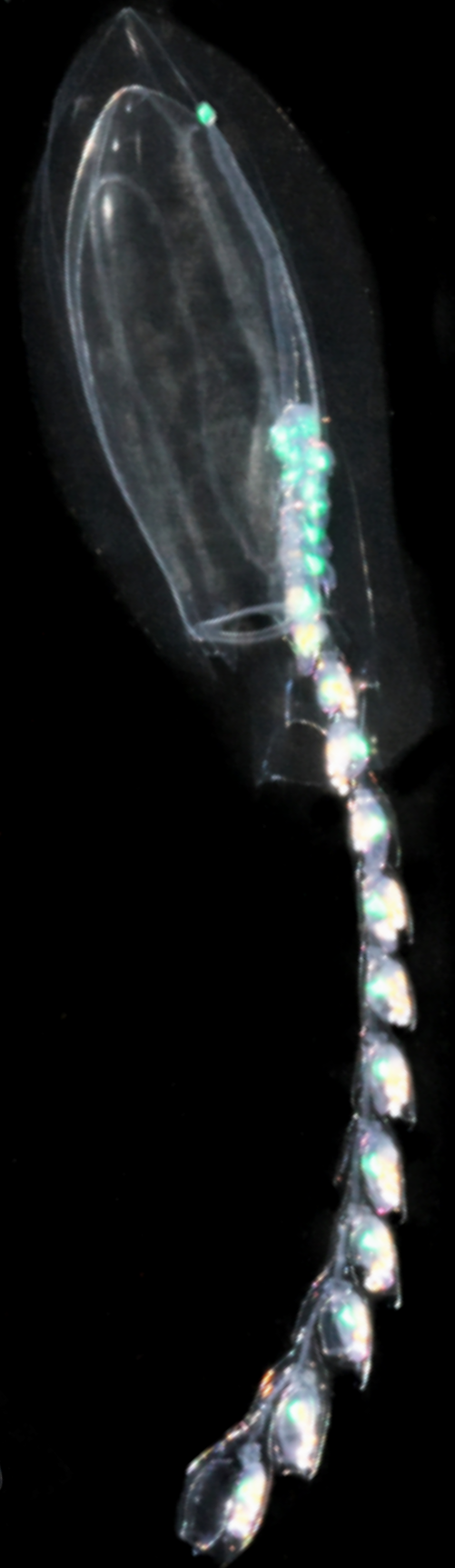


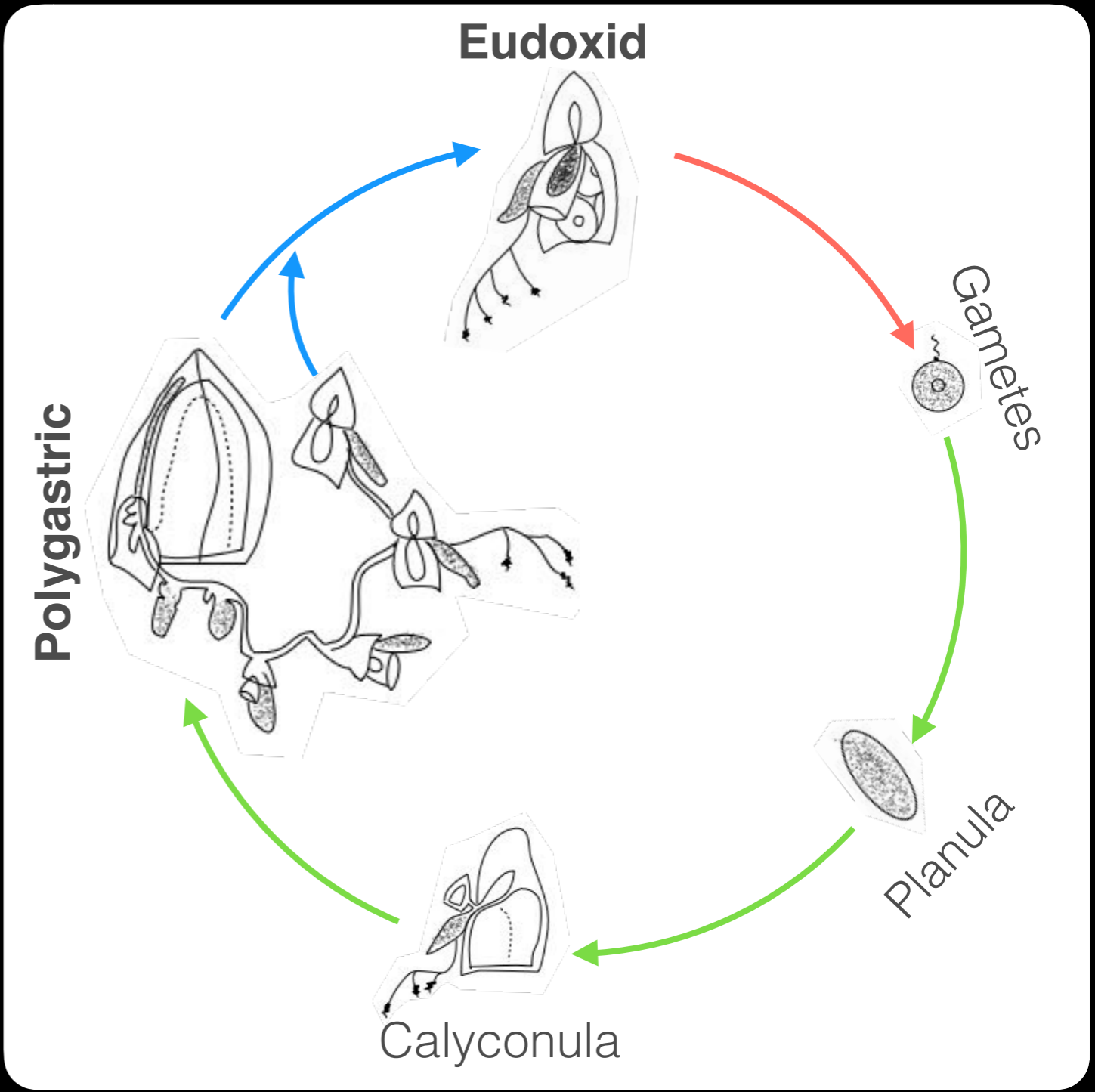
# Biology and ecology of *Muggiaea atlantica* in the northeast Atlantic

Mike Blackett



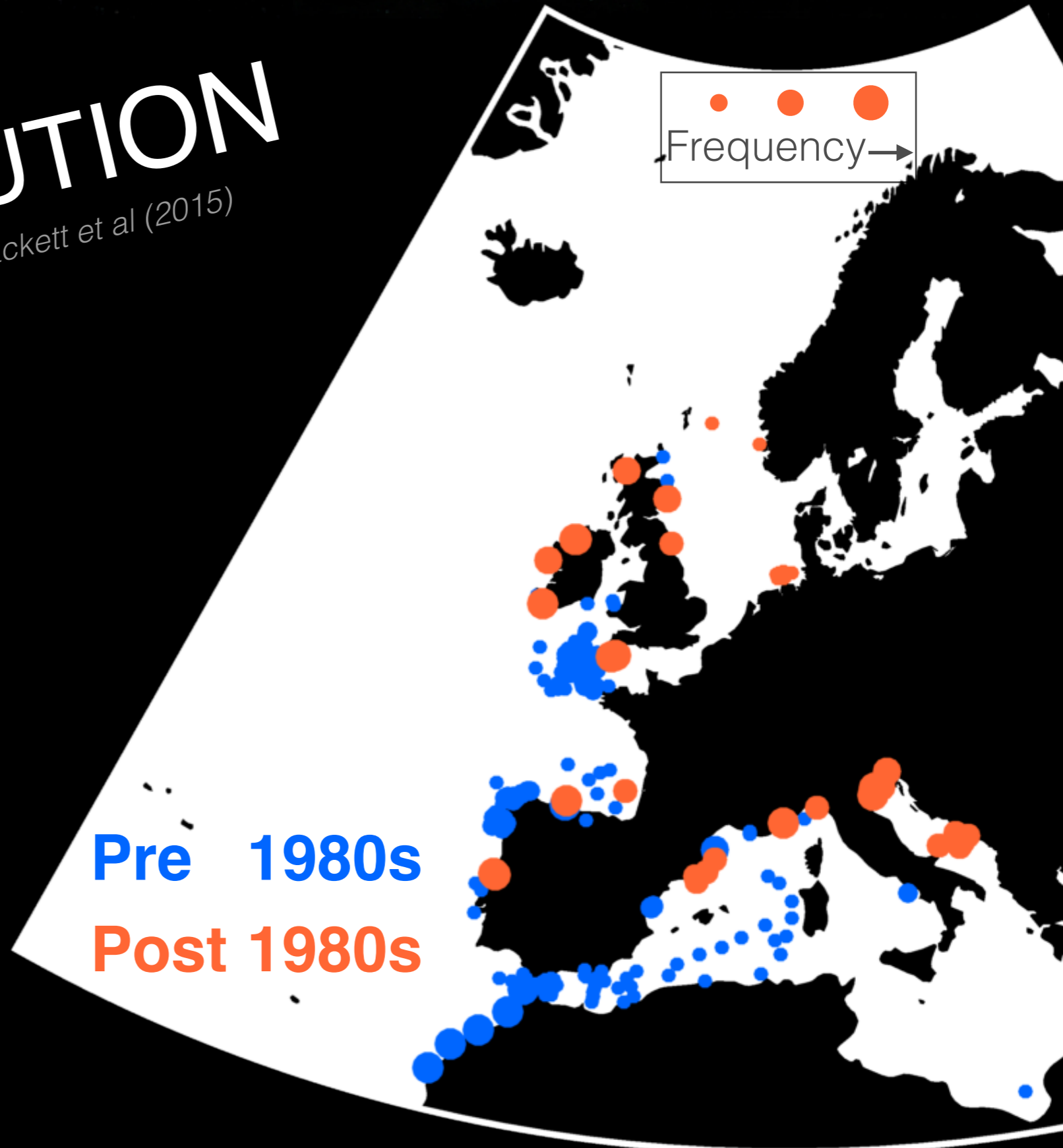
# *Muggiæa atlantica*

- Holoplanktonic
- **ASEXUAL** and **SEXUAL** reproduction
- **RAPID** development



# EXPANDING DISTRIBUTION

Licandro et al (2012), Malej et al (2013), Blackett et al (2015)



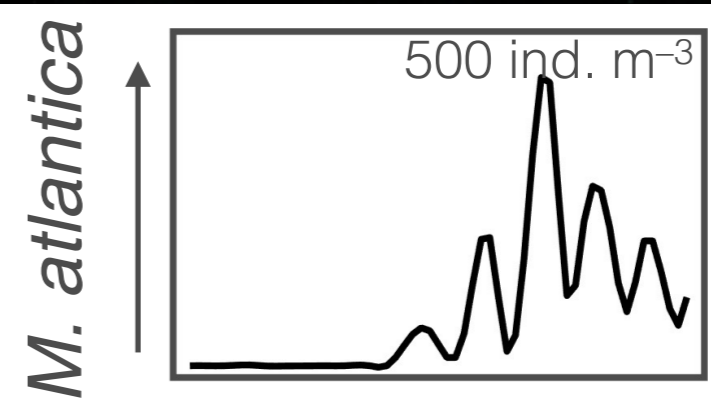
**Pre 1980s**  
**Post 1980s**

# EXPANDING DISTRIBUTION

Licandro et al (2012), Malej et al (2013), Blackett et al (2015)

# ECOLOGICAL IMPACTS

Greve (1994), Krsinic & Njire (2001)



Weeks →

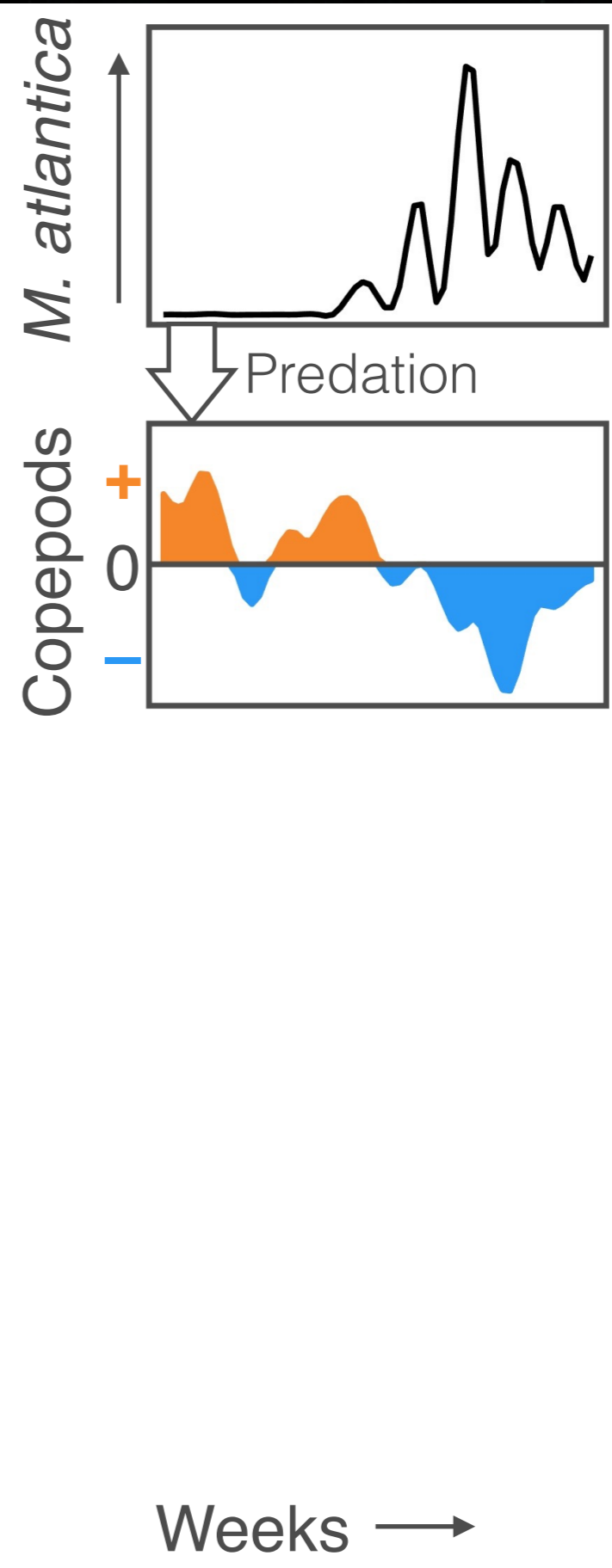
Data source: Greve (1994) The 1989 German Bight Invasion of *Muggiaea atlantica*

# EXPANDING DISTRIBUTION

Licandro et al (2012), Malej et al (2013), Blackett et al (2015)

# ECOLOGICAL IMPACTS

Greve (1994), Krsinic & Njire (2001)



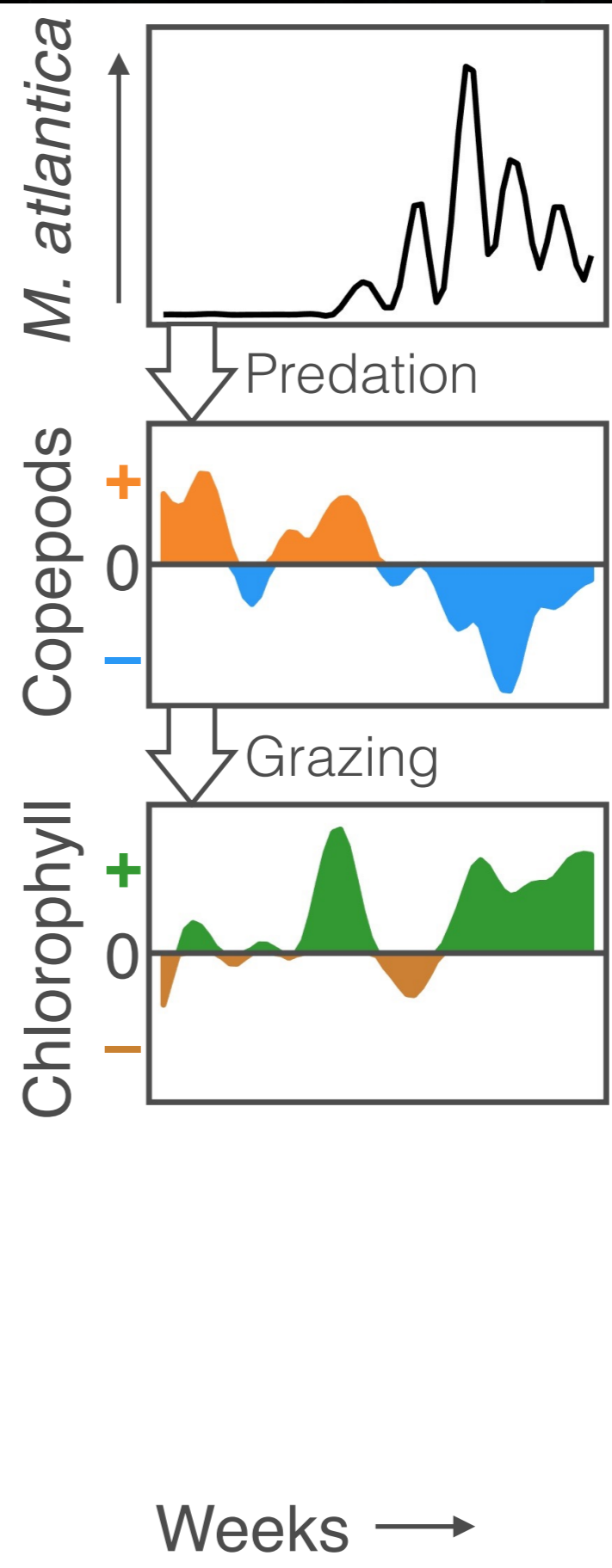
Data source: Greve (1994) The 1989 German Bight Invasion of *Muggiaea atlantica*

# EXPANDING DISTRIBUTION

Licandro et al (2012), Malej et al (2013), Blackett et al (2015)

# ECOLOGICAL IMPACTS

Greve (1994), Krsinic & Njire (2001)



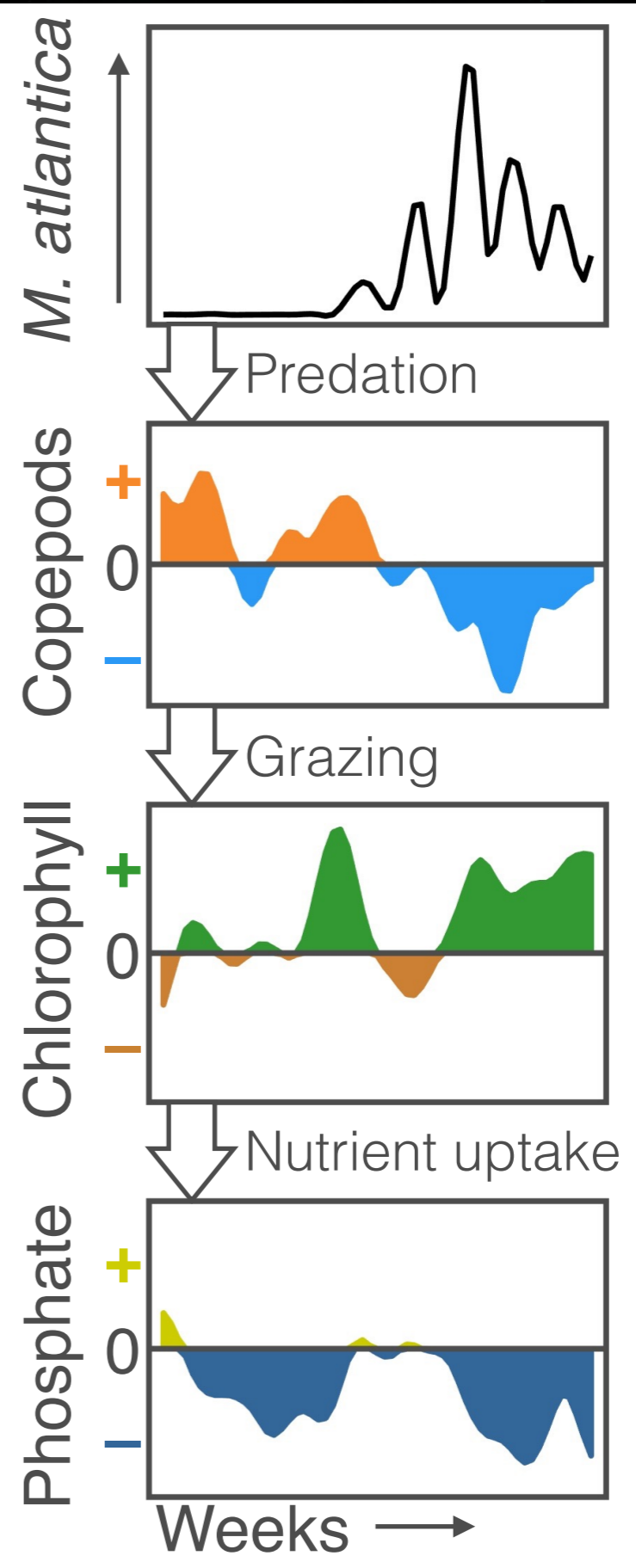
Data source: Greve (1994) The 1989 German Bight Invasion of *Muggiaea atlantica*

# EXPANDING DISTRIBUTION

Licandro et al (2012), Malej et al (2013), Blackett et al (2015)

# ECOLOGICAL IMPACTS

Greve (1994), Krsinic & Njire (2001)



Data source: Greve (1994) The 1989 German Bight Invasion of Muggiaea atlantica

# EXPANDING DISTRIBUTION

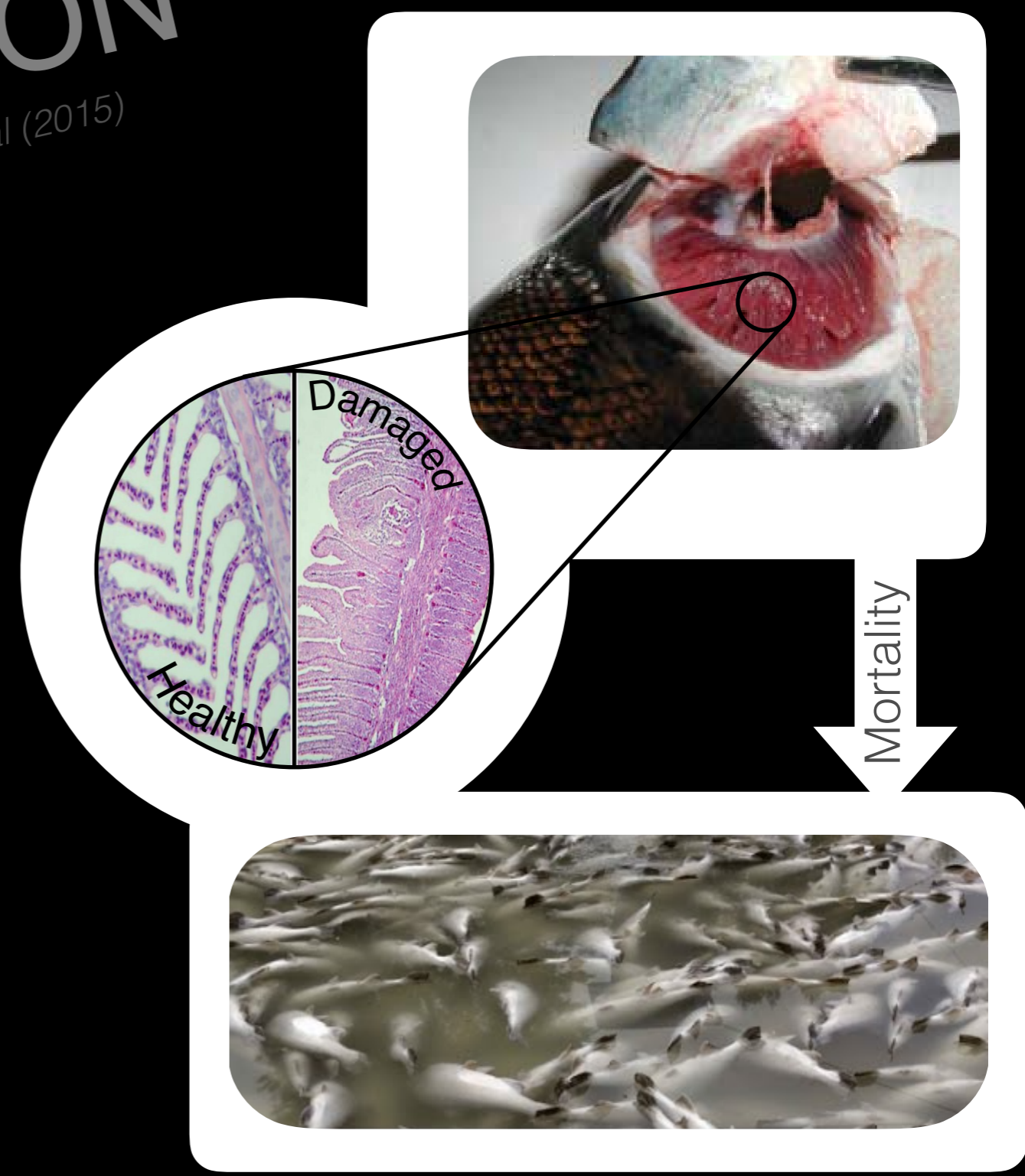
Licandro et al (2012), Malej et al (2013), Blackett et al (2015)

# ECOLOGICAL IMPACTS

Greve (1994), Krsinic & Njire (2001)

# AQUACULTURE IMPACTS

Fosså et al 2003, Baxter et al 2011





# Sampling locations

**Loch Ewe**   
(2003–2013)

*Scottish  
Continental  
Shelf*

**Stonehaven**   
(1999–2013)

**L5** (1930–2013)  **L4** (2009–2013)

*Western  
English  
Channel*

marinescotland  
science



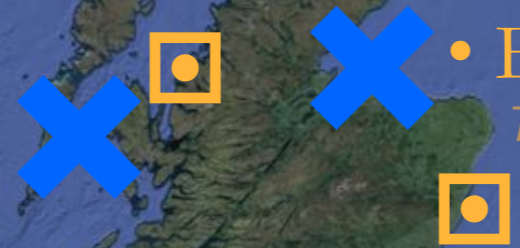
**PML** | Plymouth Marine  
Laboratory



# Historical distribution

## Scottish Shelf

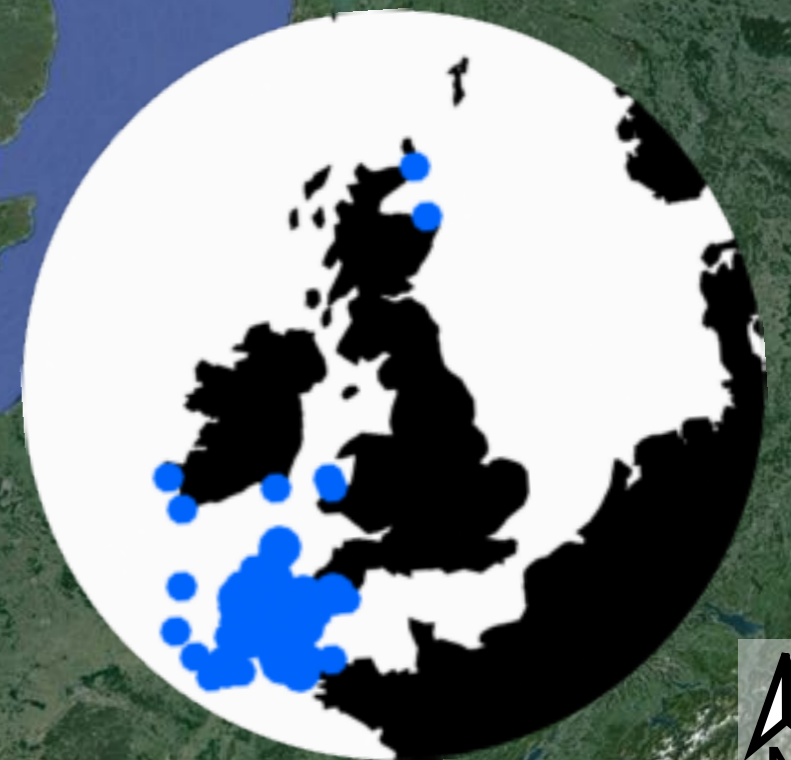
- Exceptionally rare  
*Totton & Fraser (1955)*



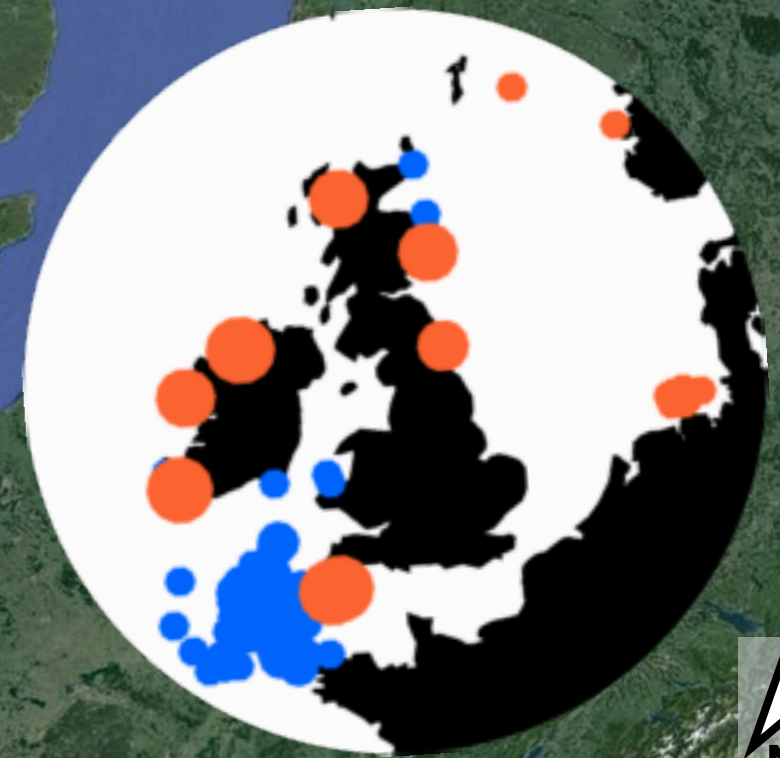
## Western English Channel

- Transient
- 'Indicator' species

*Southward et al (1995)*

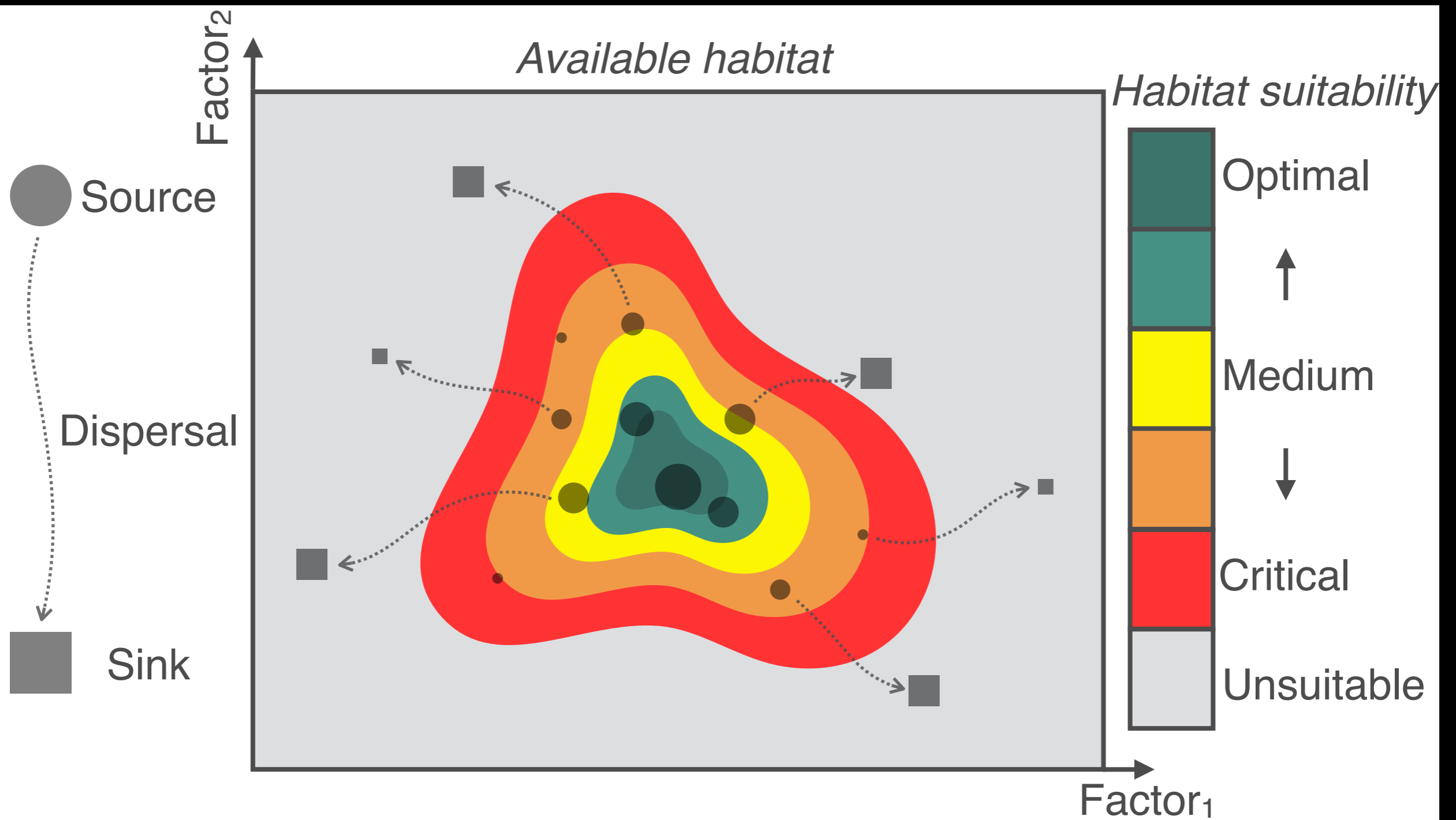


# Contemporary distribution...?




# Source-sink dynamics

*Pulliam (2000)*



*Helaouët et al (2013)*

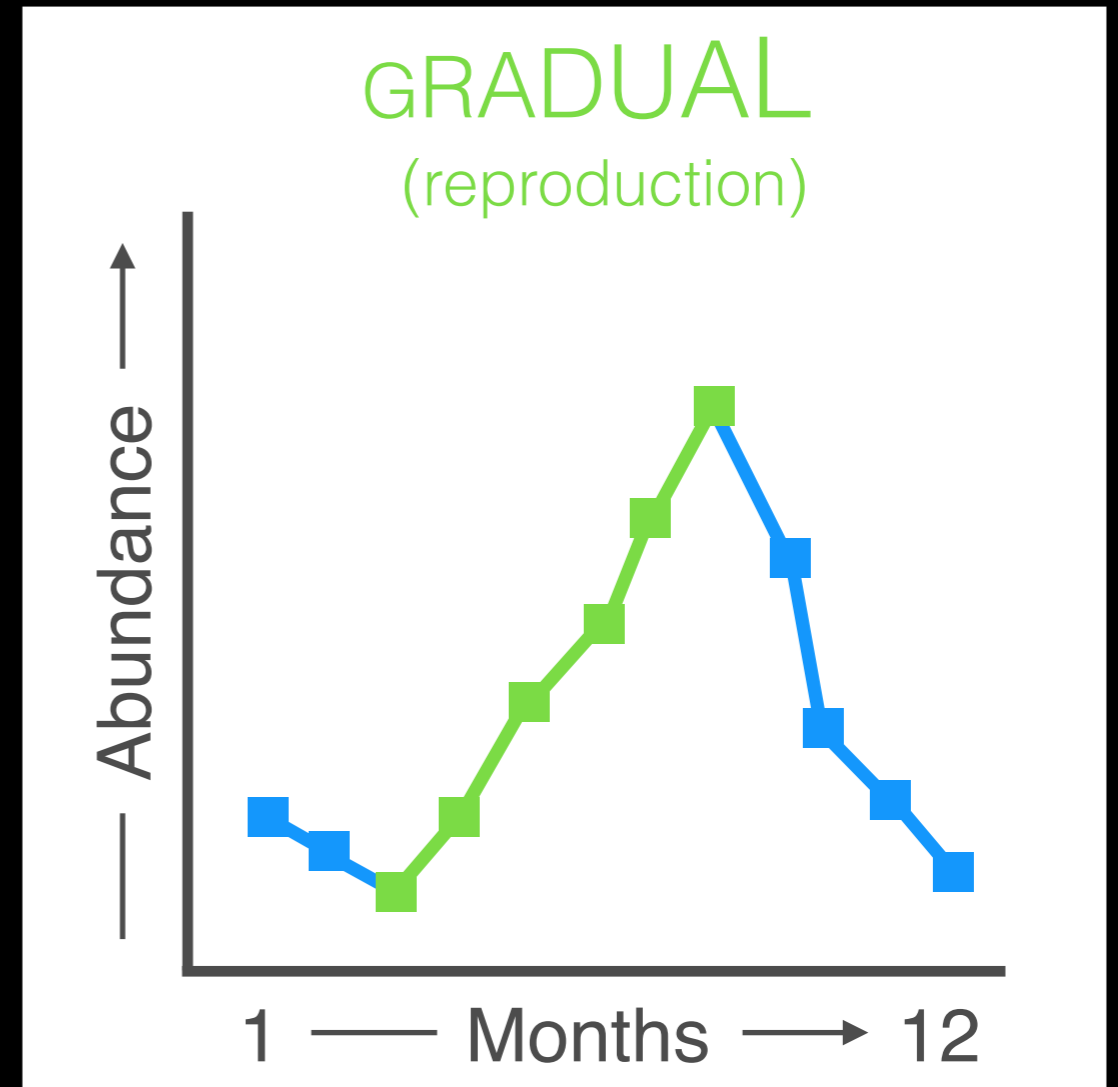
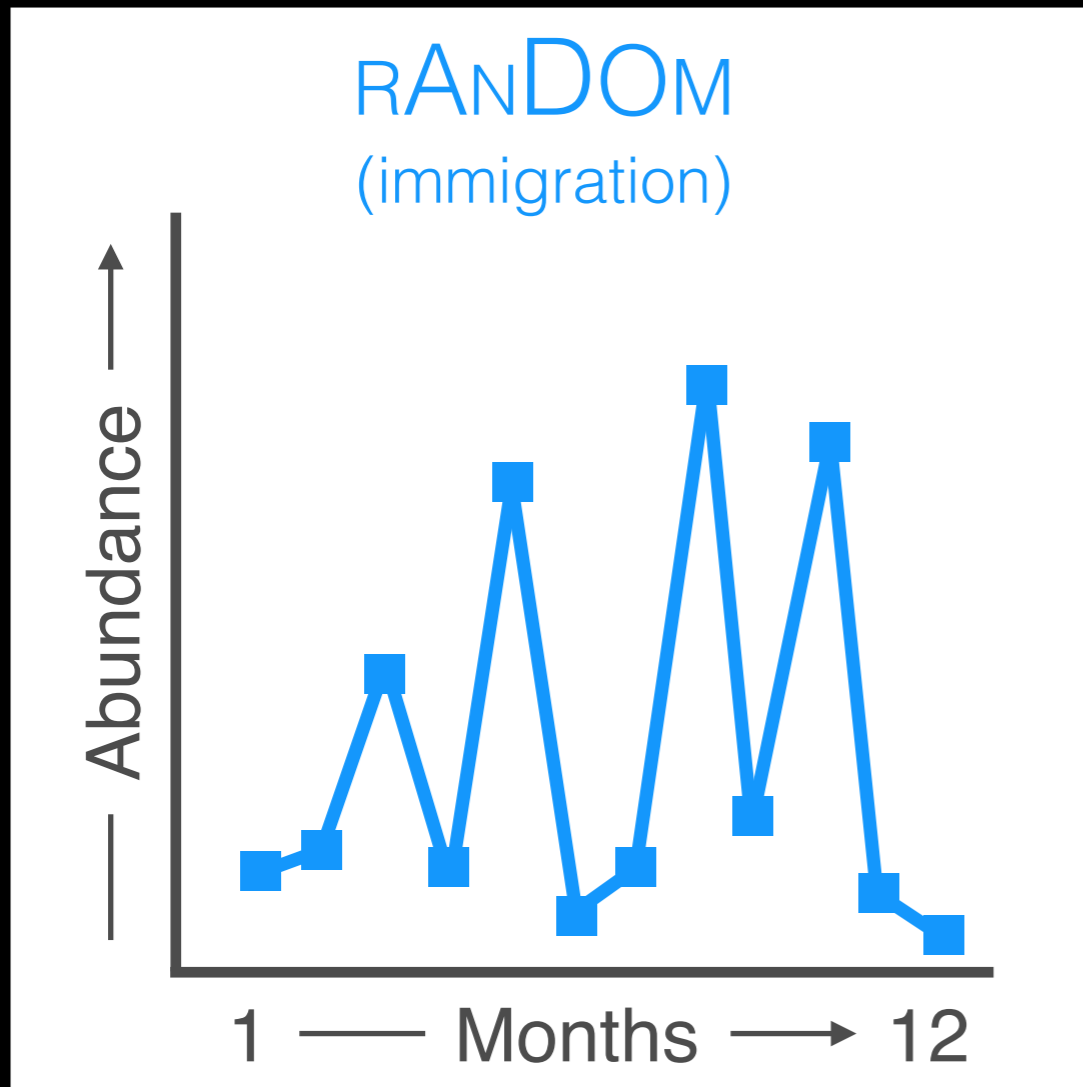


<b>Source</b>	<b>Sink</b>
Production = recruitment  $\infty$ Life history  Persist indefinitely	Production $\neq$ recruitment  $\propto$ Life history  Require immigration

*Pulliam (2000)*

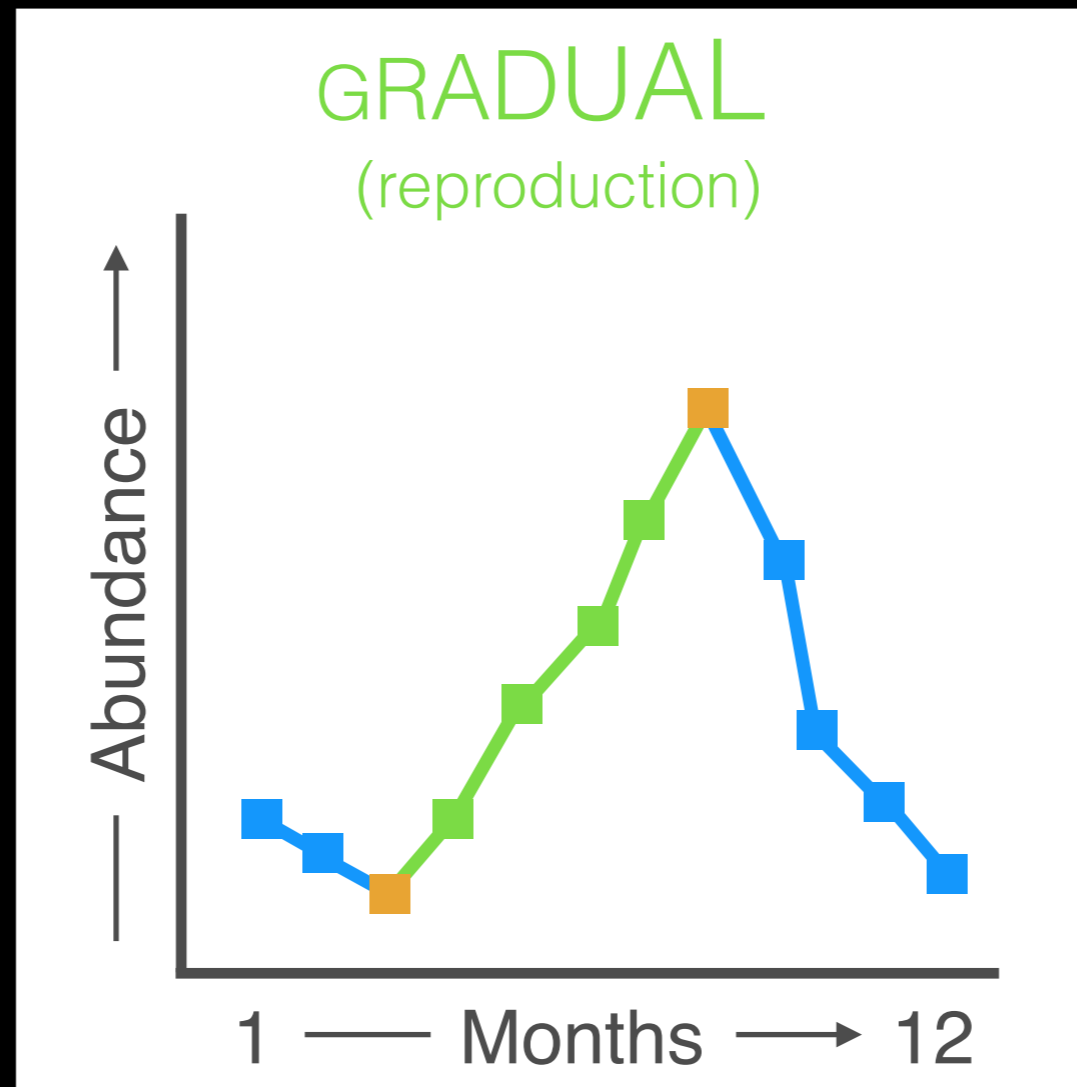
# Local production

*Blackett et al (2014)*



# Local production

*Blackett et al (2014)*

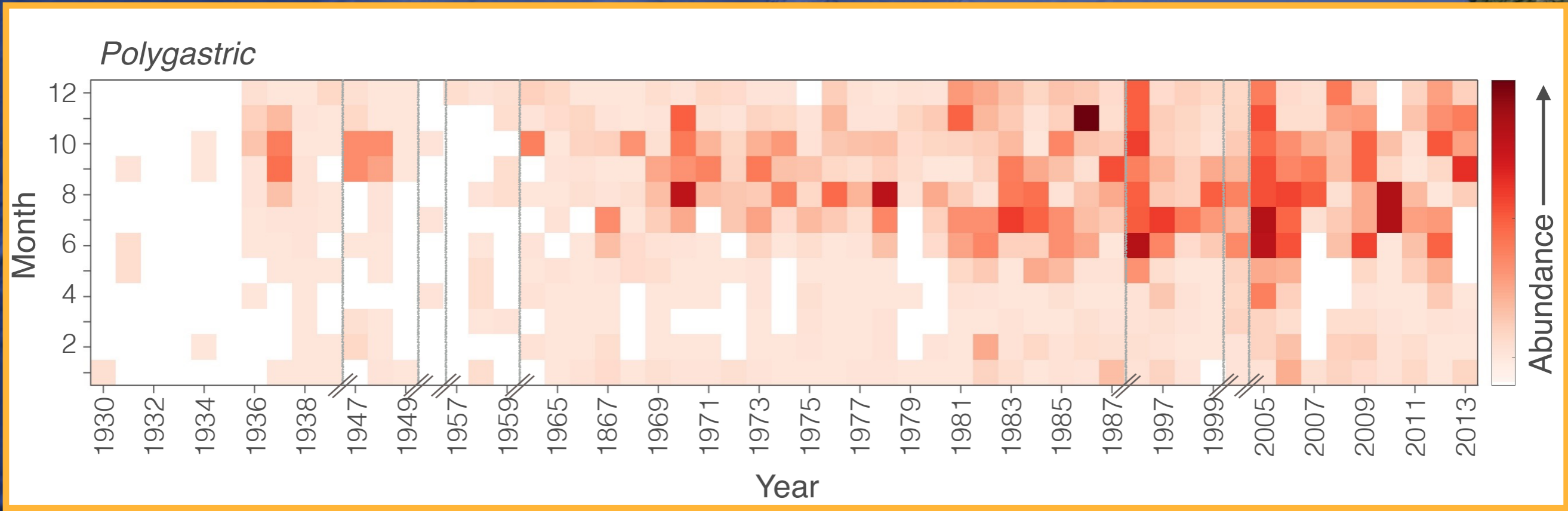


Significant  
**TROUGH**

**LOCAL PRODUCTION**

Significant  
**PEAK**

*Kendall (1976), Ibañez (1982)*



*Blackett et al (2014)*

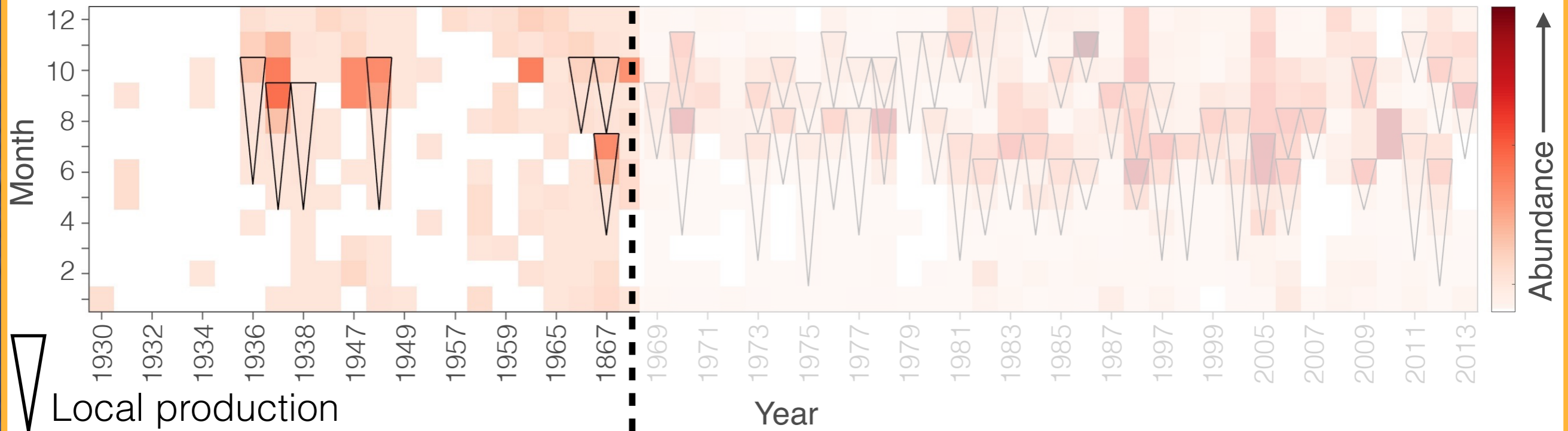
Western  
English  
Channel







~80% RANDOM

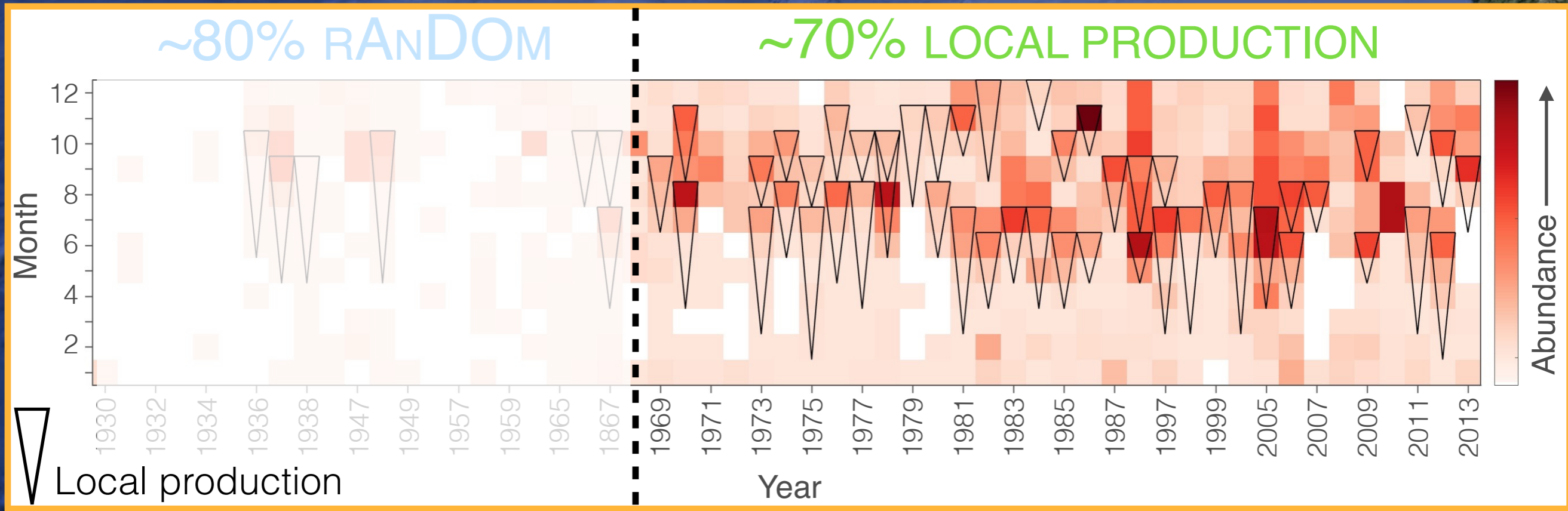


Blackett et al (2014)

✕ **Reproduction = recruitment**

Western English Channel



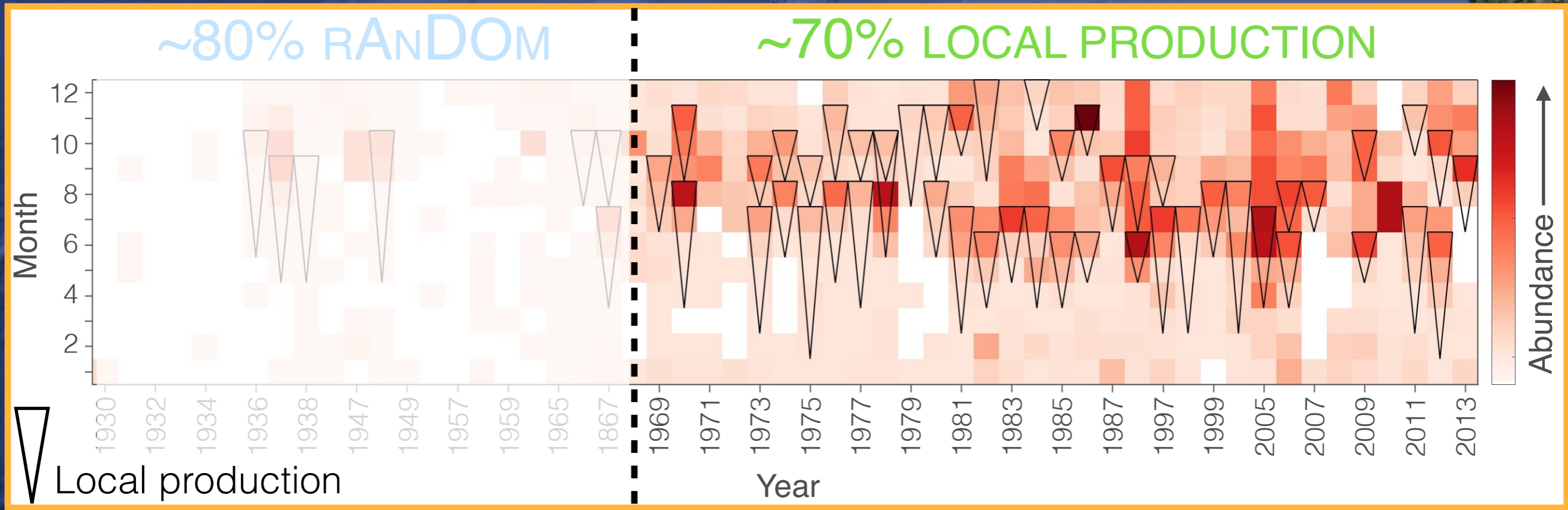


Blackett et al (2014)

✓ **Reproduction = recruitment**

Western English Channel





Blackett et al (2014)

✓ Reproduction = recruitment

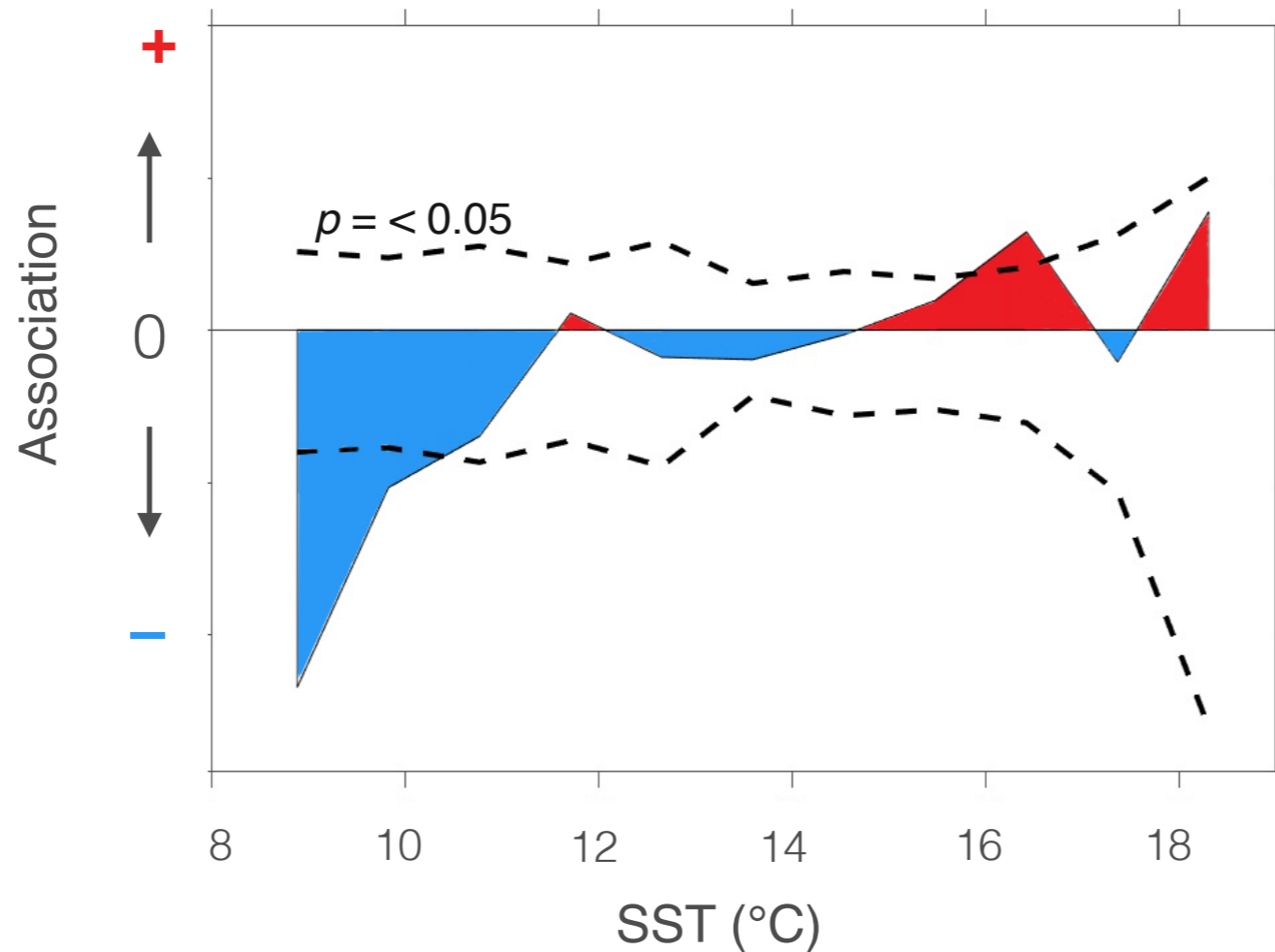
∞ Life history?

Persist indefinitely?

Western English Channel



## Local production vs. temperature



*Blackett et al (2014)*

✓ Reproduction = recruitment

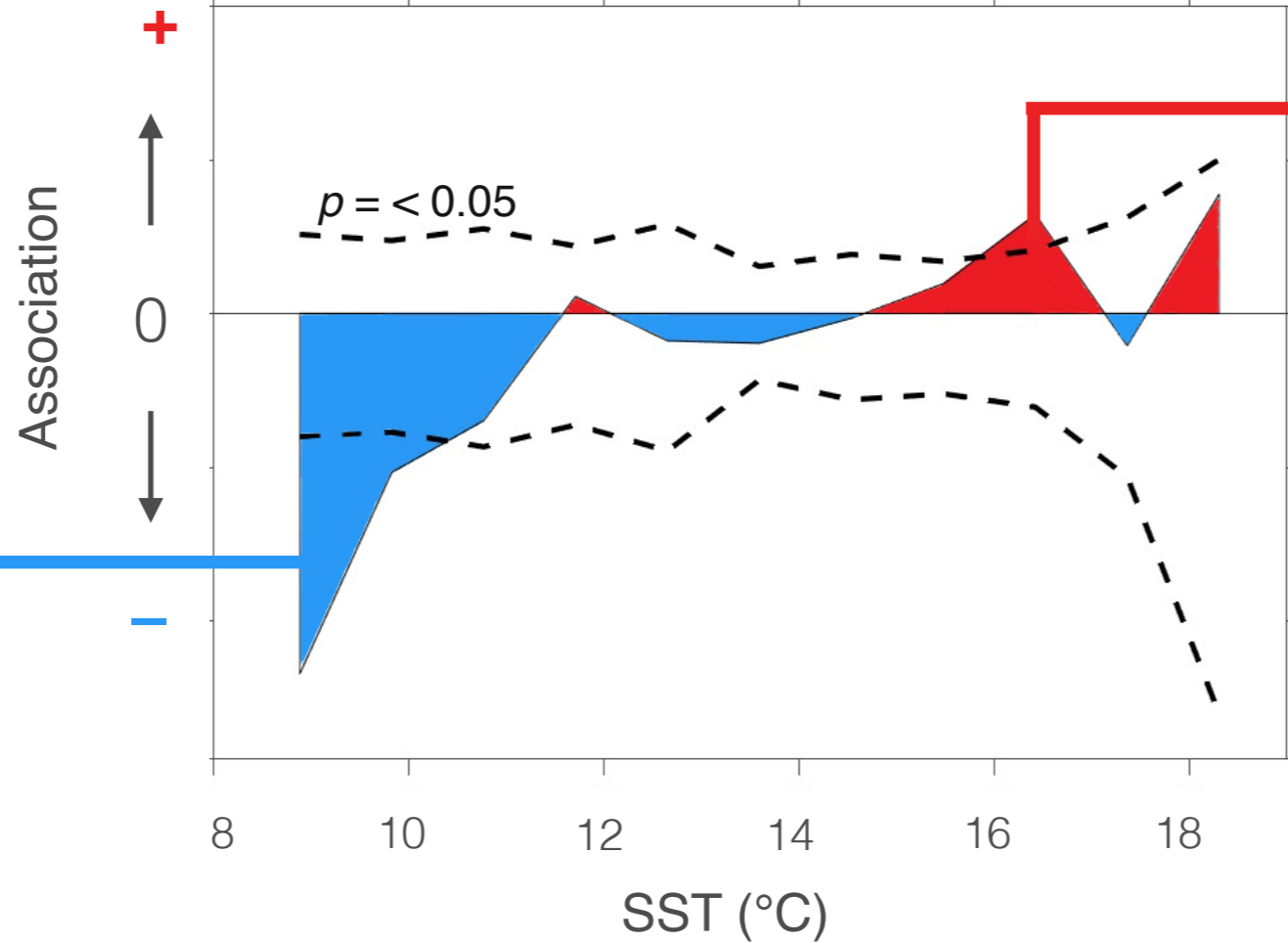
∞ Life history?

Persist indefinitely?

Western  
English  
Channel



# Local production vs. temperature



9–10 °C

15–16 °C

Blackett et al (2014)

Western English Channel

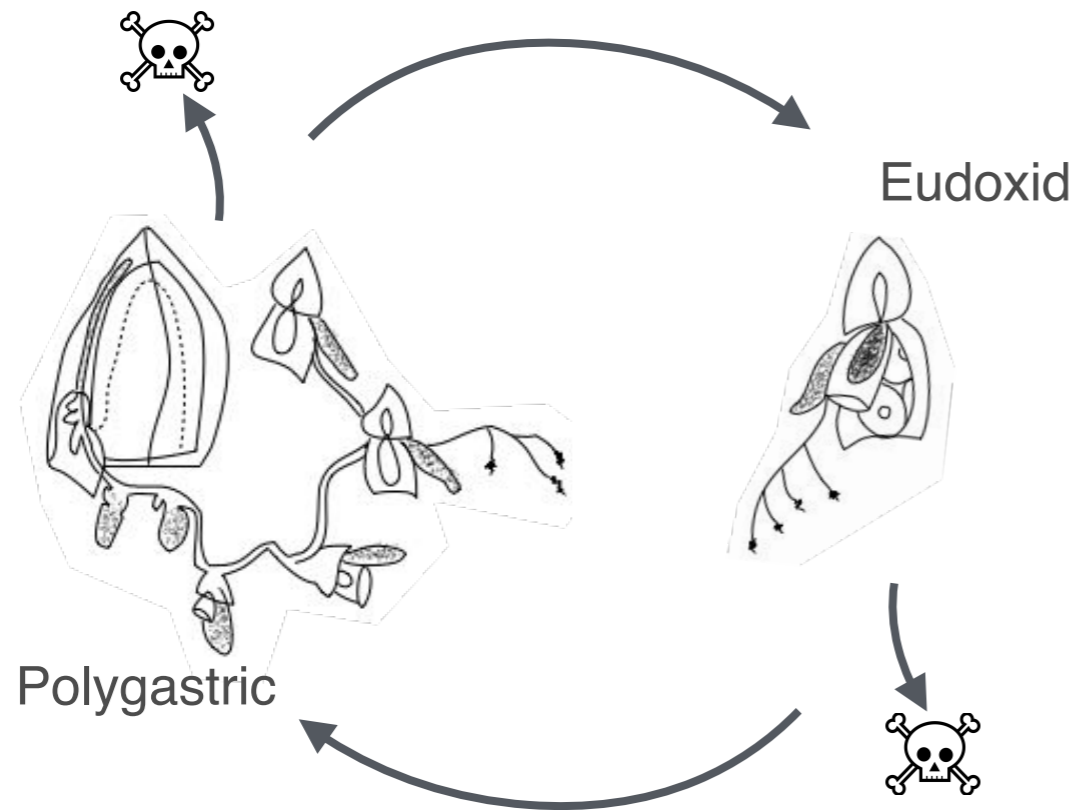
✓ Reproduction = recruitment

✓ ∞ Life history

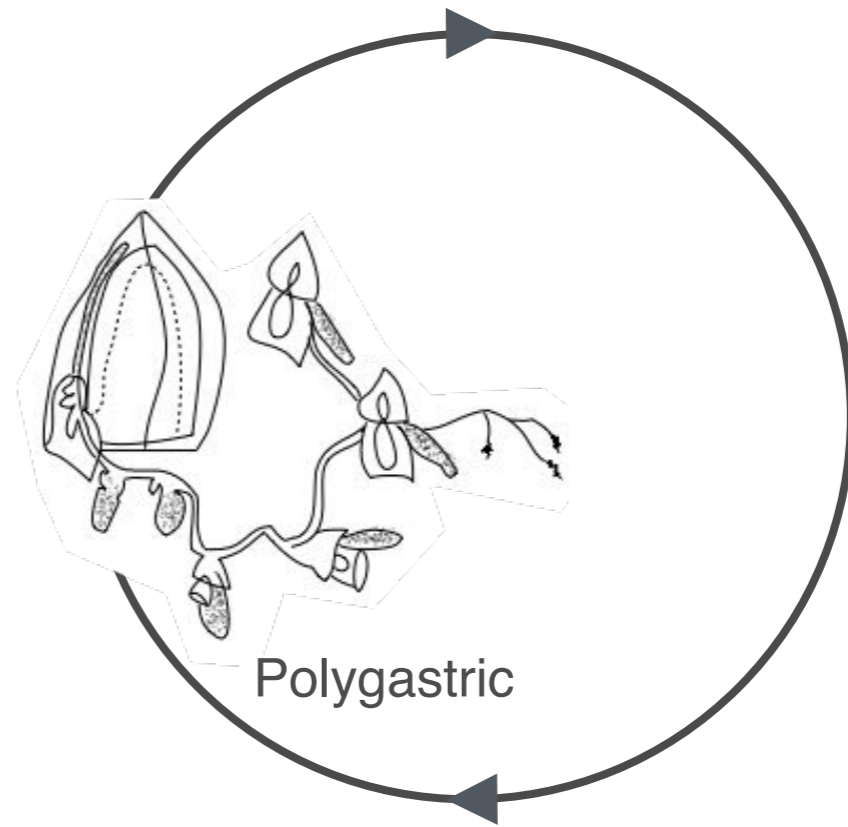
Persist indefinitely?



Spring/autumn



Winter



*Carré & Carré (1991)*

✓ Reproduction = recruitment

✓ ∞ Life history

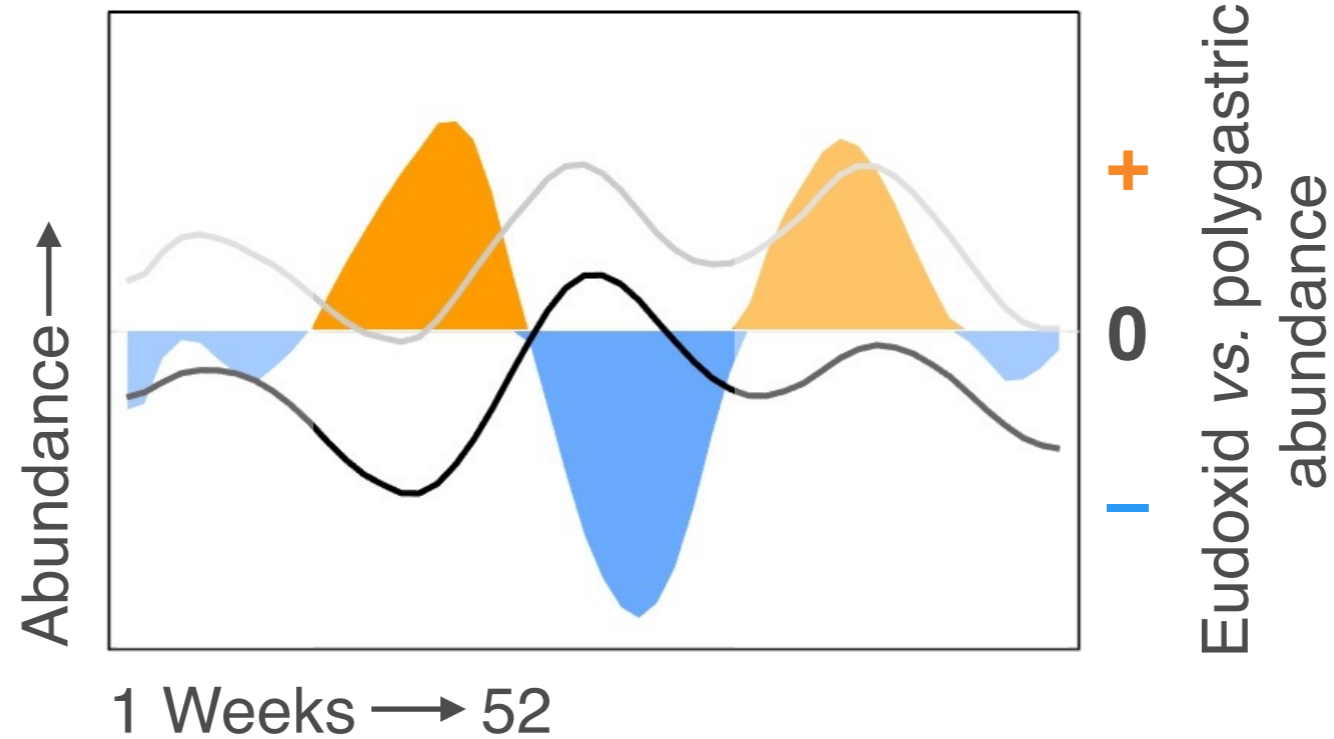
Persist indefinitely?

Western  
English  
Channel



~  
Eudoxid

~  
Polygastric



*Blackett et al (2015)*

✓ **Reproduction = recruitment**

✓ **∞ Life history**

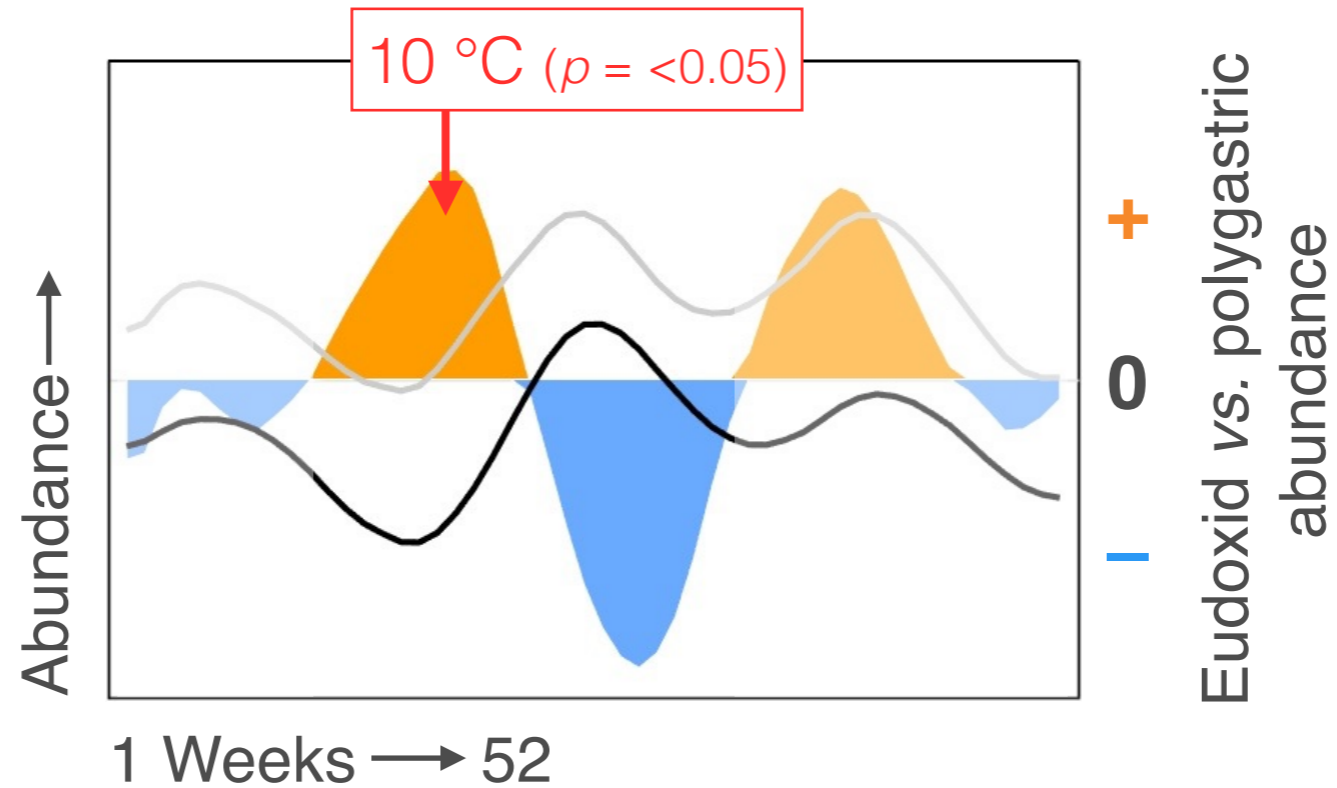
**Persist indefinitely?**

Western  
English  
Channel





~  
Eudoxid  
~  
Polygastric



*Blackett et al (2015)*

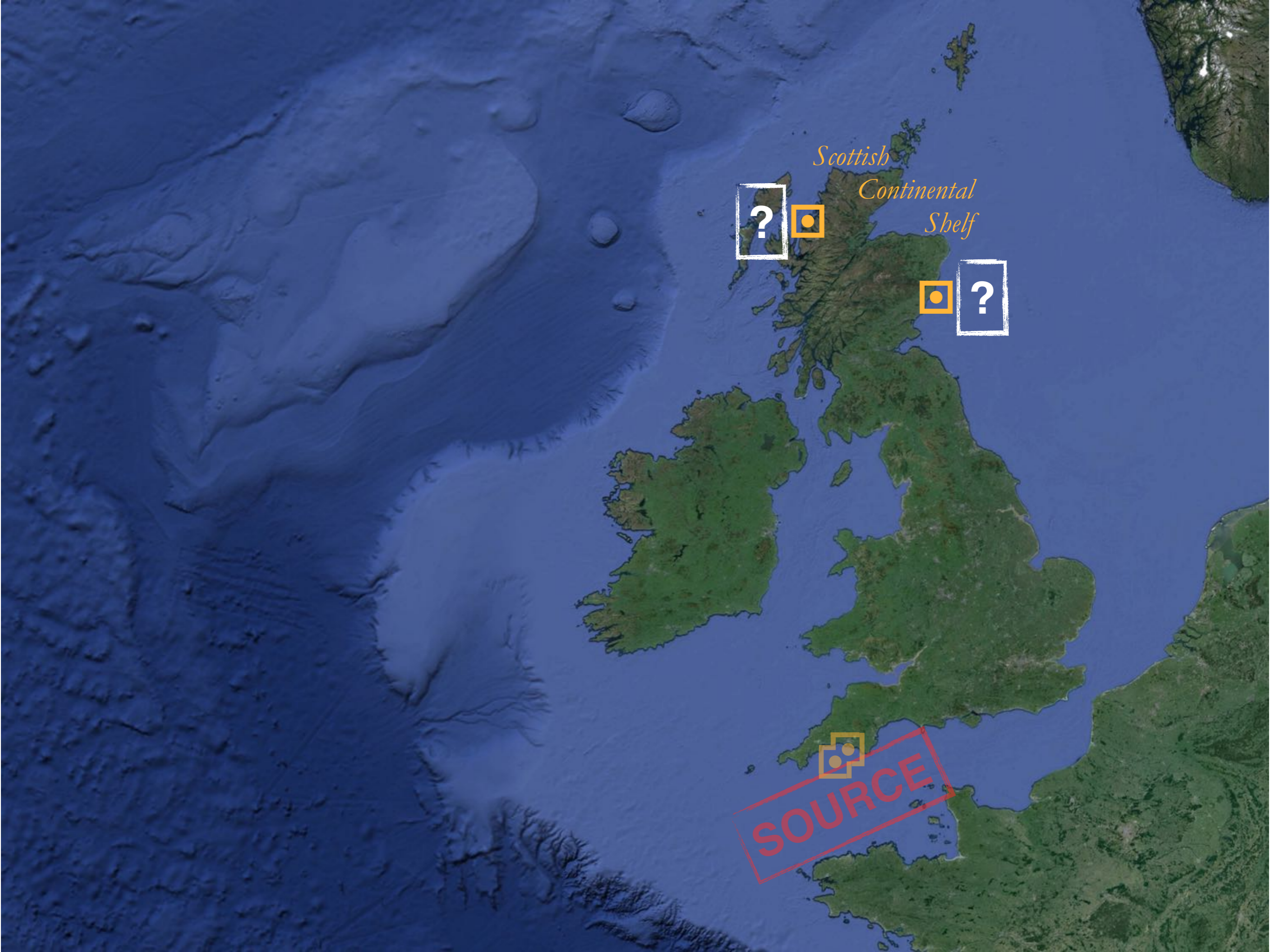
- ✓ **Reproduction = recruitment**
- ✓ **∞ Life history**
- ✓ **Persist indefinitely**

Western  
English  
Channel



- ✓ **Reproduction = recruitment**
- ✓  **$\infty$  Life history**
- ✓ **Persist indefinitely**





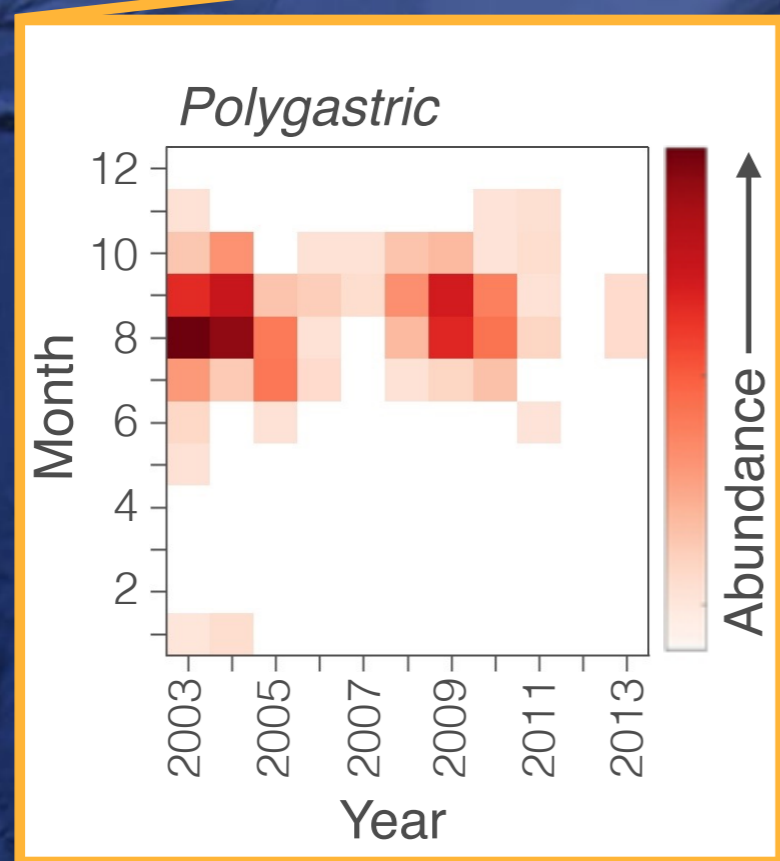
*Scottish*

*Continental  
Shelf*

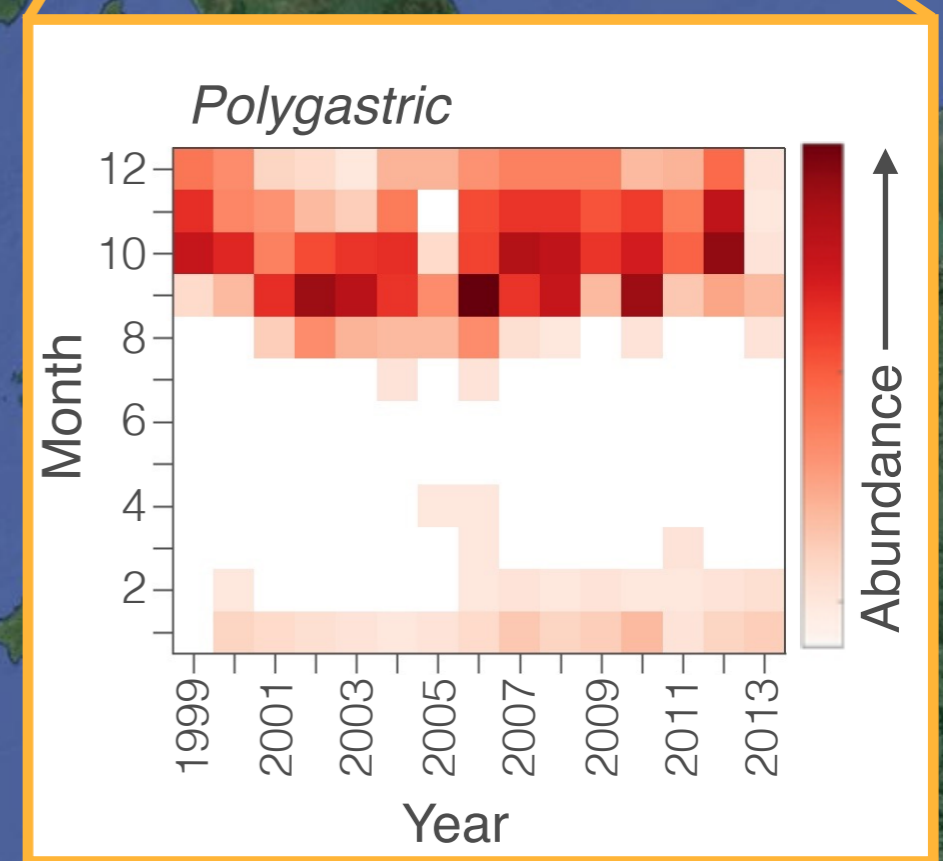


**SOURCE**

*Scottish  
Continental  
Shelf*



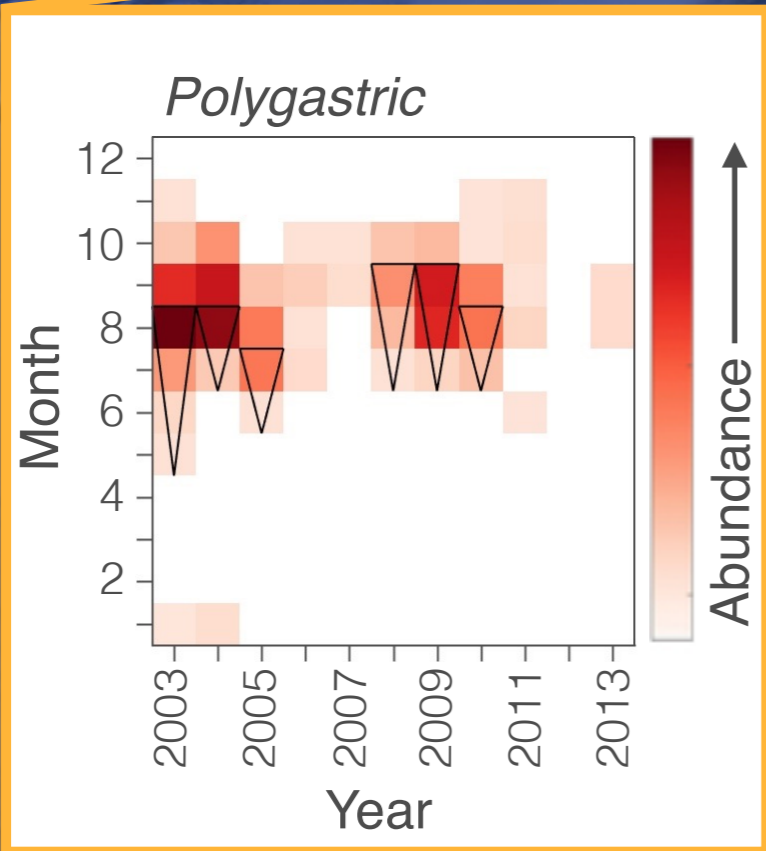
*Blackett et al (submitted)*



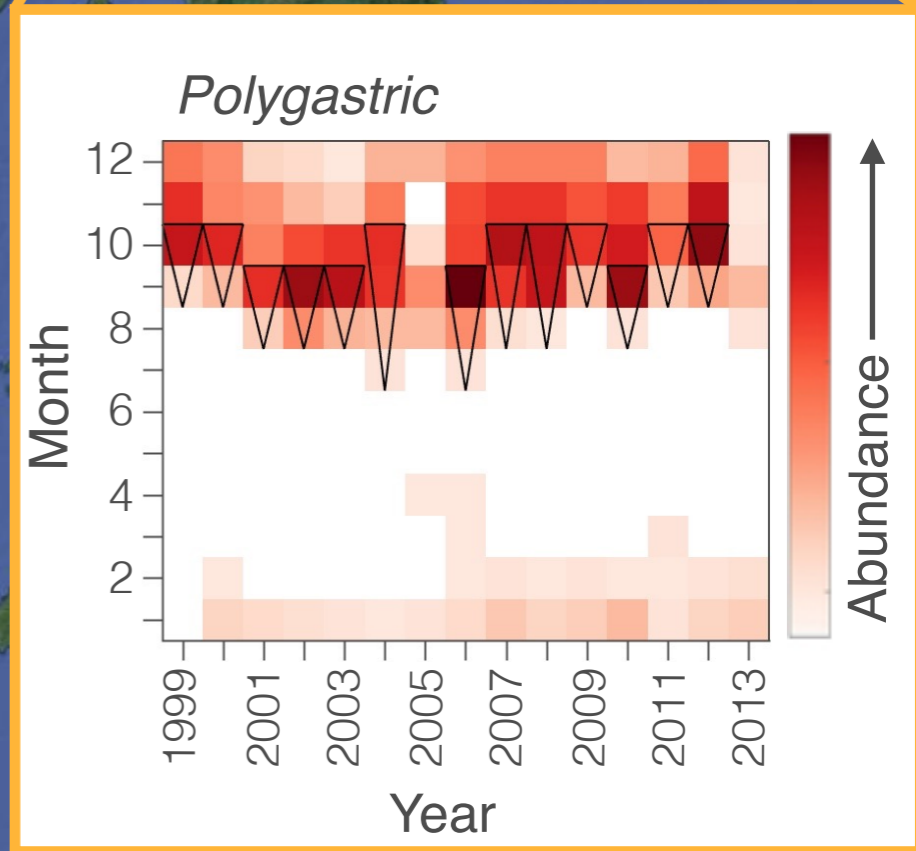
*Blackett et al (submitted)*

# × Reproduction = recruitment

Scottish  
Continental  
Shelf



*Blackett et al (submitted)*



*Blackett et al (submitted)*

✗ Reproduction = recruitment

∞ Life history?

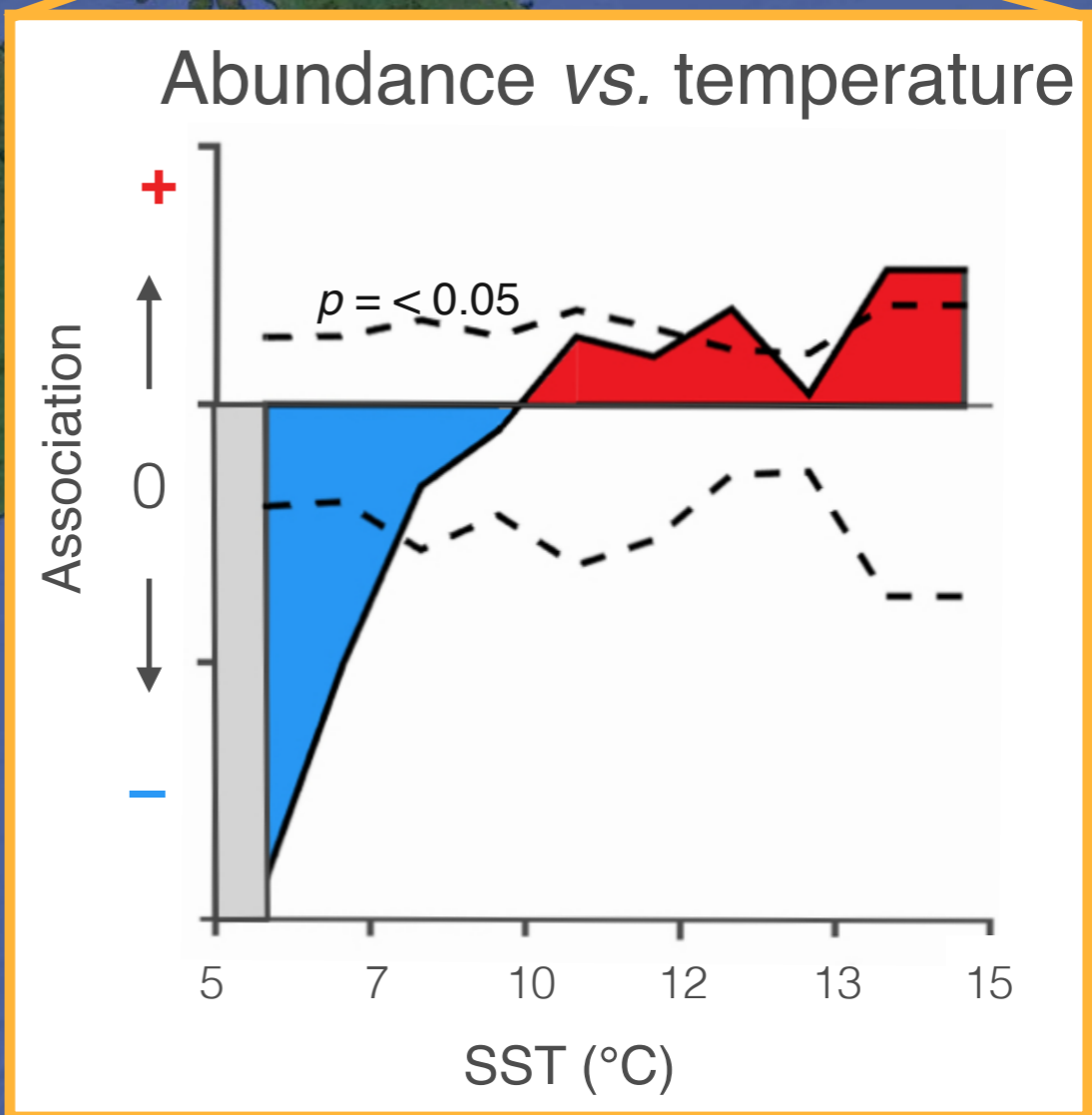
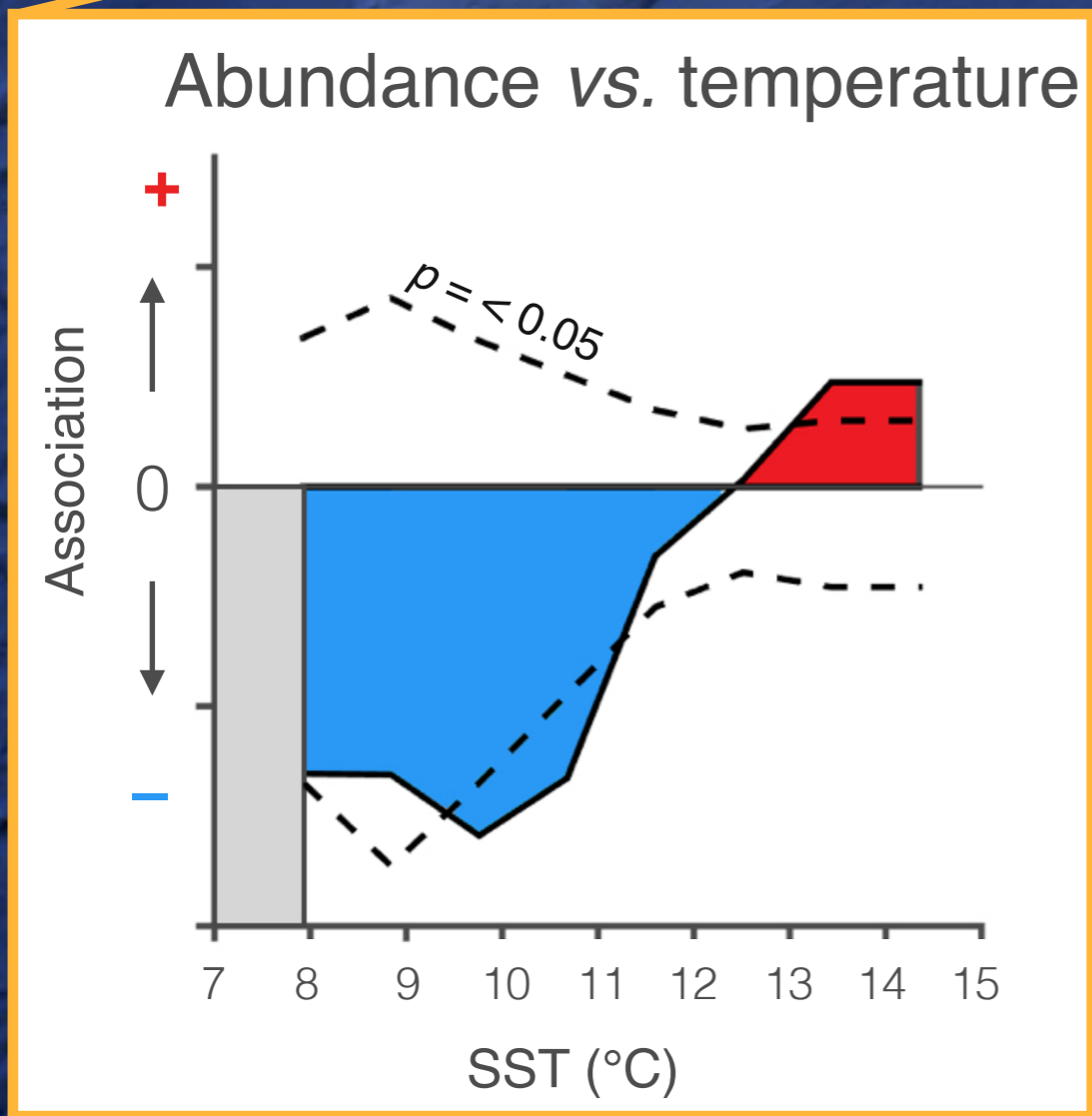
Persist indefinitely?

13–15 °C

< 11 / 8 °C

< 8 / 6 °C

Scottish  
Continental  
Shelf

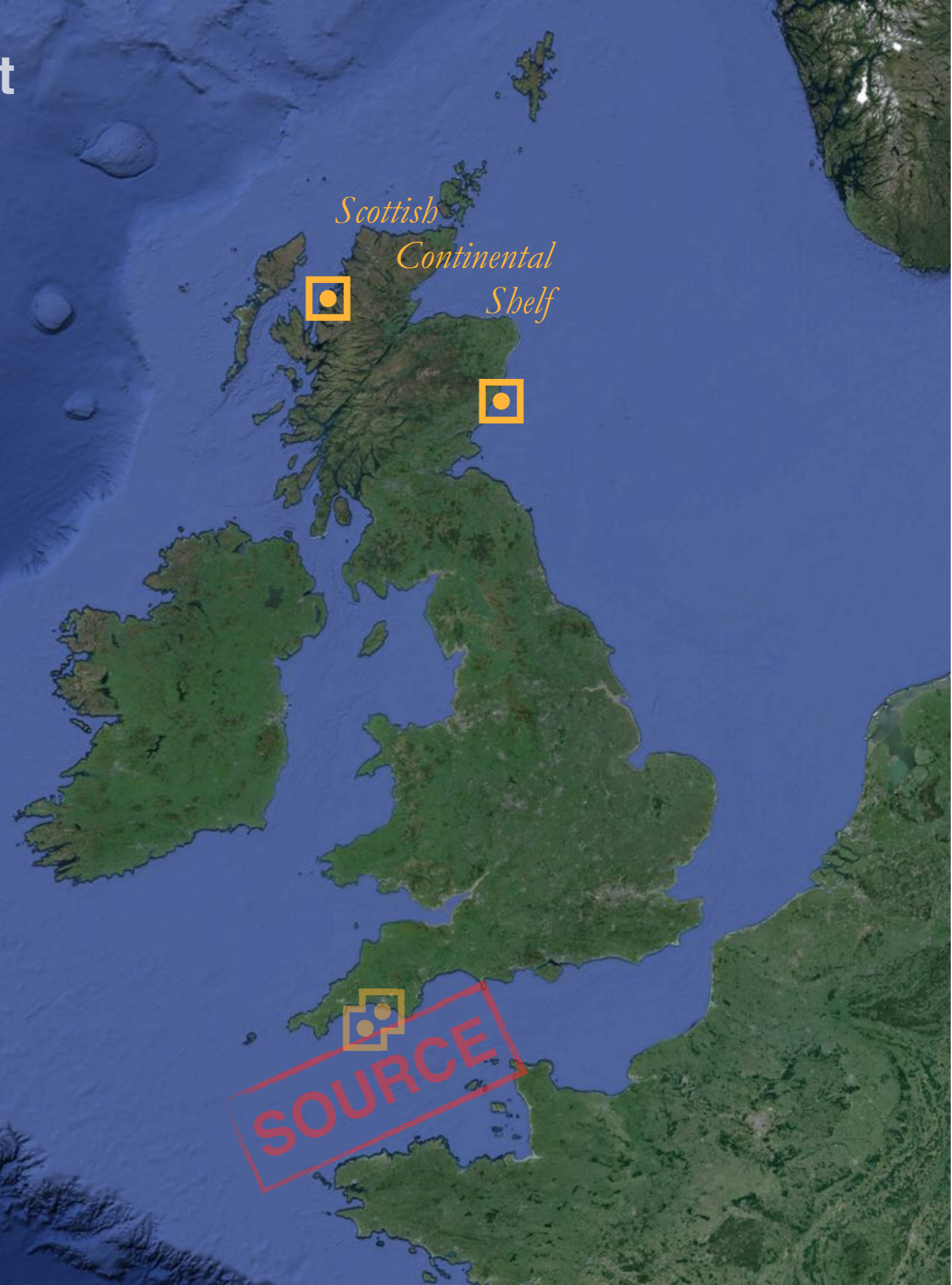


✗ Reproduction = recruitment

✗ ∞ Life history

✗ Persist indefinitely

Immigration?



*Scottish*

*Continental Shelf*

**SOURCE**

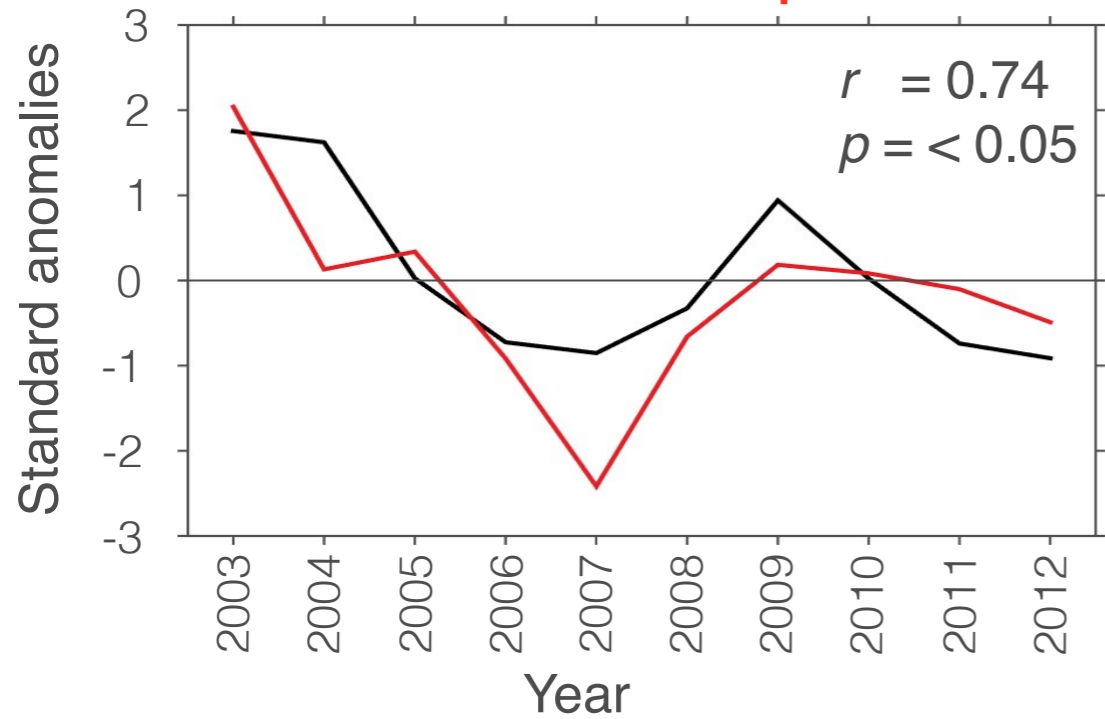
# European Slope Current

- Poleward flow
- Warm, saline water
- Disperses plankton





# *M. atlantica* vs. Slope Current



Blackett et al (submitted)



 Slope Current sampling stations

Xu et al 2015

*Muggiaea atlantica*

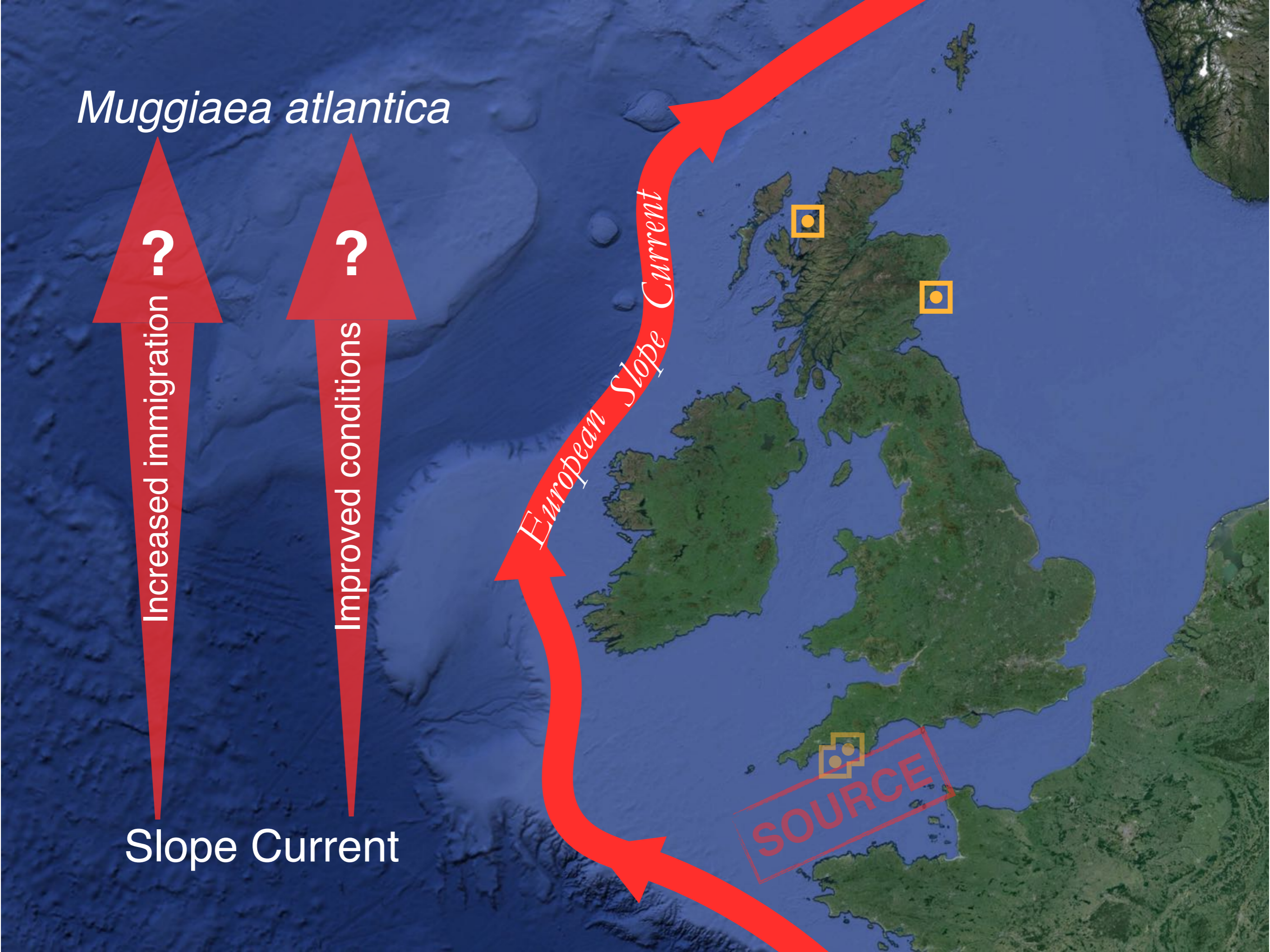
Increased immigration ?

Improved conditions ?

Slope Current

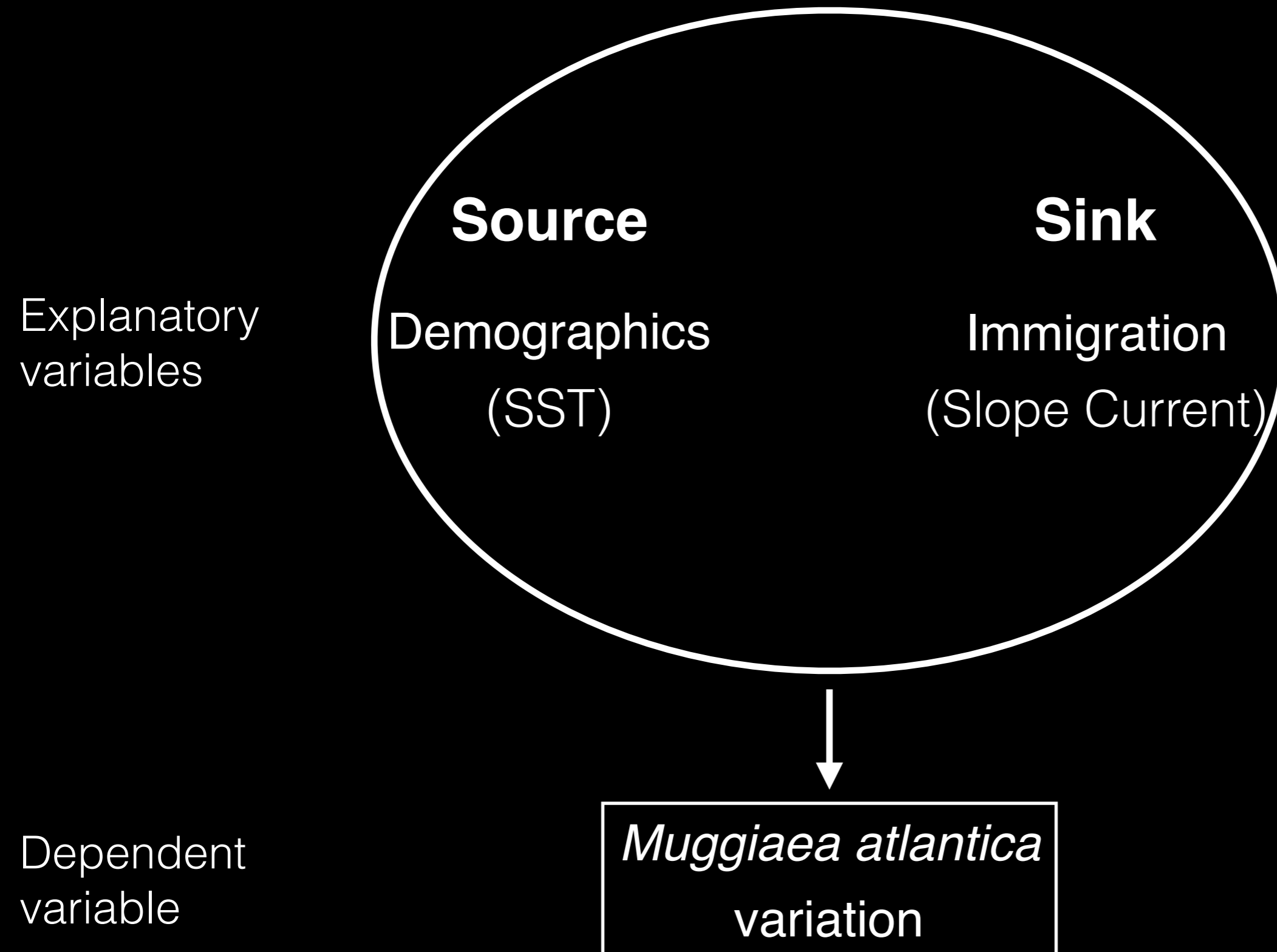
European Slope Current

SOURCE



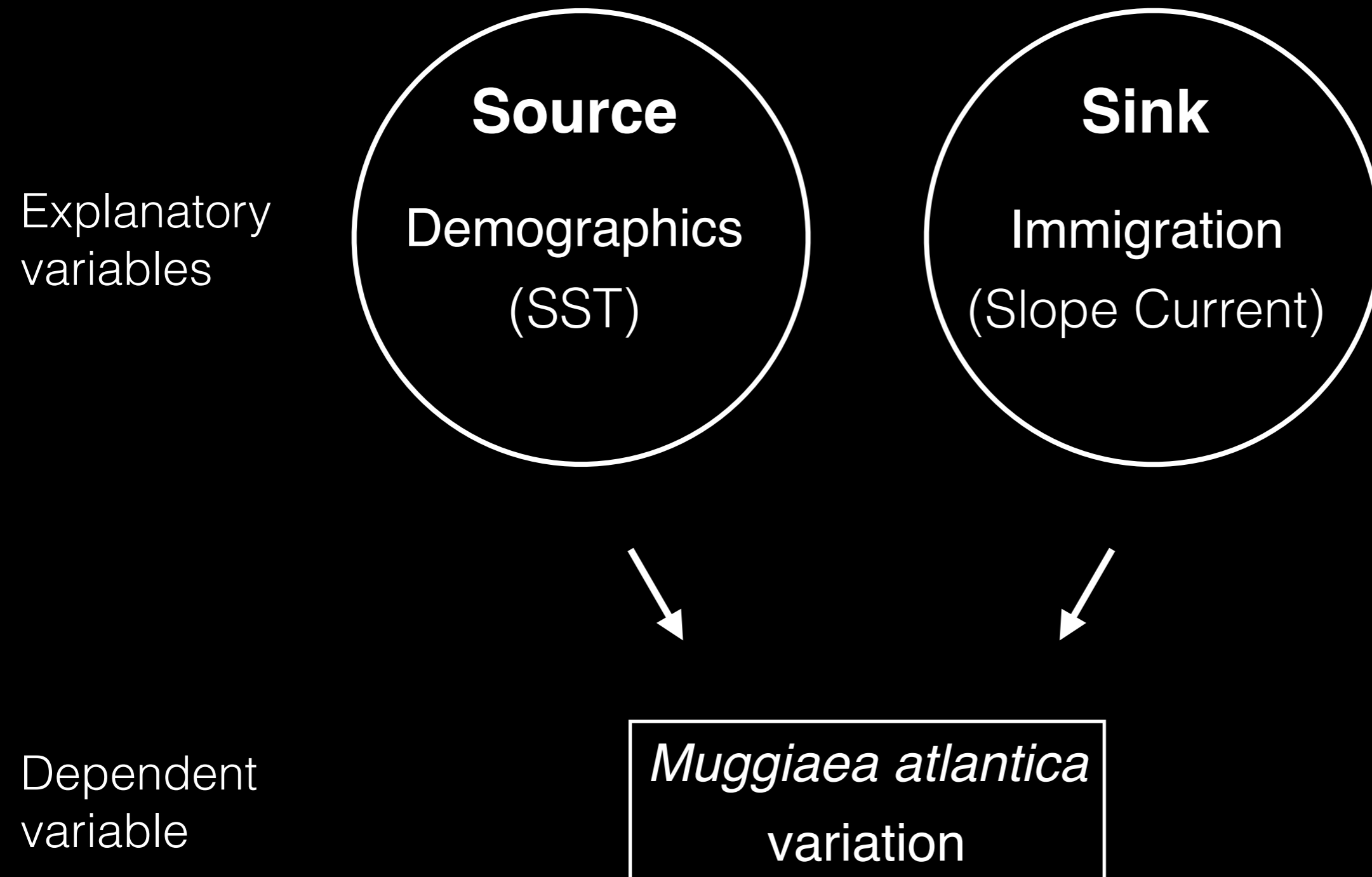
# Partial linear regression

*Peres-Neto et al (2006)*



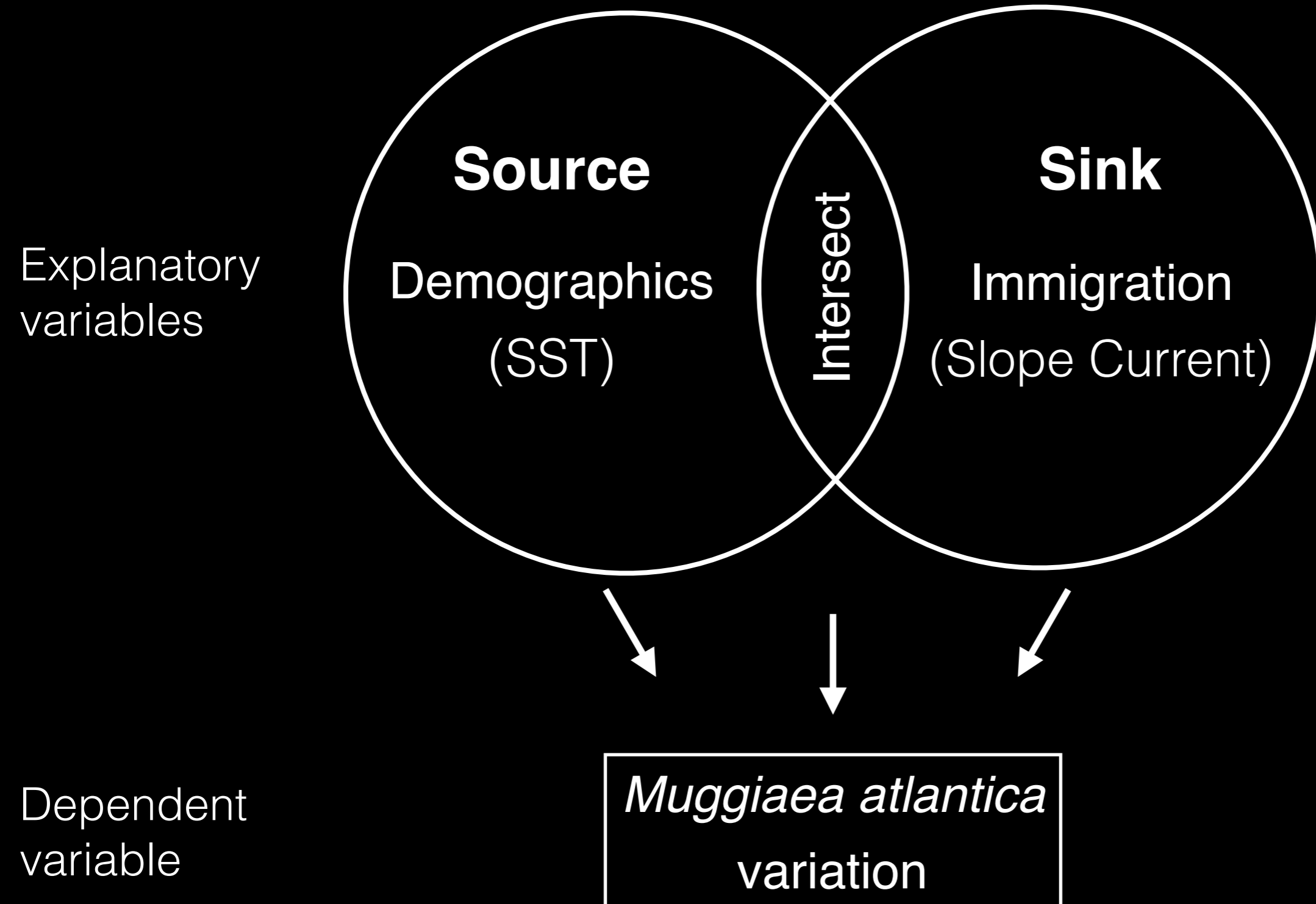
# Partial linear regression

*Peres-Neto et al (2006)*

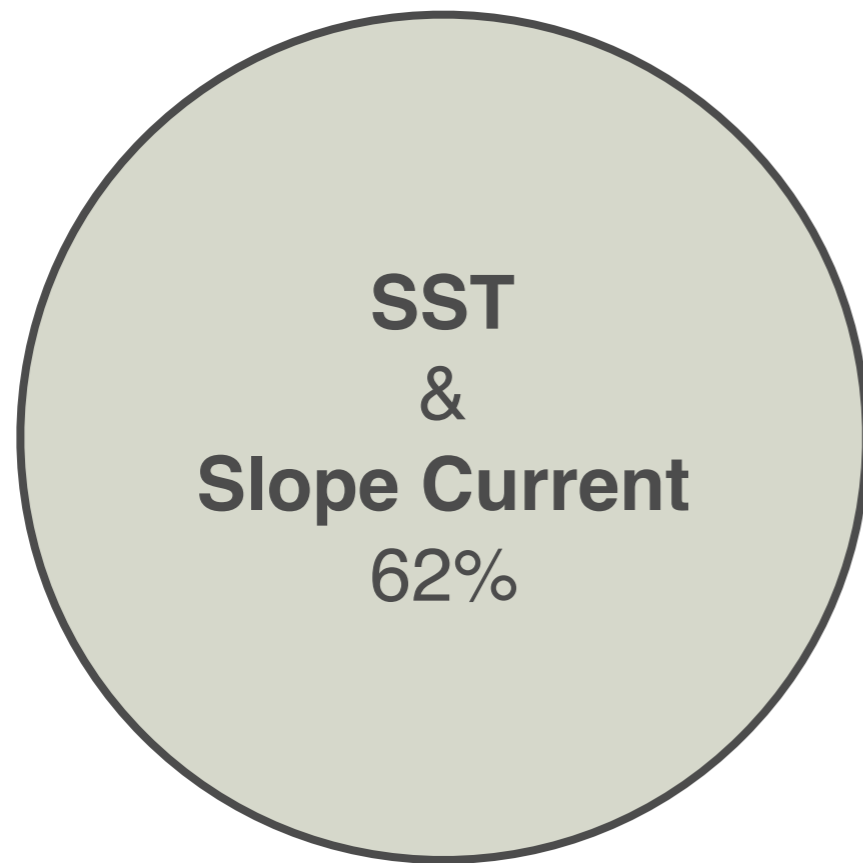


# Partial linear regression

*Peres-Neto et al (2006)*

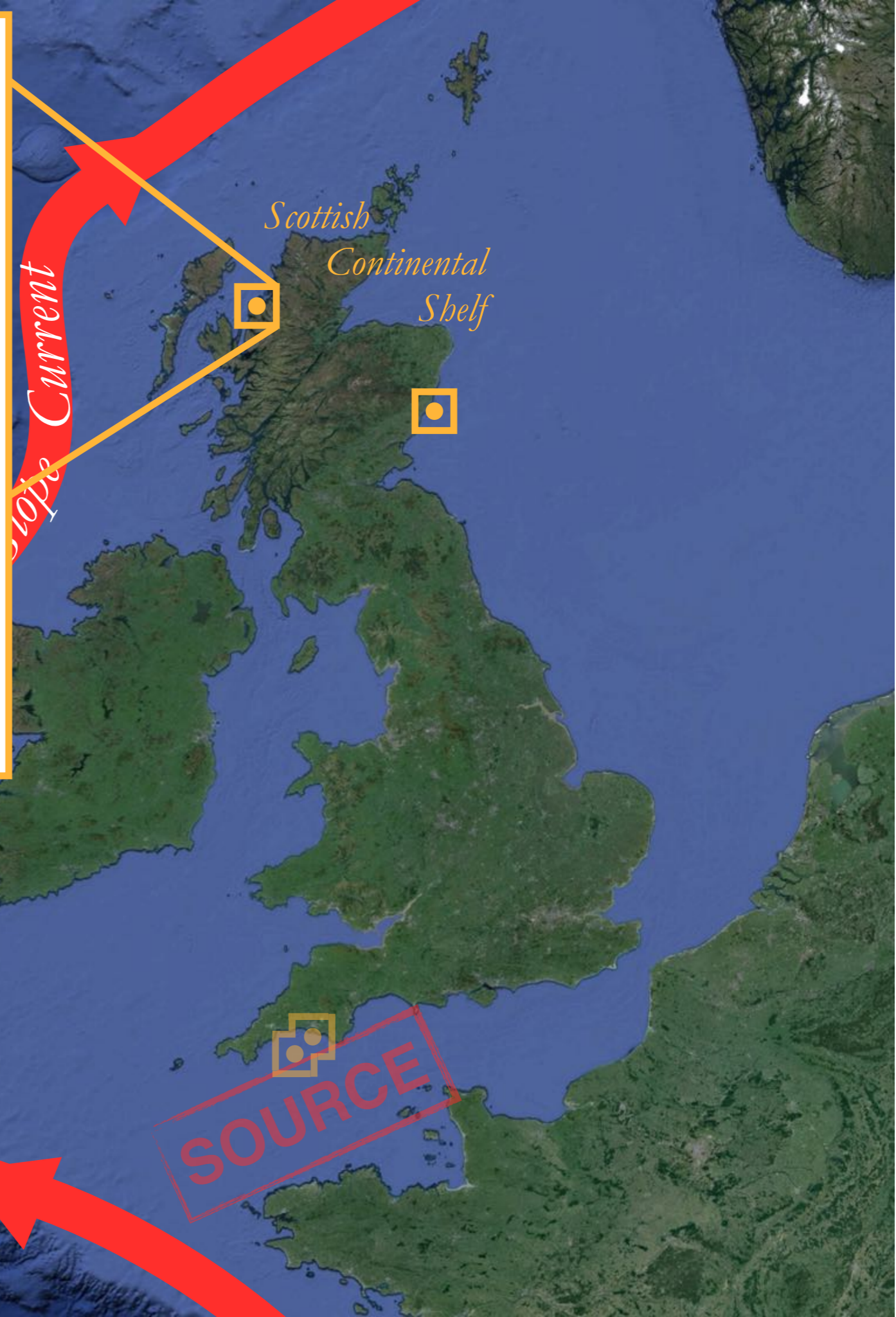


% of explained variation in  
annual abundance



$p = < 0.05$

*Blackett et al (submitted)*



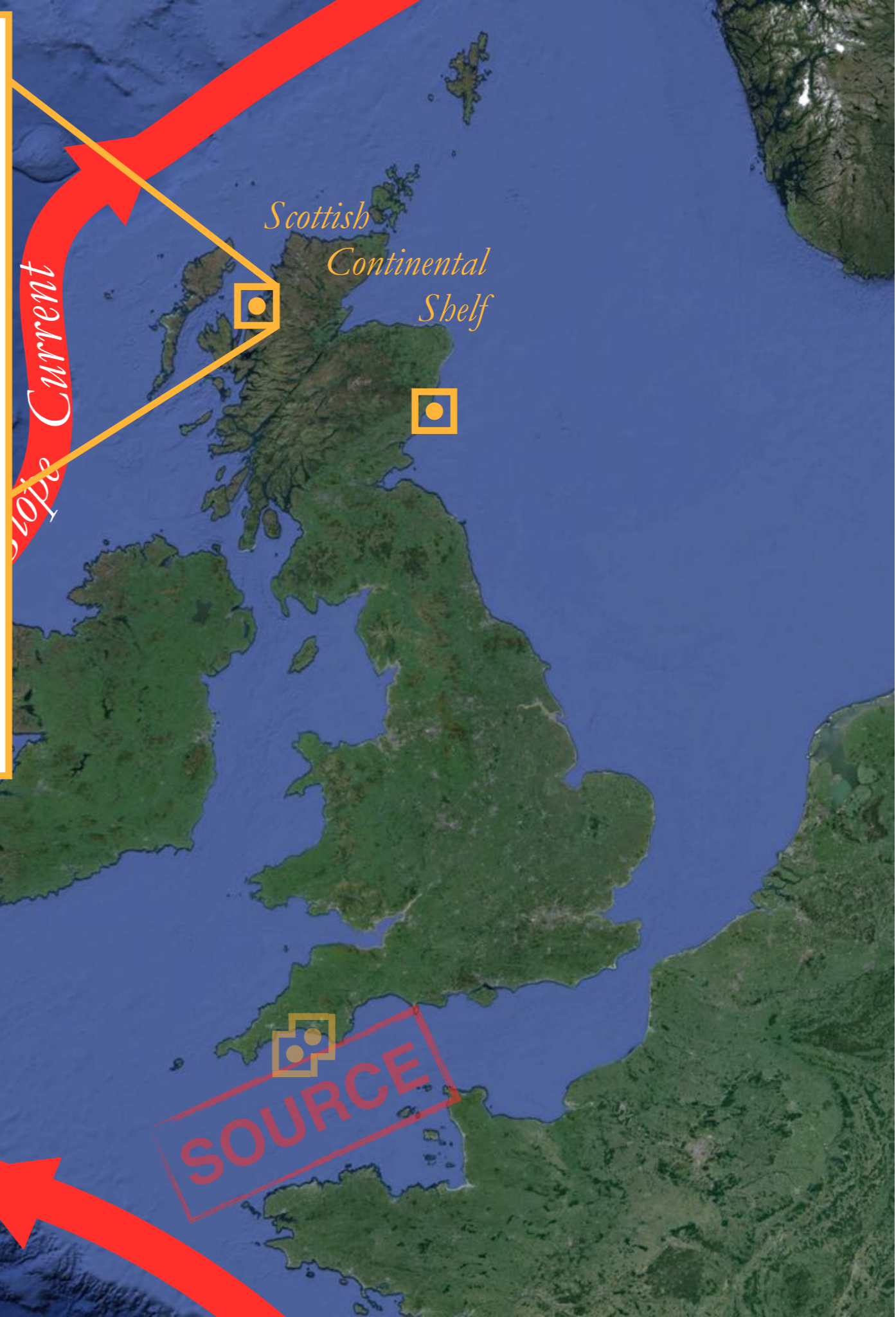
% of explained variation in  
annual abundance

**SST**  
33%

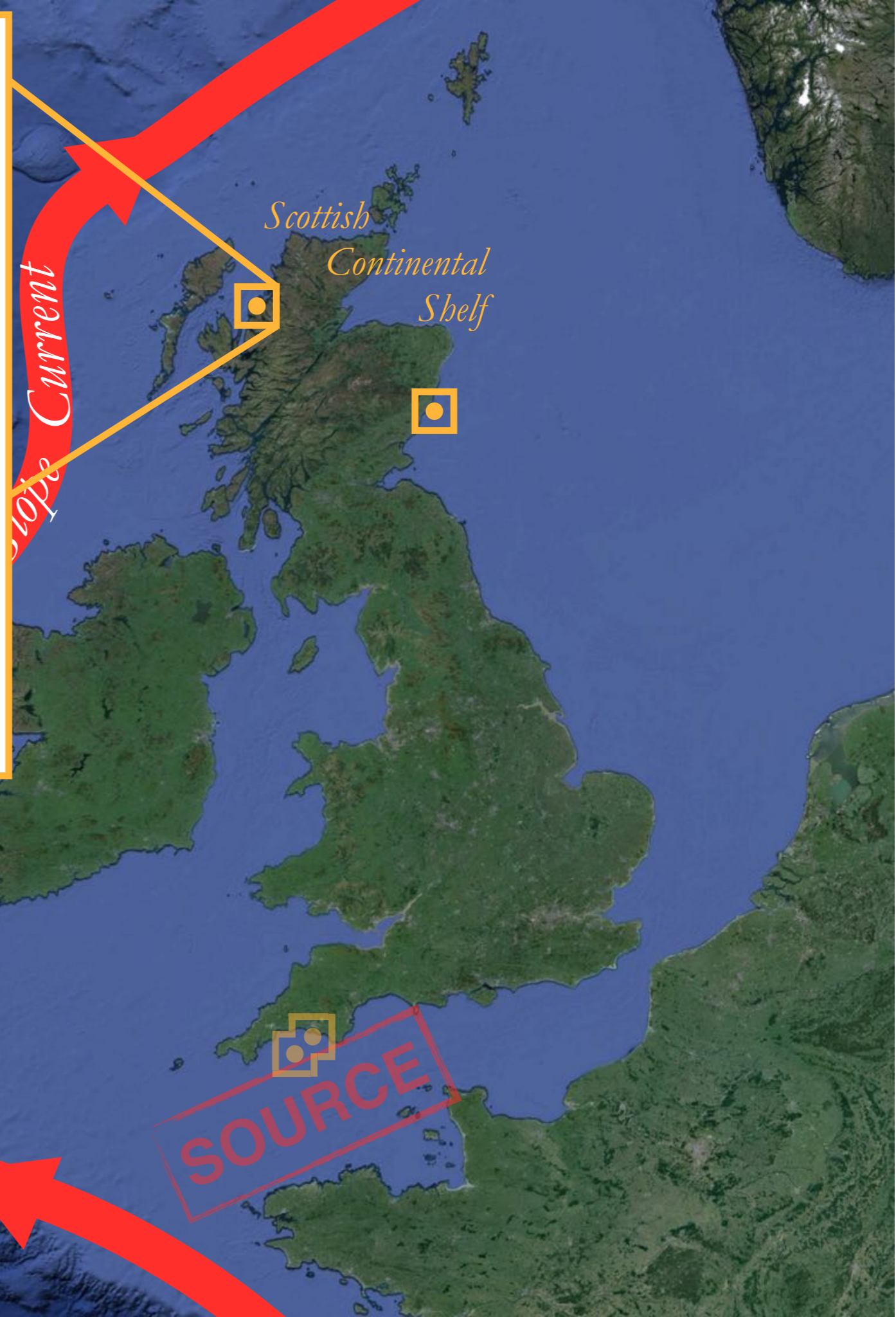
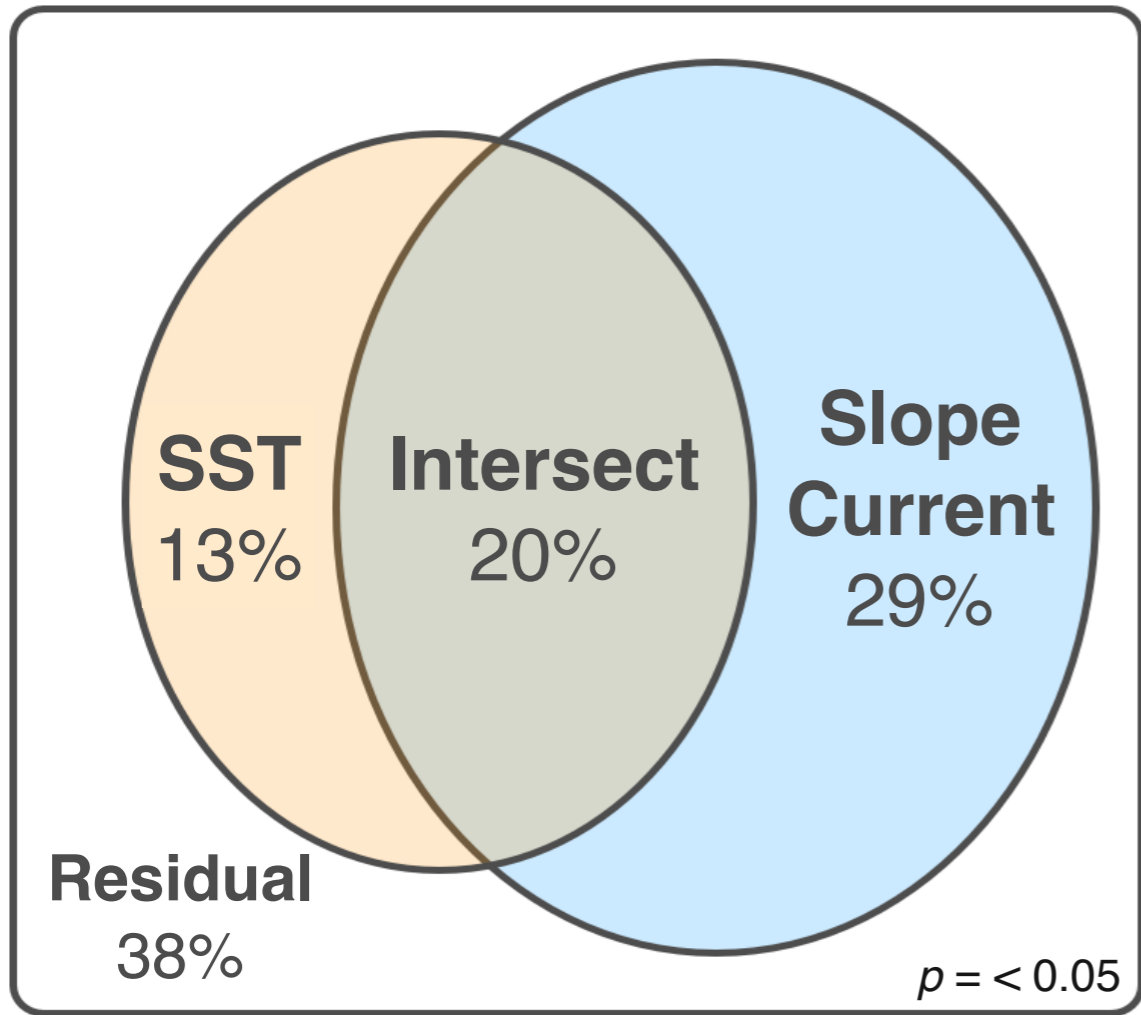
**Slope  
Current**  
49%

$p = < 0.05$

*Blackett et al (submitted)*



# Total variation (100%)



*Blackett et al (submitted)*





European Slope Current

**SINK**

*Scottish  
Continental  
Shelf*

**SOURCE**





# Summary

*Muggiaea atlantica* has expanded its northern distribution in the northeast Atlantic

- Established a resident population in the Western English Channel
- Established transient populations on the Scottish shelf
- Complex interaction of habitat-specific demography and current driven dispersal

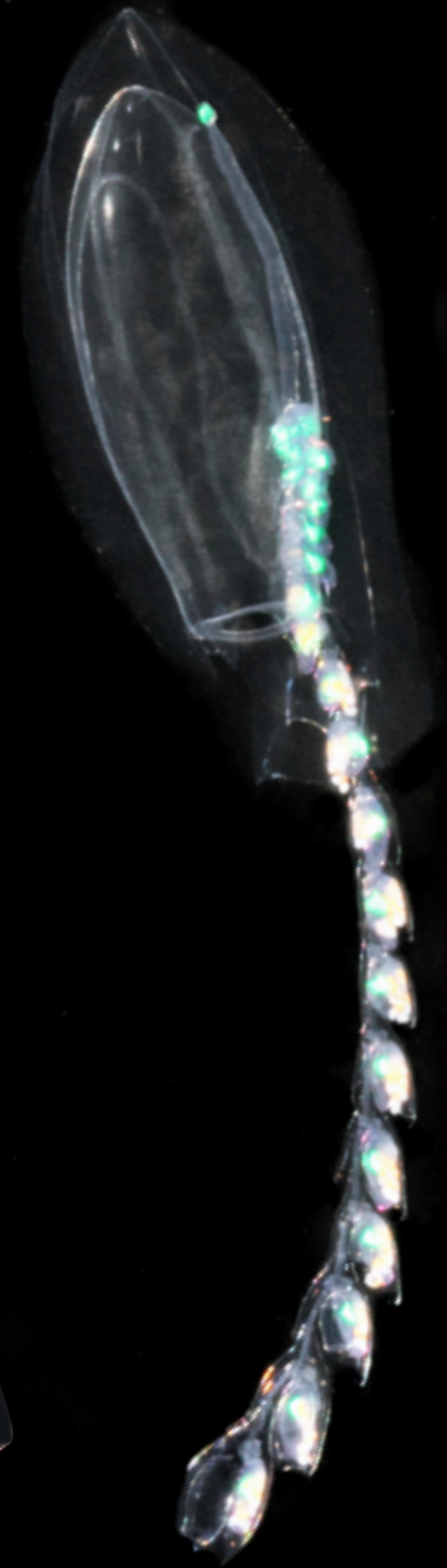
# Acknowledgements

**PML** | Plymouth Marine  
Laboratory



marinescotland  
science







# References

Blackett M, Licandro P, Coombs SH and Lucas CH (2014) **Long-term variability of the siphonophores *Muggiaea atlantica* and *M. kochi* in the Western English Channel.** Progress in Oceanography. 128, 1-14.

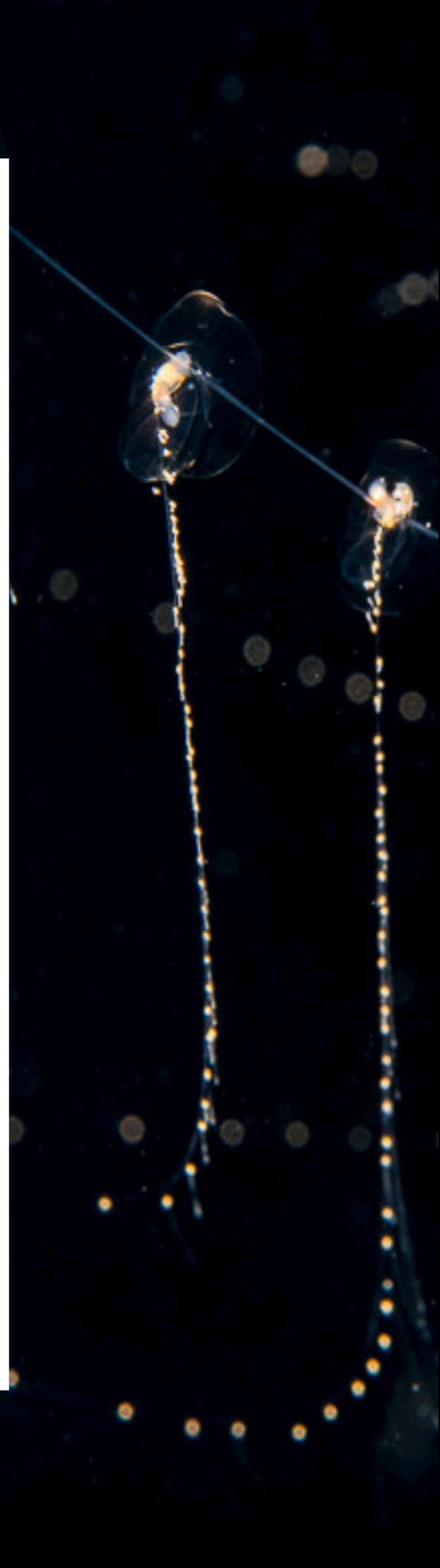
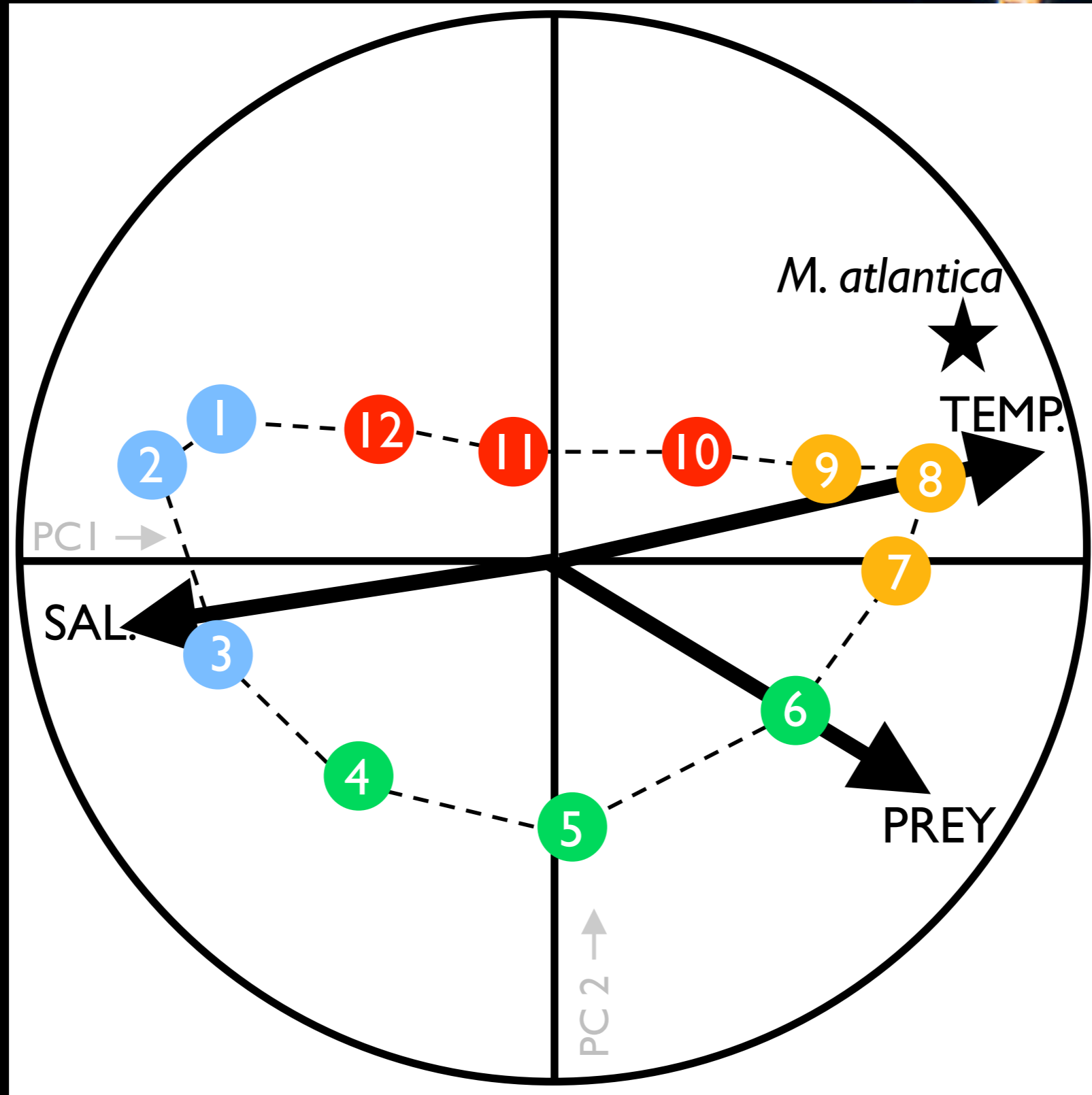
Blackett M, Lucas CH, Harmer RA and Licandro P (2015) **Population ecology of *Muggiaea atlantica* (Cnidaria, Siphonophora) in the Western English Channel.** Marine Ecology Progress Series. 535, 129–144.

Blackett M (2015) **Biology and ecology of *Muggiaea atlantica* in the northeast Atlantic.** PhD Thesis. University of Southampton.

Blackett M, Lucas CH, Cook K and Licandro P (Submitted) **Blooms of the siphonophore *Muggiaea atlantica* in Scottish coastal waters: source or sink?** Journal of Plankton Research.

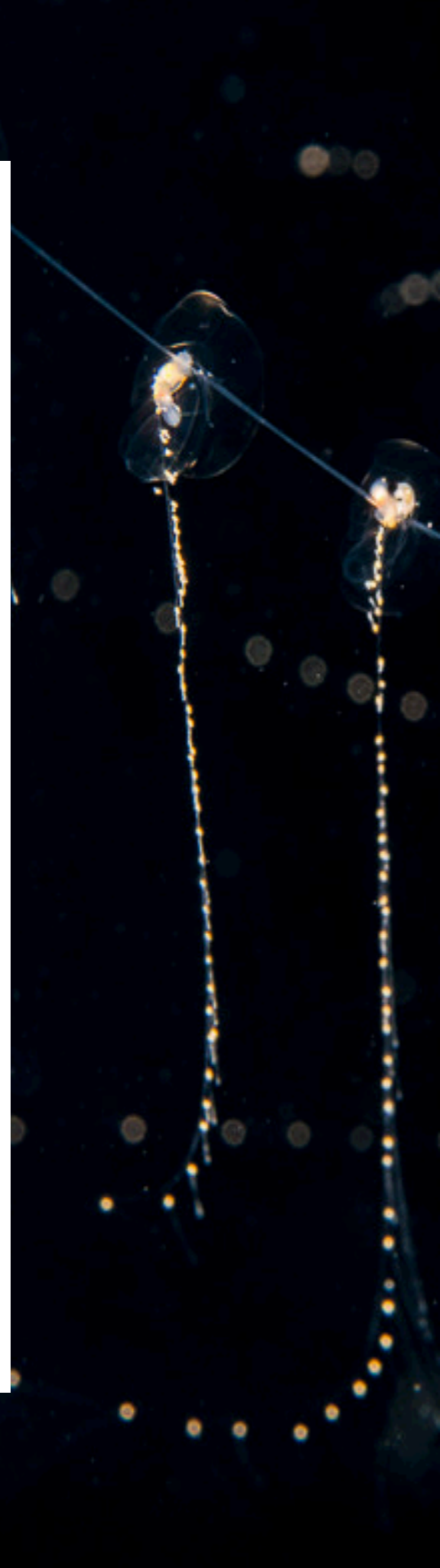
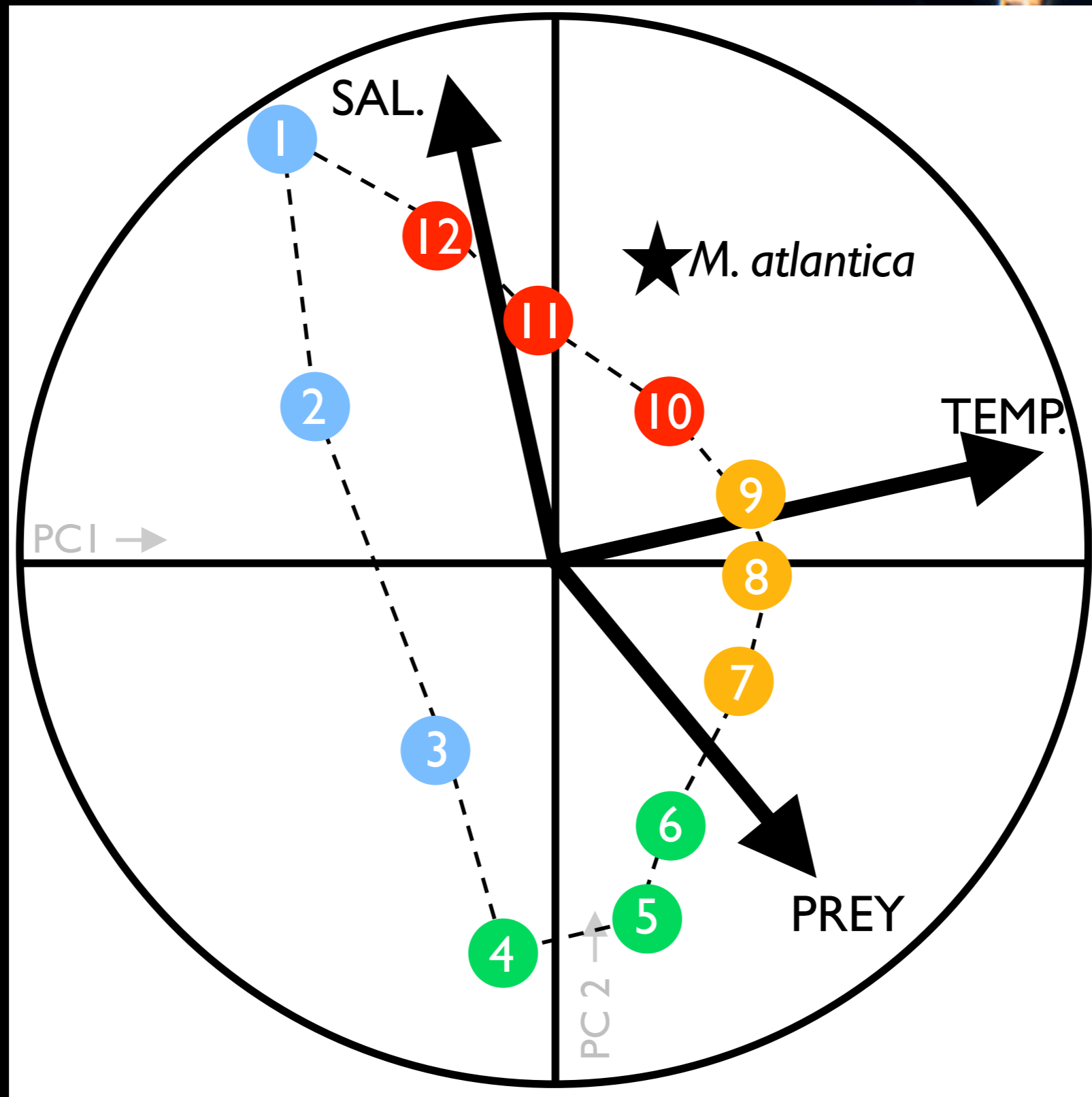


# Average annual cycle (compromise)





# Individual annual cycles (trajectories)







# Inter-annual environmental variability

