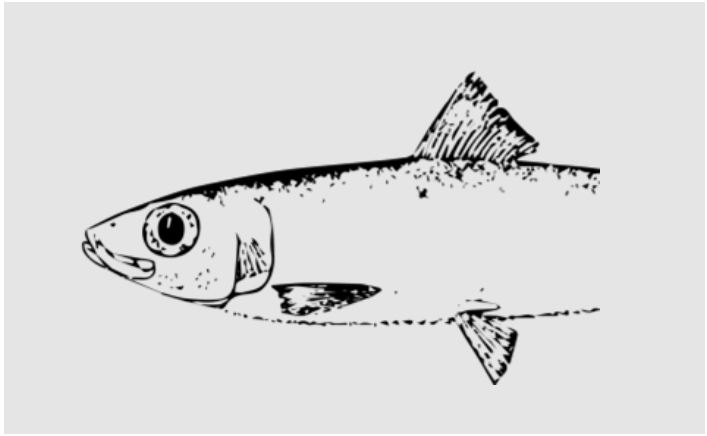
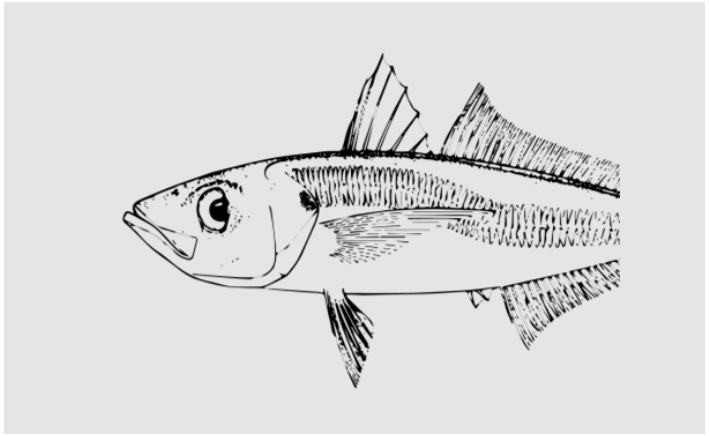
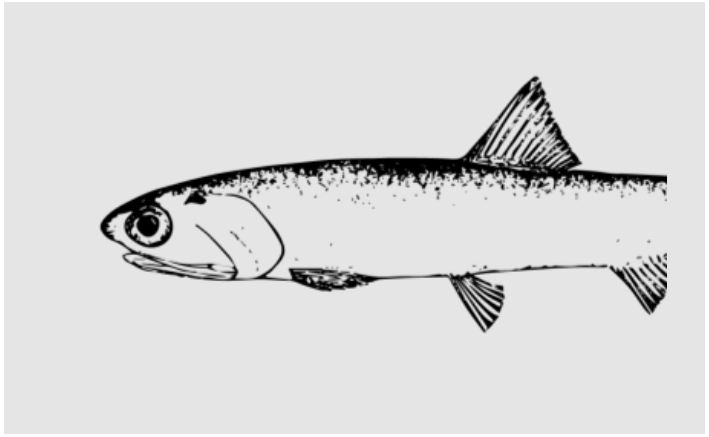
Condition factor and Length-weight relationship for small pelagic fishes in the Atlantic Iberian coast







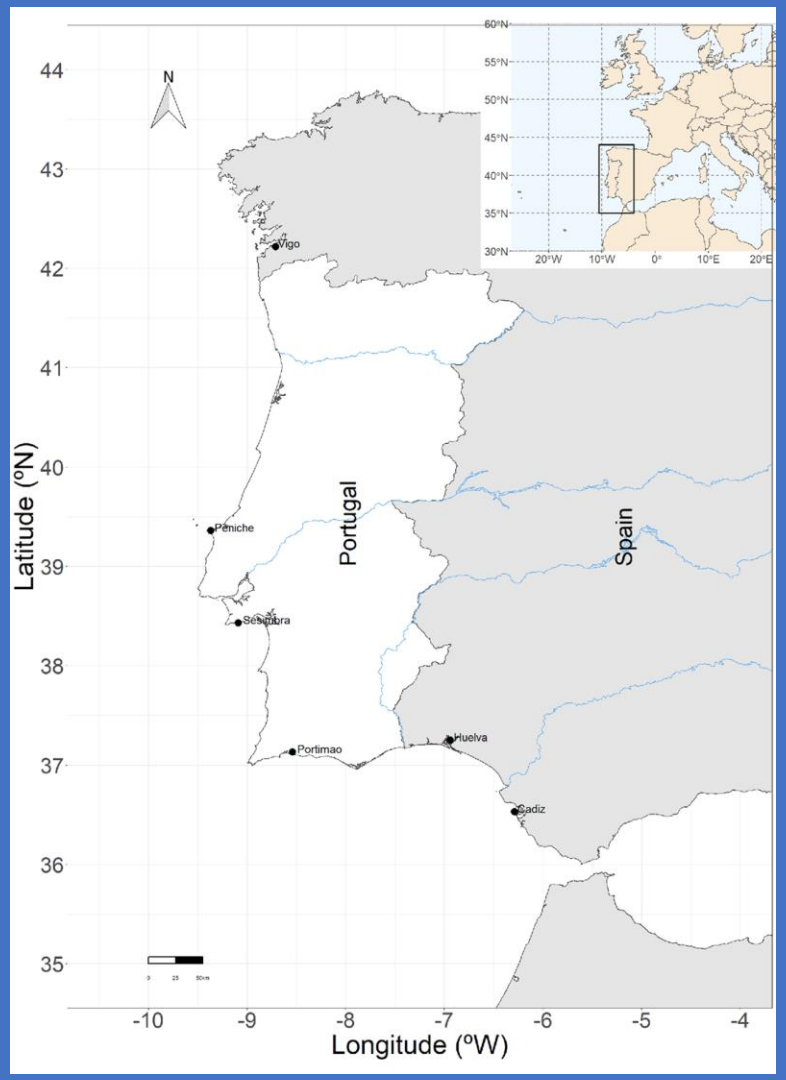
Andreia V. Silva, Diana Feijó, Alberto Rocha, Pedro Amorim, Ana Moreno & Cristina Nunes

IPMA
Instituto Português do Mar e da Atmosfera

Introduction

- Length, Weight and their relationship of marine fish have been gained interest in the context of the ecosystem approach to fisheries and global change.
- Body conditions are influenced by environmental variability at seasonal and annual scales and are often used to evaluate growth patterns and reproductive potential at both individual and population levels.
- The already existing studies showed a decreasing trend in body condition for Small Pelagic Species (SPF) which could impact the fishing and seafood industry sector.
- In the Atlantic Iberian Area, the sources of variability in SPF fish condition are so far not accurately understood.

Material and methods



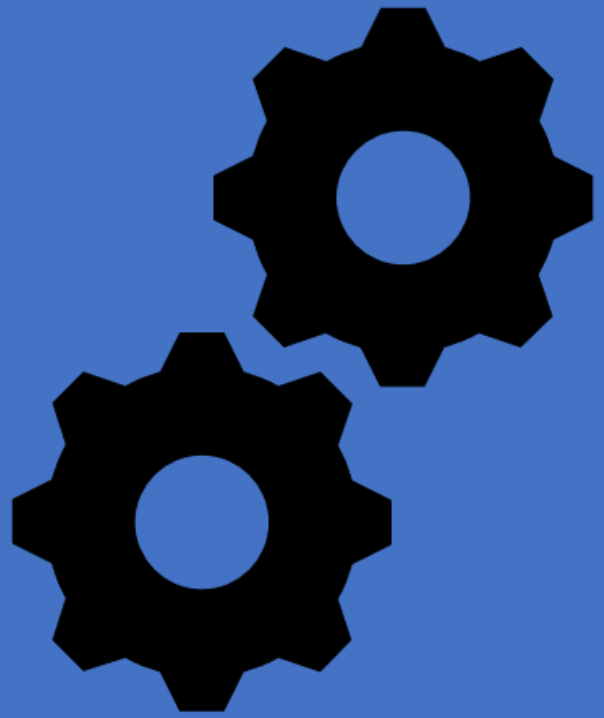
- Study area: Portugal coast (see map)
- Data:

SPFs targeted by purse-seine fleet in the Portuguese Coast:

  - Sardine (*Sardina pilchardus*): PIL
  - Anchovy (*Engraulis encrasicolus*): ANE
  - Chub mackerel (*Scomber colias*): MAS
  - Horse Mackerel (*Trachurus trachurus*): HOM
- Around 30 years of morphometric data (1982-2018)
- Acoustic scientific surveys and market samples

						Length	Weight
especies	**type**	**Years**	**N**	**N.º of hauls/trips**	**Age_range**	**range**	**range**
ane	market	jul 2011 - out 2018	2177	36	0-3	10.5-19.7	6.65-52.69
ane	survey	fev 1996 - nov 2018	16296	236	0-4	7.2-21.8	2-82
hom	market	fev 1987 - jan 2017	54256	1135	0-9	11.7-49.8	13.68-948.61
hom	survey	mar 2002 - nov 2018	4361	111	-	9.7-35.3	7-324
mas	market	mar 1982 - dez 2018	15444	390	0-9	13.9-64.7	18.14-2100
mas	survey	abr 2008 - nov 2018	7039	166	0-7	7.5-39.9	2-554
pil	market	jan 1987 - set 2018	289825	1550	0-9	8.1-28.7	3.44-205.9
pil	survey	mai 1995 - nov 2018	86730	915	0-9	7.5-26.1	3-147

Material and methods



- Length-Weight relationships for the 4 SPF species studied
- Fulton's Condition (k) Index: **K** = Gutted weight/Length^3 x 100
- Portuguese Landings for 4 SPFs for the period 1995-2020
- Environmental variables for the period 1995-2018:
  - **Sea Surface Temperature (SST)** and **Chlorophyll-a** (**CLO**): extracted from Copernicus Marine Service (CCMS, http://marine.copernicus.eu/)
  - **Atlantic Multidecadal Oscillation (AMO)** obtained from National Oceanic and Atmospheric Administration (NOAA) Physical Sciences Division-Earth System Research Laboratory (http://www.esrl.noaa.gov/psd/data/timeseries/AMO)
  - **North Atlantic Oscillation (NAO)** obtained from Climatic Research Unit of the East Anglia University (http://www.cru.uea.ac.uk/cru/data/nao/).

Statistical analyses

- ***Characterizing trends in Length-Weight relationships***
  - The WLRs were calculated by sex, year, quarter.
  - Regression log (α) over β to check unbalanced samples

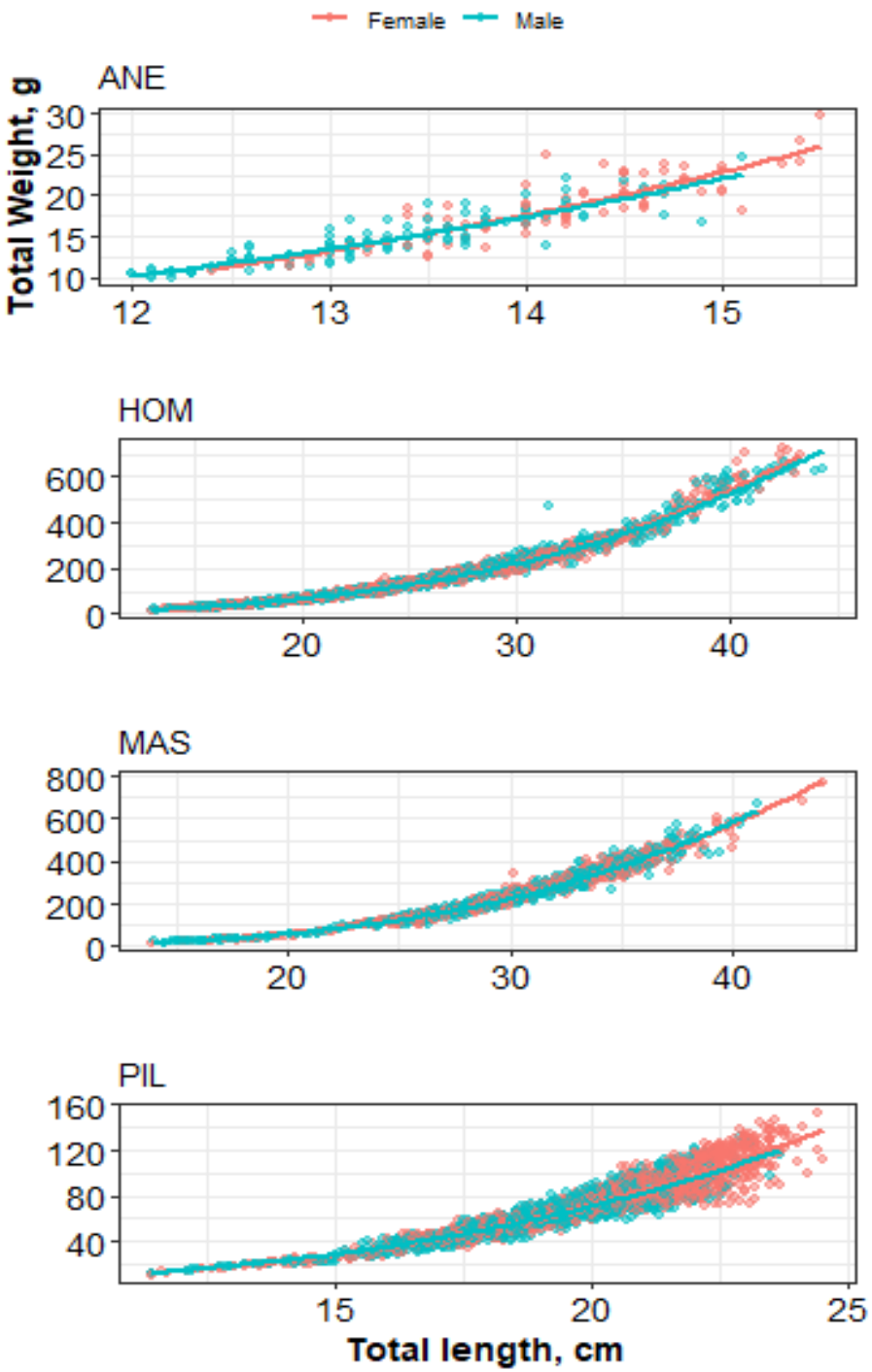
- ***Characterizing trends in body length***
  - Generalized Additive Models (GAM).
  - Length ~ Age + Sex + s(year).

- ***Body condition and its dependence upon various factors***
  - Generalized Additive Models (GAM).
  - body ~ Sex + s(year).

- ***Characterizing changes in body condition with environment factors***
  - Principal Component Analysis (PCA).

Results

Length-Weight Relationship



Example - results for 2016:

Statistical differences between sexes and years:

PIL: F= 459.5, *pvalue* < 2.2e-16 (sig.)

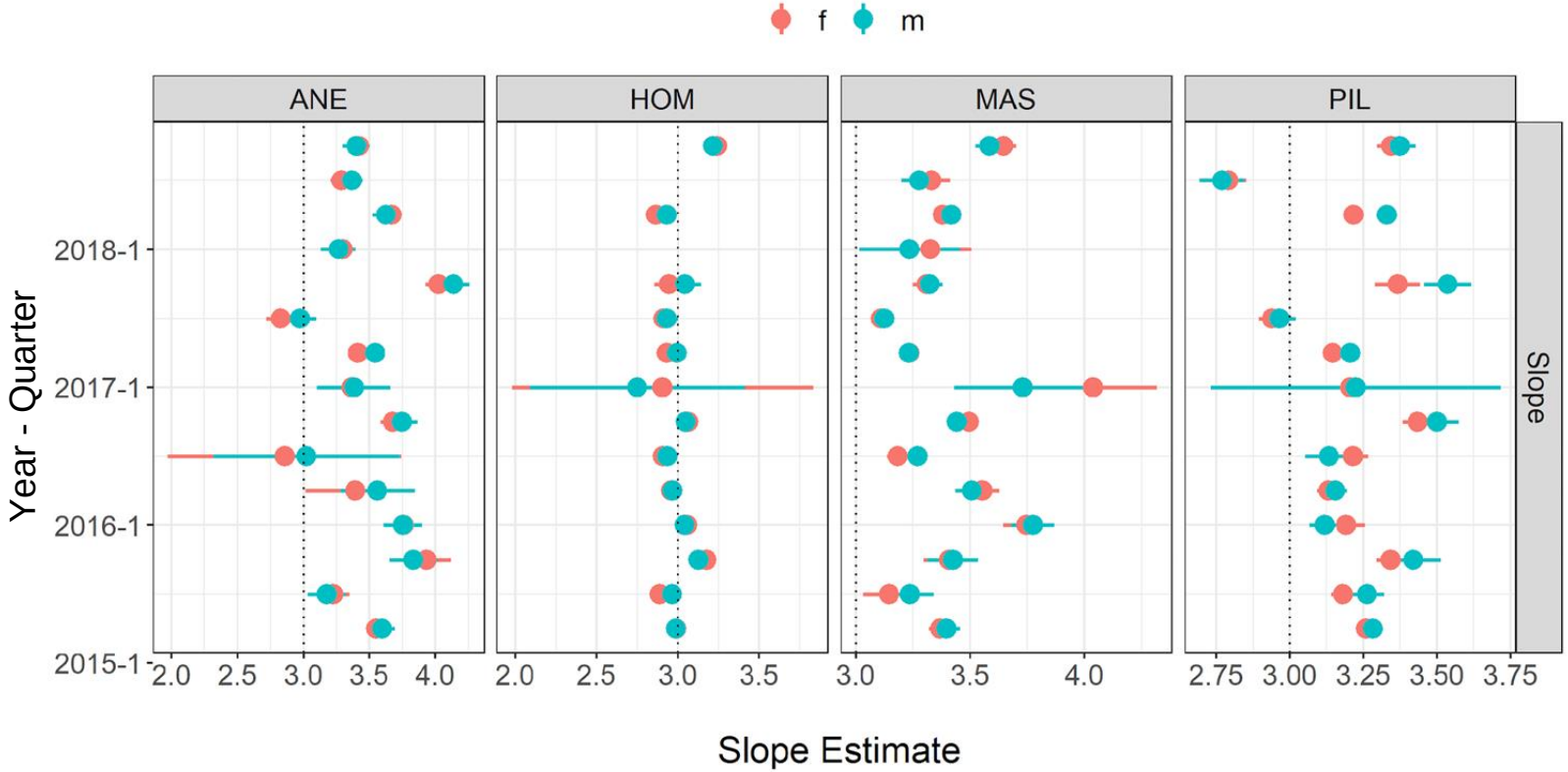
ANE: F=11.7, *pvalue* = 0.0006 (sig.)

HOM: F= 5.1, *pvalue* = 0.02 (sig.)

MAS: F= 1.2, *pvalue* = 0.91 (non sig.).

Results

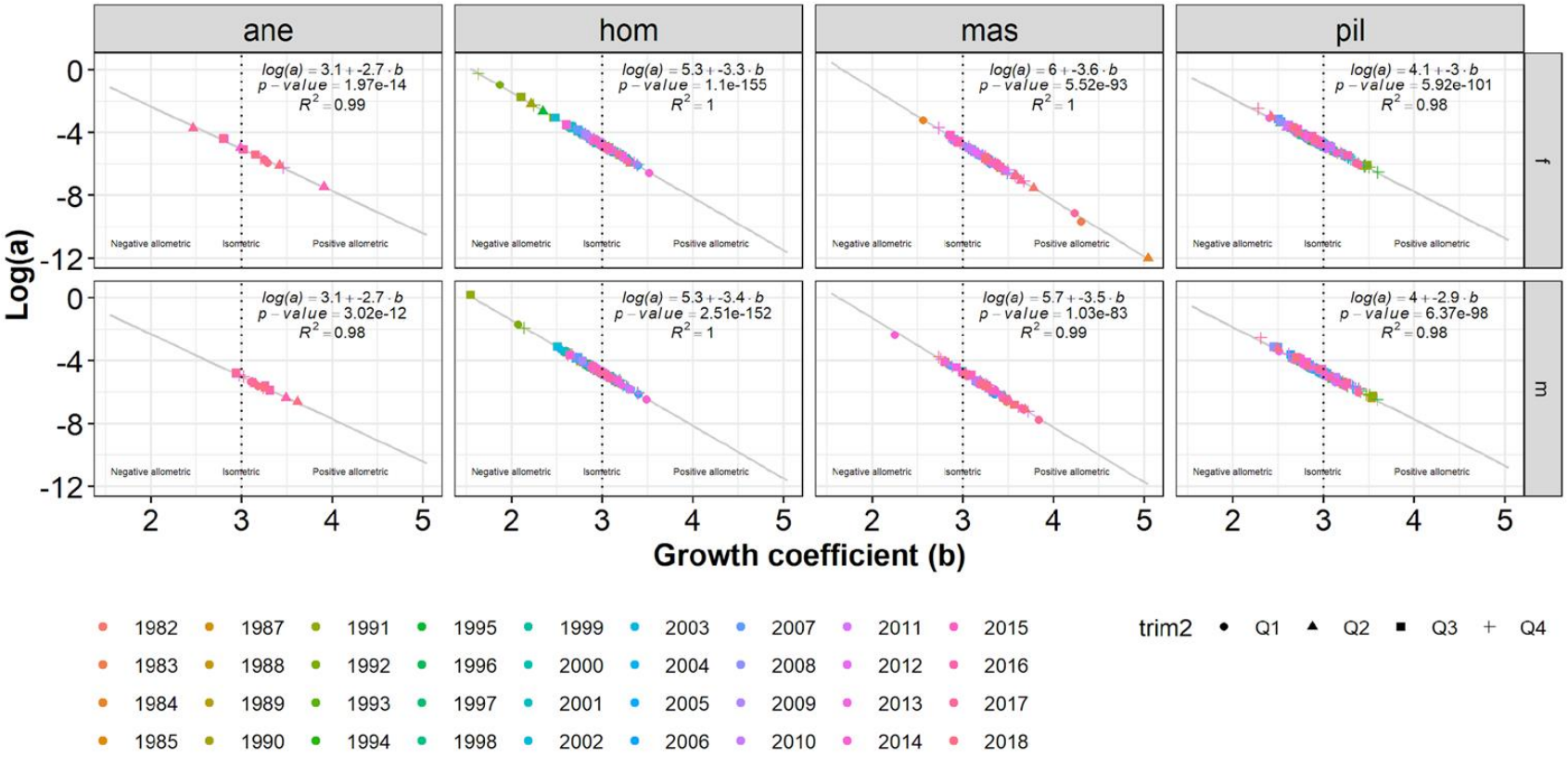
Length-Weight Relationship



- ANE, MAS and PIL shows a positive allometric growth, consistently ($\beta>3$)
- HOM presents an isometric growth

Results

Length-Weight Relationship



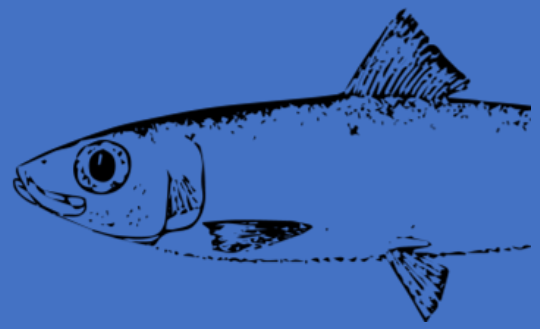
Plot log (α) over β for all sex-specific weight-length relationships (WLRs) estimated for each quarter of each year.

The regression analysis allows to identify outliers of WLRs that are questionable and in this preliminary study, for the 4 SPFs no outliers were found.

Results

Body Length at-Age

Sardine



Age		Length range			Weight range		
1	38139	7.5-22.9	16.69	1.97	3-120.49	39.75	16.13
2	43596	11.7-23.5	18.63	1.23	10-142.4	54.53	14.76
3	43147	15.3-24.5	19.66	1.08	26.7-147	63.56	14.84
4	32784	16.9-25.3	20.39	0.96	30-154	69	14.03
5	18537	16.4-25.1	20.88	0.91	30-142	72	14.12
6+	25978	8.5-28.7	18.35	3.66	4-205.9	53.08	28.05
Total	**202181**						

Age, sample size (N), length and weight (ranges, mean and SD) included in the analyses (study period: 1982 – 2018).

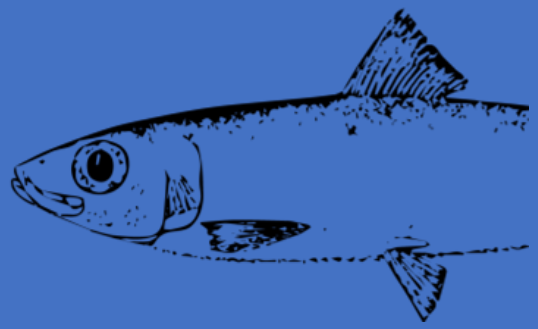
species	model	residual deviance	% explained Deviance	AIC
pil	lenght~age	323243.2	57.26	641465.5
pil	length~age+sex	310232.9	58.98	633639.6
pil	length~age+sex+age:sex	308663.9	59.19	632685.4
pil	length~age+sex+age:sex+s(year)	192550	61.38	486033.3
pil	length~age+sex+age:sex+s(year,by=age)	187135	62.47	481541.4
pil	length~age+sex+age:sex+s(year,by=age:sex)	186593.2	62.58	481191.1

Main statistics from GAMs applied to sardine body length as a function of age, sex and year. % of deviance explained and AIC are presented for each tested model. Selected model is denoted by grey band.

Results

Body Length at-Age

Sardine



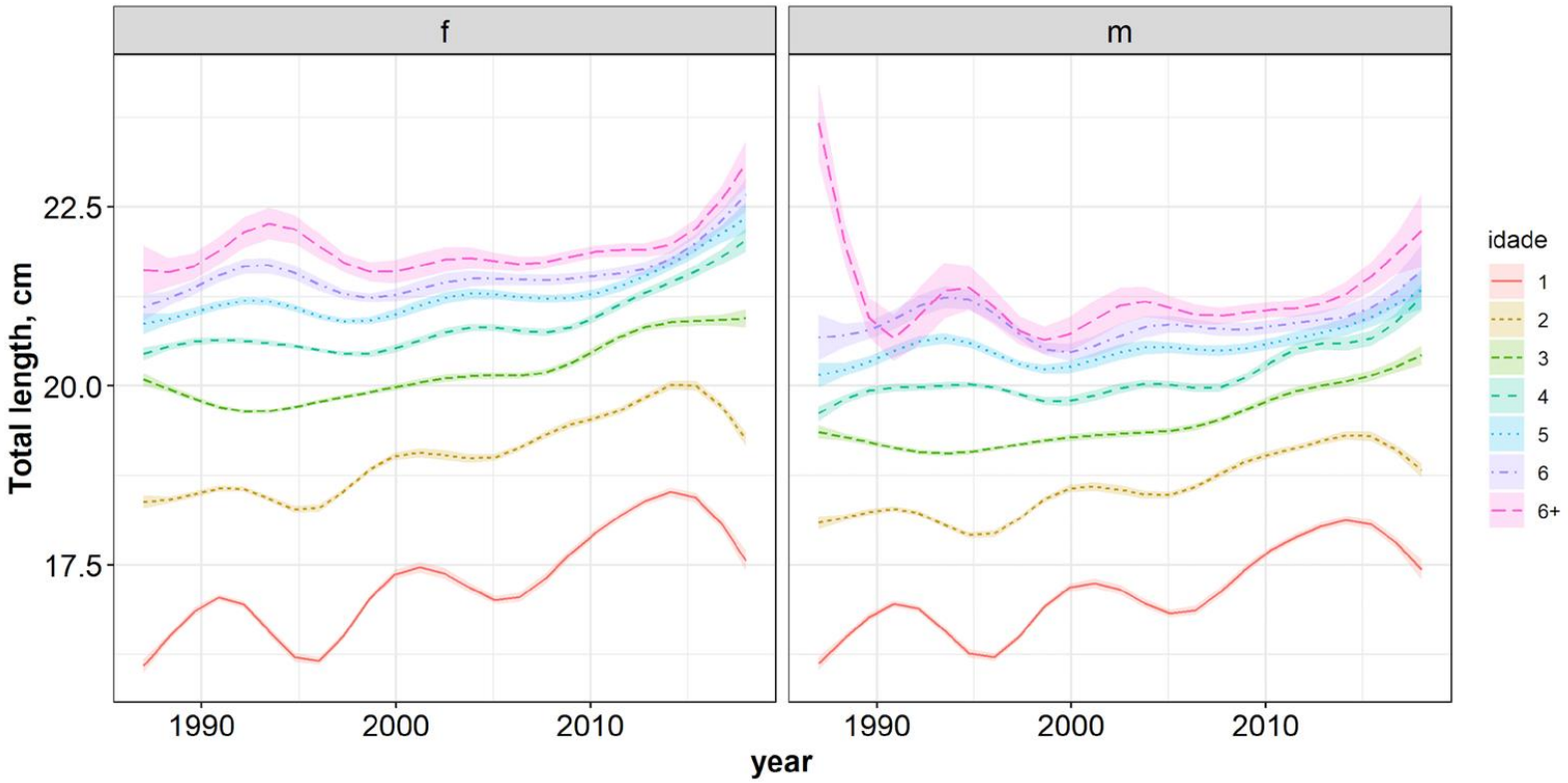


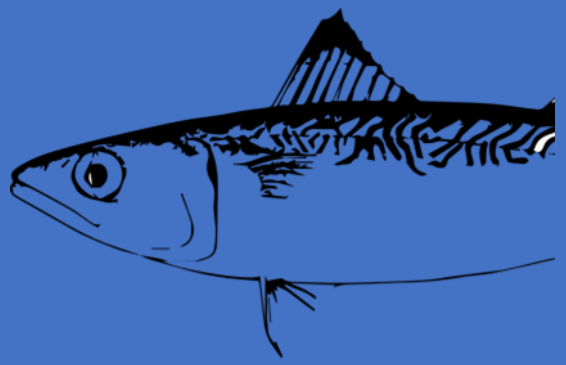
Fig. Long-term changes in sardine body length at-age over the study period. Lines correspond to the fit of the GAM model. The shaded bands represent the 95% confidence interval.

An increasing trend on length at age for sardine seems to exist, with oscillations over the years.

Results

Body Length at-Age

Chub Mackerel



		Length			Weight		
Age	**n**	**range**	**mean**	**SD**	**range**	**mean**	**SD**
1	2825	7.5-38.2	22.79	4.06	2-490.5	103.12	66.31
2	3487	13.3-38.5	26.47	3.71	32-599.8	160.22	77.53
3	1849	21.5-43.5	29.93	3.51	65-884.66	238.45	99.55
4	1219	23.2-50.9	31.74	3.51	92-1259.1	286.54	109.45
5	756	23.2-49	33.69	3.47	88-1142.36	344.14	126.06
6	394	23.8-49.8	34.86	3.6	88-969.13	387.74	133.84
7	197	27.8-48.4	36.07	3.32	161.33-1008.42	423.94	130.16
8+	852	13.9-54	26.47	10.73	18.14-1524.05	247.96	304.58
Total	**11579**						

Age, sample size (N), length and weight (ranges, mean and SD) included in the analyses (study period: 1982 – 2018).

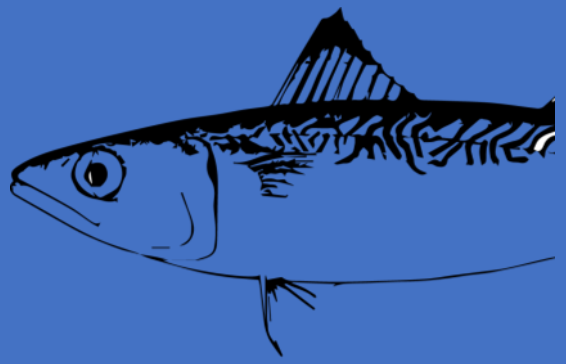
species	model	residual deviance	% explained Deviance	AIC
mas	lenght~age	154448.93	57.82	60381.4
mas	length~age+sex	154427.73	57.82	60381.89
mas	length~age+sex+age:sex	154245.62	57.87	60382.88
mas	length~age+sex+age:sex+s(year)	80030.94	58.93	39809.34
mas	length~age+sex+age:sex+s(year,by=age)	69877.76	64.14	38872.41
mas	length~age+sex+age:sex+s(year,by=age:sex)	69619.61	64.28	38931.2

Main statistics from GAMs applied to sardine body length as a function of age, sex and year. % of deviance explained and AIC are presented for each tested model. Selected model is denoted by grey band.

Results

Body Length at-Age

Chub Mackerel



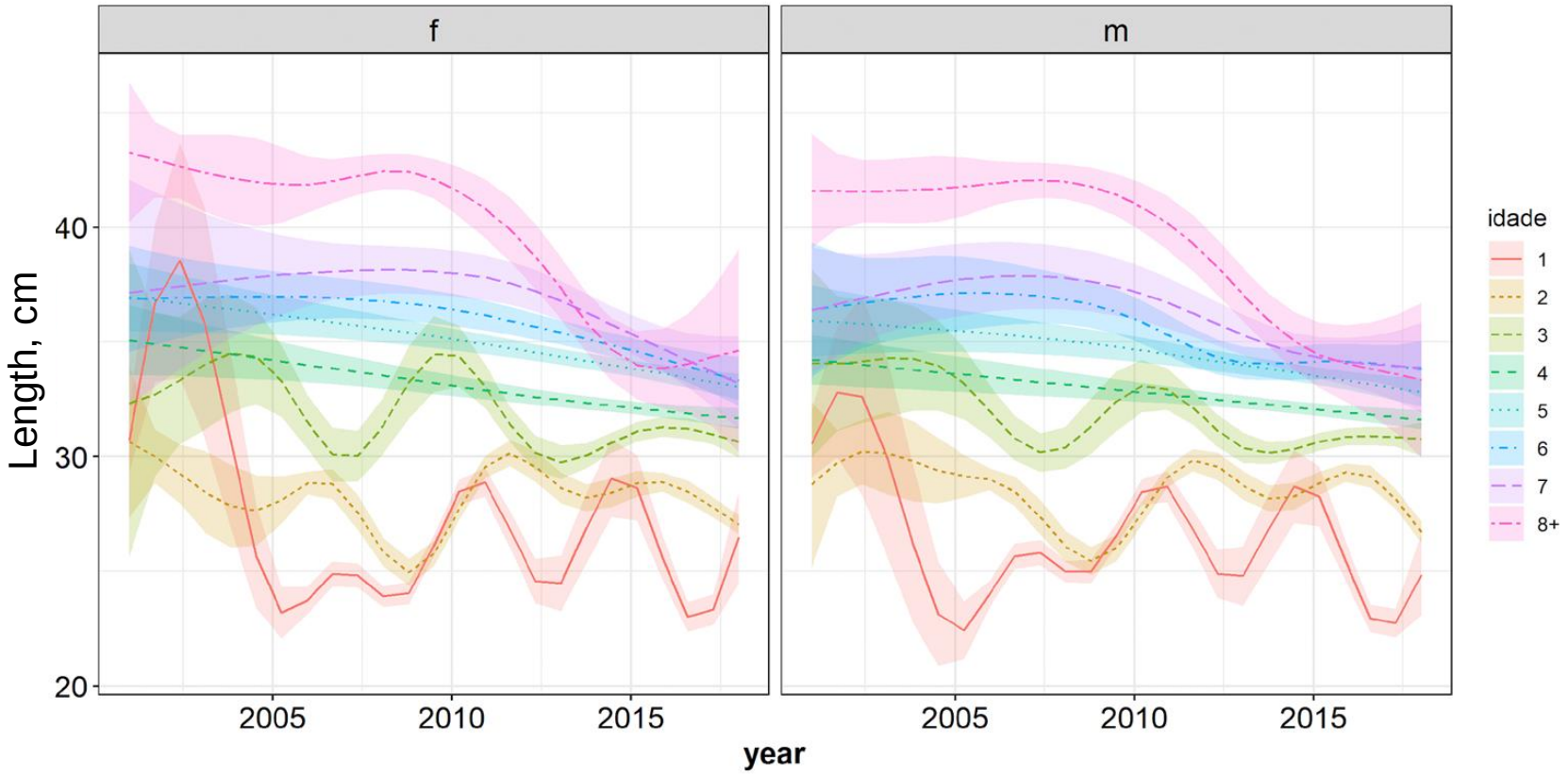


Fig. Long-term changes in chub-mackerel body length at-age over the study period. Lines correspond to the fit of the GAM model. The shaded bands represent the 95% confidence interval.

No clear trend on length at age for chub mackerel, with large oscillations, especially for the first-year individuals.

Results

Body Length at-Age

Anchovy

		Length			Weight		
Age	**n**	**range**	**mean**	**SD**	**range**	**mean**	**SD**
1	2595	7.2-18.9	13.02	2.15	2-47.15	15.52	8.67
2	876	9.7-19.7	14.94	1.76	6-52.69	23.57	9.12
3	169	12.5-18.5	15.97	1.27	12-49	28.07	7.67
4+	551	7.8-18.3	11.9	2.51	2-40.22	11.88	8.8
Total	**4191**						

Age, sample size (N), length and weight (ranges, mean and SD) included in the analyses (study period: 1982 – 2018).

species	model	residual deviance	% explained Deviance	AIC
ane	lenght~age	15020.43	18.42	15497.309
ane	length~age+sex	14701.043	20.15	15421.075
ane	length~age+sex+age:sex	14696.024	20.18	15423.832
ane	length~age+sex+age:sex+s(year)	1914.06	34.24	3874.474
ane	length~age+sex+age:sex+s(year,by=age)	1906.587	34.49	3876.724
ane	length~age+sex+age:sex+s(year,by=age:sex)	1883.637	35.28	3873.125

Main statistics from GAMs applied to sardine body length as a function of age, sex and year. % of deviance explained and AIC are presented for each tested model. Selected model is denoted by grey band.

Results

Body Length at-Age

Anchovy

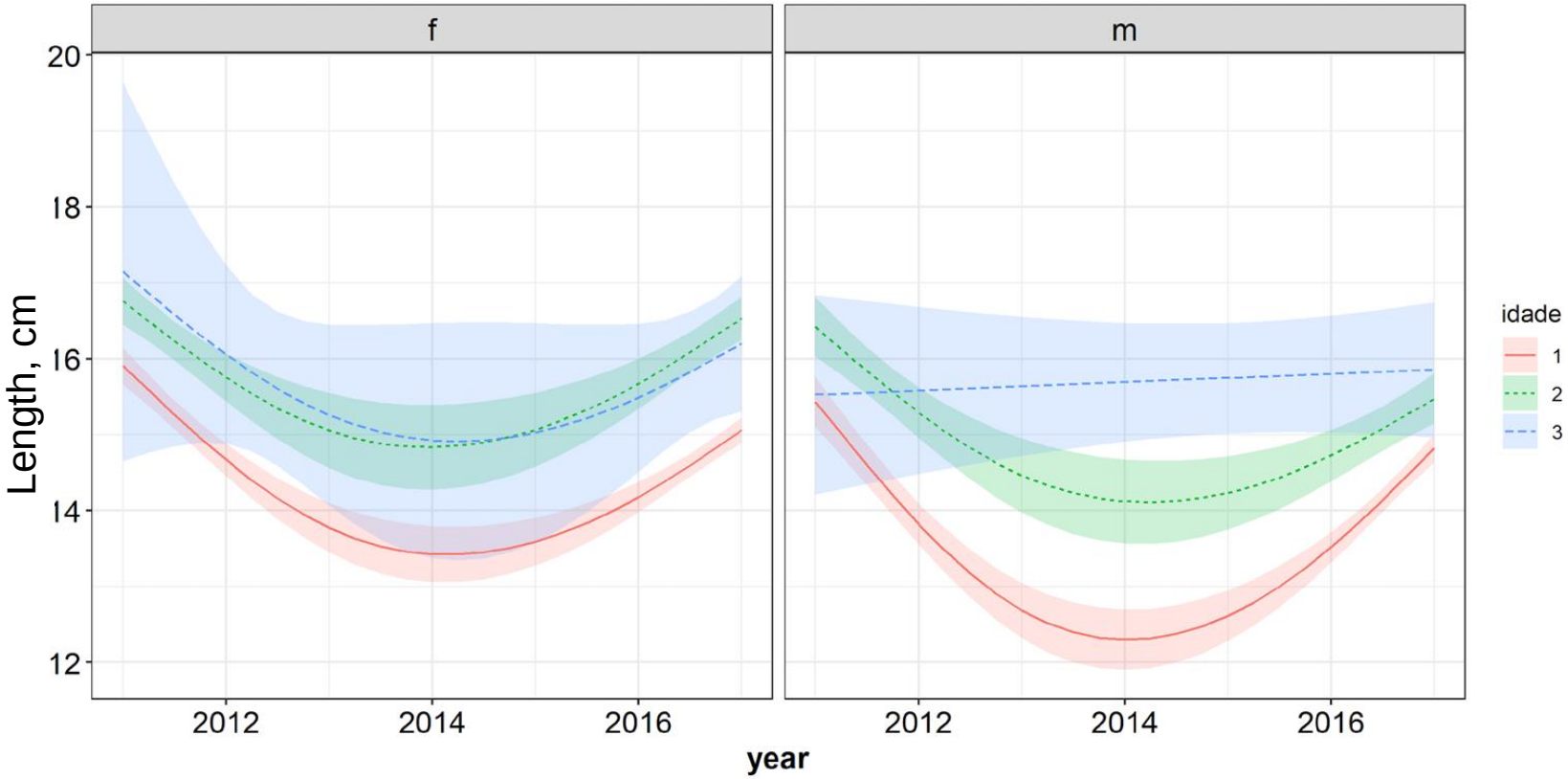


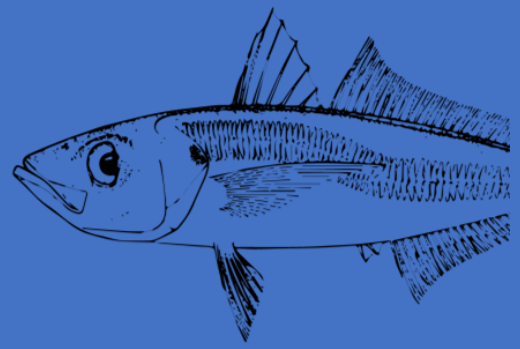
Fig. Long-term changes in chub-mackerel body length at-age over the study period. Lines correspond to the fit of the GAM model. The shaded bands represent the 95% confidence interval.

No clear trend on length at age for anchovy.

Results:

Body Length at-Age

Horse Mackerel



		Length			Weight		
Age	**n**	**range**	**mean**	**SD**	**range**	**mean**	**SD**
1	1182	11.7-34	16.74	1.77	13.68-337.8	39.86	16.74
2	2767	14.1-28.5	19.04	1.77	21.95-187	58.96	18.3
3	4573	17-33.4	21.68	1.65	35.58-296.09	86.9	22.25
4	4591	19.5-30.3	23.68	1.45	60.87-321.1	112.91	24.11
5	3100	20.2-32.2	25.42	1.27	58.2-322.3	139.31	25.27
6	2215	21.5-37.1	26.9	1.27	80.7-372.9	164.88	28.16
7	1975	23.2-35.4	28.18	1.33	96.52-361.1	190.05	33.36
8	1780	24.6-36.7	29.28	1.42	122.3-427.59	211.71	36.61
9+	9210	12.7-47.6	33.59	4.22	16.39-948.61	334.4	125.61
Total	**31393**						

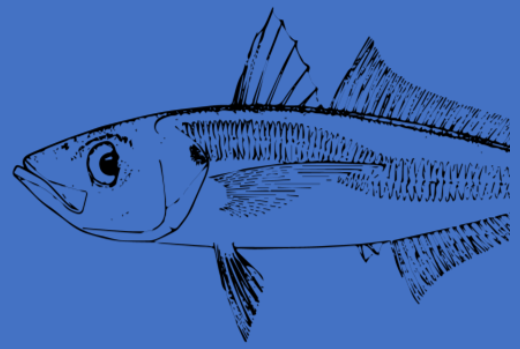
Age, sample size (N), length and weight (ranges, mean and SD) included in the analyses (study period: 1982 – 2018).

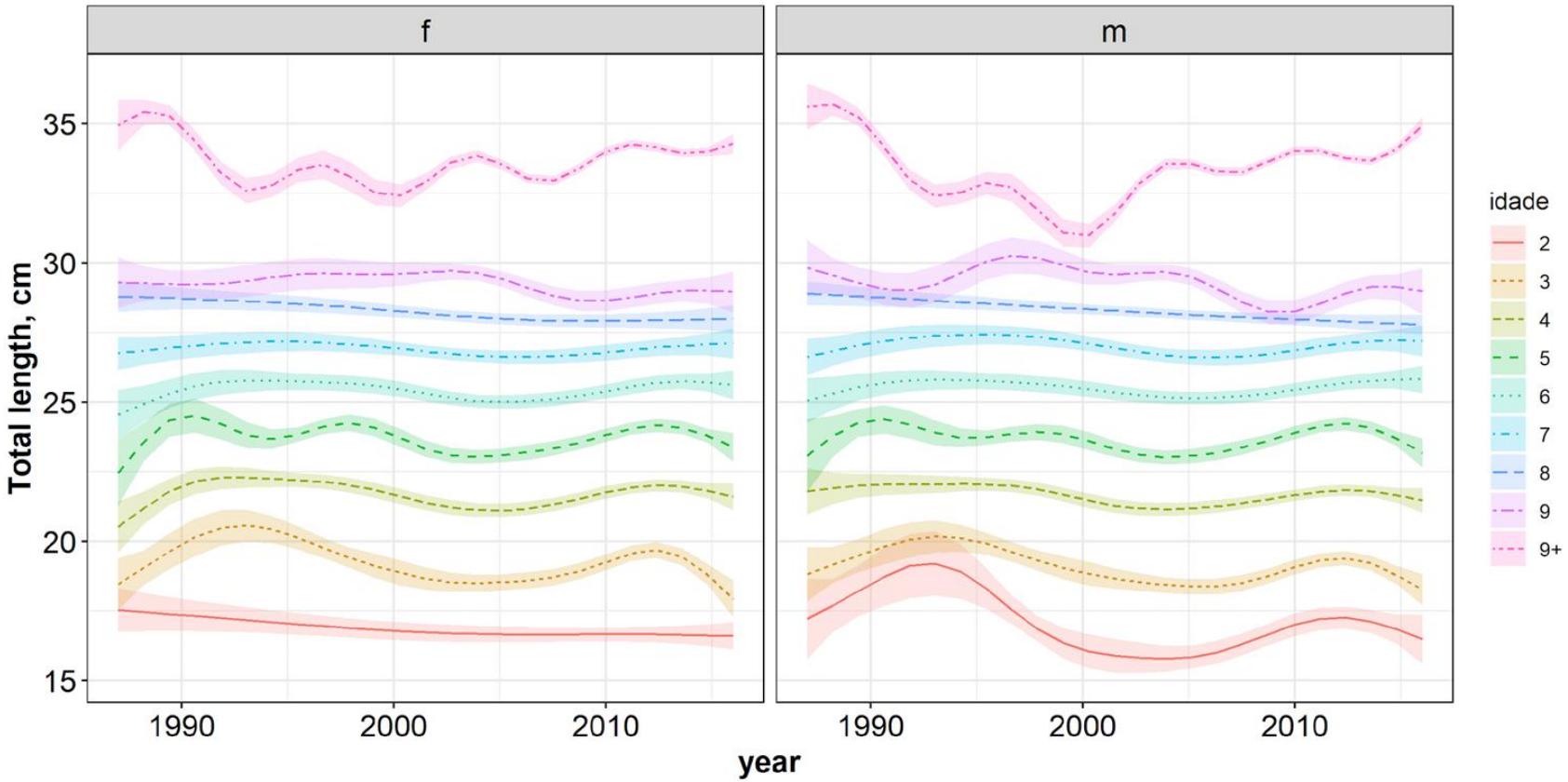
species	model	residual deviance	% explained Deviance	AIC
hom	lenght~age	193283.343	82.44	145949.14
hom	length~age+sex	193278.07	82.44	145950.28
hom	length~age+sex+age:sex	193238.843	82.45	145959.92
hom	length~age+sex+age:sex+s(year)	189770.931	82.76	145410.43
hom	length~age+sex+age:sex+s(year,by=age)	185124.905	83.18	144766.47
hom	length~age+sex+age:sex+s(year,by=age:sex)	184766.446	83.22	144816.79

Main statistics from GAMs applied to sardine body length as a function of age, sex and year. % of deviance explained and AIC are presented for each tested model. Selected model is denoted by grey band.

Results:
Body Length at-Age

Horse Mackerel



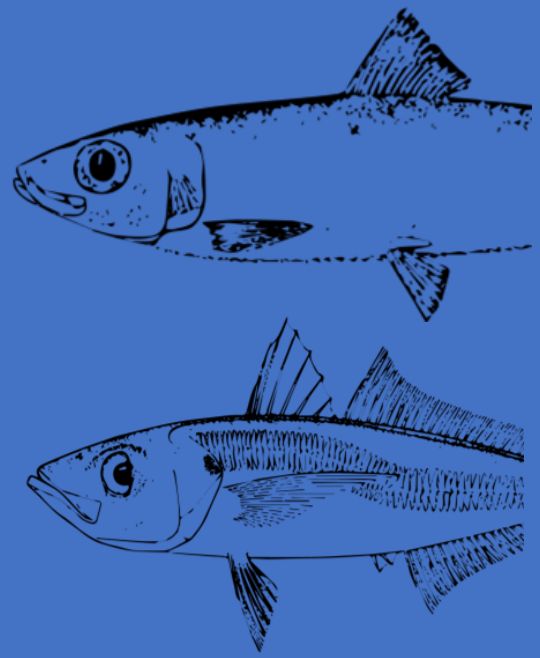


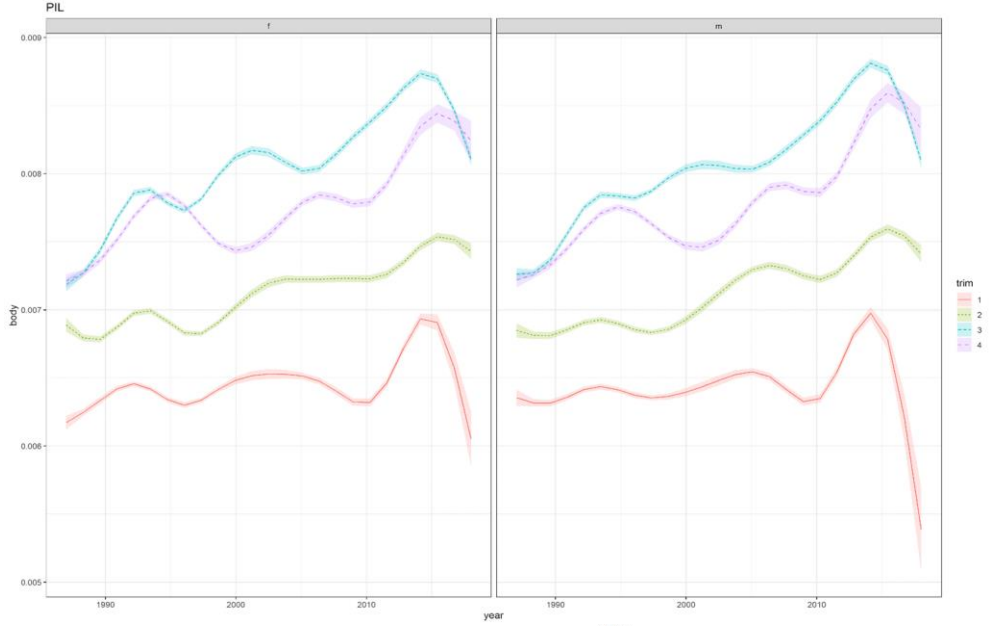
Long-term changes in chub-mackerel body length at-age over the study period. Lines correspond to the fit of the GAM model. The shaded bands represent the 95% confidence interval.

No trend on length at age for horse mackerel.

Results

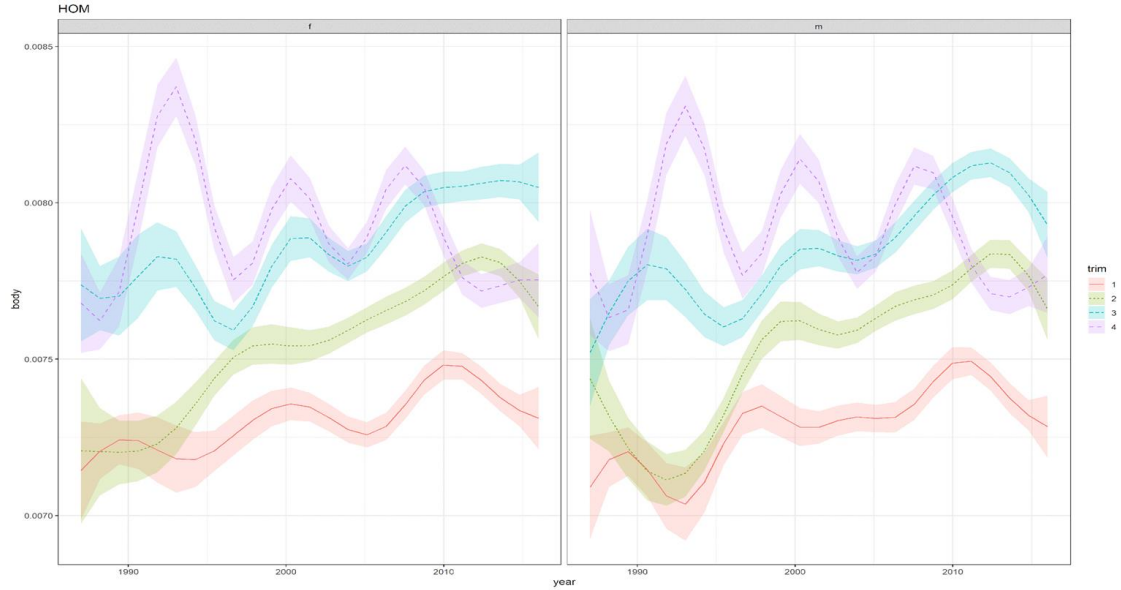
Trend in body condition





Sardine

Horse mackerel

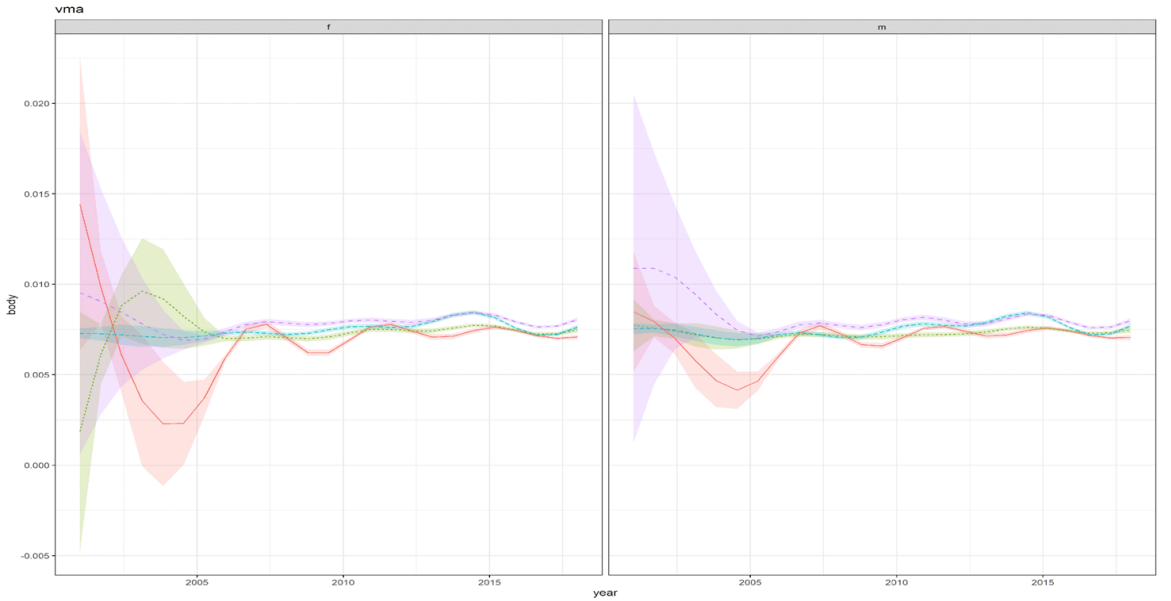


In these preliminary analyses, differences were observed in the prediction of body condition by year and quarter for sardine and horse-mackerel. Further analyses to be done in the future.

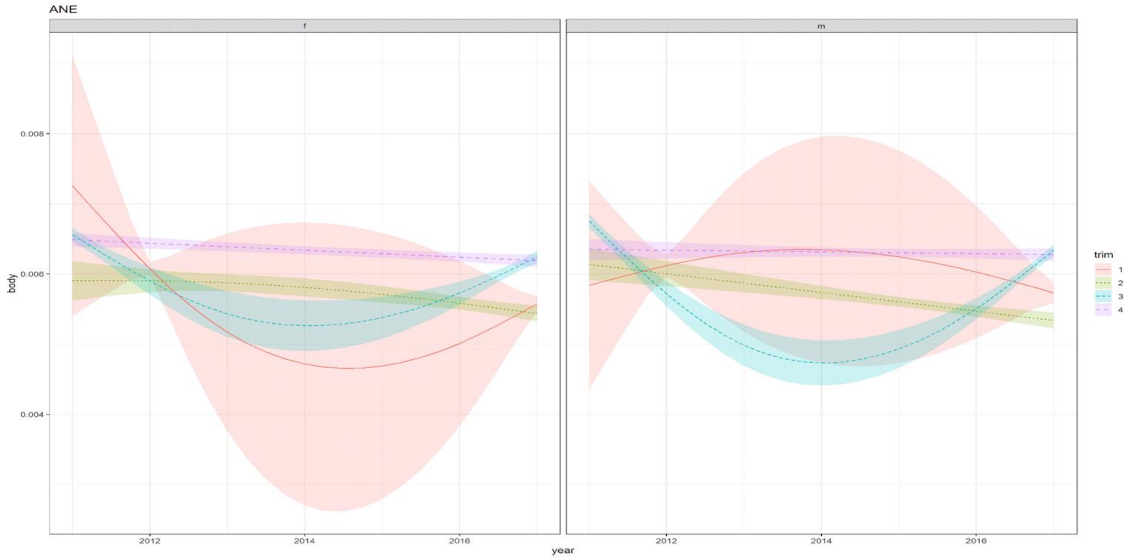
Results

Trend in body condition

Chub mackerel



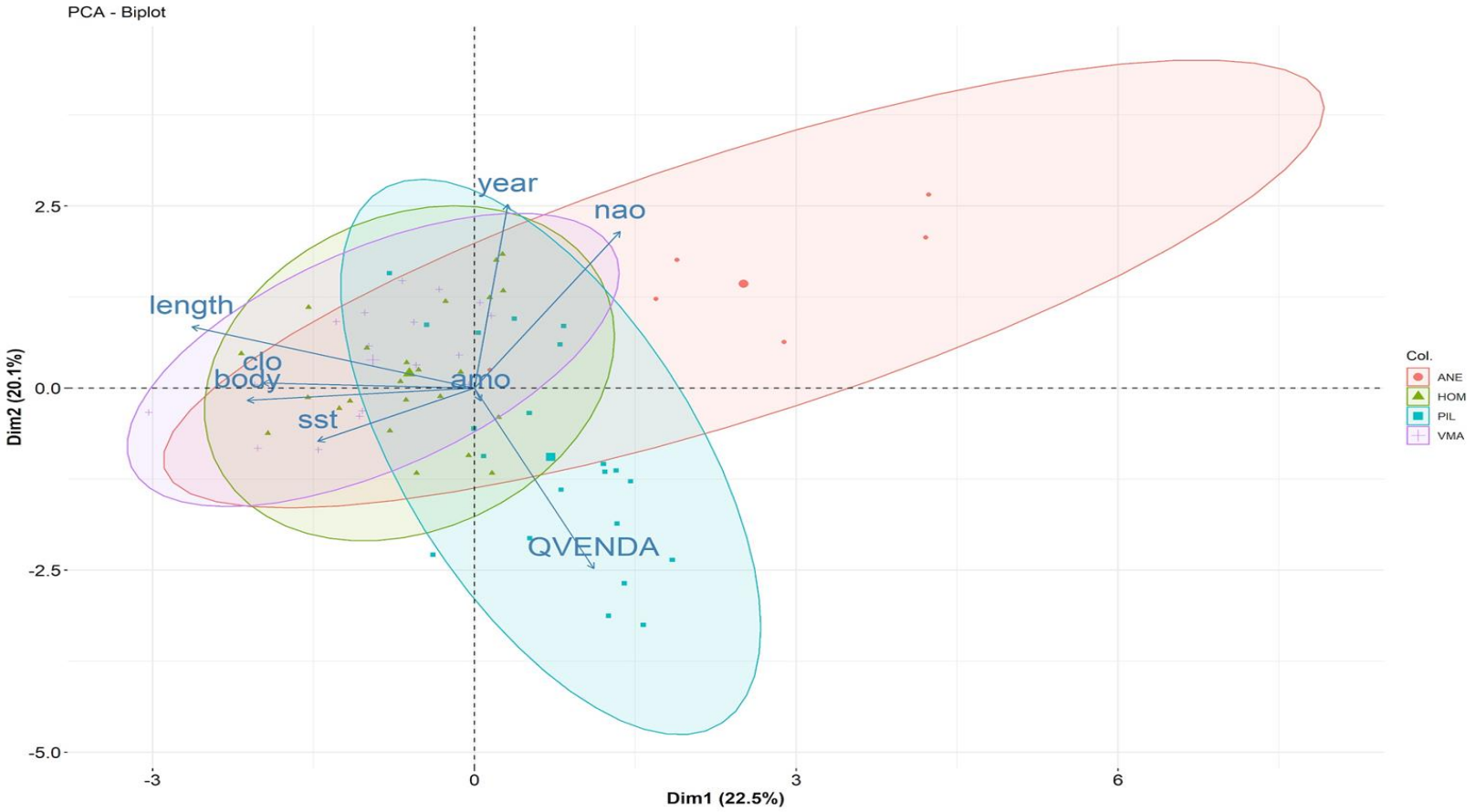
Anchovy



For chub-mackerel, no differences were obtained in predicting body condition by year and quarter. For anchovy, data are insufficient to obtain accurate predictions.

Results

PCA



- The two components explained 42.5% of the total variance
- PCA separates ANE from the other 3 species.
- K and TL are associated to SST and CLO (PC2).
- PIL more associated with negative correlation of Landings (QVENDA) and NAO index

Conclusions

- First study for the Portuguese Coast addressing the time variability in body condition and growth and its responses to environmental changes for the main SPF species: Sardine, Anchovy, Chub mackerel and Horse Mackerel.

- Study aimed at contributing for improving the understanding of long-term trends and the possible sources of variability in SPF fish condition and growth in the Atlantic Iberian Area.

- The results obtained indicated an increasing trend in sardine body condition, whereas for the other 3 species, no clear time evolution pattern was observed. These patterns were successfully modelled with GAM, except for anchovy due to insufficient data available.

- Comparably to other areas studied as Bay of Biscay and West Mediterranean, the pattern obtained for sardine off the Portuguese coast is opposite.

- The relationship between large scale environmental indices and fish landings levels on the inter annual variability of body condition could partly explain the results obtained.

Future work

- ➔ Update database with more information, especially anchovy biological data
- ➔ Redo GAMs models, with significant sample improvements
- ➔ Check if there are other more explanatory environmental variables
- ➔ Redo PCA analyses with more explanatory environmental variables, catches (different than landings) for each fishing gear and for each species
- ➔ Try new statistical approach and model selection, such Independent Linear Mixed Effect models (LMEs, Eq.)

Acknowledgments

- Project SARDINHA2020 - Abordagem Ecossistémica para a gestão da pesca da sardinha (Mar2020)
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- Direção Geral de Recursos Naturais Segurança e Serviços Marítimos (for providing the data on daily landings)
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cnunes@ipma.pt