SJÁVARÚTVEGS RÁÐSTEFNAN 2018

Mackerel and Herring
- Competition or Coexistence?

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Background

- 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.

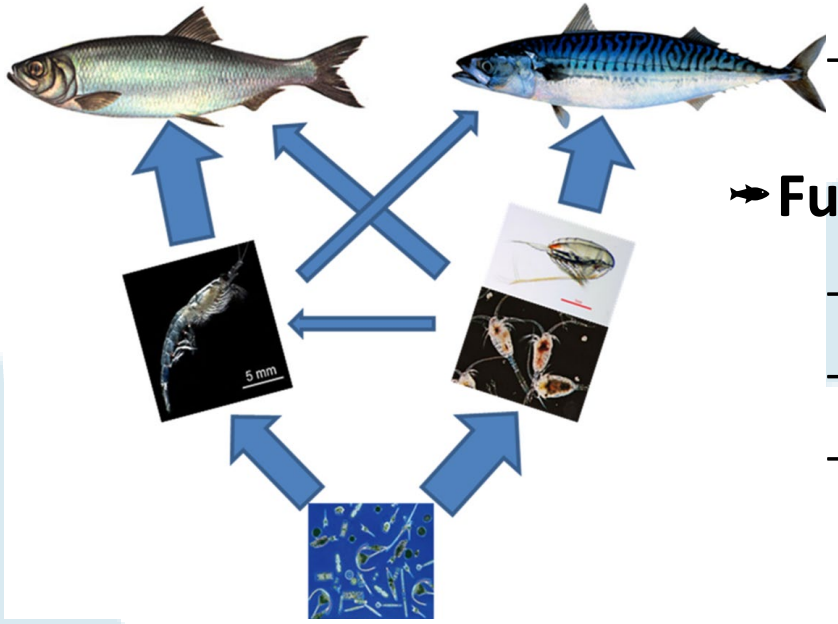
- Since 2006 Atlantic mackerel have entered into the Icelandic EEZ in large numbers during their summer feeding migration.

- This feeding migration will most likely have significant effects on the ecosystem trough interactions with native species.

Why is feeding ecology important?

Fish ecology:

- **In the simplest diet study case:**
  - Determine the most frequently consumed prey (prey selectivity)
  - Presence/absence of a particular food item
- **In other instances:**
  - Fish nutrition
  - Energy transfer
  - Consumption rate
  - Foraging trade-offs
  - Resource partitioning



Management and conservation:

- **Can invasive ("new") species be threatening native organisms?**
  - Competition between two similar species for (limited) resources
  - Predation by invaders on native fishes
- **Further understanding for EBFM**
  - Habitat preferences
  - Food web
  - Spawning success

Species of interest

Mackerel

- One stock, but comprised of three main spawning components:
  - Bay of Biscay, the British Iles and the North Sea
- Avid swimmer
  - schooling behaviour
  - lacks swim bladder
- Prefers temperatures above 7°C
- No diurnal migration
- Largely found in the upper 50 meters
- Filter and particulate feeder

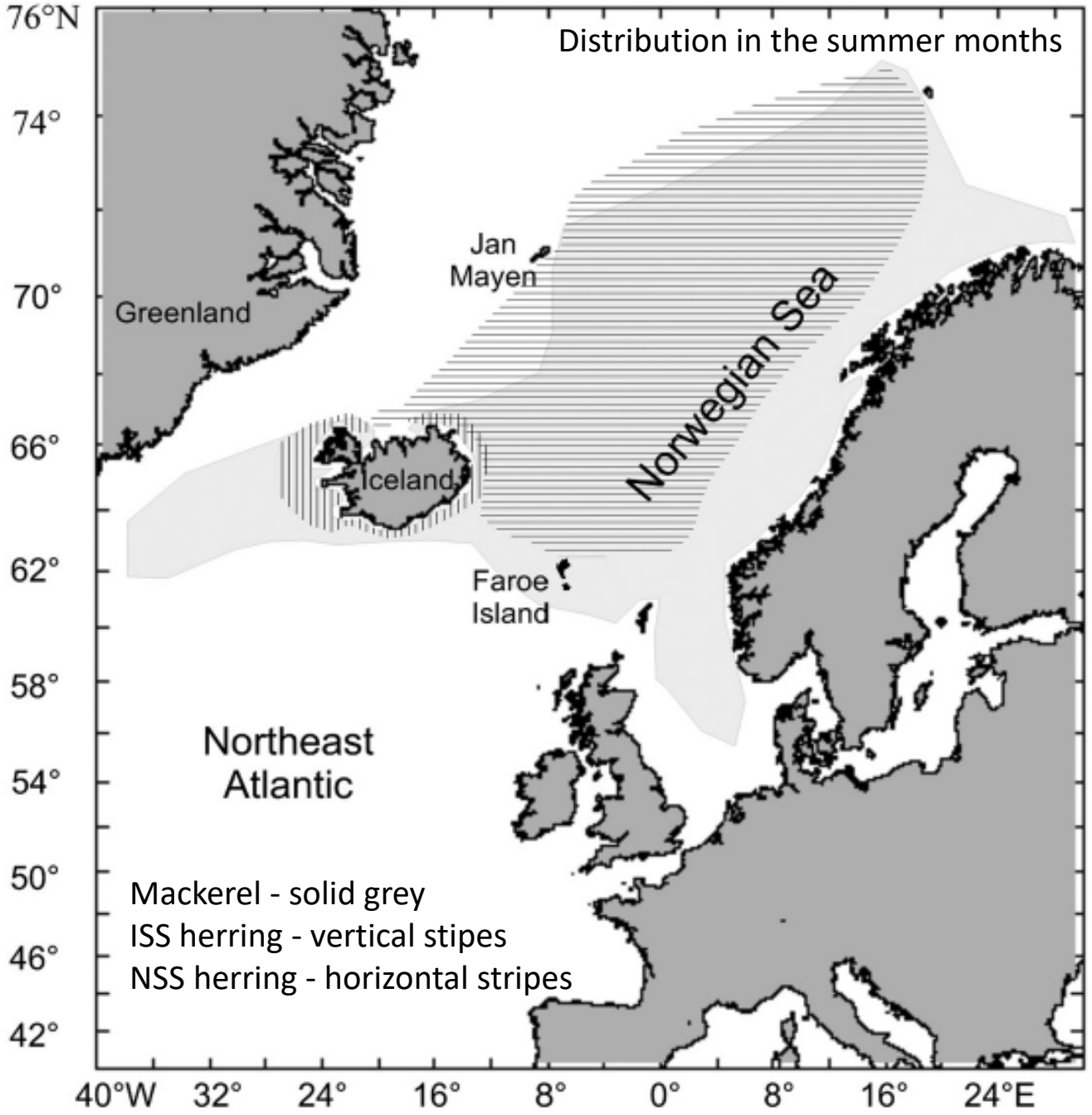
Herring

- Two stocks:
  - Icelandic Summer Spawning (ISS) herring
  - Norwegian Spring Spawning (NSS) herring
- Avid swimmer
  - schooling behaviour
  - has swim bladder
- Prefer temperatures from 2°C to 8°C
- Mainly found in 0 - 200 meter water column
- Diurnal migration
- Filter and particulate feeder

Mackerel meets herring

- NSS herring begin their feeding migration in April
- ISS herring move off the shelf for feeding after spawning in July
- Mackerel start their feeding migration after spawning (January-July)
- Mackerel feeding area has expanded by 50% from 2006-2013 (Ólafsdóttir et al., 2015)

Figure from Óskarsson et al., 2016

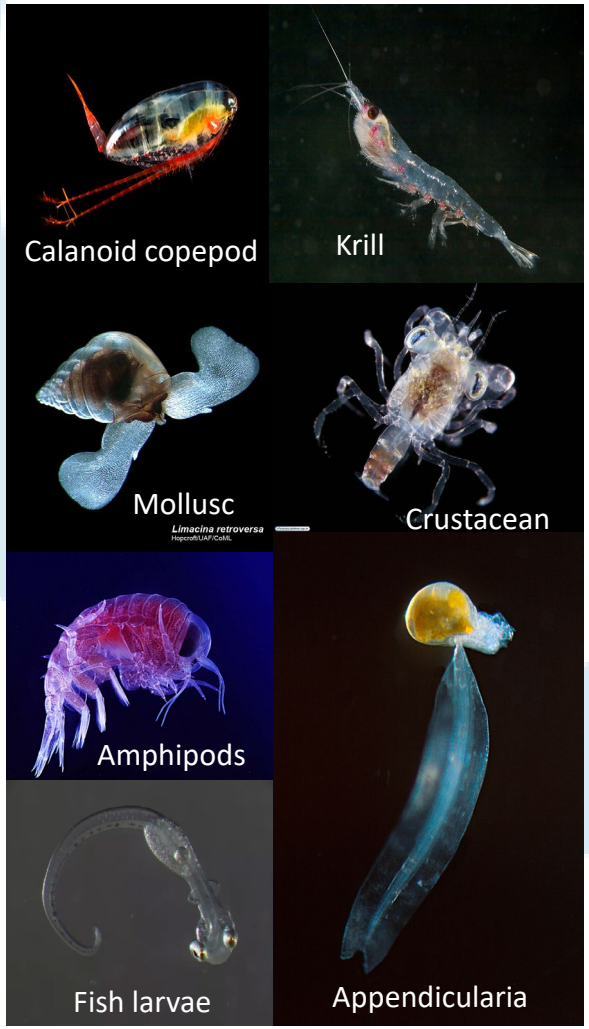


What we already know

- previous studies in the NEA

Mackerel feeding ecology

- Main prey
  - Calanoid copepods
    - especially *Calanus finmarchicus (rauðáta)*
- Other prey
  - Krill
  - Amphipods
  - Molluscs
  - Crustaceans
  - Fish larvae



Herring feeding ecology

- Main prey
  - Krill
  - Amphipods
  - Appendicularia
  - Calanoid copepods
- Other prey
  - Crustaceans
  - Fish
  - Molluscs

What are we working with?

Materials

- **Fish stomachs**
  - Years 2010-2014 (minus 2013)
  - 602 ISS herring stomachs
  - 986 NSS herring stomachs
  - 2419 Mackerel stomachs

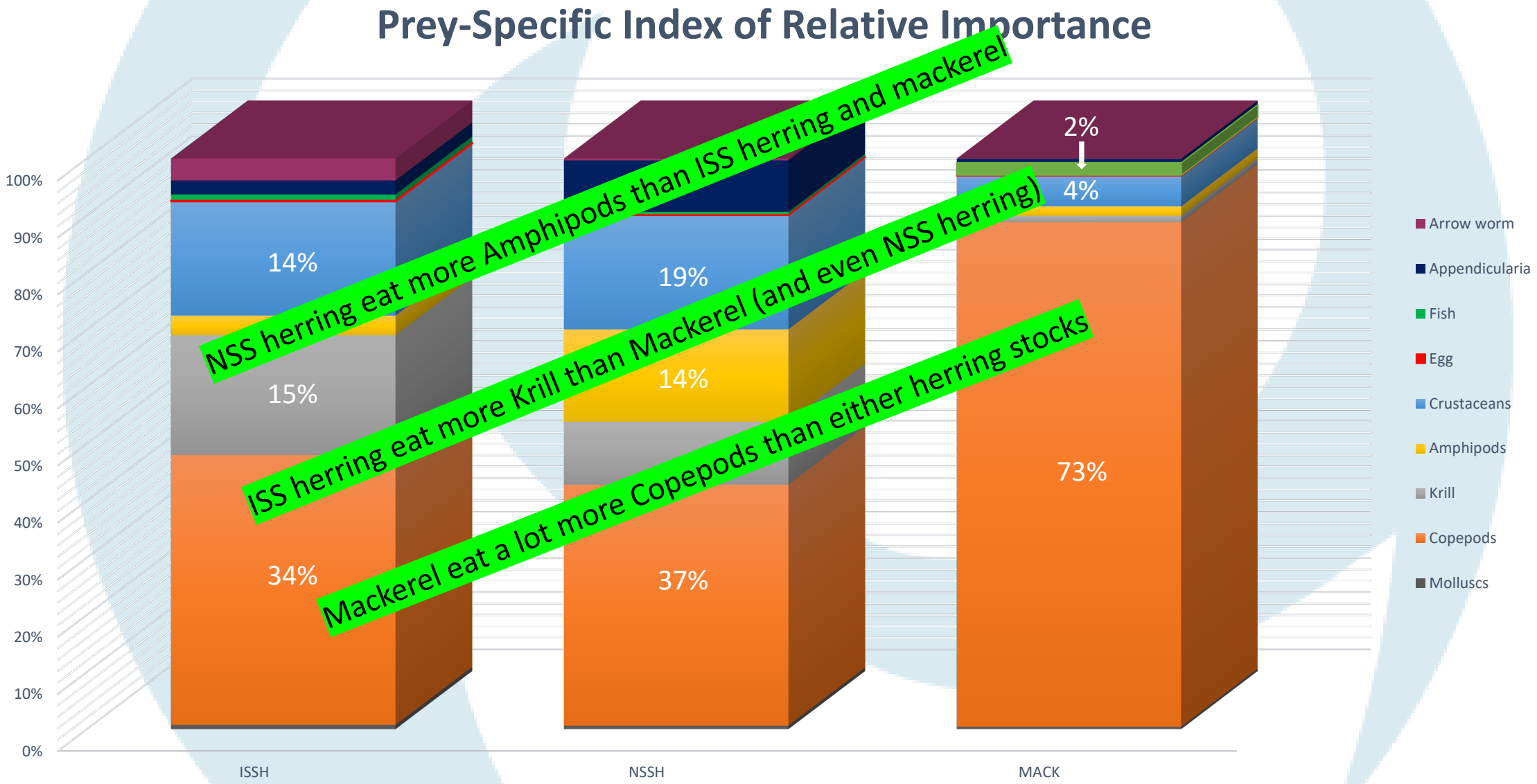
Methods

- **Visual Analysis**
  - Numbers (counts)
  - Weight (wet weight in g)
  - Frequency (%)
  - Prey specificity (only including stomachs with specific prey)
- **Statistical analysis**
  - Grouped prey
  - Transforming data (number bias)
  - PERMANOVA and Kruskal-Wallis

Prey found in mackerel and herring in Icelandic waters

- **Molluscs - Lindýr** (squids, snails - *limacina* sp, mussels)
- **Amphipods - Marflær** (*Themisto* sp, *Hyperia* sp, *Gammaridae* sp)
- **Krill - Ljósáta** (*Thysanoessa* sp, *Meganyctiphanes norvegica*)
- **Crustacea – Krabbadýr** (Mostly larvae from: *Leucon* sp, *Carcinus* sp, *Hymenodora* sp, *Eusergestes* sp, *Balanus* sp)
- **Copepods - Krabbaflær** (*Calanus* sp (rauðáta), *Acartia* sp, *Microcalanus* sp, *Pseudocalanus* sp, *Temora* sp, *Oitona* sp, and many more…)
- **Fish – Fiskur** (Sandeel (Sandsíli)), Capelin (Loðna), Cod (þorskur), Haddock (Ýsa), Whiting (Lýsa), Blue whiting (Kolmunni), Herring (Síld), Spottet wolffish (Hlýri), and many more..)
- **Appendicularia - Möttuldýr** (*Oikopleura* sp)
- **Arrow worm - Pílormar** (*Sagitta* sp)
- **Eggs – Egg** (fish and other)

Feeding Preferences



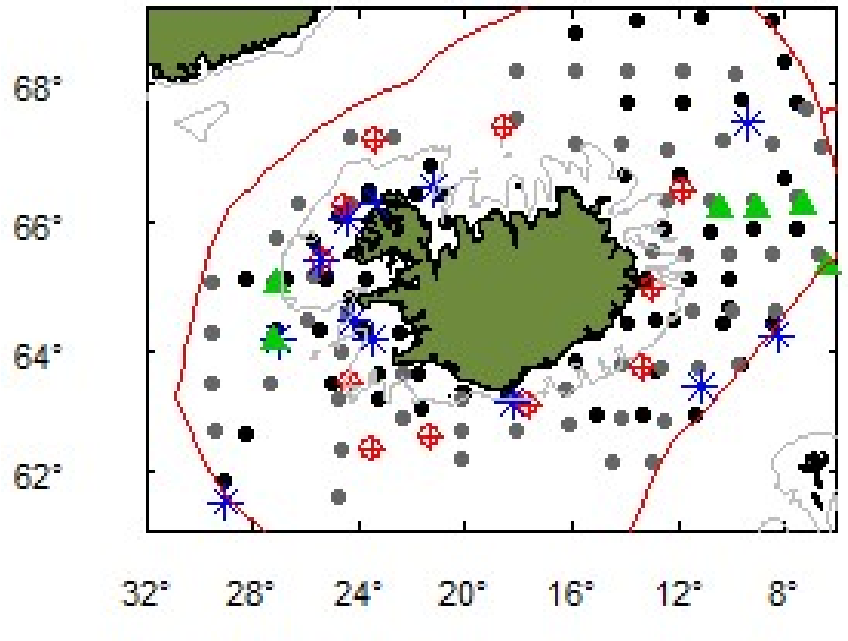
Stable Isotope Analysis

What are we working with?

Materials

- **Dorsal muscle of predator**
  - 117 mackerel
  - 20 ISS herring
  - 40 NSS herring
- **Prey**
  - Zooplankton samples
  - Inhouse samples (Copepods, Amphipods, Krill and Fish larvae)

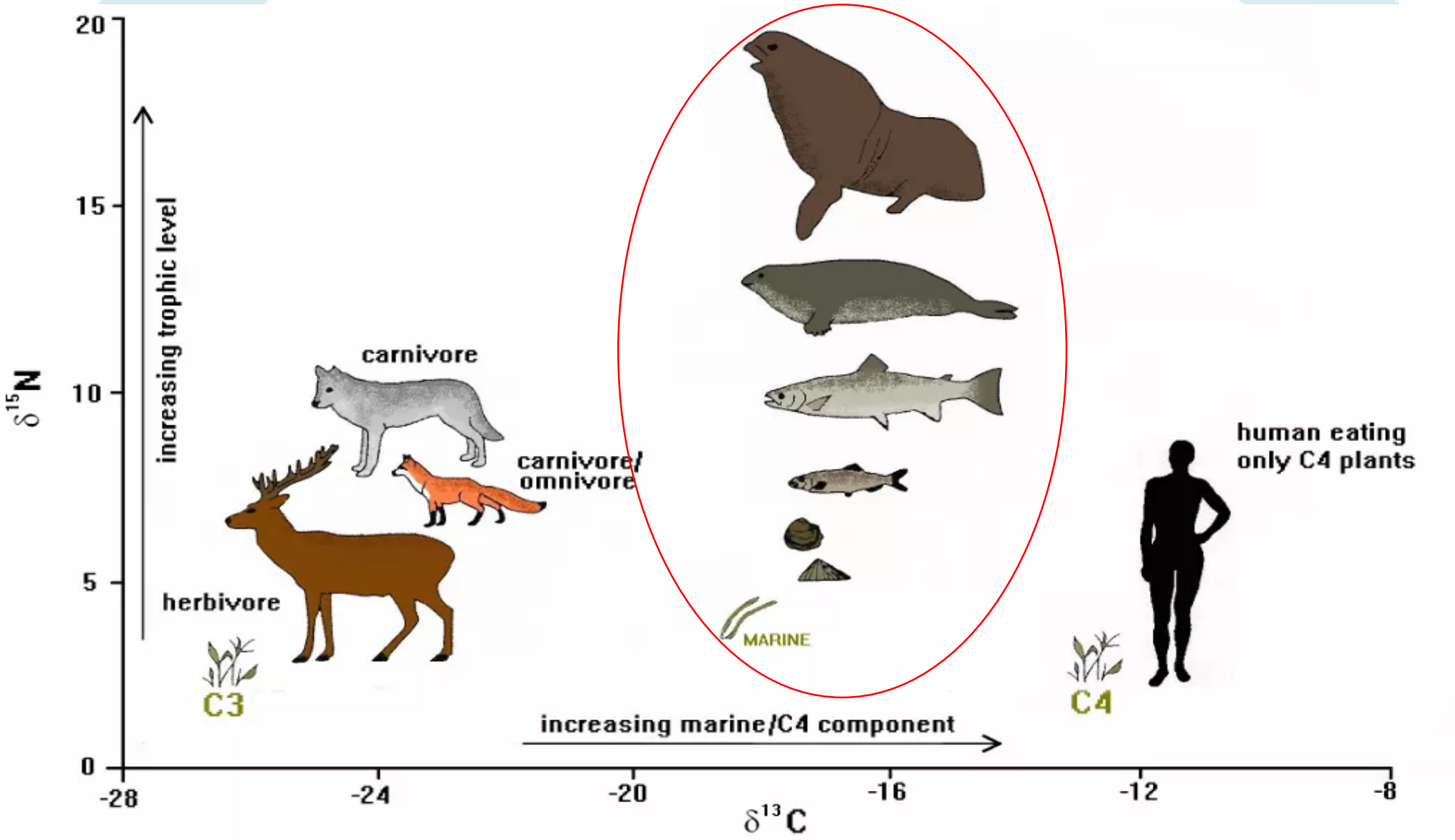
Herring, Mackerel, Prey



Methods

- **Mass spectrometry**
  - Samples dried and grounded
  - Output (δ15N and δ13C)
- **Stable Isotope Analysis**
  - Bayesian Mixing model (MixSIAR)
  - Bayesian Ellipses (SIBER)

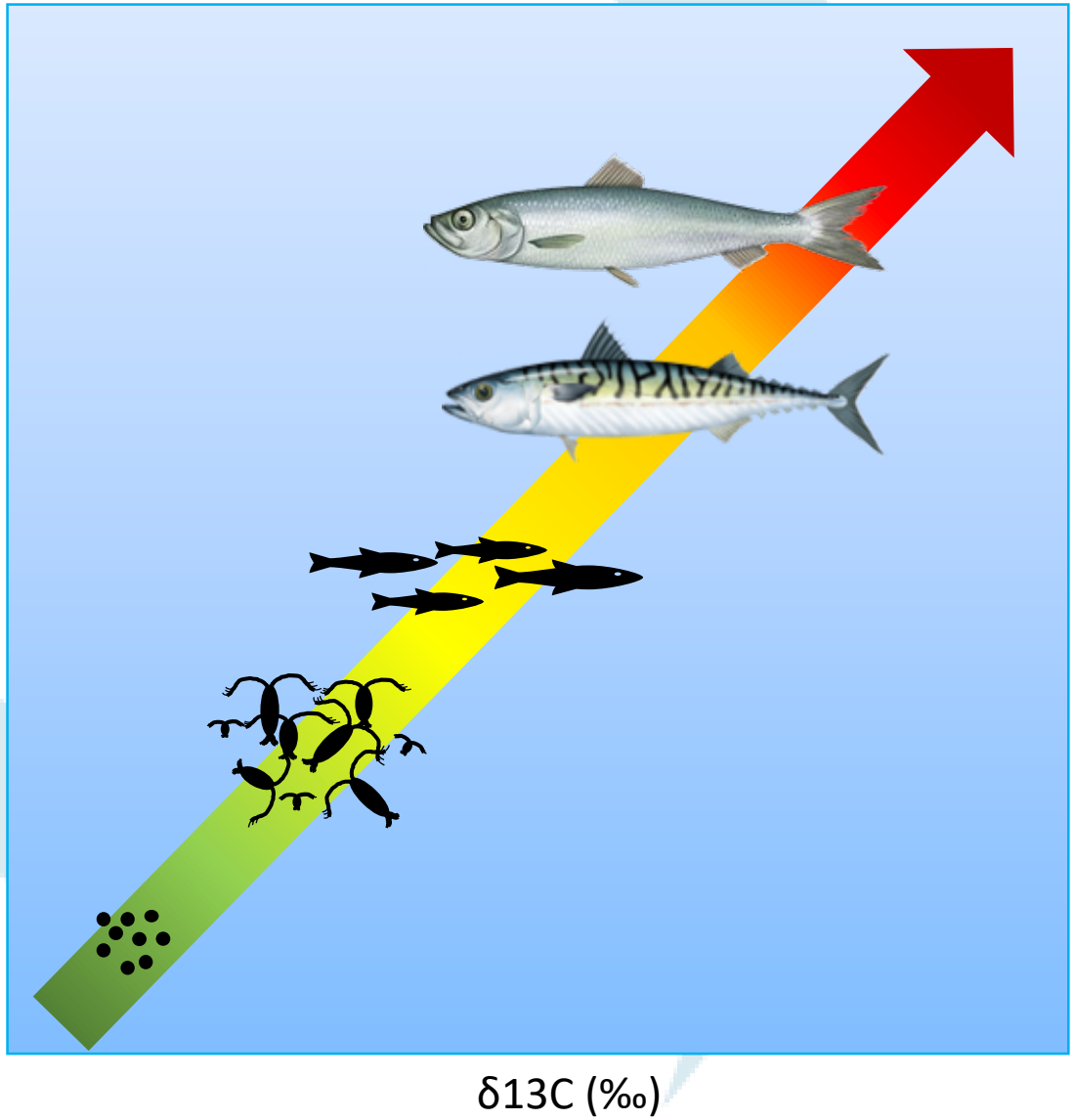
What is stable isotope analysis?



Graph from: https://www.filthymonkeymen.com/2015/05/27/whats-significant-about-carbon-isotopes/

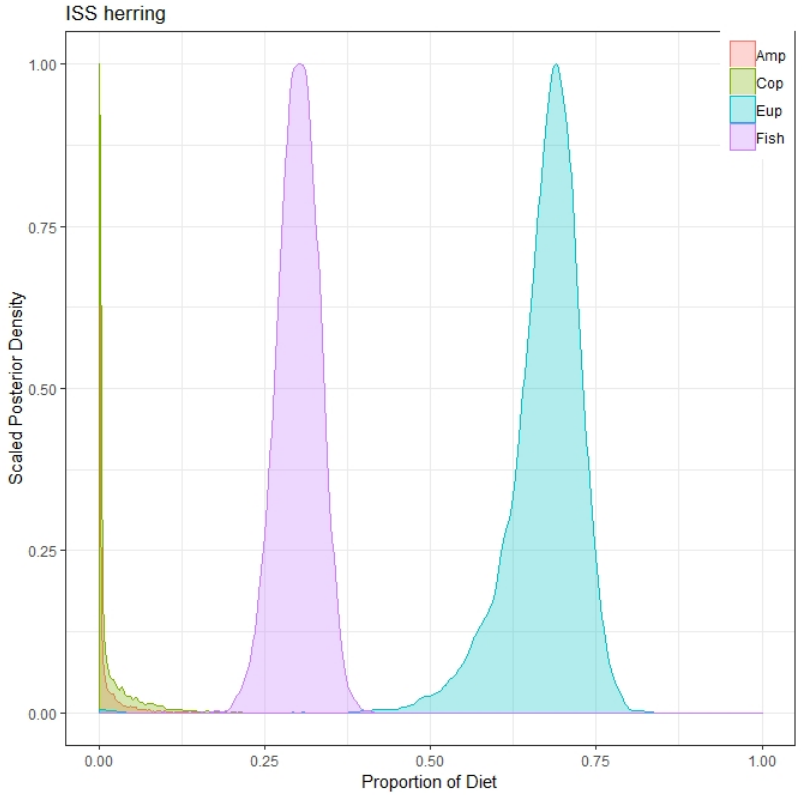
Stable isotope analysis in this study

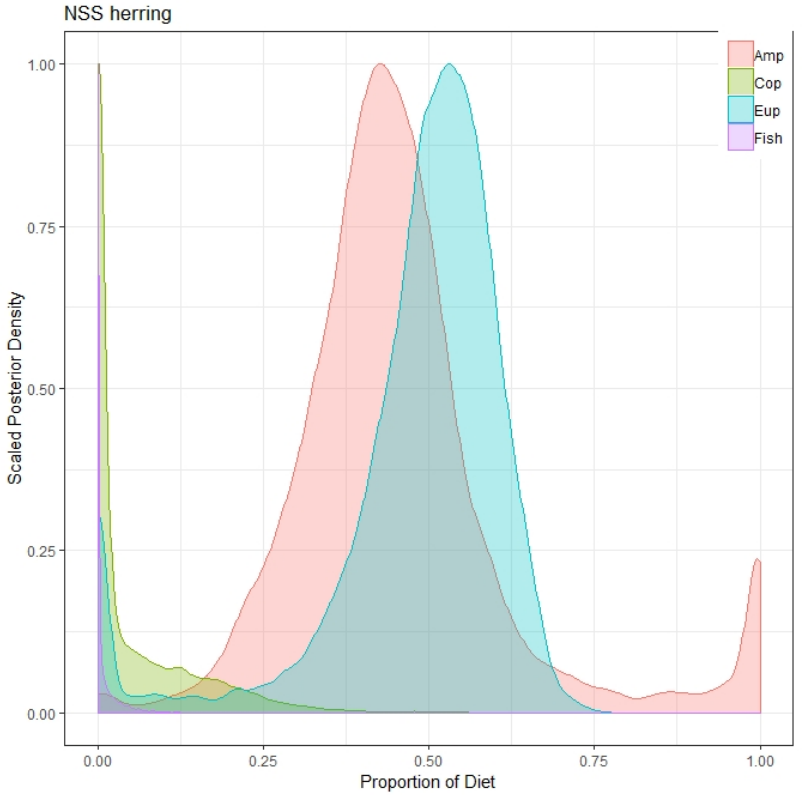
- Identification of isotopic signature and chemical elements within a compound.
- Evaluate dietary components and trophic level of fish
  - δ13C and δ15N
  - Diet switch and/or distribution shifts
  - Ecological dietary niche
- Tissue renewal – at least 3 months (probably more)

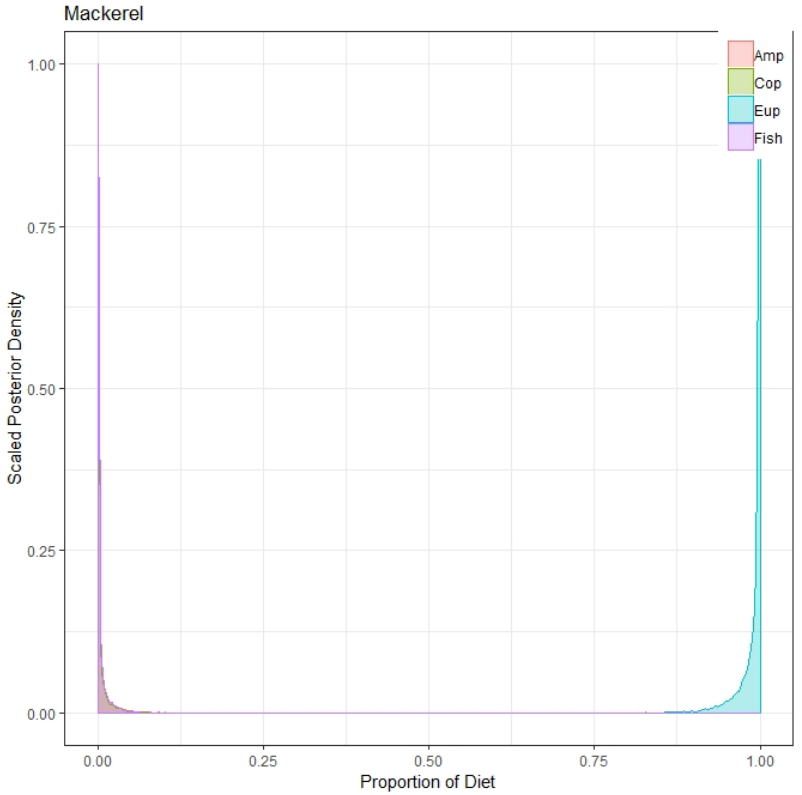


Stable isotopes

-results from a mixing model (MixSIAR)







Prey	50%	CI
Amphipods	0.2%	0-8.5%
Copepods	2.7%	0-22.8%
Krill	64.8%	43.9-75.1%
Fish	30%	23.9-35.4%

Prey	50%	CI
Amphipods	37.4%	18-53%
Copepods	6%	0-29%
Krill	54.3%	39.9-65.9%
Fish	0.1%	0-5.1%

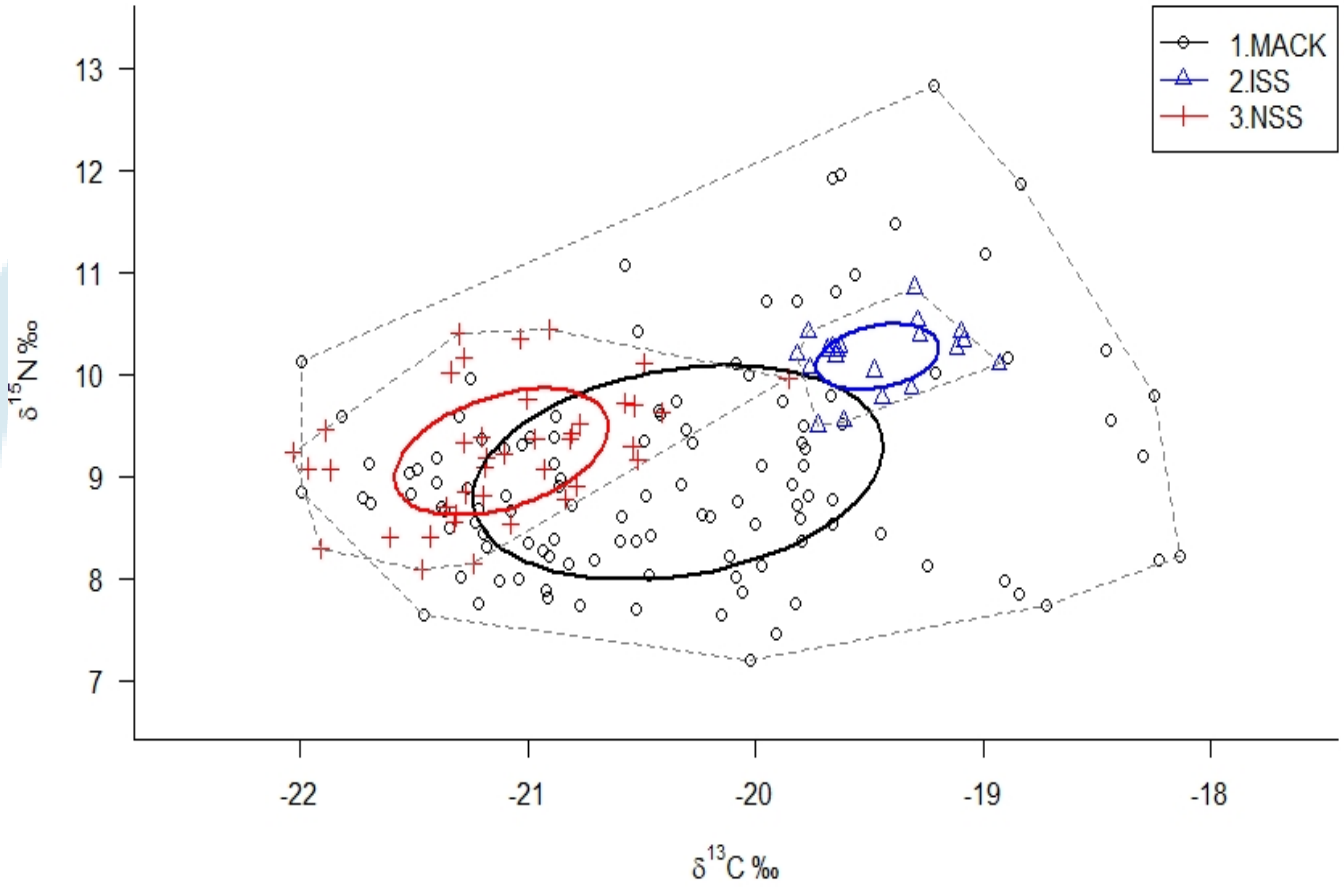
Prey	50%	CI
Amphipods	0%	0-2.2%
Copepods	0%	0-2.8%
Krill	99.8%	95-100%
Fish	0%	0-2.3%

Stable isotopes

Niche – Sess

Standard Ellipse Area

- 42% overlap between NSS herring and mackerel
- 0.12% overlap between ISS herring and mackerel
- No overlap between the ISS and NSS herring



Competition or coexistence?

What we know now!

- **Visual analysis**
  - Copepods are the main prey item in mackerel
  - Amphipods and krill are large contributors to the diet of NSS herring
  - Krill and crustaceans are the are important in ISS herring diet

- **Isotope analysis**
  - Krill are the main contributor to mackerel diet during winter/spring
  - Amphipods and krill are the main contributor to NSS herring during winter/spring
  - Krill and fish are the main contributor to ISS herring during winter/spring
  - ISS and NSS herring occupy different niches
  - Mackerel occupy a broad niche

Industry meets science

-where do we go on from here

- Roughly the presented diet only represent 0.1% of mackerel and 0.02% of herring stocks in Icelandic waters for all the years.
- Diet studies are needed from the rest of the year
- In depth study of pelagic predation of fish larvae (especially by ISS herring)
- Sustainability
- Develop Long-Term Objectives
- Shared Knowledge

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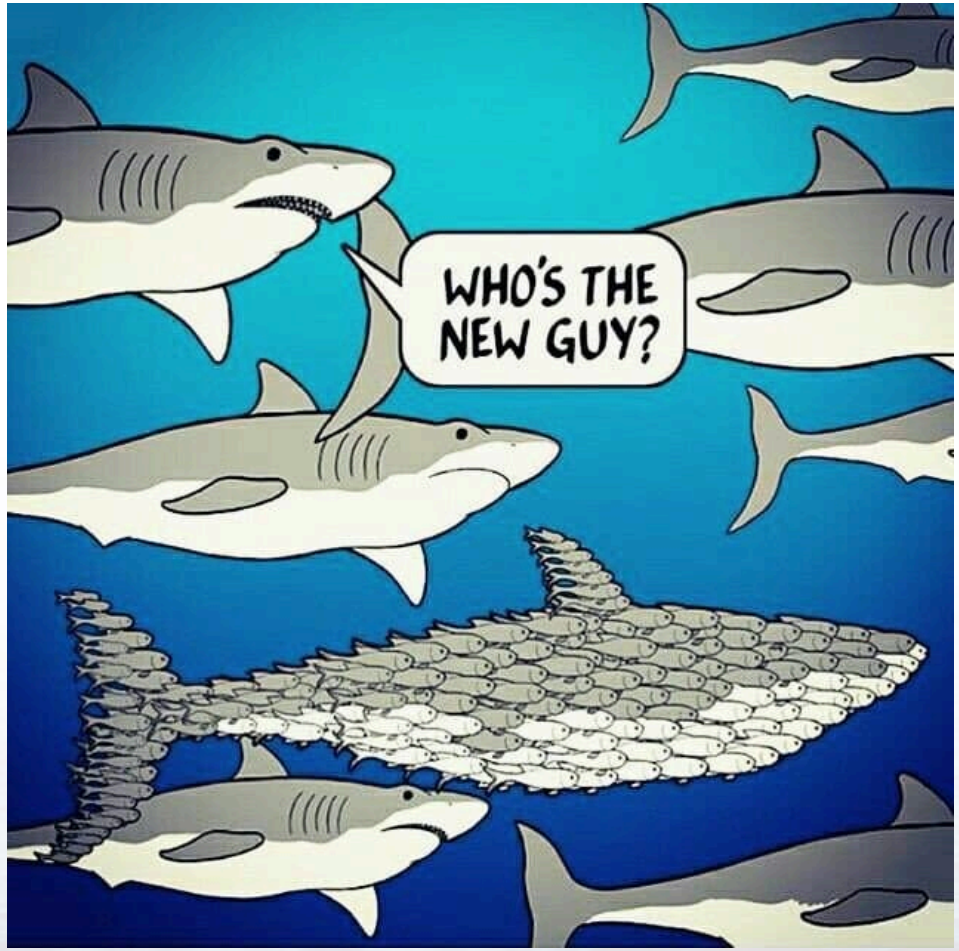
Thank you!



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