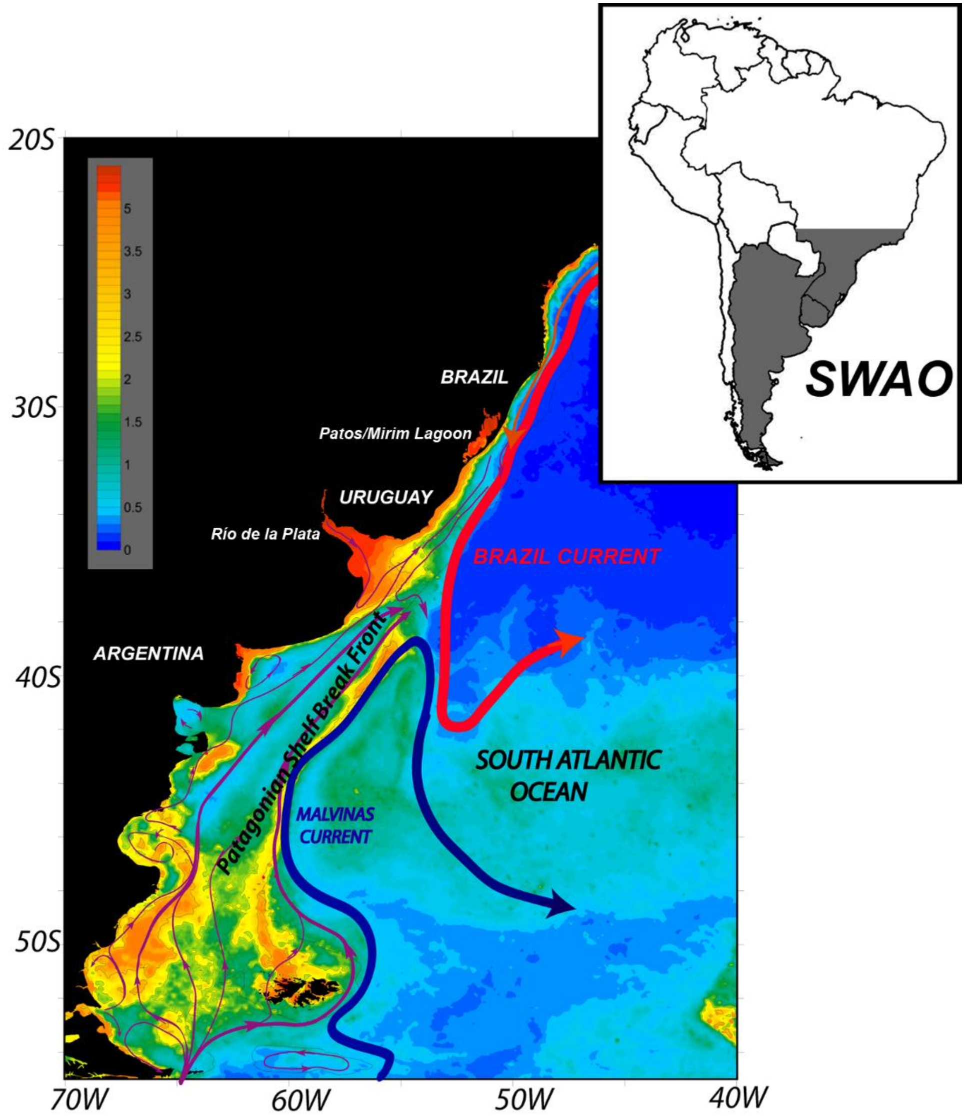


Yang et al. (2016)

SST indices of the five **WBCs** after removing the globally averaged **SST** anomaly.

Positive trends are observed, indicating that the **ocean surface warming over the WBCs is outpacing other regions.** Moreover, the **SST** indices of **WBCs** share similarities with the global warming signal.

Southwestern South Atlantic Ocean (SWAO)



Subtropical warm waters are carried southward by the **Brazil Current** along the shelf break, while **subantarctic cold waters** are advected northwards by the **Malvinas Current**.

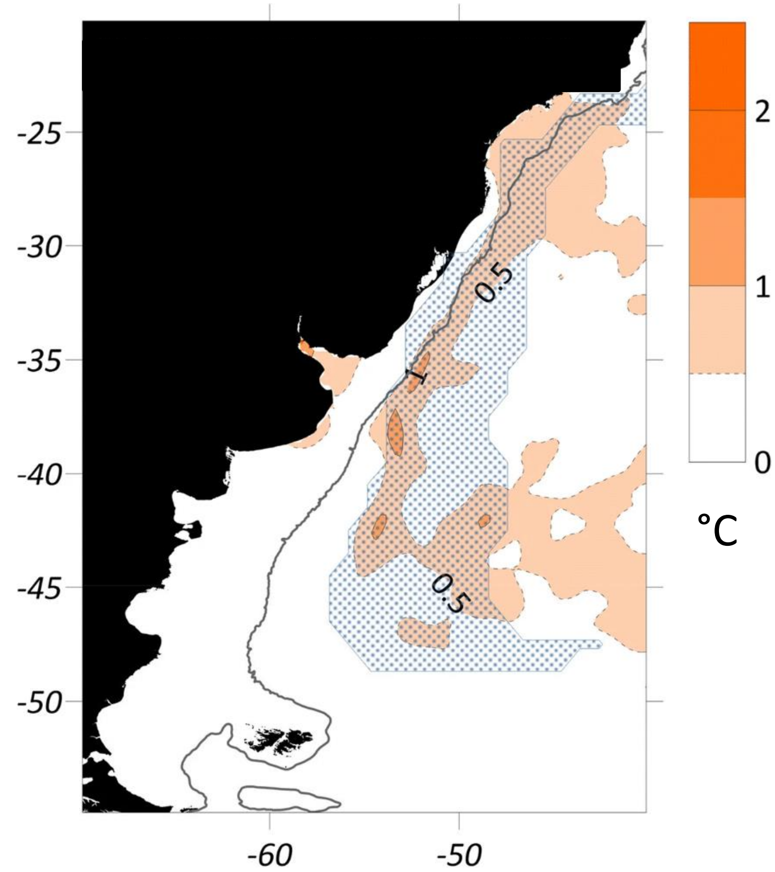
Their confluence (**BMC**) is marked by an array of strongly contrasting water types that define a very energetic and complex region.

Additionally, the **Río de la Plata estuary**, the major freshwater discharge in the area (average discharge of 22.000 m^3s^{-1}), injects buoyancy and nutrients.

Marine hotspots are regions where the **SST** has increased most fast over the period 1950−2000 and are projected to continue changing at a faster rate than the global average (Hobday & Pecl 2014).

As marine species respond to ocean warming, **these hotspots could affect the distribution, abundance and life history traits of fish and invertebrates, thus affecting catch levels and fisheries targeting traditional resources.**

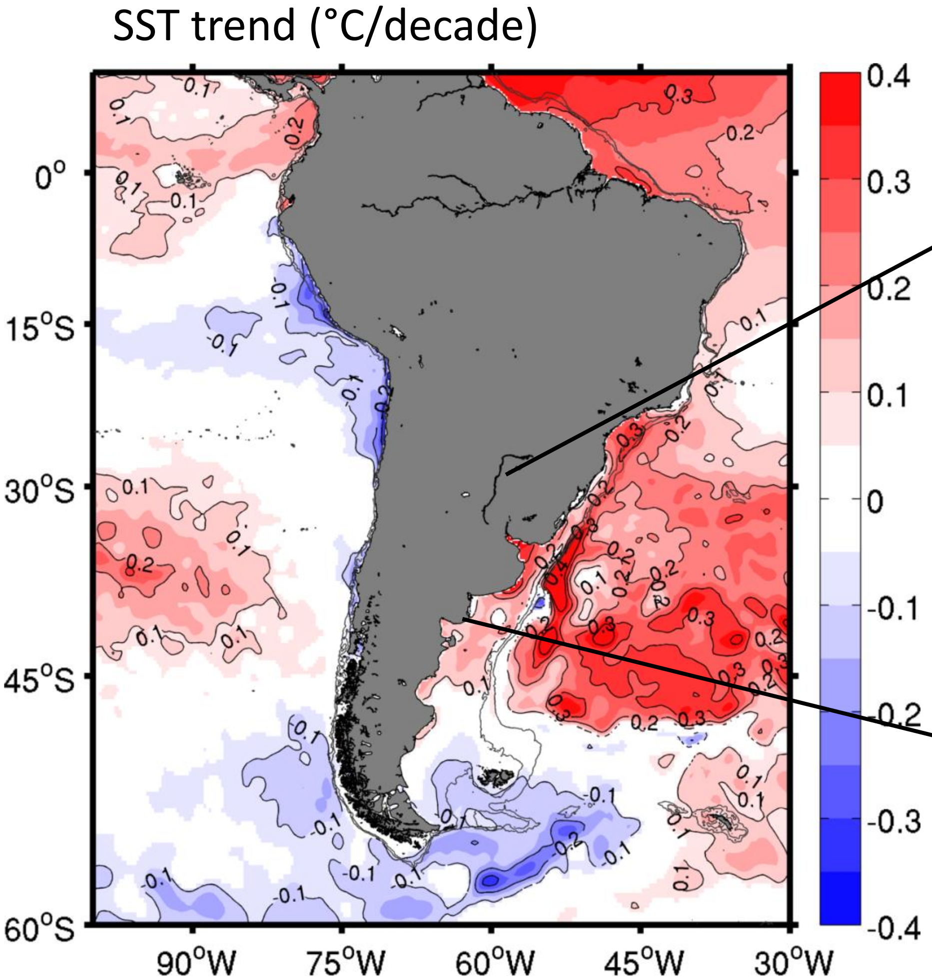
Several approaches have been applied to understand and project impacts of climate change in fisheries.

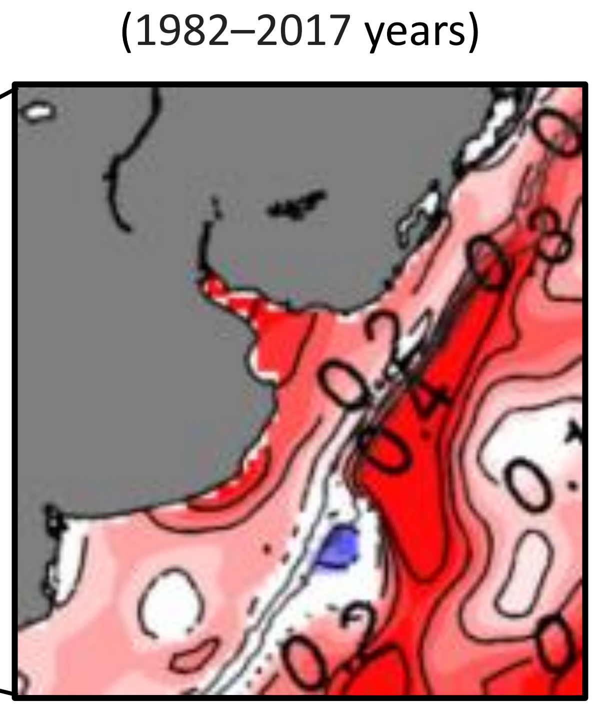


Franco et al. (2020a)

The Southwestern South Atlantic Ocean (**SWAO**) **embraces one of the largest marine hotspot of the South Atlantic Ocean.**

SST trend in the continental shelf of southern Brazil, Uruguay, northern of Argentina, Río de la Plata and BMC regions.





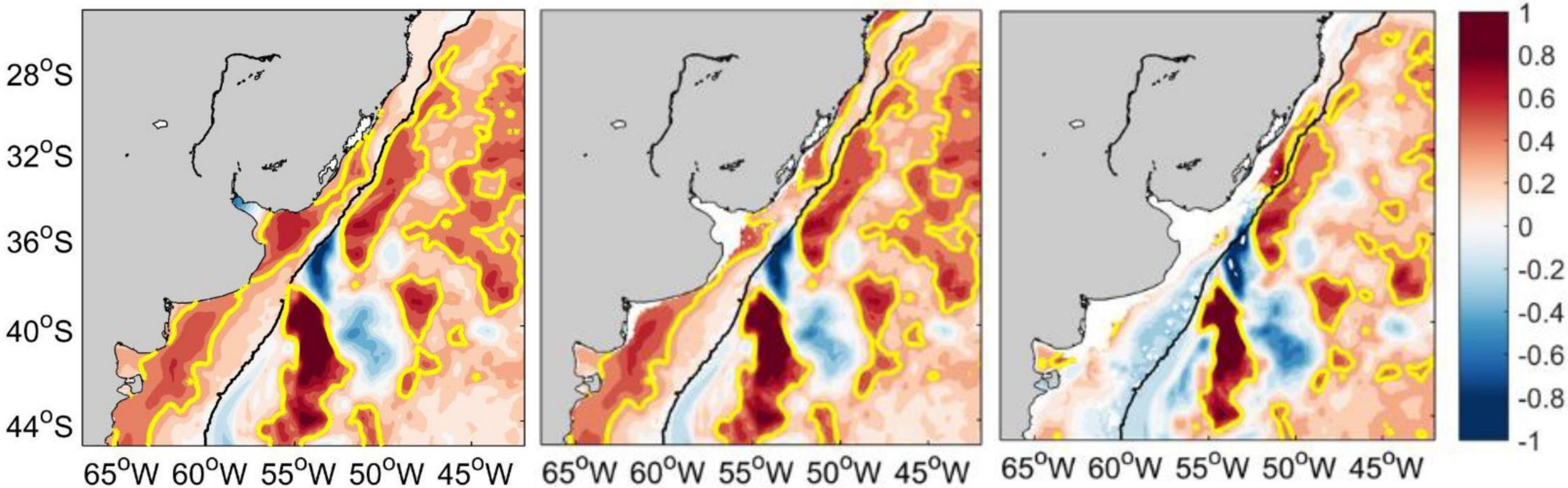
Risaro et al. (2022)

The latest recorded observations suggest that there is more advection of warm waters from the **BC to the southern Brazil and Uruguayan shelf.**

Sea surface and subsurface temperature trend (°C/decade) in the SWAO

Sea temperature trend (°C/decade) at 0 m, 20 m, and 50 m depth during 2003–2017 (GLORYS12, 1/12° global Mercator Ocean reanalysis). The yellow contour corresponds to the 0.4°C/decade isoline. The 200 m isobath is shown in black.

Surface **20 m depth** **50 m depth**



Franco et al. (2020b)

Ocean warming impacts on marine fisheries (SWAO)

1. The **Brazilian sardine (*Sardinella brasiliensis*)**, a small pelagic fish with biomass estimates up to 1.2 million t, has been the main resource in the southeastern Brazil seine fishery (23°–29°S) during the past several years.

   Brazilian sardine moved to colder and deeper waters, leading to a southward shift of about 4-5 latitudinal degrees in its distribution. A persistent southward shift of its distribution during the past 20–30 years that may be associated with the **intensification and poleward shift of the BC.**

2. The **Argentine hake (*Merluccius hubbsi*)** (cold-water affinity species) represented the most important fishery in Uruguay during the past 60 years. Decline in catch per unit of effort and landings were observed in the past 25 years.

Ocean warming impacts on marine fisheries (SWAO)

3. Long-term observations on estuaries and sandy beaches at Sepetiba Bay (~ 23° S) suggest that boundaries of fish fauna distribution **may have displaced poleward**, presumably in response to ocean warming. Changes in the presence and relative abundance of species over four decades (1980–2010) suggest that the region is facing a **"tropicalization"** of the marine community. **Some fishes responded to ocean warming with faster population growth rates, whereas others disappeared or drastically decreased their abundance.** The plausibility of the "tropicalization" process in the region agrees with the poleward expansion of tropical fish.

4. The **yellow clam (*Mesodesma mactroides*)** is an intertidal bivalve with **cold-water affinities** that has been commercially exploited in sandy shores of **southern Brazil, Argentina, and Uruguay**. The yellow clam populations, and associated small-scale fisheries, have been affected by **mass mortality events, which expanded poleward.** The yellow clam fishery has been closed during 14 years in Uruguay and is still closed in Brazil and Argentina**, affecting economic incomes and local community livelihoods**. Clam populations have not recovered to pre-mass mortality abundance levels, **denoting a high sensitivity to warming and a low resilience capacity**.

SHIFTS IN THE FISHERY LANDINGS:

Evidence of ocean warming in Uruguay's fisheries landings: the mean temperature of the catch approach.

1. Defined the mean 'optimum' temperatures for each of the species recorded in the catches.

2. Optimum temperatures were used to calculate annual 'mean temperatures of the catches' (**MTC**, Cheung et al., 2013). **MTC** is an index of aggregated **thermal affinities of species** contained in the catches. Recent studies are using the **MTC** method as a first attempt to address climate change effects on fisheries:

MTC is computed as the average of the temperature preference of exploited fishes and invertebrate species weighted by their annual catch (**MTC**, Cheung et al. 2013).

$$\mathrm{MTC}_{yr} = \frac{\sum_i^n T_i C_{i,yr}}{\sum_i^n C_{i,\,yr}}$$

Where ***Ci,yr*** is the catch of species ***i*** in year ***yr***, ***Ti*** is the median temperature preference of species ***i*** and ***n*** is the total number of species reported from landings.

3. **MTC** time series (1973−2017) for long-term Uruguayan industrial fishery landings was composed.

Gianelli et al. (2019)

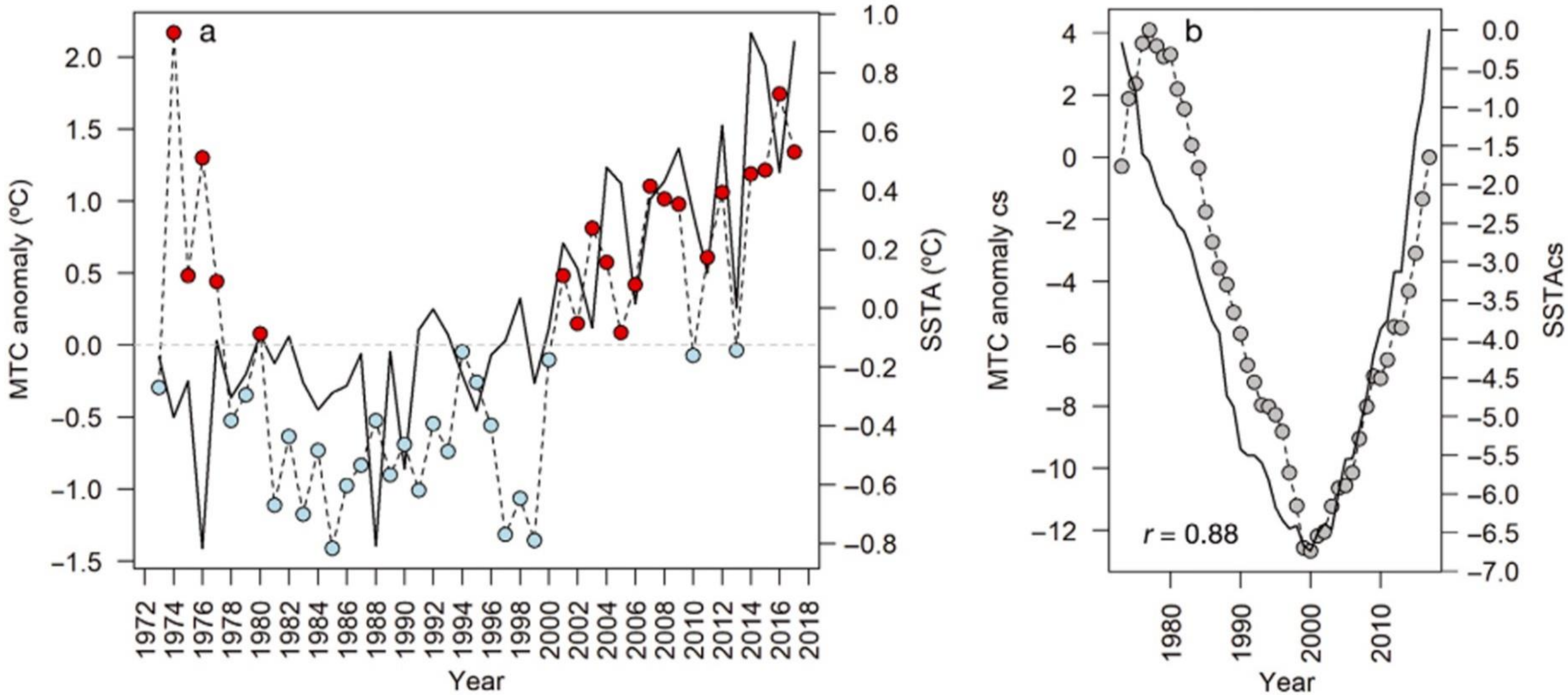


Fig. 4. Long-term variations (1973–2017) in (a) mean temperature of the catch (MTC; °C, dashed line) anomaly and sea surface temperature anomaly (SSTA; °C, solid line), and (b) cumulative sum of mean temperature of the catch anomaly (MTC anomaly cs; grey dots and dashed line) and sea surface temperature anomaly (SSTAcs; solid line). In (a), red and light-blue dots represent positive and negatives anomalies in MTC, respectively

Gianelli et al. (2019)

A significant and consistent association between **surface ocean warming** and **MTC** increase was observed.

SHIFTS IN DEMERSAL MEGAFAUNA COMMUNITY COMPOSITION:

Historical catches reveal signs of 'Tropicalization' of demersal fishing in the SW South Atlantic Ocean (Brazilian Meridional Margin, 20°-34°S).

1. Defined the mean 'optimum' temperatures for each one of the species recorded in the catches.

2. Optimum temperatures were used to calculate annual 'mean temperatures of the catches' (**MTC**, Cheung et al., 2013) during **2000-2019**.

3. **MTC** time series showed a sharp increasing trend from **2012** onwards, significantly explained by increasing **sea bottom temperatures**.

4. Applying spatial and temporal community analyses they demonstrated that the **MTC** positive trend derived from **biomass losses of cold-water species** and **gains of warm-water species** in the catches, consistent with a general process of **tropicalization of industrial fishing off southern Brazil and Uruguay**.

iAtlantic Newsletter (2022) and Perez and Sant'Ana et al. (Under Review, Communications Earth & Environment)

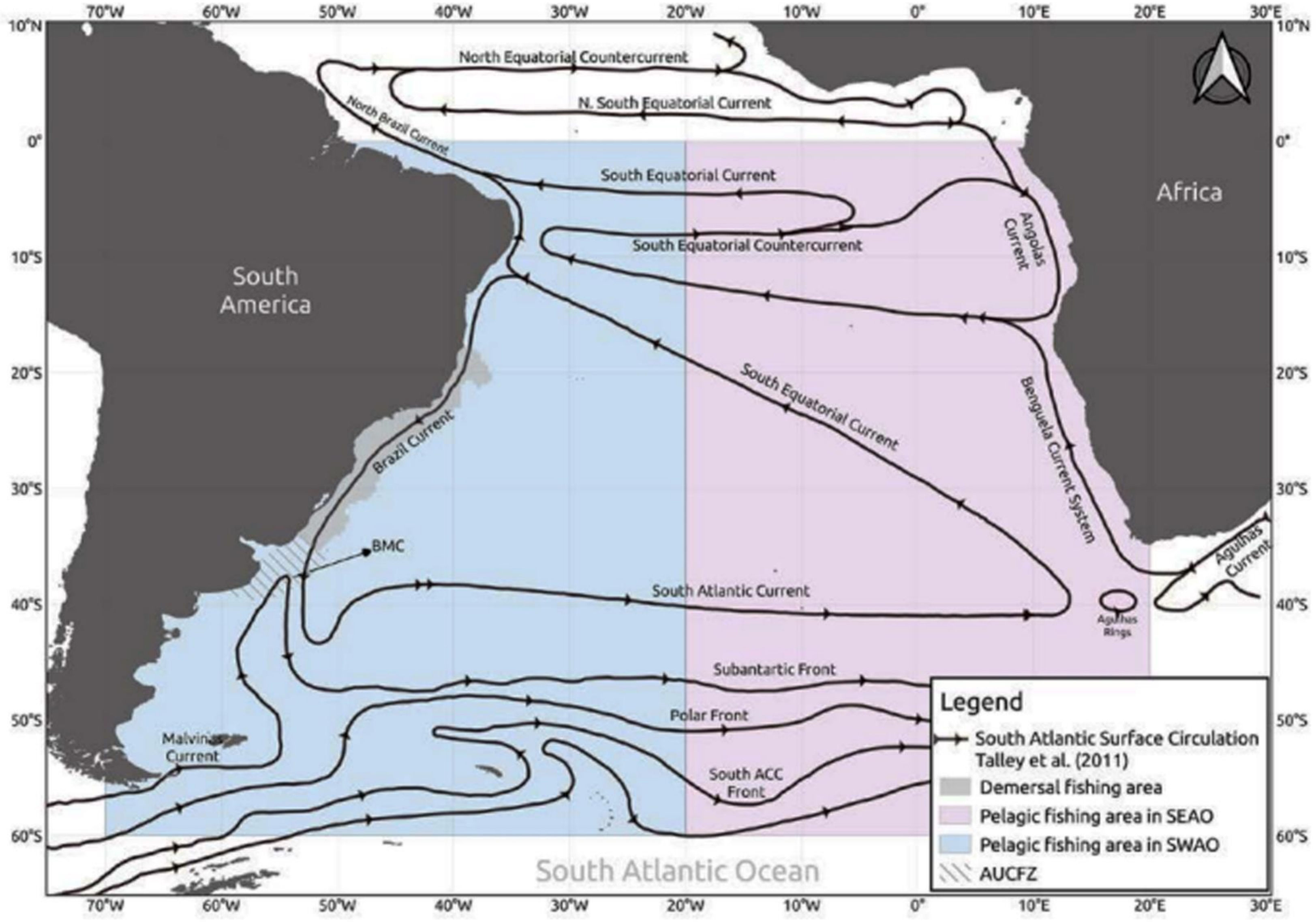


Figure 1: South Atlantic Ocean with schematic view of surface circulation. Also indicated are the study areas of demersal and pelagic fishing time series. BMC: Brazil-Malvinas Confluence; AUCFZ: Argentinian-Uruguayan Common Fishing Zone.

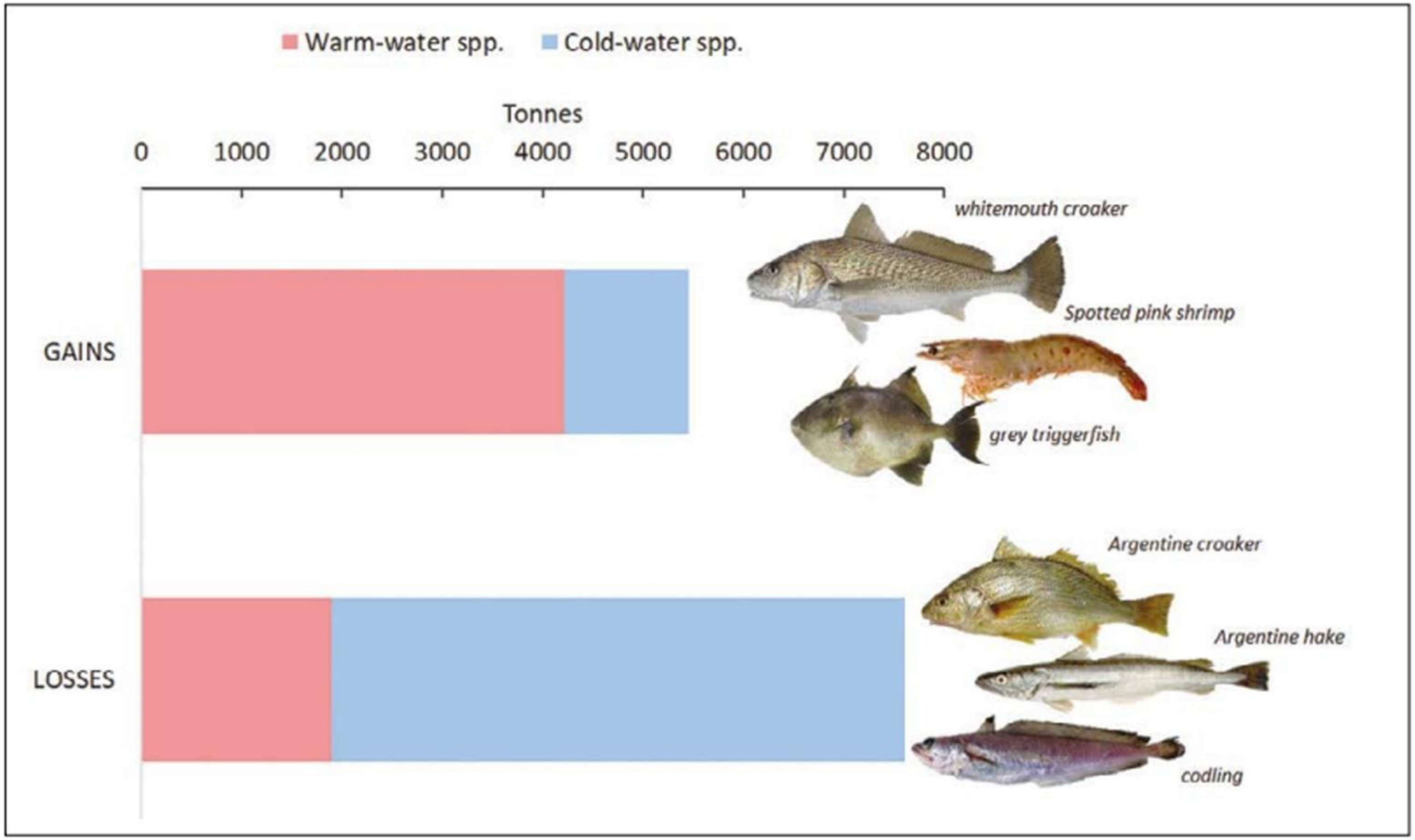


Figure 2: Average biomass gains and losses in the demersal catches in the Brazilian Meridional Margin between 2000-2002 and 2017-2019. Biomass gains and losses are dominated by warm- and cold-water species, respectively. Fish images: www.fishbase.org, www.pt.wikipedia.org , INIDEP, www.demersais.furg.br , Luciano Fischer, FAO, https://pt.frwiki.wiki/

Catches of over 29,000 multispecies **demersal fishing** operations were analyzed in the Brazilian Meridional Margin. This region (20°S - 34°S) encompasses a biogeographical subtropical/warm temperate fauna transition zone highly influenced by the dynamics of the **Brazil Current**.

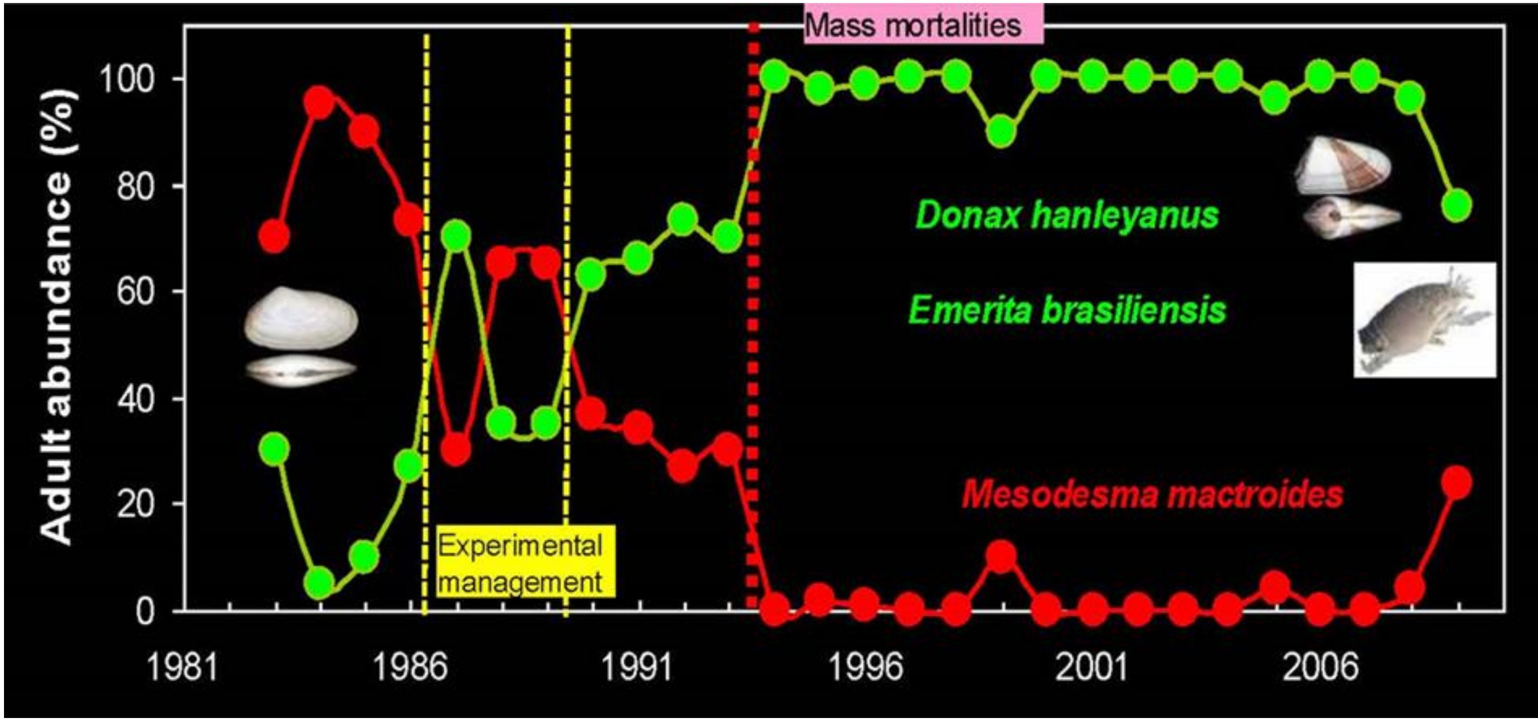
Low resilience to increased SST **can lead to mass mortality of** cold-water affinity species

- ***Sandy beach clams:***

- Mass mortality of **cold-water yellow clams** decimated populations throughout the Southwestern South Atlantic Ocean (Brazil, Uruguay, Argentina).

- The structures of marine communities and ecosystems changed dramatically.

https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-world/



Cortesy of O. Defeo

The occurrence of **mass mortality** in populations of yellow clams (*Mesodesma mactroides*) and the subsequent long-lasting decline in abundance of this species has seriously affected the **livelihoods of local communities throughout Brazil, Uruguay and Argentina**.

KEY MESSAJES:

1) **Climate change** drives **oceanographic changes**;

2) **Thermohaline properties of the ocean and circulation patterns** have impacts on **fish fauna composition** and **fisheries**;

3) **Fisheries** have strong **socioeconomic, food security and livelihood impacts.**

You MUST have a multidisciplinary knowledge and work in teams with experts in each discipline.

Interdisciplinary studies: Atmosphere – Physical Oceanography – Marine Ecology – Fisheries – Socioeconomic.

FUTURE QUESTIONS:

1) How will the fishing industry in these areas of the South Atlantic Ocean adapt to changes in the availability of traditional and non-traditional targets?

2) Which fishing economic strategies will no longer be viable and which ones may emerge to explore expanding stocks of subtropical species?

3) What adaptive measures can be incorporated in fishing management regimes (both national and transnational) to attain ecological and economic objectives in the coming decades?

These are critical questions that will guide further applications and improvements of these analytical approaches in the South Atlantic and other ocean regions.

"There is a need to consider the effects of environmental changes to properly manage fisheries stocks located in a dynamic warming hotspot, particularly those shared by neighboring countries."

KEY REFERENCES

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Interdisciplinary studies: Atmosphere – PhysOc – MarEcol – Fisheries – Socioeconomic

Climate change has been **warming the upper layer waters of the BC**. **Climate change** has been also **intensifying and shifting southwards the BC** during the past decades. **Warming** of the upper layer waters of the BC may lead to a **strengthening and shallowing of the vertical stratification of the water column**. The **surface warming** can induce a **southward shift of some cold-water affinity marine species**. **The poleward shift of the BC** is presumably responsible for the **poleward shift of commercially important pelagic species**. **Some marine invertebrates**, which does not have the ability to swim and have a low resilience capacity, can suffer from diseases and even die. **Long-term warming of the BC waters** then has been leading to a **long-term shift from cold-water to warm-water affinity pelagic species** in **landing compositions along the Brazilian continental shelf.** This has been leading to the need for **better management techniques for regional fisheries**. Changes in the **fish fauna composition** have been impacting the **regional fisheries**, which have **strong socioeconomic, food security and livelihood consequences.**