The following supplement accompanies the article

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

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1. *Analyzing the effect of El Niño Southern Oscillation (ENSO)*

1.1. *Cross-correlations: ONI vs. MTC, SSTA and Río de la Plata discharge*

The annual mean of the Oceanic Niño Index (ONI), a measure of the El Niño-Southern Oscillation (ENSO), was used as a proxy of ENSO effects on the region. Firstly, we analyzed the cross-correlation between of the ONI annual mean and the mean temperature of the catch (MTC), sea surface temperature anomaly (SSTA) and the Río de la Plata discharge anomaly (RdlPA: Fig. S1). Cross-correlations results supported our hypothesis of an increase in the discharge of the Río de la Plata concurrently with positive ONI values (Fig. S1)[1]. No other variable showed a significant correlation with ONI.

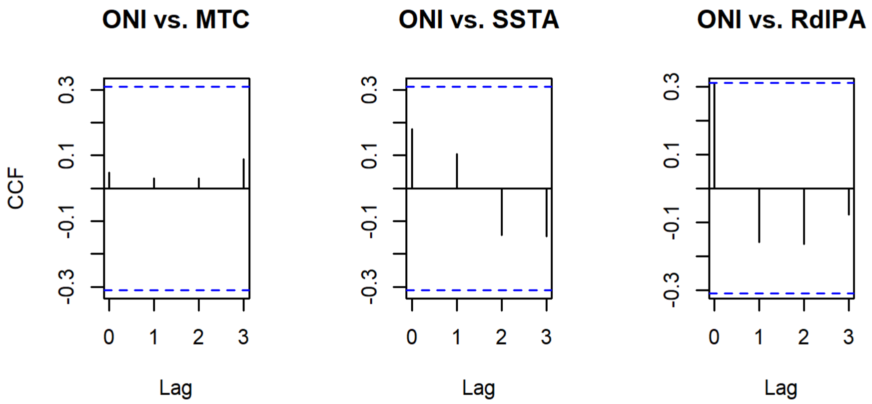

Figure S1. Cross-correlation functions (CCF) between the annual mean of the Oceanic Niño Index (ONI) and the mean temperature of the catch (MTC), sea surface temperature anomaly (SSTA) and the Río de la Plata discharge anomaly (RdlPA) at times lags of 0, 1, 2 and 3 years. The dashed lines indicate the values beyond which autocorrelations are statistically significantly different from zero at the 95% confidence level.

1.2. *Linear model including the annual mean of the ONI as a continuous fixed effect*

In addition to the final model presented in the manuscript, we also modeled the effect of the ONI annual mean as a continuous fixed effect in a linear model. The results of this analysis indicated that the ONI effect was not statistically significant in explaining the annual MTC variations through time (Table S1).

[1] It is very likely that the cross-correlation between ONI and RdlPA would significantly increase if monthly data (2 to 4-month time-lag) were used. The relationship between ENSO and the discharge of the main two tributaries of the RdlP (Río Paraná (Depetris et al. 1996) and Río Uruguay/Negro (Mechoso et al. 1992)) was well established at monthly scale. As landings were reported annually, analyses considering shorter time scales were unfeasible.

Table S1. Linear model relating the mean temperature of the catch (MTC) with the sea surface temperature anomaly (SSTA), the fishing fleet diversity (Simpson Index), the Río de la Plata (RdlP) discharge and the annual mean of the Oceanic Niño Index (ONI) as a measure of the El Niño-Southern Oscillation (ENSO) continuous variations. S.E.: standard error. ** $p<0.01$.

Variable	Estimate	S.E.	IC95%	p-value
z-score SSTA	0.41	0.14	[0.13; 0.70]	0.0056**
z-score Simpson Index	-0.46	0.14	[-0.75; -0.18]	0.0020**
z-score RdlP discharge	-0.17	0.10	[-0.37; 0.04]	0.10
z-score ONI	-0.06	0.10	[-0.26; 0.15]	0.58
Intercept	0	0.10	[-0.19; 0.19]	1.00

1.3. Linear model including the ONI as a binary variable (positive and negative phases)

We also tested the potential effect of ONI modeled as a binary variable with negative (annual average of ONI variations less than zero) and positive phases (annual average of ONI variations greater than zero). The analysis indicated that ONI phases are not statistically significant between them and thus, in explaining MTC variations through time (Table S2).

Table S2. Linear model relating the mean temperature of the catch (MTC) with the sea surface temperature anomaly (SSTA), the fishing fleet diversity (Simpson Index), the Río de la Plata (RdlP) discharge and the Oceanic Niño Index (ONI) considered as a binary variable representing the negative and positive phases of the oscillations. S.E.: standard error. **$p<0.01$.

Variable	Estimate	S.E.	IC95%	p-value
z-score SSTA	0.40	0.14	[0.12; 0.69]	0.0065**
z-score Simpson Index	-0.46	0.14	[-0.75;-0.17]	0.0025**
z-score RdlP discharge	-0.19	0.10	[-0.39; -0.01]	0.06
ONI: positive phase	0.02	0.20	[-0.39; 0.43]	0.92
Intercept	-0.01	0.14	[-0.30; 0.28]	0.94

1.4. Linear mixed models including ENSO categories as random intercepts

Other potential consequences of different ENSO conditions are possible, but not well documented. Thus, we performed an additional linear mixed model directed to consider unknown effects of ENSO oscillations on MTC variations. We follow Null (2018) in categorizing the Oceanic Niño Index (ONI) into eight ENSO discrete ranges (Table S3). ENSO categories were included in linear models as a random intercept, since this grouping variable encompasses several distal effects that are not well understood and documented, yet could be important for modeling MTC variations. The rationale behind this approach was to consider the variation of each covariate among climatic modes.

Table S3. El Niño Southern Oscillation (ENSO) categorization and number of years included in each category during the period 1977-2016.

ENSO categories	n
Weak El Niño	6
Moderate El Niño	4
Strong El Niño	4
Very strong El Niño	5
Neutral	9
Weak La Niña	5
Moderate La Niña	2
Strong La Niña	5

This analysis indicated that ENSO, as random intercept, was not useful for model fitting purposes (null variance). This could be due to at least two reasons: (1) the categorization of ENSO was indeed not useful in explaining part of the variance; or (2) the number of years per each ENSO category was not enough to allow a proper fit (i.e. the random effects structure is too complex to be supported by annual data only), leading to singular results in the modeling process.

2. Linear model residual analysis

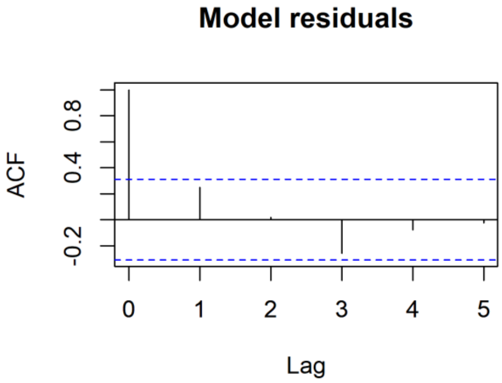

Figure S2. Autocorrelation function (ACF) of the residuals of the final linear model including the sea surface temperature anomaly (SSTA) and the fishing fleet diversity (Simpson Index) as predictors. The dashed lines indicate the values beyond which the autocorrelations are statistically significantly different from zero at the 95% confidence level.

Literature cited

Depetris PJ, Kempe S, Latif M, Mook WG (1996) ENSO-controlled flooding in the Paraná River (1904–1991). Naturwissenschaften. 83: 127−129

Mechoso CR, Iribarren GP (1992) Streamflow in southeastern South America and the southern oscillation. J Climate. 5: 1535−1539