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**The Central North Atlantic Marine Historical Ecology Project**  
**Cod and Iceland through the last Millennium**  
**National Science Foundation**  
**Navigating the New Arctic Program Grant #2022656**



# NABO

## North Atlantic Biocultural Organisation

- International – 32 collaborating institutions in 14 nations.
- Interdisciplinary – combines natural sciences, social sciences, history, education, outreach
- Founded 1992 (NSF Workshop), funded by US, UK, Scandinavian sources
- UNESCO BRIDGES Affiliate
- Major Meetings NY 1992, Glasgow 94, Tromsø 96, St. John's 97, Glasgow 01, Copenhagen 04, Quebec 06, Bradford 08, Edinburgh 09, Akureyri 2013, Quebec 2019, Reykjavik 2022, Reykjavik 2026
- Support – Denmark, Iceland, UK, Norway, Canada, US:  
c \$35 million since 1997
- Website: [www.nabohome.org](http://www.nabohome.org)

# Marine Historical Ecology

- Marine historical ecology examines how ocean ecosystems have changed over time by combining historical records (like old fishing logs, nautical charts, and naturalist accounts) with archaeological and paleontological data.
- reveals what marine environments looked like before industrial-scale human impacts, providing crucial baseline data about past abundance, distribution, and ecosystem structure.

# Why? – Shifting Baselines Syndrome

- Each generation accepts degraded ocean conditions as "normal" because they lack knowledge of historical abundance. Historical ecology documents that many fish populations were 10-100x larger just centuries ago, helping us understand the true scale of decline and set appropriate recovery targets.

# Why? – Climate Adaptation

- By studying how marine species responded to past climate changes, we can better predict and manage current responses to ocean warming and acidification. Historical range shifts and population collapses offer lessons for today's conservation strategies.

# Why - Restoration

- Understanding pre-disturbance conditions helps set realistic restoration targets. For instance, historical oyster reef extent shows these structures once protected many coastlines now vulnerable to storms - informing nature-based coastal defense projects.

# Why – Biodiversity Management

- Understanding the extent of species diversity in the past can help in restoration efforts as well as understanding the potential of marine systems in the future.
- Whales before the great kill-off.

# Why? Fisheries Management

- Historical catch records reveal that many "sustainable" fishing quotas are based on already-depleted baselines. This has led to reforms in how we calculate maximum sustainable yield and ecosystem-based management approaches.

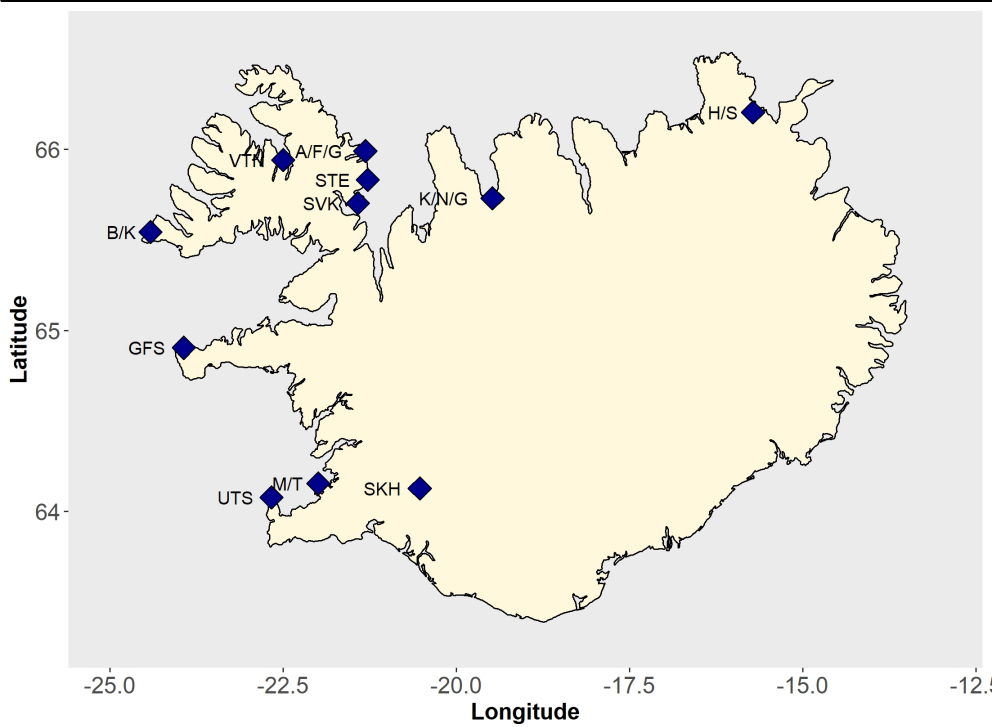
# Building a Millenium Scale Paleoecology for the Icelandic North Atlantic

- Mobilizing archaeological and historical material to address 'Shifting Baselines' in marine systems by creating deeper time records of the relationship between Atlantic Cod, Humans, and the environment/climate
- Heavily influenced and inspired by Marine Historical Ecology and the OPI initiative as well as the work of Guðbjörg Olafsdóttir and Ragnar Edvardsson and many others



# How? Using fish bones from archaeological sites dating from the 9<sup>th</sup> to the 19<sup>th</sup> centuries in Iceland: Sites Samples (MNI measurable elements)

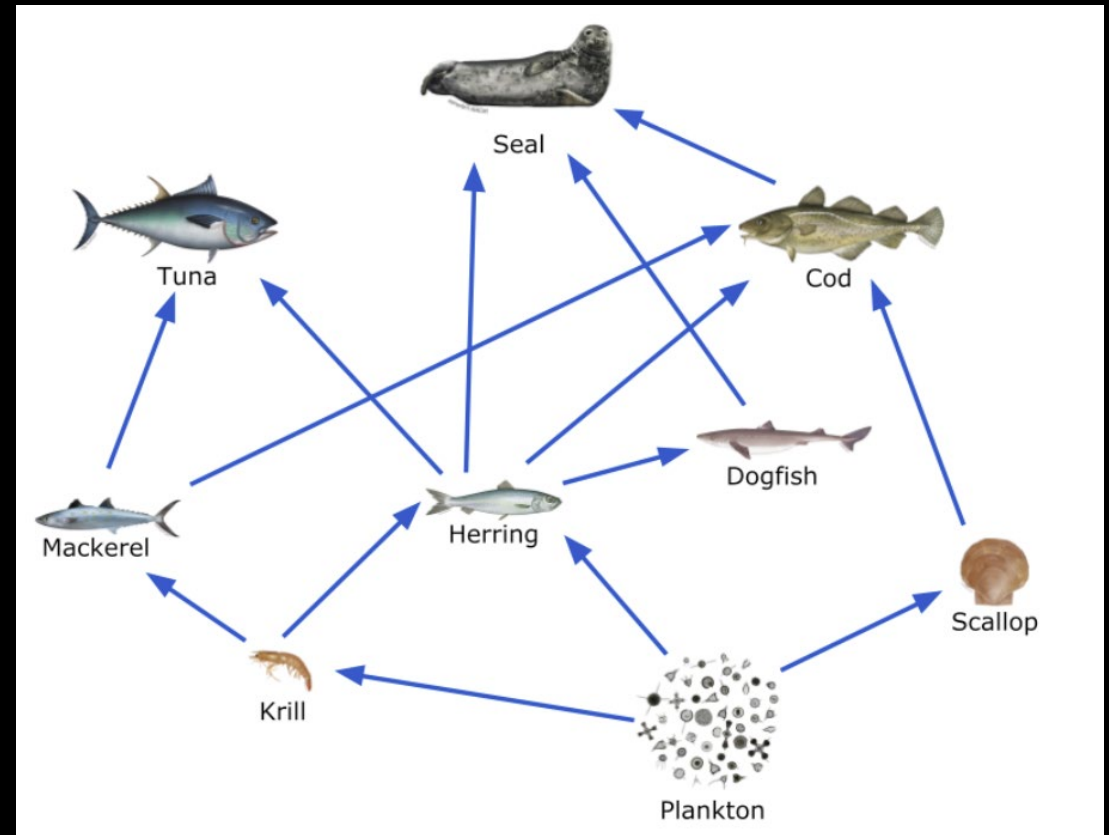
Site	Dates	Location	Ref	Lat	Long	Num.otoliths
Akurvik	mid 12th-16th century	NW Fjords - Húnaflói	Amundsen et al 2004	65.9918	-21.3149	48
Gjogur	14th century	NW Fjords - Húnaflói	Kirovgorskaya et al 2005	65.9877	-21.3506	3
Gufuskalar	15th century	West coast - Snæfellsnes	Feeley et al 2010	64.9040	-23.9360	54
Finnbogastadir	18th century	NW Fjords - Húnaflói	Edvardsson et al 2004	66.0124	-21.4948	0
Skalholt	late 17th century	South	Hambrecht 2011	64.1281	-20.5291	0
Tjarnagata 3c	late 18th early 19th century	Reykjavik	Perdikaris et al 2002	64.1454	-21.9442	0
Sandvik	10th century	NW Fjords - Húnaflói	n/a	65.7027	-21.4240	0
Moakot	18th century	Reykjanes Peninsula	n/a	64.1551	-21.9956	0
Hjalmarvik	10th - 14th century	NE Iceland	Dupont-Hebert 2020	66.2218	-15.6464	0
Utskalar	early 11th-mid12th century	Reykjanes Peninsula	n/a	64.0778	-22.6673	6
Kollsvik	mid 18th century	NW Fjords - Breiðafjörður	Edvardsson et al 2020	65.6070	-24.3416	48
Kotid	late 9th-10th century	Skagafjord	Cesario 2021	65.7296	-19.4785	6
Svalbard	15th-18th century	NE Iceland	Dupont-Hebert 2020	66.2045	-15.7186	0
Vatnsfjord	18th-early 19th century	NW Fjords - Húnaflói	McGovern et al NORSEC 2005	65.9420	-22.4987	42
Strakey	11th century	NW Fjords - Húnaflói	n/a	65.8324	-21.2805	12
Næfurstaðir	10th century	Skagafjord	Hegranes Cesario	65.6902	-19.4636	12
Grænagerði	10th century	Skagafjord	Hegranes Cesario	65.7202	-19.4681	14
Breidavik	early 15th-19th century	NW Fjords - Breiðafjörður	Edvardsson et al 2020	65.5435	-24.4145	368



Fornleifastofnun Islands/Archaeology Institute Iceland, NABO,  
 University of Iceland, University of Massachusetts Boston,  
 Universite Laval, Quebec, University of Maryland, City University of New York

# Trophic and primary productivity reconstruction – Moshfeka/Misarti/Efird

- Changes in Atlantic Cod diet over the last 1100 years around Iceland
  - Proxy for marine ecological change
- Compound specific analysis for primary productivity proxies – plankton productivity through time.
- Following Olafsdóttir and Patterson and others.... But building on the Pacific experience – Misarti, West, Szpak etc.



# Age-size relationships in Atlantic Cod Campana/Moshfeka/Efird

- Growth rates through time.
- Memory and perception
  - How 'big' is a big fish?
    - We are tracking this across the last millennium
  - How old is a big fish?
    - Investigate spawning years.
- Coupling the size data with trophic data from the same specimen.
- Building on and possibly changing our NABO fish trade story.



Images from the Idaho Virtual Museum

# Historical Context - Juliusson

- Fish demographics have led to a rewrite of Icelandic human demographics.
- Every specimen we are using was recovered by a human.
- The historical work gives us data on the motivations and constraints operating in Iceland
- Dr Arni Daniel Juliusson

1478.

HJARÐARHOLT.

165

eignar og frialz forræðiss með ollum þeim gognum og giædum sem greindre jordu fylger og fylgtt hefur að fornu og nýju og hann varð fremst eigandi að skilldi optnefndur herra Magnus suara lagaripptingum a greindri jordu. enn þráttnefndur Ormur<sup>1)</sup> hallda til laga.

og til sanninda hier vm et cetera.

162.

4. Október 1478. á Helgafelli.

SAMNINGUR milli þeirra Halls prests Þórarinssonar og Böðvars prests Jónssonar með ráði Magnúsar biskups í Skálholti, að séra Böðvar lofar smá saman, eptir því sem honn aflist fé, að greiða Hjarðarholtakirkju fimtán hundruð i porcionem um þau sextán ár, sem hann hélt þann stað.

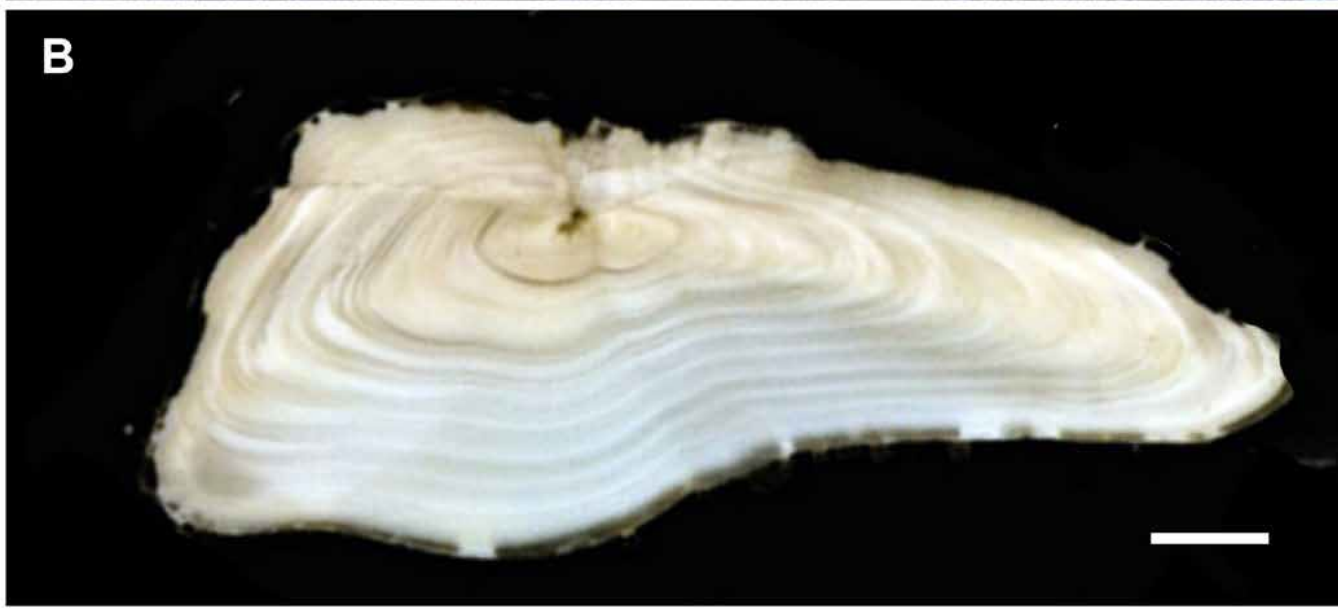
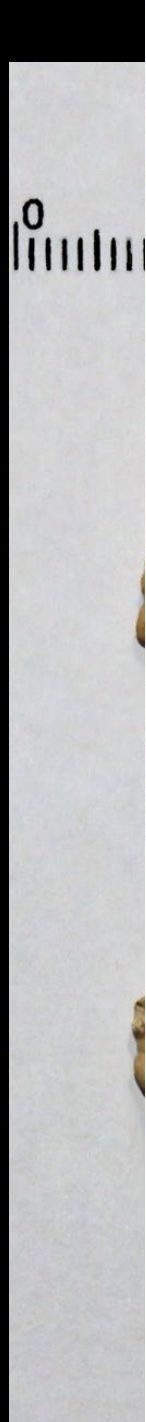
AM. Apogr. 2278 „Ex originali Hiardarholt. accuratissime. Inn-eiglen eru öll fra brefinu, og sialft brafed so meirt og fued, að það innann skams af sialfu tier forgeingur, og hanger nu ecki saman. Er og þegar so að kalla eydelagt. Það sem hier er understrikad<sup>2)</sup>, er nu burt mollnad ur brefenu, enn þeir underpunctudu staferner eru miög litt læser. Epter þennan dag mun eingenn þetta bref lesa“. (AM.). Af-skriptin er með hendi Árna Magnússonar.

Þat giorum wer oddur prestur oddzson. narfe þ[or-u]all[dz]son. einar þorolfsson. helgi þornalldzson [jon einar]son<sup>3)</sup> godum monnum uiturligt með þessu woru opnu brefi. anno domini. M. cd<sup>o</sup>. lxx. octauo. a sunnudaginn næsta efter michaelsmessu j [ab]otastofunne á helgafelli. worum wær j hia sáum ok heyrðum á ord ok handaband þessara manna. af einne alfu herra magnus med gudz nad biskup(s) j schalholte ok sira hallz þórarinssonar. enn af annari sira boduars jónssonar. at suo firir skildu. at greindur herra magnus giordi suo felldan giorning ok sáttmala mille adr skrifadra presta sira hallz ok sira boduars. at sira boduar jónsson lofade at giallda kirkiunne j hiardarholte j laxardal j

<sup>1)</sup> Svo. <sup>2)</sup> Hér í hornklofum. <sup>3)</sup> „Hier hefur staded eitthvad stutt safn, so sem vera kynni jon einarsson eda annad þvilikt“ (AM.).

Otoliths – (if a fish had an ear this would be its ear bone)  
Campana et al 2025 – Science Advances

- O18 SST
- Age-at-death
- Size (forklength)
- Individual growth rates
- Trophic data
- When larger numbers are present - mortality curves.
- Campana and Misarti



<https://www.science.org/doi/10.1126/sciadv.adt4782>

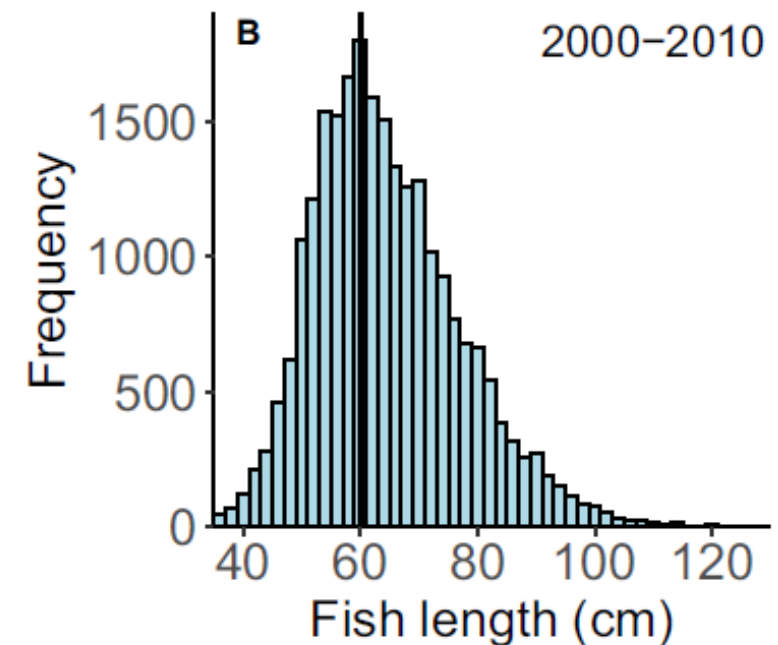
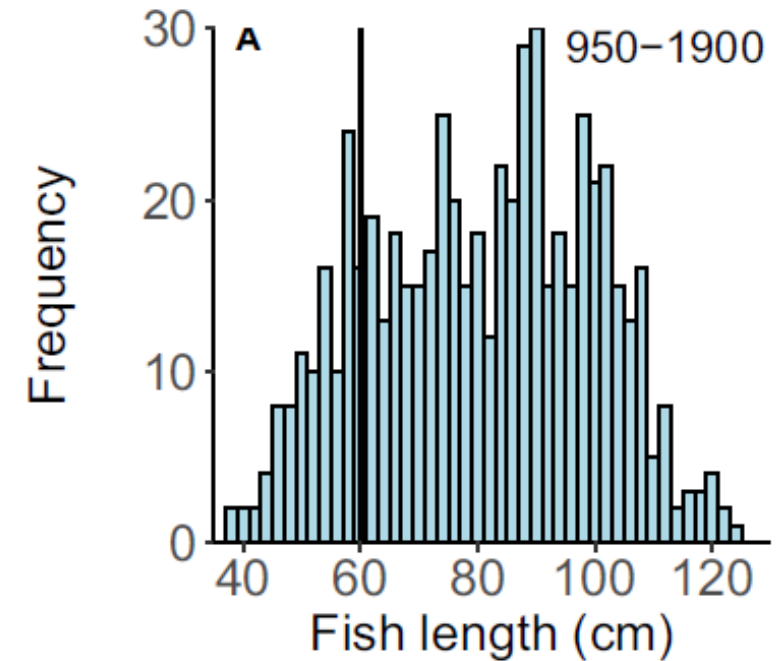
2025 Campana, Hambrecht, Misarti, Moshfeka, Efird, Shaal, Olafsdóttir, Edvardsson, Júlíusson, Hjörleifsson, Feeley, Cesario, Palsdóttir

The screenshot shows the Science Advances website interface. At the top, the journal name "ScienceAdvances" is displayed in red and black. Navigation links include "Current Issue", "First release papers", "Archive", and "About". A "Submit manuscript" button and "GET OUR E-ALERTS" link are also visible. The article title "Mortality drives production dynamics of Atlantic cod through 1100 years of commercial fishing" is prominently displayed in bold black text. Below the title, the authors' names are listed: STEVEN E. CAMPANA, GEORGE HAMBRECHT, NICOLE MISARTI, HABIBA MOSHFEKA, MARY EFIRD, SÁRA M. SCHAAL, GUDBJÖRG ÁSTA ÓLAFSDÓTTIR, RAGNAR EDVARDSSON, ÁRNI DÁNIEL JÚLÍUSSON, and LILJA BJÖRK PALSÓTTIR. The article is categorized as a "RESEARCH ARTICLE" in "ECOLOGY". The abstract begins with: "Most edible fish species have been fished for centuries or millennia, leaving little record or understanding of their population responses prior to human impact and thus no baseline for population conservation. Here, we reconstruct the population dynamics of Atlantic cod, one of the world's most harvested fish species, from the pristine state during the Viking era through more than 1100 years of fishing. Analysis of cod otoliths recovered during archaeological excavations of Icelandic fish processing sites revealed that cod in the 10th to 12th centuries were 25% larger and up to 300% older than modern, despite slower density-dependent growth rates attributed to the sixfold increase in abundance. Fishing mortality came to dominate a time-invariant natural mortality rate and other population characteristics after the 14th century, with minimal evidence of environmental effects at the continental scale." The right side of the page features a "CURRENT ISSUE" section with a cover image of a green leaf and two article titles: "Traction force and mechanosensitivity mediate species-specific implantation patterns in human and mouse embryos" and "Complex II assembly drives metabolic adaptation to OXPHOS dysfunction".



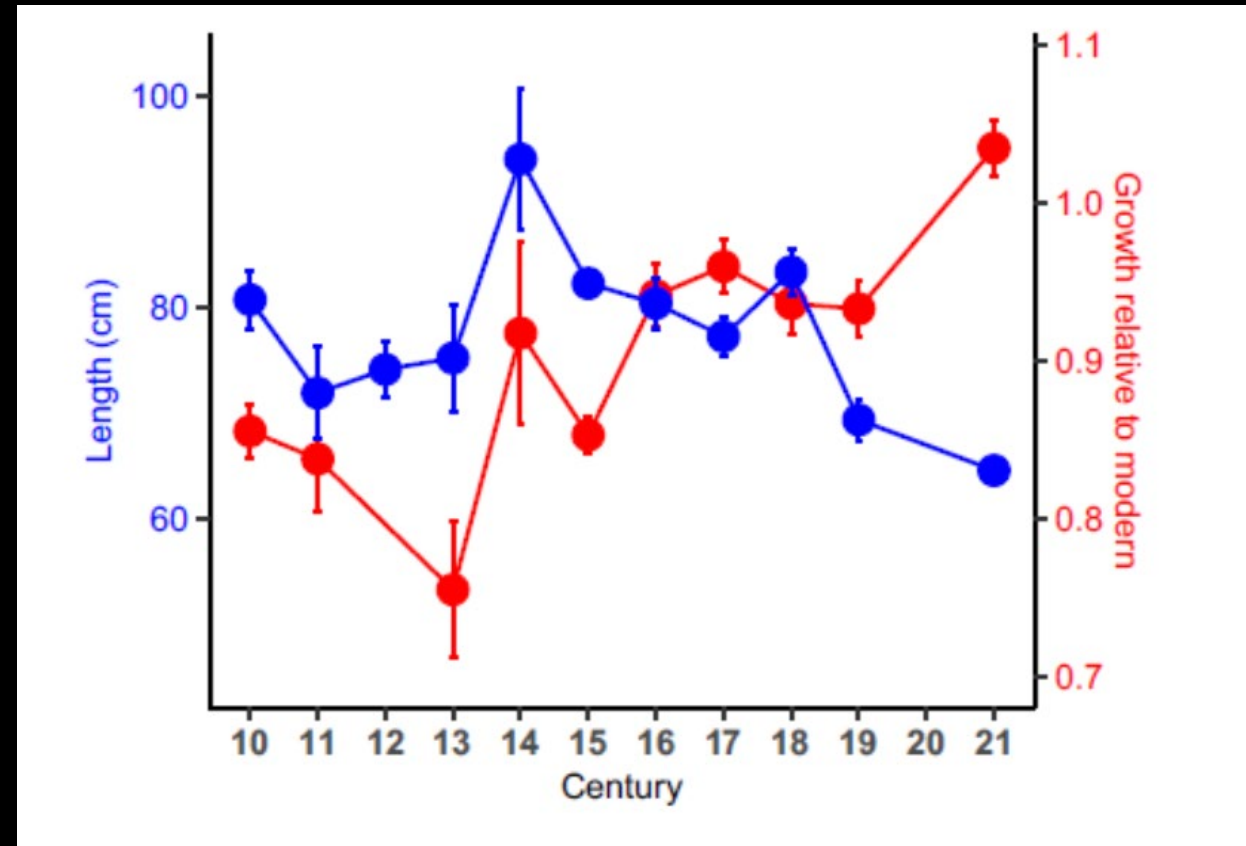
# Size Change through Time

- Our size record goes back to 950 CE
- Possibly an obvious point – but now very well illustrated
  - Cod were a lot bigger before the advent of modern fisheries



# Size and Growth Rate

- Fish were bigger and they also grew much more slowly in the past
  - Density dependence – more fish meant more competition and slower growth
- Possible disconnect between size and age
  - The size of a fish might no longer correlate with perceived age
  - The big ones are younger than we might think – increased pressure on reproductive capacity...



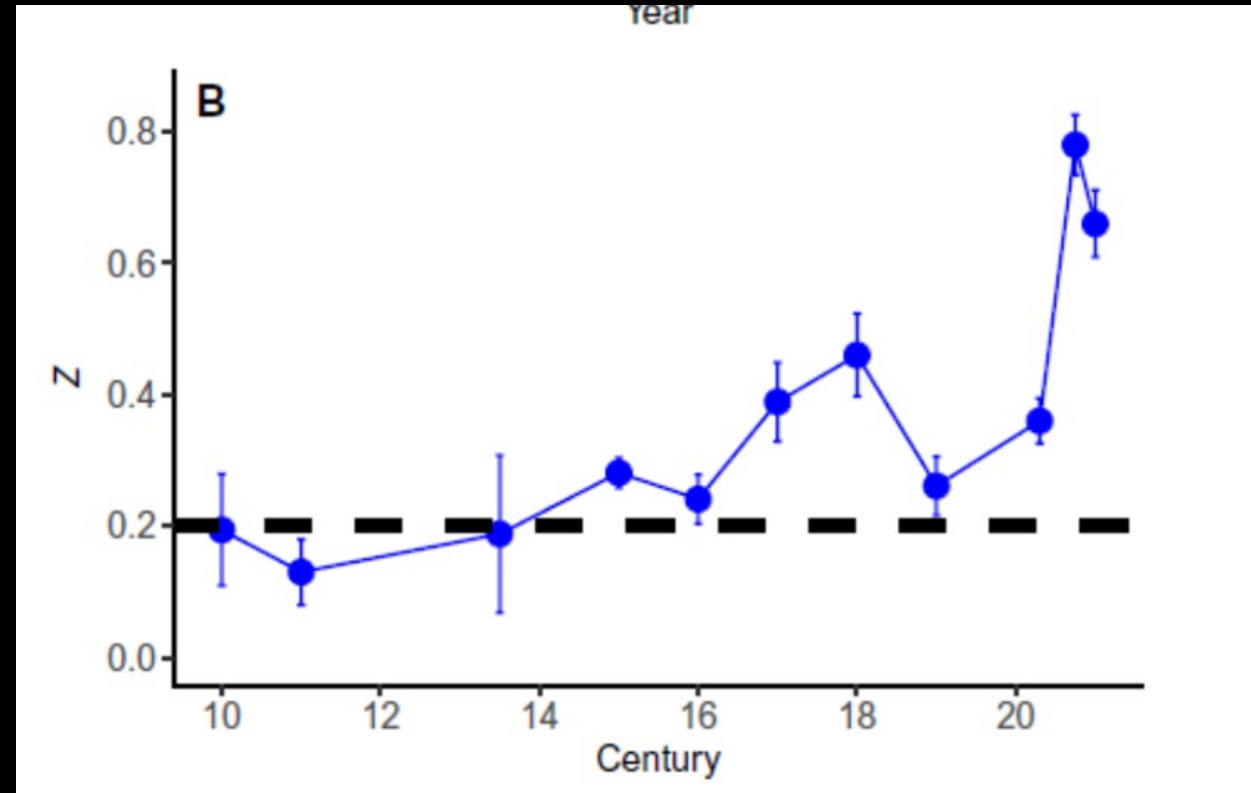
# Mortality Curves for Atlantic Cod Campana

- Mortality curves and demographic change in Atlantic Cod – through otolith analysis as well as SI and allied aDNA projects.
- Preliminary results are surprising and have been presented to fisheries stakeholders....
- While we anticipate that all of our data will be of interest to fisheries stakeholders – this first dataset has created great interest.
- Campana



# Mortality Curves

- How many fish die in a population that is not being fished – how many die naturally?
- This ( $z$ ) is a baseline statistic fisheries use to determine catch levels.
- Today, Atlantic Cod ' $z$ ' is assumed to be .2 (this translates to a rough 18% natural mortality rate)
- We were able to test this metric against a 1000 years of data on Atlantic Cod – *what was especially important was our ' $z$ ' in the periods before intensive fishing.*
- Our data is telling us that the fisheries assumed ' $z$ ' is correct.



# Way forward

- Possible way to determine age of sexual maturity
- Trophic reconstruction – paleoecology of the Icelandic coastal marine ecology
- Trophic life histories of individual fish through time – SI analysis of vertebral increments – Efir
- aDNA parallel pathways
- Communication with fisheries industry



If the past  
teaches what  
does the  
future learn?

- Our work suggests that in the case of Icelandic Cod fisheries 'z' is correct. Overfishing is a more complex problem than a misaligned mortality rate.
- Human induced pressure on Icelandic Cod begins in the 15<sup>th</sup> century (not the 19<sup>th</sup>)
- The relationship between size and age changes through time – the size of a fish is not guarantee of age (and reproductive potential/capacity) – this particular point is not a new discovery, it is just something that can now be well illustrated with archaeological data.
- Is any of this useful to modern fisheries managers?
- 2025. Campana, Hambrecht, Misarti, Moshfeka, Efird, Shaal, Olafsdottir, Edvardsson, Juliusson, Hjorleifsson, Feeley, Cesario, Palsdottir. Mortality Drives Production Dynamics of Atlantic Cod Through 1100 Years of Commercial Fishing. Science Advances, vol 11, issue 6. - <https://www.science.org/doi/full/10.1126/sciadv.adt4782>



**REYKJAVÍKURAKADEMÍAN**

