Long term variations in the population dynamics of Iberian sardine (*Sardina pilchardus)* and its relation to environmental conditions and exploitation history

Malta T.[a] , Santos A. M.[a], Santos P.[b] and Silva A.[a]

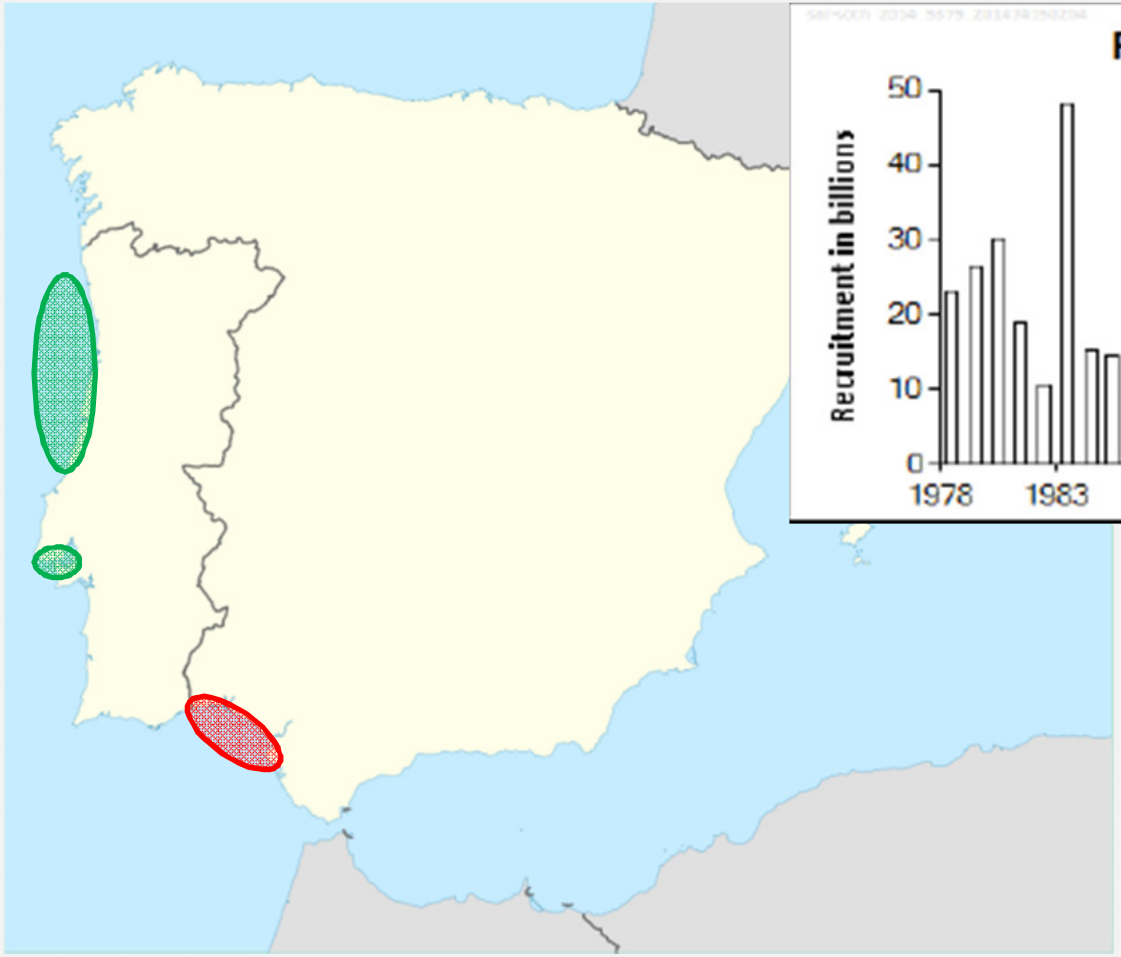
2014

[a]IPMA – Instituto Português do Mar e da Atmosfera

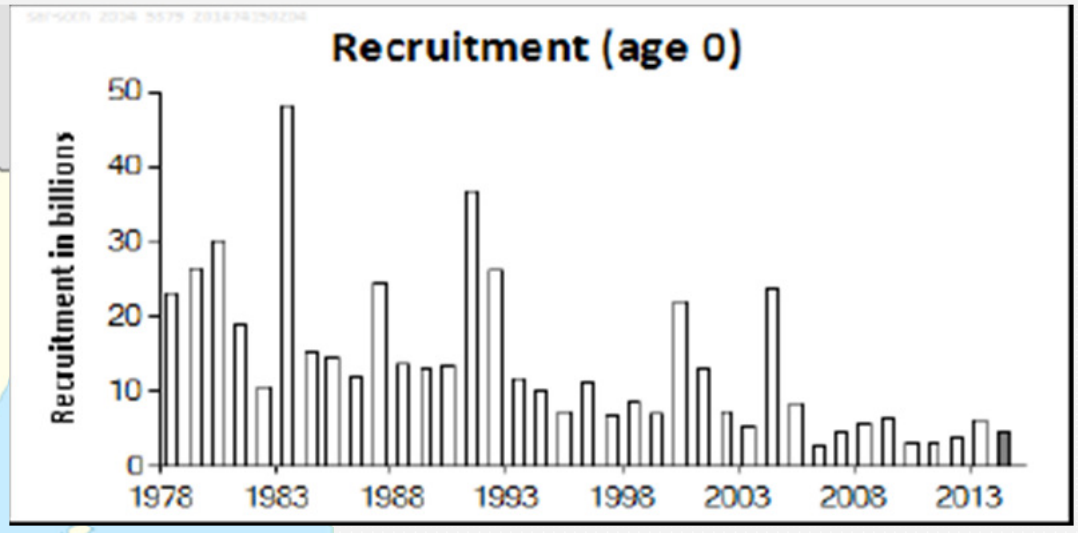
[b]FCUP – Faculdade de Ciências da Universidade do Porto

This study was supported by project **CERTIFICA (PROMAR)**

|Study what? Why? Where?



Map downloaded from:
http://www.clipartbest.com/clipart-ycoKa67cE (September, 2014)

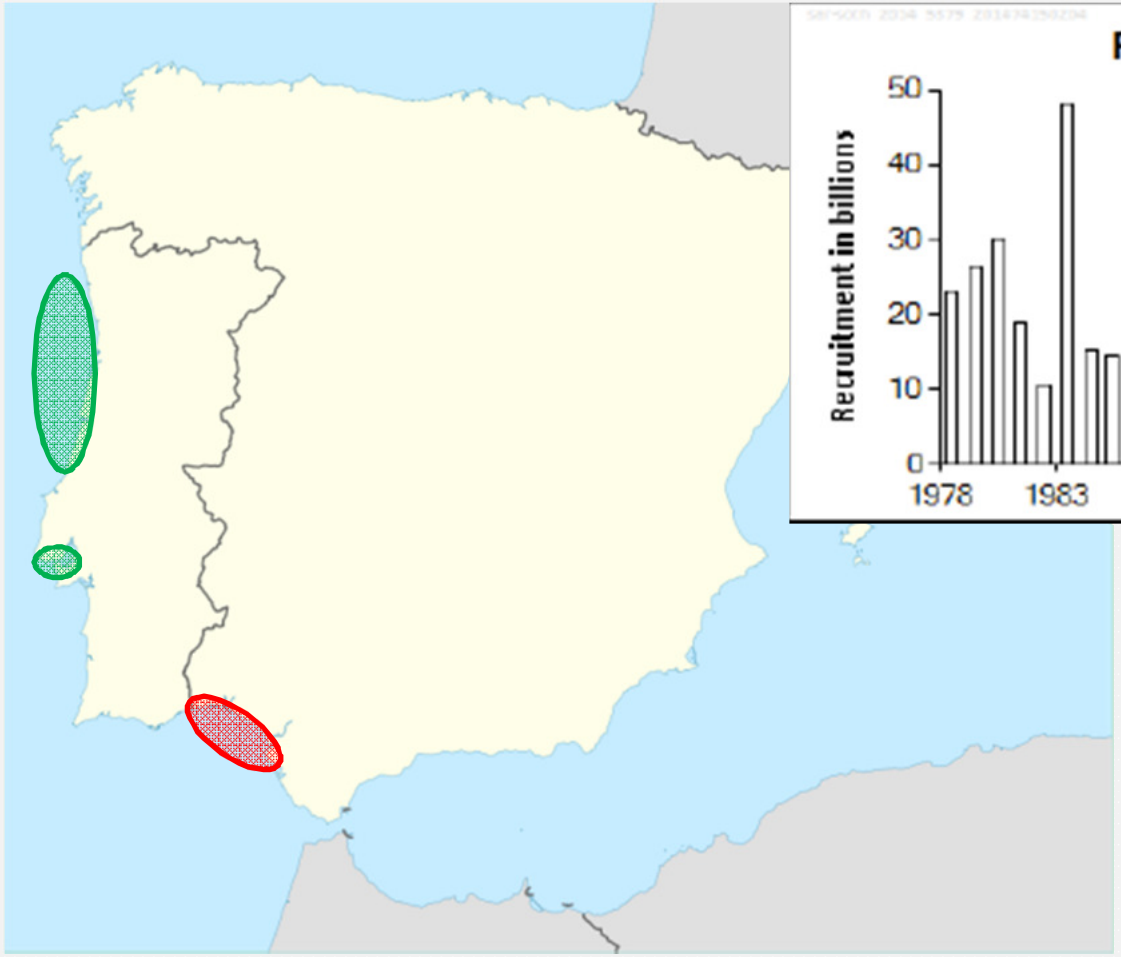


ICES Advice, 2014

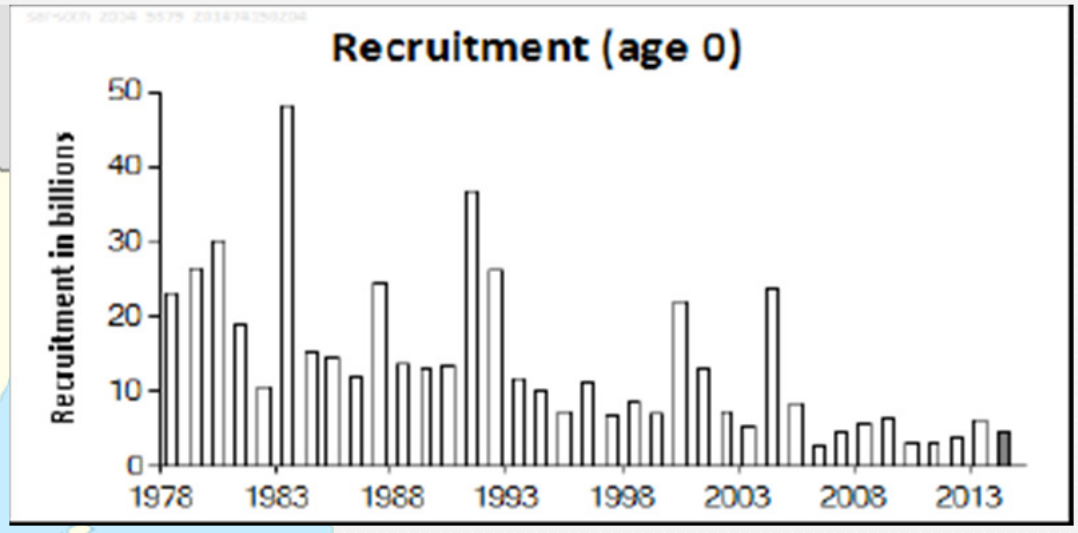
Study objectives:

- Create a longer recruitment data series
- Model the environmental effects on the recruitment variation
- Compare the fisheries history with the recruitment index

|Study what? Why? Where?



Map downloaded from:
http://www.clipartbest.com/clipart-ycoKa67cE (September, 2014)

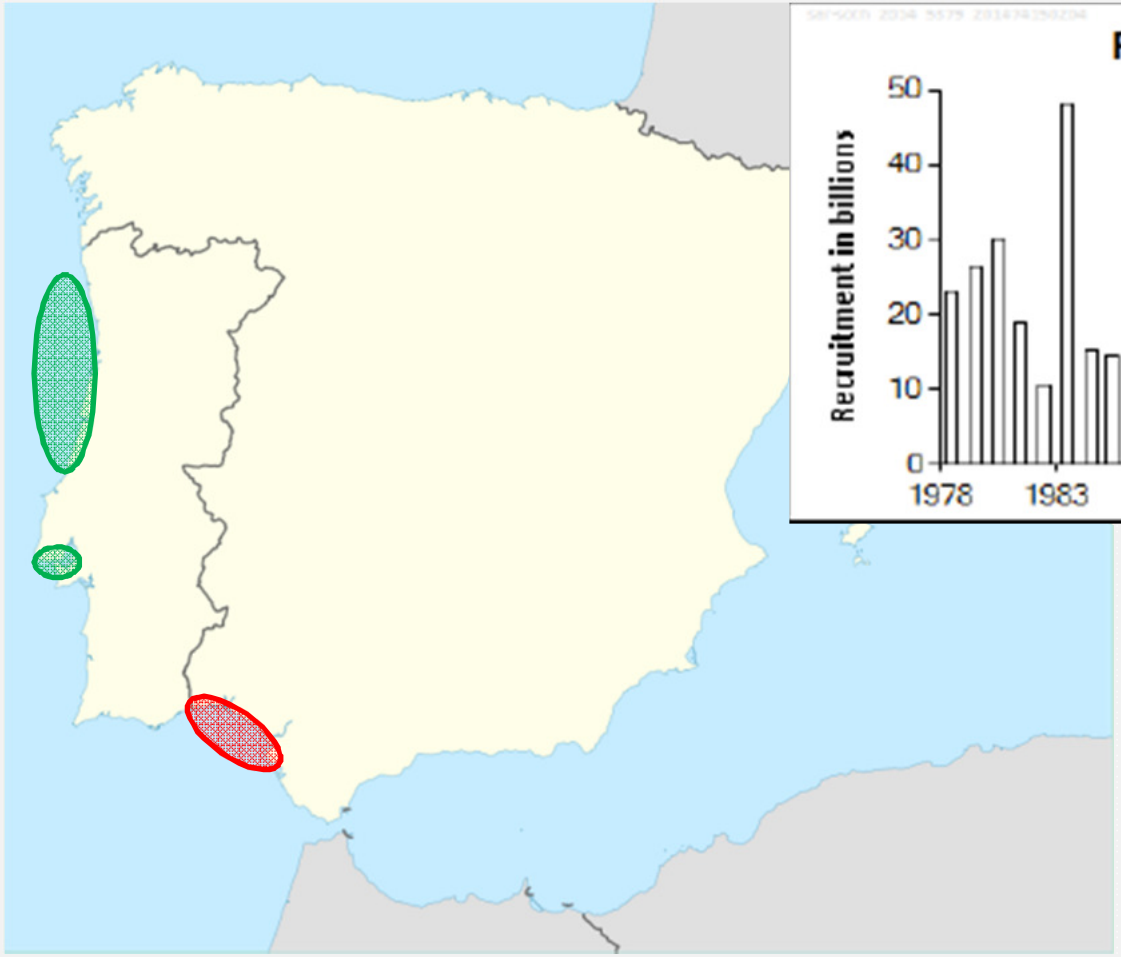


ICES Advice, 2014

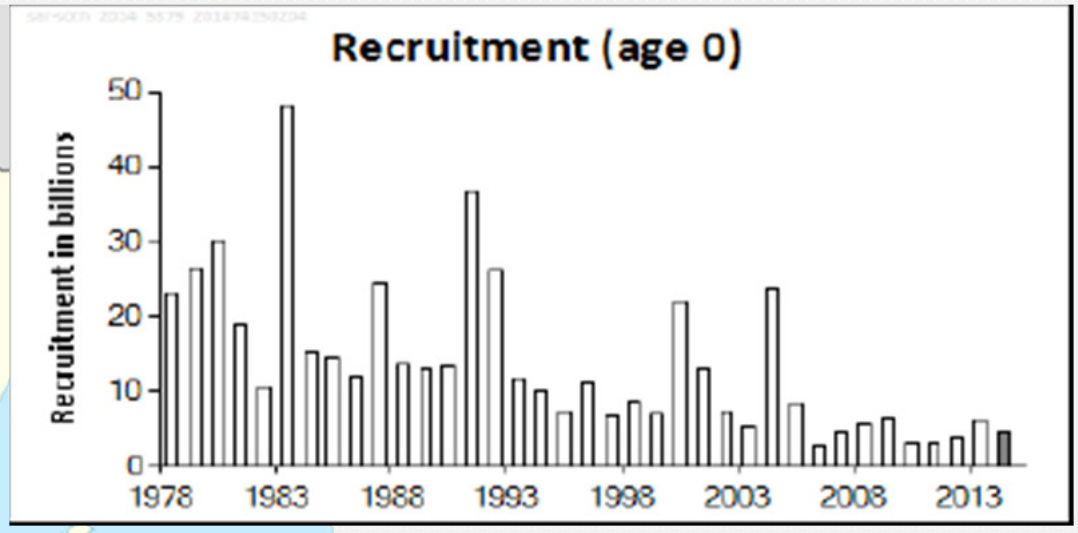
Study objectives:

- Create a longer recruitment data series
- Model the environmental effects on the recruitment variation
- Compare the fisheries history with the recruitment index

|Study what? Why? Where?



Map downloaded from:
http://www.clipartbest.com/clipart-ycoKa67cE (September, 2014)



ICES Advice, 2014

Study objectives:

- Create a longer recruitment data series
- Model the environmental effects on the recruitment variation
- Compare the fisheries history with the recruitment index

Material and Methods

Data

- Fisheries data (1947-2012)
  - Monthly sardine landings
  - Length and weight distribution samples
- Environmental data (1949-2012)
  - Upwelling Index
  - **S**ea **S**urface **T**emperatures
  - **N**orth **A**tlantic **O**scillation Index
  - **E**ast **A**tlantic Pattern Index
  - **A**tlantic **M**ultidecadal **O**scillation Index

Methods

- Development of **H**istorical **R**ecruitment **I**ndex (HRI)
  - Estimates of **number of recruits per kg landed**
- **HRI** vs Environmental variables
  - **G**eneralized **A**dditive **M**odels
- Sardine fisheries historical compilation
  - Published papers, official reports and grey literature

Material and Methods

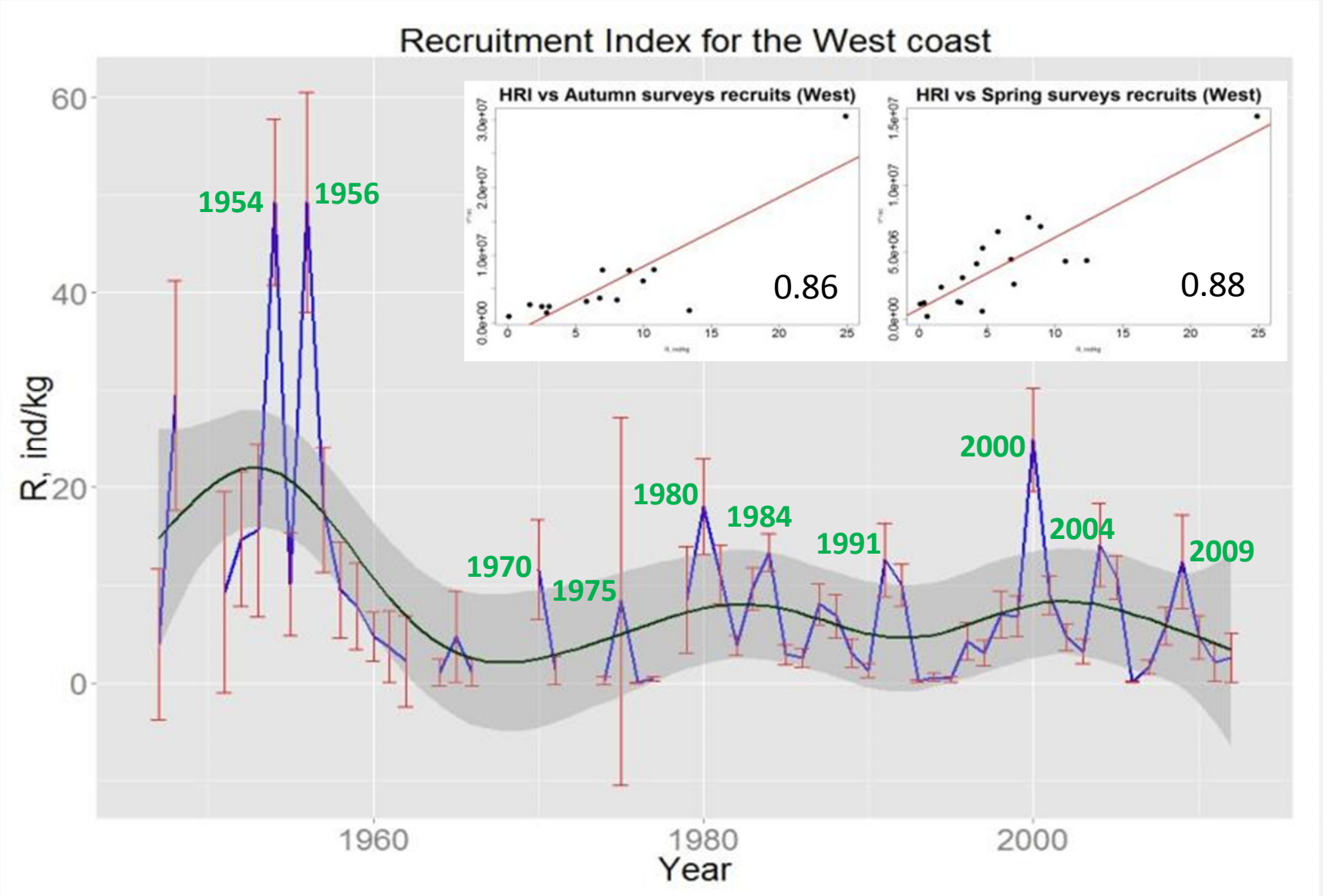
Data

- Fisheries data (1947-2012)
  - Monthly sardine landings
  - Length and weight distribution samples
- Environmental data (1949-2012)
  - Upwelling Index
  - **S**ea **S**urface **T**emperatures
  - **N**orth **A**tlantic **O**scillation Index
  - **E**ast **A**tlantic Pattern Index
  - **A**tlantic **M**ultidecadal **O**scillation Index

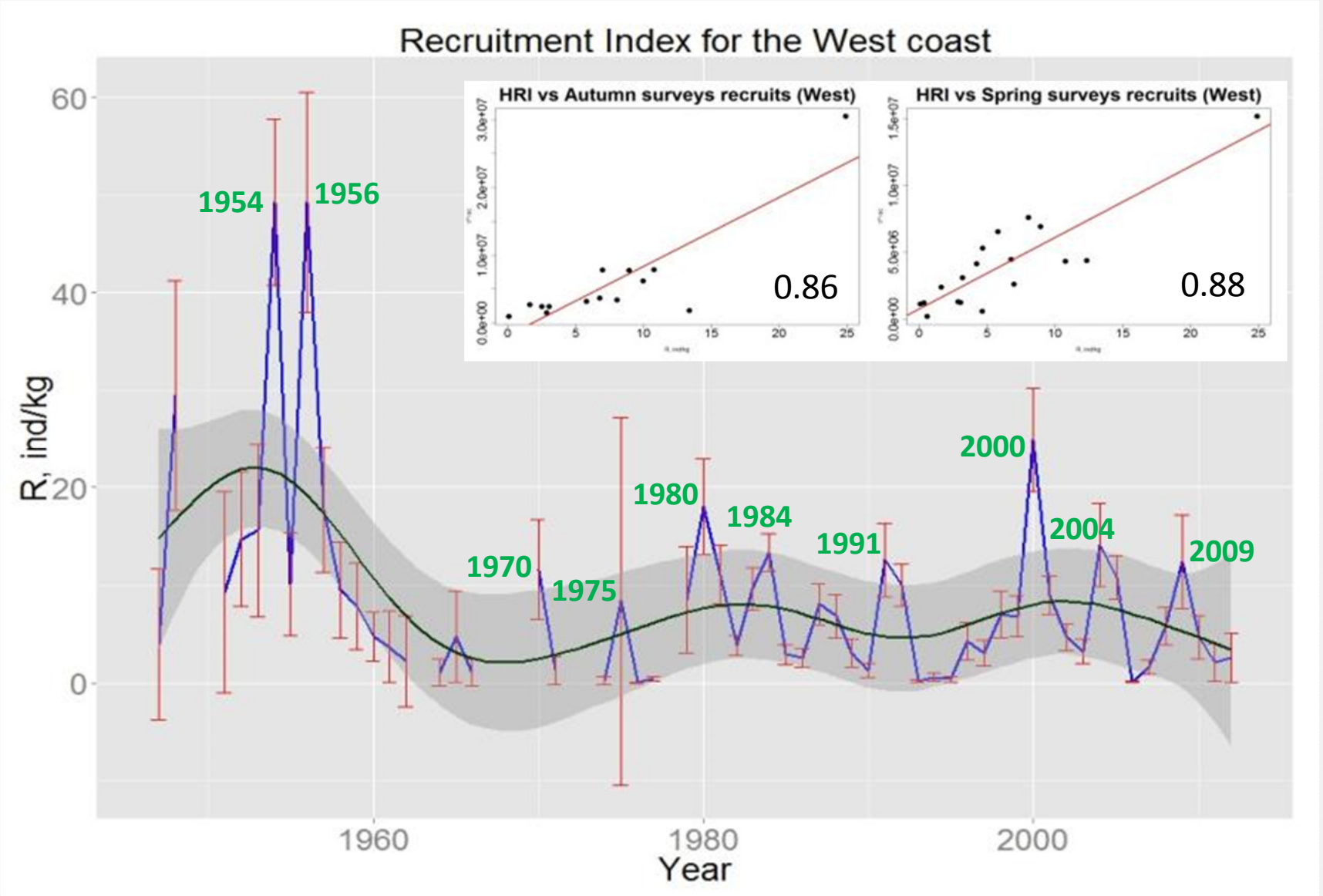
Methods

- Development of **H**istorical **R**ecruitment **I**ndex (HRI)
  - Estimates of **number of recruits per kg landed**
- **HRI** vs Environmental variables
  - **G**eneralized **A**dditive **M**odels
- Sardine fisheries historical compilation
  - Published papers, official reports and grey literature

HRI


Recruitment Index for the West coast
HRI vs Autumn surveys recruits (West)
HRI vs Spring surveys recruits (West)
0.86
0.88
1954
1956
1970
1975
1980
1984
1991
2000
2004
2009
R, ind/kg
Year
60
40
20
0
1960
1980
2000

HRI


Recruitment Index for the West coast
HRI vs Autumn surveys recruits (West)
0.86
HRI vs Spring surveys recruits (West)
0.88
1954
1956
1970
1975
1980
1984
1991
2000
2004
2009
R, ind/kg
Year
1960
1980
2000
0
20
40
60

| HRI vs environmental factors

Initial Model

- **HRI** ~ s(NAOw) + s(NAOs) + s(SSTw) + s(SSTs) + s(EAw) + s(EAs) + s(aflo.w) + s(aflo.s) + s(AMO.annual)

Final Model

- **HRI** ~ s(NAOs) + s(AMO.annual) + SSTs + aflo.w
- AMO.anual (p=**0.0004**); NAOs (p=**0.002)**; SSTs (p=**0.003**) & aflo.w (p=**0.01**)
- Deviance explained = **46.2%**

| HRI vs environmental factors

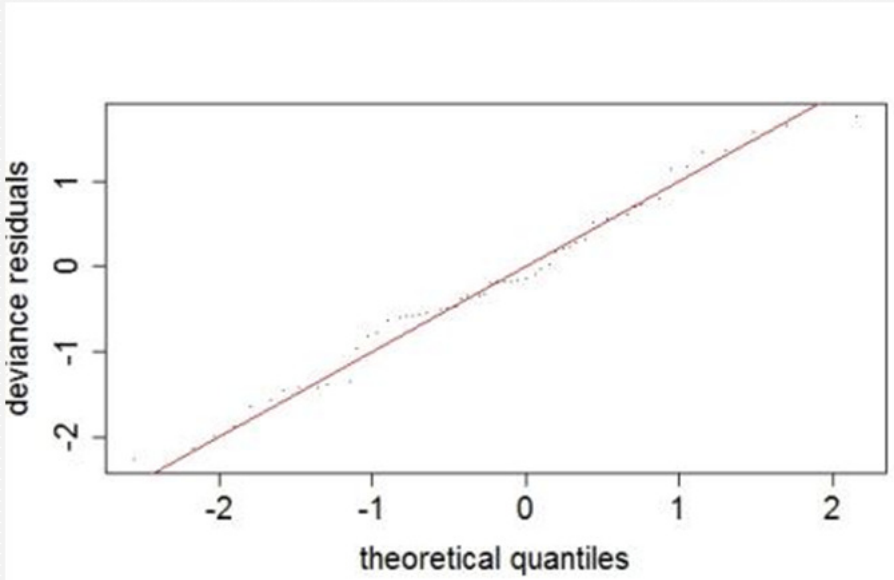
Initial Model

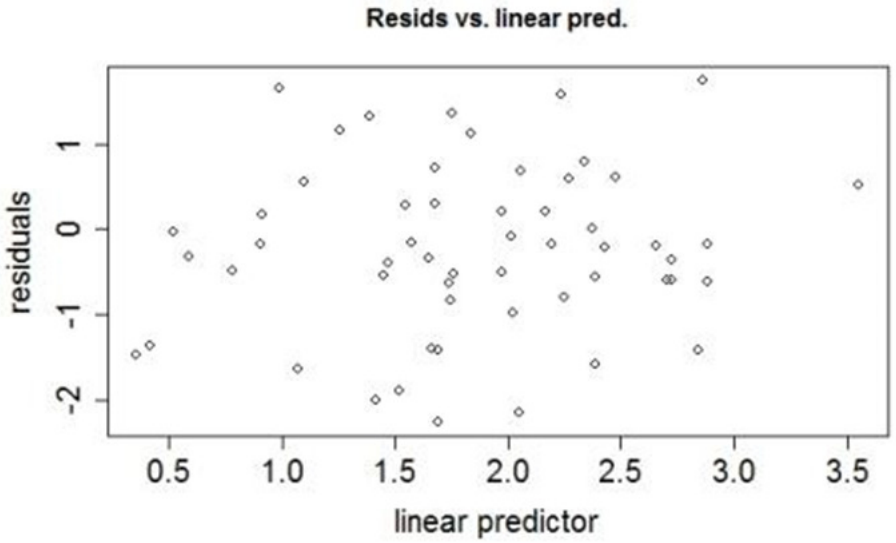
- **HRI** ~ s(NAOw) + s(NAOs) + s(SSTw) + s(SSTs) + s(EAw) + s(EAs) + s(aflo.w) + s(aflo.s) + s(AMO.annual)

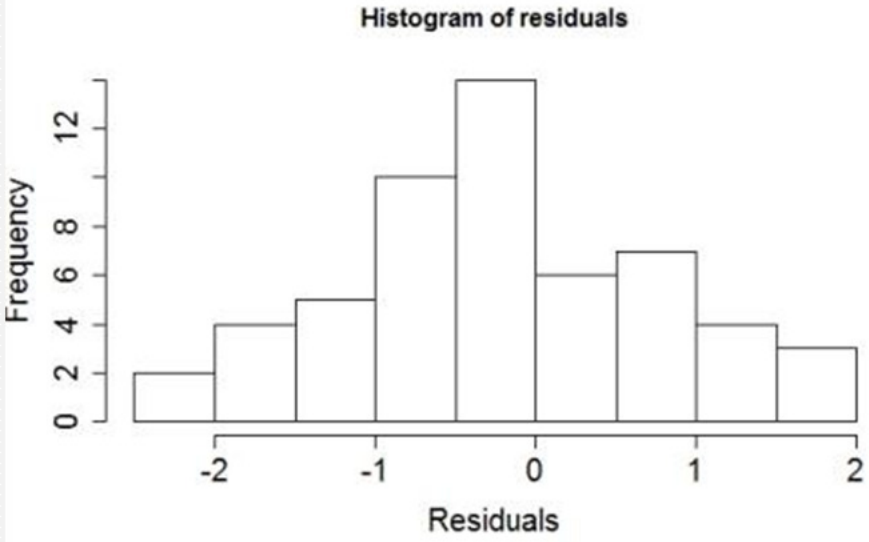
Final Model

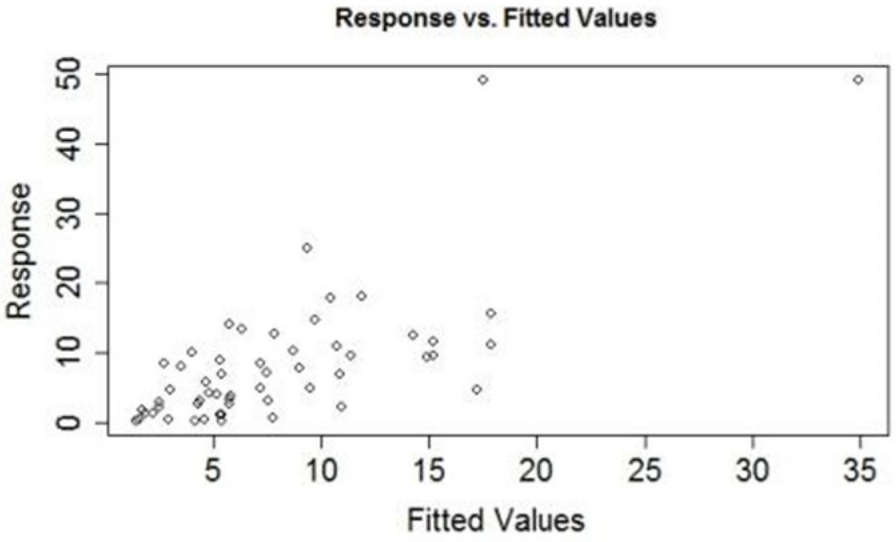
- **HRI** ~ s(NAOs) + s(AMO.annual) + SSTs + aflo.w
- AMO.anual (p=**0.0004**); NAOs (p=**0.002)**; SSTs (p=**0.003**) & aflo.w (p=**0.01**)
- Deviance explained = **46.2%**

HRI vs environmental factors

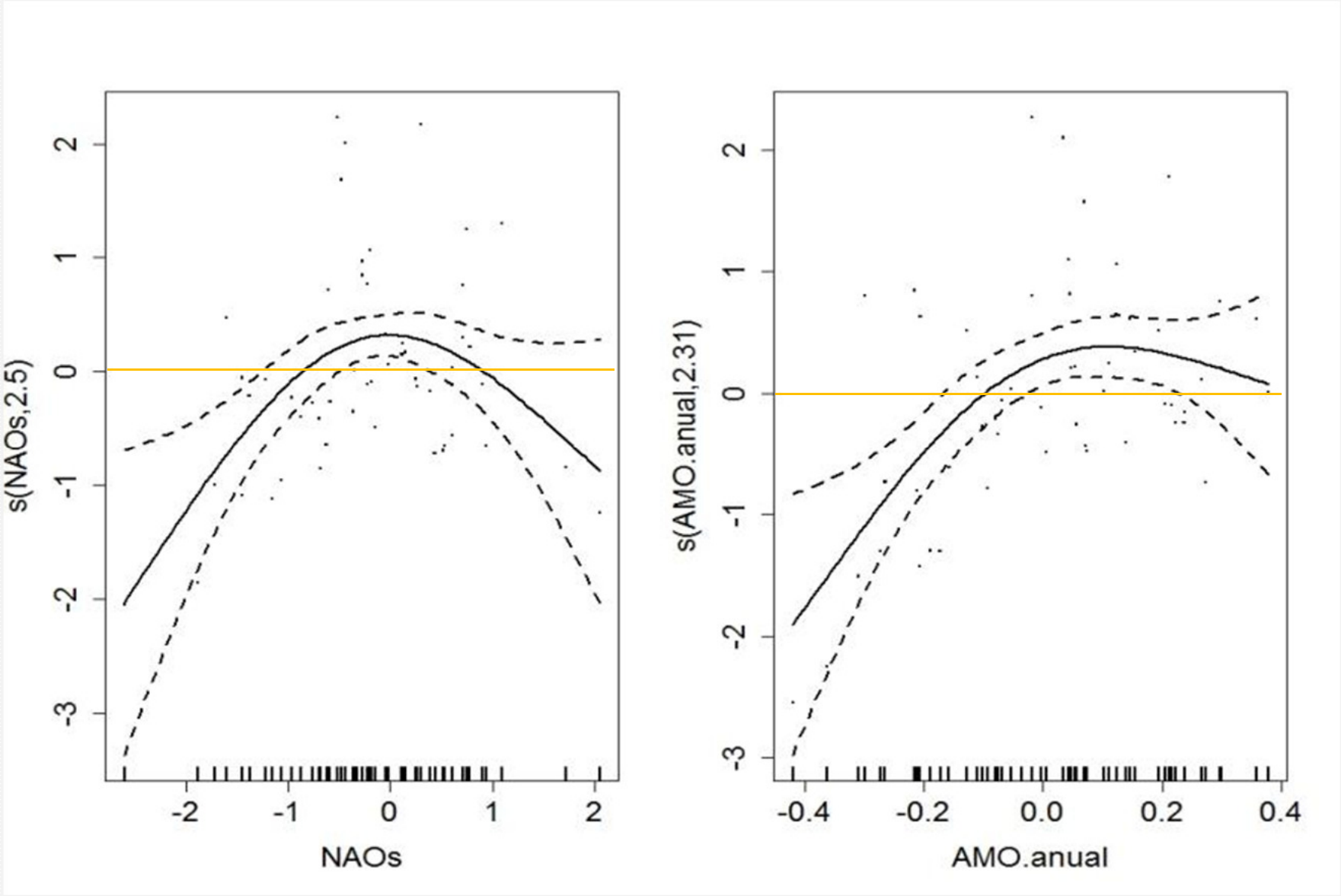




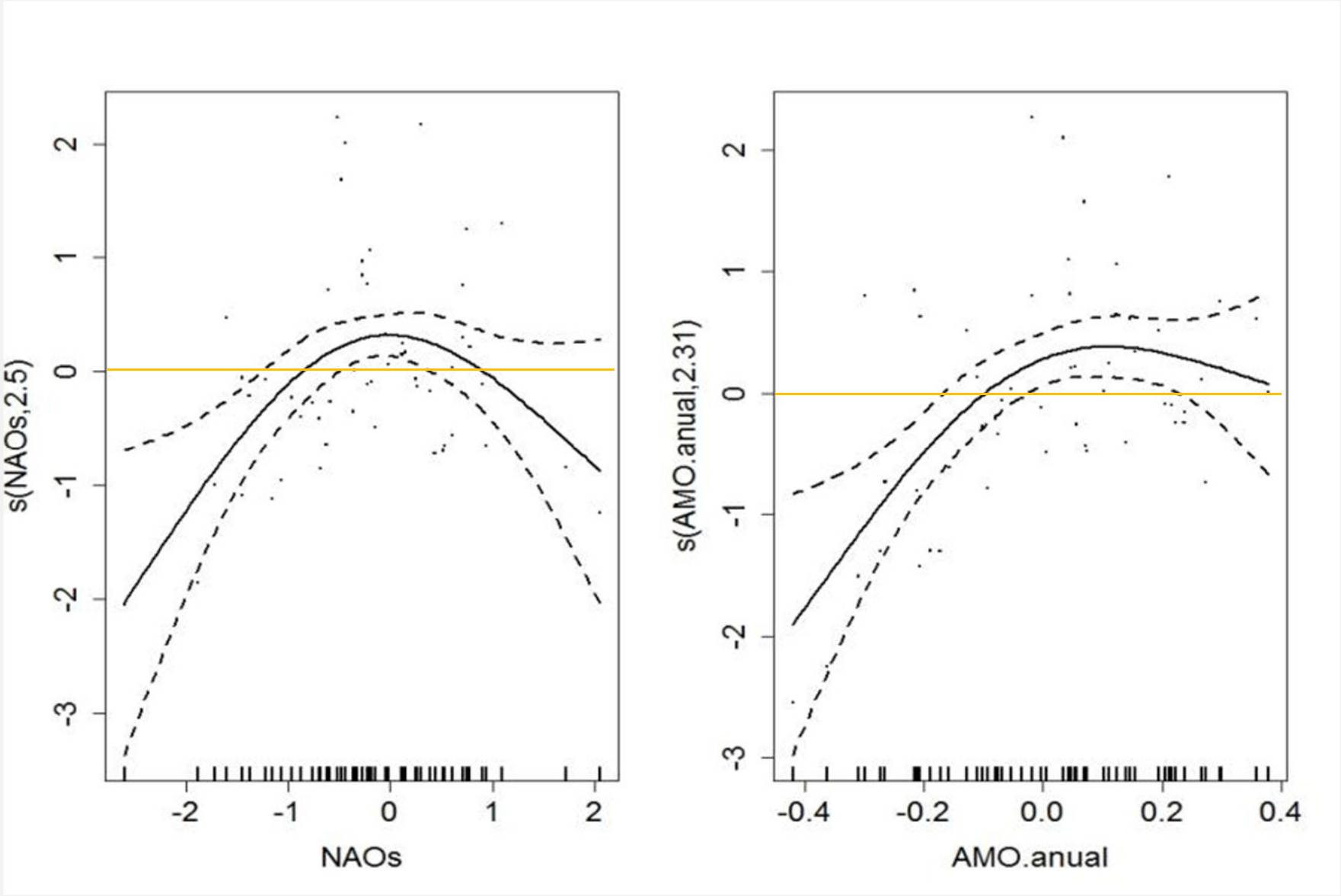




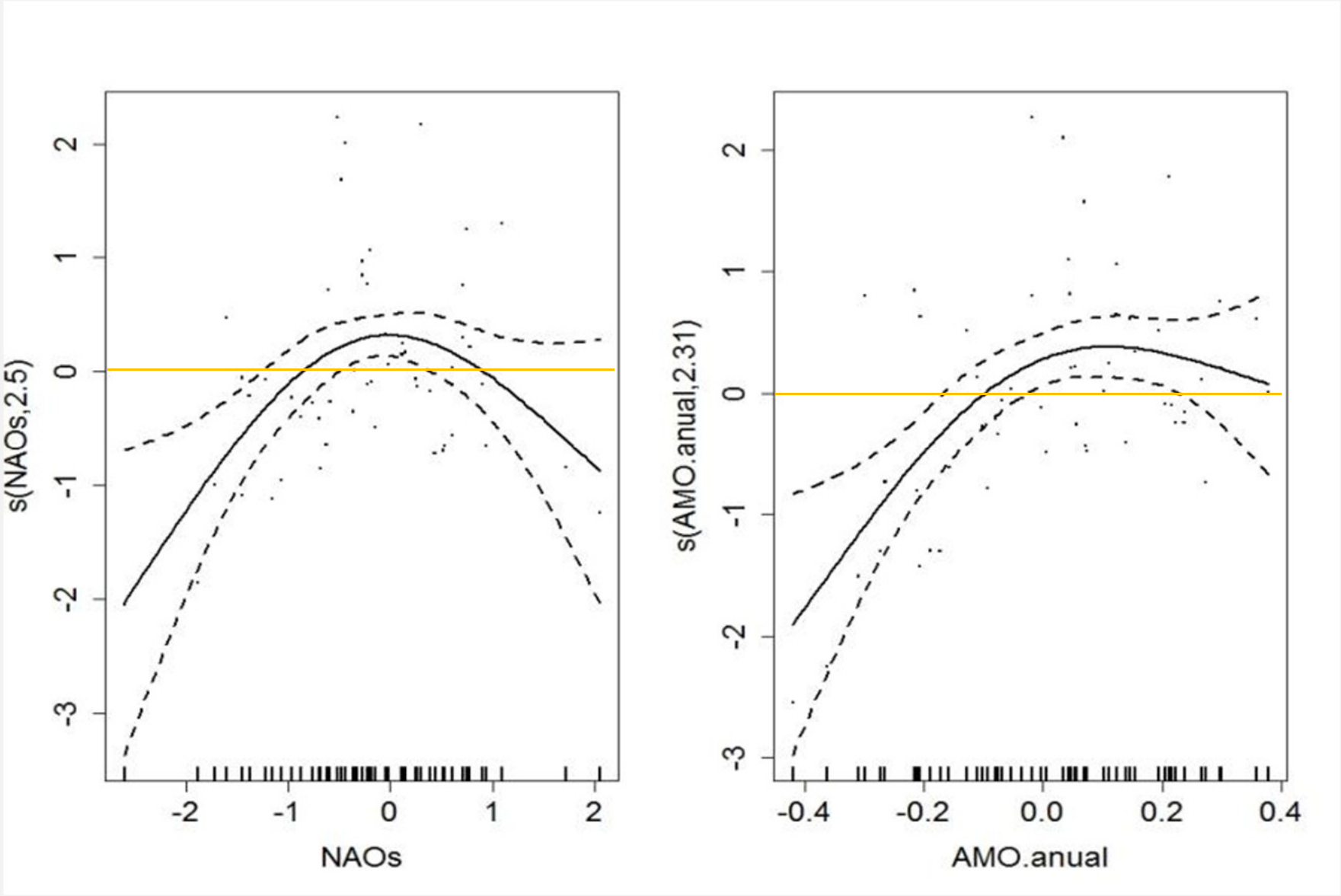
HRI vs environmental factors



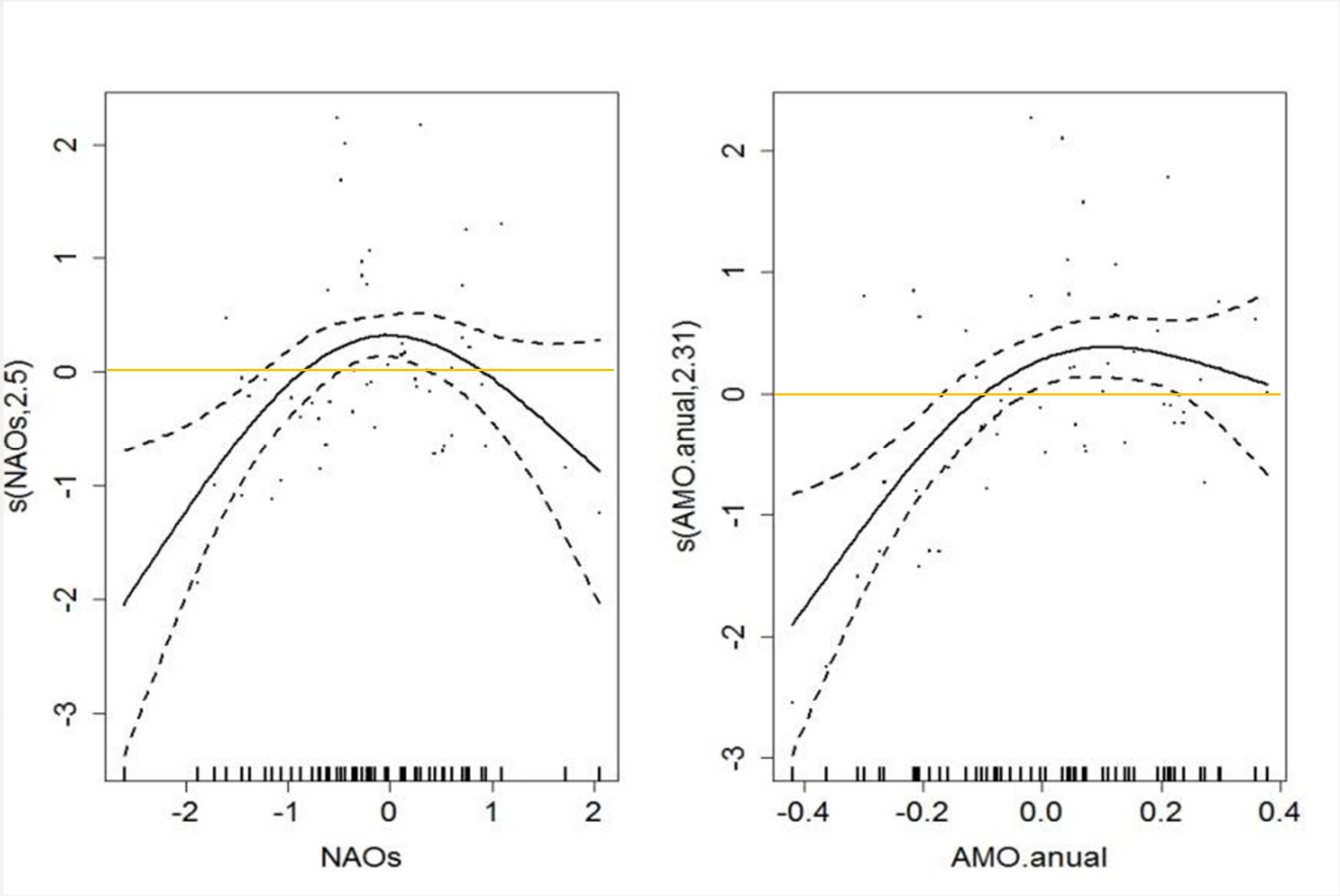
HRI vs environmental factors



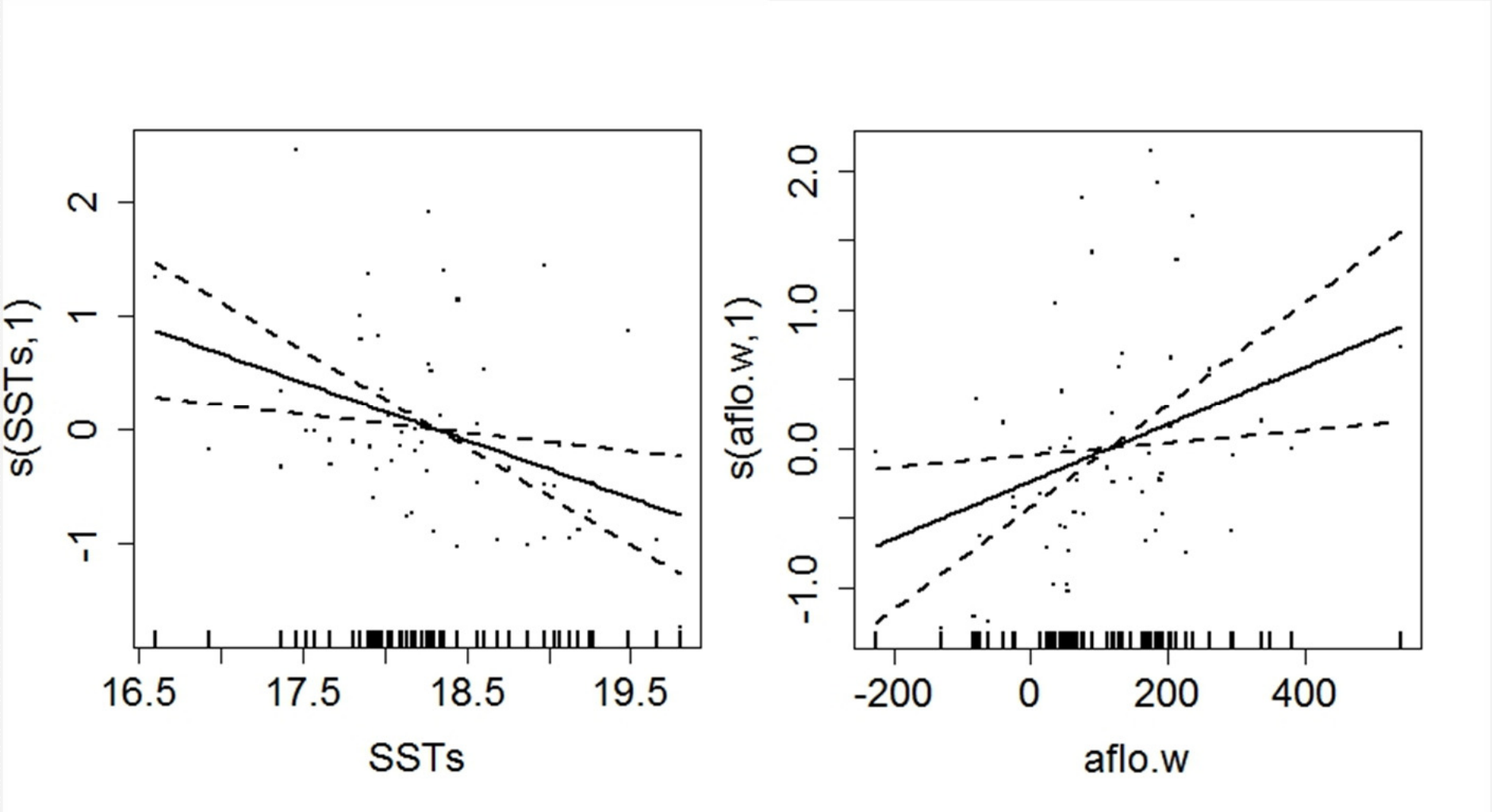
HRI vs environmental factors



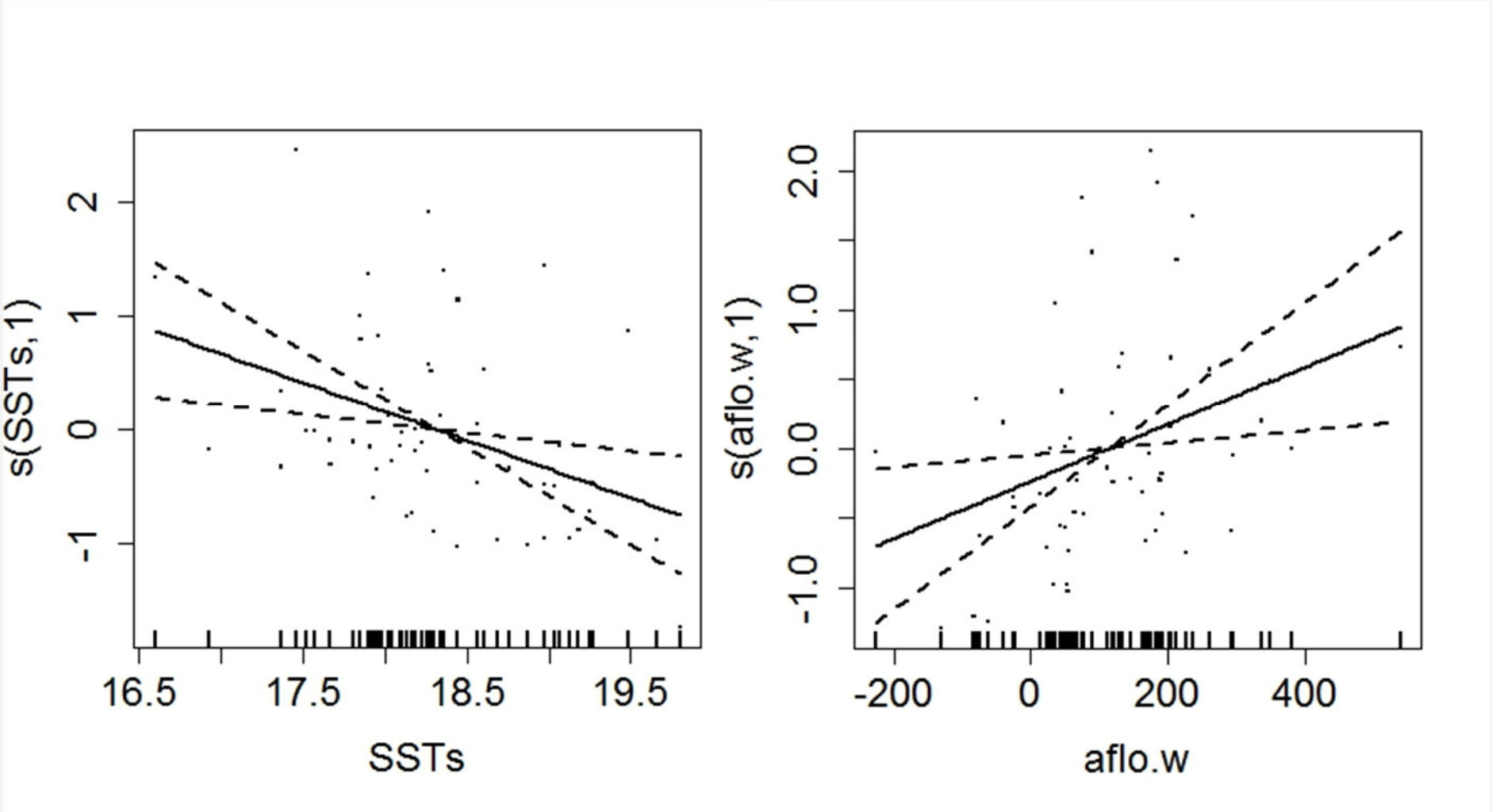
HRI vs environmental factors



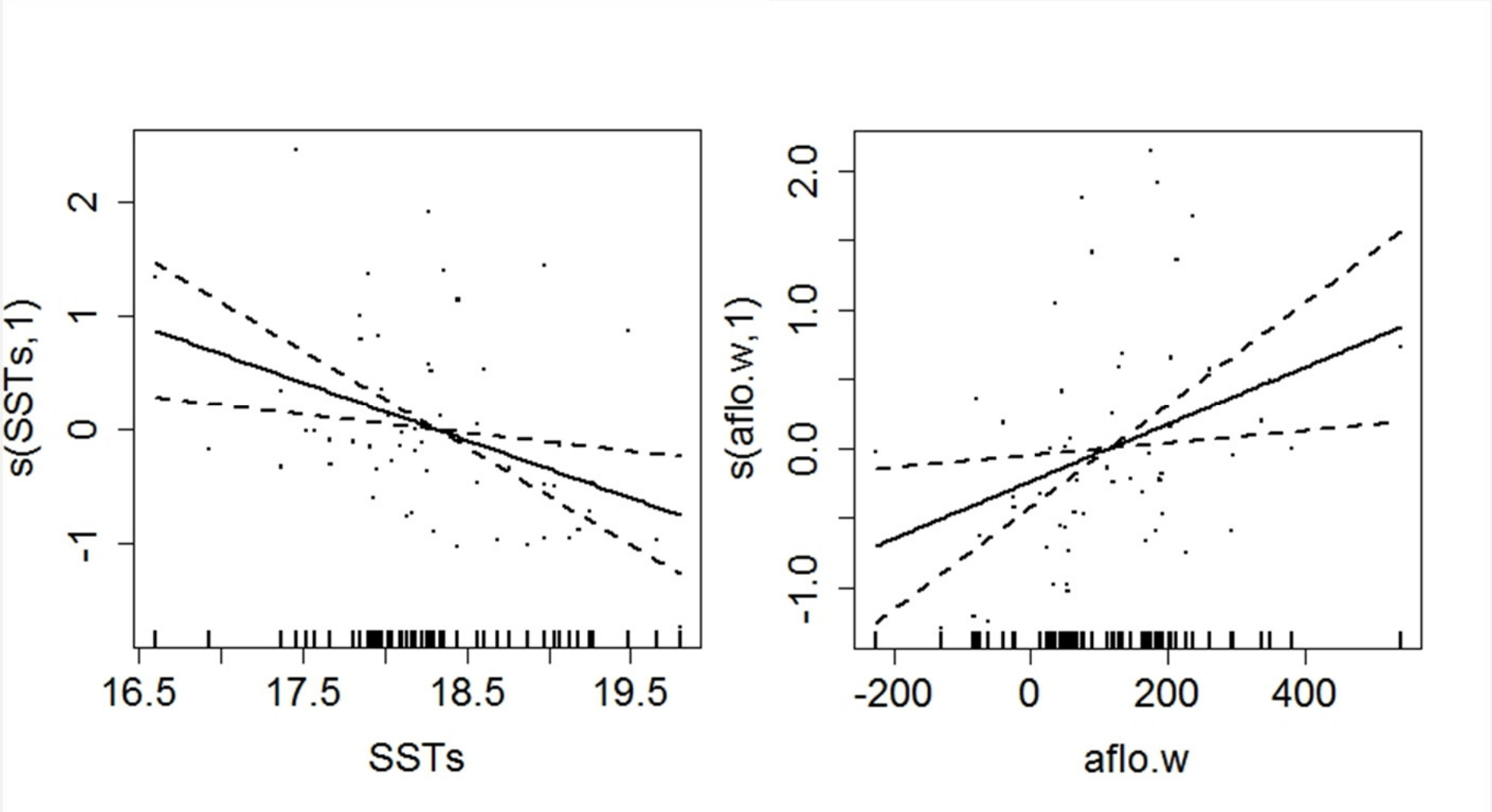
|HRI vs environmental factors



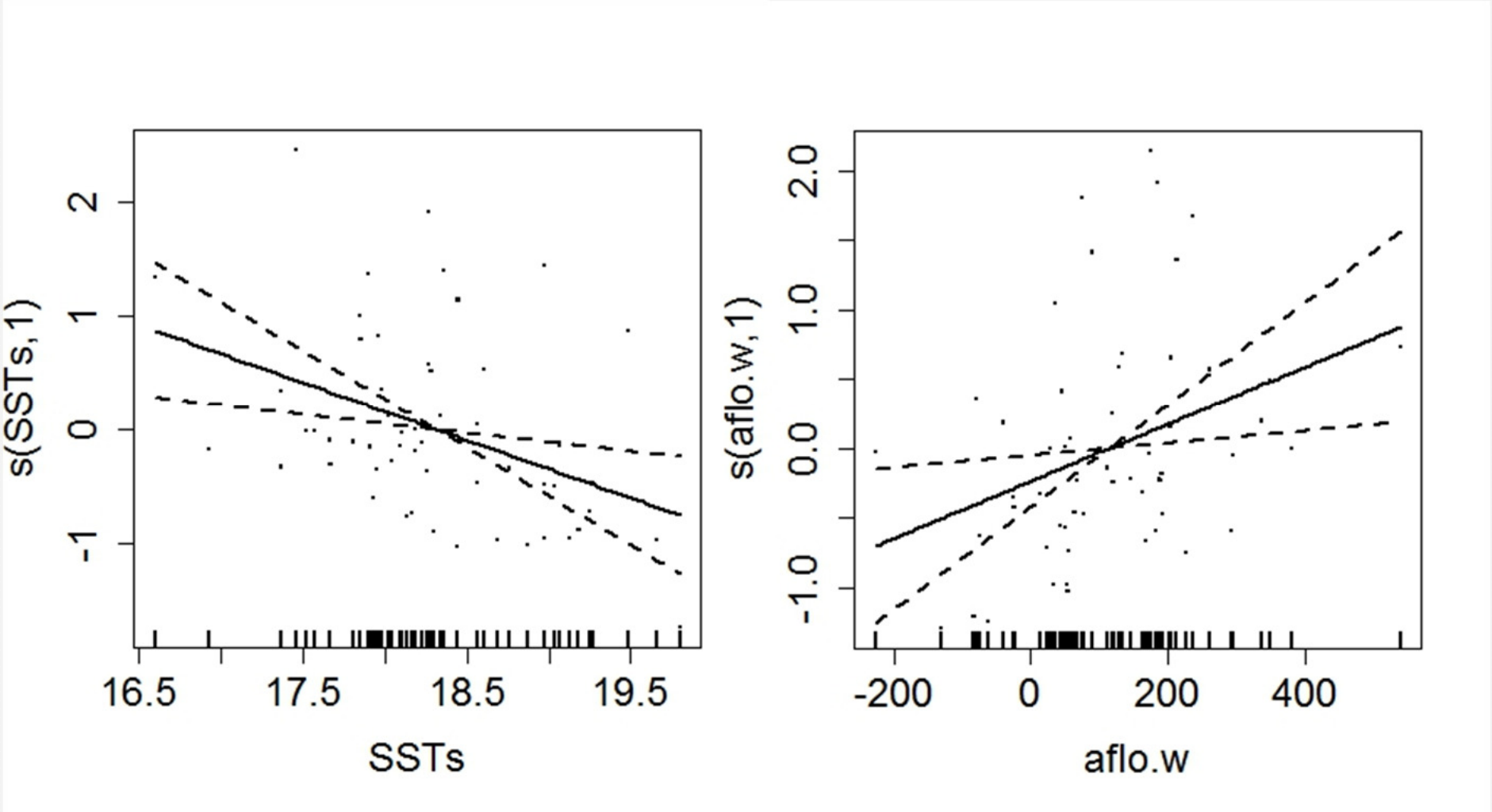
HRI vs environmental factors



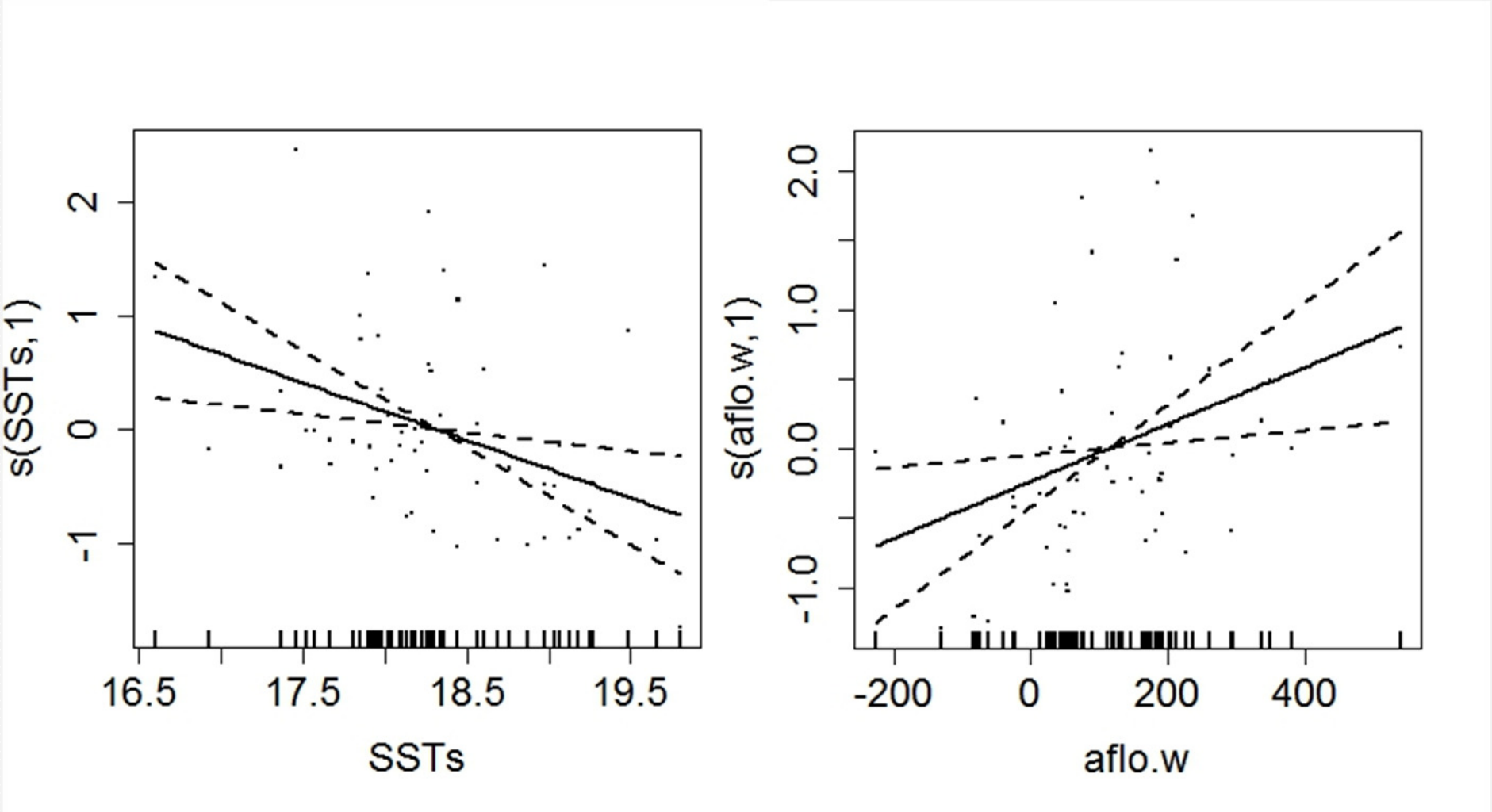
HRI vs environmental factors



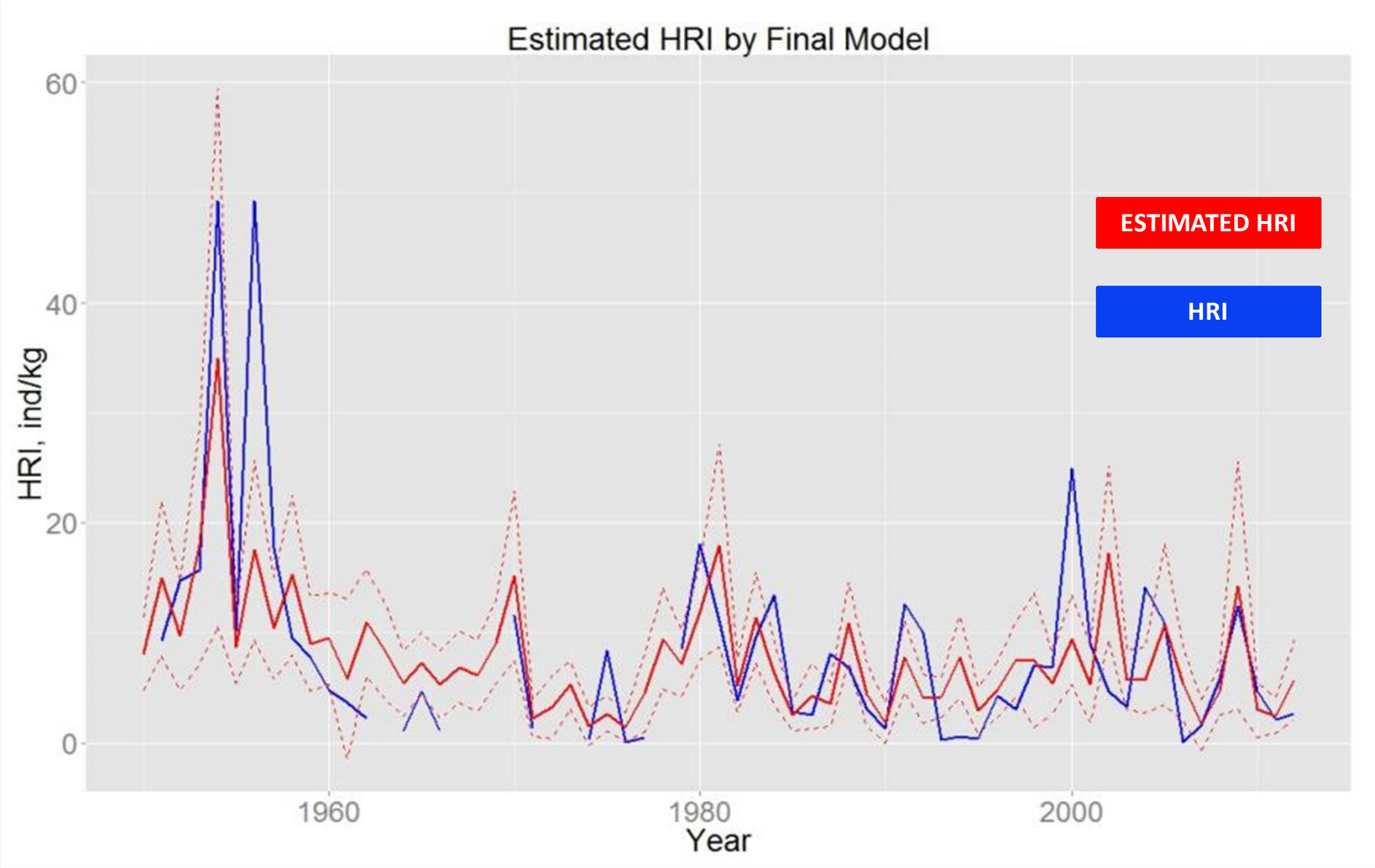
HRI vs environmental factors



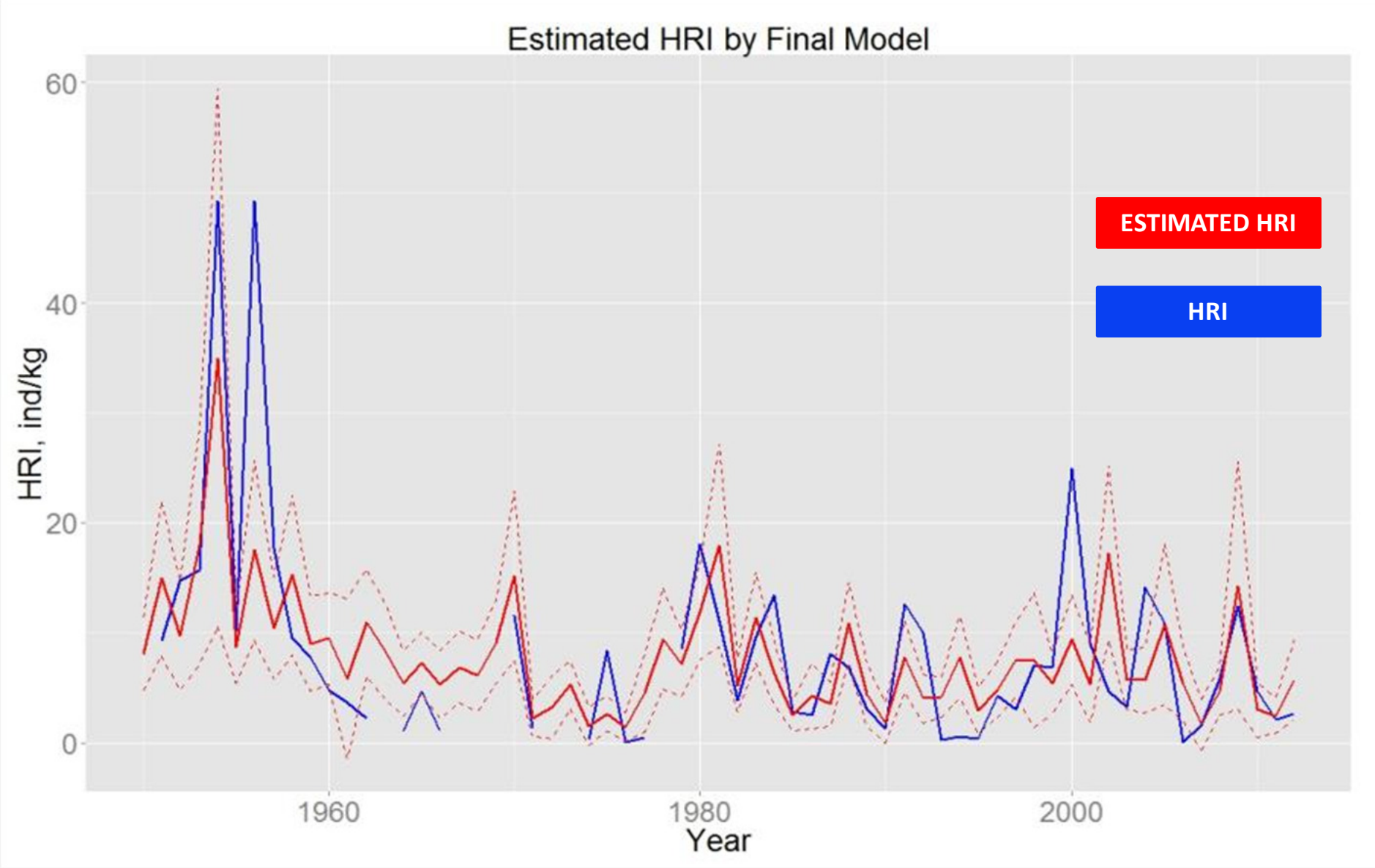
|HRI vs environmental factors



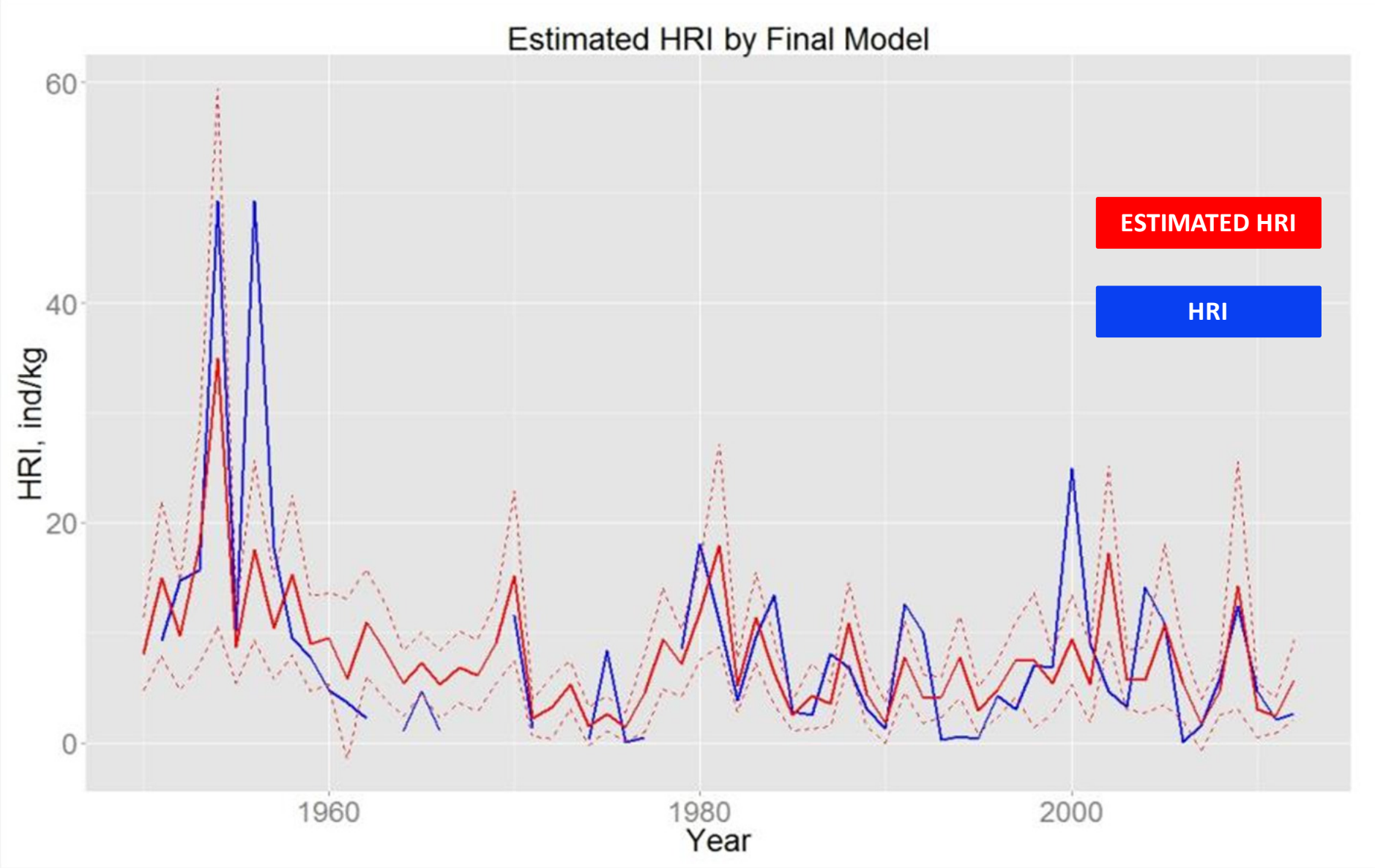
Estimated HRI



Estimated HRI



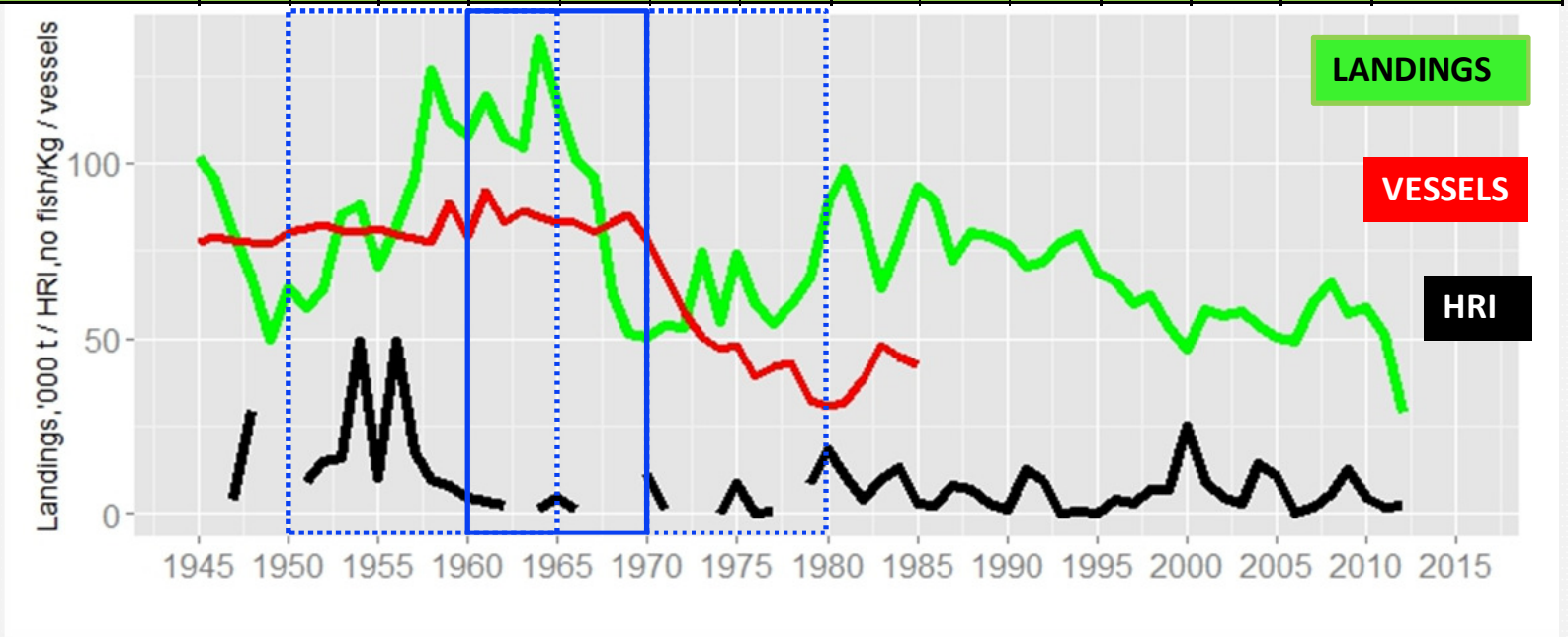
Estimated HRI



Explotation history vs HRI

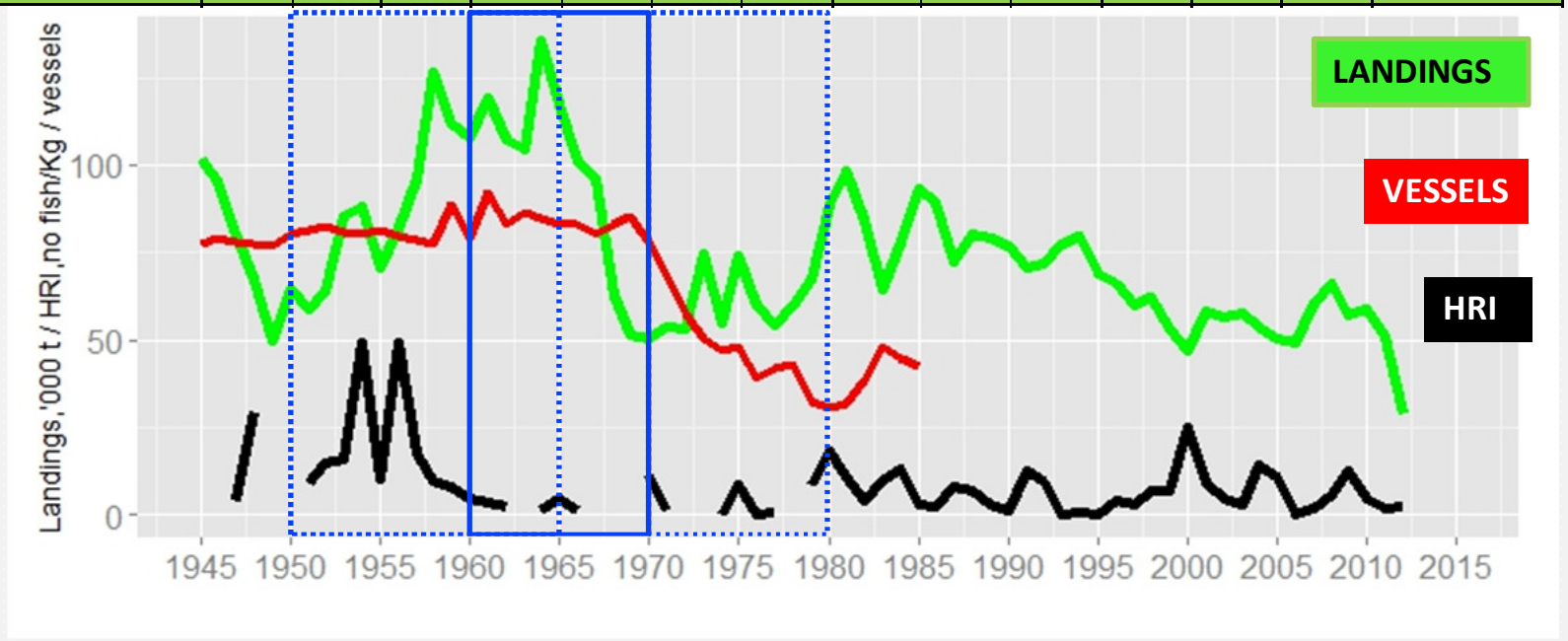
World War II

Events	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Socio-economic	Increased search and consumption, impulse to the canning industry	Difficulty to access raw material for canning			Crisis in the canning sector, high operating costs, market saturation			Crisis canning sector, increase of labour costs						Gradual recovery of the canning industry, increase in exports	
Technological	Expansion of modern purse seine, diesel propulsion		Introduction of synthetic fibers, echosounder, power blocks				Decrease in effort: no. vessels and fishing days/year halved	Gradual improvement of fishing power and efficiency due to upgrade of engines, navigation systems and echolocation equipement							
Fisheries management	"General Regulation of the sardine fishery in the Portuguese coast" (1903) and addendum: areas, periods, gear specifications and effort for sardine fisheries.									Gen. reg. conservation of fish. resources: net/ mesh size, areas, MLS		Additional regulations: annual quotas (2000-2004), effort limitations, seasonal closure in the north			Long-term management plan: annual quotas, effort limitation, seasonal closure
Half-decades	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010



Explotation history vs HRI

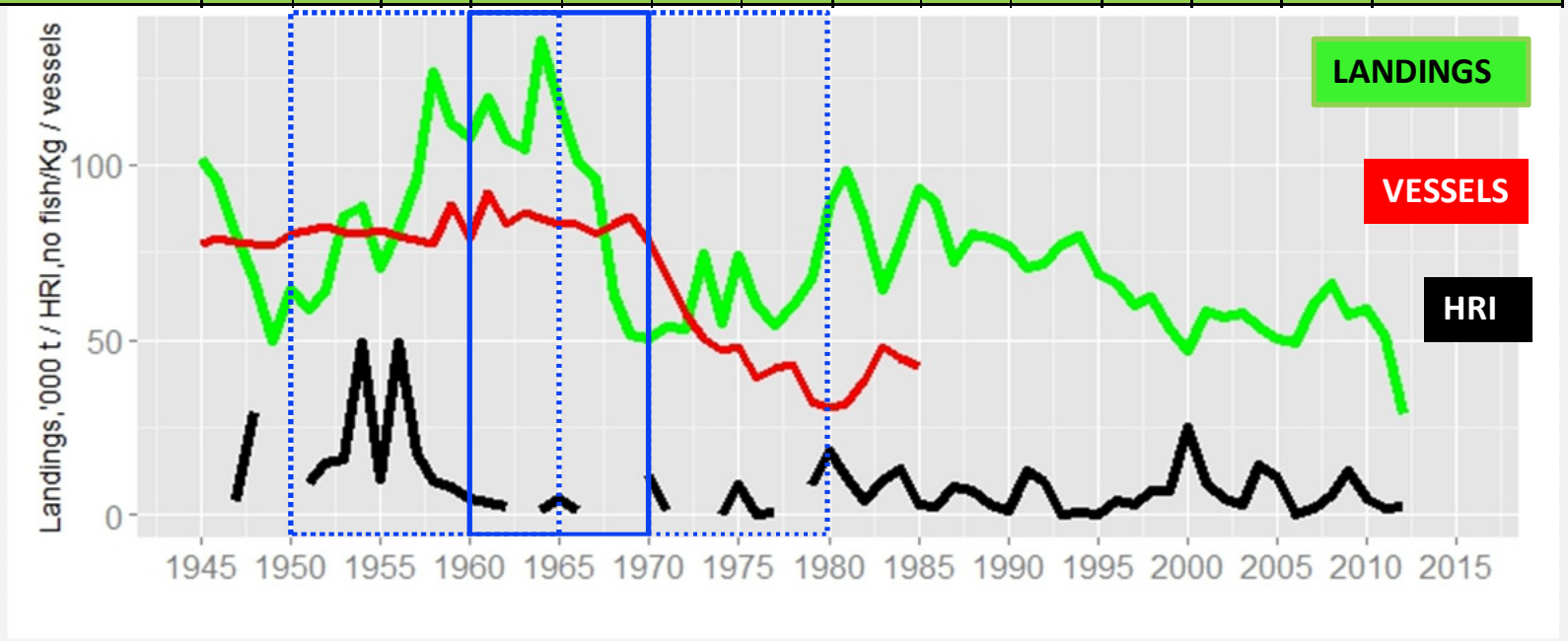
	World War II														
Events	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Socio-economic	Increased search and consumption, impulse to the canning industry	Difficulty to access raw material for canning			Crisis in the canning sector, high operating costs, market saturation			Crisis canning sector, increase of labour costs						Gradual recovery of the canning industry, increase in exports	
Technological	Expansion of modern purse seine, diesel propulsion		Introduction of synthetic fibers, echosounder, power blocks				Decrease in effort: no. vessels and fishing days/year halved	Gradual improvement of fishing power and efficiency due to upgrade of engines, navigation systems and echolocation equipement							
Fisheries management	"General Regulation of the sardine fishery in the Portuguese coast" (1903) and addendum: areas, periods, gear specifications and effort for sardine fisheries.									Gen. reg. conservation of fish. resources: net/ mesh size, areas, MLS		Additional regulations: annual quotas (2000-2004), effort limitations, seasonal closure in the north			Long-term management plan: annual quotas, effort limitation, seasonal closure
Half-decades	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010



Explotation history vs HRI

World War II

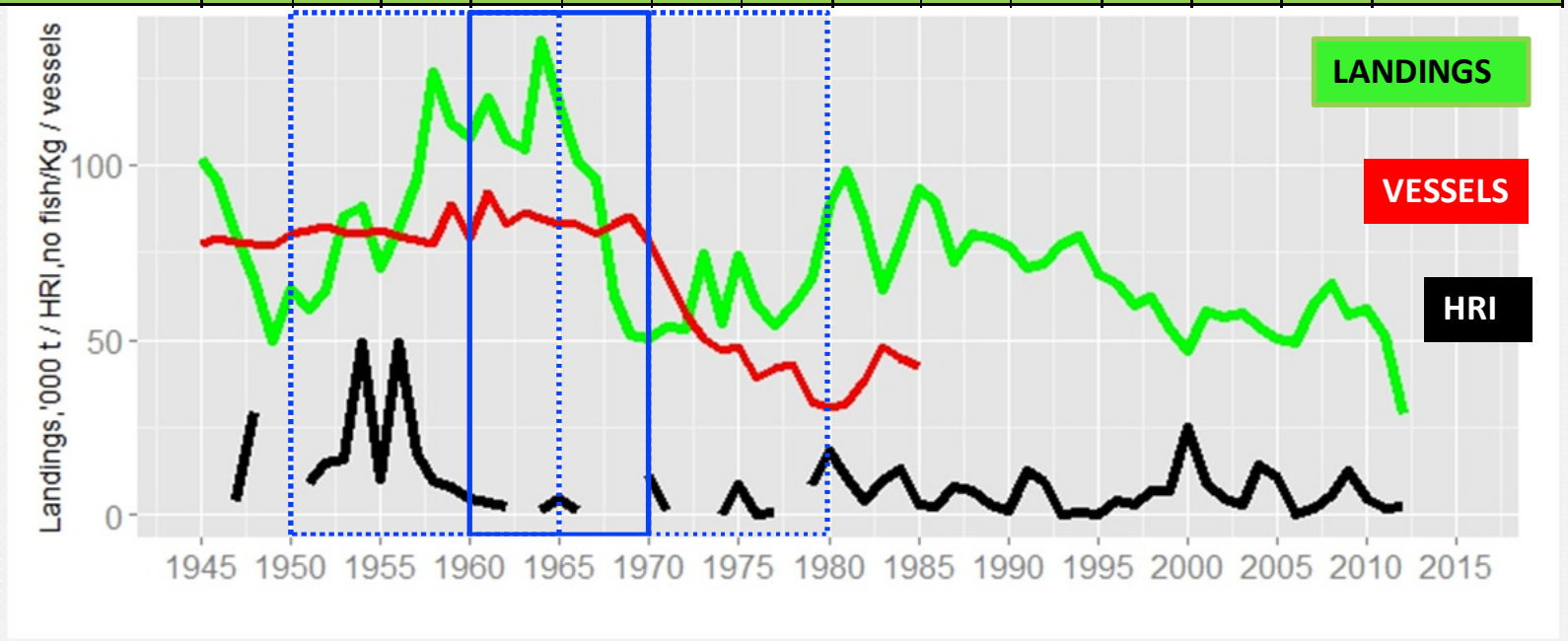
Events	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Socio-economic	Increased search and consumption, impulse to the canning industry	Difficulty to access raw material for canning			Crisis in the canning sector, high operating costs, market saturation			Crisis canning sector, increase of labour costs						Gradual recovery of the canning industry, increase in exports	
Technological	Expansion of modern purse seine, diesel propulsion		Introduction of synthetic fibers, echosounder, power blocks				Decrease in effort: no. vessels and fishing days/year halved	Gradual improvement of fishing power and efficiency due to upgrade of engines, navigation systems and echolocation equipement							
Fisheries management	"General Regulation of the sardine fishery in the Portuguese coast" (1903) and addendum: areas, periods, gear specifications and effort for sardine fisheries.									Gen. reg. conservation of fish. resources: net/ mesh size, areas, MLS		Additional regulations: annual quotas (2000-2004), effort limitations, seasonal closure in the north			Long-term management plan: annual quotas, effort limitation, seasonal closure
Half-decades	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010



Explotation history vs HRI

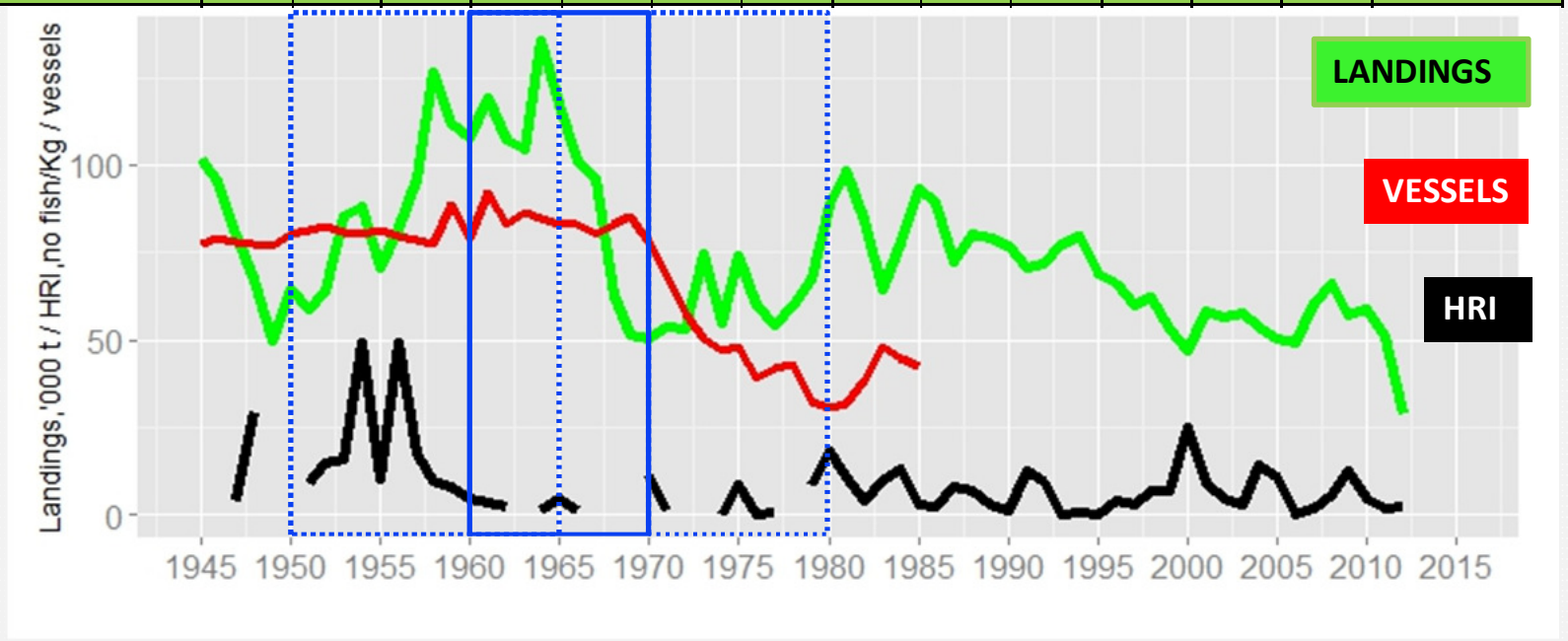
World War II

Events	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Socio-economic	Increased search and consumption, impulse to the canning industry	Difficulty to access raw material for canning			Crisis in the canning sector, high operating costs, market saturation			Crisis canning sector, increase of labour costs						Gradual recovery of the canning industry, increase in exports	
Technological	Expansion of modern purse seine, diesel propulsion		Introduction of synthetic fibers, echosounder, power blocks				Decrease in effort: no. vessels and fishing days/year halved	Gradual improvement of fishing power and efficiency due to upgrade of engines, navigation systems and echolocation equipement							
Fisheries management	"General Regulation of the sardine fishery in the Portuguese coast" (1903) and addendum: areas, periods, gear specifications and effort for sardine fisheries.									Gen. reg. conservation of fish. resources: net/ mesh size, areas, MLS		Additional regulations: annual quotas (2000-2004), effort limitations, seasonal closure in the north			Long-term management plan: annual quotas, effort limitation, seasonal closure
Half-decades	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010



Explotation history vs HRI

	World War II														
Events	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Socio-economic	Increased search and consumption, impulse to the canning industry	Difficulty to access raw material for canning			Crisis in the canning sector, high operating costs, market saturation			Crisis canning sector, increase of labour costs						Gradual recovery of the canning industry, increase in exports	
Technological	Expansion of modern purse seine, diesel propulsion		Introduction of synthetic fibers, echosounder, power blocks				Decrease in effort: no. vessels and fishing days/year halved	Gradual improvement of fishing power and efficiency due to upgrade of engines, navigation systems and echolocation equipement							
Fisheries management	"General Regulation of the sardine fishery in the Portuguese coast" (1903) and addendum: areas, periods, gear specifications and effort for sardine fisheries.									Gen. reg. conservation of fish. resources: net/ mesh size, areas, MLS		Additional regulations: annual quotas (2000-2004), effort limitations, seasonal closure in the north			Long-term management plan: annual quotas, effort limitation, seasonal closure
Half-decades	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010



|Summary & Conclusions

•The **H**istorical **R**ecruitment **I**ndex proved to be a good indicator of recruitment for the West Portuguese coast;

•The final model with Annual AMO, summer NAO, summer SST and winter upwelling as covariables, explained 46% of the recruitment variation;

•Both recruitment and fisheries historical events appear to influence the Portuguese sardine total landings.

|Summary & Conclusions

- The **H**istorical **R**ecruitment **I**ndex proved to be a good indicator of recruitment for the West Portuguese coast;

- The final model with Annual AMO, summer NAO, summer SST and winter upwelling as covariables, explained 46% of the recruitment variation;

- Both recruitment and fisheries historical events appear to influence the Portuguese sardine total landings.