



# Navigating Changes in Small Pelagic Fish and Forage Communities: Climate, Ecosystems, and Sustainable Fisheries

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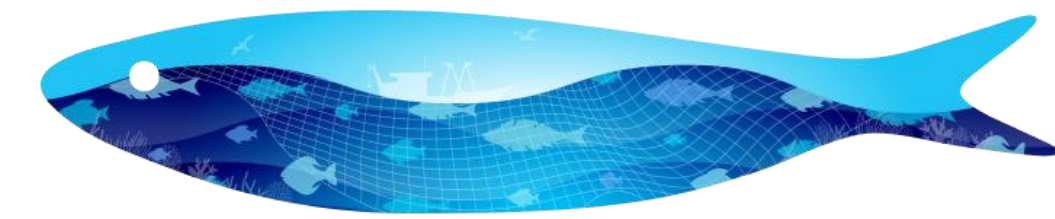


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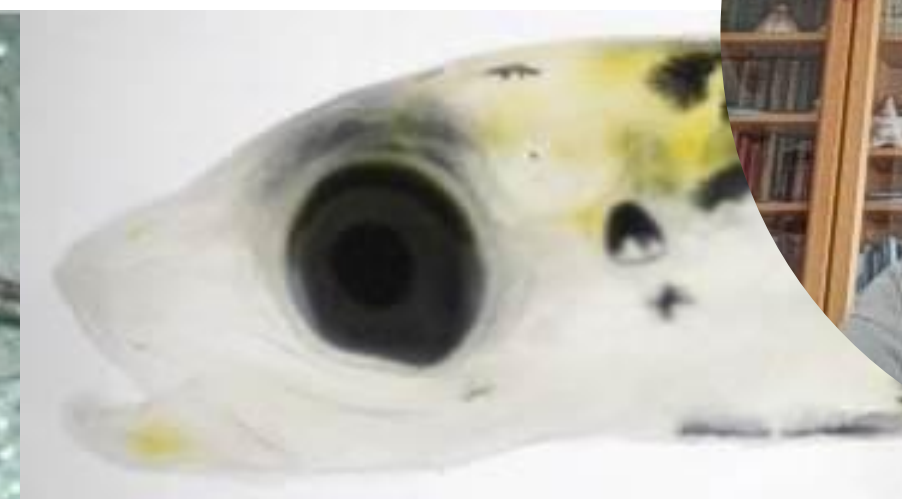
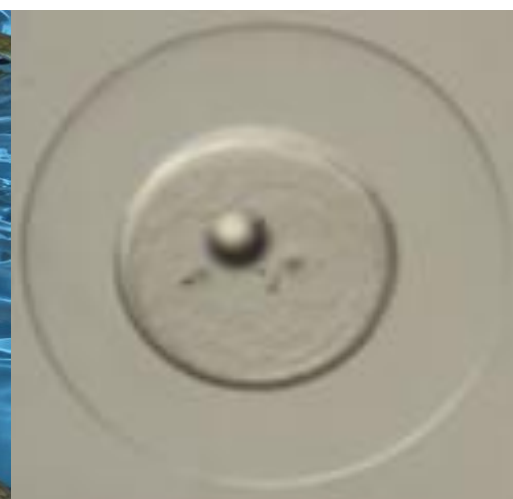


# IPMA



# Estimating slipping rates and survivorship in the Portuguese purse-seine fishery: Implications for small pelagic stock assess

Diana Feijó, Alberto Rocha, Ana Marçalo, Laura Wise, Isabel Riveiro, Alexandra A. Silva



# Portuguese purse-seine fishery

## It's the most important fishery in Portugal. Why?

In 2024, purse-seine landings represent in Portugal:

- 58,1 % in weight
- 26 % in value in the first sale (DGRM, 2025)

165 vessels

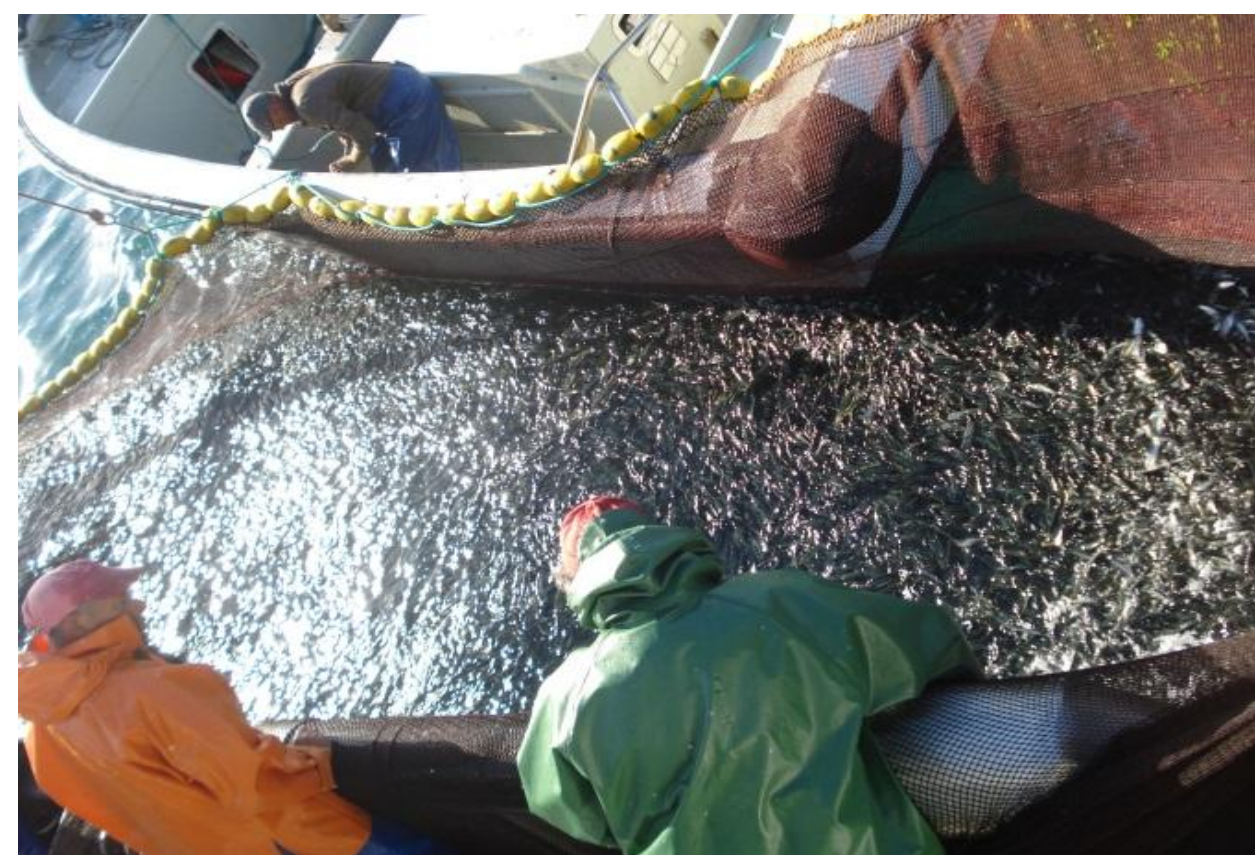
≈ 2 thousand fishermen

(DGRM, 2025; INE, 2021)

+ 10 thousand indirect workers

In 2023:

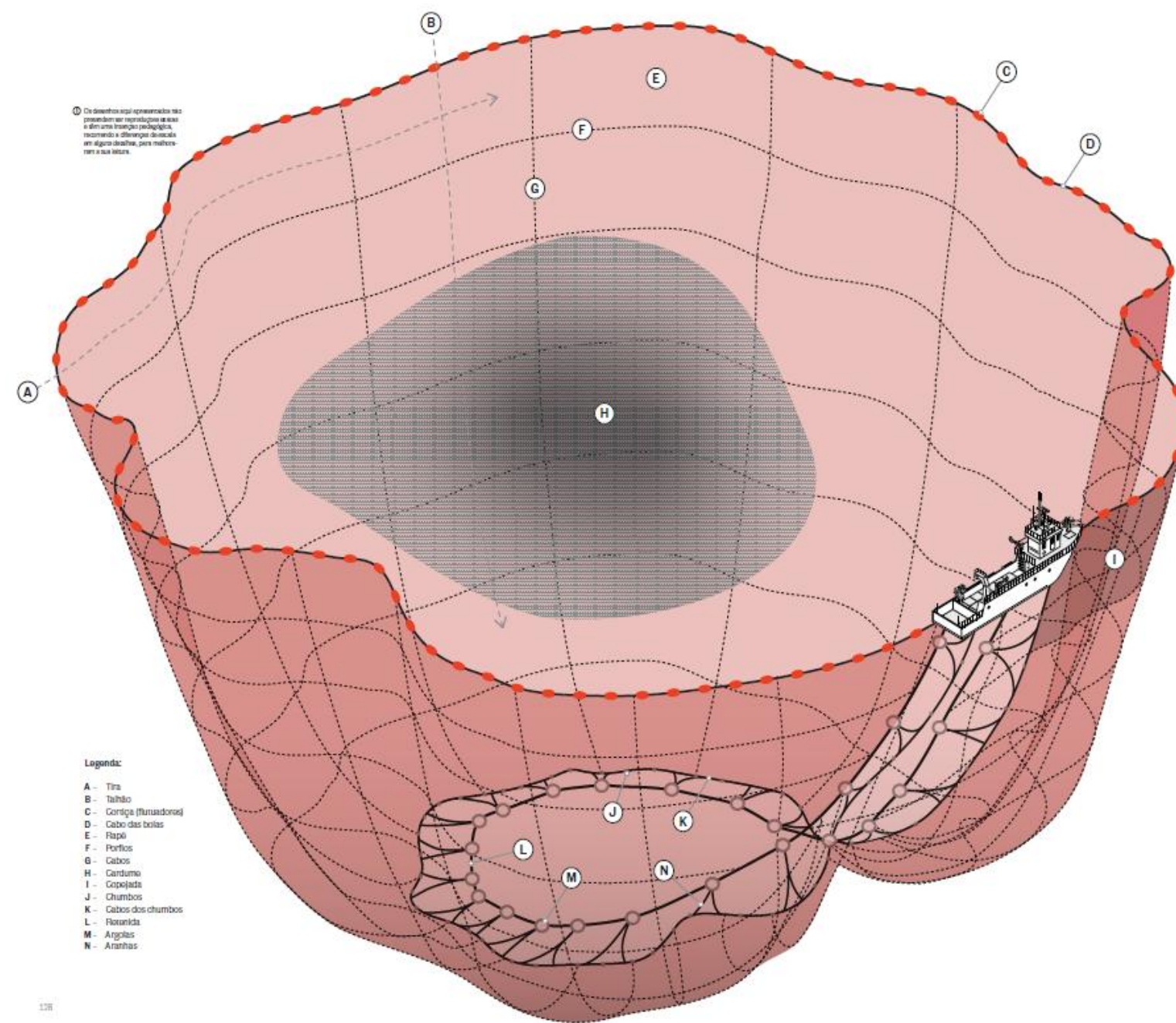
- 67,7 thousand tons canned fish = 466 millions € (INE, 2025)
- 19.6% of them were sardine = 83 millions € (DRGM, 2025; INE, 2025)



# What is purse-seine fishery and targets?

A large wall of netting deployed around an entire area or school of fish.

- floats along the top line
- lead line threaded through rings along the bottom.



in Sardinha, Helder Luis (2022).

Purse-seine targets other pelagic fish, among other species:

- **Sardine** (*Sardina pilchardus*) – main target species
- **Chub-mackerel** (*Scomber colias*)
- **European anchovy** (*Engraulis encrasicolus*)
- **Scads** (*Trachurus trachurus*, *T. picturatus*, *T. mediterraneus*)



# Why Catch ≠ Landing in purse-seiners?

Capture

Landings



Slipping

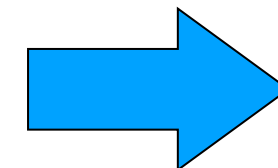


Discards  
at sea or  
ports



- Multi-species sets - lower fish price
- Species below minimum landing size
- Lack of consumption (swimming crab)
- Low or no commercial value
- Oversupply in the market sales
- Daily landing limit by Purse-seine Producer Organizations (for ex. Sardine  $\approx$  4-6 ton/day)
- Reached quota/TAC
- Limit of the vessel transport capacity ( $\approx$  30 ton)

Slipping  
and/or  
Discards



# What is slipping?

The **skipper** may choose to **release the catch** back into the sea after the **purse-seine net has been closed**.

The decision is done before transferring the fish from the net.

The **release could be total or part of catch**.

This maneuver allows the **release of live fish**, which **slip over** the cork line of the net, hence the term **slipping**.

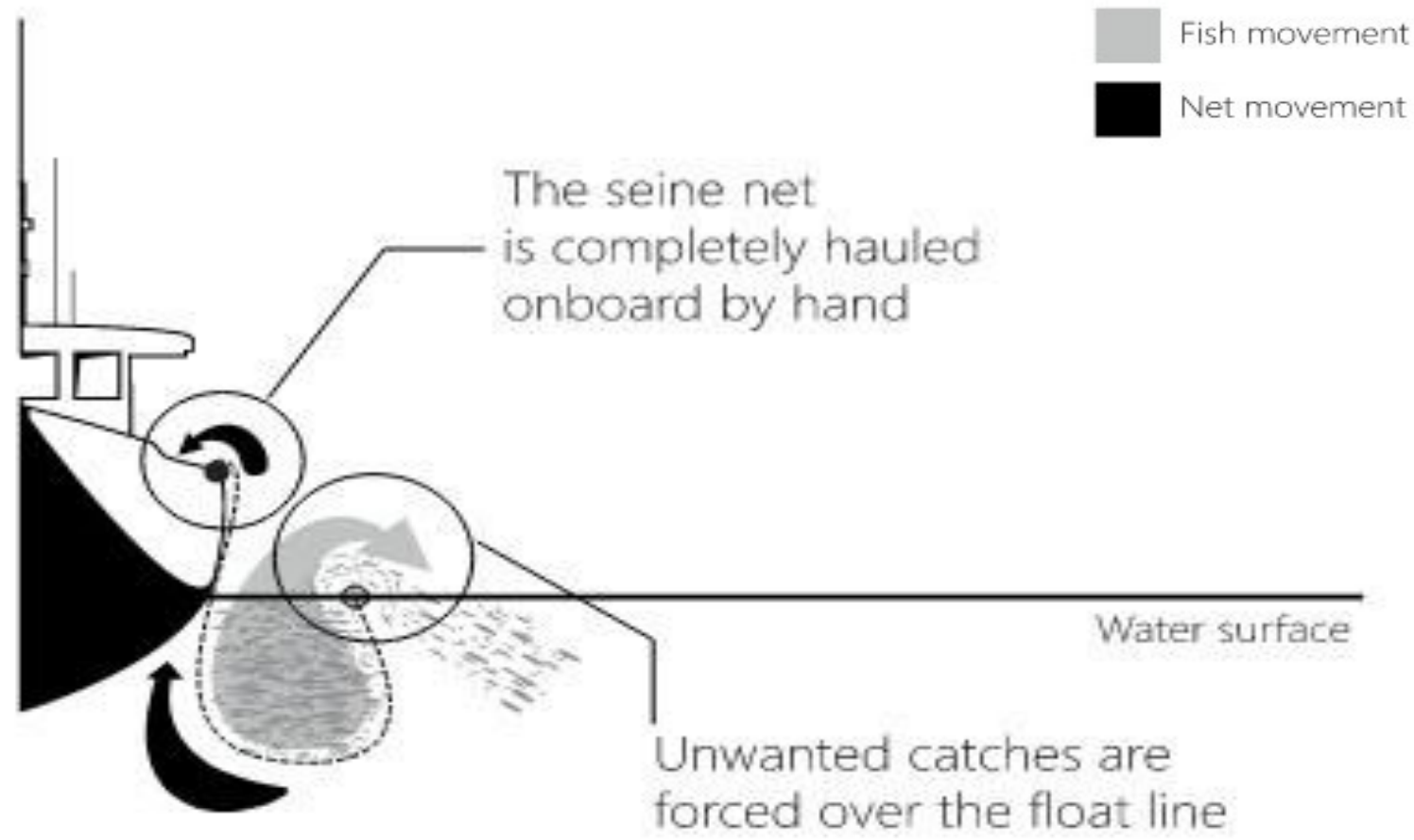


Diagram illustrating the slipping method (Marçalo et al. 2018).

# Objectives

This work aims to estimate **slipping rates** using onboard data in purse-seine fishery:

- Using Cochran' ratios (Cochran, 1977)
- Using Bayesian hierarchical modelling (RTBM package; Kristensen, 2025)

Case study:

- Scenarios of fishing mortality for sardine and chub-mackerel was used to establish different **mortality rates during the slipping practice**. Literature-based from Portugal' experimental studies, were calculated average, minimum and maximum mortality rates.
- How could these results be applied to the **stock assessment** and management of pelagic species?





## Cochran' slipping ratios

- Slipping estimates (tons) from onboard samples by species, area and year

$$\hat{R} = \frac{\bar{y}}{\bar{x}} = \frac{\sum_{i=1}^n \text{slipping}}{\sum_{i=1}^n \text{catch}}$$

$$\widehat{\text{Var}}(\hat{R}) = \frac{1}{n\bar{x}^2} \cdot \frac{1}{n-1} \sum_{i=1}^n (y_i - \hat{R}x_i)^2 \qquad \text{CV}(\hat{R}) = \frac{\sqrt{\widehat{\text{Var}}(\hat{R})}}{\hat{R}}$$

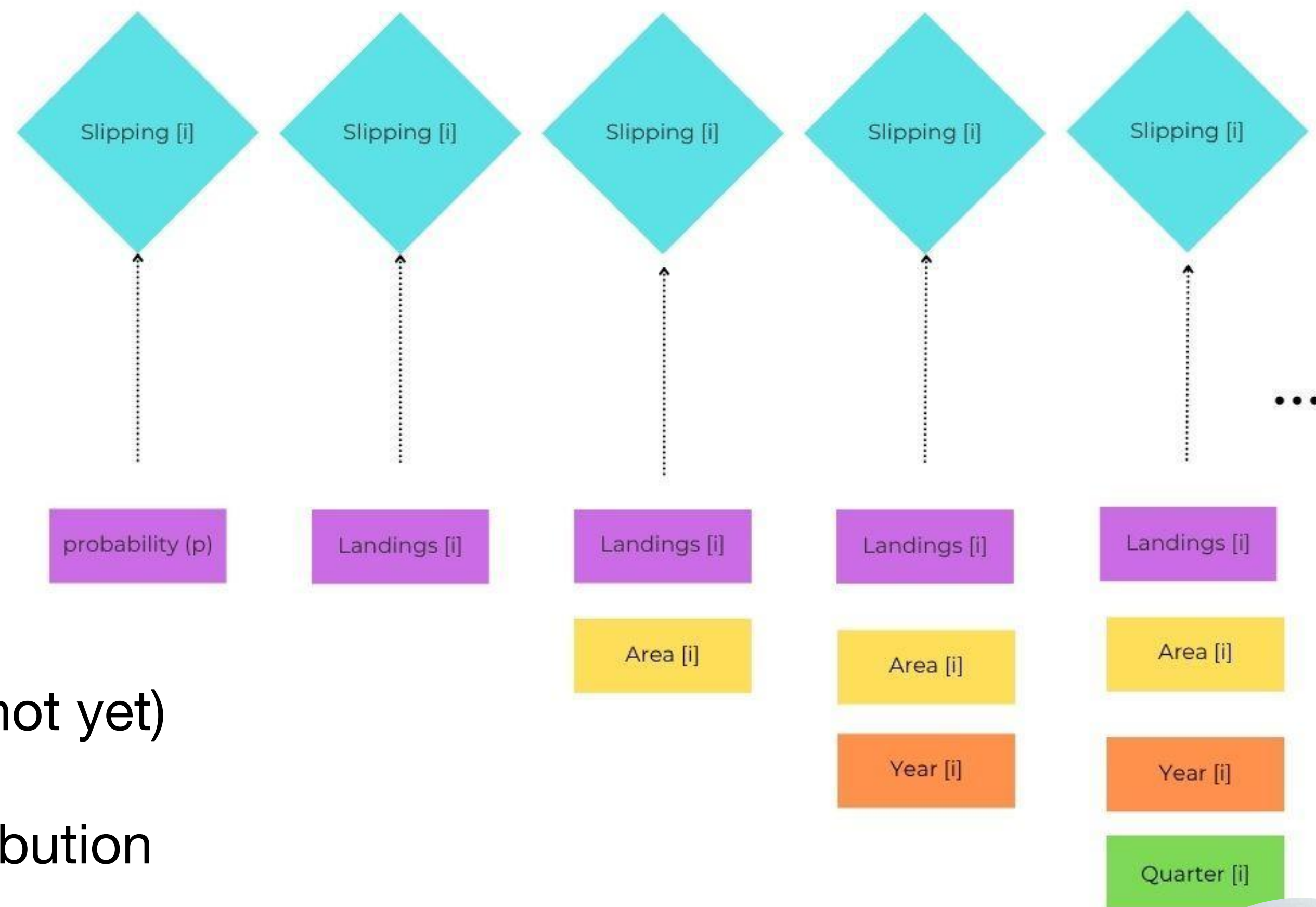
- Catches estimates: using daily landing data + slipping raised to fleet level, by species, area and year

$$\text{Catch Estimated} \approx \text{Landings} + \text{Landings} \times \hat{R}$$



# Bayesian hierarchical modelling (RTBM package)

- **Slipping does not occur frequently** in fishing set and/or trip
- 20% slipping occurrence = 80% zeros
- **zero inflated distribution**



Gamma distribution does not run in RTMB (not yet)

For this, we decided to use log-normal distribution

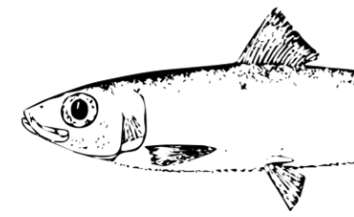
$jnl = jnl - \log(1-p) - \text{dnorm}(\log(Y[i]), \text{mean}, \text{sd}, \text{log} = \text{TRUE})$



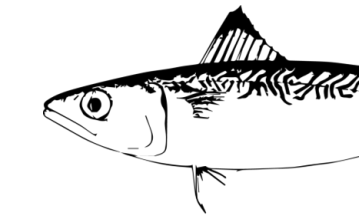
# Results

## Propositions of species observed onboard data

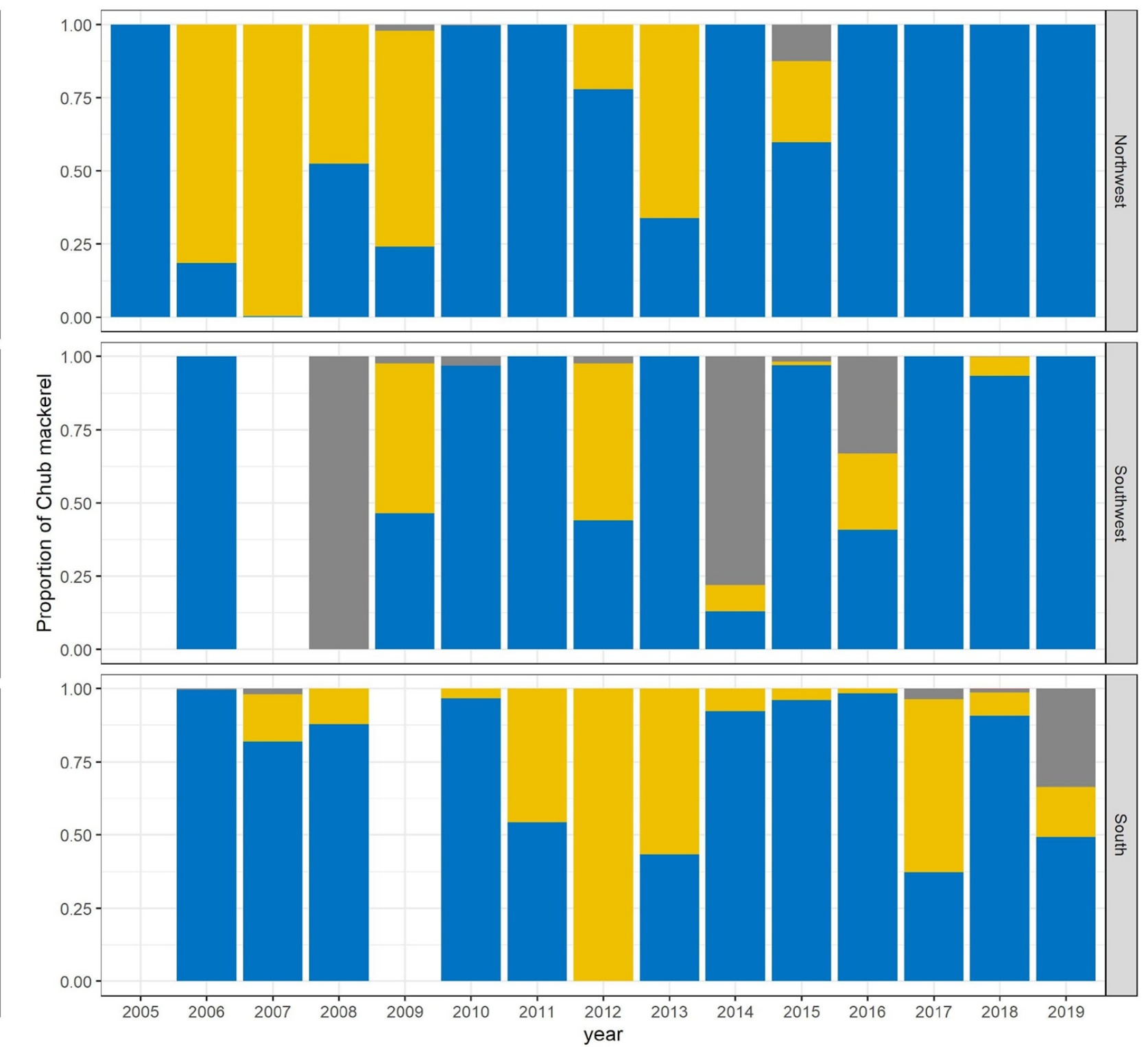
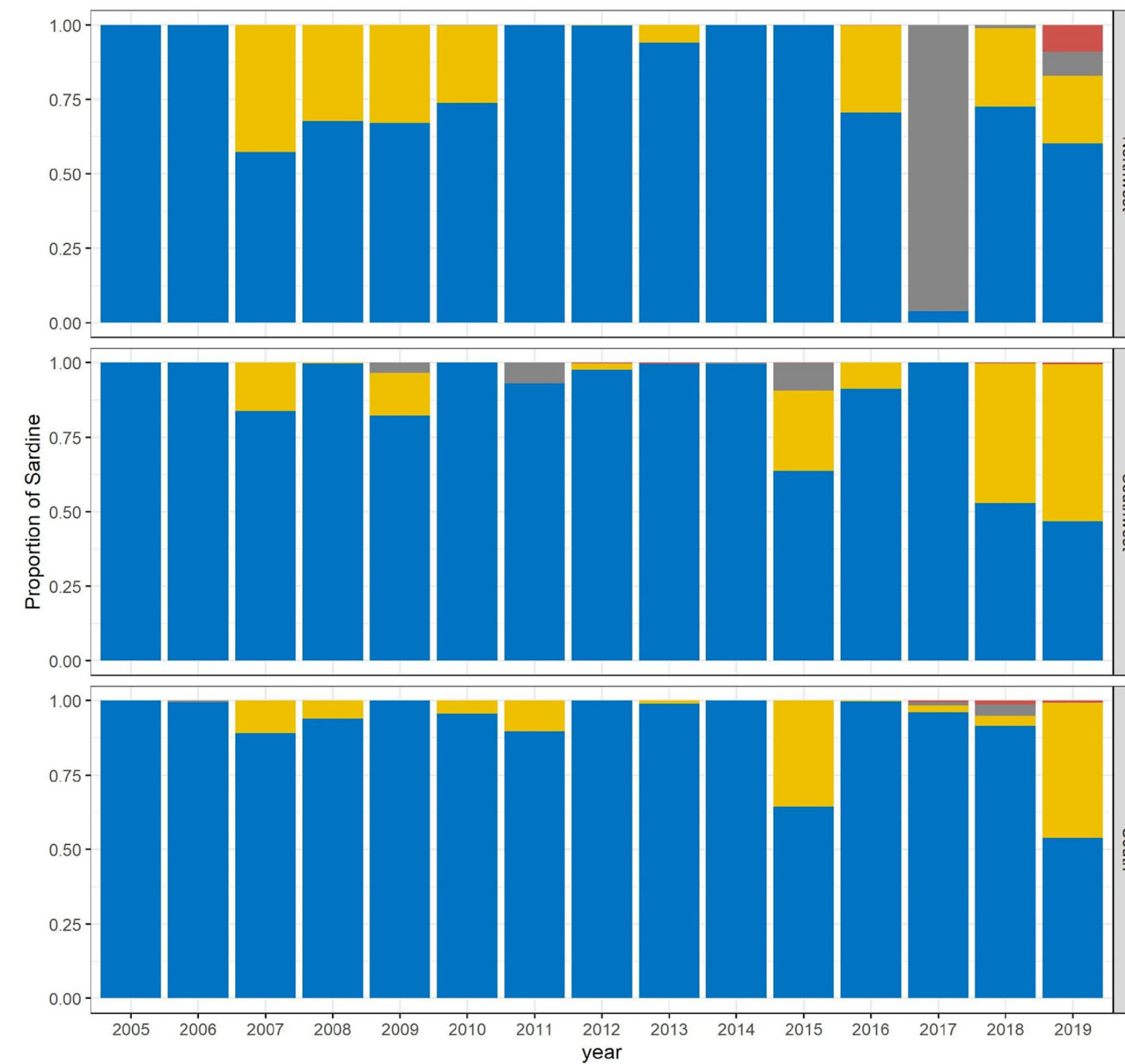
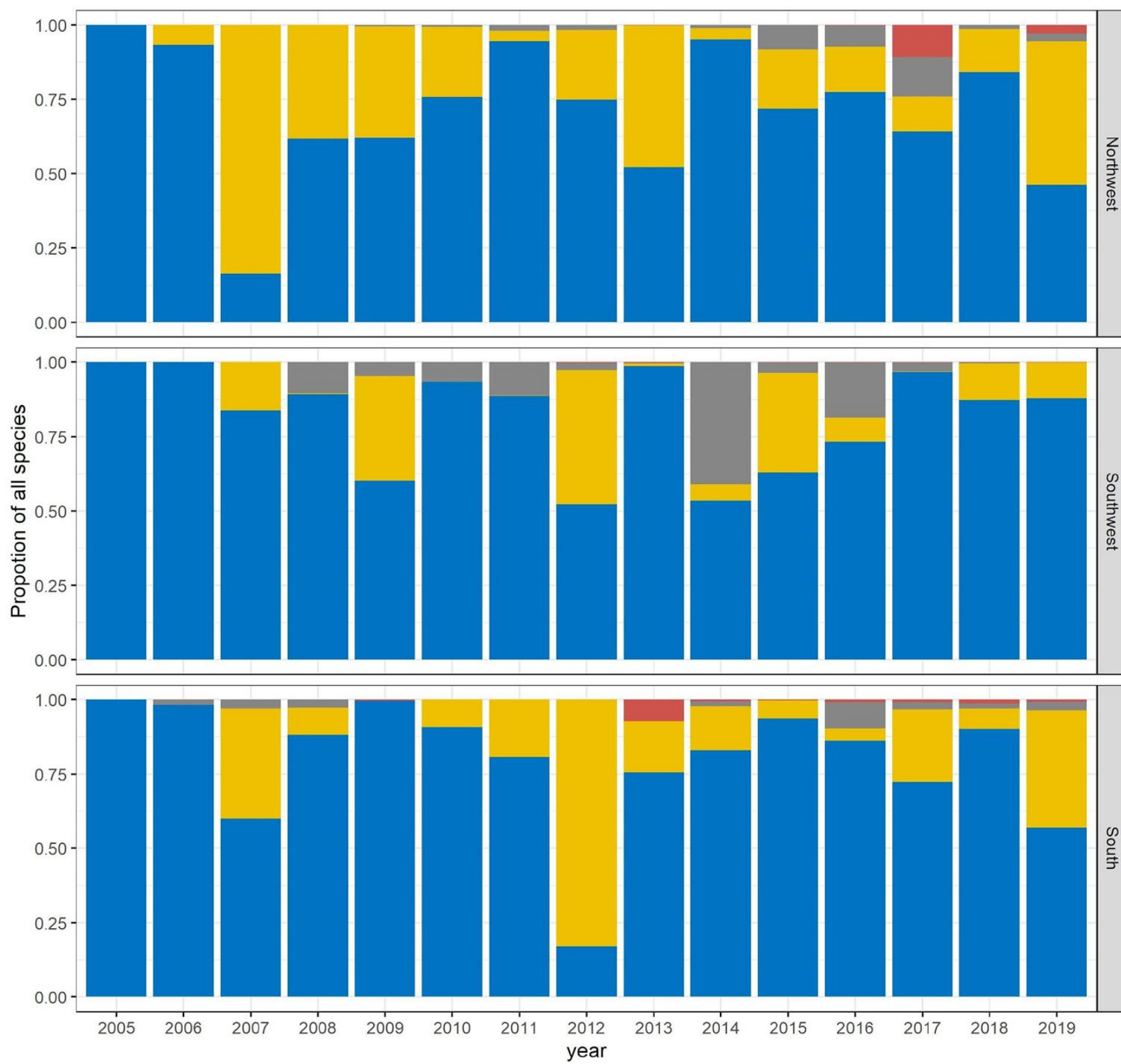
All species



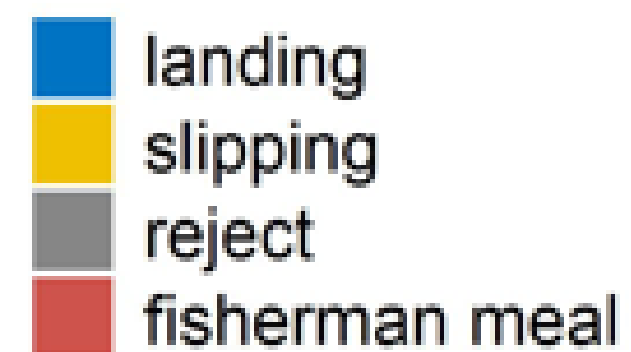
Sardine



Chub mackerel



fraction



Observed purse seine trips/catches showed **greater heterogeneity.**



# Results

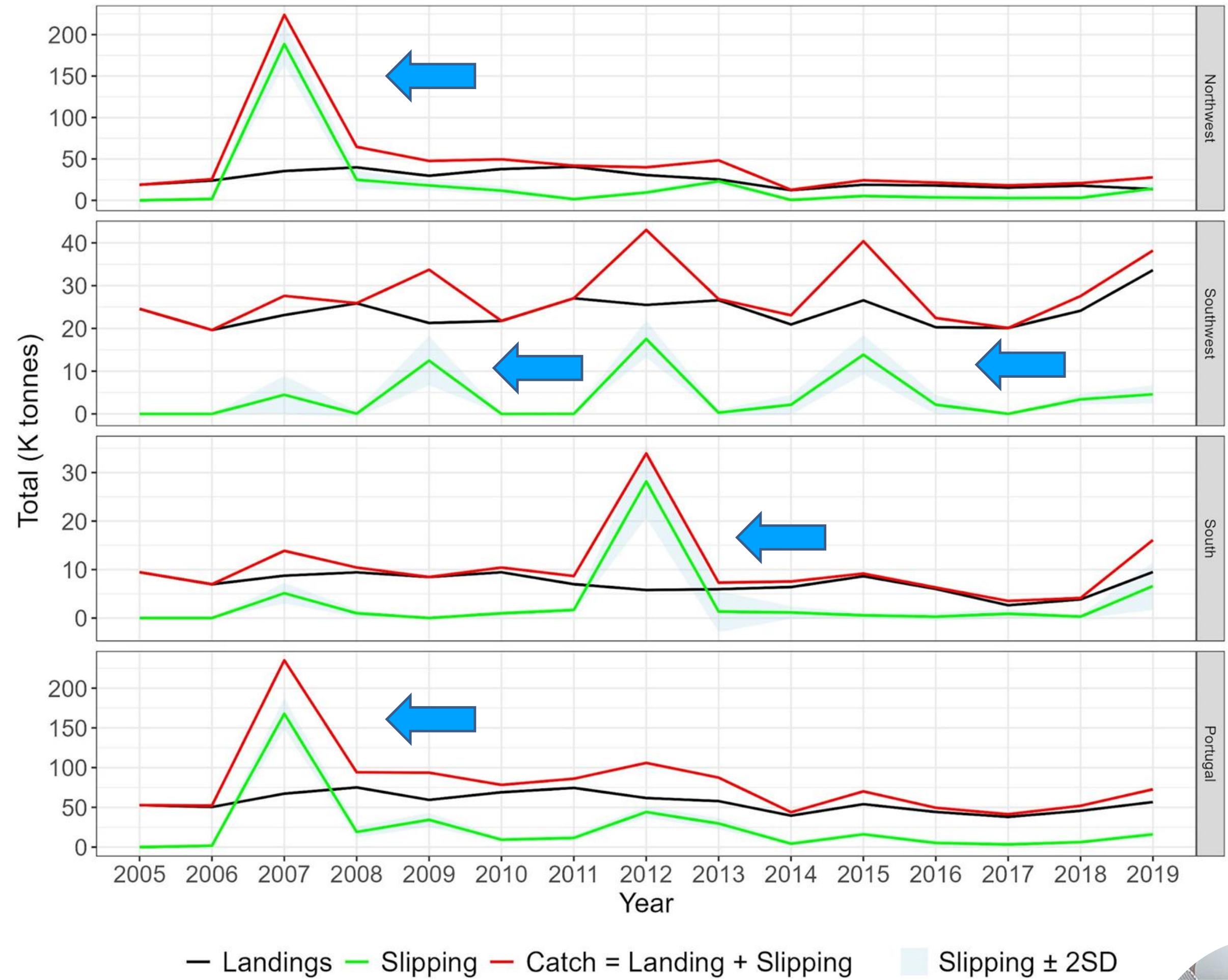
## using Cochran' slipping ratios

- Number of **fishing trips heterogeneous** across:

- **time** (year, quarter)
- **space** (ports, area)

Adverse weather conditions, fishing closures, and other constraints

- Trips without fishing set
- **20% slipping occurrence**
- When slipping occurs, observed **large CVs**
- **Not all caught species were slipped**



# Results

## using Bayesian hierarchical modelling (RTMB)

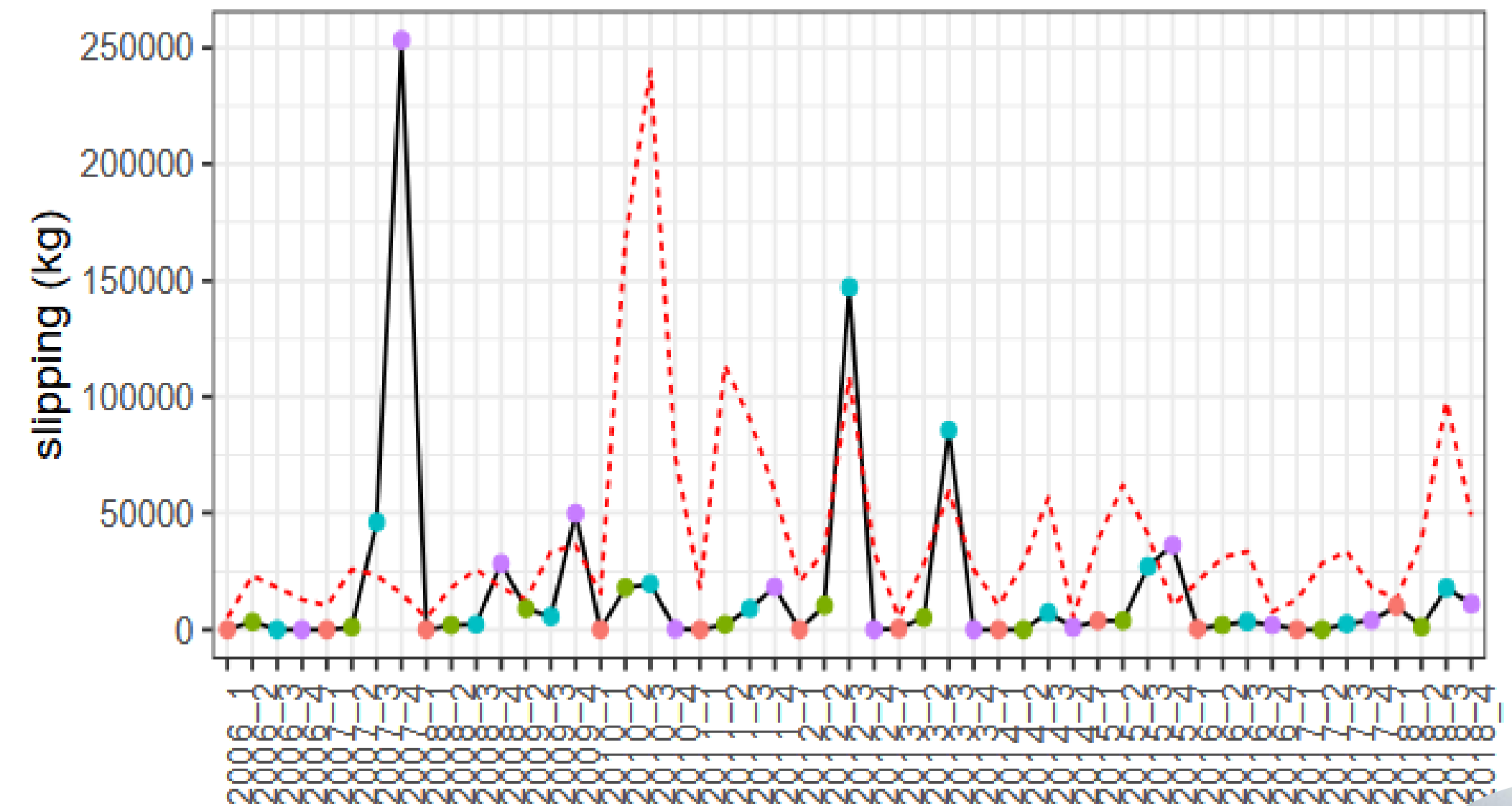
Hypothesis 1: Slipping occurs with probability  $p$

$$S_i = \begin{cases} 0, & \text{w. p. } p \\ N(\log(\mu_S), \sigma_S) & \text{w. p. } (1 - p) \end{cases}$$

	Estimate	Std. Error
logitp	1.34	0.09
mean	6.31	0.20
logsd	0.92	0.06

**Joint negative log-likelihood:**

```
for(i in 1:length(Y)){
  if(Y[i]==0){
    jnll <- jnll - log(p)
  }
  if(Y[i]>0){
    jnll <- jnll - log(1-p) -
    #log-normal distribution
    dnorm(log(Y[i]), mean , sd, log = TRUE)
  }
}
```



# Results

## using Bayesian hierarchical modelling (RTMB)

Hypothesis 2:

Linear model with (L)andings, (Y)ear, (Q)uarter, (A)rea and ratio of PIL and VMA in the slipping fraction

Random effects and interactions with Landings are estimated for Year

$$\theta_1 L_i + \theta_2 Q_i + \theta_3 A_i + \theta_4 PIL_i + \theta_5 VMA_i + \theta_{i \times i} Y_i : L_i + u_i Y_i$$

Joint negative log-likelihood:

```
mu = as.vector(D %*% theta + Z %*% u_year)

# Initialize negative log-likelihood
jnll_val = 0

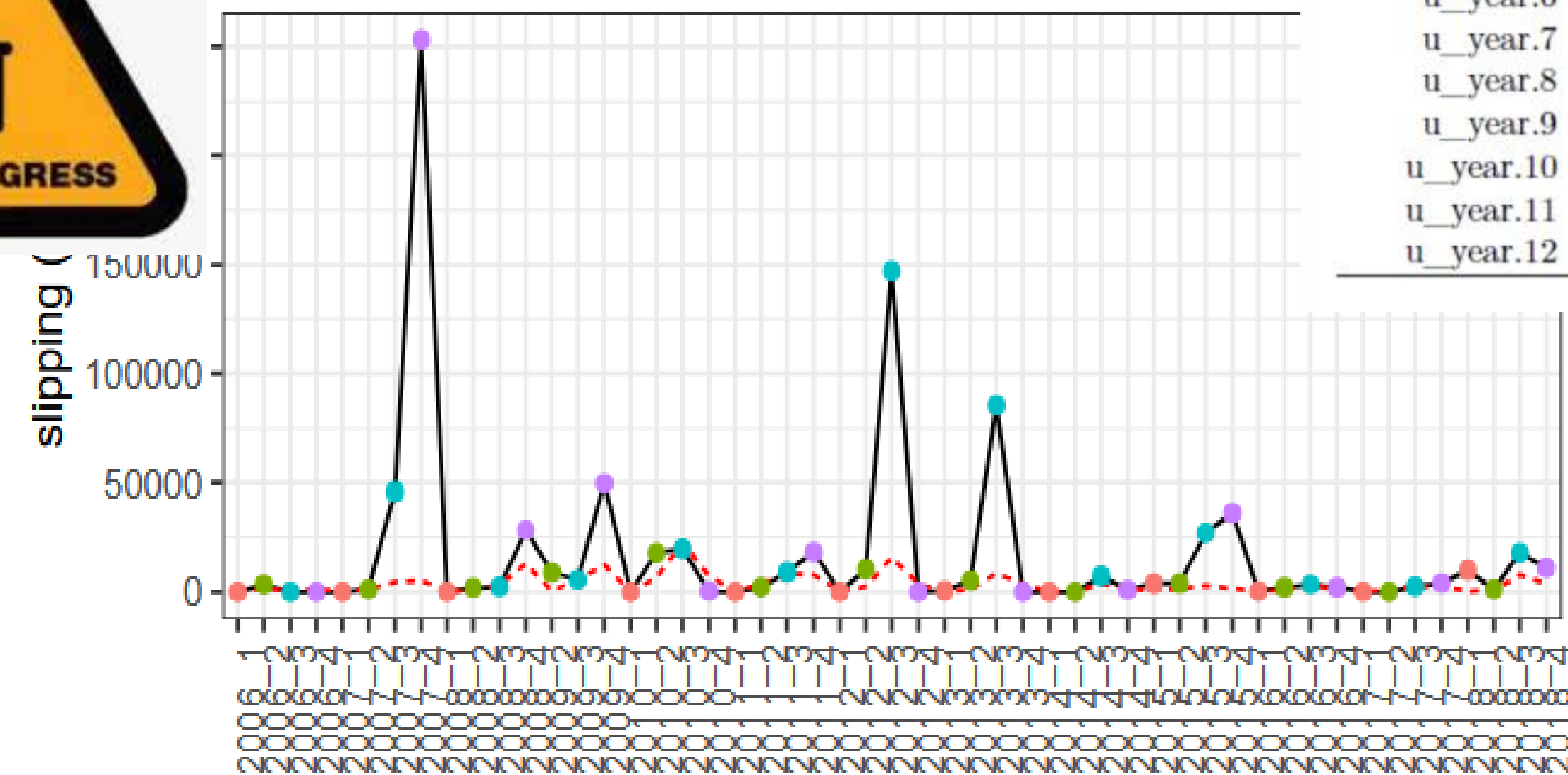
# Loop over observations
for (i in seq_along(Y)) {
  # For zeros, use the zero-inflation probability p
  if (Y[i] == 0) {
    jnll_val <- jnll_val - log(p)
  } else {
    # For positive observations, weight by (1-p) and use the
    # log-normal likelihood
    jnll_val <- jnll_val - log(1 - p) -
      dnorm(log(Y[i]), mean = mu[i], sd = sd_obs, log = TRUE)
  }
}
```



Table 4: Model Comparison Table

Model	AIC	WAIC
$S_i + \epsilon_i$	1559.663	-1518.691
$\theta \cdot X + u \cdot Y + \epsilon_i(2)$	1536.546	1195.631

	Estimate	Std. Error
logitp	1.34	0.09
logsd	0.78	0.06
log_sigma_u	-1.21	1.06
theta	4.56	0.94
theta.1	0.62	0.76
theta.2	0.76	0.78
theta.3	1.83	0.75
theta.4	2.10	0.76
theta.5	-0.44	0.24
theta.6	1.01	0.38
theta.7	1.28	0.36
theta.8	-0.01	0.08
u_year	0.03	0.30
u_year.1	0.13	0.36
u_year.2	-0.12	0.35
u_year.3	0.07	0.30
u_year.4	0.01	0.26
u_year.5	0.02	0.28
u_year.6	0.28	0.52
u_year.7	0.13	0.36
u_year.8	-0.03	0.29
u_year.9	-0.23	0.46
u_year.10	-0.10	0.33
u_year.11	-0.10	0.34
u_year.12	-0.08	0.30



## How is this knowledge useful?

The purse-seine fishery **depended** almost exclusively on the **sardine quota until 2012**.

Although the **fishery is selective**, market demand for sardine remains high during certain times of the year (e.g., during “Popular Saints Festivals” in the summer).

Since the implementation of the sardine management plan, the purse-seine fleet has **redirected fishing effort** toward **other** fishing grounds and **species**.

Reduction of sardine quota, daily limits and long periods of sardine capture ban

+

Redirection of fishing effort towards other pelagic species mixed with sardine

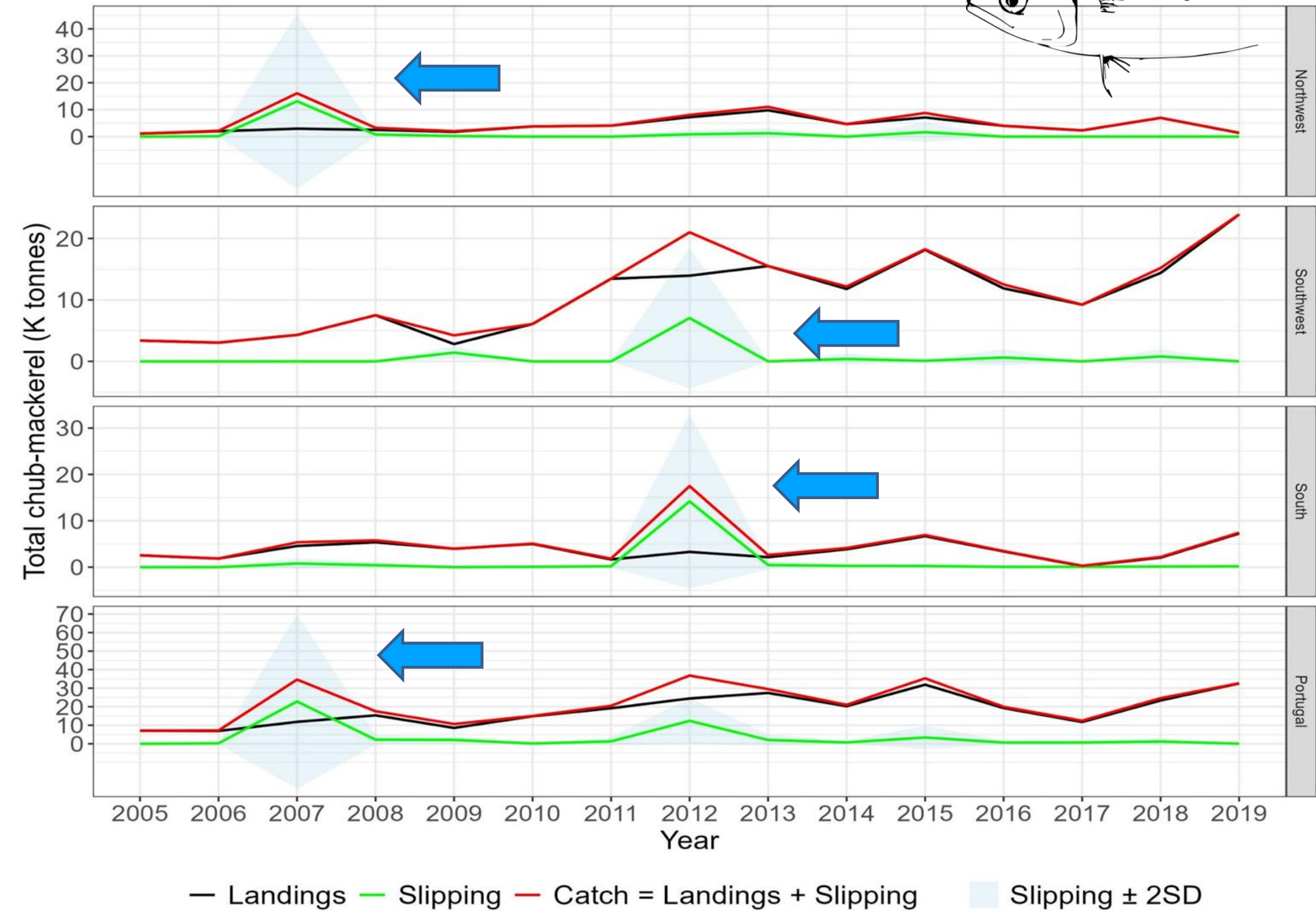
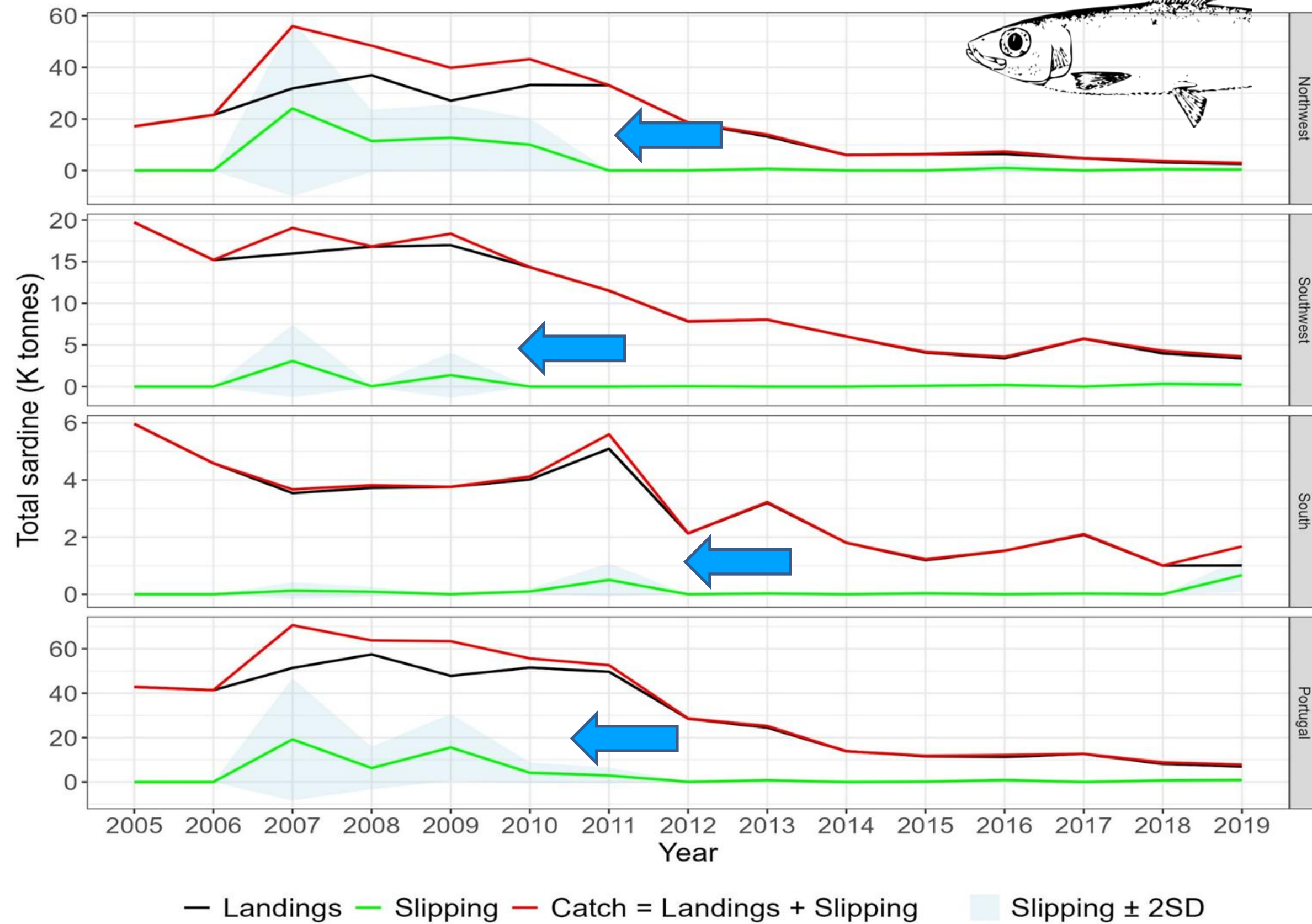
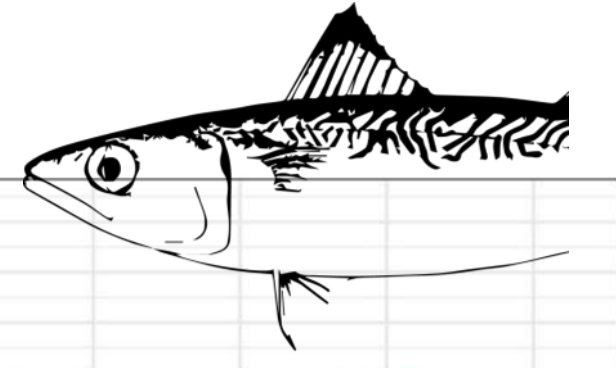
**Was expected**

- Increase of frequency and volume of slipped sardine
- Potential decrease in survival of slipped species after manoeuvre



# Results

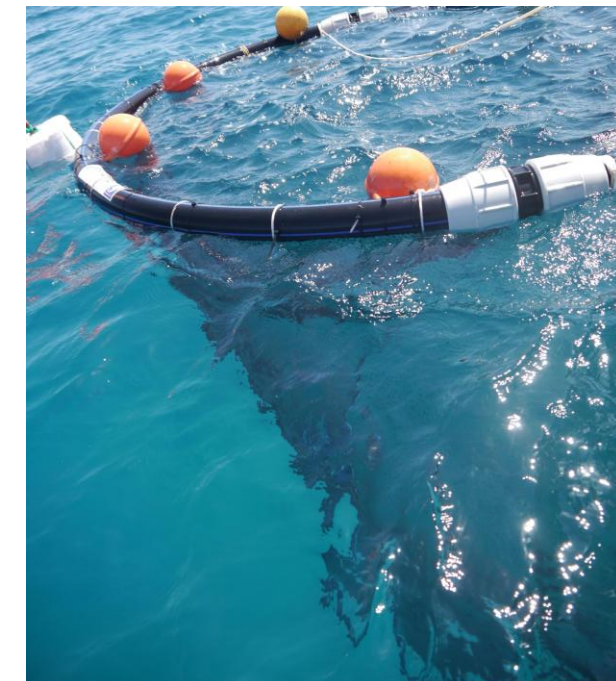
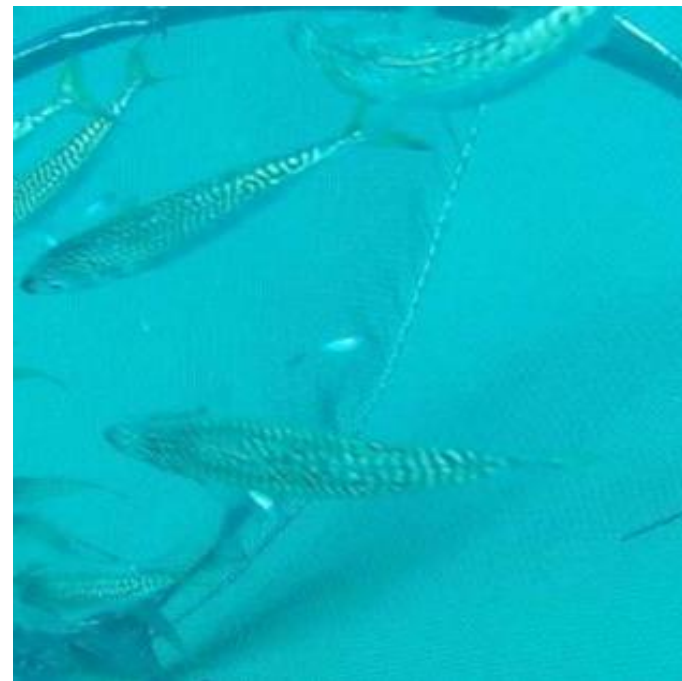
## using Cochran' slipping ratios



- Before 2012, **sardine slipping** occurred **less frequently** but involved substantially **larger volumes** compared to recent years.
- **Chub-mackerel slipping** was concentrated in 2007 and 2012, with **large quantities released**. In recent years, slipping events have **decreased due to increased market demand**.



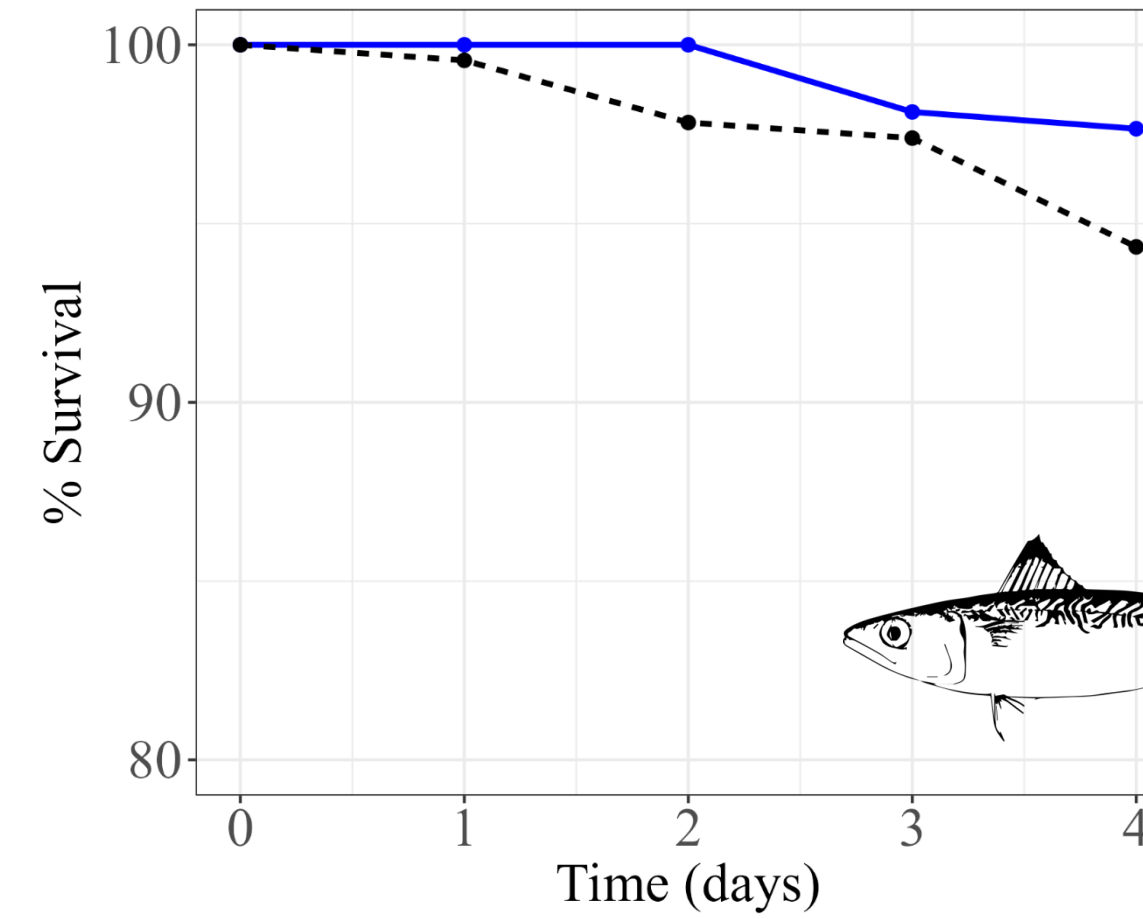
# Survival rates from open-sea survival experiments



Three experiments were carried out:

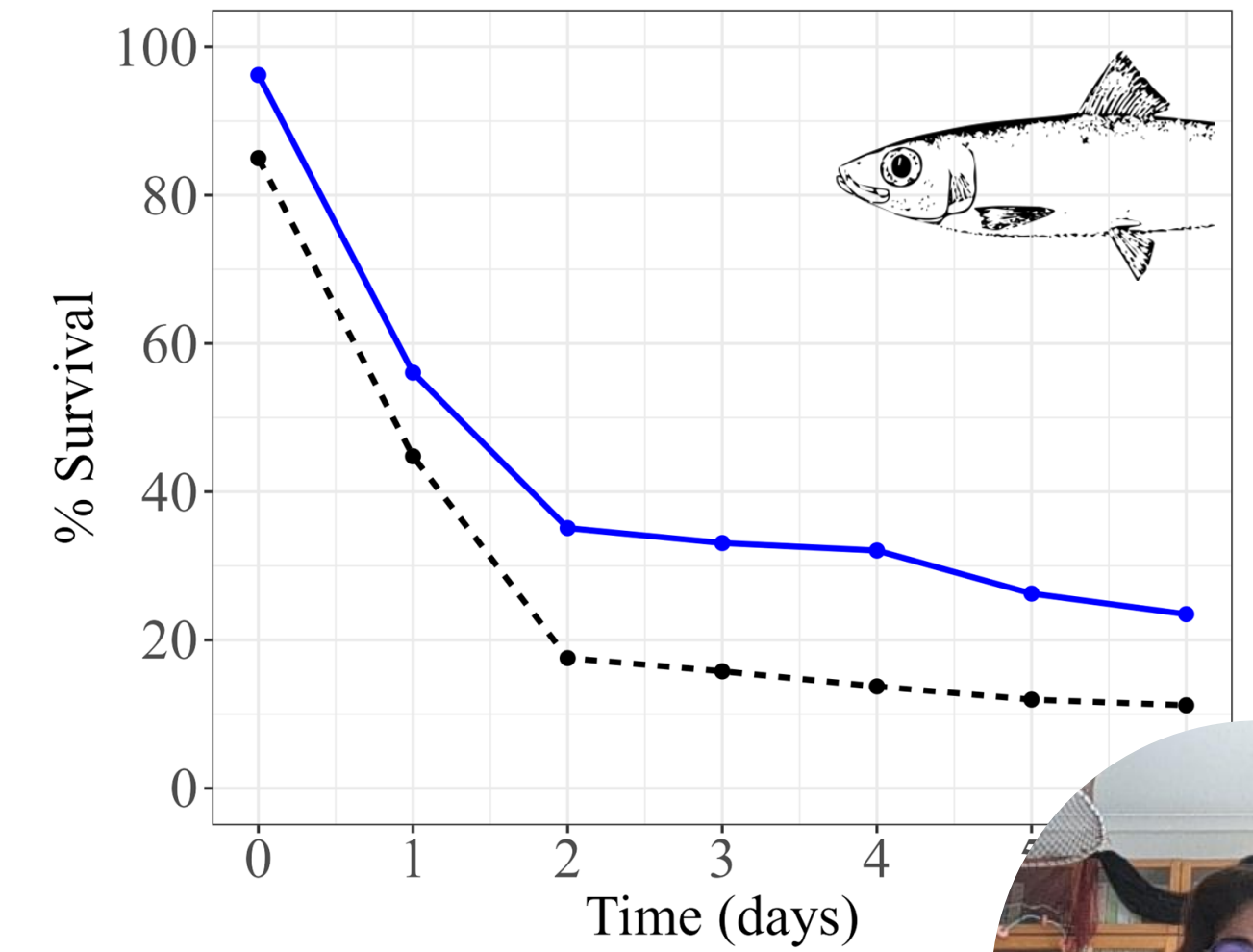
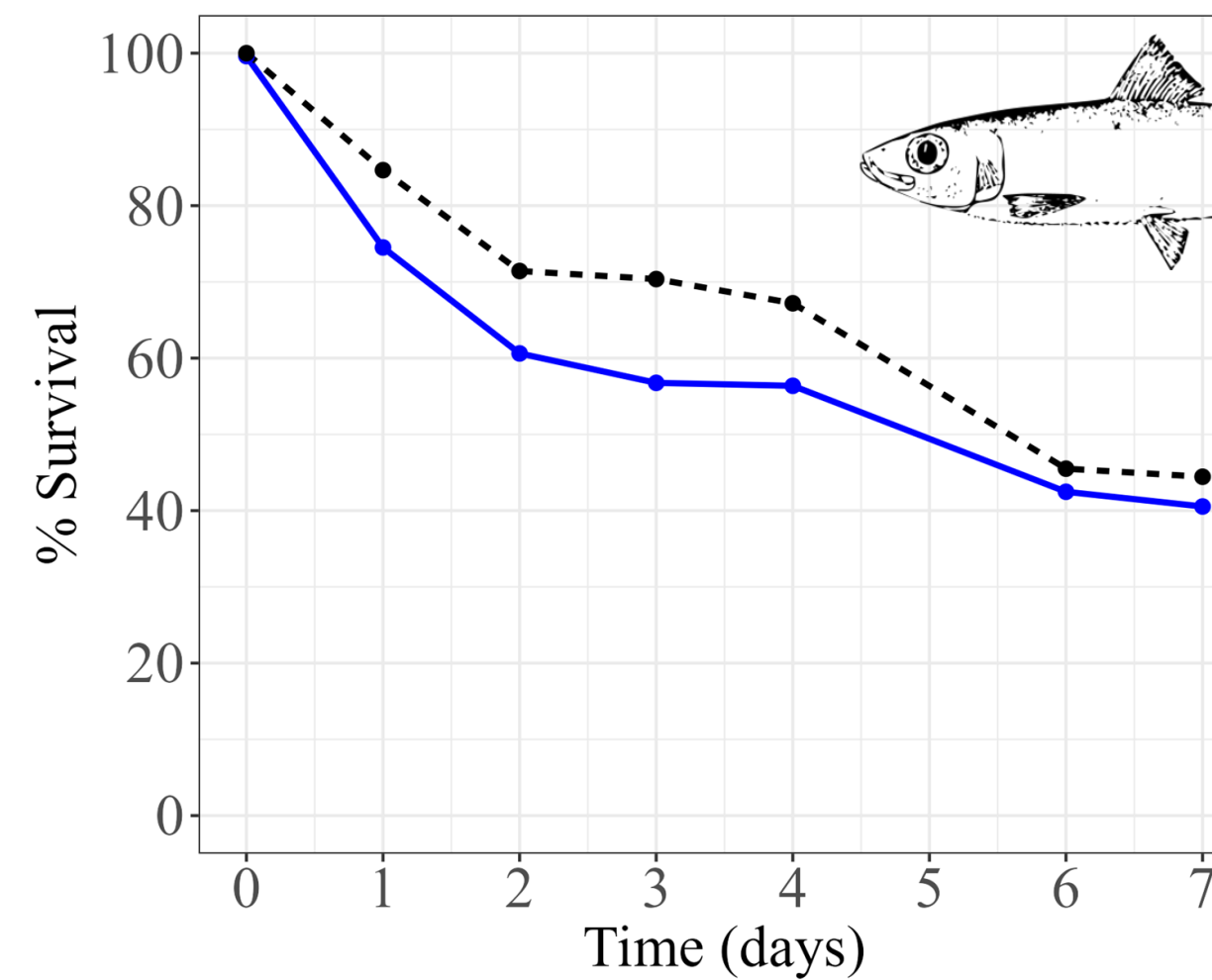
- **Chub mackerel – Sesimbra – July 2020**
- **Sardine – Olhão – April 2021**
- **Sardine – Olhão – September 2021**

## • Survival rate for chub mackerel



In Dias et al., 2022

## • Survival rate for sardine



Feijó et al., 2026 (in press)



# Survival rates from experiments in Portugal (literature-based)

## Mortality Rates:

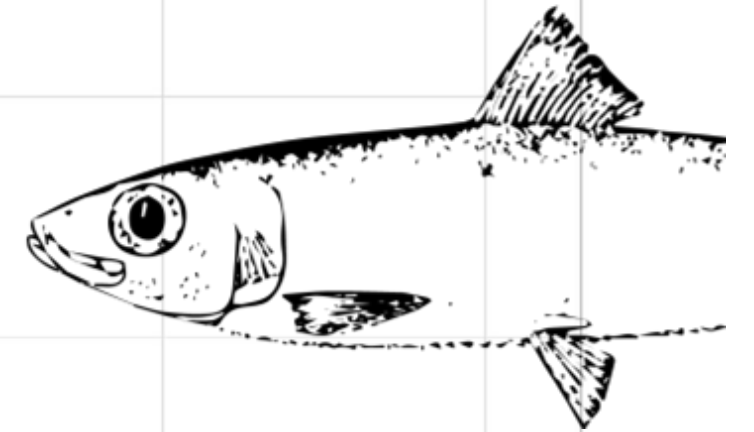
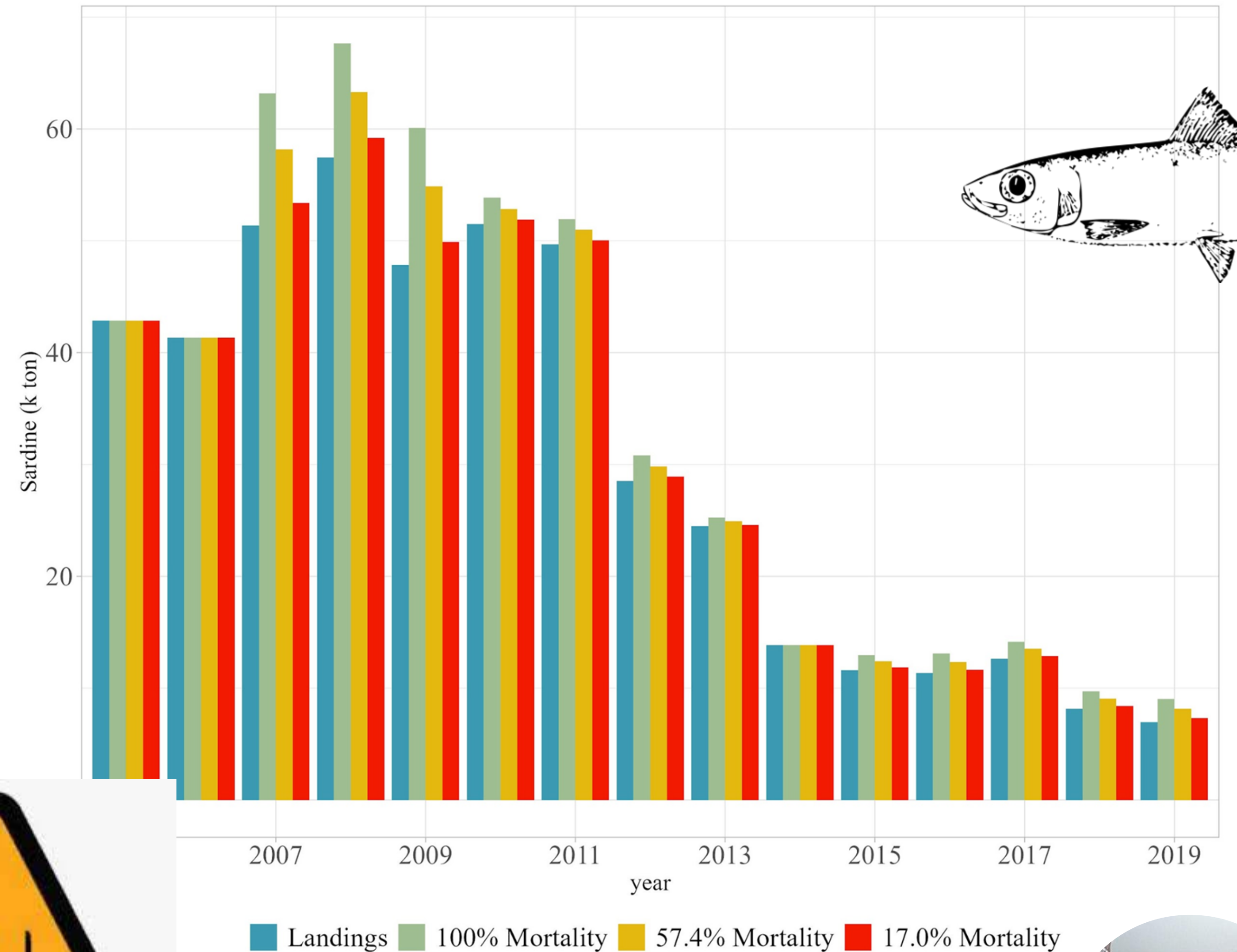
- **Sardine = highly variable**
  - Several operational and environmental conditions
  - ranging from **5.1% to 88.8%**
  - Minimum = 17 %
  - Average = 57.4 %
- **Chub mackerel = much lower**
  - ranging from **2.3% to 6%**
- **Information for chub mackerel is limited**, being based on a **single study**.

Species	Reference	Environment	Time of Year	Length Range (cm)	Treatment Condition	Mortality (Mean %)	
						Control	Treatment
Chub mackerel ( <i>S. colias</i> )	Dias et al. (2022)	Sea	July	20.0 – 28.5	Slipping (1h crowding)	2.3	6.0
	<b>Mean mortality rate across experiments</b>						<b>2.3</b>
Sardine ( <i>S. pilchardus</i> )	Marçalo et al. (2008)	Captivity	Various	14.5 – 22.4	High Density Transport (21.8 kg/m <sup>3</sup> )	4.6	50.0
			July	16.0 – 18.7	Thermal Shock (+5°C)	< 20.0	~35.0
	Marçalo et al. (2010)	Captivity	Feb – June	14.5 – 20.2	Short Confinement (10–20 min)	0.0	< 30.0
			July	14.5 – 20.2	Long Confinement (40–60 min)	< 20.0	~70.0
	Marçalo et al. (2013)	Captivity	Feb – April	19.0 – 19.9	Mild Stress (20 min simulation)	1.1	5.1 (3.0-7.3)
				19.0 – 19.9	Severe Stress (40 min simulation)		56.1 (42.6-69.6)
	Marçalo et al. (2018)	Captivity	April	12.2 – 15.1	Standard Slipping (Roll-over)	56.4	88.3
				12.2 – 15.1	Modified Slipping (Weights)		55.3
	Feijó et al. (2026)	Sea	April	14 – 21	Early net tightening	-	67.3
					Late net tightening	-	66
Feijó et al. (2026)	Sea	September	15 – 20	Early net tightening	-	76.52	
				Late net tightening	-	88.8	
<b>Mean mortality rate across experiments</b>						<b>17.0</b>	<b>57.4</b>



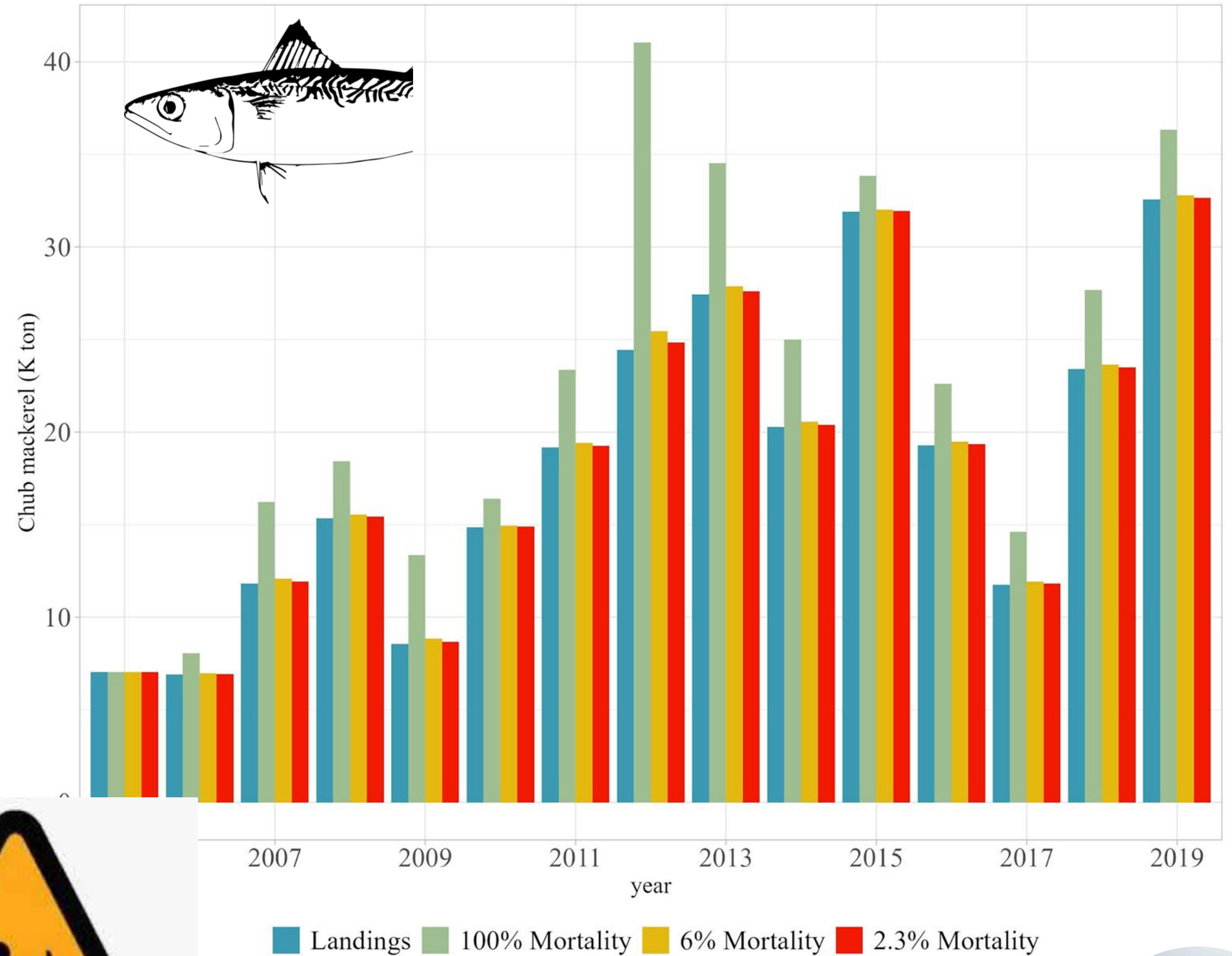
# How mortality rates could be applied to slipping estimates?

- **Slipping** ranged from **0.06 to 75%**
- Zero slipping was also observed
- Coefficient of variation (**CV**) ranged from **0.43 to 1.48**
- Sardine survival = highly variable
- Applied mortality rates: 17, 57.4, 100%



# How mortality rates could be applied to slipping estimates?

- **Slipping** ranged from **0.004 to 444%**
- Zero slipping was also observed, less times than sardine
- Coefficient of variation (**CV**) ranged from **0.35 to 1.22**
- Chub mackerel survival - single study, further research is needed
- Applied mortality rates: 2, 6 and 100%



## How this knowledge could be applied to the stock assessment?

- **Slipping** is a **significant but overlooked** component of total removals, with high variability and **zero-inflation**.
- **Species-specific survival matters:**
  - **sardine = high sensitivity**
  - **chub-mackerel = high resilience** (further research needed)
  - **More studies** should be done in **other species**
  - Species-specific survival must be explicitly included in models
- **Stock assessments may be biased** if slipping is not accounted for. Including slipping requires avoiding the assumption of 100% mortality of released individuals.



# Management Implications

Incorporating survival into stock assessments can:

- **Improve estimates of fishing mortality**
- **Reduce bias in catch data**
- Support **more accurate TAC/quota** decisions

Potential management strategies:

- Shift from **daily to weekly landing quotas**
- Improve **shoal identification and selectivity**
- Promote **better use of catches and reduce unnecessary slipping**



# Conclusions

In Portugal, the **purse-seine is a very important fishery**:

- target species is sardine (much appreciated by Portuguese people)
- great socio-economic value dependent on this fishery (canning industry)

The purse-seine fishery shows considerable **regional and annual variability**, depending on the movements and recruitment of pelagic shoals. Further studies are required to achieve more robust results.

The **reduction of annual quotas** and the establishment of **daily catch limits** could lead to an **increase in slipping**, creating discrepancies between catches and landings. Promoting a **shift to weekly quotas** could improve the **sustainability of the fishery**, by reducing fishing mortality.

**Ignoring slipping and survival leads to biased stock assessments.**

Our results are relevant to stakeholders, as they provide insight into **temporal changes** in the fishery at both **national and regional scales**.



# ACKNOWLEDGMENTS

- *Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos* (DGRM) for providing the data on purse seine daily landings
- National Producer Organizations (PO) of purse seine fishery
- Skippers and crews of many purse seiners
- All projects' technicians, biologists and observers through time collecting data onboard (2005-2019)
- Julia Yazvenko for all support (from SPF2026 Organization)

**Thank you! Muchas gracias!**  
**Any questions, please email me!**  
**[dfeijo@ipma.pt](mailto:dfeijo@ipma.pt)**



- Project for Financial support:



Os Fundos Europeus mais próximos de si.

- Collaboration Projects:



sardinha  
2020

