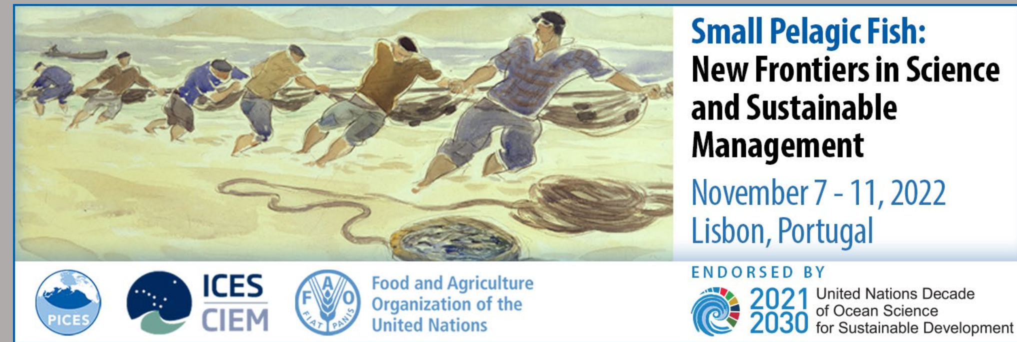
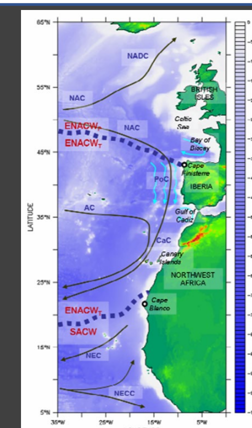
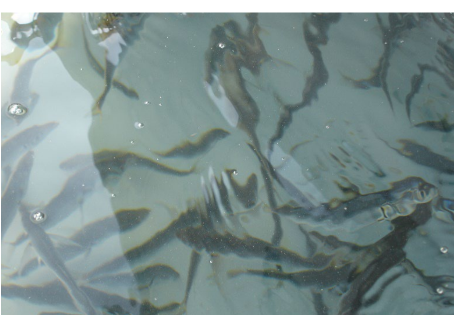


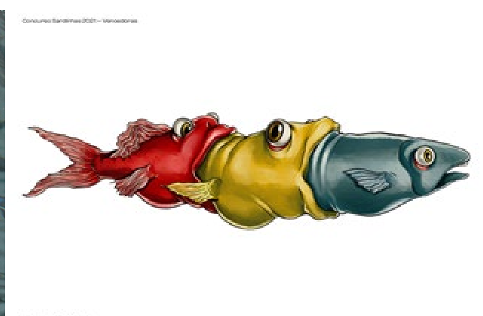
Spatio-temporal patterns of feeding intensity and relationship with productivity cycles in Portuguese waters

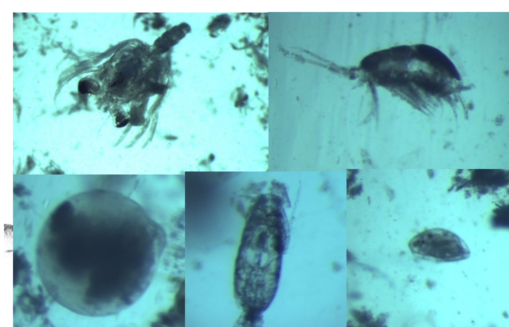
Susana Garrido & **Hugo Mendes**

IPMA









BACKGROUND

- Extensive data of fish feeding intensity allow to investigate environmental shifts and long-term ecosystem fluctuations

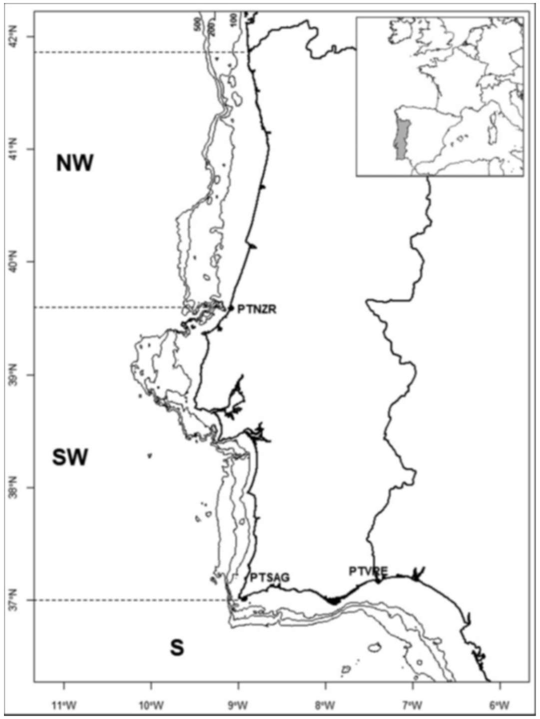
- However, weighting stomach contents is a time-consuming task that is generally carried out on small samples/studies collected over a short period of time.

- Fast, empirical indices to classify stomach fullness permits the collection of large temporal dataseries that could allow description basic aspects of feeding biology:
  - differences in feeding intensity between sexes, length classes, and maturity stages
  - Seasonal and interannual variability in feeding intensity
  - Spatial variations in feeding intensity
  - Environmental-related variation in feeding behaviour
  - Variation in feeding intensity could have impact on patterns of abundance

OBJECTIVE

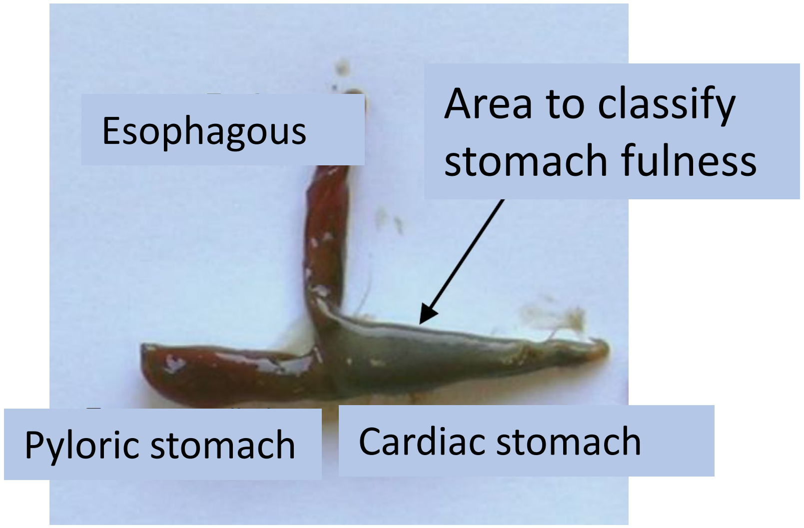
- **Study variations in the feeding intensity of several small pelagic and medium pelagic in Portuguese waters, using data collected from commercial vessels and research cruises**

DATA AVAILABILITY



- ➢ Stomach data collected by IPMA in Portuguese coast:
- Commercial data (auction market samples)
- Survey data (e.g. pelagic, demersal, crustacean)
- > 50 species with data on fullness index
  - non-regular sampling
    random studies
    irregular sampling protocols
- ➢ Lack of quantitative data (stomach contents and weights)
- ➢ Qualitative fullness data is available for demersal species e.g. hake, anglerfishes, squids, gurnards
- ➢ Pelagic species were selected based on data availability

STOMACH FULLNESS SCALE



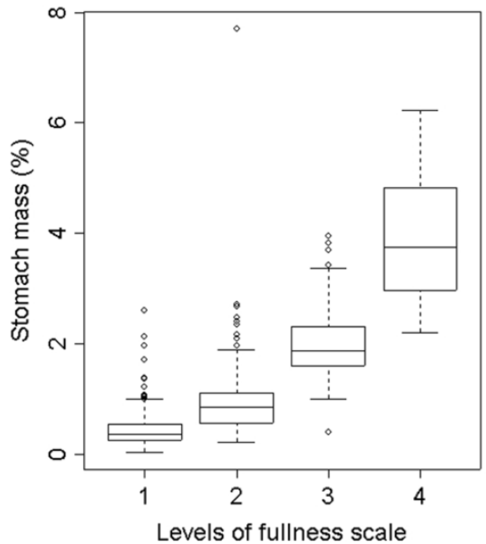
Fullness scale:
1= empty
2= almost empty (<50%)
3 = half full (>50%)
4= full (bursting)

CALIBRATION FULLNESS SCALE

J. Mar. Biol. Ass. U.K. (2005), **85**, 425–431
Printed in the United Kingdom

The use of stomach fullness and colour indices to assess *Sardina pilchardus* feeding

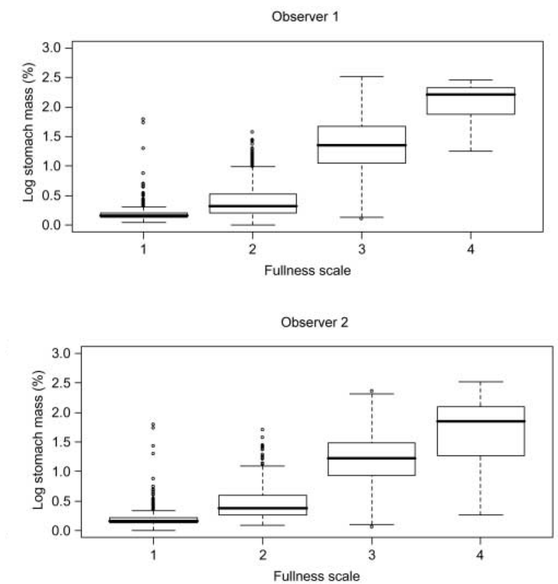
Maria Emília Cunha*, Susana Garrido and Joaquim Pissarra



ICES Journal of Marine Science Advance Access published October 24, 2008
Page 1 of 8

Horse mackerel (*Trachurus trachurus*) stomach fullness off Portugal: index calibration and spatio-temporal variations in feeding intensity

Susana Garrido, Alberto G. Murta, Ana Moreira, Maria João Ferreira, and Maria Manuel Angélico



- No published calibration for other pelagic species
- stomach weight (and contents) not available

➢ However, knowledge exchange between samplers

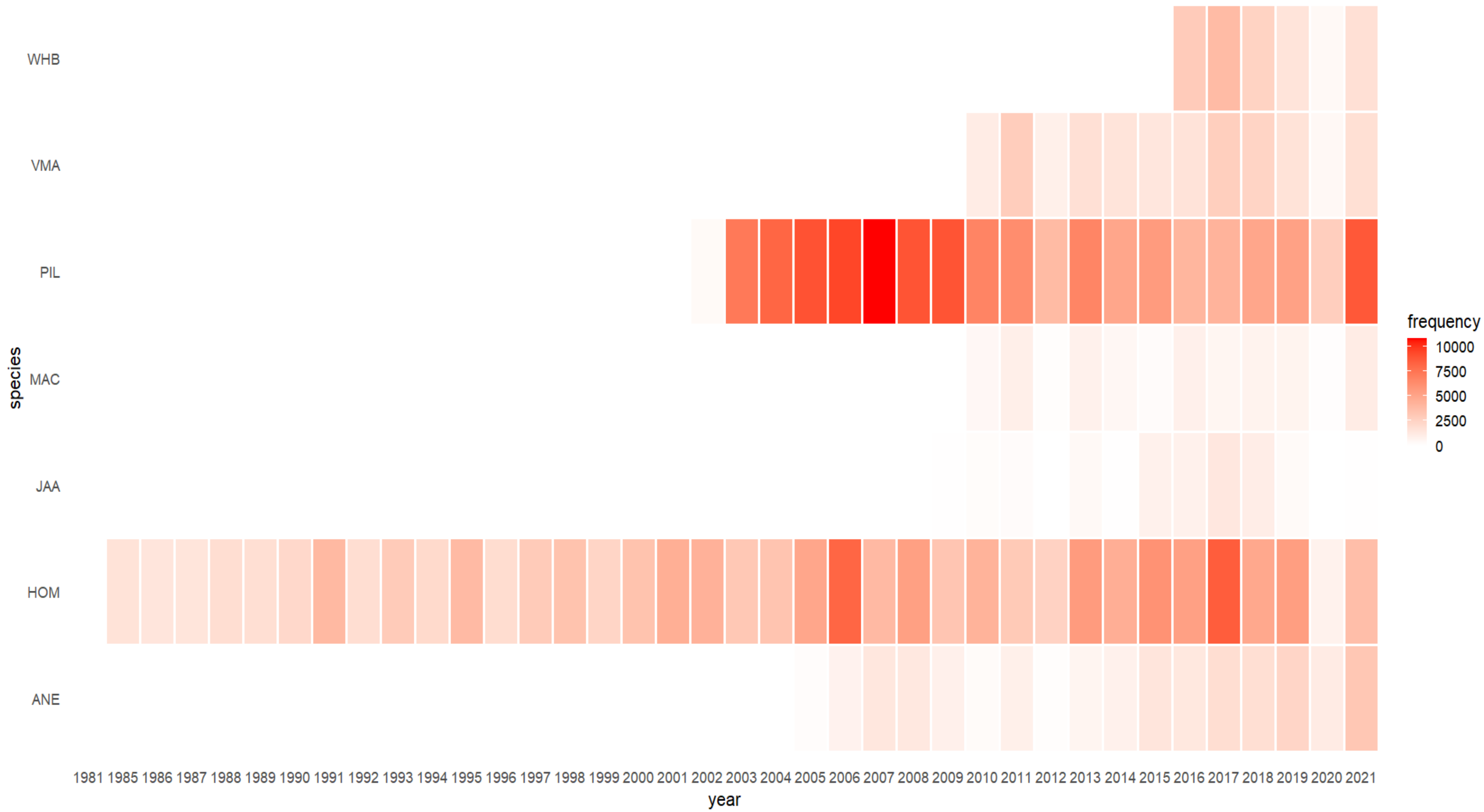
DATA DESCRIPTION – COMMERCIAL & SURVEYS

Species	Habitat	Size Guild*	Trophic Guild*	Fisheries Guild*	Nr. Market/ survey	Year range	Diet
Horse mackerel HOM	Semi-pelagic	small pelagic	pelagic piscivore	Pelagic	68560 65577	1987-2021 1981-2021	Planktivore /piscivore
European sardine PIL	pelagic	Small pelagic	Pelagic planktivore	Pelagic	72872 53743	2003-2021 2002-2021	planktivore
Atlantic chub mackerel VMA	Semi-pelagic	Small pelagic	Pelagic planktivore	Pelagic	10847 9101	2010-2021 2010-2021	Planktivore /piscivore
Anchovy ANE	Pelagic	Small pelagic	Pelagic planktivore	Pelagic	4163 17169	2011-2021 2005-2022	planktivore
Atlantic Mackerel	Semi-pelagic	medium pelagic	pelagic piscivore	Pelagic	2702 4079	2010-2021 2011-2021	Planktivore /piscivore
Blue whiting	Bathypelagic /demersal	medium bathypelagic	pelagic planktivore	pelagic	5879 6965	2016-2021 2014-2021	Planktivore /piscivore
Blue jack mackerel	Semi-pelagic	small pelagic	pelagic piscivore	Pelagic	3549 1541	2015-2021 2009-2019	Planktivore /piscivore
Bogue	Semi-pelagic	small pelagic	pelagic piscivore	Pelagic	920	2013-2021	Planktivore /piscivore
Mediterranean horse mackerel		small pelagic		Pelagic	382	2009-2019	Planktivore /piscivore

*ICES St

DATA DESCRIPTION – COMMERCIAL & SURVEYS

Sampling ➢ Variability between species



DATA ANALYSIS - METHODS

- Biological parameters
  - Sex
  - Maturation
  - Length

→ Ordinal regression for each biological variable/species

- Commercial data
  - Seasonal
  - interannual
  - Spatial/Port
- Survey data
  - Interannual
  - diel cycle
  - Spatial/Depth
- Environmental variables
  - SST
  - Salinity

→

$$\mathrm{PI}_i = \log\left(\frac{p_i}{p_{i+1} + \ldots + p_n}\right) i = 1, \ldots, n-1,$$

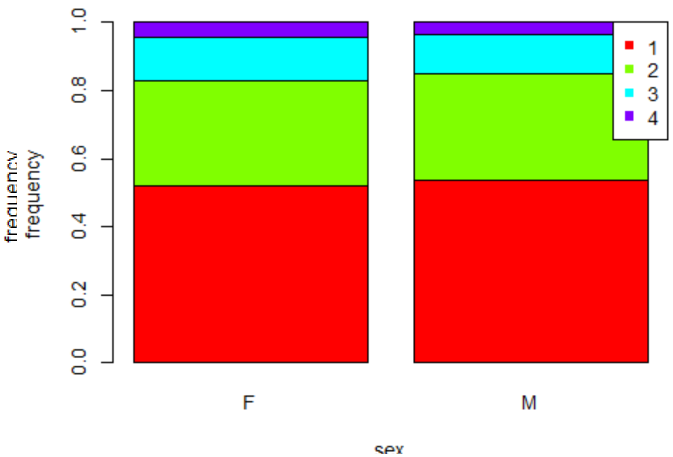
Rindorf and Lewy (2001)

GAM with binomial response/logit link

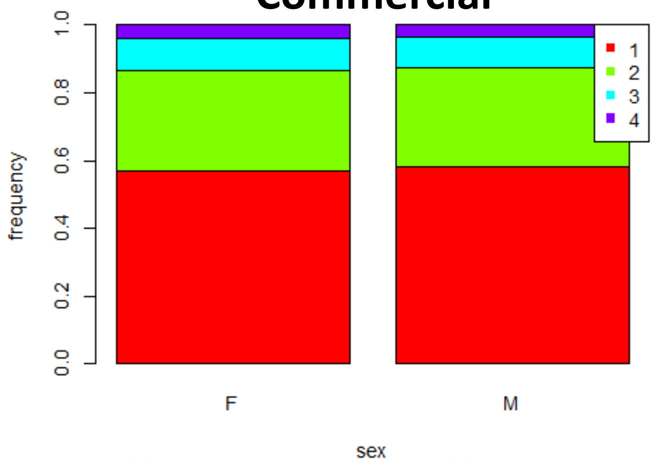
FULLNESS vs BIOLOGICAL - SEX

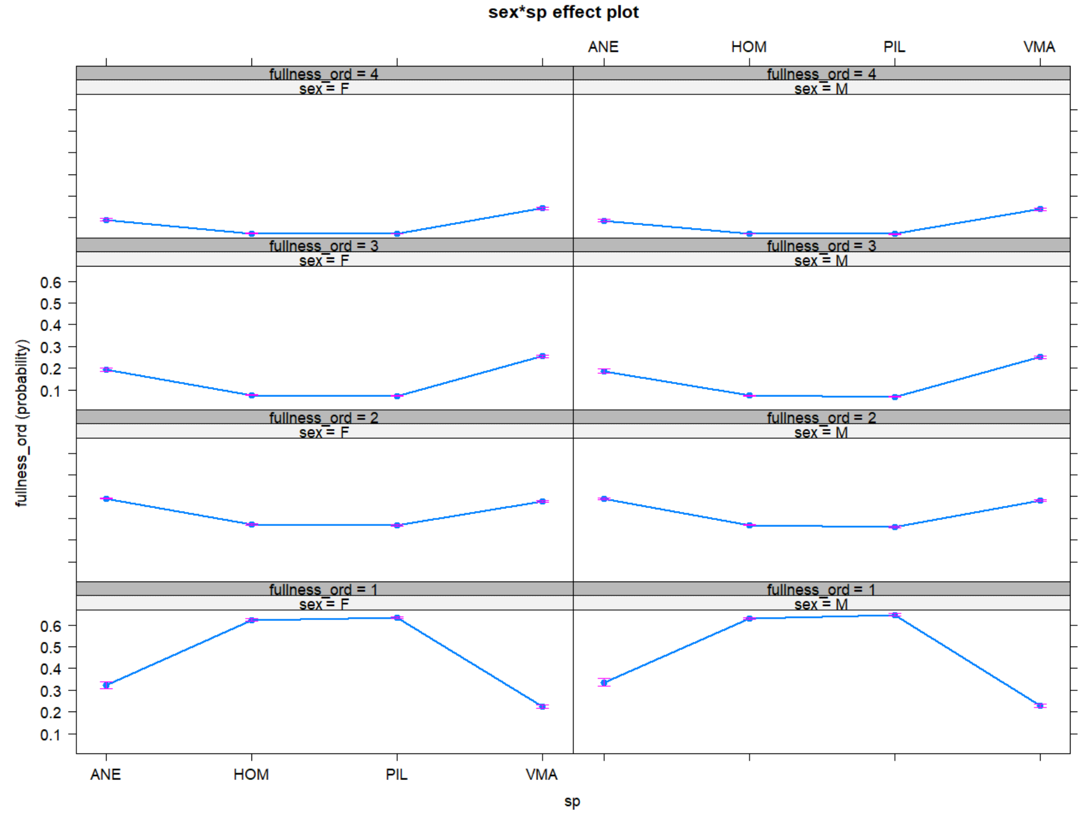
polr(fullness_ord ~ sex+sp+sex*sp)

Surveys



Commercial



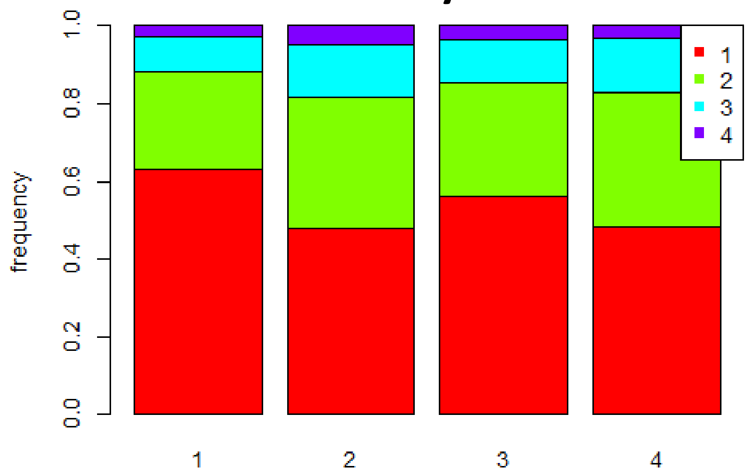


- No effect of sex on fullness levels
- Variability fullness within species
    - PIL-HOM
    - ANE-VMA

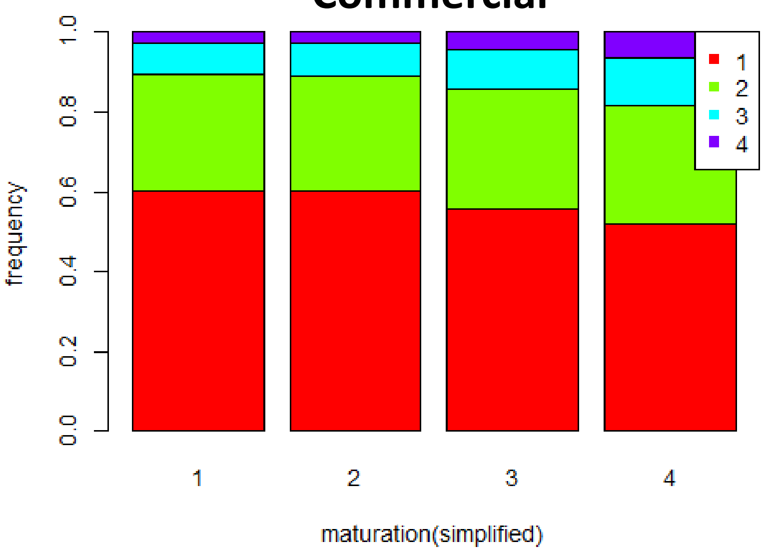
FULLNESS vs BIOLOGICAL - MATURATION

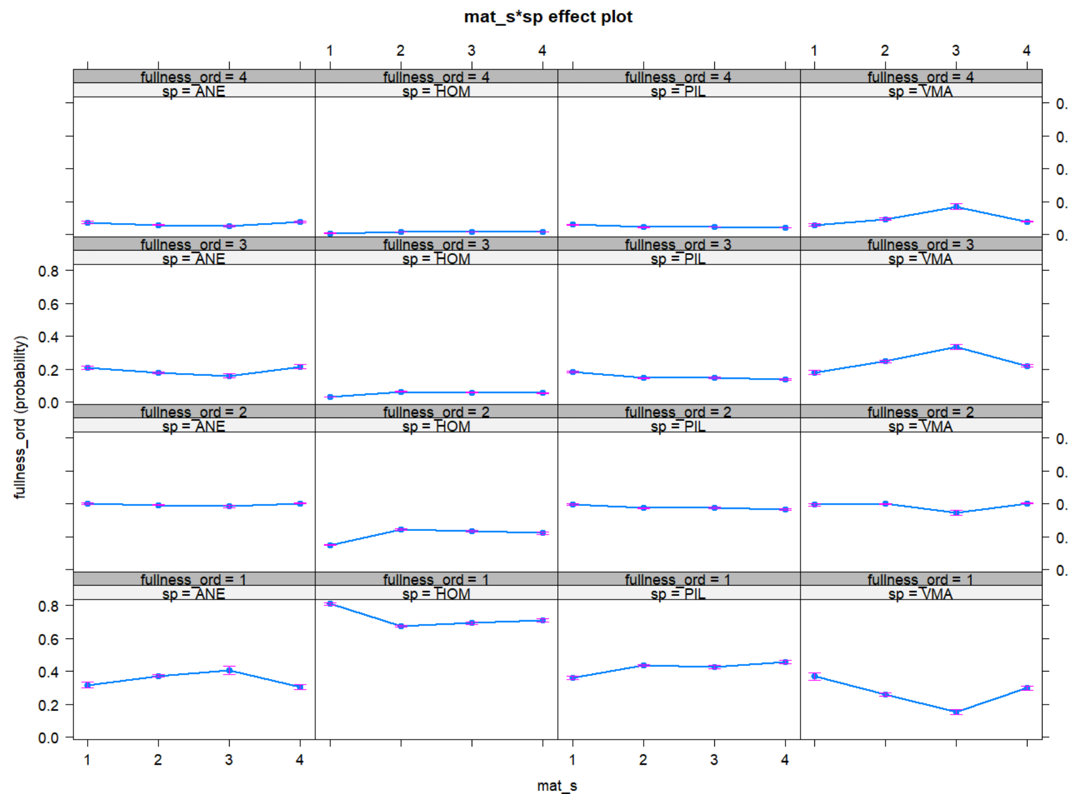
polr(fullness_ord ~ maturation+species+maturation*species)

Surveys



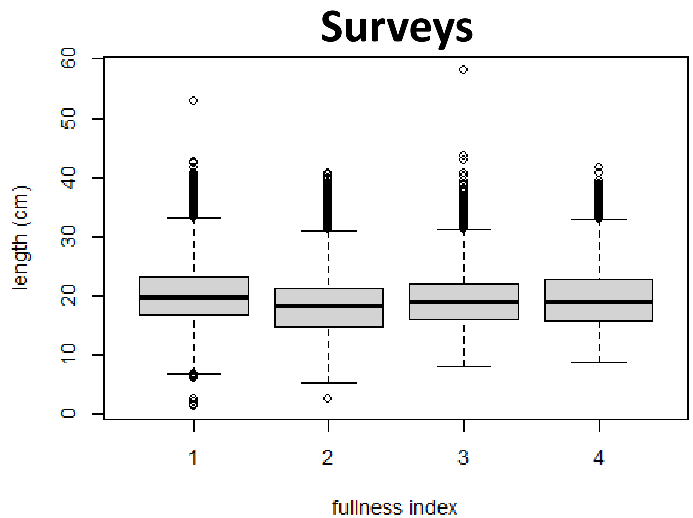
Commercial

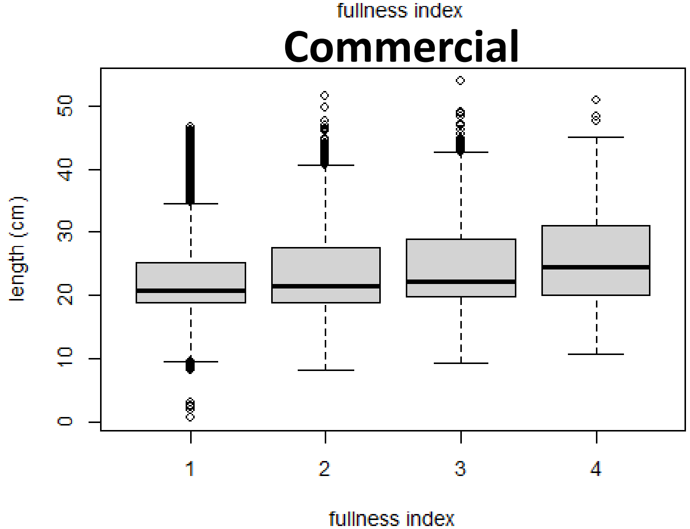


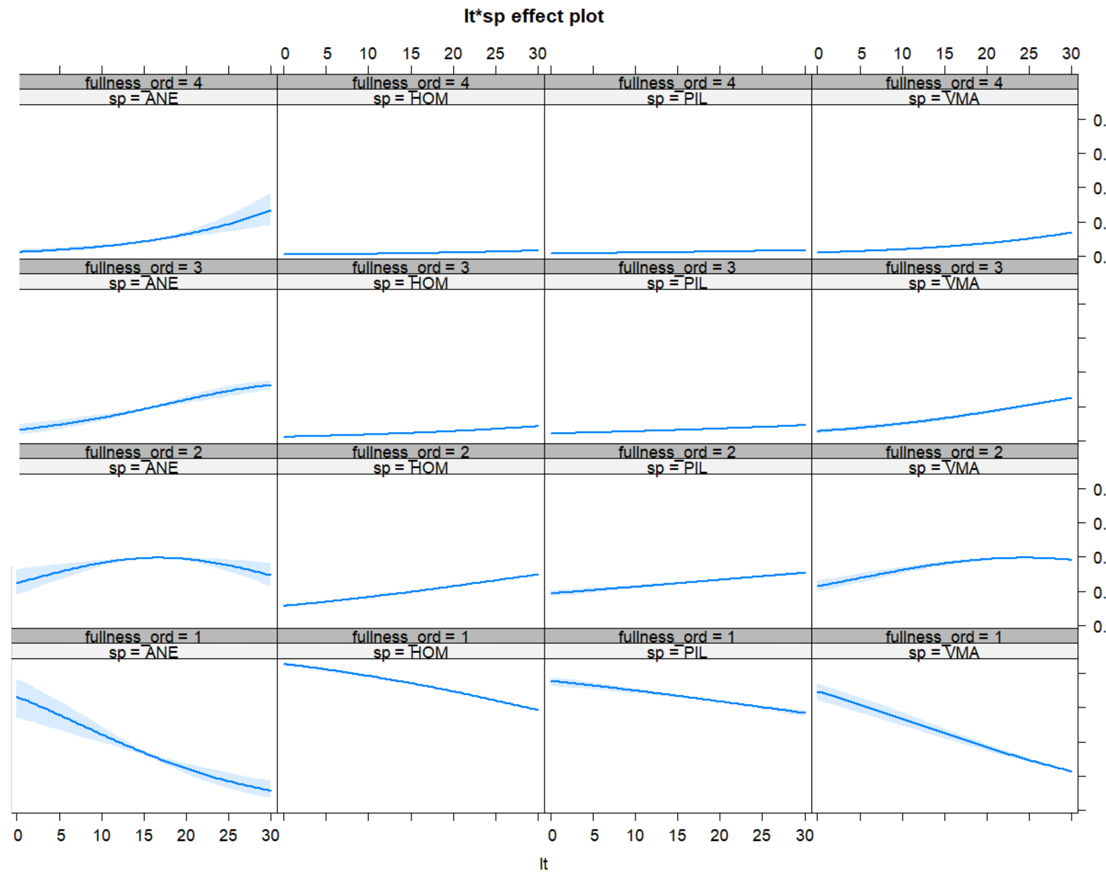


- Effect of maturation on fullness levels
- Variability within species
  - ANE-VMA vs HOM-PIL

FULLNESS vs BIOLOGICAL - LENGTH



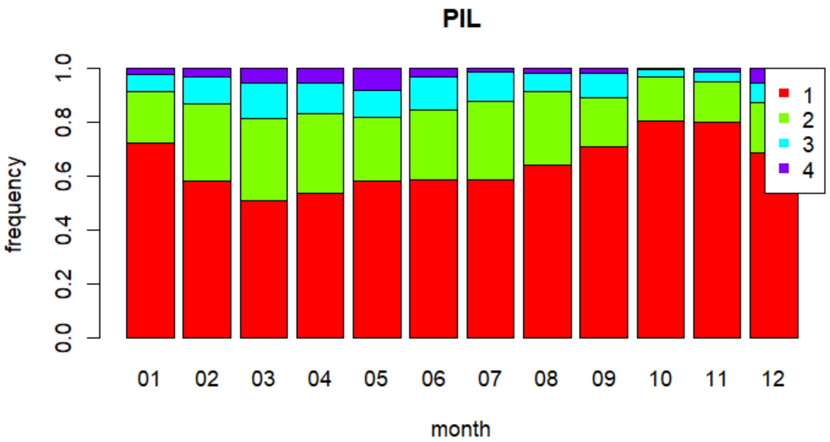


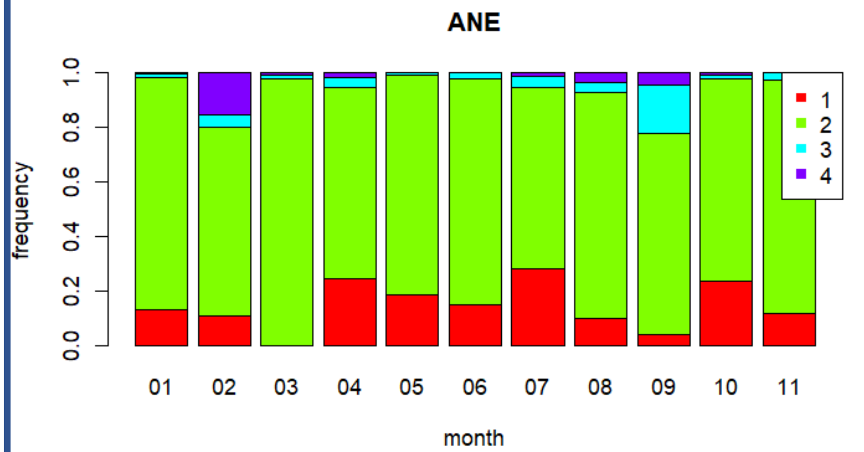


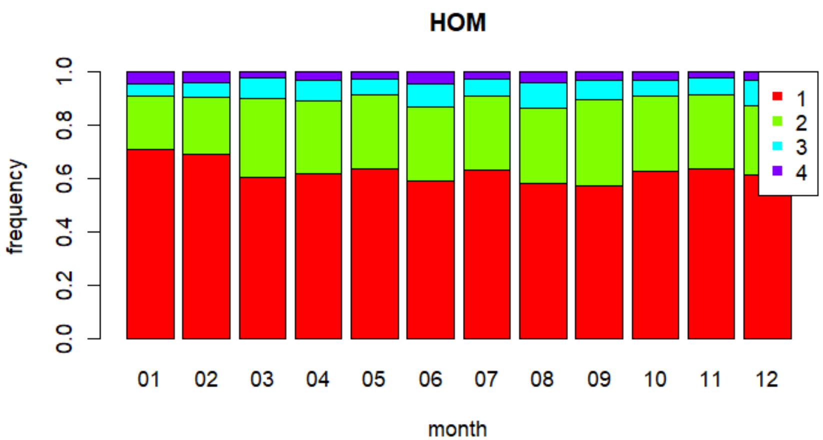
- Effect of length on fullness levels

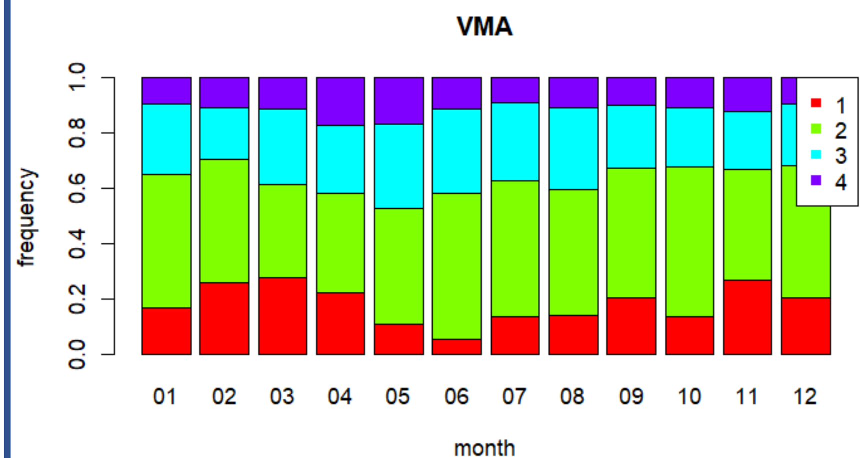
- Variability within species
  - ANE-VMA vs HOM-PIL?

ANE-VMA vs PIL-HOM









- Faster growth – higher feeding intensity

DATA SUMMARY - BIOLOGICAL VARIABLES

- No variability within sex

- Developing/maturation stages increases fullness levels. No changes when reaching resting/post-spawing

- Increase of fullness with length

- Mixed variability within species/biological variables
  - PIL and HOM similar behaviour
    high percentage of empty stomachs
    fullness seasonality in sardine

  - ANE and VMA
    low percentage of empty stomach
    feeding intensity

DATA ANALYSIS - METHODS

- Biological parameters
  - Sex
  - Maturation
  - Length

Ordinal regression with interaction term for each biological variable/species

- Commercial data
  - Seasonal
  - interannual
  - Spatial/zone/port

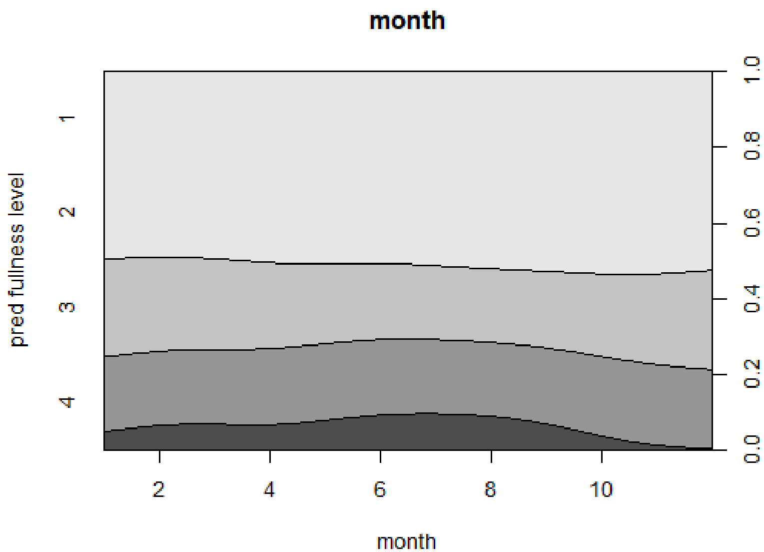
$$\mathrm{PI}_i = \log\left(\frac{p_i}{p_{i+1} + \ldots + p_n}\right) i = 1, \ldots, n-1,$$

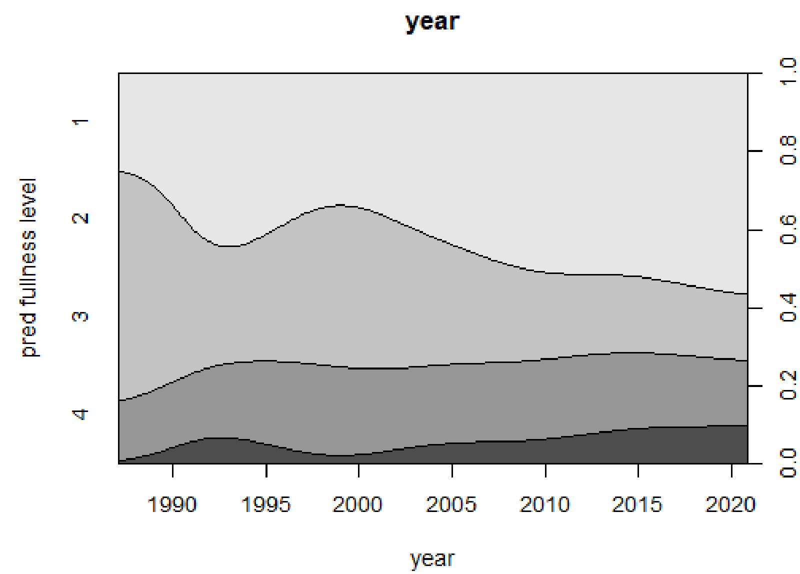
Rindorf and Lewy (2001)

GAM with binomial response/logit link

GAM SEASON/YEAR EFFECTS – ALL SPECIES

PI_all ~ s(fullness, year) + s(fullness, month) + length + zone
R-sq.(adj) = 0.189   Deviance explained = 17.2%

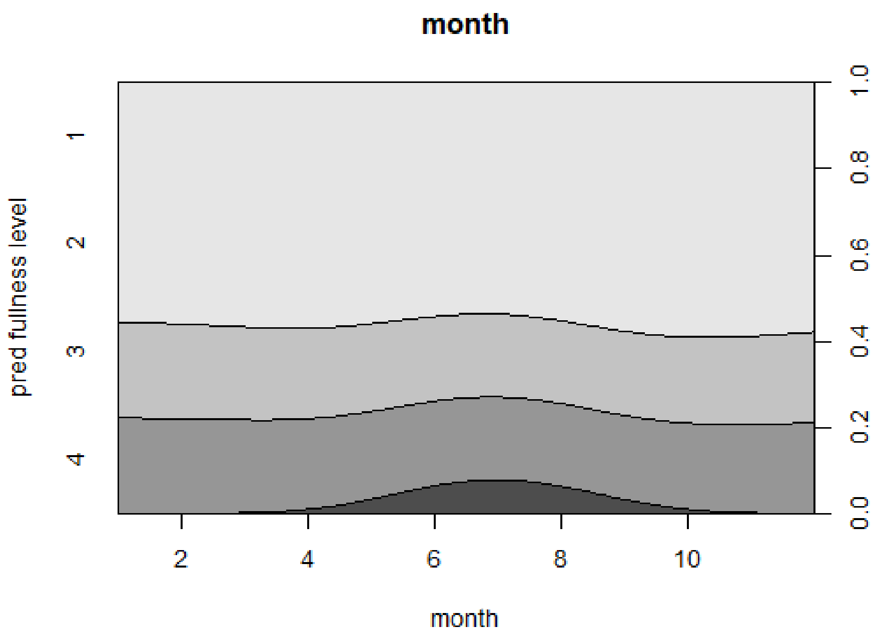


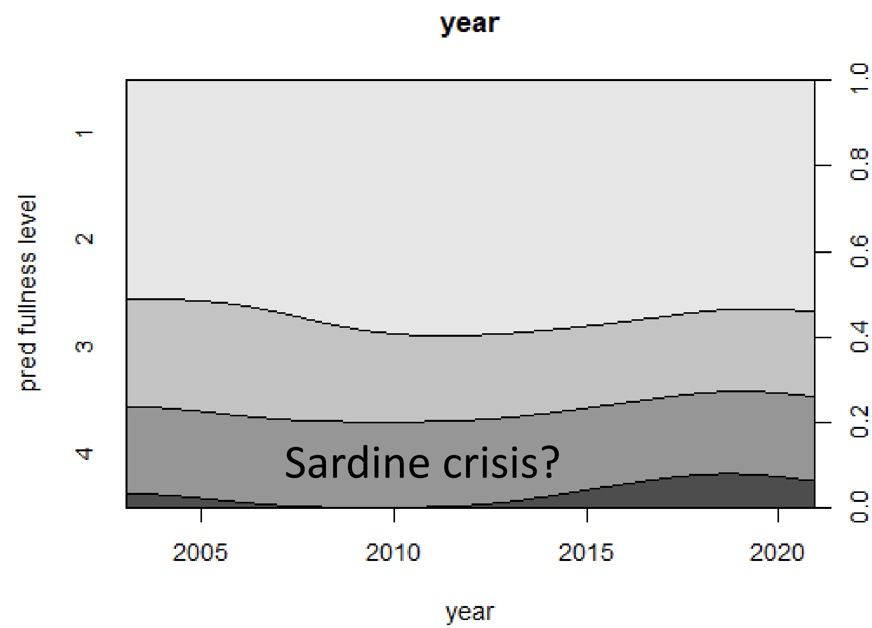


- Slight decrease of fullness during winter
- Interannual variability
- Effects from several species mixed

SEASON/YEAR - SARDINE

PI_pil ~ s(fullness, year) + s(fullness, month) + length
R-sq.(adj) = 0.204 Deviance explained = 18.6%

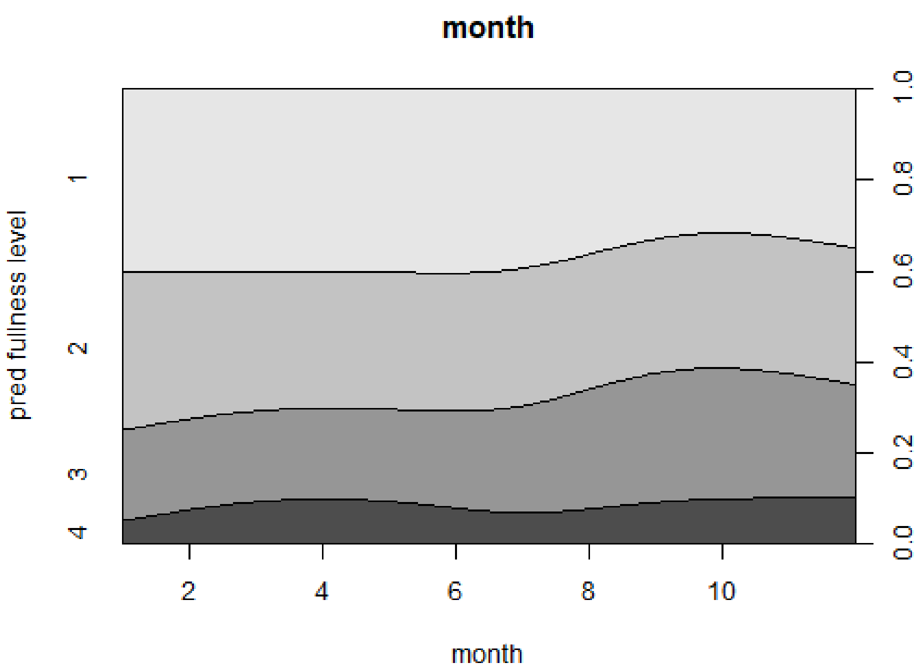


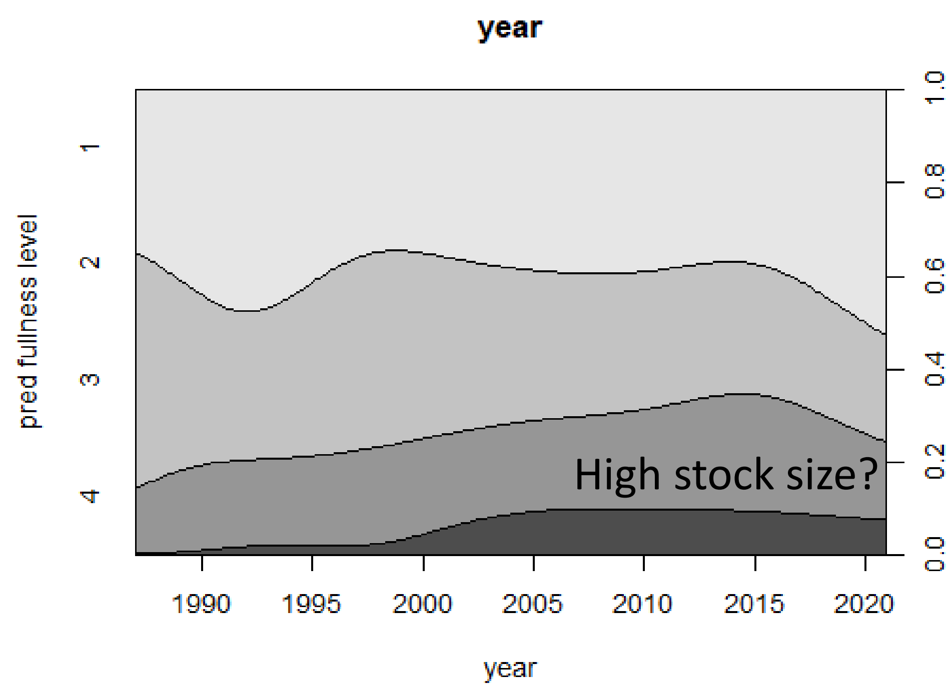


- Slight increase of fullness during summer
- Interannual variability

SEASON/YEAR - HORSE MACKEREL

PI_hom ~ s(fullness, year) + s(fullness, month) + length
R-sq.(adj) = 0.274 Deviance explained = 25.8%





- No seasonality
- Interannual variability

DATA ANALYSIS - METHODS

- Biological parameters
  - Sex
  - Maturation
  - Length

Ordinal regression with interaction term for each biological variable/species

- Commercial data
  - Seasonal
  - interannual
  - Spatial/Port

- Survey data
  - Interannual
  - diel cycle
  - Spatial/Depth

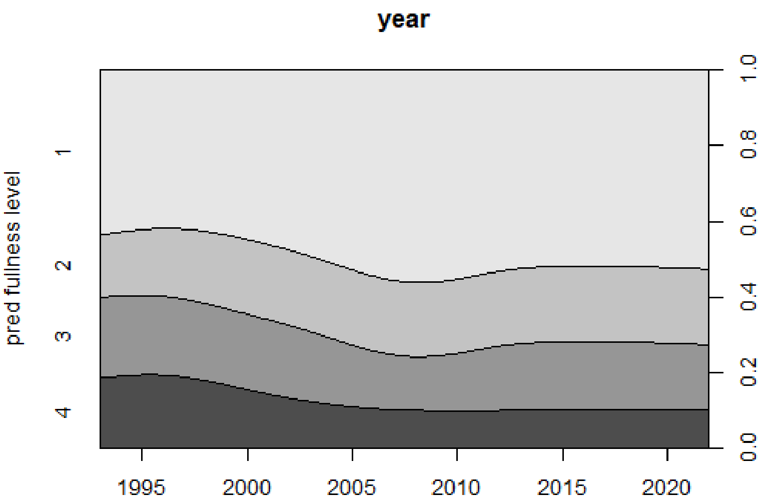
$$\mathrm{PI}_i = \log\left(\frac{p_i}{p_{i+1} + \ldots + p_n}\right) i = 1, \ldots, n-1,$$

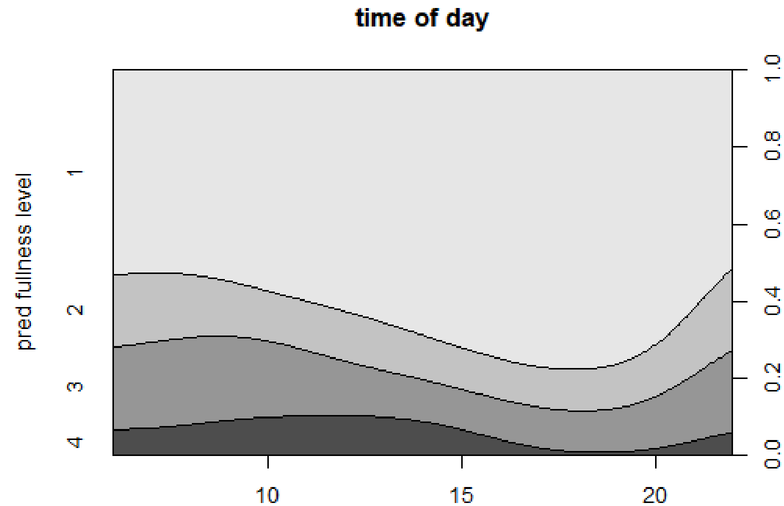
Rindorf and Lewy (2001)

GAM with binomial response/logit link

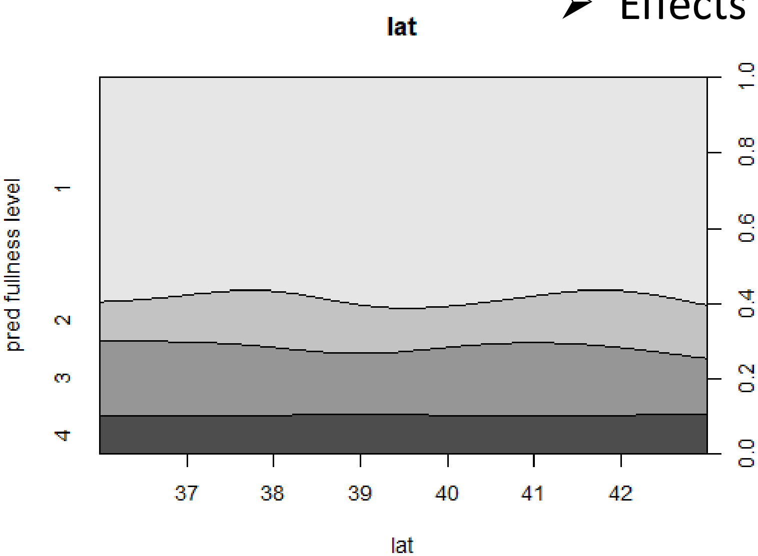
SURVEY VARIABLES EFFECTS - ALL SPECIES

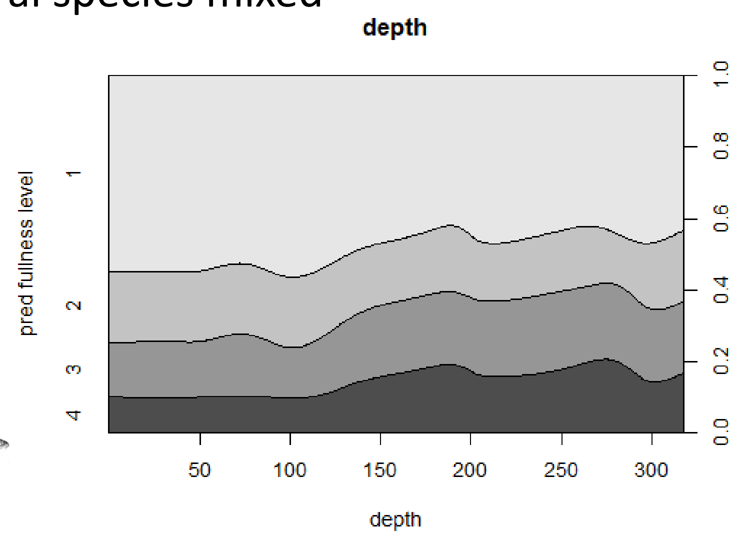
PI_all ~ s(fullness, year) + s(fullness, lat) + s(fullness, hour) + s(fullness, depth)
R-sq.(adj) = 0.256 Deviance explained = 22.5%





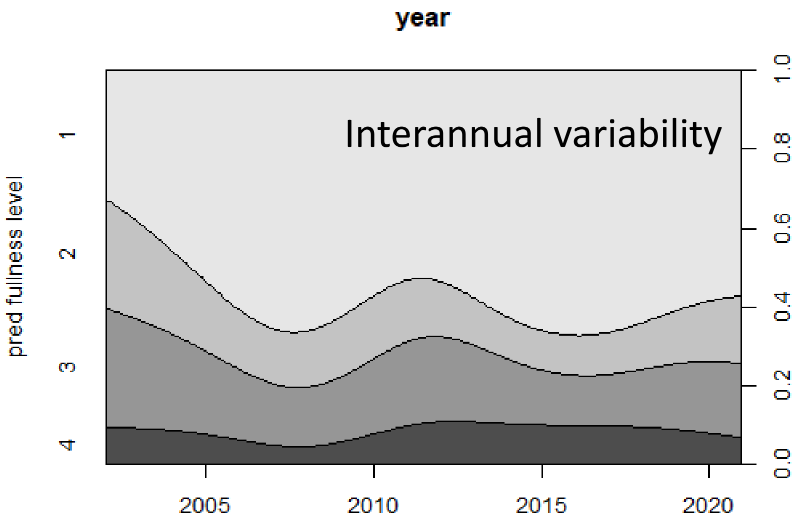
- ➢ Effects from several species mixed

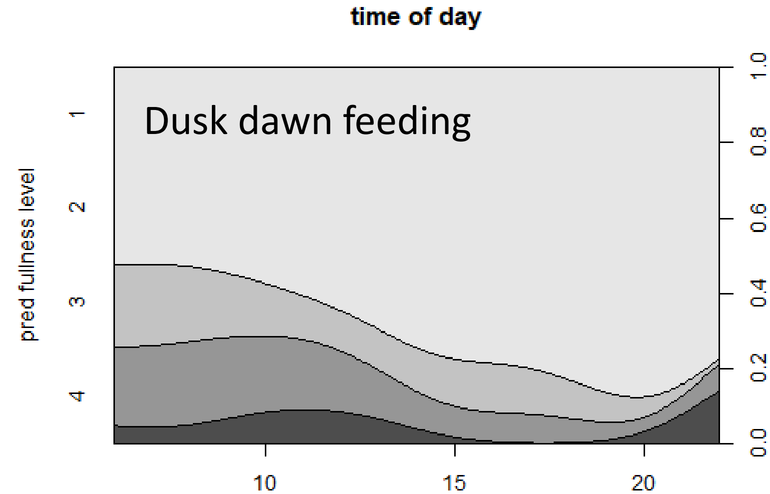


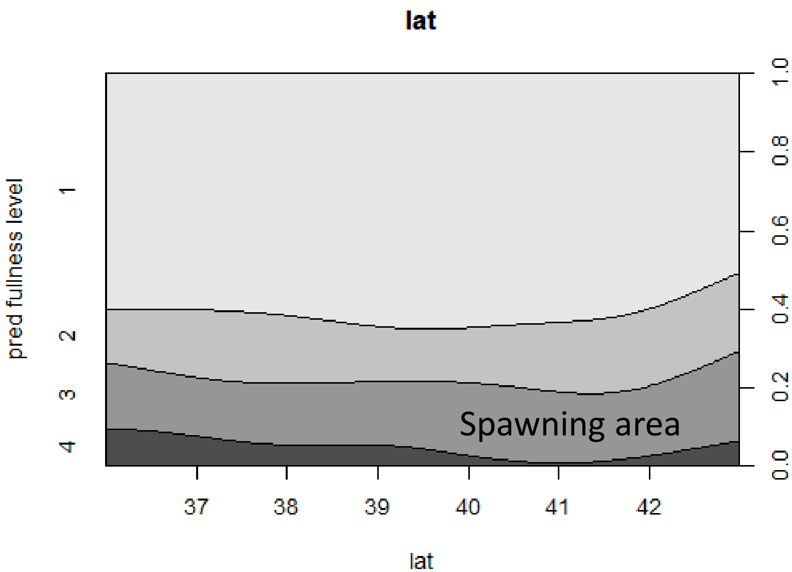


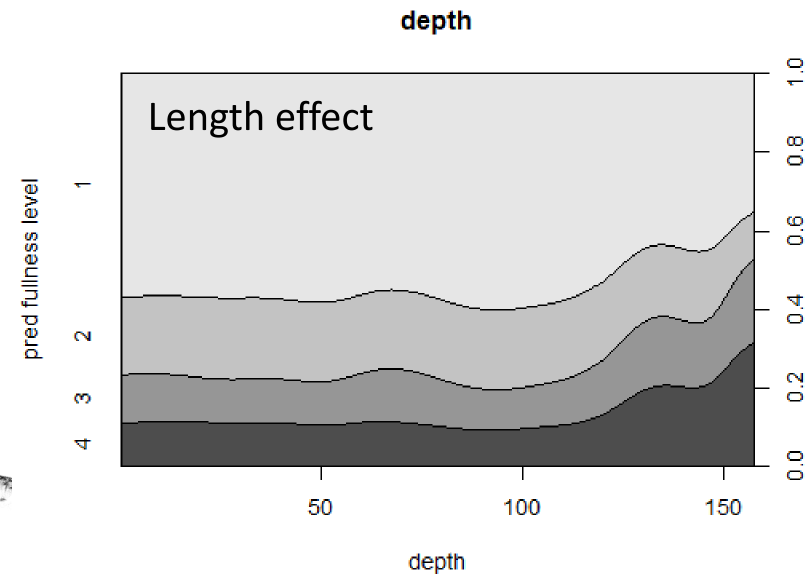
SURVEY VARIABLES EFFECTS - SARDINE

PI_all ~ s(fullness, year) + s(fullness, lat) + s(fullness, hour) + s(fullness, depth)
R-sq.(adj) = 0.352 Deviance explained = 32.3%



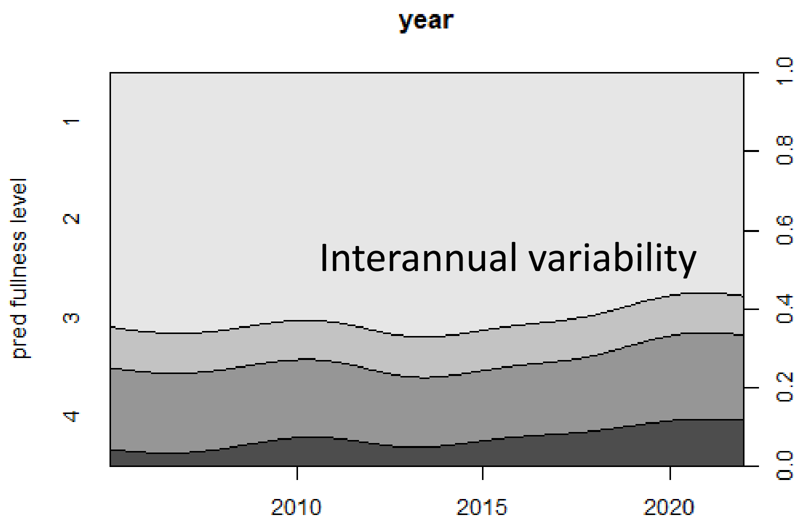


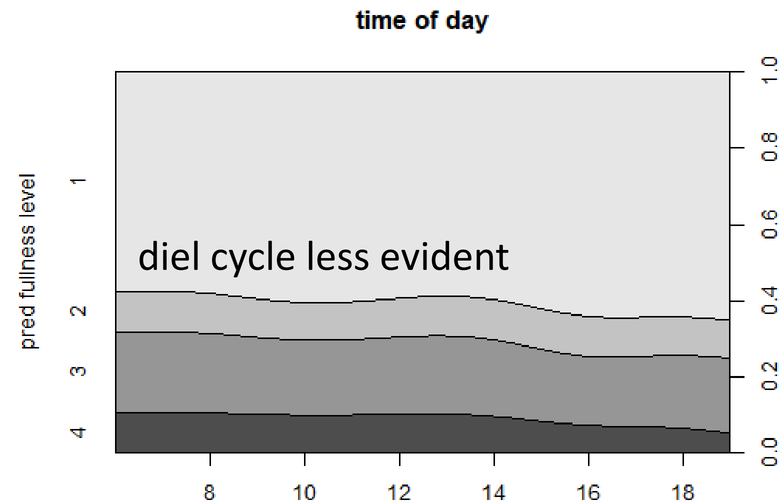


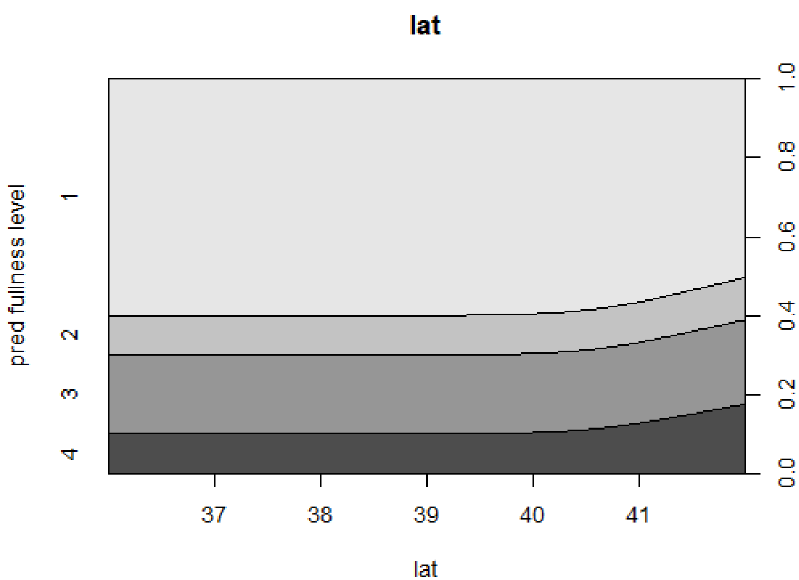


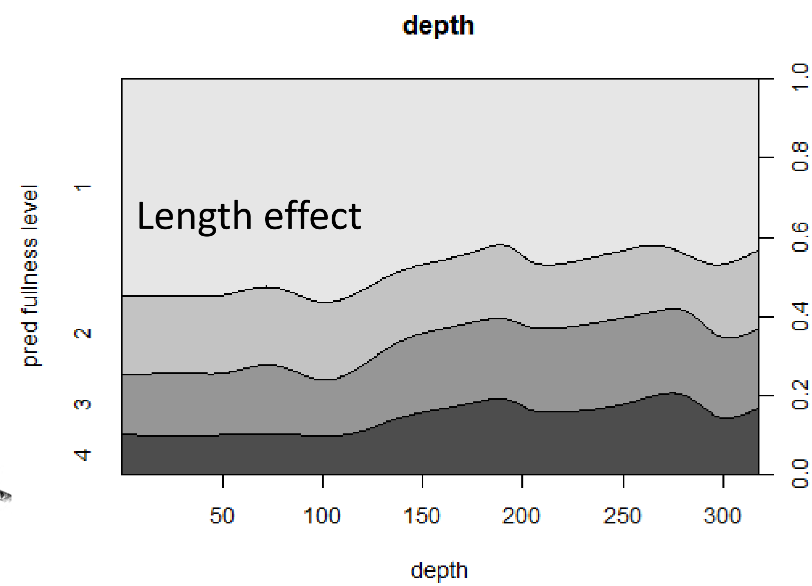
SURVEY VARIABLES EFFECTS - HORSE MACKEREL

PI_HOM ~ s(fullness, year) + s(fullness, lat) + s(fullness, hour) + s(fullness, depth)
R-sq.(adj) = 0.546 Deviance explained = 50.7 %









DATA ANALYSIS - METHODS

- Biological parameters
  - Sex
  - Maturation
  - Length

Ordinal regression with interaction term for each biological variable/species

- Commercial data
  - Seasonal
  - interannual
  - Spatial/Port

- Survey data
  - Interannual
  - diel cycle
  - Spatial/Depth
- Environmental variables
  - SST
  - Salinity

$$\mathrm{PI}_i = \log\left(\frac{p_i}{p_{i+1} + \ldots + p_n}\right) i = 1, \ldots, n-1,$$

Rindorf and Lewy (2001)

GAM with binomial response/logit link

FEEDING PATTERNS VS ENVIRONMENTAL VARIABLES

- No significant linear or non-linear effects of in-situ salinity and temperature variables
  - Further exploration needed as temperature is a key factor governing metabolism and behaviour.

- Other key factors to explore:
  - Available prey (plankton-density related variables)
  - Currents / Winds
  - Turbulence / light levels

CONCLUSIONS

- No variability within sex
- Developing/maturation stages increases fullness levels. Also related to increase of fullness with length
- Fullness levels has the potential to inform on life cycles fluctuations and species behaviour and resilience
- Easy/cheap method that can inform on the trophodynamic behaviour of several species/ecosystem
- Given the potential, calibration of stomach levels for several species is advised
- The study of the variability of fish feeding intensity in space and time for long periods of time allows the investigation of the degree of adaptability of the fish to different long-term ecosystem fluctuations.

Obrigado!

Questions and suggestions