Trophic interaction of mackerel (*Scombrus scomber*) and herring (*Clupea harengus*) on the Icelandic shelf

- a study of diet using stable nitrogen and carbon isotopes

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Context

- Warming of the world's oceans has caused an expansion of suitable areas and changes in distribution and feeding migration pattern of pelagic fish stocks.
- Results from international surveys in 2013 and 2014 indicated that at least 1.5 and 1.6 million tonnes (respectively) of mackerel had entered the Icelandic waters for feeding.
- That amount almost doubled in 2015.
- An invasion on such a large scale will most likely have significant effects on the ecosystem.

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Denmark
Norwegian
Sea
Barents
Sea
White
Sea
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Kalfshamarsvik
Akureyri
Höfn
Vestmannaeyjar
Lofoten
NORWAY
SWEDEN
FINLAND
Gulf of Bothnia
Hammerfest
Tromsø
Narvik
Kirkenes
Murmansk
Ivalo
Kiruna
Torne Älv
Rovaniemi
Luleå
Bodø
Avidsjaur
Storuman
Oulu
Raahe
Umeå
Vaasa
Archangel´sk
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Florø
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Denmark
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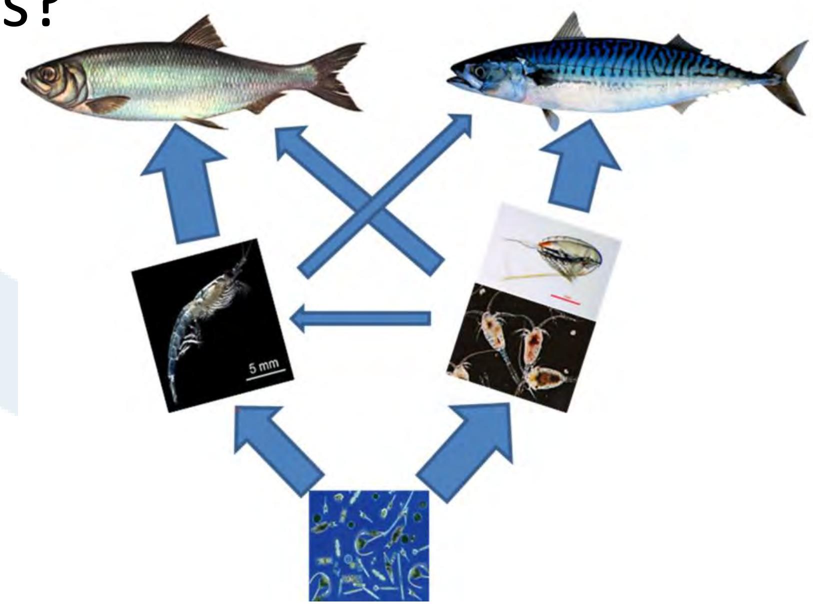
Aim of study

- Main questions:
  - Who eats whom?
  - Specific foraging strategies?
  - Inter/intraspecific competition?
  - Diet proportions?
  - Effect on ecosystem?



Material and Methods

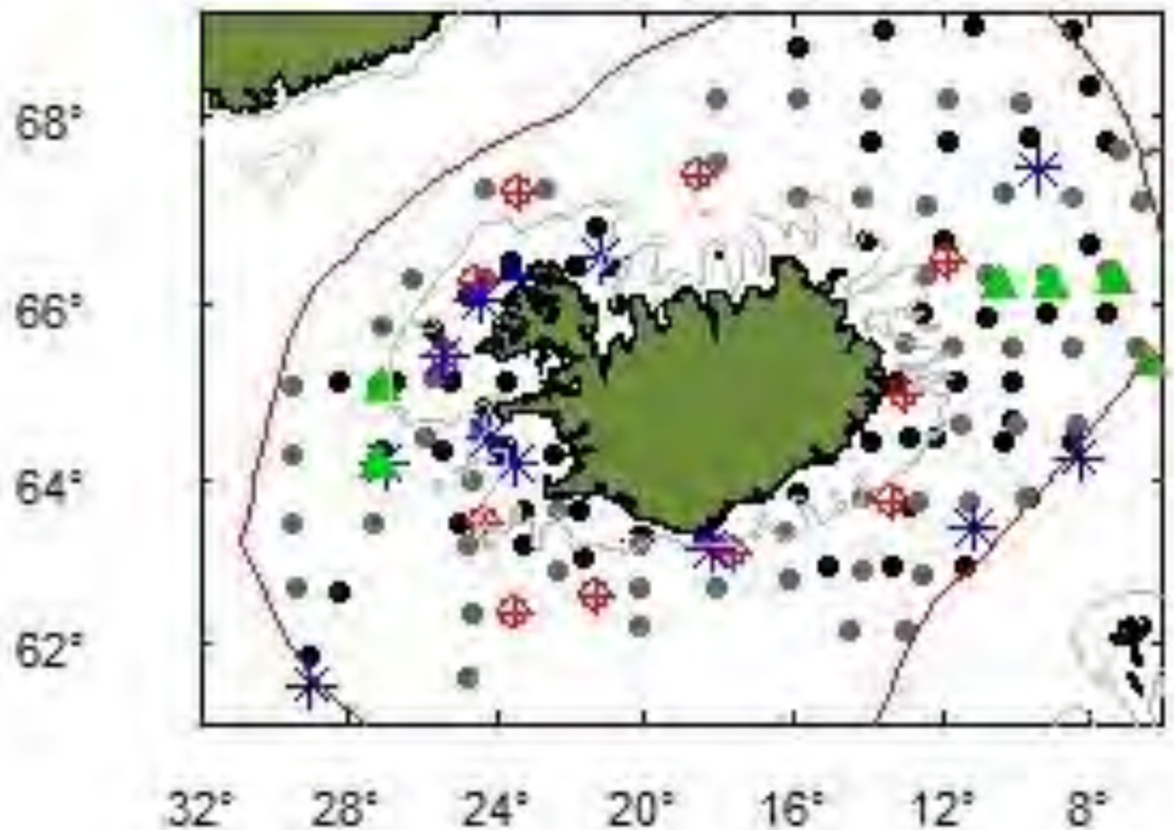
- **Samples 2012-2014**
  - Fish stomachs and white muscle of mackerel, Icelandic summer spawning herring (ISSH) and Norwegian spring spawning herring (NSSH) – (2012 and 2014)
  - Bongo tows for small zooplankton (2014)
  - In-house isotope data from macrozooplankton tows (2013)
- **In house isotope data 2007-2008**
  - Capelin and Sandeel
- **Visual analysis**
  - In-house microscopic analysis of stomach content.

Survey stations

2012 ●
2014 ●

Isotope samples

Herring
Mackerel
Prey



Material and Methods

- **Stable isotope analysis of samples**
  - Samples dried, homogenized, weighed.
  - Analysed by Colorado Plateau Stable Isotope Laboratory (CPSIL), Northern Arizona University.
  - δ15N and δ13C

- **Stable isotope data analysed in R (v. 3.3.2)**
  - MixSIAR, v. 3.1.7, a Bayesian mixing model (Stock and Semmens, 2013).
  - SIBER: Stable Isotope Bayesian Ellipses in R, v. 2.0.3 (Jackson et al , 2011).

Visual analysis

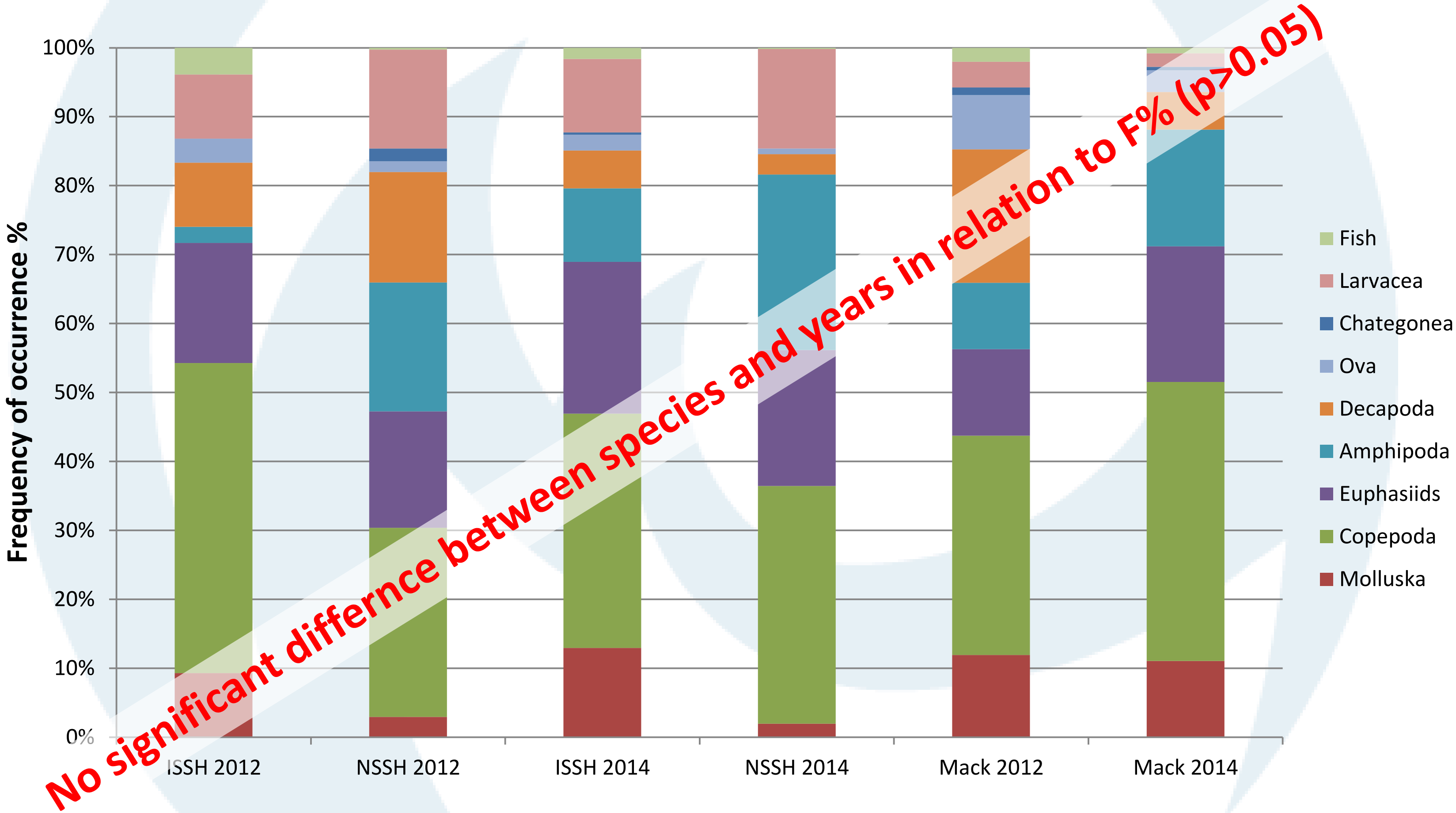
All stomach data was analyzed using standardized methods:

- Numerical (N%), gravimetric (W%), frequency of Occurence (F%), Hyslop 1980.
- Prey specific Index of Relative Importance (PSIRI%),Brown et al. 2012.
- Pianka´s measure of niche overlap (O),Pianka 1973.

Prey was identified down to 47 species and divided in to 9 major groups:

- Molluska (e.g. Gastropods, Bivalvia, Cephalopods)
- Copepoda (e.g. Calanus, Acartia, Temora, Oitona)
- Euphasiidae (Thysanoessa spp, Meganyctiphanes n.)
- Amphipoda (Themisto spp, Gammaridae spp)
- Decapoda (Carcinus, Hymenodora, Eusergestes)
- Ova
- Chategonea
- Larvacea
- Fish (e.g. Ammodytes spp, Clupids, Gadoids)

Results



Frequency of occurrence %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
ISSH 2012
NSSH 2012
ISSH 2014
NSSH 2014
Mack 2012
Mack 2014
Fish
Larvacea
Chategonea
Ova
Decapoda
Amphipoda
Euphasiids
Copepoda
Molluska
No significant differnce between species and years in relation to F% (p>0.05)

PSIRI% of the top 5 prey species

2012

Mackerel	ISSH	NSSH
66,5% Copepoda	45,9% Copepoda	39,9% Copepoda
16		
1,8% Larvacea	8,7% Euphasiids	14,6% Amphipoda
1,4% Euphasiids	6,0% Larvacea	5,3% Euphasiids
1,		

Statistical difference of amphipoda between species ($p< 0.05$)

Statistical differnce of decapoda between years ($p< 0.05$)

2014

Mackerel	ISSH	NSSH
83,2% Copepoda	50,7% Copepoda	44,8% Copepoda
4,		
2,8% Euphasiids	12,8% Larvacea	12,8% Euphasiids
1,0% Fish	2,6% Amphipoda	12,5% Larvacea
0,8% Larvacea	0,9% Fish	0,3% Decapoda

No statistical difference between the remaining prey groups

Pianka´s measure of overlap

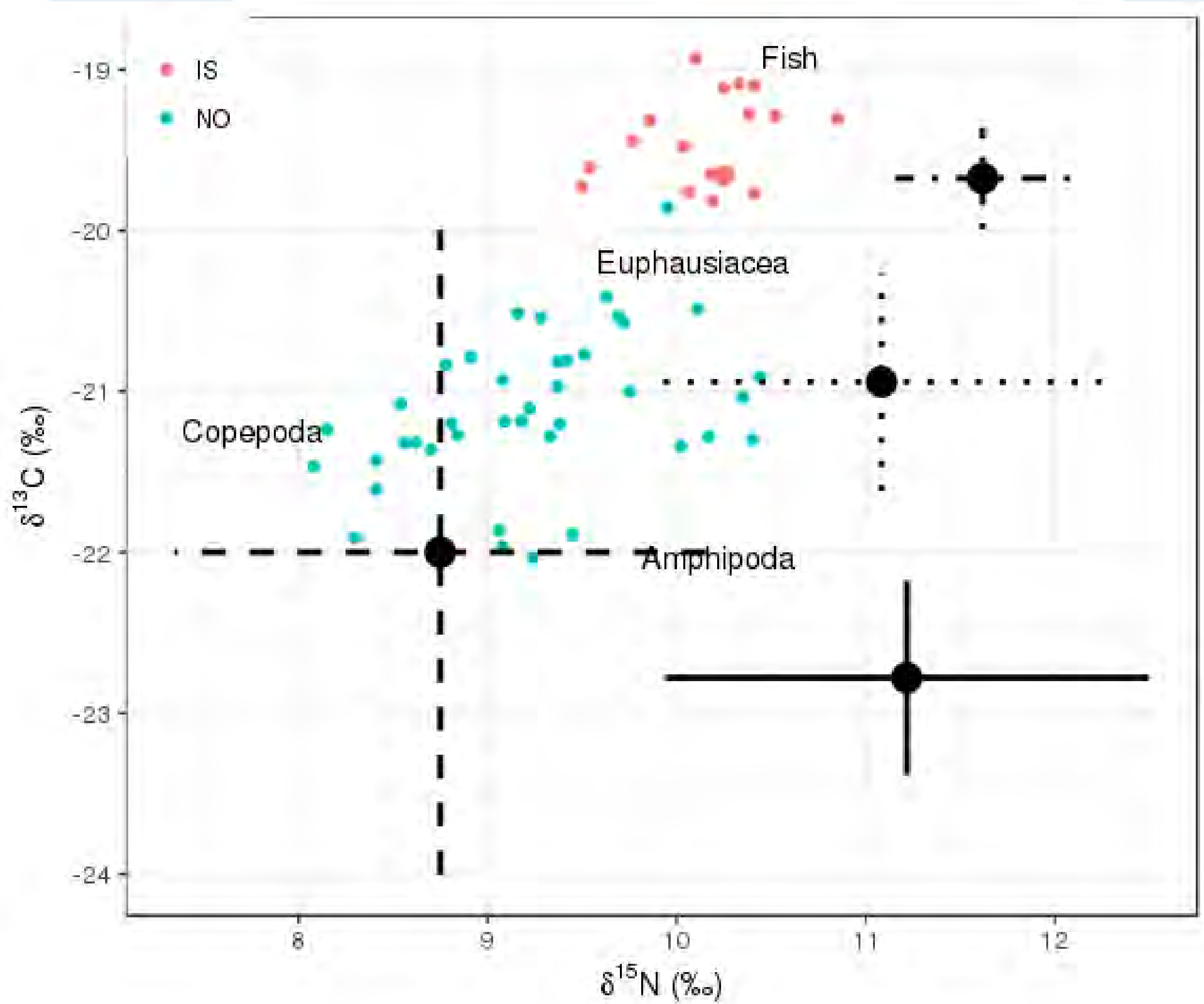
"Green" is 2012 and "Blue" is 2014

	Mackerel	ISSH	NSSH
Mackerel		0,96	0,99
ISSH	0,91		0,95
NSSH	0,87	0,98	

Complete overlap; O > 0.5

No statistical difference in Pianka´s niche overlap between years and species ($p > 0.05$)

Stable isotopes – NSSH and ISSH



Histograms:

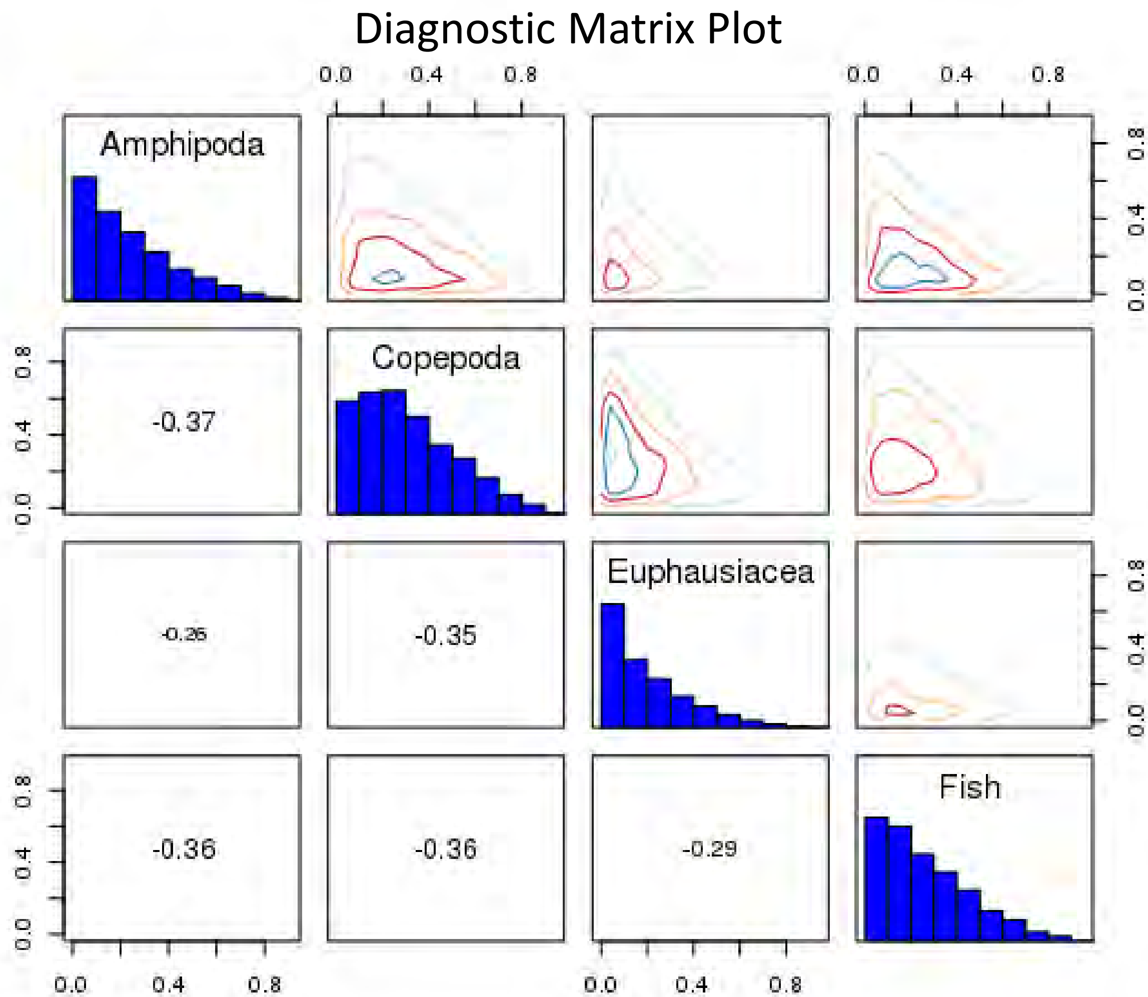
Posterior probability distributions for each of the four food sources.

Contour plots:

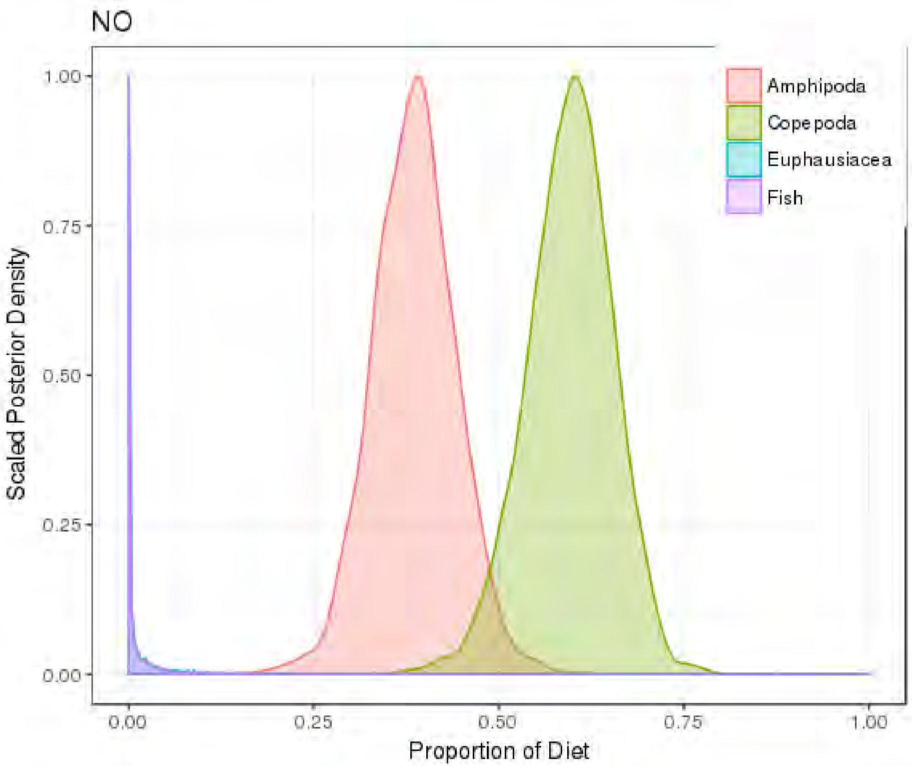
Correlation of pairs of posterior distributions.

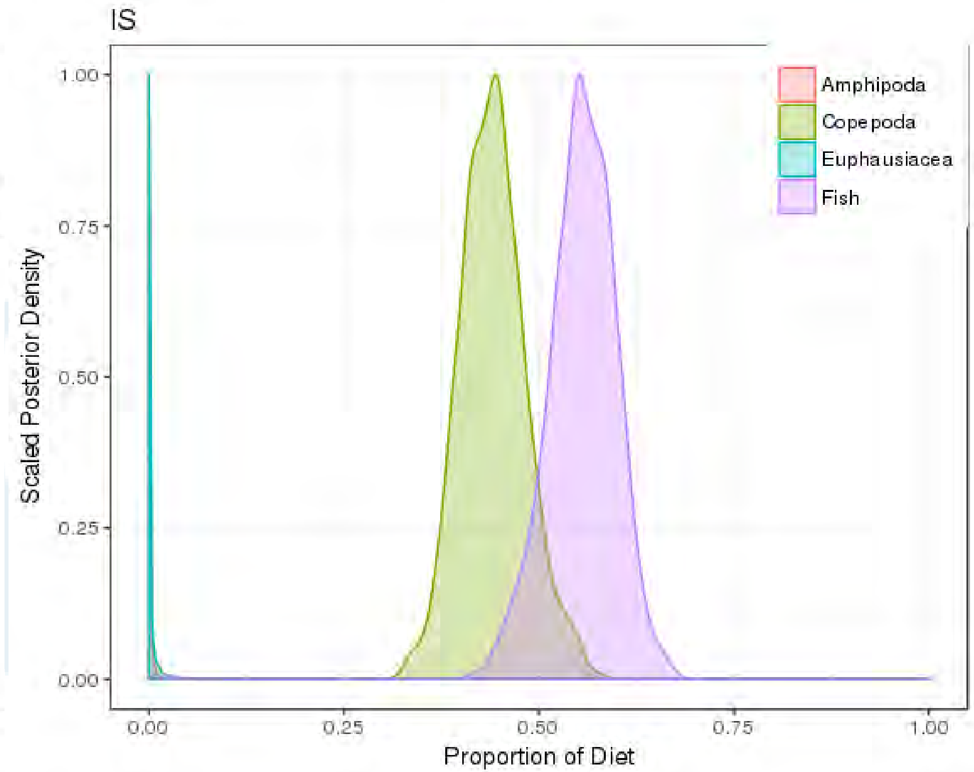
Numbers:

Actual correlation coefficient



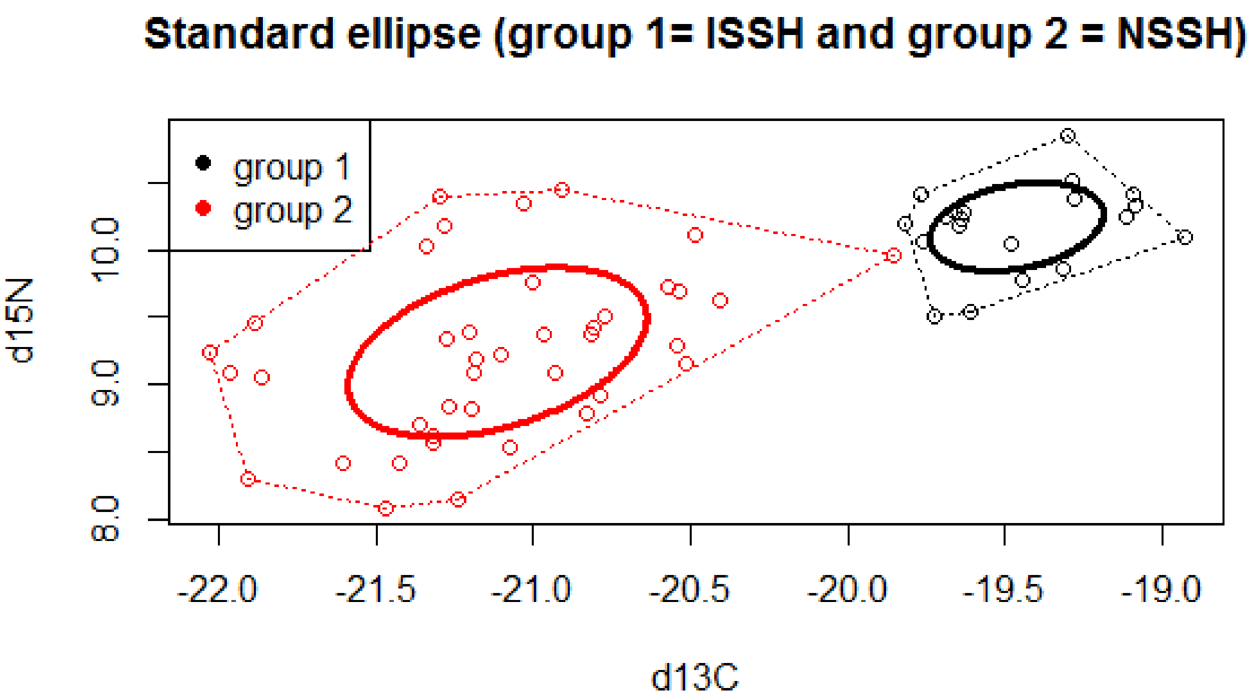
Median diet proportions within 95% CI - NSSH and ISSH





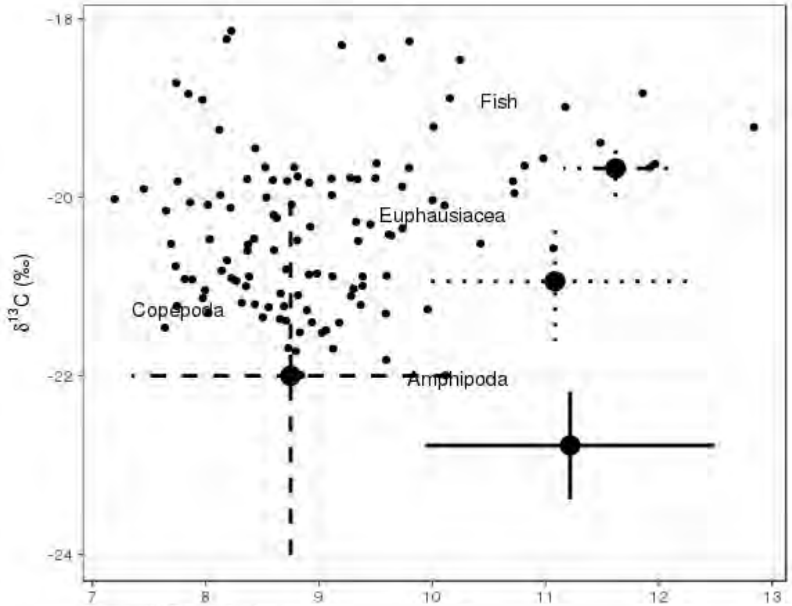
	Cop	Amp	Eup	Fish
NSSH	59,9%	38,6%	0%	0%
ISSH	44 %	0%	0%	55,7%

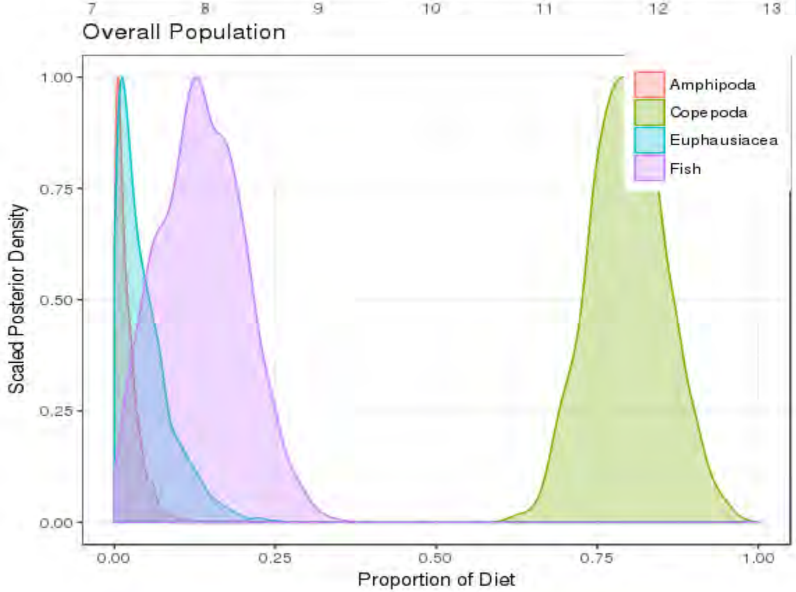
Niche width

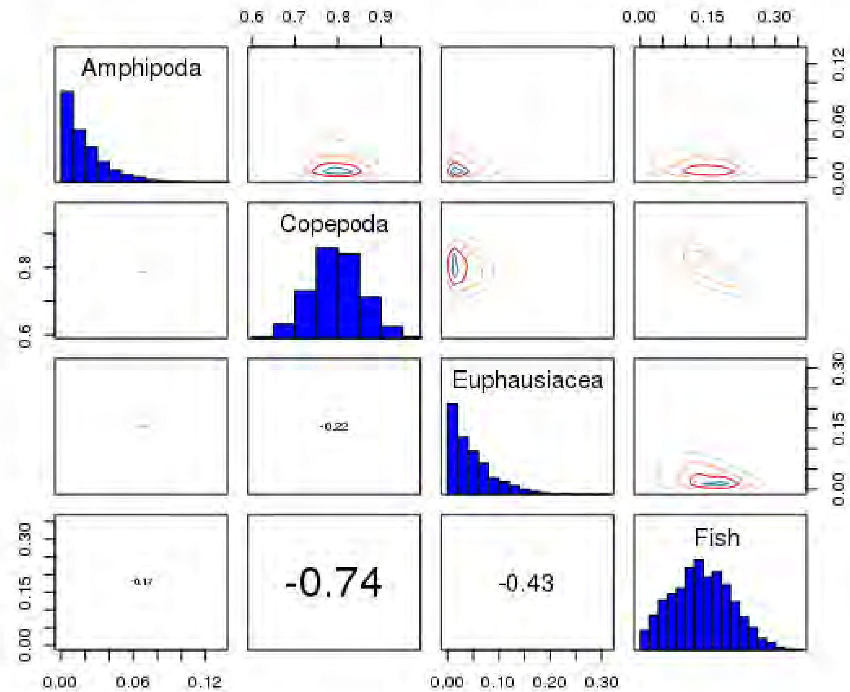


- Each ellipse contains 40% of the datapoints
- Niche overlap ranges from 0-1
- No niche overlap between ISSH and NSSH

Median diet within 95% CI - mackerel

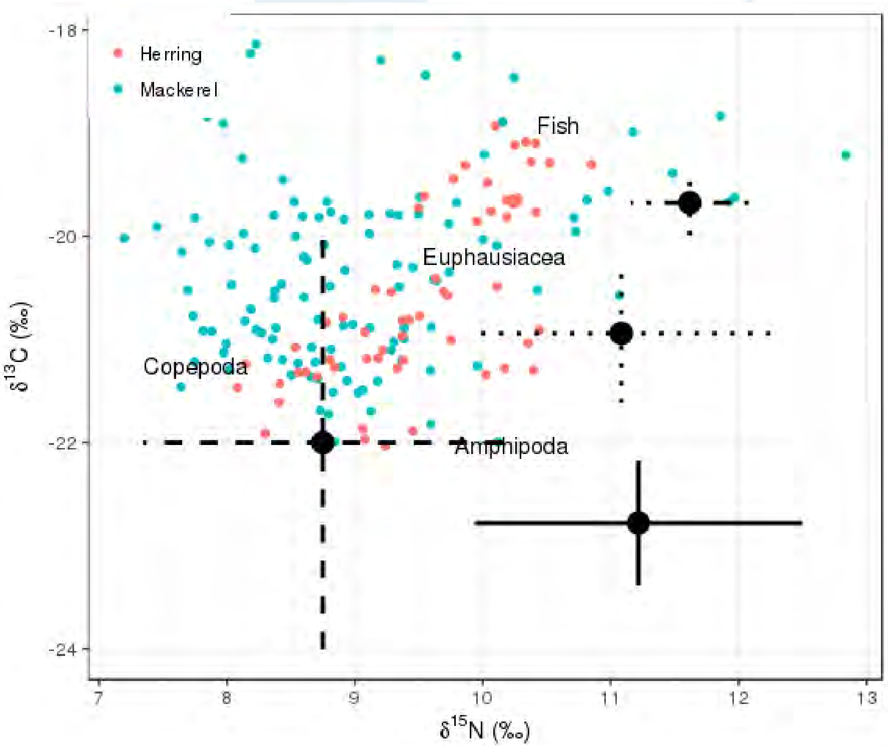


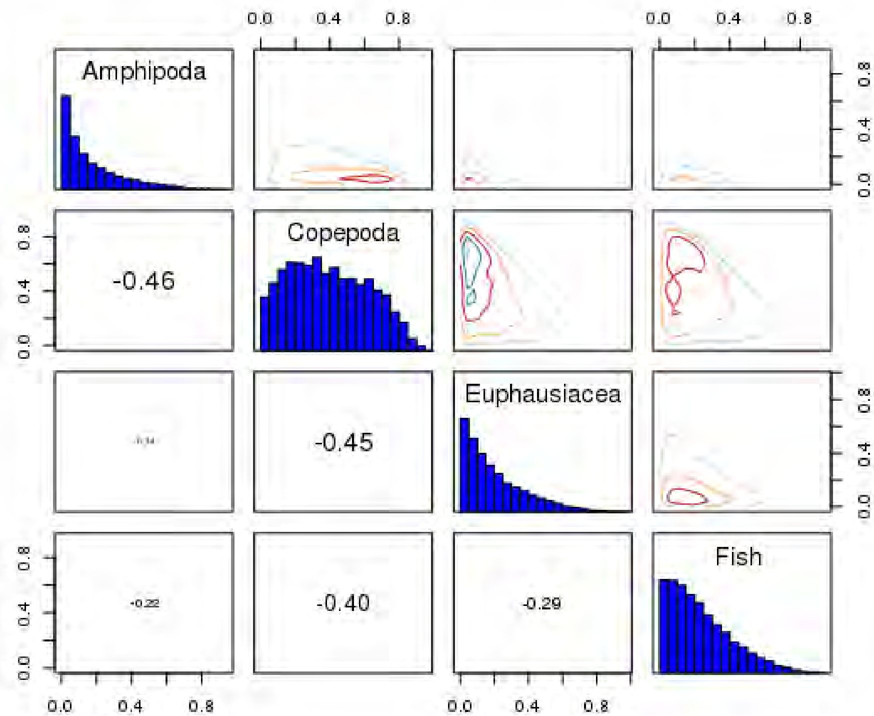




	Cop	Amp	Euph	Fish
Mackerel	79,6%	1,4%	3,5%	13,4%

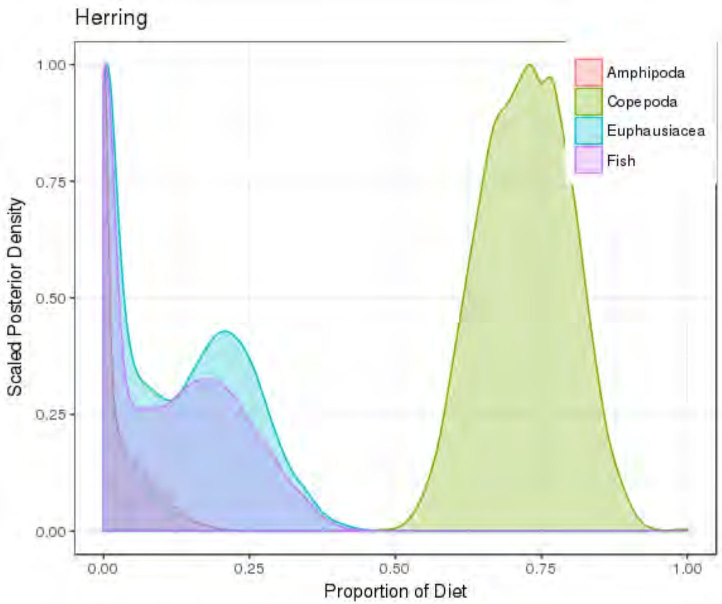
Mackerel and Herring

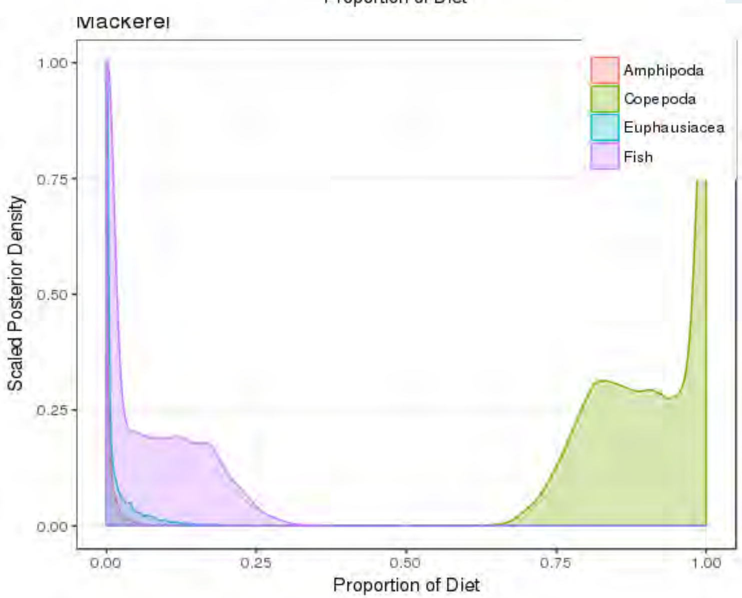


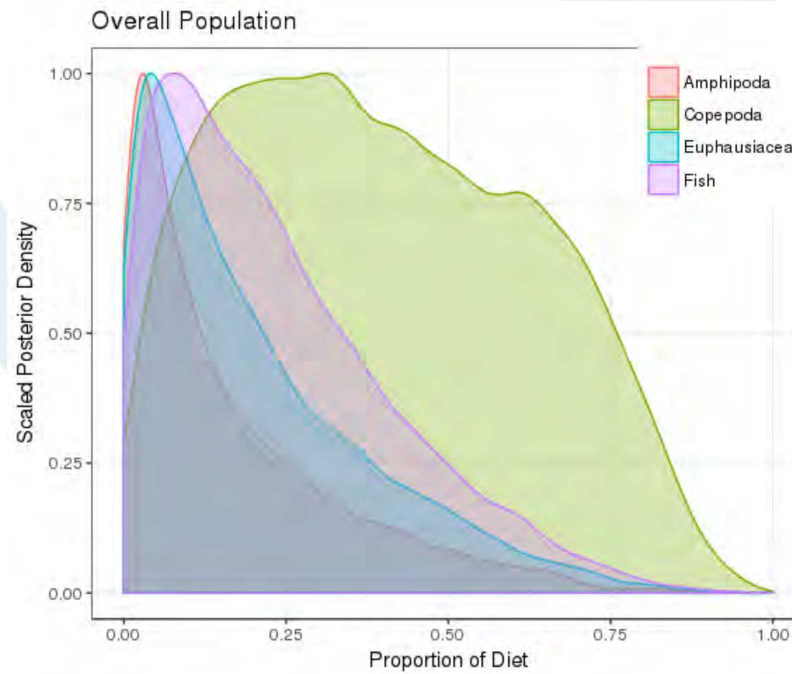


Median diet proportions - within 95% CI

	Cop	Amp	Eusp	Fish
Makerel	91,9%	0,1%	0,2%	4,1%
Herring	72,4%	1,2%	12,1%	10,1%

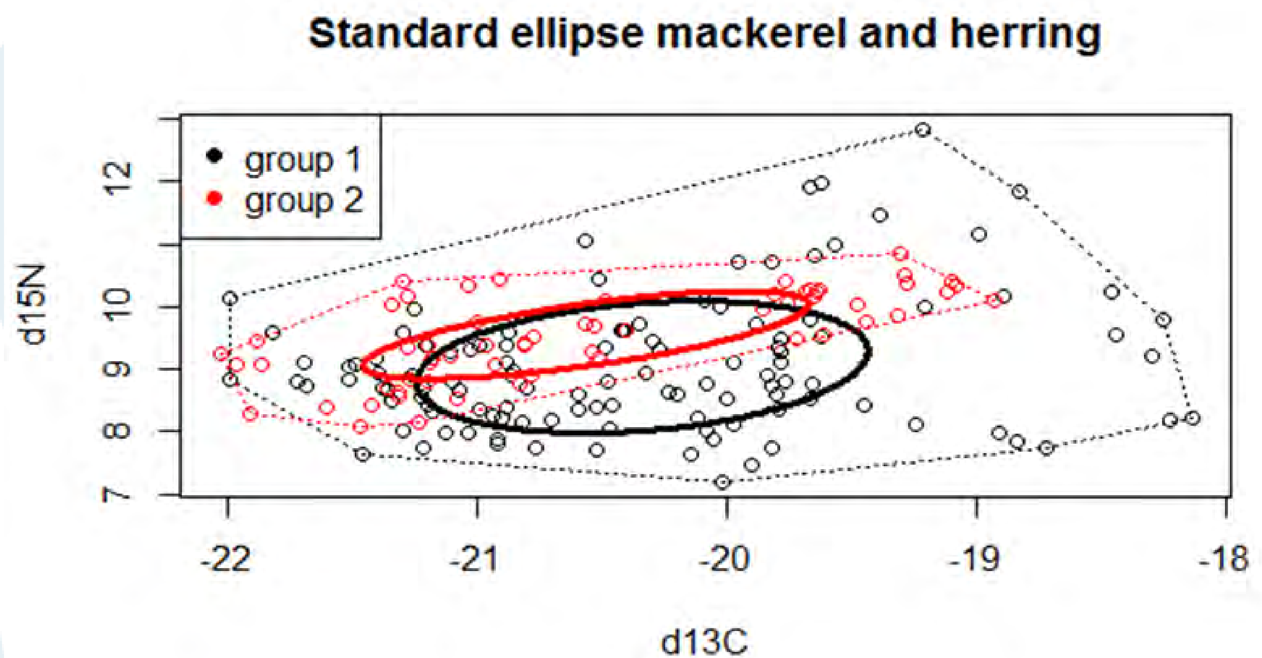






Niche width

- 40% of the datapoints overlap at 0.97
- Complete overlap of the convex hulls (containing all datapoints)



Summary

Visual analysis

- Mackerel: different copepods are the main source of food (filter feeding), but also seek to selectively eat larger prey (e.g. Squid, fish, shrimp)
- Herring: no apparent difference between ISSH and NSSH in food selectivity though copepods are their larges contributor they tend to have large abundance of small krill and amphipods in their diet as well.

Stable isotopes

- Gives insight into a longer look back in time.
- Supports the visual data that copepods are the largest contributor to the diet of mackerel and herring.
- Indicates that the ISSH and NSSH are divided not only geographically, but also regarding to main prey contributions to their diet.
- Mackerel encompass a large niche width.

Thank you!

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