Exploring relationships between decapods, cod and temperature through time-series analysis: What we have learned in the northwest Atlantic

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Inspiring Minds

Background

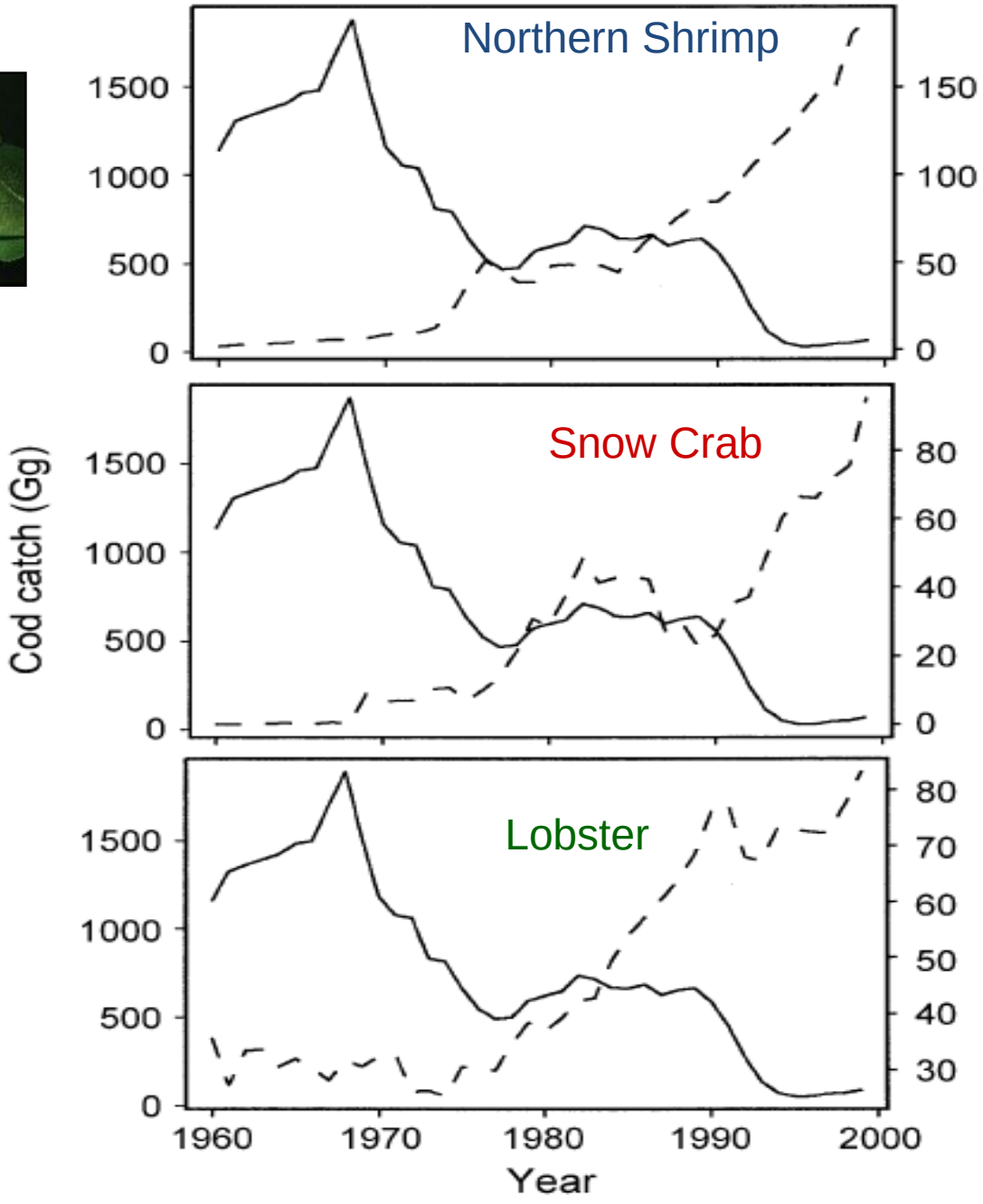
- Lucrative invertebrate fisheries worldwide can show rapid declines, slow recovery
  - Red King Crab, Sea Urchins, Abalone
- Different trend in Atlantic Canada
  - Snow crab, American Lobster
- Proposed Mechanisms:
  - Temperature (climate)
  - Release from predation (top-down)

2009 Economic Value of Atlantic Canada's Commercial Landings (Million dollars)

American Lobster	= $ 495 M CAD
Snow Crab	= $ 311 M CAD
Shrimp	= $ 190 M CAD
Atlantic Cod	= $ 24 M CAD

- Socio-economic: On average 91% of the income of inshore fishers in SW Nova Scotia came from lobster fishing (N= 42/937)

http://www.dfo-mpo.gc.ca/stats/commercial/land-debarq/sea-maritimes/s2009av-eng.htm



Worm & Myers, 2003.
Ecology 84(1) 162-173

Research Questions

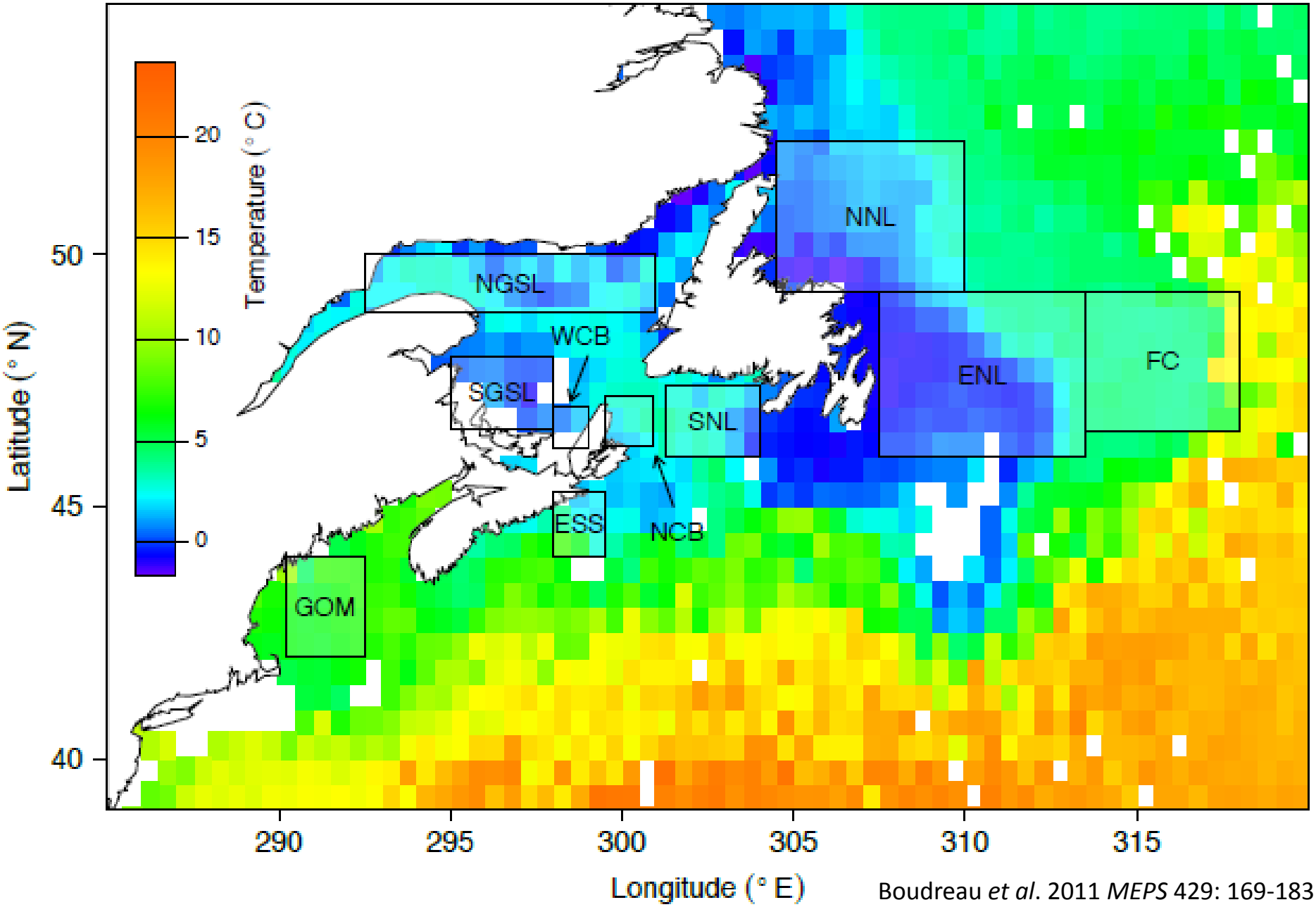
Mechanisms regulating decapod abundance:

- H_1: **Top-down control**
  - negative correlations between cod (predator) and decapod (prey)
- H_2: **Climate control**
  - correlations with ocean temperature
- H_3: **Bottom-up control**
  - positive correlations between cod and decapod

General Approach

- Realization of large-scale predator removal experiment
- Examined correlations between available time series across regions in the NW Atlantic.
- Data:
  - Atlantic cod *Gadus morhua* (NAFO & DFO)
  - Northern shrimp *Pandalus borealis* (NAFO)
  - Snow crab *Chionoecetes opilio* (DFO, NEFSC, IIM)
  - American lobster *Homarus americanus* (NMFS, LEK)
  - Temperature (DFO)
- Time lags when appropriate

Study Regions & Temperature Regimes

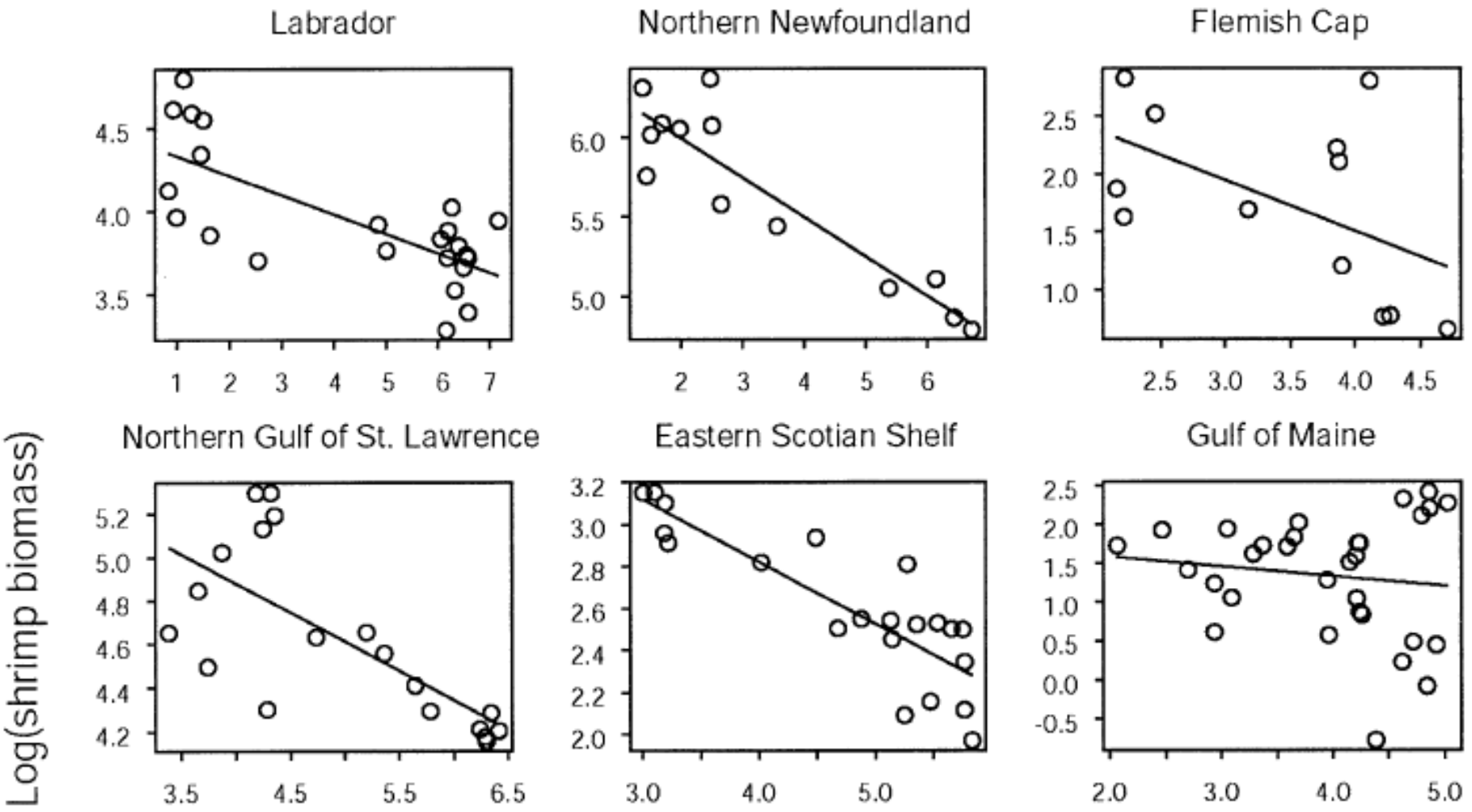


Boudreau *et al*. 2011 *MEPS* 429: 169-183

Top-Down: Atlantic Cod Diet (averaged across studies)

- Northern shrimp (*Pandalus borealis*)
  - 5.0 – 9.3% (Number of studies=6)
- Snow crab (*Chionoecetes opilio*)
  - Occurred 5.0 – 15.0 % (N=6)
- American lobster (*Homarus americanus*)
  - Occurred 0.05 – 0.31 % (N=2)

Atlantic Cod and Northern Shrimp Biomass in the Northwest Atlantic Ocean



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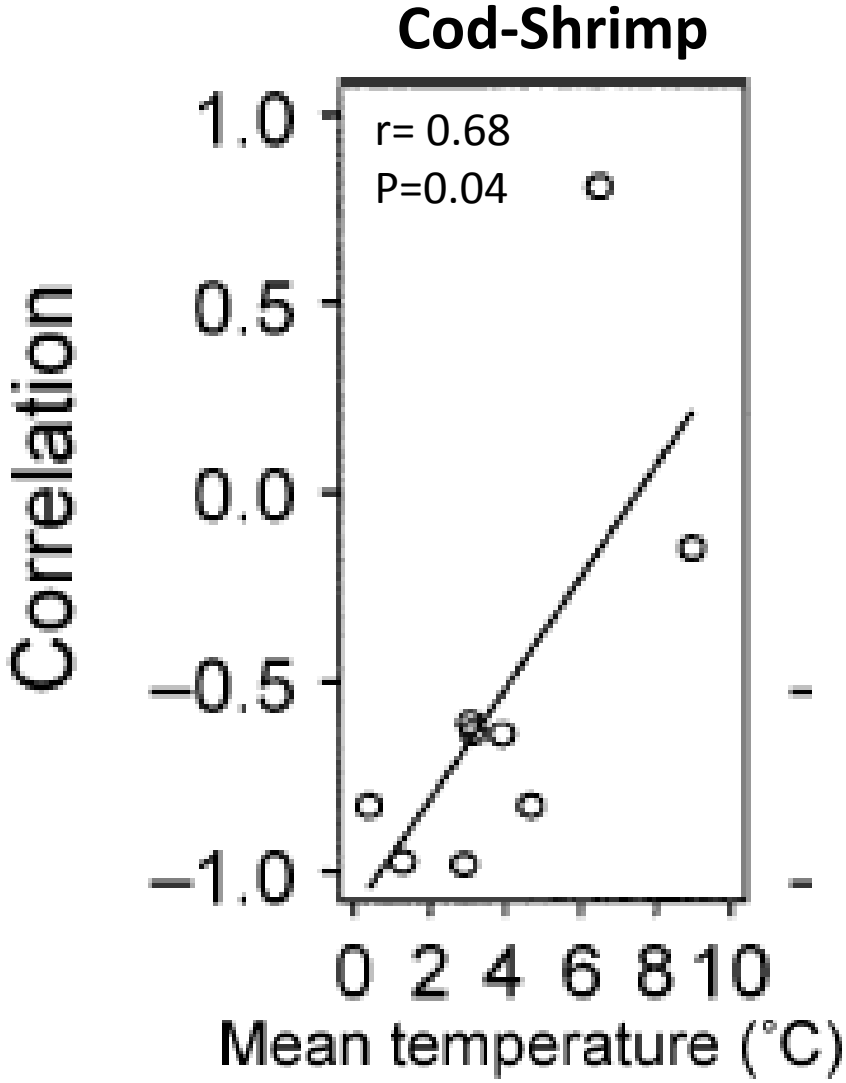
Cod & Shrimp Correlations with Temperature

Meta-analysis

(weighted mean r):

Correlation	r	P-value
Cod-Shrimp	- 0.636	**0.007**
Cod-Temperature	0.494	**0.000**
Shrimp-Temperature	- 0.240	0.094



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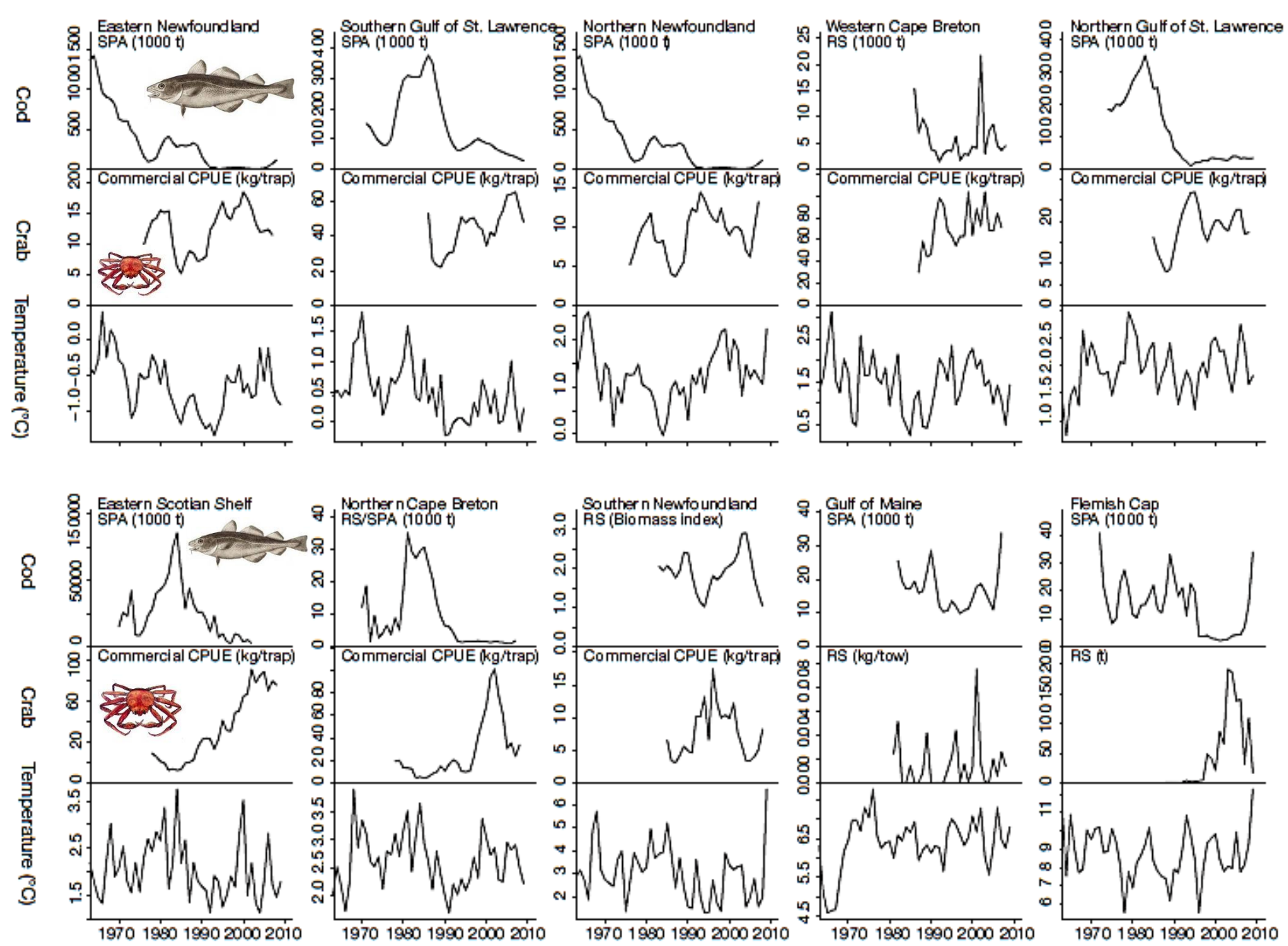

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Meta-analysis

Analyzing replicated time series from multiple regions together can provide insight into ecosystem interactions

Data: Cod and snow crab abundance time series from 10 regions in the NW Atlantic

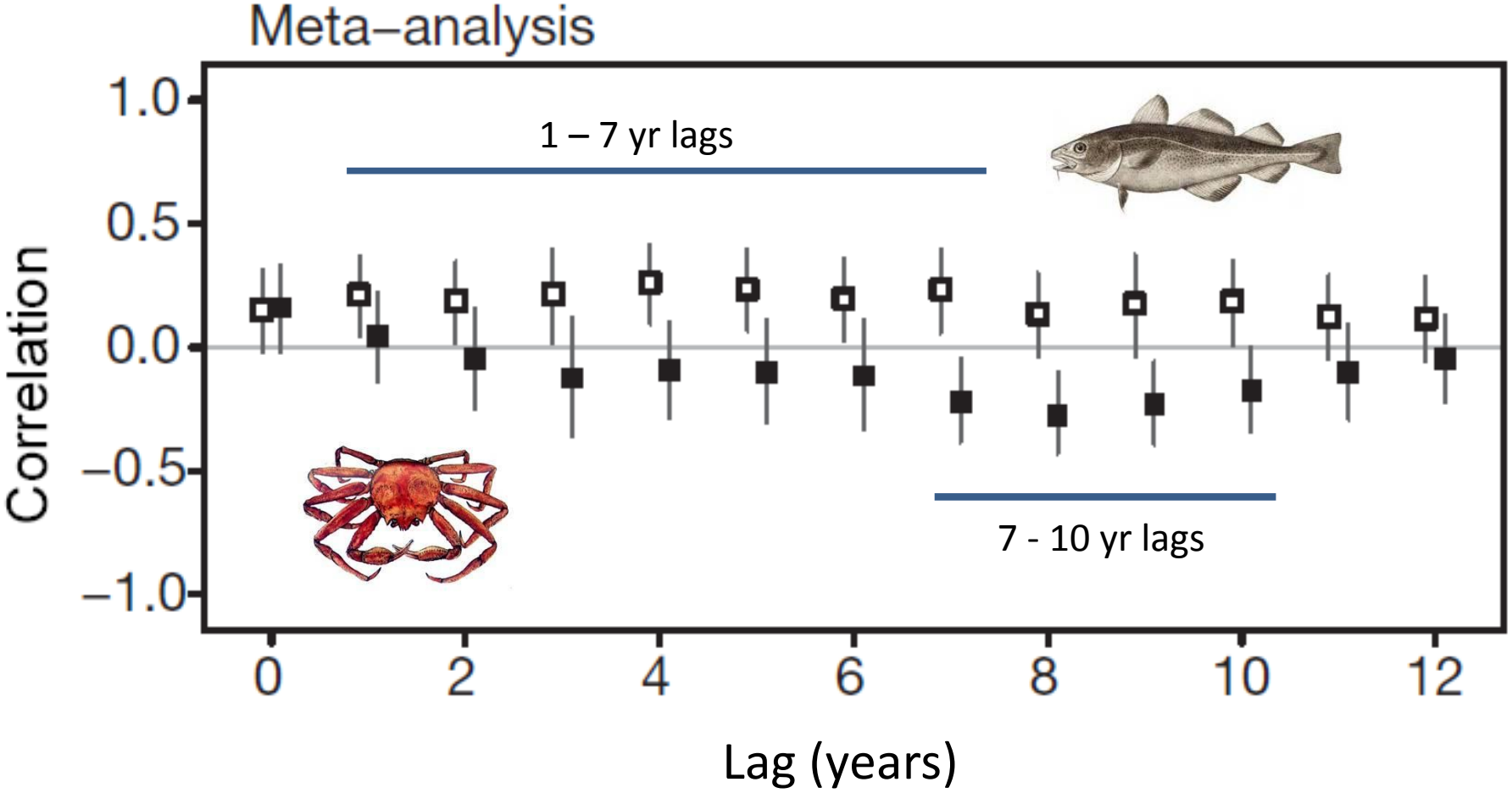
- Extended the Worm & Myers (2003) approach
  - Time lags (0 to 12 yrs, egg to fishery)
  - Partial correlations (r_{part}) control for temperature
- Log-transformed, corrected for autocorrelation, & correlated
- Combined in the meta-analysis

  (random-effects inverse-variance-weighted)

Boudreau *et al*. 2011 *MEPS* 429: 169-183

Temperature effects on snow crab & cod

- With time lags



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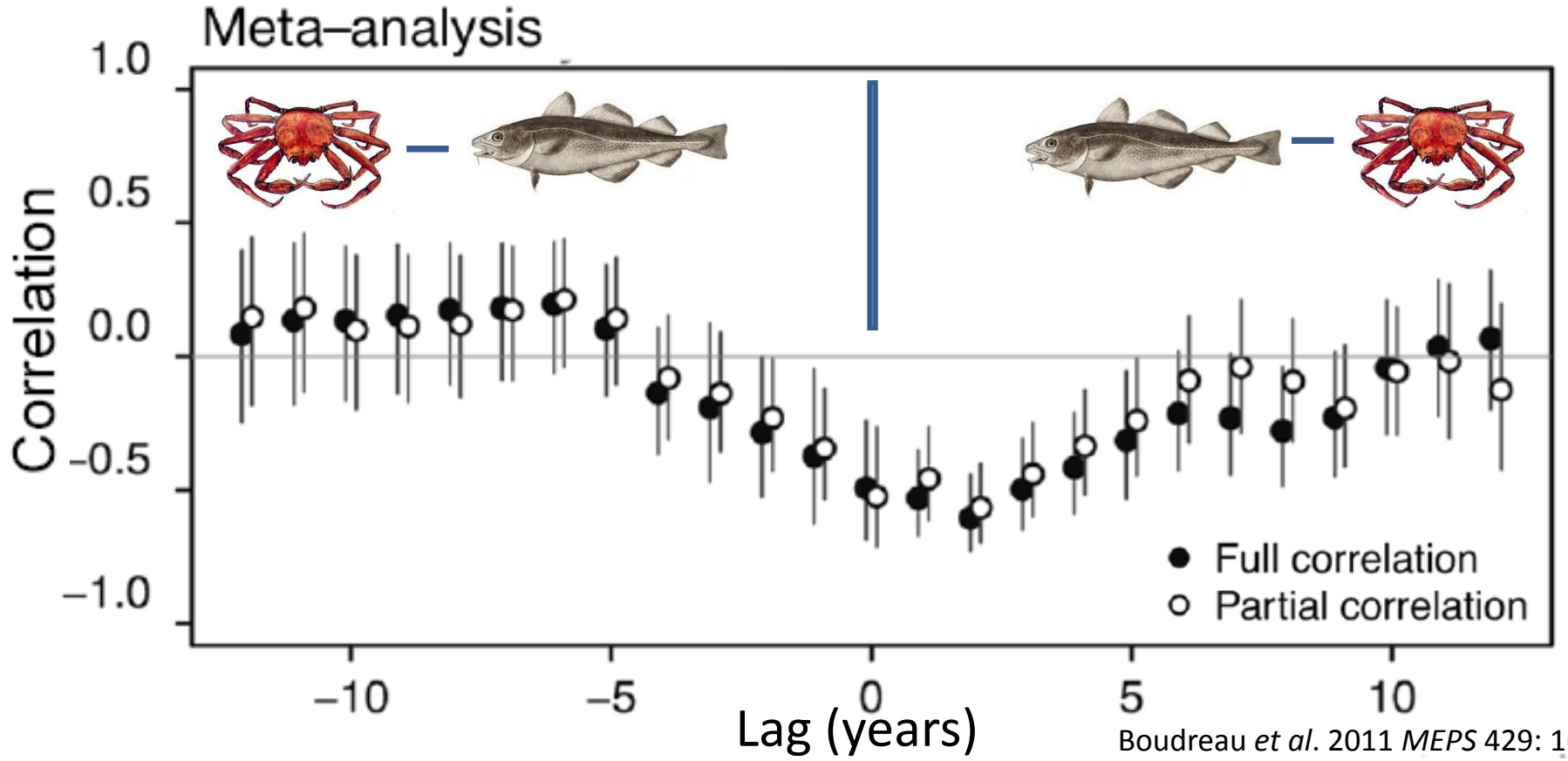
Effects of cod on snow crab with & without temperature

- Full and partial correlations, r_{part} corrected for temperature with lag of 7 years



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Discussion

- **Temperature:** Consistent with the literature
- **Top-down:** Diet studies, expected longer time lags

(i.e. Chabot *et al*. 2008. *MEPS* 363: 227-240)

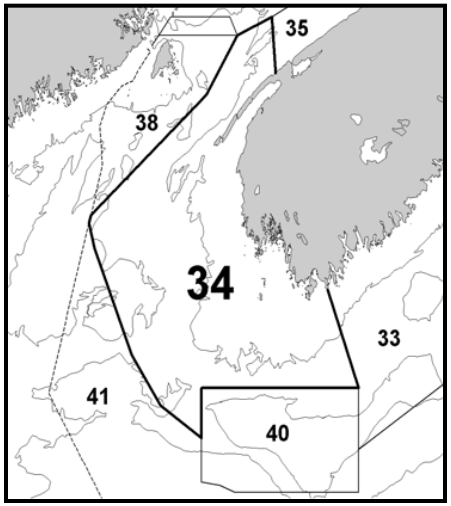
  - Larger crabs would have to be soft-shelled
  - Smaller cod = smaller prey (Shackell *et al*. 2009. *Proc R Soc B* 277: 1353-1360)
  - Robust across alternative combinations of areas

- **Other possibilities**: Density Dependence, Skates

Conclusions: Snow crab abundance largely influenced by temperature during early post-settlement years & becomes increasingly regulated by top-down mechanisms during the years approaching fishery recruitment

- Meta-analysis is useful: multiple causalities

Local Ecological Knowledge Survey

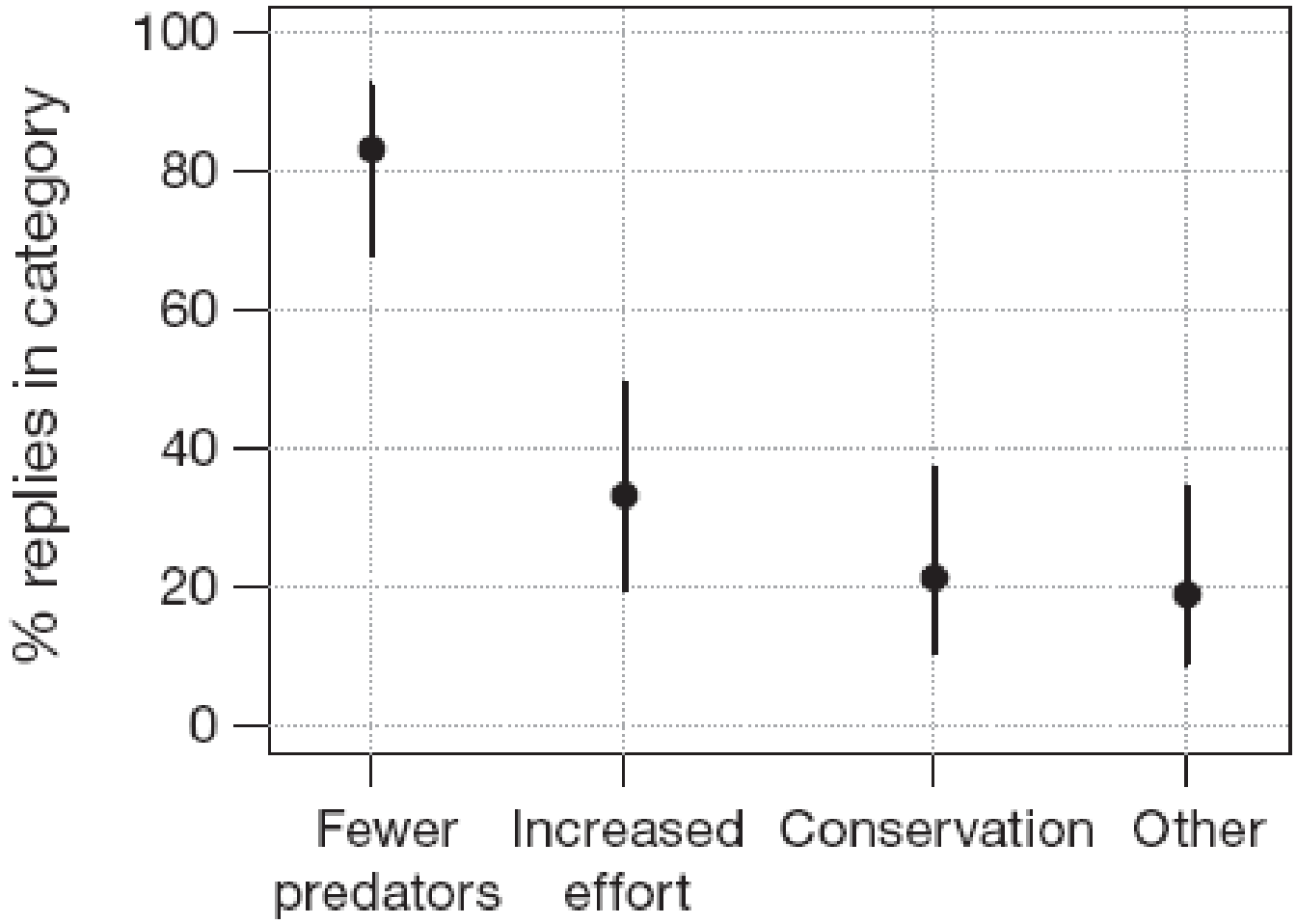


- Inshore region data limited
- 40% of Canada's lobsters caught in LFA 34
- 42 of 937 class A licence holders interviewed
- Semi-structured, snowball sampled in person
- June 14-October 27, 2007

The fishermen: average of 35 yrs of fishing & 55 yrs old

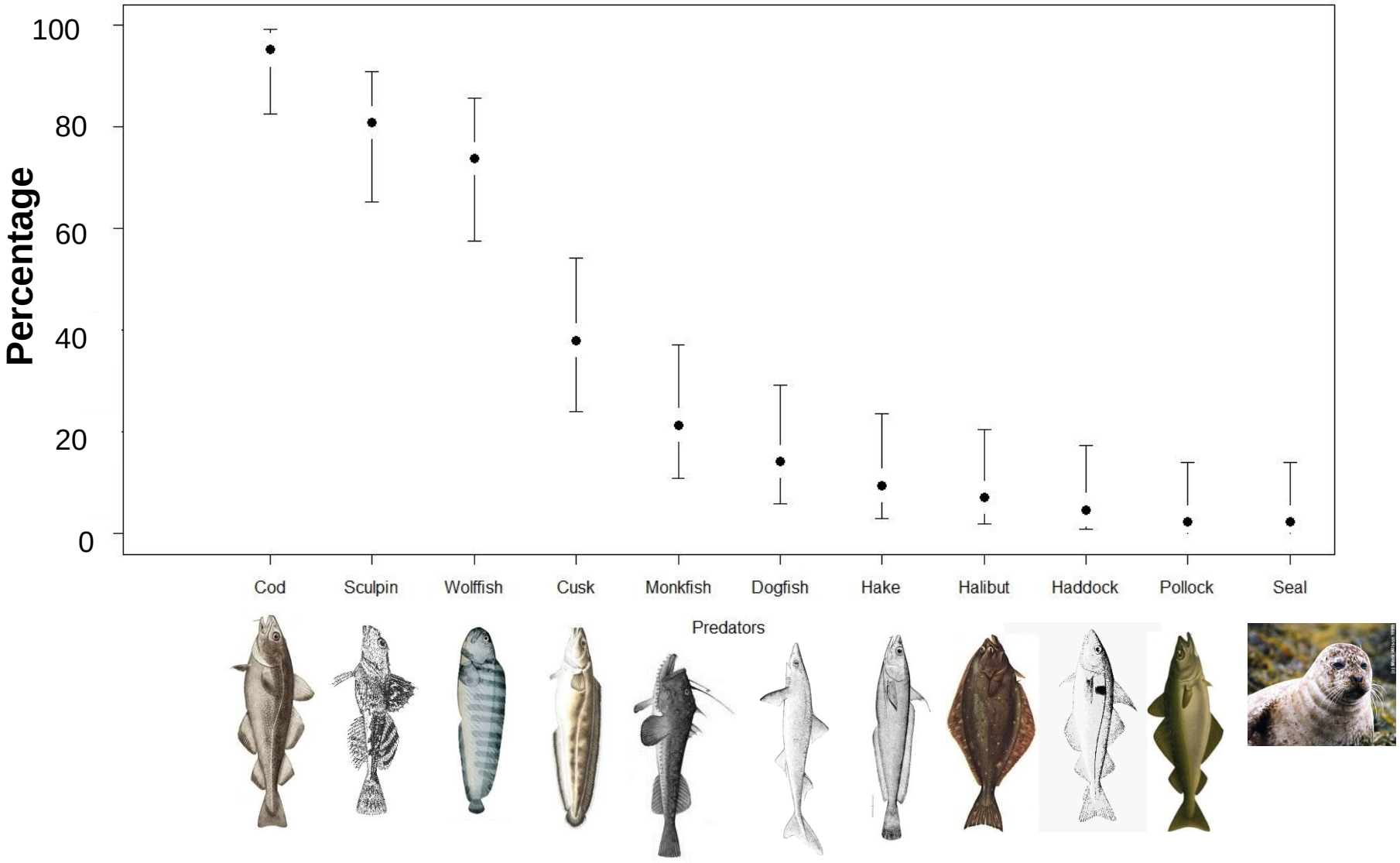
Boudreau & Worm 2010, *MEPS* 403: 181-191

Why are lobster landings at an all-time high?

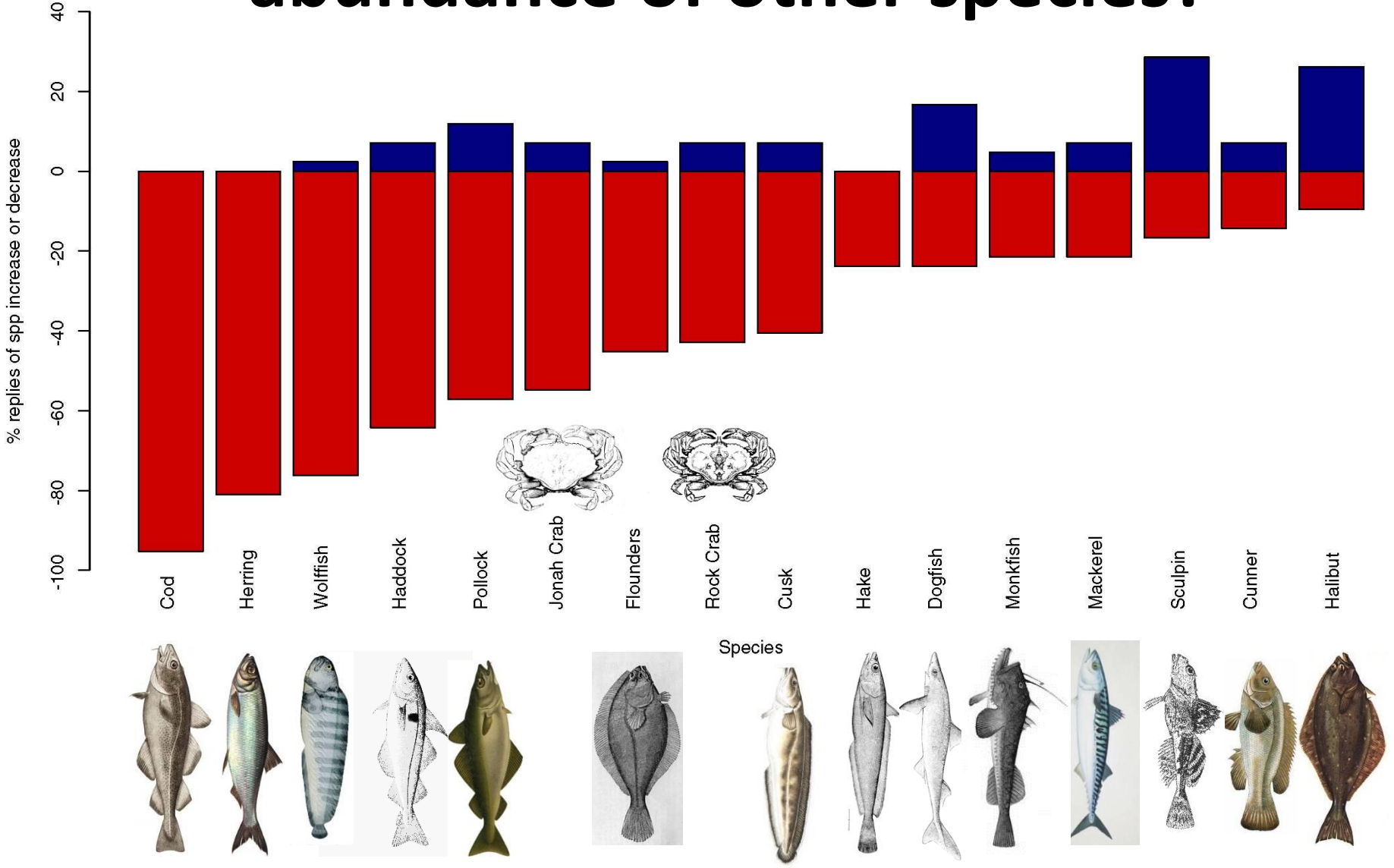


Boudreau & Worm 2010, *MEPS* 403: 181-191

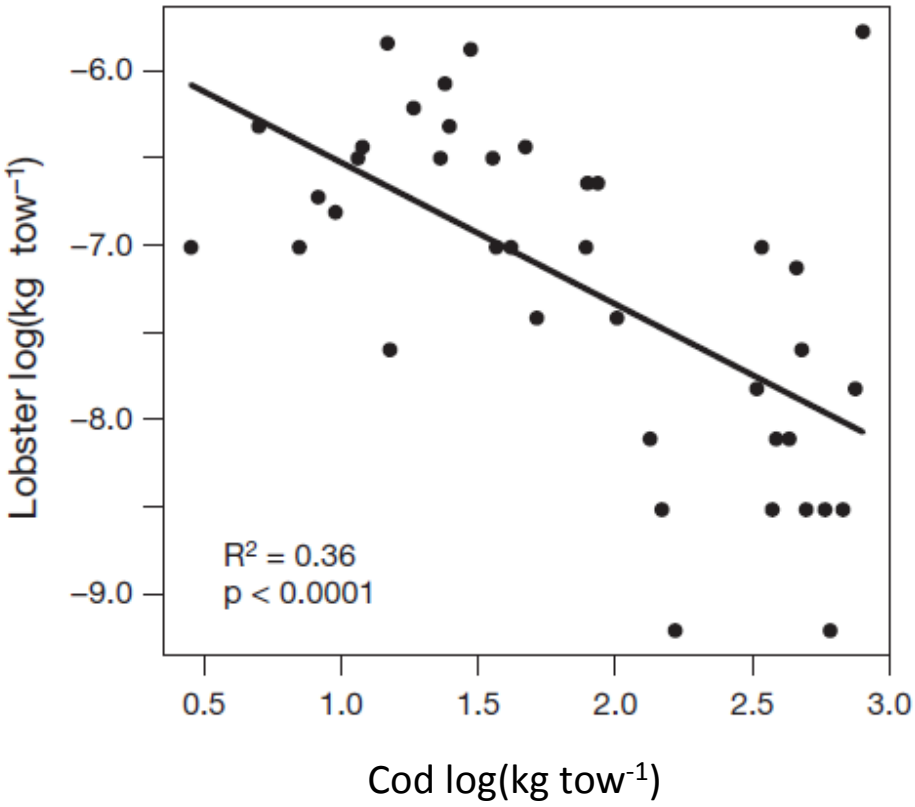
What fish have you dressed and found lobster in its stomach?

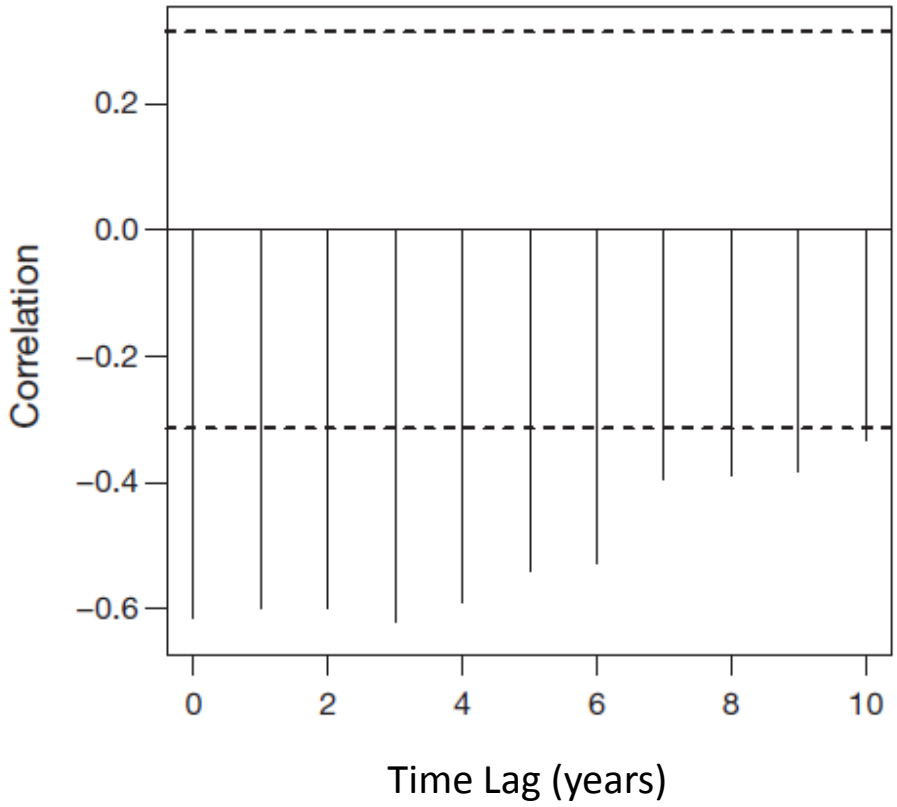


Have you observed changes in the abundance of other species?



Lobster and Cod Abundance in the Gulf of Maine (trawl surveys)





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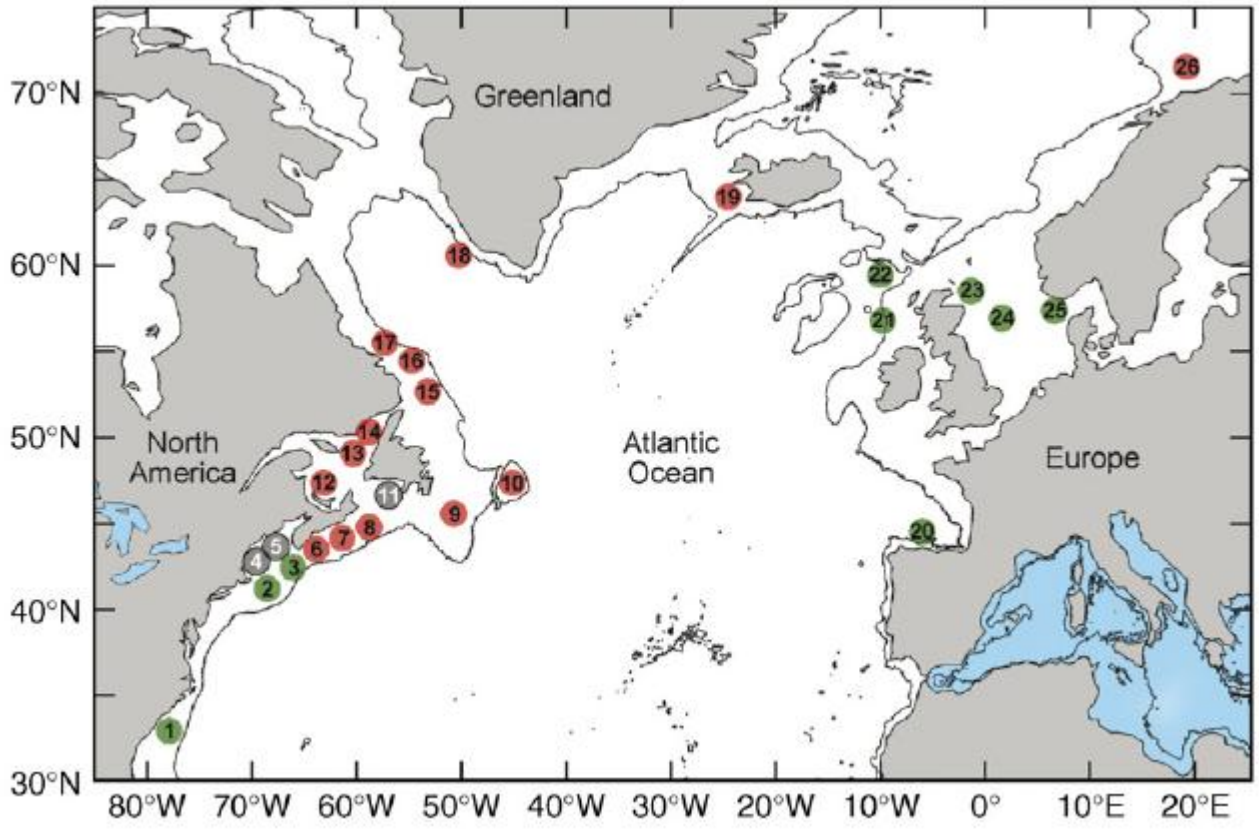
Trophic Control in the North Atlantic



- Review, included spp of different trophic-levels
- Evidence of top-down control in colder regions (red), and bottom-up in warmer (green)

Frank *et al*. 2007, *TREE* 22: 236-242

Conclusions

H_1: **Top-down** - Strong evidence across the 3 spp.

H_2 : **Climate control** - Strong evidence of temperature effects on cod & snow crab

H_3 : **Bottom-up** - Little evidence for species-pairs examined

- Decreases in predator populations can affect increases at lower trophic levels
- Changes in ocean temperature can affect both predator & prey, as well as the strength of their interactions.

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