CAtch rate Standardisation of finfishes targeted by the GAlician (NE Atlantic) Small-Scale fishery

Final Report ICES Science Fund

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1-The project

The project **CASGASS** - "CAtch rate Standardisation of finfishes targeted by the GAlician (NE Atlantic) Small-Scale fishery" funded by the ICES Science Fund with 6500 euros was carried out through the period April 2014 - April 2015.

The principal aim of this study was to standardize catch and effort data obtained from observers on commercial fishing vessels for a number of finfish species targeted by the small-scale fishing fleet off the Galician coast (ICES areas IXa and VIIIc). This would allow the development of indices of abundance to be used as inputs in future stock assessments.

A secondary objective was to investigate the degree of synchronicity among trends in species' abundance in relation to environmental conditions and life history traits.

1.1-Reseach Team

The research team was composed by scientist of two institutions:

- **Academic scientists**: Consejo Superior de Investigaciones Científicas, CSIC
  - Instituto de Investigaciones Marinas, IIM: Alonso-Fernández, J. Otero, X.A. Álvarez-Salgado. Data analysis and model development.
- **Government scientists**: Xunta de Galicia
  - Unidade Técnica de Peca de Baixura, UTPB: R. Bañón, J.M. Campelos, F. Quinteiro-Fernandez: Data handling and management purposes.

1.2-Motivation

The proposal built on various pillars of the current strategic plan. It specifically looked for an understanding of the dynamics and structure of key biotic components from an integrated perspective (Goals 1 and 2). It also fostered the use of sound statistical models to analyze new data sets (Goals 4), and provide credible advice for management needs (Goal 3).

This project fitted with ICES Science Fund goals according to the following reasoning: i) small-scale fisheries have a strong socio-ecological importance for the region and are understudied (1), ii) they are of interest within the Common Fisheries Policy (CFP), and iii) ICES has manifested the importance of gathering information for species subjected to exploitation in EU coastal waters though not included in management plans yet (ICES Report).

1.3-Background

The Galician small-scale fishery (Fig. 1) is a multi-species and multi-gear fishery that, despite its importance, lacks of basic scientific research regarding species and fleet dynamics which would allow the implementation of robust management plans. The governmental agency UTPB ("Technical Unit of Artisanal Fisheries") runs a monitoring fishery-dependent program since mid-1990s that serves the autonomous government ("Xunta de Galicia") to develop simple exploitation plans together with the several fisheries associations ("Cofradías"). However, these data have never been further used outside the regional domain, thus we considered that this monitoring was a unique source of information to explore the application of advanced statistical tools for robust standardization of abundance and deliver the results to the assessment and management bodies.

Figure 1: Typical boat that operate in Galician small-scale fisheries.

Briefly, data are recorded by UTPB observers onboard fishing vessels randomly selected within the artisanal fleet. The sampling procedure is assumed to be random within the commercial catch among the set of numerous gears, seasons and with a sufficient spatial coverage. The current usage of this information by the UTPB is mainly related to technical reports for specific resources, and also, some research collaborations with academic institutions (2-5). However, the proposal was focused on analyzing jointly a set of 13 species of equal interest for both the regional government and ICES. Overall, this set of species covered a wide range of different taxa of the coastal fish community in the area.

2-Brief Methodology and Material description

2.1-Study area

Galicia (NW Spain) is one of the main fishing regions in Spain and Europe (1), with a fleet of more than 4000 small fishing boats representing ~88% of the total fleet in this area. Galician waters are at the northern boundary of the Iberian-Canary Current upwelling system (6). Coastal winds at these latitudes (42° to 44° N) are seasonal; however, more that 70% of the total variability of coastal winds occurs during periods of less than 1 mo, so that the upwelling season appears as a succession of wind stress/relaxation cycles of periods lasting 10 to 20 d (7).

2.2-Biological data

Sampling was undertaken off the Galician coast (NW Spain), between the mouth of the Eo River (43° 32' N to 7°01'W) and the Miño River estuary (41° 50' N to 9°40'W), comprising ICES Divisions IXa and VIIIc. Catch data was obtained from the historical (1999 to 2013) artisanal fishing sampling program run by the UTPB. The sampling program covers the full set of multiple artisanal gears used in Galician waters (mainly hooks and lines, traps and nets). This fishery-dependent approach provides a wider spatio-temporal coverage than a fishery-independent survey.

Figure 2 shows the spatial distribution of hauls performed with the main five fishing gears along the Galician coast. Three of them were gillnets that differed in the number of netting (single or triple) and the depth and soak time of operation. The other two were traps (octopus creels), which had the best temporal and spatial coverage, and longlines.

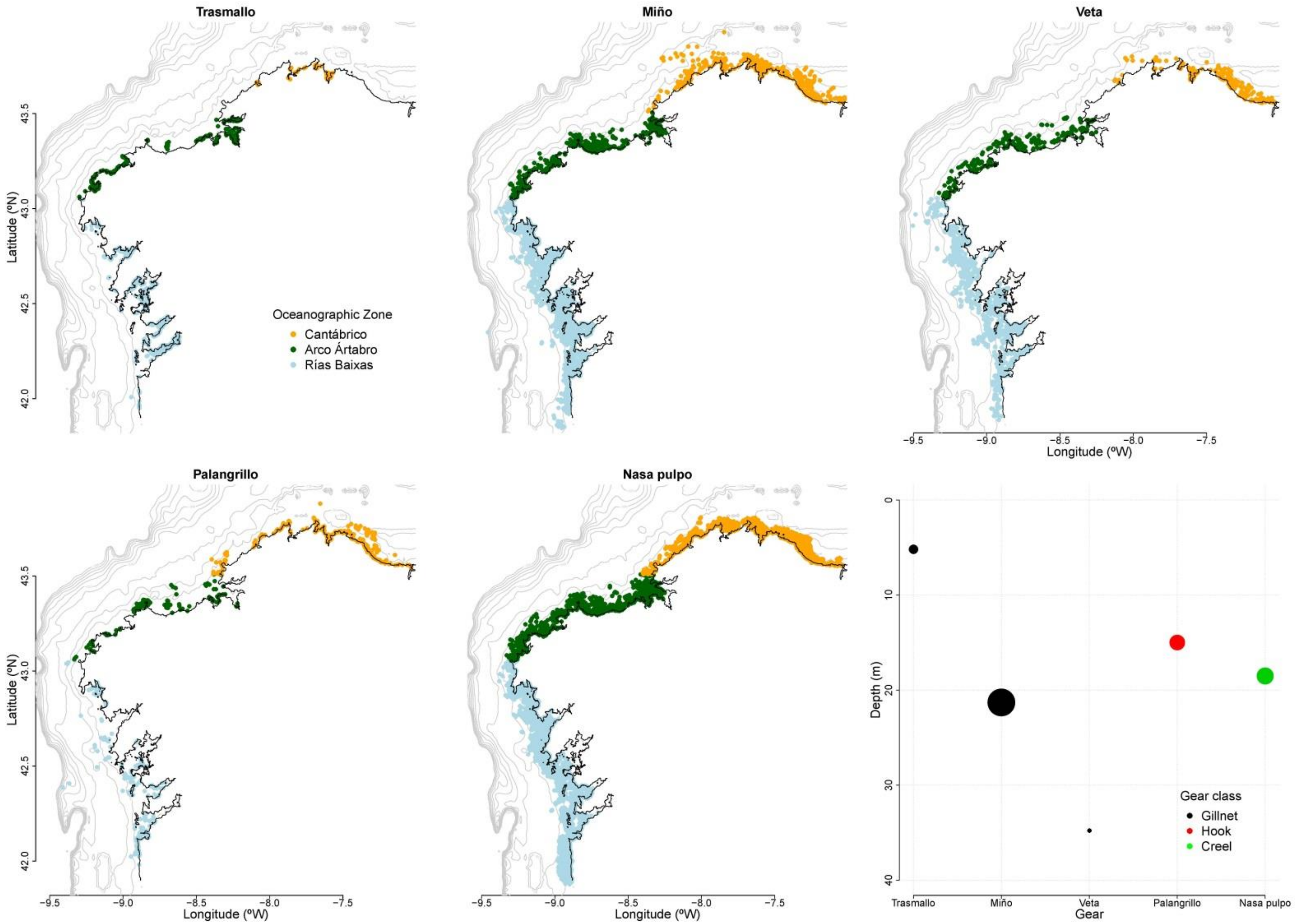


Figure 2: Spatial location of the sampled hauls performed by the main five fishing gears along the Galician coast during the period 1999 to 2013. Three gears were anchored gillnets with triple ("Trasmallo" and "Miño") and single netting ("Veta"). The other was a small longline ("Palangrillo"), and a trap/creel targeting octopus ("Nasa pulpo"). It is also shown in the lowest right panel the average operation depth by each gear. The size of the dots varies according to the mean soak time for each gear.

2.3-Environment and Life History Trais

To evaluate the role of environmental variables we compiled data on sea surface temperature (SST, in °C) and upwelling intensity (-Q_X, in $m^3/s \cdot km$). First, optimum interpolation SST data available at weekly 1° latitude × 1° longitude grid resolution from a combination of satellite and in situ measurements were obtained from the NOAA Earth System Research Laboratory (http://www.esrl.noaa.gov/psd/) for the period 1998 to 2013. Second, the upwelling intensity was computed in a 2° × 2° cell centered at 43°N, 11°W (Fig. 3) from geostrophic winds calculated from the surface atmospheric pressure fields analyzed every 6 h by the Fleet Numerical Meteorology and Oceanography Center (http://www.usno.navy.mil/). Data were obtained for the period 1998 to 2013 and downloaded from http://www.indicedeafloramiento.ieo.es/.

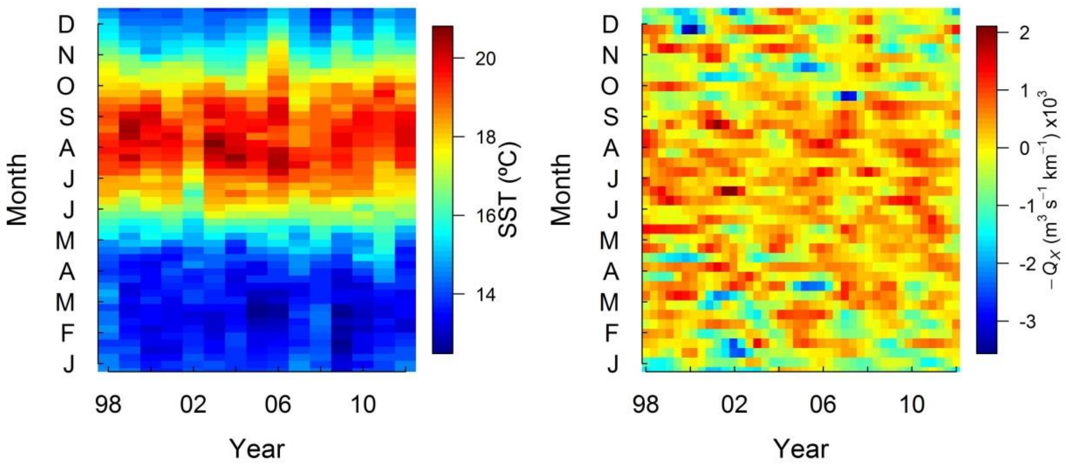


Figure 3: Temporal (seasonal and annual) variation of environmental variables used in the current analysis. Distribution of (left panel) sea surface temperature (SST) and (right panel) upwelling index (Q_X) for Galician waters during the study period 1998 to 2013.

Life history trait (LHT) data were used to relate the dynamics of the community with the species-specific characteristics. Information was compiled from FishBase. We used only those LHT that were available for the entire list of finfish species considered in the study. This included parameters from the Von Bertalanffy growth equation: L-infinity (Linf, cm) and K (1/y). Species-specific averages for these LHT were computed when more than one parameter were available.

2.4-Data analysis

The aim of standardization is to obtain indices of relative abundance once removed the impact on catch rates of factors other than abundance (8). These indices can be later used to feed assessment models in order to provide reliable advice. This method is frequently used to study large pelagic stocks, mainly sharks and tunas (9-11) for which fishery-independent data is non-existent, though rarely used for other species (but see 12).

Fishery data is usually non Gaussian (count data) and errors not independent in time and/or space, thus there is a need to use appropriate statistical methods to provide robust time series of abundance. To this end, we will explore the use of several models including generalized linear models (GLMs), so as zero-inflated models (ZI) that allow the accommodation of null samples (13-15). An offset was introduced in each model to account for gear-specific fishing effort, and abundance was related to operational (boat size, crew), temporal (year, day of the year), spatial (latitude, longitude, depth) and environmental (upwelling, temperature) variables.

Regarding the secondary objective, we put together the whole set of indices of abundance obtained from the earlier GLM standardization procedure and run the following analyses. First, the time trend and coefficient of variation for each index of abundance was computed. Second, a Principal Component Analysis (PCA, 16) was applied to the matrix of indices in order to extract a common pattern and the loadings of each index in the first component. Third, each abundance index was correlated with an annual time series of sea surface temperature and upwelling strength lagged one year. Finally, all this information characterized individually each index of abundance and was correlated with the matrix of life history traits using ordinary least squares and standardized major axis (SMA) regression.

All analyses and treatment of data were performed using R (17).

3-Research Outputs

Congress attendance and contributions:

- Attendance to the Johan Hjort Symposium on Recruitment Dynamic and Stock Variability in October 2014 held in Bergen (Norway). Alexandre Alonso-Fernández presented in the Symposium the firsts results of the project: "Standardizing Trends in Abundance of a *Pollachius pollachius* Stock along the Galician Coast (NE Atlantic)". This work was already submitted to the ICES Journal of Marine Science: Otero J., Alonso-Fernández A., Villegas-Ríos D. & Bañón R. (submitted) Standardising trends in catch rates of *Pollachius pollachius* harvested by the small-scale fishery along the Galician coast (NE Atlantic).
- It is also planned to attend to the ICES ASC to be held on 21-25 September 2015 in Copenhagen (Denmark) to show final results of the project at the Theme Session F dedicated to Small-Scale fisheries under data-limited scenarios. Tentative titles for three communications at the ICES ASC 2015:
    - Coastal community CPUE standardization in the Galician Small-Scale Fishery (southeastern Atlantic shelf) from 1999 to 2013 using on board observer data
    - Life history traits determine the shape and response to environmental conditions of a coastal community targeted by a Small-Scale Fishery
    - Monitoring fishing effort of a data-limited artisanal fishery. The case of common octopus small-scale fleet operating in the Galician coast (southeastern Atlantic shelf)

Research publications in SCI journals:

- Villegas-Ríos, D., J. Alós, M. Palmer, S. K. Lowerre-Barbieri, R. Bañón, A. Alonso-Fernández & F. Saborido-Rey, 2014. Life-history and activity shape catchability in a sedentary fish. Mar. Ecol. Prog. Ser. 515: 239-250.
- Alonso-Fernández, A., J. Otero, D. Villegas-Ríos & R. Bañón, 2014. Drivers of body size changes in a *Pollachius pollachius* stock in NE Atlantic coastal waters. Mar. Ecol. Prog. Ser. 511: 223-235.
- Currently, more research publications are in preparation:
    - Otero et al. (In prep) Abundance trends of main invertebrate species from standardized multi-gear small-scale fishery catch rates off the Galician coast (NE Atlantic).
    - Alonso-Fernández et al. (In prep) Coastal community CPUE standardization in the Galician Small-Scale Fishery (southeastern Atlantic shelf) from 1999 to 2013 using on board observer data
    - Alonso-Fernández et al. (In prep) Life history traits determine the shape and response to environmental conditions of a coastal community targeted by a Small-Scale Fishery
    - Alonso-Fernández et al. (In prep) Drives of sex-ratio variation of an octopus population off the southeastern Atlantic shelf

Training activites:

- Attendance to the training course “Quantitative Fisheries Science Using FLR and a4a” imparted by members of the G03 Maritime Affairs Unit of the Joint Research Centre in Ispra, Italy from 25 to 29 August 2014. Alexandre Alonso-Fernández and Jaime Otero attended this course that had duration of 32 hours, and covered the use of the Fisheries Library in R (FLR) and the Assessment for All a4a models to evaluate the status of fish stocks and the provision of management advice.

4-Results

4.1-Sampling effort

Galician small-scale fleet comprises a complex multi-species and multi-gear fishery. The UTPB monitoring program, starting in 1999, counts a total of 41.359 hauls performed by 1611 different vessels using 29 different fishing gears. However, sampling effort is not equally distributed among fishing gears (Fig. 4).

Moreover, the studied species depended on gear selectivity. For instance, octopus creels caught practically all sampled octopuses; whereas European conger was efficiently fished by different gears (Fig. 5).

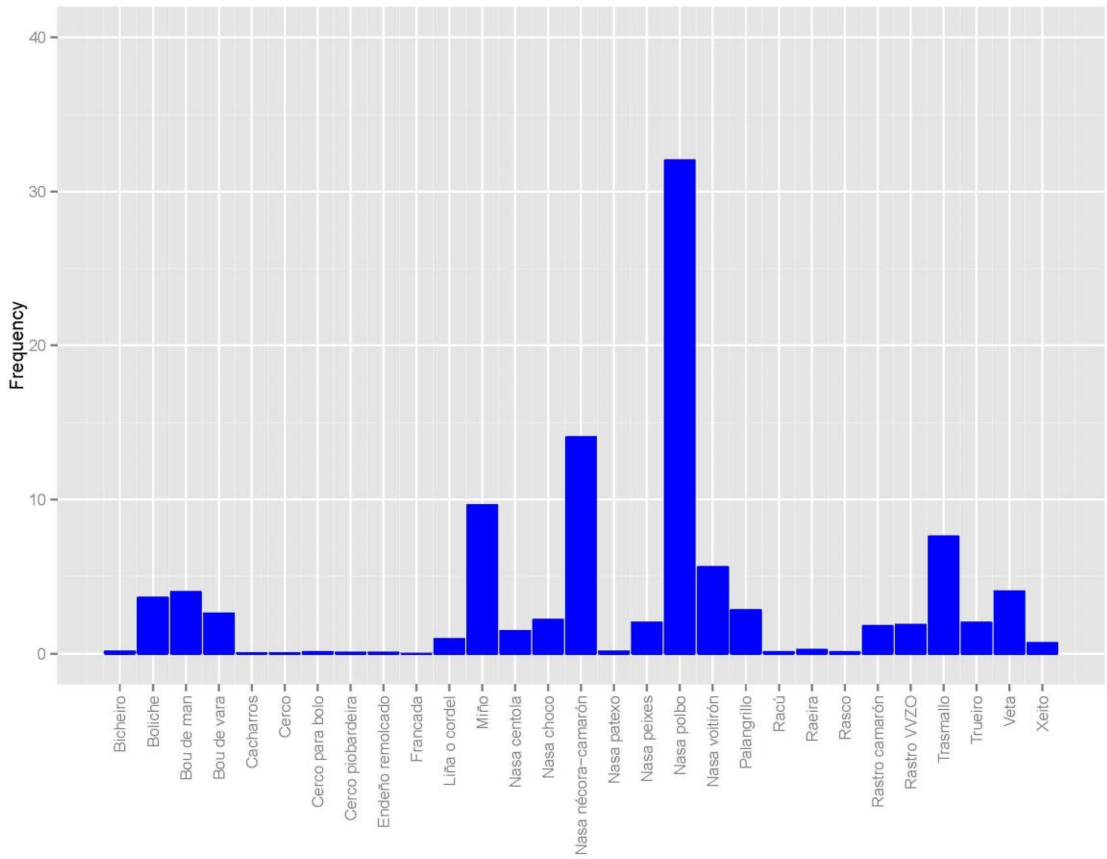


Figure 4: Percentage of total hauls sampled per gear in the UTPB 1999-2013 monitoring program.

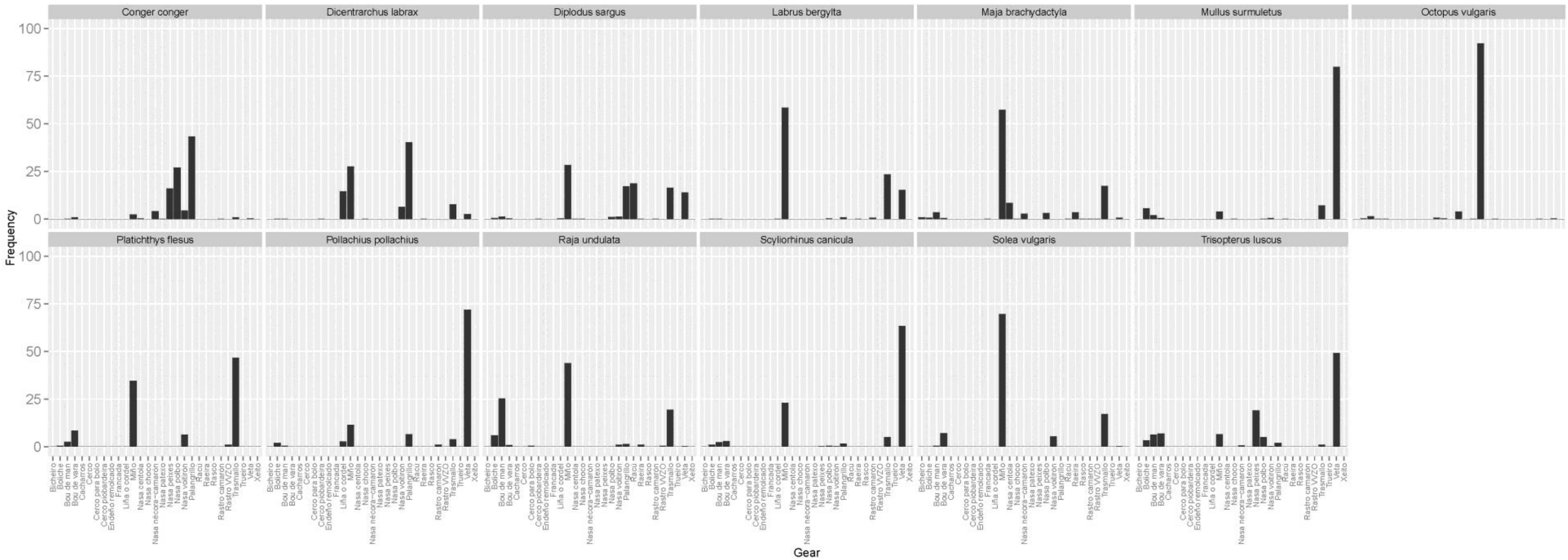


Figure 5: Percentage of total individuals sampled per gear for each of the species studied in the UTPB 1999-2013 monitoring program.

This preliminary exploration of sampling distribution allowed the selection of the fishing gears that were more selective for each studied species. Two main criteria were used to select an appropriate fishing gear: i) total number of fish sampled during the time series and ii) good temporal and spatial coverage of hauls sampled. As a result, the following fishing gears were used for each species' abundance modelling: i) Gillnets (Trasmallo, Miño, Veta) ii) Traps (Nasa pulpo) and iii) Longline (Palangrillo) (Table 1).

Table 1: Fishing gears selected to estimate time series of abundance index for each especies.

Species	Fishing type	Fishing gears	Sampling period
Conger conger	Traps	Nasa pulpo	1999-2013
Dicentrarchus labrax	Hook and line	Palangrillo	2001-2013
Diplodus sargus	Gillnets	Trasmallo, Miño, Veta	1999-2013
Labrus bergylta	Gillnets	Miño	1999-2013
Maja brachydactyla	Gillnets	Trasmallo, Miño	1999-2013
Mullus surmuletus	Gillnets	Veta	1999-2013
Octopus vulgaris	Traps	Nasa pulpo	1999-2013
Platychis flessus	Gillnets	Trasmallo, Miño	1999-2013
Pollachius pollachius	Gillnets	Miño, Veta	1999-2013
Raja undulata	Gillnets	Trasmallo, Miño	1999-2013
Scyliorhinus canicula	Gillnets	Trasmallo, Miño	1999-2013
Solea solea	Gillnets	Trasmallo, Miño	1999-2013
Trisopterus luscus	Gillnets	Miño, Veta	1999-2013

Artisanal vessels in this region can license up to 5 different gears that might shift along the fishing season adding more complexity to the system. Consequently, the UTPB monitoring program represents a small fraction of the total fishing activity in the area (Fig. 6 and 7).

It should be noted that that registered licenses (i.e. vessels allowed to use a specific fishing gear) are total figures, however, it is not possible to know if each of those vessels went actually fishing, thus numbers could be overestimated. Note also that days are the maximum number of potential fishing days; however, it is not possible to know how many days were actually effective fishing days, thus, again, numbers could be overestimated.

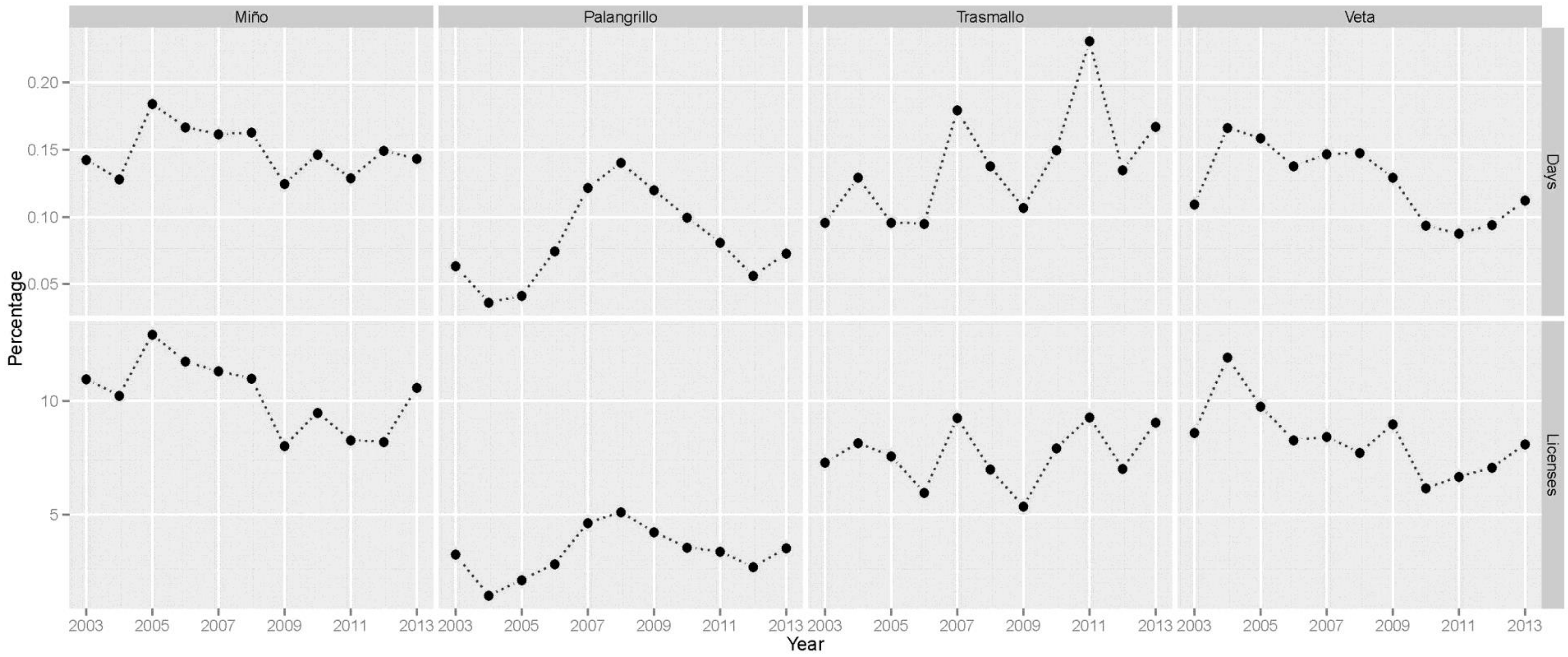


Figure 6: *Percentage of total operational days and vessels sampled during the UTPB 1999-2013 monitoring program for gillnets and longlines.*

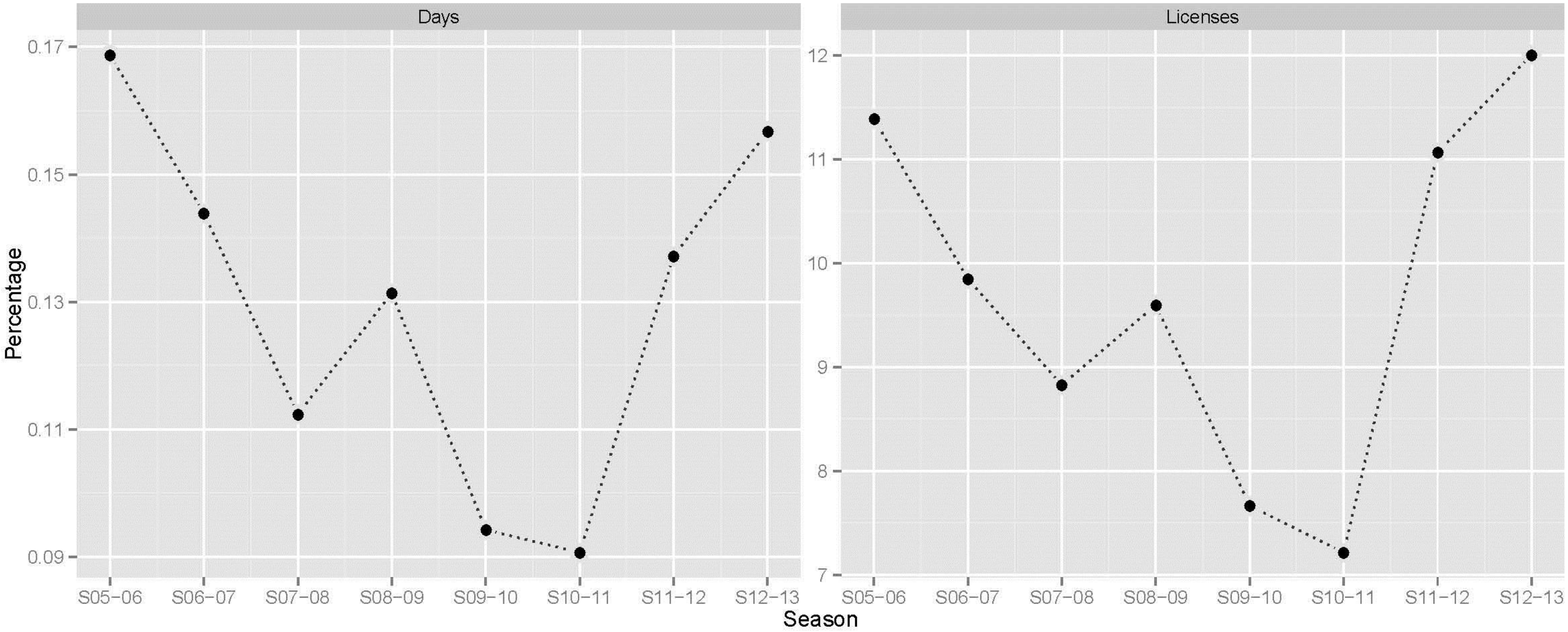


Figure 7: Percentage of total operational days and vessels sampled during the UTPB 1999-2013 monitoring program for trap fishery).

4.2-Abundance models

Here, we present results for each species' model for standardizing catch and effort data. Information of the modelling approach, fishing gears used in the model, a summary table of the final model and a plot of the estimated relative abundance, nominal catch per unit effort and total landings are provided. Although the variable year was included in all the models as a factor, corresponding coefficients are not shown in the summary table to simplify the display of the data. However, year trends illustrate the resultant indices of relative abundance for each species (Fig. 8-20). Some species present more than one index, because interactions were included in certain formulations.

European conger (Conger conger)

GLM (Negative Binomial)

Traps (Nasa pulpo)

Coefficient	Estimate	SE	p-value
(Intercept)	-8.0895	0.1244	< 2e-16
ICES-VIIIc	0.2978	0.1734	0.0860
DoY	3.2515	3.0088	0.2799
DoY^2	8.7409	3.1789	0.0060
DoY^3	-8.1128	2.9369	0.0057
Soak time at night	-1.5302	0.1452	< 2e-16
Seafloor(mixed)	-0.1622	0.0656	0.0134
Seafloor(soft)	-0.4430	0.0782	0.0000

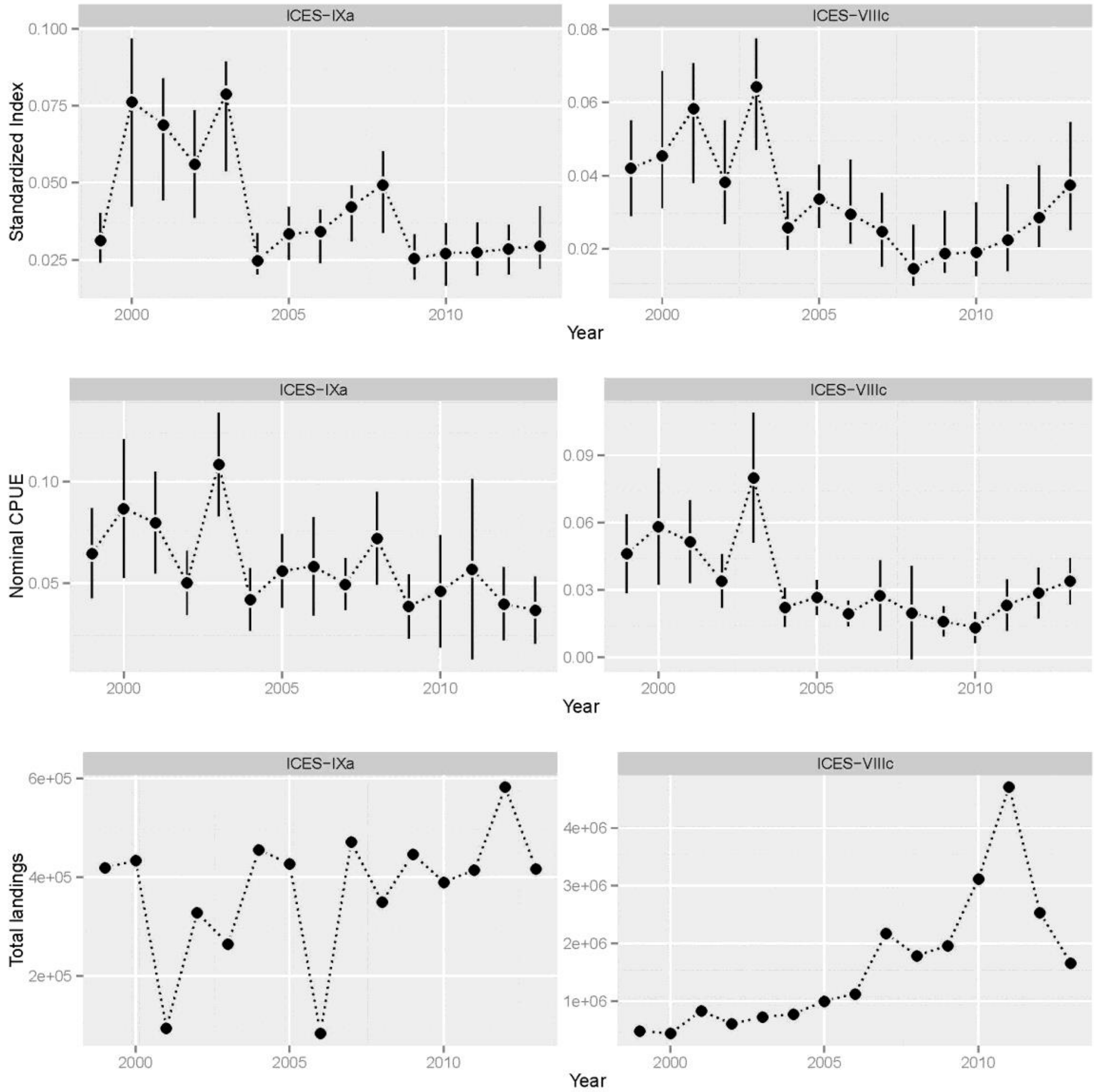


Figure 8: European conger. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

European seabass (Dicentrarchus labrax)

Zero Inflated (Negative Binomial)

Longline (Palangrillo)

Coefficient	Estimate	SE	p-value
Count part			
Intercept	-9.1100	0.9100	<0.0001
Gear(palangPequeño)	5.6500	0.7600	<0.0001
GRT	-0.5500	0.1200	<0.0001
DoY	-0.1900	1.8400	0.9200
DoY^2	10.1200	2.3000	<0.0001
SST	0.3100	0.0800	<0.0001
Soak time at night	-1.3900	0.3500	<0.0001
Zero part			
Intercept	-23.0100	4.4700	<0.0001
Depth	6.1200	1.2000	<0.0001

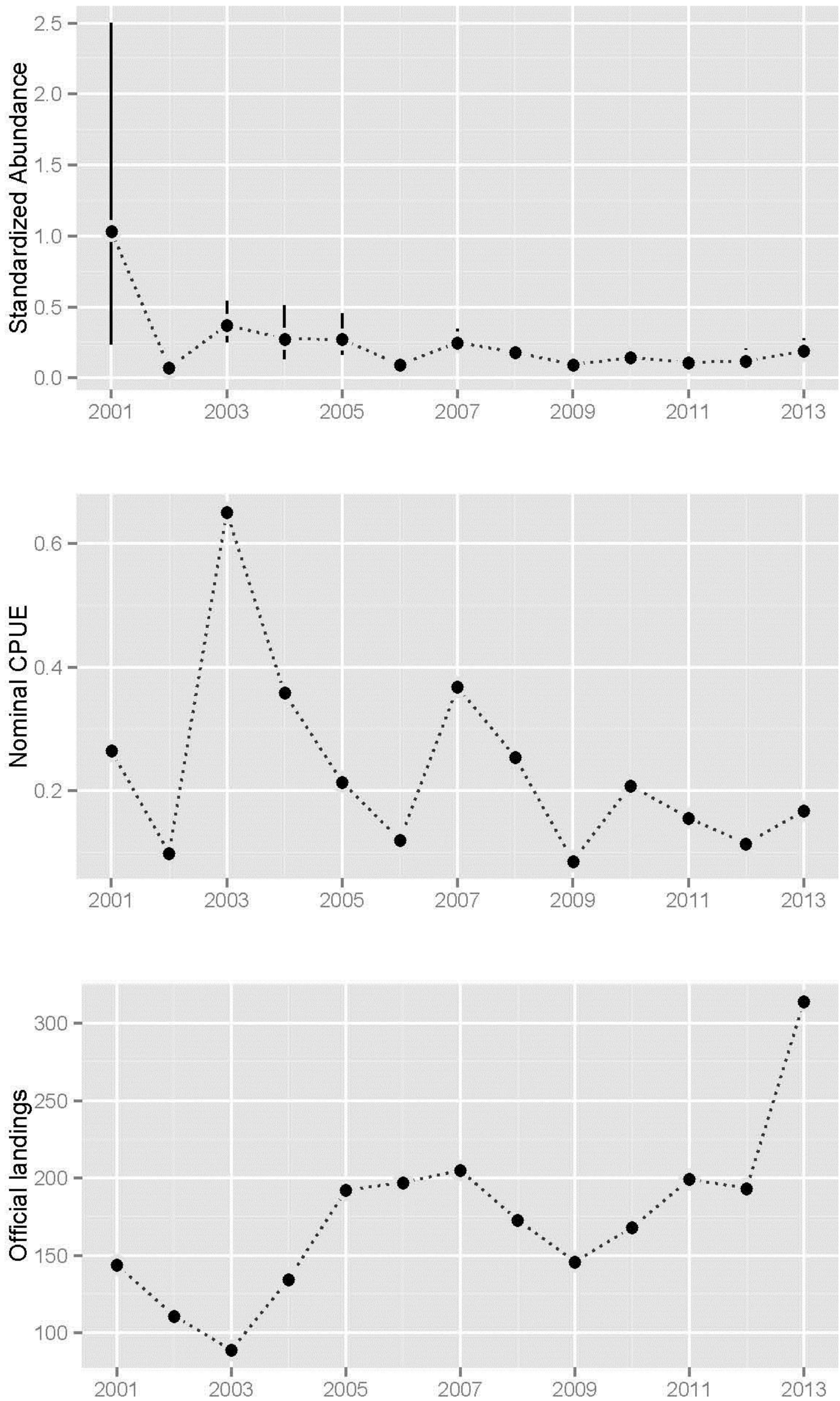


Figure 9: European seabass. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

White seabream (Diplodus sargus)

Zero Inflated (Negative Binomial)

Gillnets (Trasmallo, Miño, Veta)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-10.2085	0.7058	< 2e-16
ICES-VIIc	-0.5952	1.6437	0.7173
Gear(Miño)	-0.7672	0.8070	0.3418
Gear(veta)	1.0931	1.5881	0.4912
log(GRT)	0.3943	0.1386	0.0044
DoY	18.2275	7.7351	0.0184
DoY^2	-40.5748	9.0384	0.0000
log(Depth)	0.6774	0.2615	0.0096
Soak time at night	0.1043	0.5971	0.8613
Seafloor(mixed)	-0.8678	0.4028	0.0312
Seafloor(soft)	-0.3129	0.4321	0.4689
Gear(Miño):log(Depth)	-0.6161	0.3247	0.0578
Gear(Veta):log(Depth)	-1.8164	0.4979	0.0003
Gear(Miño):Soak time at night	1.4038	0.8927	0.1158
Gear(Veta):Soak time at night	5.5984	1.1130	0.0000
Gear(Miño):Seafloor(mixed)	-0.0981	0.4467	0.8262
Gear(Veta):Seafloor(mixed)	-1.5601	0.6184	0.0116
Gear(Miño):Seafloor(soft)	0.4642	0.4825	0.3360
Gear(Veta):Seafloor(soft)	0.8915	0.7657	0.2443
Zero part			
(Intercept)	-4.5991	0.6716	0.0000
log(Depth)	1.5992	0.1930	< 2e-16
Seafloor(mixed)	-0.6235	0.2983	0.0366
Seafloor(soft)	1.9068	0.2837	0.0000

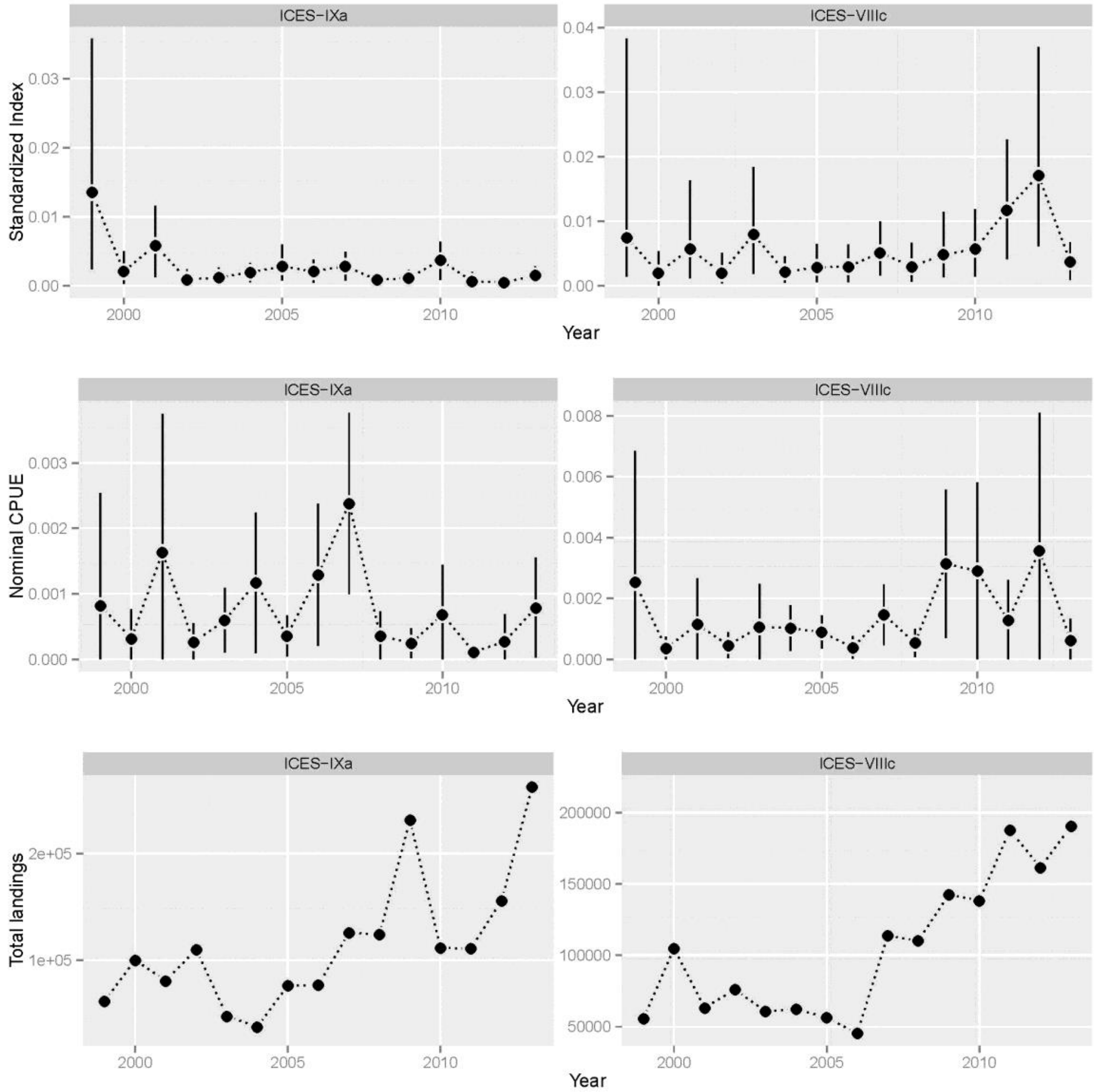
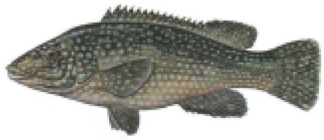


Figure 10: White seabream. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Ballan wrasse (Labrus bergylta)



Zero Inflated (Negative Binomial)

Gillnets (Miño)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-8.4634	0.6054	< 2e-16
ICES-VIIIc	0.3392	0.8785	0.6994
log(GRT)	0.3392	0.8785	0.6994
DoY	-7.6895	2.4770	0.0019
DoY^2	-21.8592	3.3199	0.0000
log(Depth)	-0.6795	0.0639	< 2e-16
Soak time at night	1.7835	0.3550	0.0000
Seafloor(mixed)	-0.8626	0.0868	< 2e-16
Seafloor(soft)	-1.1139	0.9129	0.2224
Zero part			
(Intercept)	-6.0239	0.5304	< 2e-16
log(Depth)	1.2259	0.1443	< 2e-16
Seafloor(mixed)	0.6604	0.2402	0.0060
Seafloor(soft)	2.6252	0.2158	< 2e-16

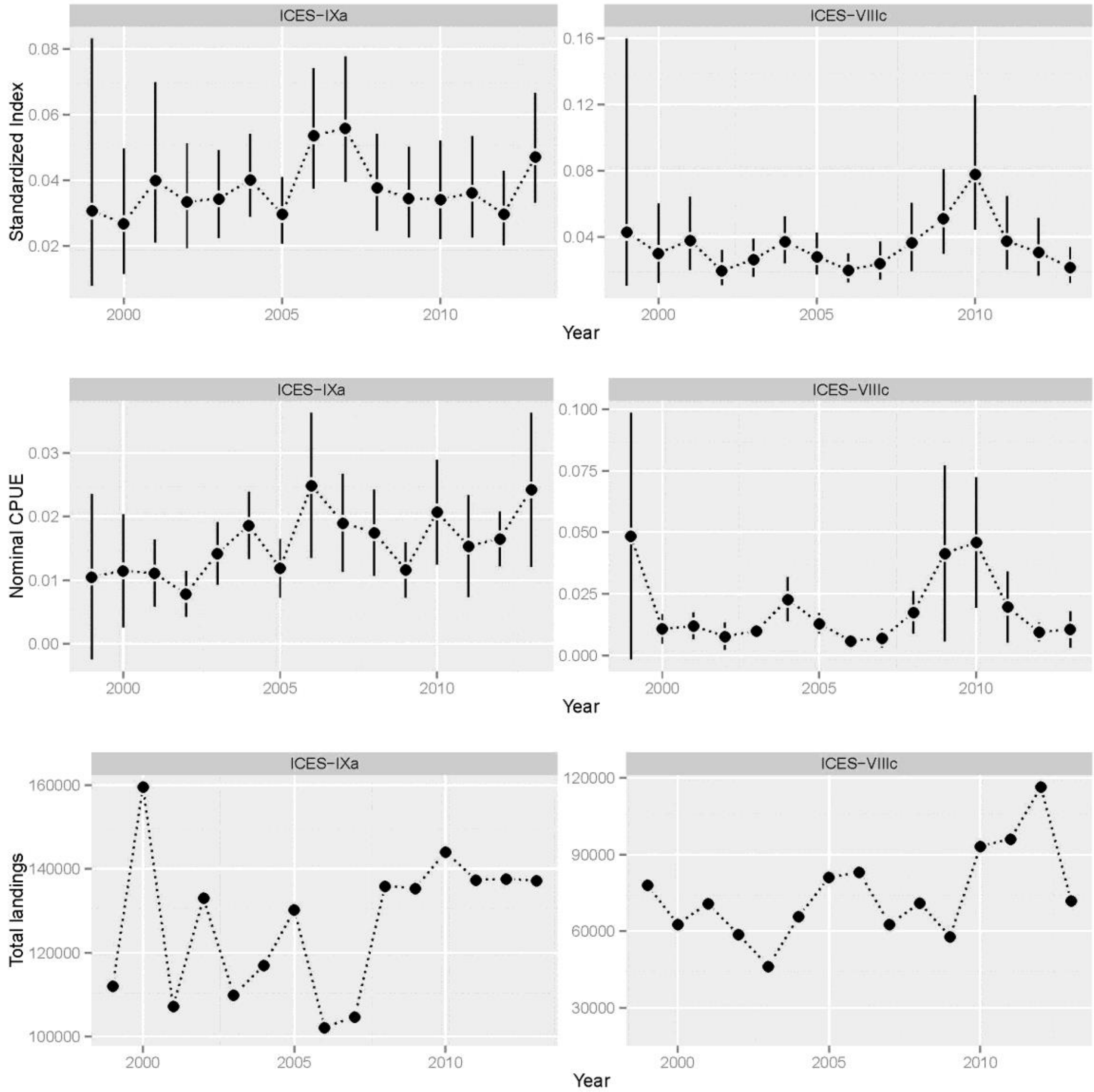


Figure 11: Ballan wrasse. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Spider crab (Maja brachydactyla)

Zero Inflated (Negative Binomial)

Gillnets (Trasmallo, Miño)

Coefficient	Estimate	SE	p-value
Count part			
Intercept	-8.5400	0.3800	<0.0001
Gear(trasmallo)	-4.2700	0.7900	<0.0001
GRT	-0.1600	0.0400	<0.0001
DoY	0.0030	0.0002	<0.0001
Depth	-1.1800	0.0400	<0.0001
SST	0.2600	0.0300	<0.0001
Soak time at night	3.4100	0.2200	0.0003
Seafloor(mixed)	0.2000	0.0700	0.0030
Seafloor(soft)	0.5500	0.0600	<0.0001
Gear(trasmallo)*DoY	-0.0010	0.0006	0.0240
Gear(trasmallo)*Depth	1.2900	0.1100	<0.0001
Gear(trasmallo)*Soak time at night	-0.9900	0.3200	0.0020
Zero part			
Intercept	4.6100	0.4400	<0.0001
Depth	-3.8600	0.3100	<0.0001

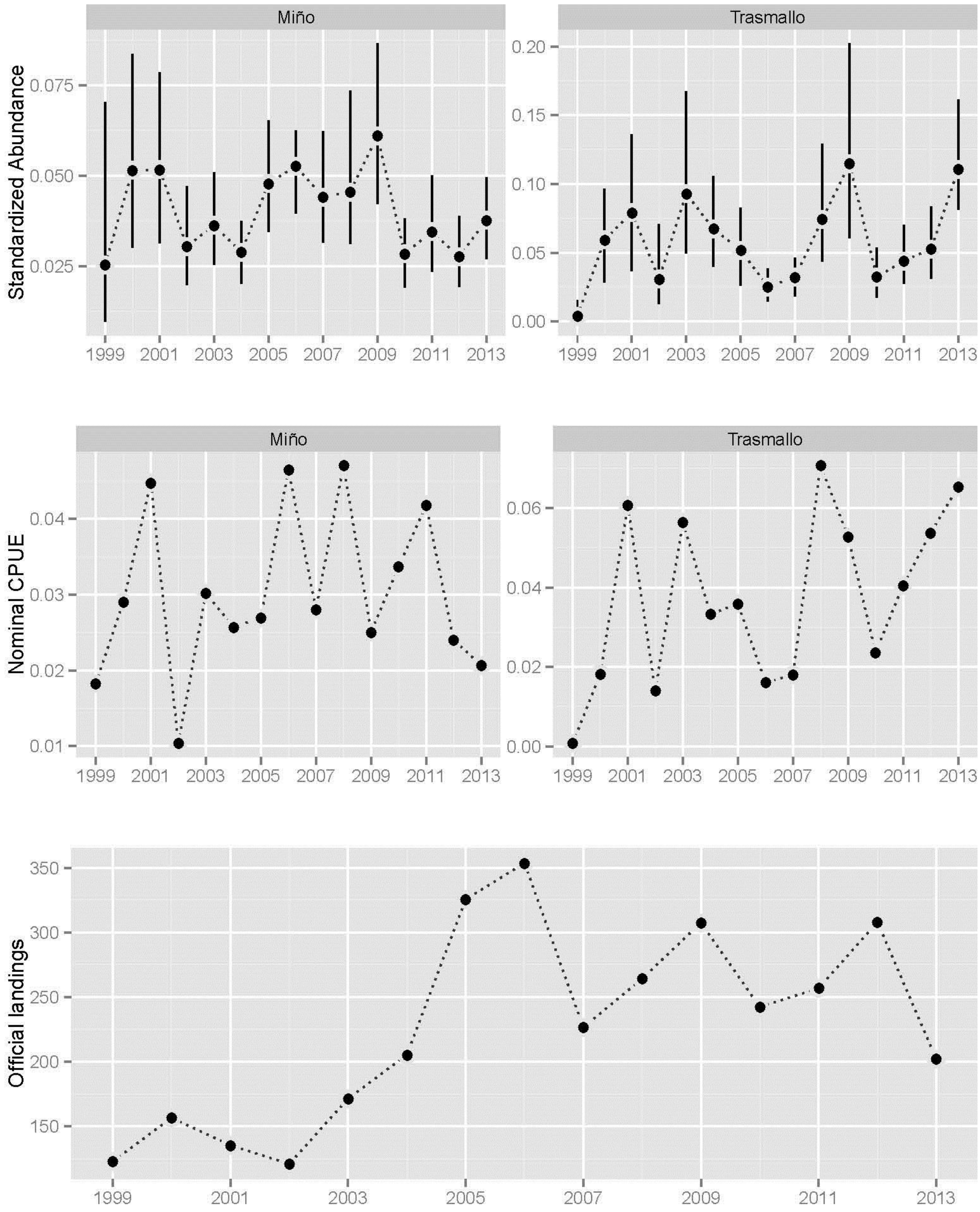
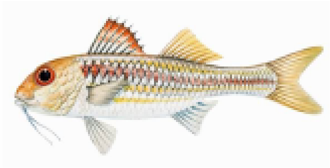


Figure 12: Spider crab. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Surmullet (Mullus surmuletus)



Zero Inflated (Negative Binomial)

Gillnets (Veta)

Coefficient	Estimate	SE	p-value
Count part			
Intercept	-7.6700	0.8300	<0.0001
DoY	1.8000	2.0500	0.3800
DoY^2	12.9900	2.4100	<0.0001
Depth	-0.6400	0.1000	<0.0001
SST	0.1300	0.0600	0.0210
Soak time at night	0.7900	0.2100	0.0002
Zone(AA)	1.3600	0.1400	<0.0001
Zone(Ca)	1.7500	0.1500	<0.0001
Seafloor(mixed)	0.9500	0.1500	<0.0001
Seafloor(soft)	0.6800	0.1500	<0.0001
Zero part			
Intercept	-15.7100	2.9000	<0.0001
Depth	3.4400	0.6500	<0.0001

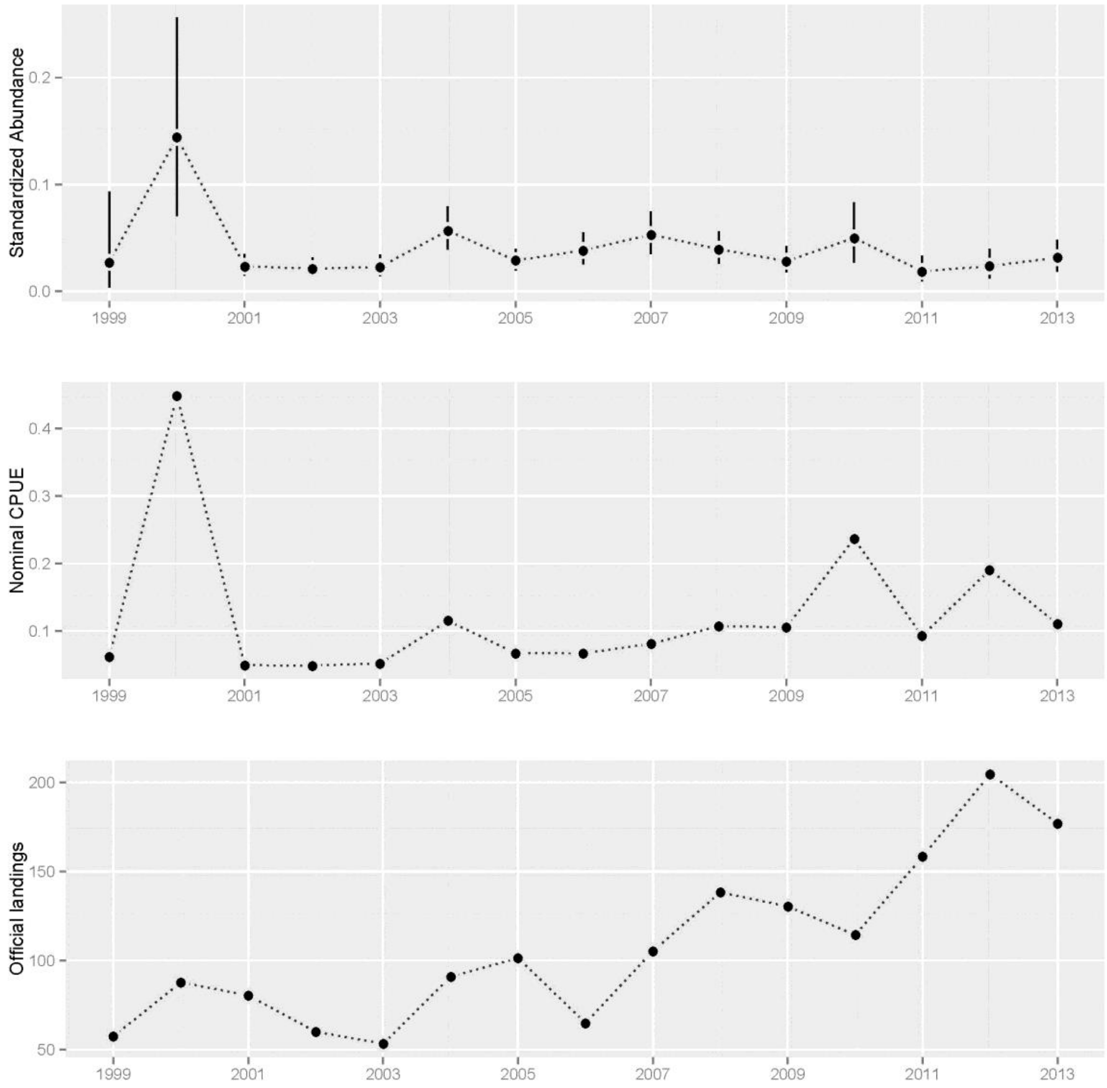


Figure 13: Surmullet. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Octopus (Octopus vulgaris)

GLM (Negative Binomial)

Traps (Nasa pulpo)

Coefficient	Estimate	SE	p-value
Intercept	-2.8500	0.0400	<0.0001
DoY	3.6600	0.8300	<0.0001
DoY^2	16.2200	0.8900	<0.0001
Depth	-0.1700	0.0100	<0.0001
SST	0.1000	0.0080	<0.0001
Qx	0.0500	0.0100	<0.0001
Soak time at night	-2.8300	0.0400	0.0003
Zone(AA)	0.0500	0.0600	0.3700
Zone(Ca)	0.2500	0.0700	0.0002
Seafloor(mixed)	-0.1500	0.0200	<0.0001
Seafloor(soft)	-0.3300	0.0200	<0.0001

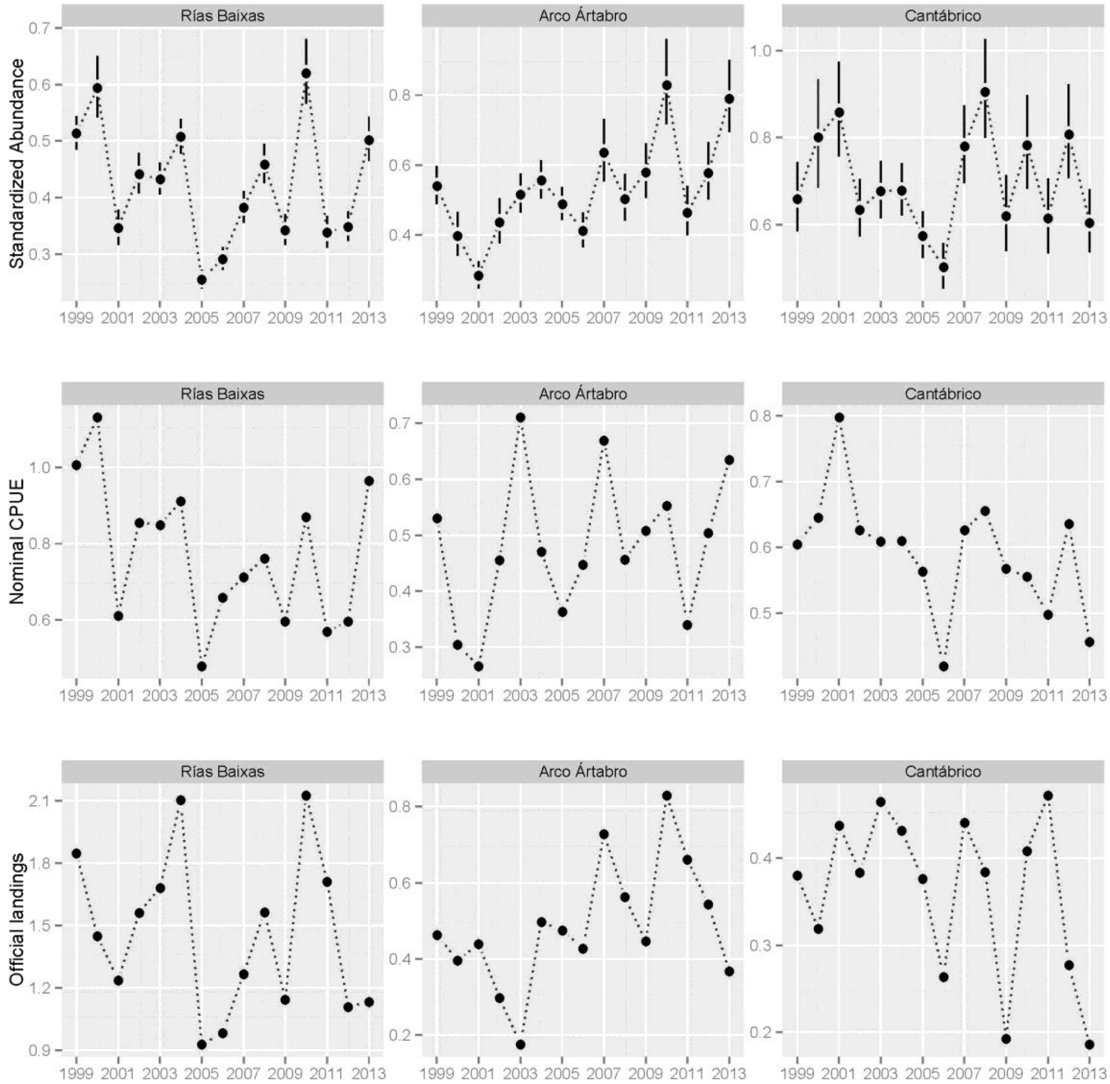


Figure 14: Octopus. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

European flounder (Platychis flessus)

Zero Inflated (Negative Binomial)

Gillnets (Trasmallo, Miño)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-10.7205	0.1925	< 2e-16
ZoneIICES-VIIIc	-0.2977	0.0544	<0.0001
Gear(Miño)	-1.2237	0.1418	< 2e-16
log(GRT)	-0.4198	0.0835	<0.0001
DoY	-76.9323	4.7233	< 2e-16
DoY^2	33.2110	4.1772	<0.0001
DoY^3	30.0864	3.0093	< 2e-16
log(Depth)	-0.6215	0.0421	< 2e-16
sstM	0.1051	0.0381	0.0059
Soak time at night	2.1672	0.1479	< 2e-16
Seafloor(mixed)	0.8548	0.1499	<0.0001
Seafloor(soft)	1.6427	0.1375	< 2e-16
Gear(Miño):log(GRT)	-0.5298	0.0972	<0.0001
Gear(Miño):log(Depth)	0.5734	0.0612	< 2e-16
Zero part			
(Intercept)	0.4560	0.1336	0.0006
log(Depth)	0.3348	0.0504	<0.0001

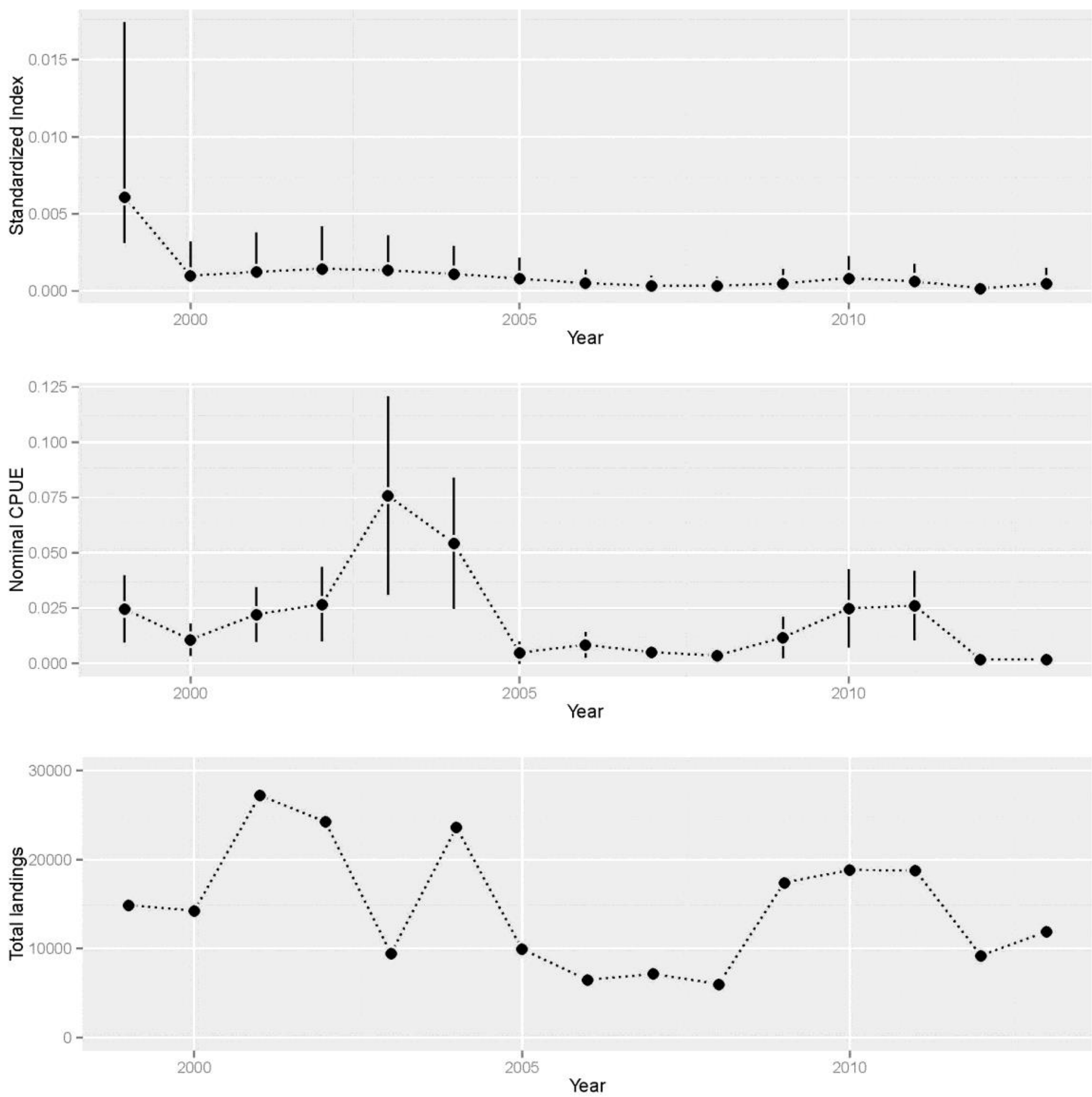
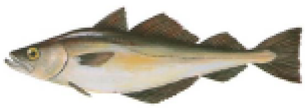


Figure 15: European flounder. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Pollack (Pollachius pollachius)



Zero Inflated (Negative Binomial)

Gillnets (Miño, Veta)

Coefficient	Estimate	SE	p-value
Count part			
Intercept	-13.4500	0.8700	<0.0001
Gear(veta)	8.0300	0.4600	<0.0001
GRT	0.0100	0.0700	0.8925
DoY	-13.6400	2.9700	<0.0001
DoY^2	-22.8000	3.7400	<0.0001
Depth	-0.3300	0.0700	<0.0001
Soak time at night	1.6400	0.4600	0.0003
Zone(AA)	2.2900	1.3600	0.0900
Zone(Ca)	1.0900	1.7000	0.5221
Seafloor(mixed)	-0.1500	0.0900	0.0913
Seafloor(soft)	-1.2100	0.0900	<0.0001
Gear(veta)*Depth	-1.2800	0.1200	<0.0001
Gear(veta)*GRT	0.5400	0.1200	<0.0001
Gear(veta)*Soak time at night	-1.5100	0.5000	0.0027
Zero part			
Intercept	-11.5800	2.5200	<0.0001
Depth	2.3100	0.5600	<0.0001

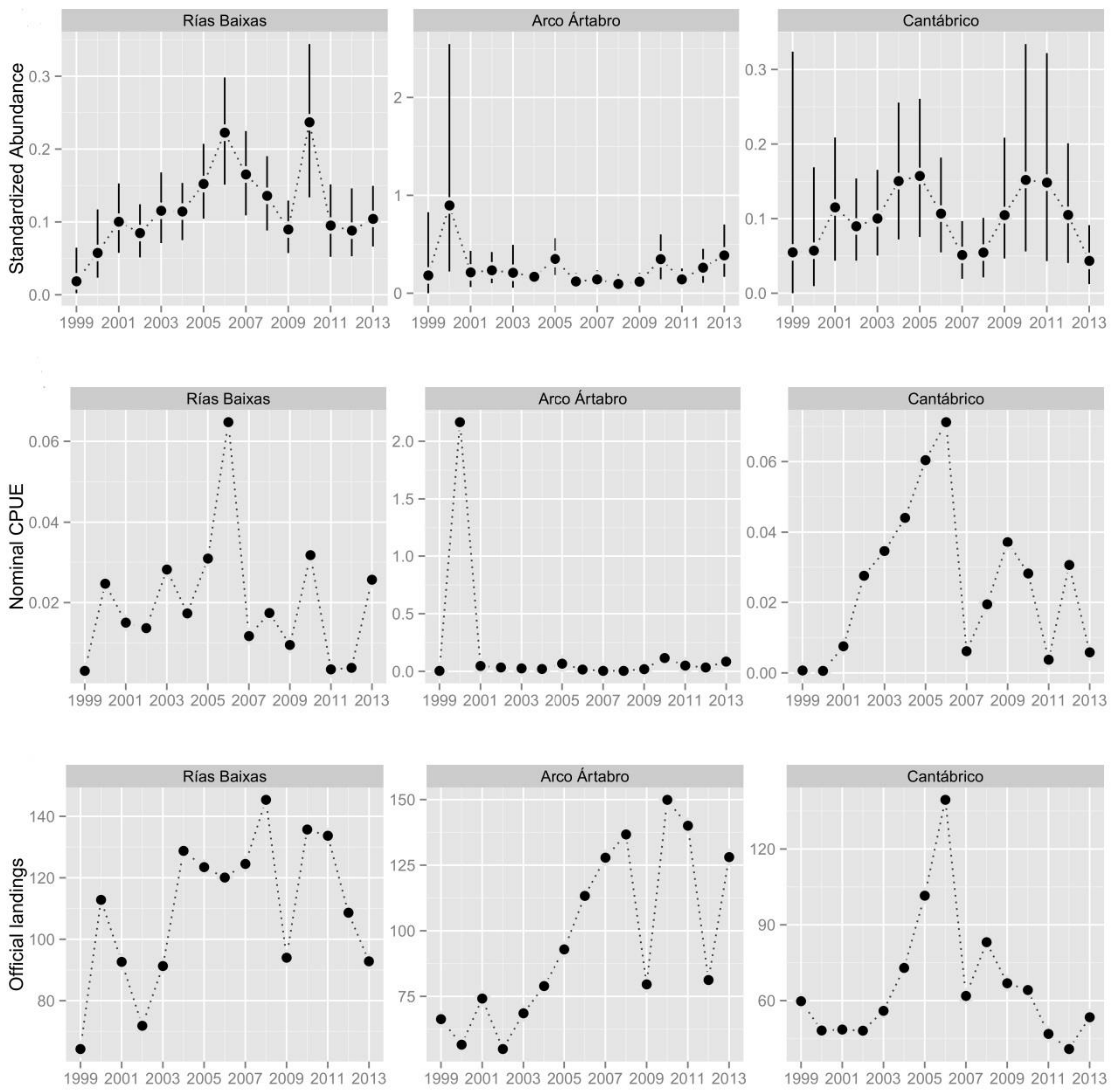


Figure 16: Pollack. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Undulate ray (Raja undulata)

Zero Inflated (Negative Binomial)

Gillnets (Trasmallo, Miño)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-12.4298	1.0570	< 2e-16
ICES-VIIIc	2.4500	1.5246	0.1081
log(Depth)	-0.7252	0.0715	< 2e-16
Soak time at night	0.8101	0.2526	0.0013
Gear(Miño)	-0.7816	0.2169	0.0003
Seafloor(mixed)	-0.3285	0.2640	0.2133
Seafloor(soft)	0.4635	0.2076	0.0255
Gear(Miño):Seafloor(mixed)	0.8411	0.2940	0.0042
Gear(Miño):Seafloor(soft)	0.3127	0.2403	0.1933
Zero part			
(Intercept)	-11.2568	1.9347	<0.0001
log(Depth)	3.7122	0.4987	<0.0001
Soak time at night	-5.3092	1.8421	0.0040

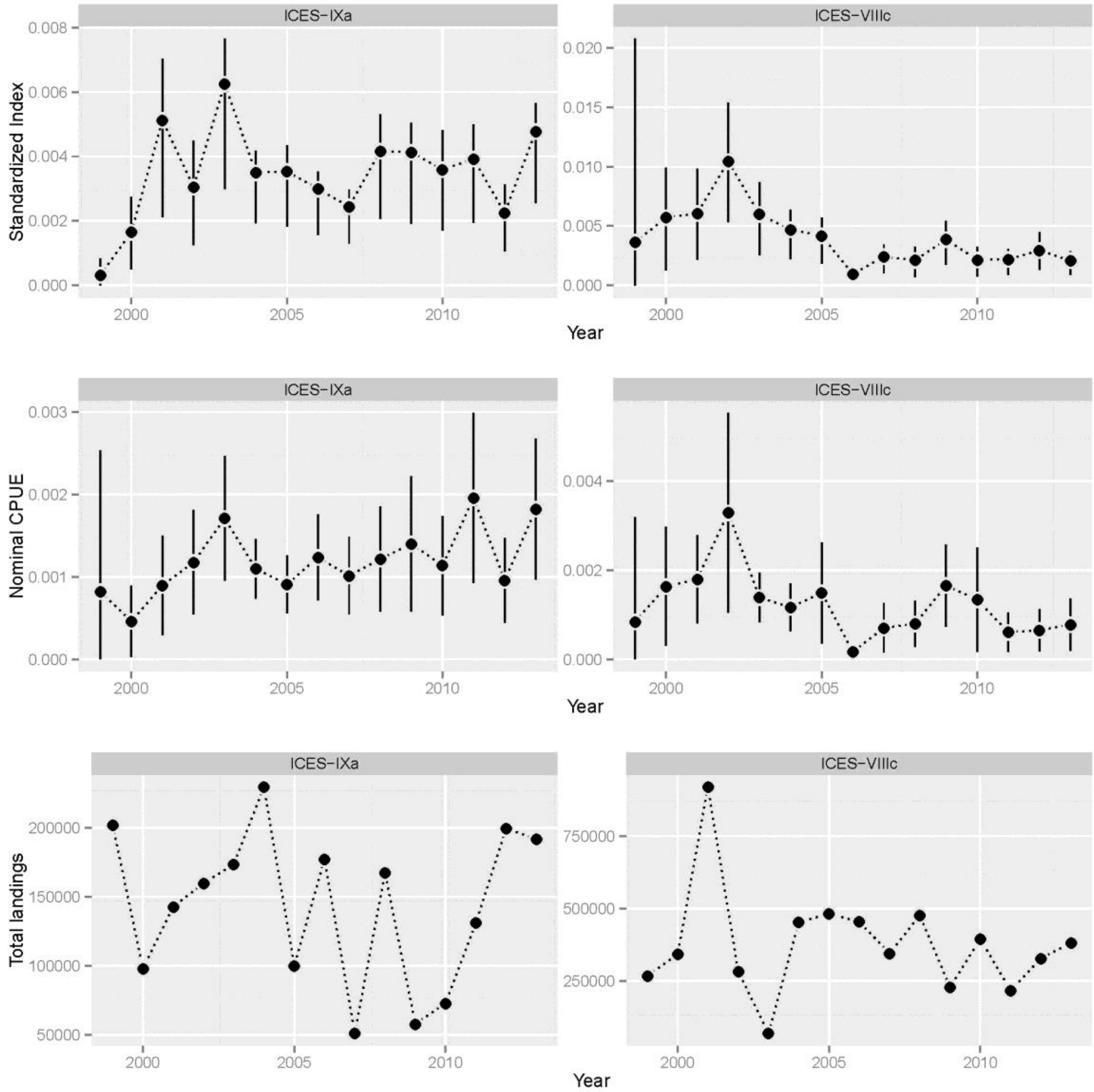
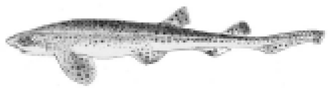


Figure 17: Undulate ray. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Lesser spotted dogfish (Scyliorhinus canicula)



Zero Inflated (Negative Binomial)

Gillnets (Trasmallo, Miño, Veta)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-13.7375	0.8928	< 2e-16
ICES-VIIIc	-3.1401	1.6301	0.0541
Gear(Miño)	-0.5168	0.9330	0.5796
Gear(Veta)	5.4603	0.9158	0.0000
log(GRT)	-0.3679	0.2698	0.1727
DoY	-3.9406	3.5179	0.2626
DoY^2	-14.0087	4.7093	0.0029
DoY^3	13.0654	3.5616	0.0002
log(Depth)	1.3687	0.2356	0.0000
Soak time at night	2.2094	0.5436	0.0000
Seafloor(mixed)	-0.0072	0.5040	0.9887
Seafloor(soft)	-0.7622	0.4588	0.0967
Gear(Miño):log(GRT)	-0.2579	0.2832	0.3624
Gear(Veta):log(GRT)	0.1831	0.2956	0.5356
Gear(Miño):log(Depth)	-0.5166	0.2633	0.0498
Gear(Veta):log(Depth)	-1.4409	0.2663	0.0000
Gear(Miño):Soak time at night	0.4488	0.7190	0.5325
Gear(Veta):Soak time at night	-1.3595	0.6029	0.0241
Gear(Miño):Seafloor(mixed)	0.3767	0.4932	0.4449
Gear(Veta):Seafloor(mixed)	0.8905	0.5253	0.0900
Gear(Miño):Seafloor(soft)	0.9932	0.4555	0.0292
Gear(Veta):Seafloor(soft)	1.2895	0.4856	0.0079
Zero part			
(Intercept)	0.2046	1.1941	0.8639
log(Depth)	0.1515	0.4441	0.7330
Gear(Miño)	0.1128	1.5066	0.9403
Gear(Veta)	7.5814	2.4324	0.0018
Seafloor(mixed)	-0.3691	0.3062	0.2280
Seafloor(soft)	-1.6238	0.4821	0.0008
Gear(Miño):log(Depth)	-0.3115	0.5174	0.5471
Gear(Veta):log(Depth)	-3.4184	1.0633	0.0013

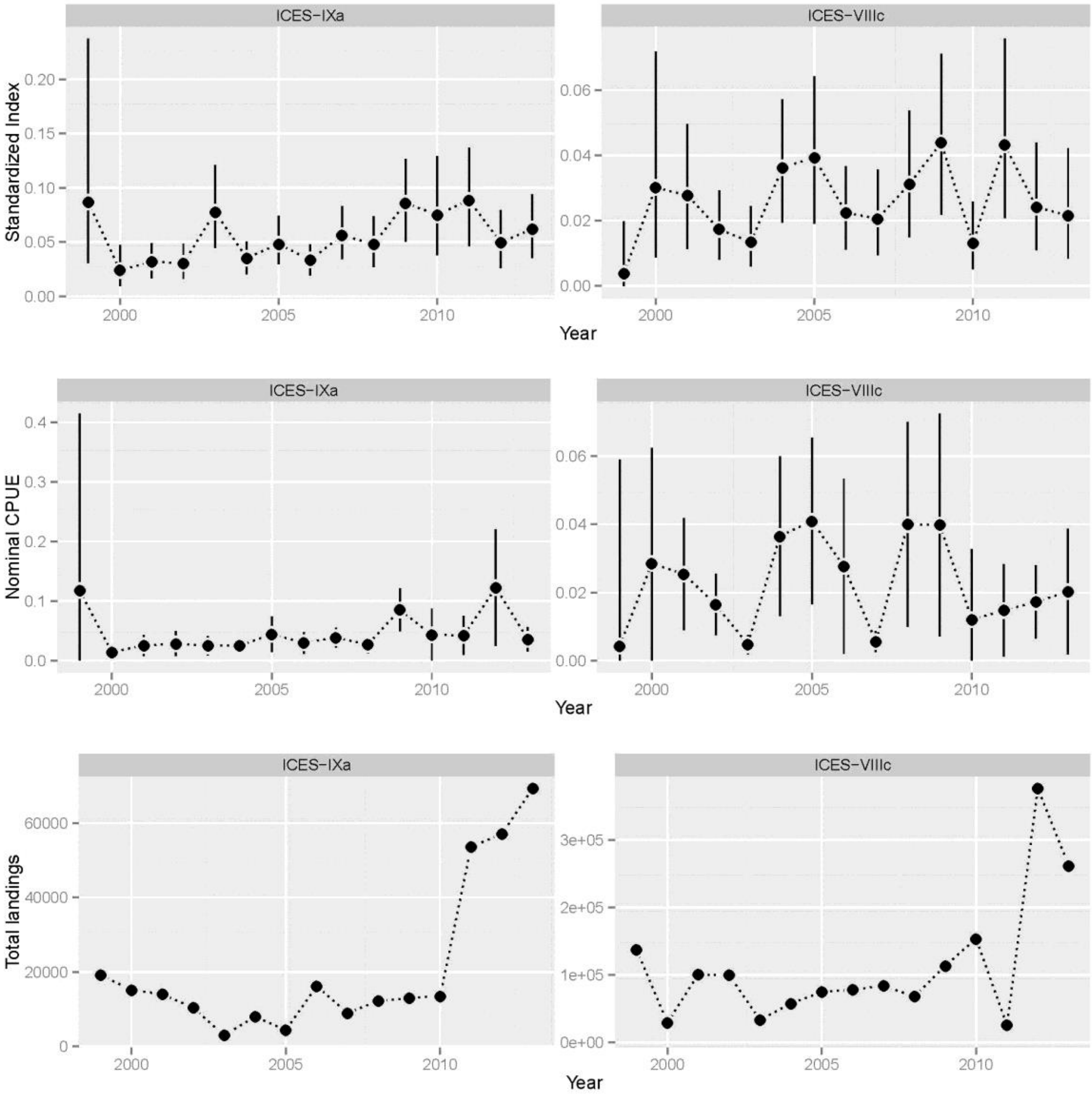
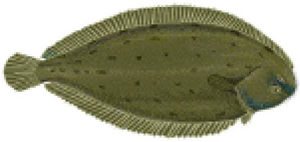


Figure 18: Lesser spotted dogfish. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Common sole (Solea solea)



GLM (Negative Binomial)

Gillnets (Trasmallo, Miño)

Coefficient	Estimate	SE	p-value
Intercept	-10.6000	0.6300	<0.0001
Gear(trasmallo)	3.4000	0.7100	<0.0001
DoY	-0.0010	0.0004	0.0200
Depth	0.6300	0.0700	<0.0001
SST	0.0240	0.0600	0.7000
Soak time at night	3.6500	0.3400	<0.0001
Seafloor(mixed)	1.1700	0.1400	<0.0001
Seafloor(soft)	2.0500	0.1200	<0.0001
Gear(trasmallo):DoY	0.0060	0.0009	<0.0001
Gear(trasmallo):SST	0.3700	0.1200	0.0030
Gear(trasmallo):Depth	-0.4100	0.1300	0.0010
Gear(trasmallo):Soak time at night	-2.0500	0.5000	<0.0001

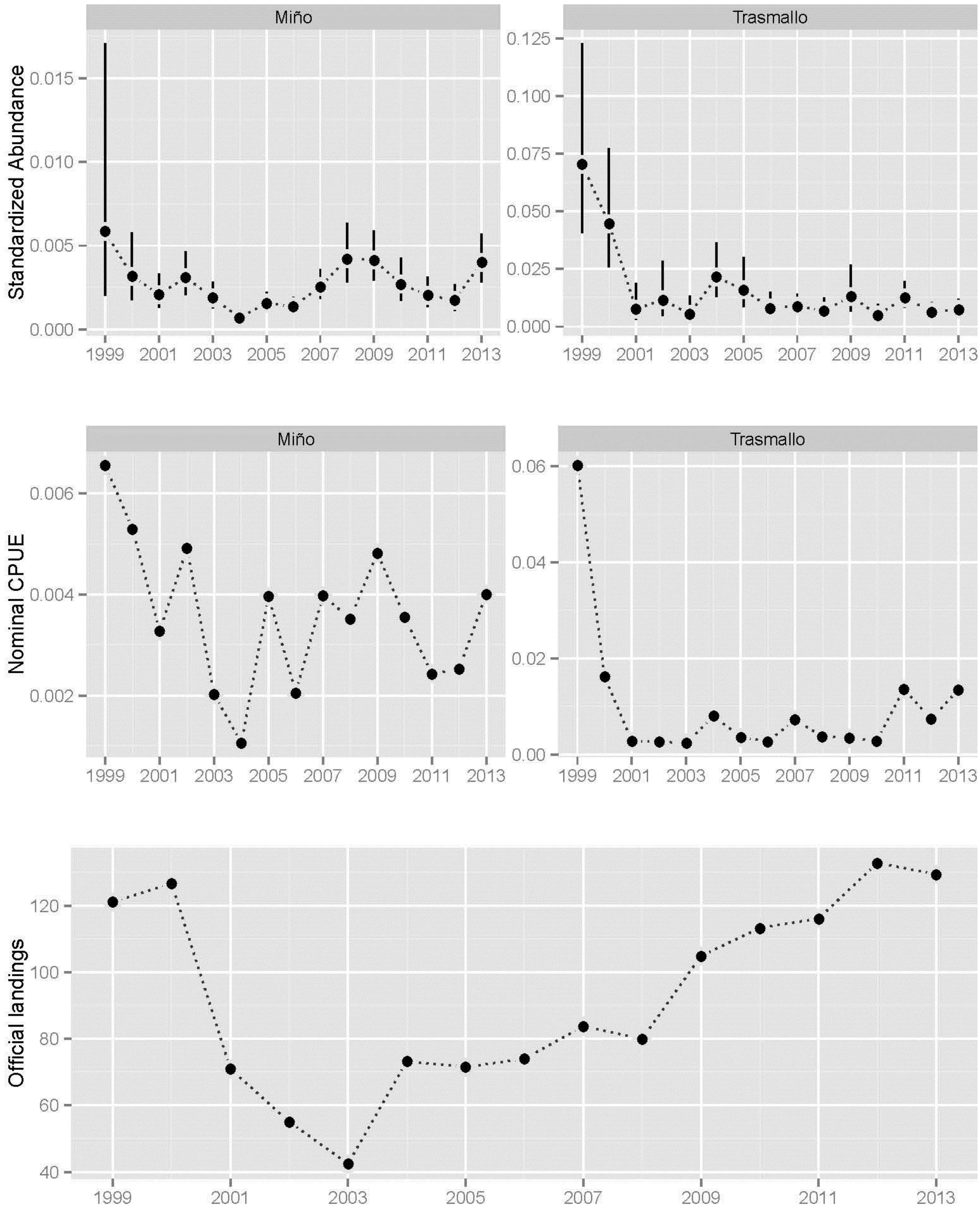


Figure 19: Common sole. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

Pouting (Trisopteurs luscus)

Zero Inflated (Negative Binomial)

Gillnets (Miño, Veta)

Coefficient	Estimate	SE	p-value
Count part			
(Intercept)	-13.88675	0.437089	< 2e-16
ICES-VIIIc	-1.25603	0.850135	0.13956
Gear(Veta)	7.221736	0.385717	< 2e-16
log(GRT)	0.003391	0.048291	0.94402
DoY	-11.51782	2.23452	2.54E-07
DoY^2	-14.541959	3.421456	2.14E-05
log(Depth)	0.574686	0.053112	< 2e-16
Soak time at night	4.146583	0.370406	< 2e-16
Seafloor(mixed)	0.043281	0.082617	0.60036
Seafloor(soft)	-0.154894	0.07713	0.04462
Gear(Veta):log(GRT)	-0.297129	0.090958	0.00109
Gear(Veta):DoY	5.29754	4.316395	0.21971
Gear(Veta):DoY^2	12.131461	5.378254	0.02409
Gear(Veta):log(Depth)	-0.675018	0.099134	9.82E-12
Gear(Veta):Soak time at night	-2.321141	0.40953	1.45E-08
Gear(Veta):Seafloor(mixed)	0.901132	0.146139	6.99E-10
Gear(Veta):Seafloor(soft)	1.514138	0.140015	< 2e-16
Zero part			
(Intercept)	4.464	0.9572	3.10E-06
log(Depth)	-3.3565	0.6142	4.63E-08

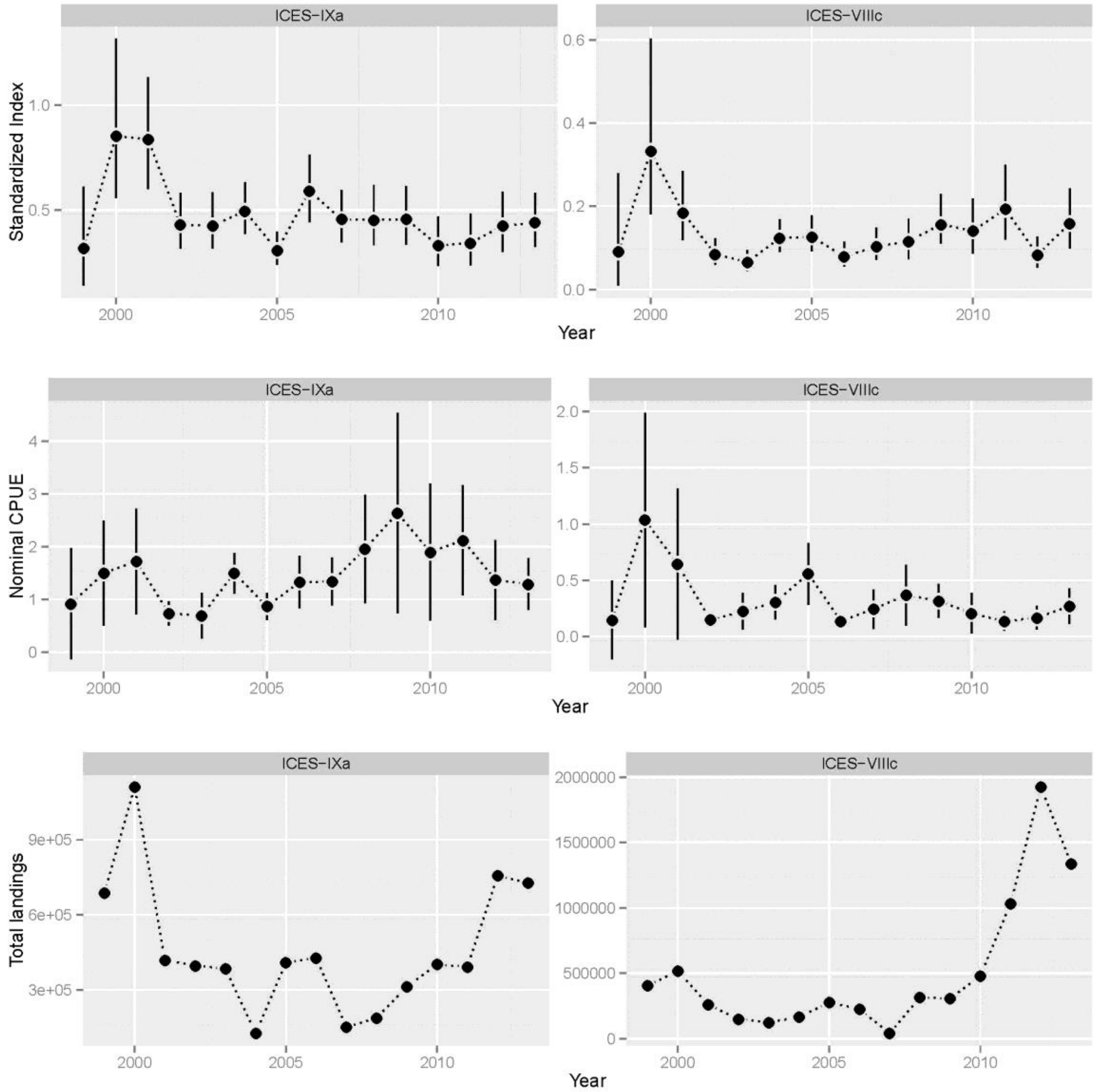


Figure 20: Pouting. Time series (1999-2013) of estimated relative abundance (Standardized abundance, upper pannel), nominal catch per unit effort assessed from observers data (Nominal CPUE, middle pannel) and total landings from PESCA DE GALICIA (Official landings, lower pannel).

All the resulting time series of standardized catch rates for each species will help the government agency to improve the exploitation plans, and data and results will be included within their regular reports and internet resources.

4.3-Standardized abundances, environmental drivers and life history traits

As a preliminary exploration of common trends among indices of abundance, simple linear regressions were applied to each species' index (Table 2). The coefficient of variation (CV) for each time series was also calculated.

Table 2: Summary table of simple linear regressions of relative abundance through time (1999-2013) for each species. Red rows represent significant trend of the time series.

Species	Index	Intercept	Slope	Pvalue	CV
Labrus bergylta	B.wrasse.IXa	-0.9515	0.0005	0.3550	0.2284
Labrus bergylta	B.wrasse.VIIIc	-1.0646	0.0005	0.5586	0.4273
Conger conger	C.conger.Trap.IXa	5.2225	-0.0026	0.0169	0.4522
Conger conger	C.conger.Trap.VIIIc	4.0271	-0.0020	0.0140	0.4291
Dicentrarchus labrax	D.labrax	72.4999	-0.0360	0.0497	1.0298
Diplodus sargus	D.sargus.IXa	4.3930	-0.0022	0.0384	1.1992
Diplodus sargus	D.sargus.VIIIc	-4.0624	0.0020	0.1414	0.7388
Maja brachydactyla	M.brachydactyla.Minho	0.3797	-0.0002	0.8102	0.2770
Maja brachydactyla	M.brachydactyla.Trasmallo	-4.2300	0.0021	0.2796	0.5504
Mullus surmuletus	M.surmuletus	4.3104	-0.0021	0.2672	0.7681
Octopus vulgaris	O.vulgaris.Art	-39.0484	0.0197	0.0132	0.2653
Octopus vulgaris	O.vulgaris.Cant	4.1776	-0.0017	0.8120	0.1648
Octopus vulgaris	O.vulgaris.RB	8.3904	-0.0040	0.5583	0.2542
Platichthys flesus	P.flesus	0.3892	-0.0002	0.0168	1.2705
Pollachius pollachius	P.polachius.Cant	-2.3309	0.0012	0.6335	0.4066
Pollachius pollachius	P.pollachius.Art	21.1909	-0.0104	0.3992	0.7718
Pollachius pollachius	P.pollachius.RB	-9.5164	0.0048	0.1696	0.4840
Raja undulata	R.undulata.IXa	-0.1749	0.0001	0.3235	0.4214
Raja undulata	R.undulata.VIIIc	0.6730	-0.0003	0.0130	0.6038
Scyliorhinus canicula	S.canicula.IXa	-3.5263	0.0018	0.1965	0.4069
Scyliorhinus canicula	S.canicula.VIIIc	-1.4906	0.0008	0.2952	0.4514
Solea solea	S.solea.Minho	0.0653	0.0000	0.7166	0.4955
Solea solea	S.solea.Trasmallo	4.9367	-0.0025	0.0158	1.0964
Trisopterus luscus	T.luscus.IXa	32.2064	-0.0158	0.1144	0.3489
Trisopterus luscus	T.luscus.VIIIc	3.8503	-0.0019	0.6604	0.4920

In general most of the time series (17 of 25) remained constant with no significant trend along the period of study. Among the significant, 7 out of 8 resulted slightly negative. We performed a Principal Component Analysis (PCA, Fig. 21) in order to reduce dimensions in the data set and infer potential clustering among the species' abundances. The loadings of first principal component (PC1) will be used to correlate with species' life history traits.

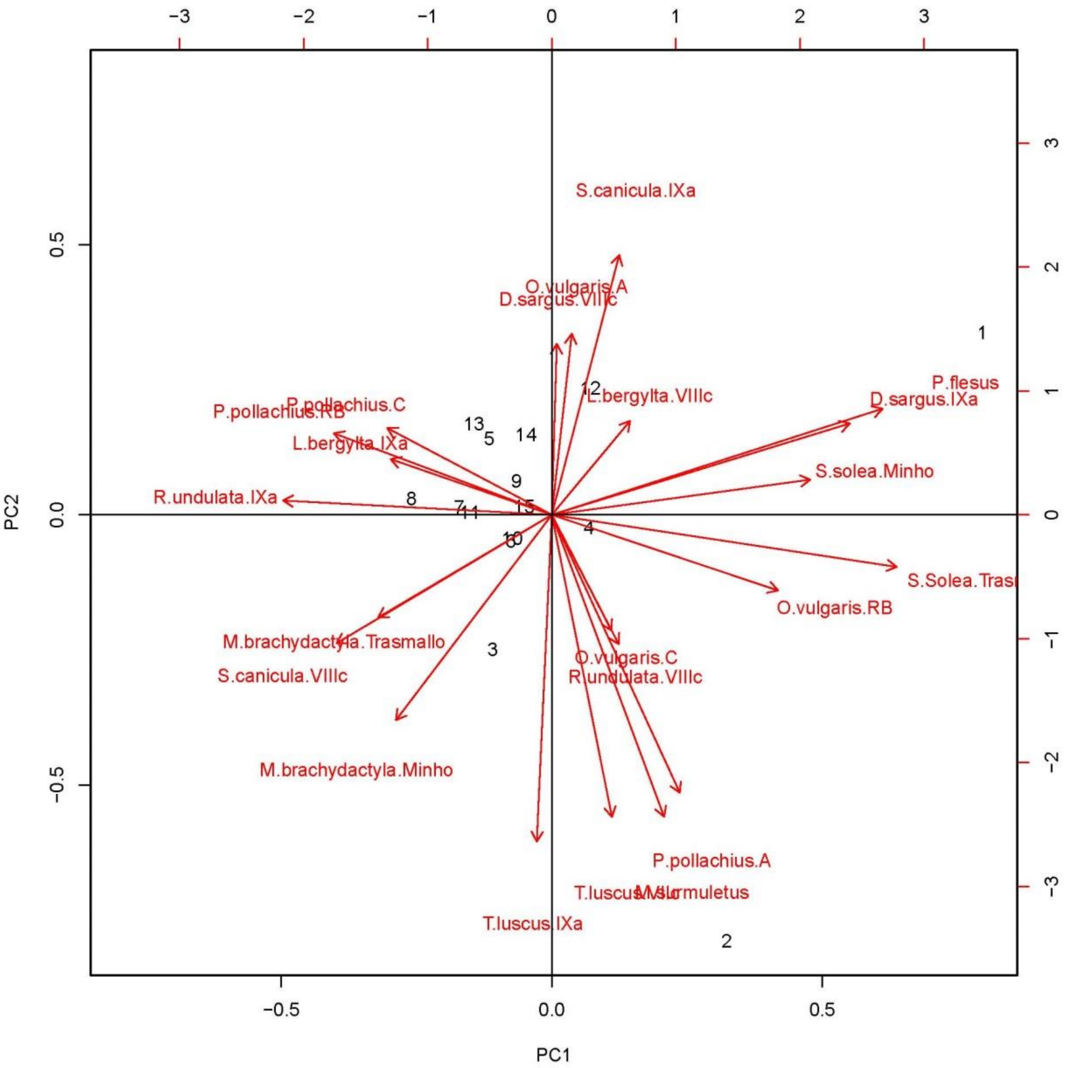


Figure 21: Biplot of the two first principal components of the PCA for the complete matrix of indices of relative abundance.

In addition, we obtained the correlation matrix for all the species studied to explore likely common trends among the different times series (Fig. 22). In general, correlations among species were weak; however, some strong relationships were also apparent. For instance, flatfishes correlated positively between them and negatively with *R. undulata* and *P. pollachius* complementing the results obtained in the PCA.

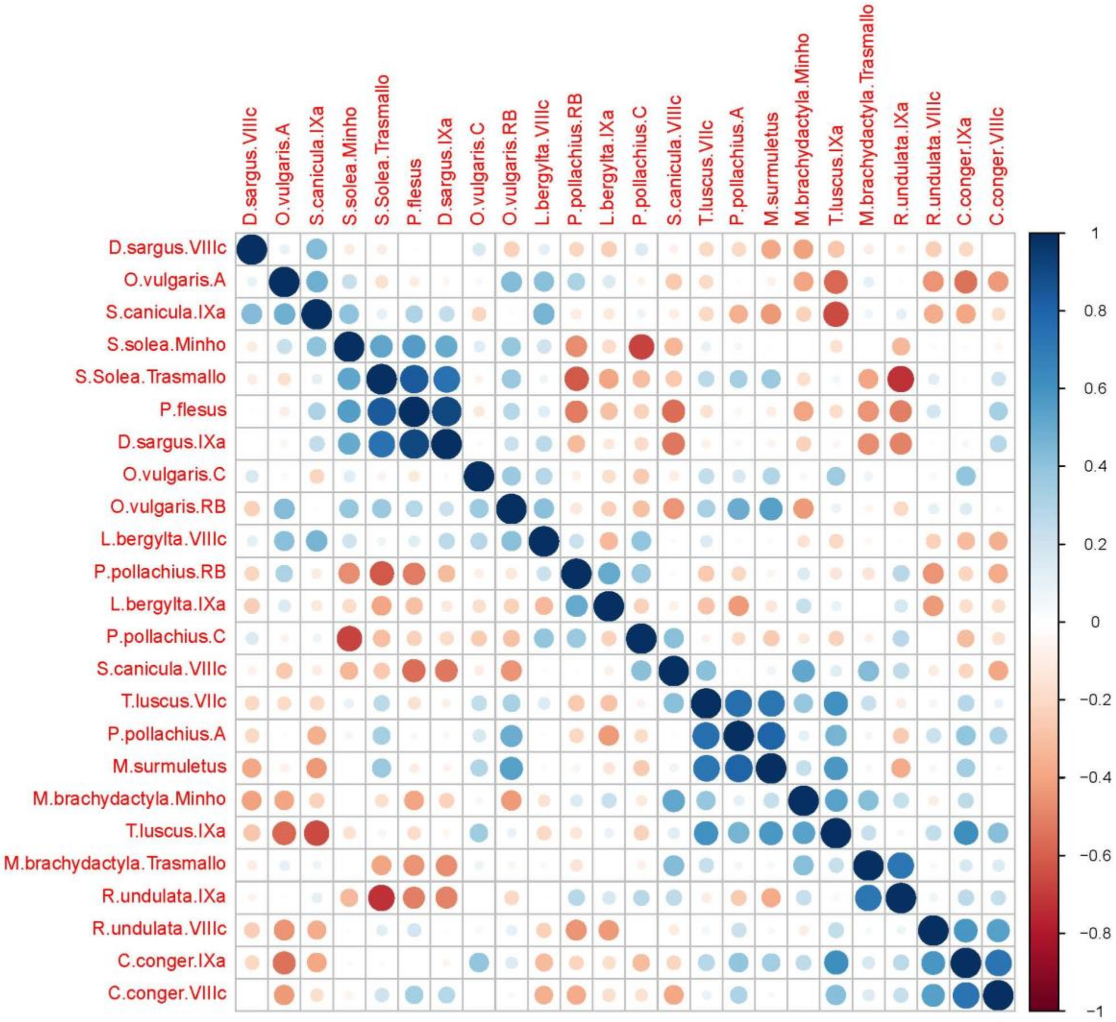


Figure 22: Correlation matrix for the whole set of relative abundance time series. Only complete time series are presented (*D. labrax* it is not shown).

In order to explore the species-specific responses to environmental conditions and the potential dependence on life history traits we first obtained Spearman Rank correlations for each of the indices of abundance and one-year lagged Qx and SST. Second, to further characterize the relative abundance time series we computed the time trend and coefficient of variation. Third, as a measure of location within the coastal assemblage we extracted the loadings of each time series on the first principal component described above.

We did not found a clear association between time trends and life history traits, however, species with larger L-infinity and slower growth rates tended to be less variable (Fig. 23). In addition, species with larger positive loadings on the first PC had smaller L-infinity and larger growth rates (Fig. 24). Finally, no clear pattern was found between traits and response to upwelling strength (Fig. 25), however, species that had higher positive association with one-yr lagged SST tended to have smaller L-infinity and larger growth rates (Fig. 26).

Table 3: Summary table showing the Spearman Rank correlation between abundance indices and environmental drivers (Upwelling index and Sea surface temperature).

Species	Abundance Index	Qx (lag 1-year)	SST (lag 1-year)
Pollachius pollachius	P.pollachius.RB	0.3893	-0.3679
Pollachius pollachius	P.pollachius.A	-0.4929	-0.1750
Pollachius pollachius	P.pollachius.C	0.1929	-0.3179
Mullus surmuletus	M.surmuletus	-0.0821	0.2893
Solea solea	S.solea.Minho	-0.2893	0.1286
Solea solea	S.Solea.Trasmallo	-0.2643	0.4893
Platichthys flesus	P.flesus	-0.1036	-0.3893
Raja undulata	R.undulata.IXa	-0.0214	-0.6071
Raja undulata	R.undulata.VIIIc	-0.4643	-0.1679
Scyliorhinus canicula	S.canicula.IXa	0.3679	0.1857
Scyliorhinus canicula	S.canicula.VIIIc	-0.1321	0.2250
Trisopterus luscus	T.luscus.IXa	-0.2500	0.0607
Trisopterus luscus	T.luscus.VIIc	-0.3964	0.0536
Labrus bergylta	L.bergylta.IXa	0.1714	0.0357
Labrus bergylta	L.bergylta.VIIIc	0.1321	0.1143
Diplodus sargus	D.sargus.IXa	-0.0250	-0.1036
Diplodus sargus	D.sargus.VIIIc	0.4929	0.1000

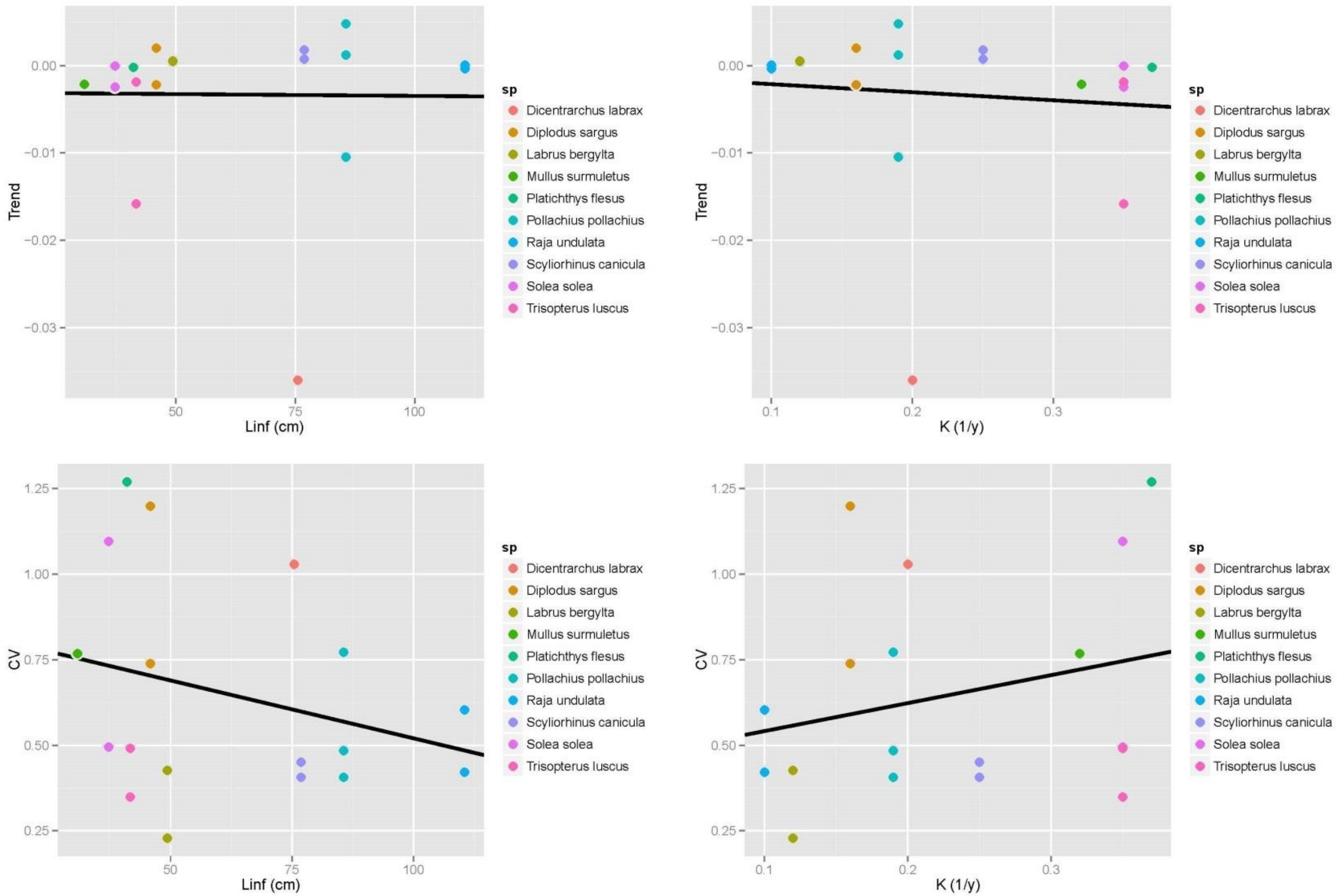


Figure 23: Relationships of slopes and coefficient of variation of each relative abundance time series with species life history traits Linf and K. Black line represents regression Type II.

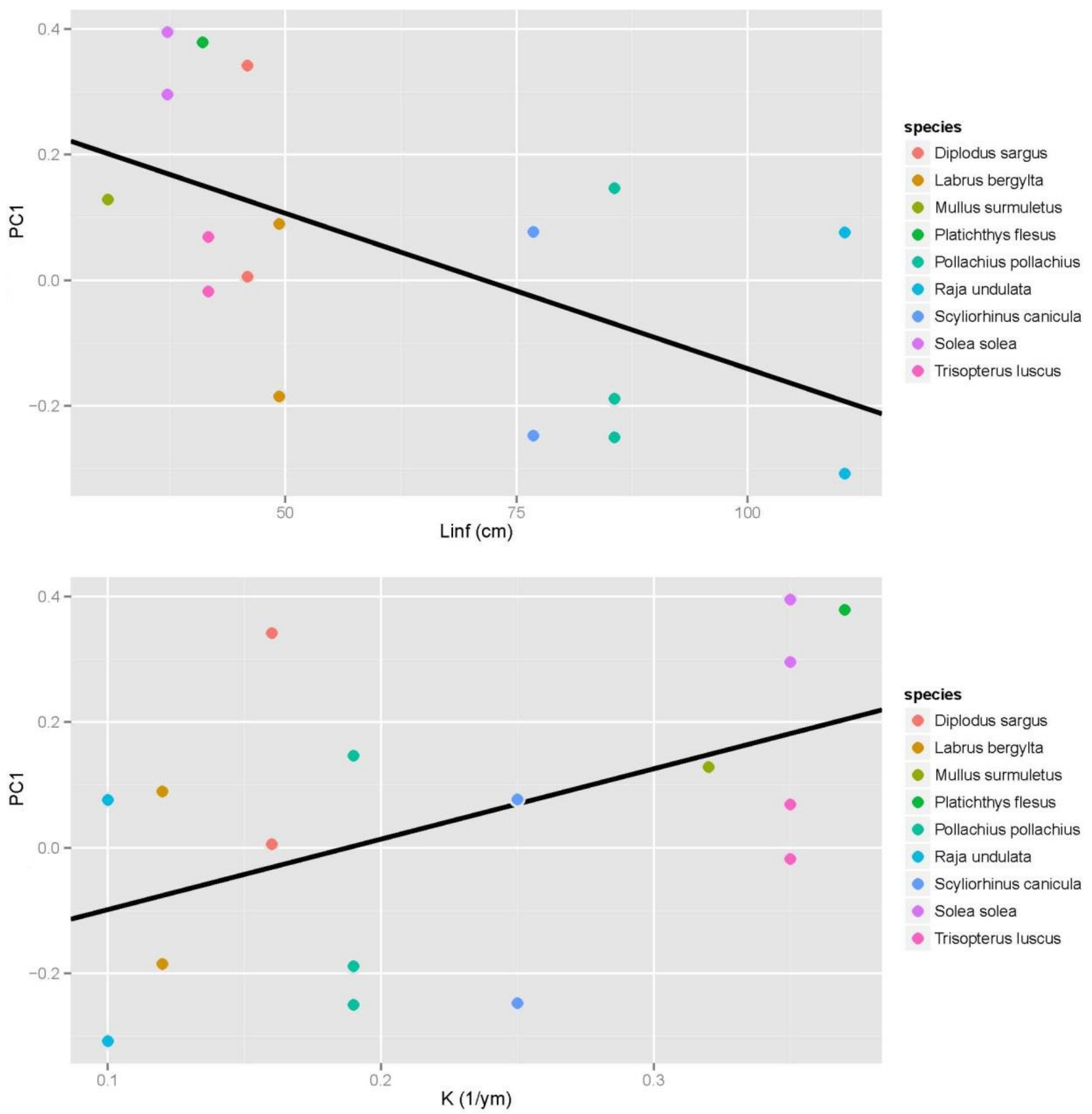


Figure 24: Relationships of loadings from PCA with species life history traits Linf and K. Black line represents regression Type II.

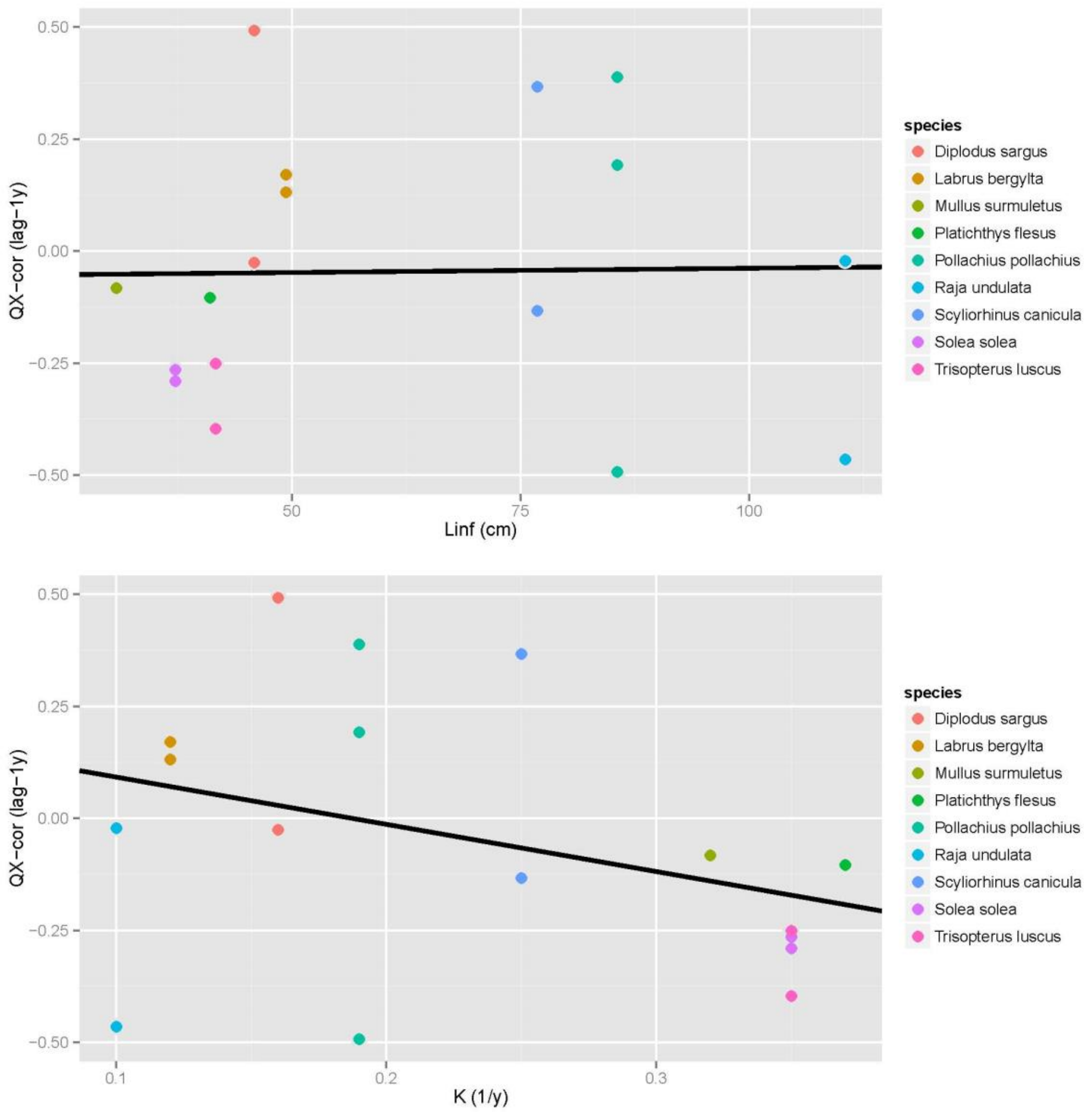
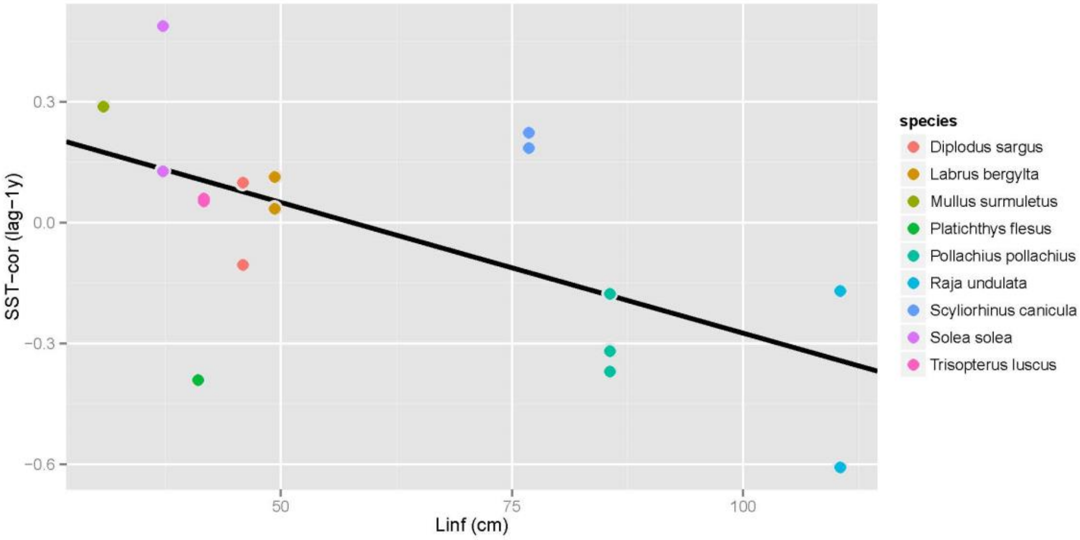


Figure 25: Relationships of Upwelling index correlations with species life history traits Linf and K. Black line represents regression Type II.



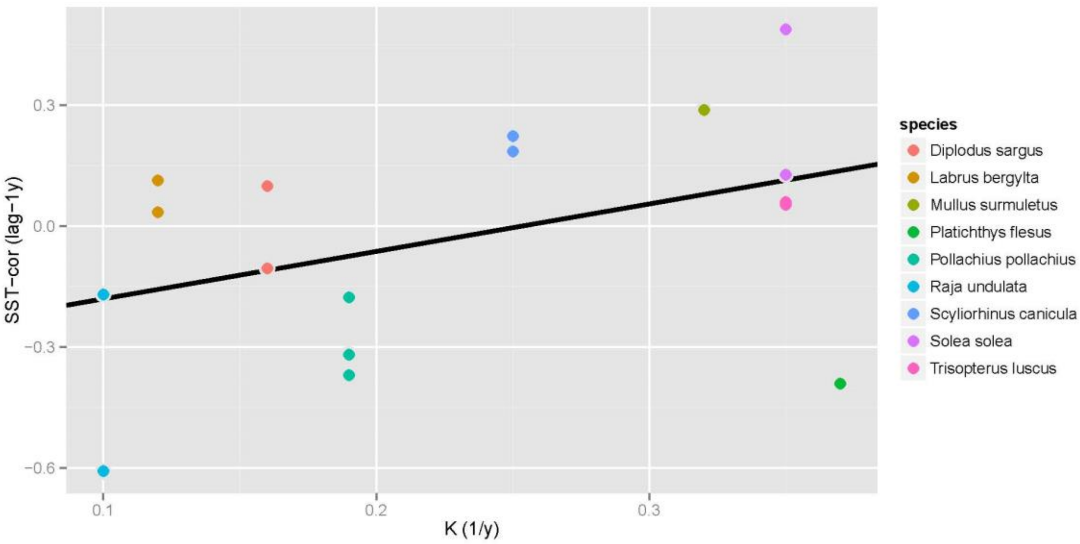


Figure 26: Relationships of sea surface temperature index correlations with species life history traits Linf and K. Black line represents regression Type II.

5-Conclusions

Official landings for the species studied here showed different patterns since mid- 1990s (Fig. 27). However, many factors such as geographic origin of the catches, discards or effort not reported in the statistics might affect the trends. For instance, gear-specific effort varies strongly (Fig. 28); therefore not accounting for at least this effect makes official landings an unrealistic index of population dynamics.

Therefore, obtaining robust indices of abundance as the ones put together through this project (Fig. 29) was timely.

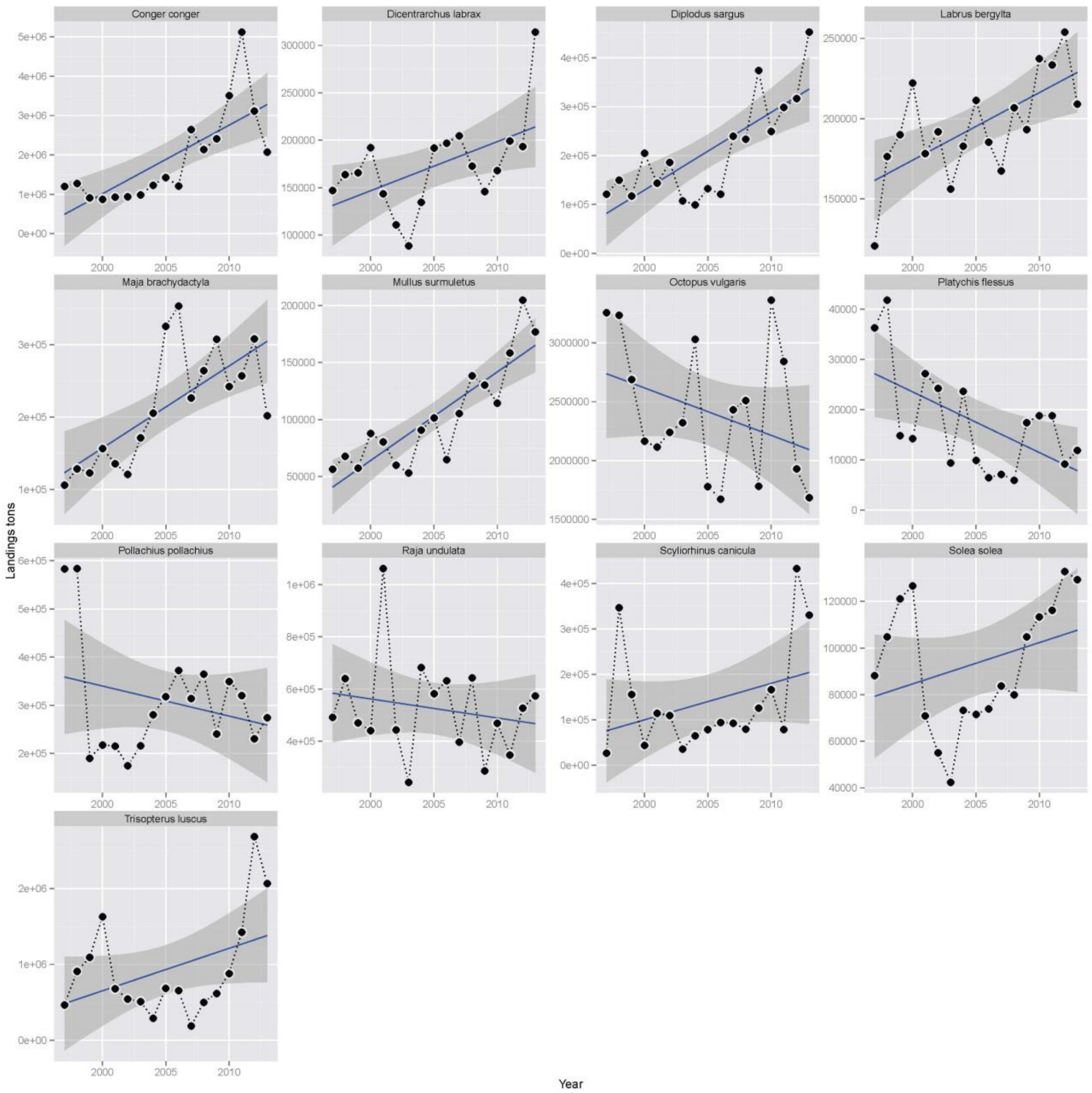


Figure 27: Temporal trends of total official landings for the species analyzed in this study. Data from PESCA DE GALICIA (1997-2013).

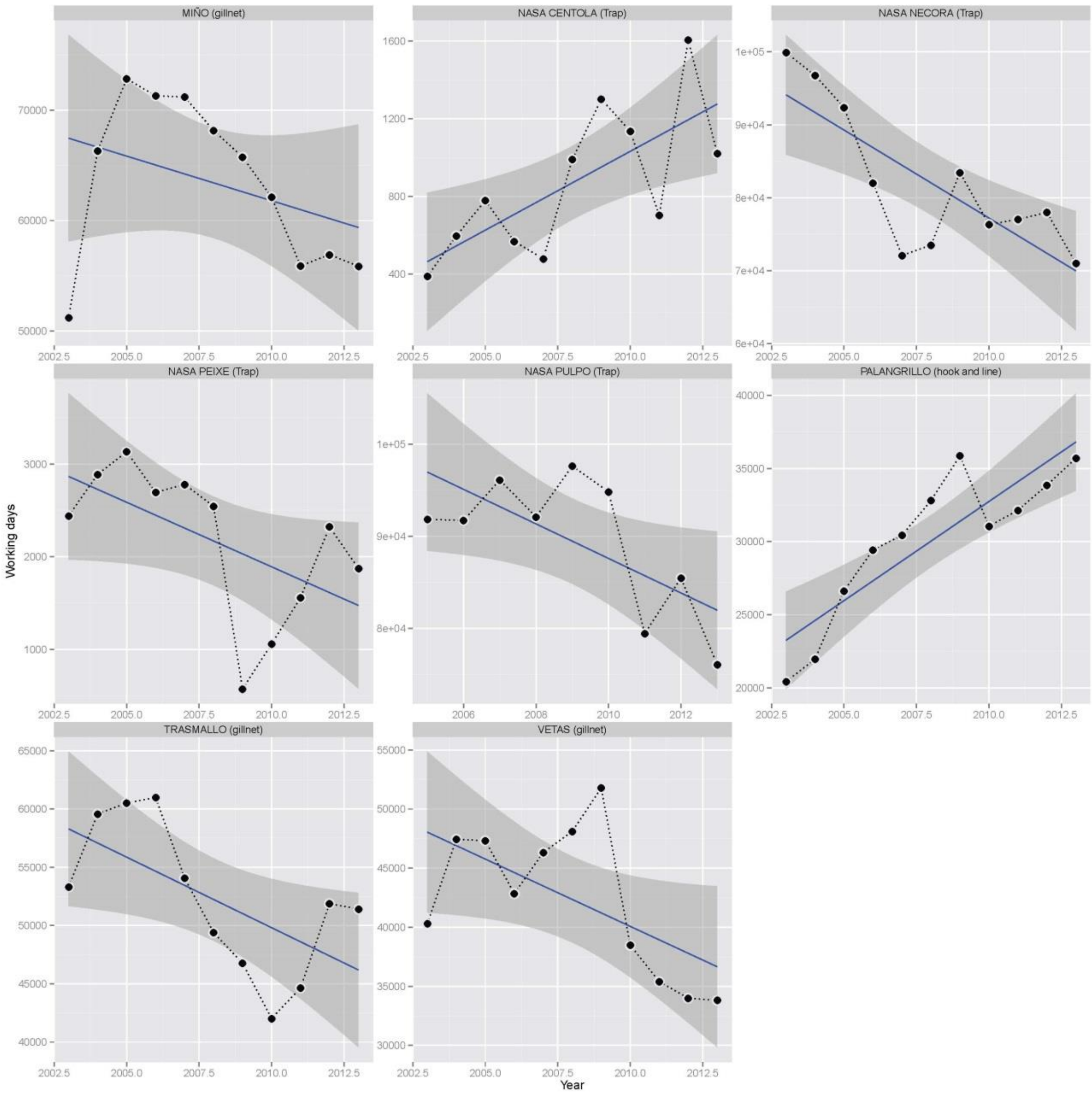


Figure 28: Temporal trends of total effort (fishing days) for the main fishing gears of the Galicia small-scale fisheries.

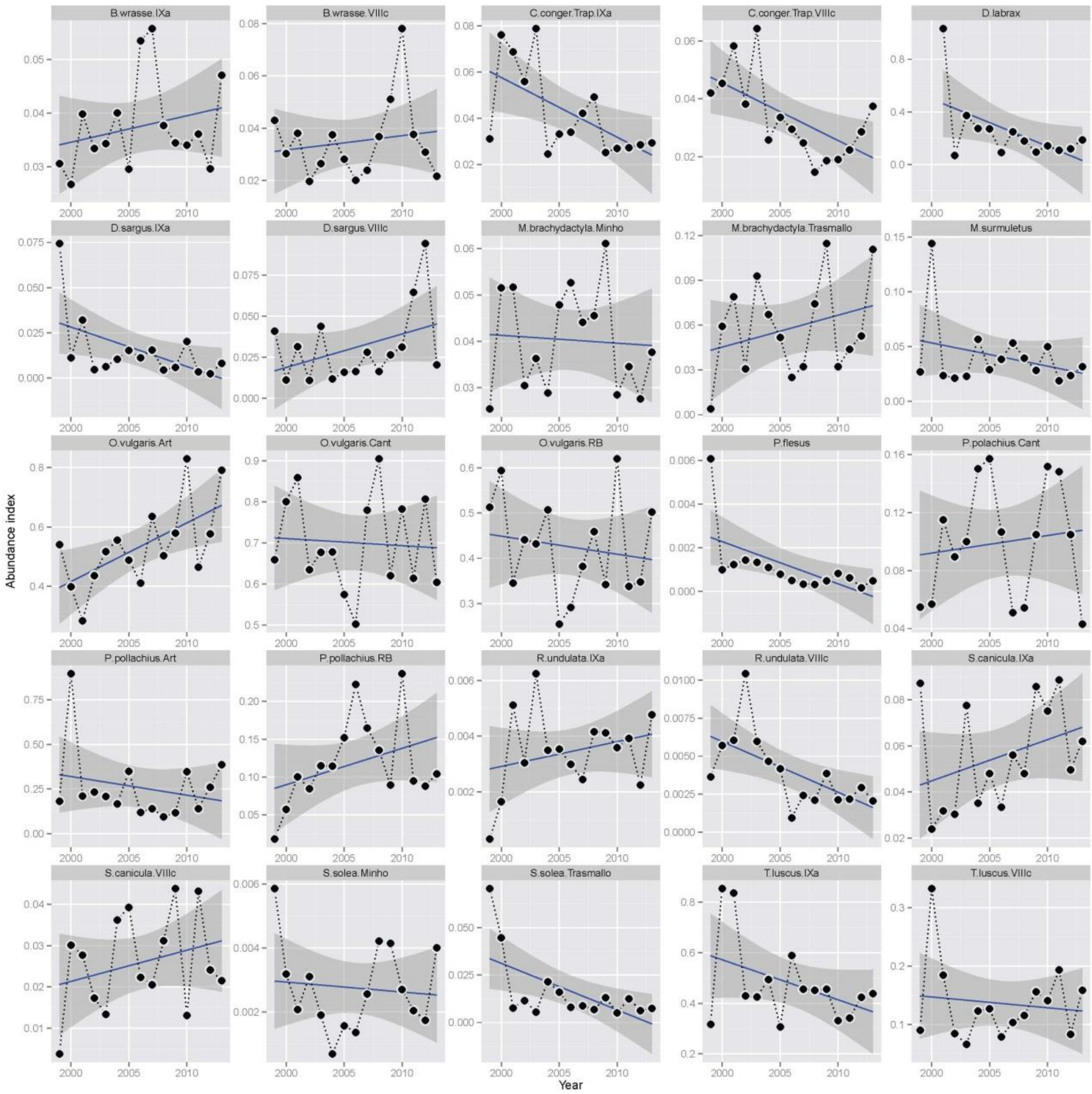


Figure 29: Temporal trends of indices of abundance for the species analyzed in this project targeted by the small-scale Galician fleet (1999-2013).

Although there is a high variability among years, in general, the abundance indices of coastal species of the Galician small-scale fishery showed relatively stable trends along the study period (1999-2013). However 8 out of the 25 time series of relative abundance showed negative trends.

Besides exploitation, life history characteristics might be a mechanism for explaining community assembly and responses to environmental conditions. Preliminary results presented here concur with ecological theory and observations. We found that species with smaller life span seemed to cluster together and had stronger relationship with temperature. Note however, that this conclusion needs further research mainly to fine tune the species-specific traits in order to develop robust relationships.

Our project aimed at shedding some light on the variability in abundance of multiple artisanal resources by means of strengthening the collaboration between the autonomous government and academia, which we think is, and will be, a topic of growing importance for both ICES and the CFP. Finally, the expected output of this project might be of interest for the European Commission initiative a4a in order to increase the number of stocks assessed in the ICES area.

Acknowledgements

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