Revisiting Stommel to Assess Spatiotemporal Scales of Gelatinous Zooplankton & Their Roles in Biogeochemical Cycles

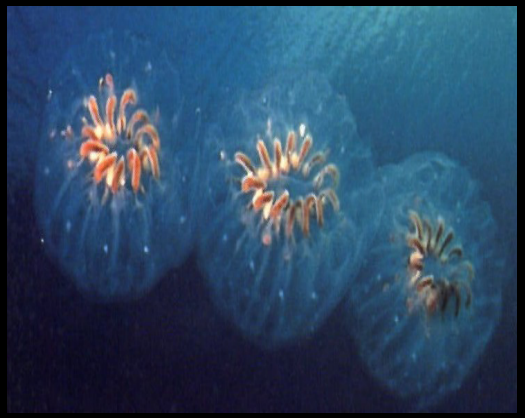
Robert Condon*, Carlos Duarte, Kylie Pitt, Cathy Lucas, Monty Graham & Global Jellyfish Group

Outline

1. What is the baseline & long term trends for gelatinous zooplankton (GZ)?

Medusae

Ctenophore



Pelagic Tunicates

1. What are the possible drivers of GZ?
2. What is the role of GZ in biogeochemical cycles

Jellyfish blooms – Global Consequences?

Pelagia noctiluca bloom in Mediterranean Sea

Sala, 2007

Nemopilema nomadica

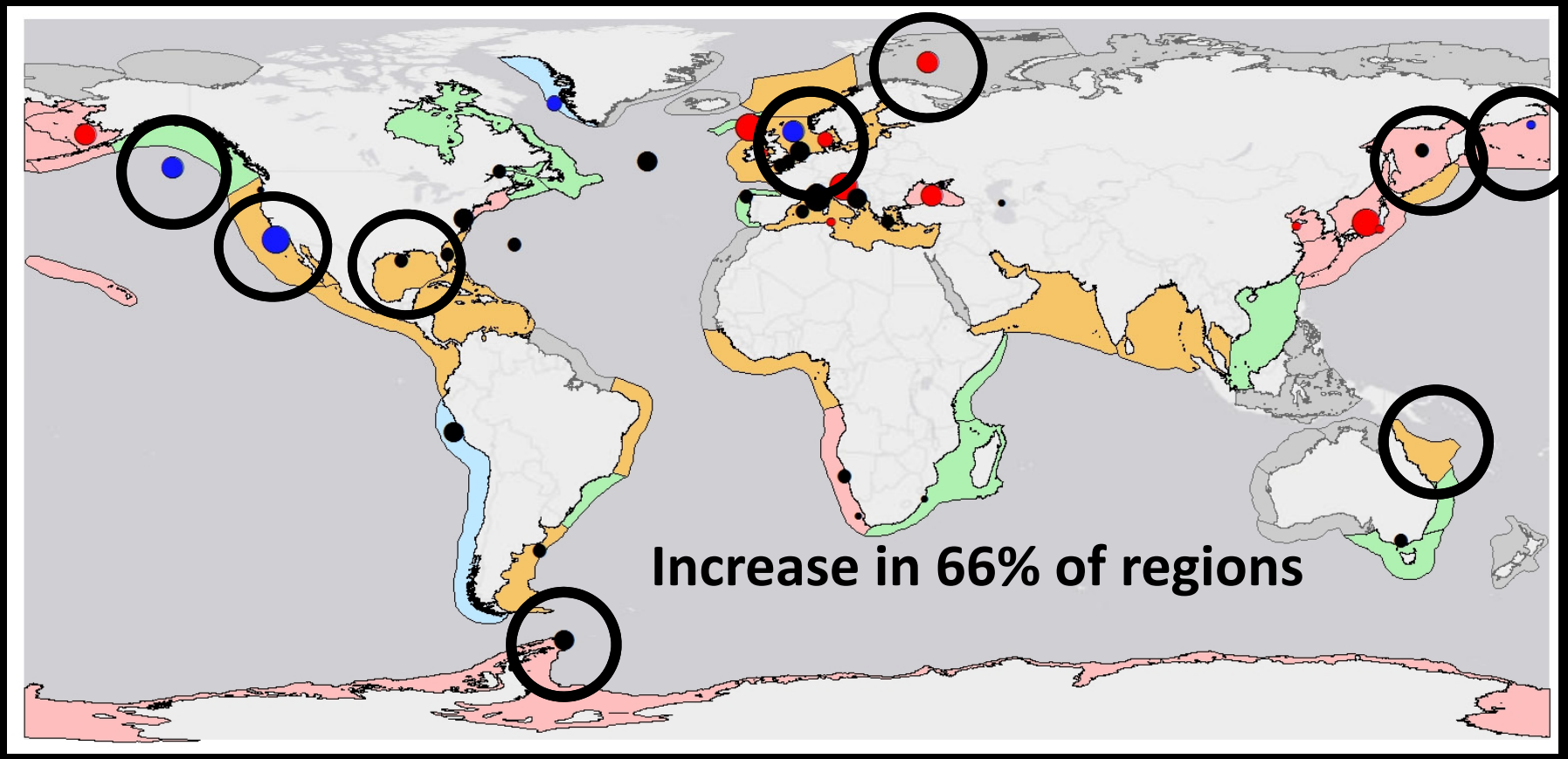
In Sea of Japan

Shin-ichi Uye

What About 70% of the Earth?

Unknown?

Increasing jellyfish populations: trends in Large Marine Ecosystems



Increase (high certainty)

Increase (low certainty)

Stable/ variable

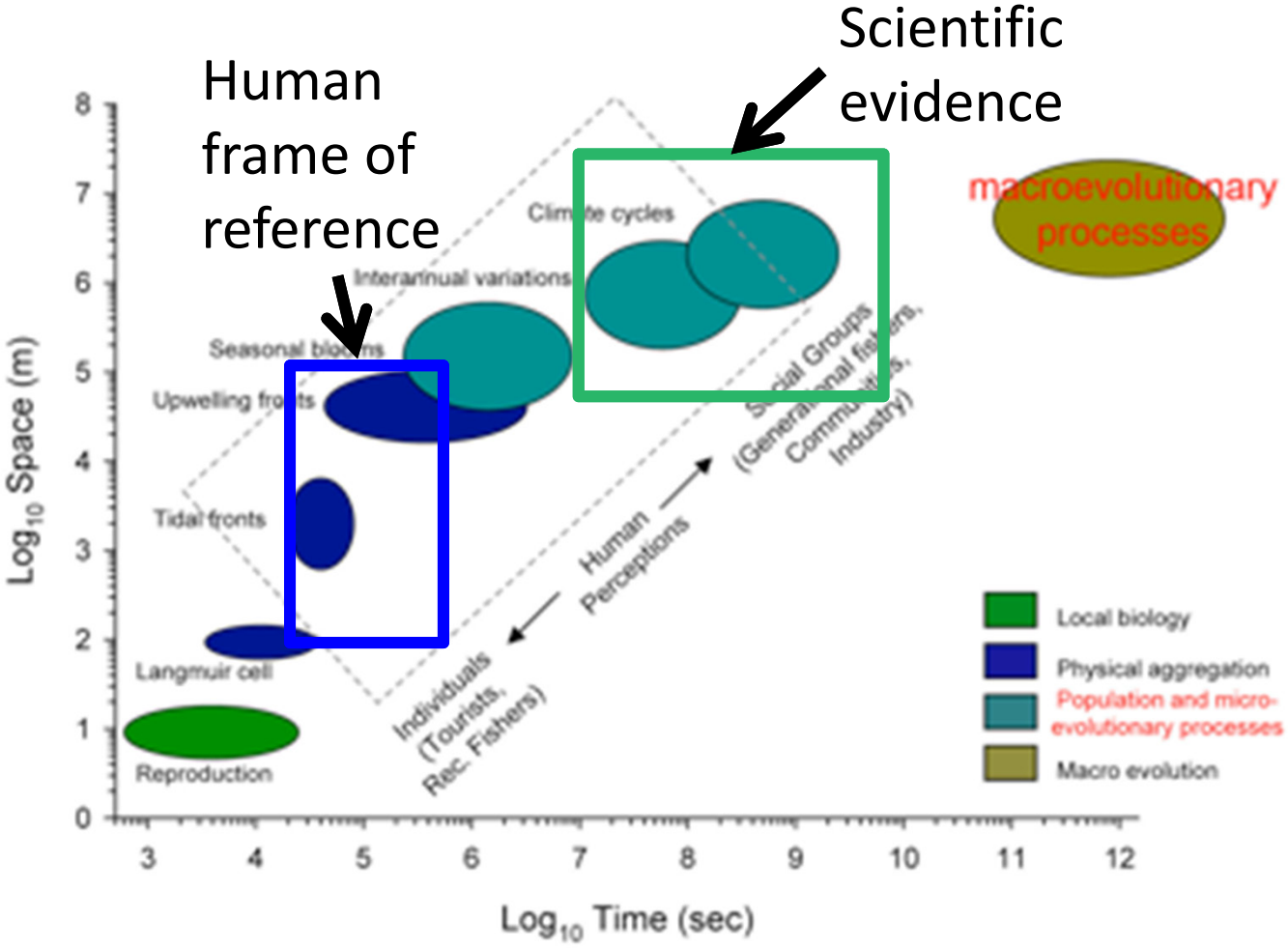
Decrease

Brotz et al. *Hydrobiologia* 2012

Paradigm Based on Myth?

Henry Stommel

Physical Oceanographer



Condon et al. *BioScience* 2012

Confusion About Validity of the Paradigm

Articles

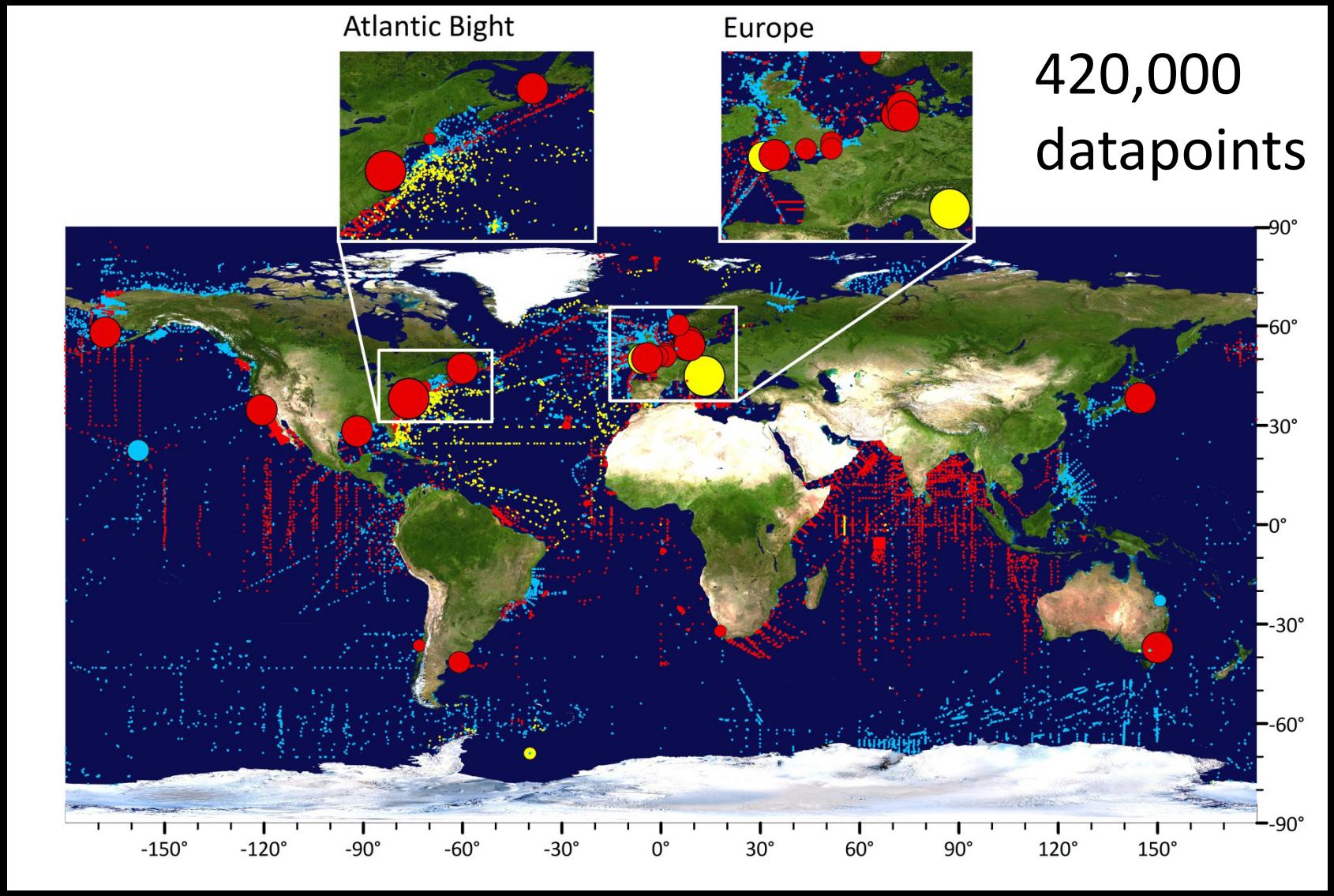
Questioning the Rise of Gelatinous Zooplankton in the World's Oceans

ROBERT H. CONDON, WILLIAM M. GRAHAM, CARLOS M. DUARTE, KYLIE A. PITT, CATHY H. LUCAS, STEVEN H.D. HADDOCK, KELLY R. SUTHERLAND, KELLY L. ROBINSON, MICHAEL N. DAWSON, MARY BETH DECKER, CLAUDIA E. MILLS, JENNIFER E. PURCELL, ALENKA MALEJ, HERMES MIANZAN, SHIN-ICHI UYE, STEFAN GELCICH, AND LAURENCE P. MADIN

BioScience 62: 160–169. ISSN 0006-3568, electronic ISSN 1525-3244. doi:10.1525/bio.2012.62.2.9

(Condon et al. *BioScience*, 2012)

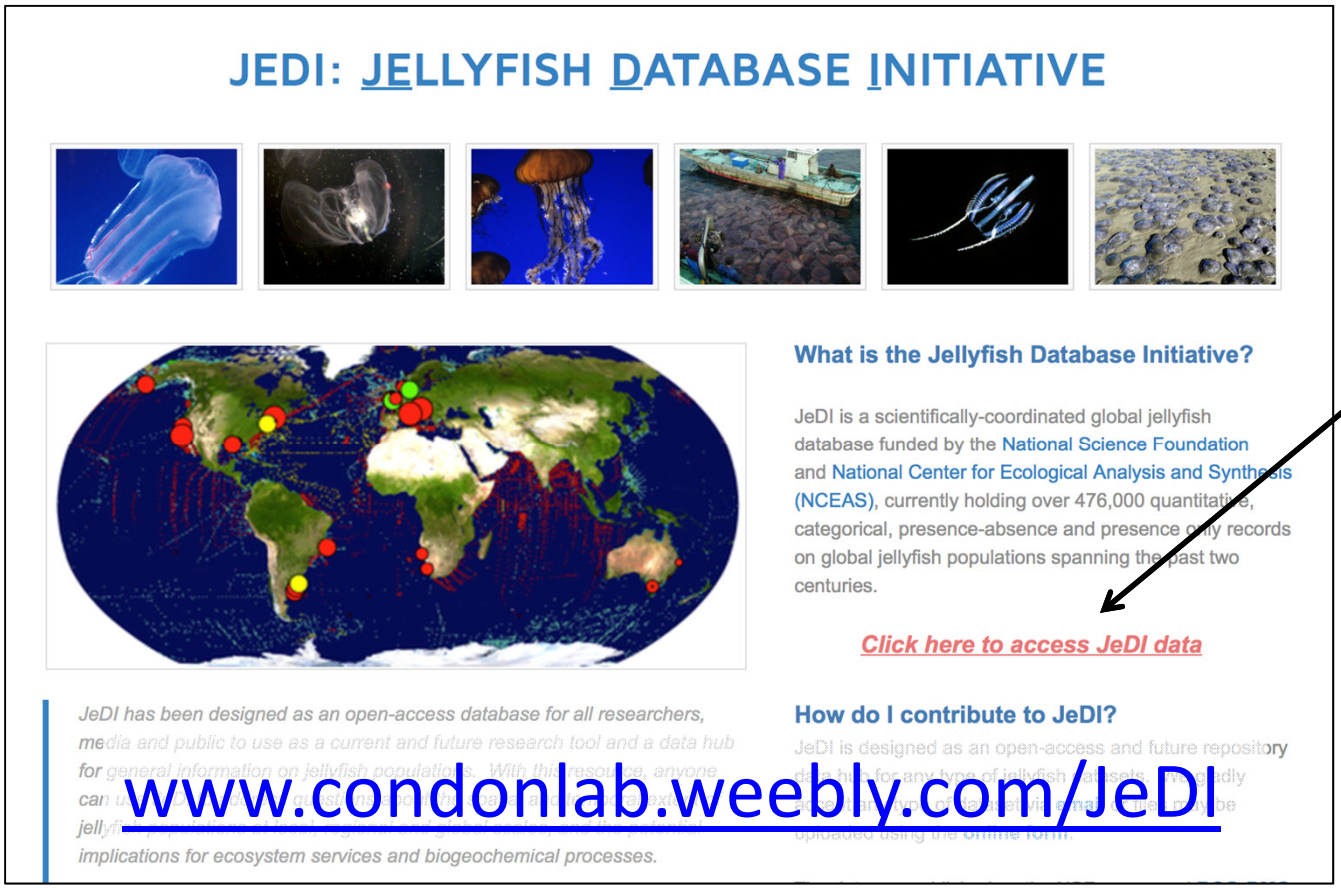
Jellyfish Database Initiative (JEDI)



condonlab.weebly.com , Condon et. al., 2015

JeDI Objectives

1. Create open access database to use as a research tool to evaluate trends in GZ



BCO-DMO
Biological & Chemical Oceanography Data Management Office

www.condonlab.weebly.com/JeDI

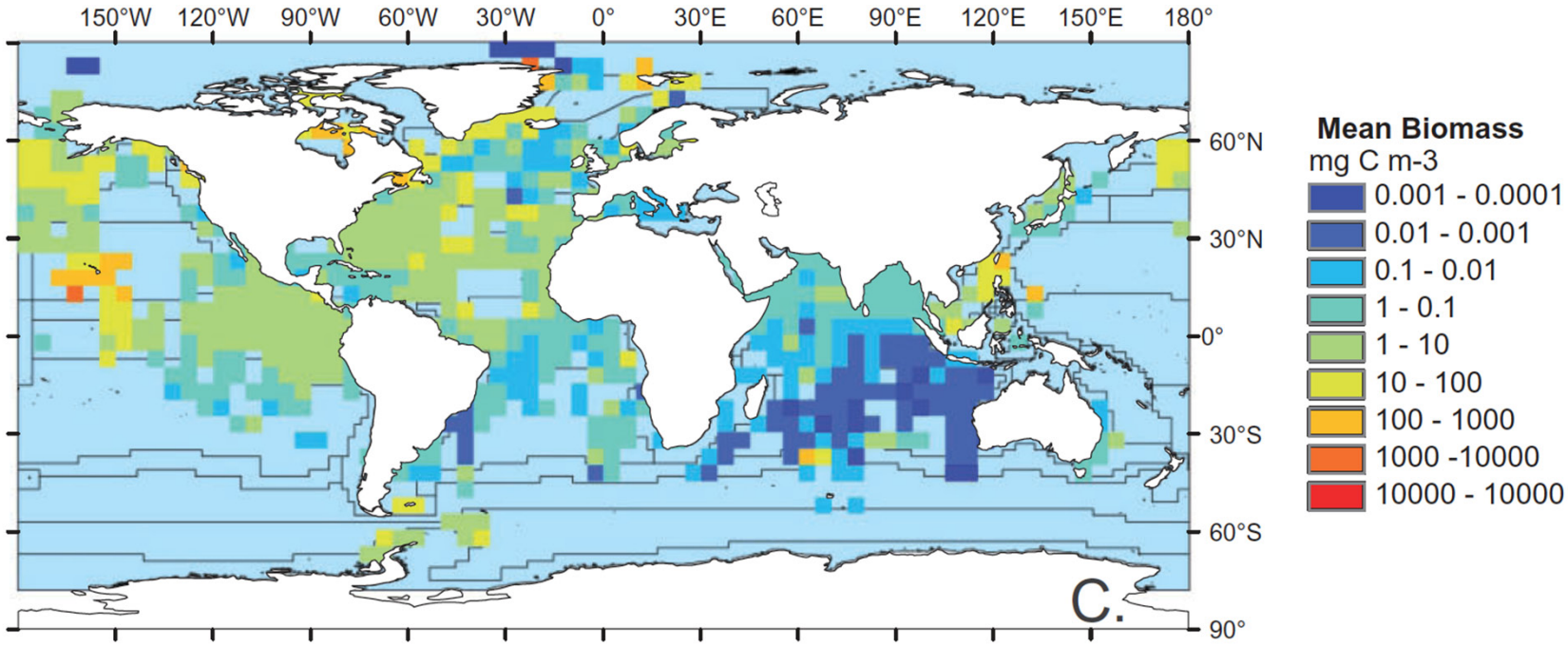
Condon et al. 2015

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2014)

RESEARCH PAPER

Gelatinous zooplankton biomass in the global oceans: geographic variation and environmental drivers

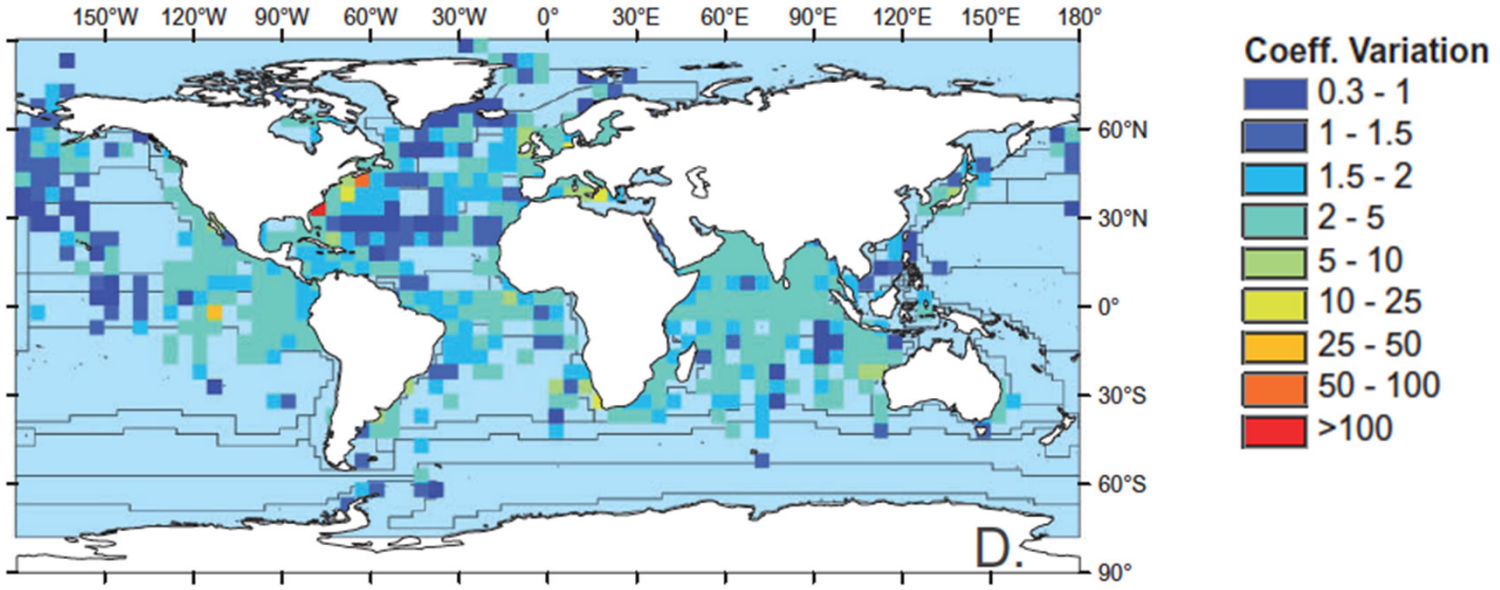
Cathy H. Lucas[1]*, Daniel O. B. Jones[1], Catherine J. Hollyhead[1,2], Robert H. Condon[3], Carlos M. Duarte[4,5,6], William M. Graham[7],



- 38 Tg C Globally, comparable biomass between open & coastal ocean, requires 0.1 – 12% PP
- Correlated with dissolved O2, AOU & SST

JeDI Objectives

2. Data hub & future repository of datasets continue to evaluate the baseline & improve forecasting capabilities
   - JeDI 2.0

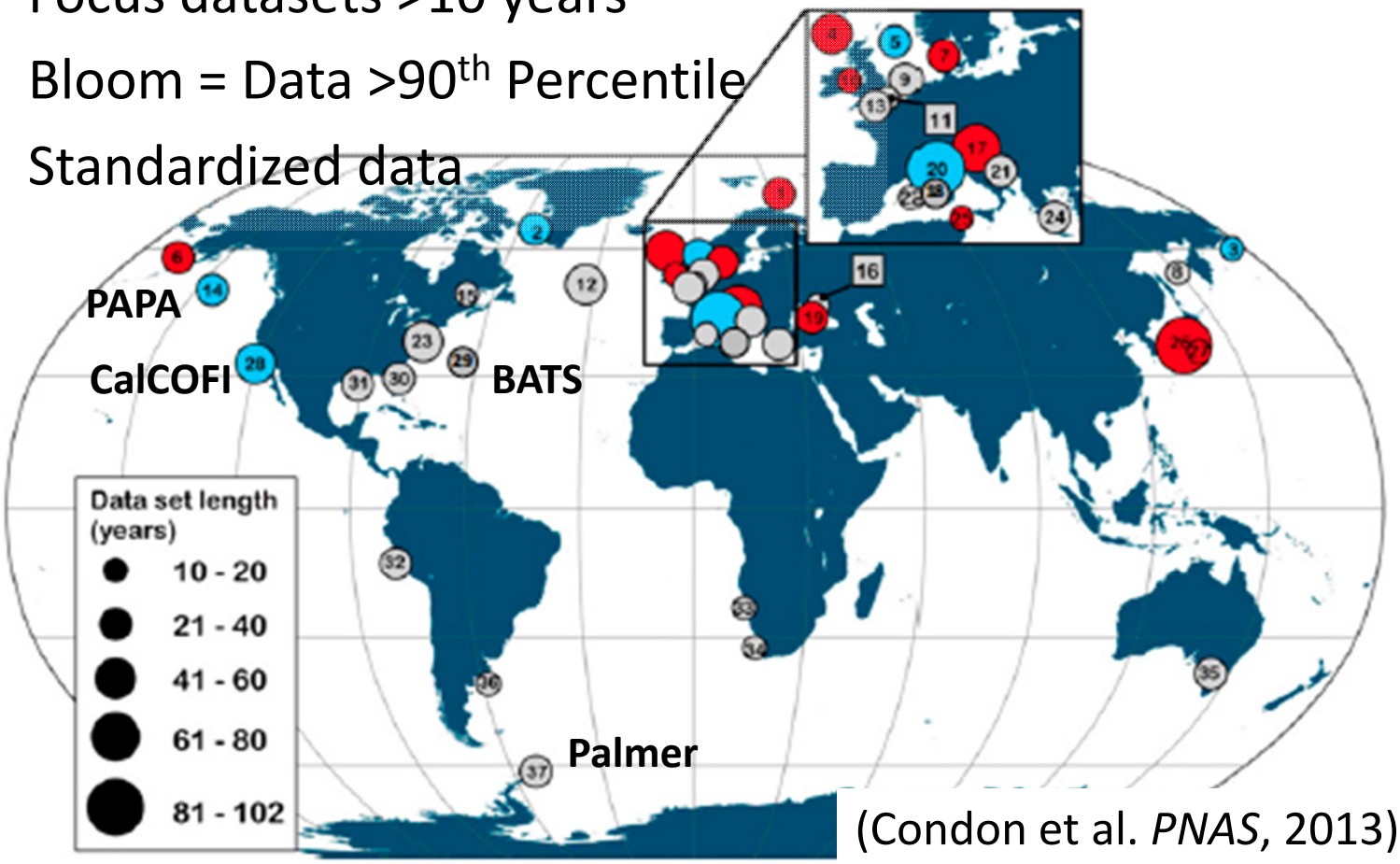


Lucas et al. *Global Ecol. Biog.* 2014

Fast Facts of Global Analyses

H_0: Jellyfish population sizes and number of blooms have not significantly increased in the world's oceans

- Focus datasets >10 years
- Bloom = Data >90th Percentile
- Standardized data



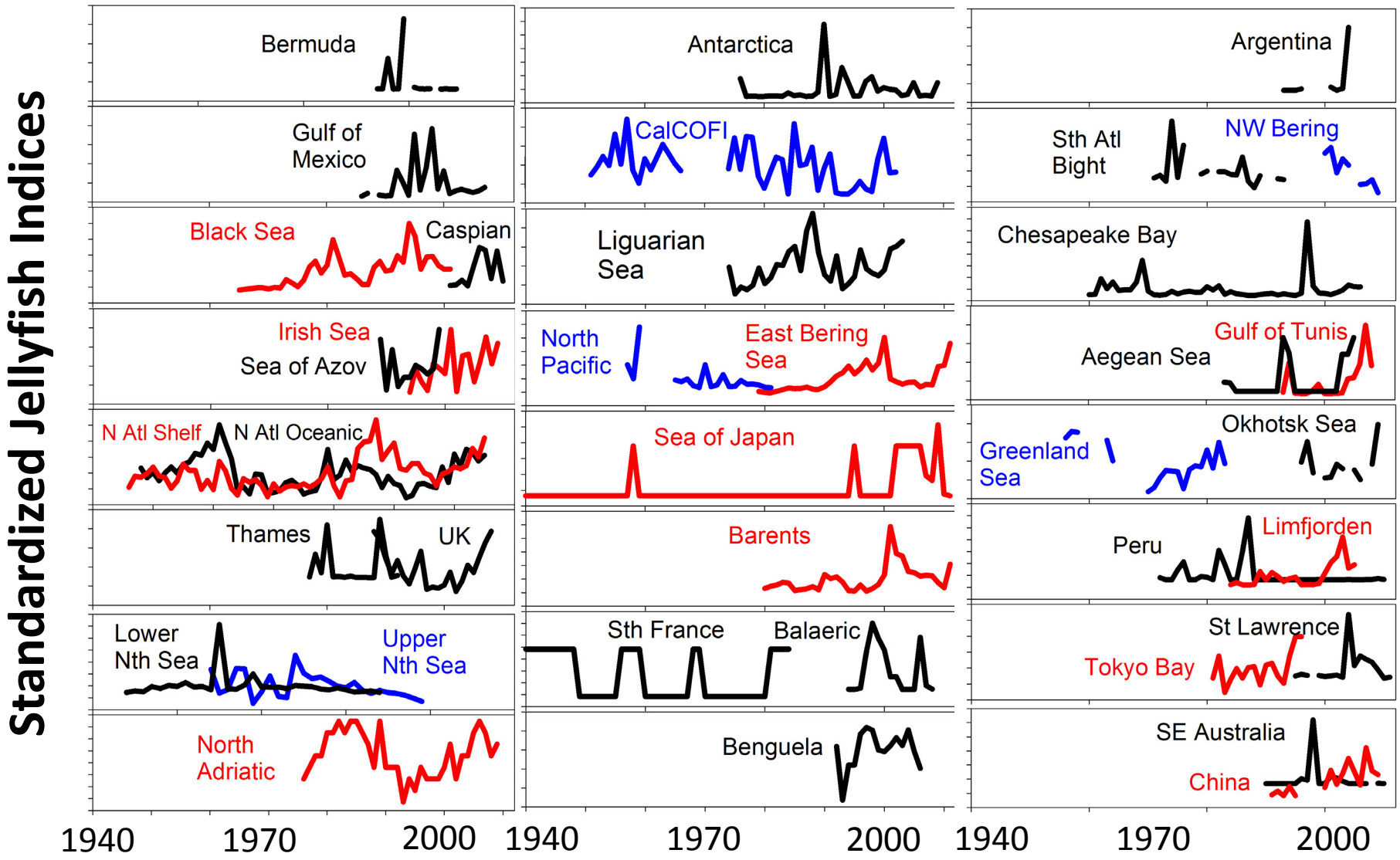
(Condon et al. *PNAS*, 2013)

Criteria for Evaluating Long-term Trends in Jellyfish

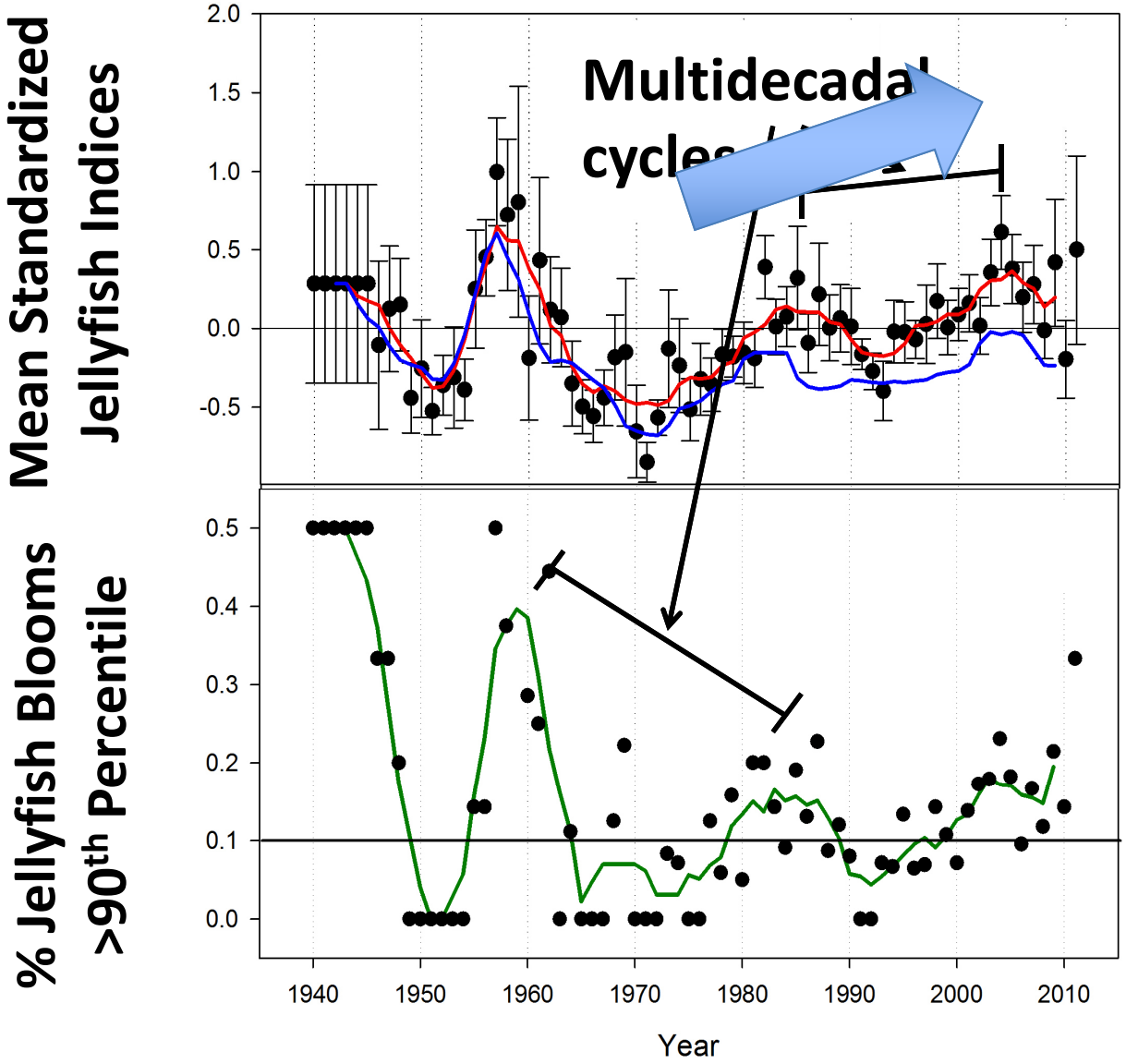
1. ***Linear and logistic (binary) mixed models*** to assess departure from standardized baseline of zero
   - Linear & non-linear components
   - Adjusted for autocorrelation (AR1)
   - Random factors
2. ***Effect size*** analysis
   - Is the magnitude of change different for increases vs. decreases

Both tests need to be significant to reject H_0

Regional Datasets > 10 years



Global Jellyfish Time-series



Caveat

Linear: p = 0.37

Nonlinear: p = 0.01*

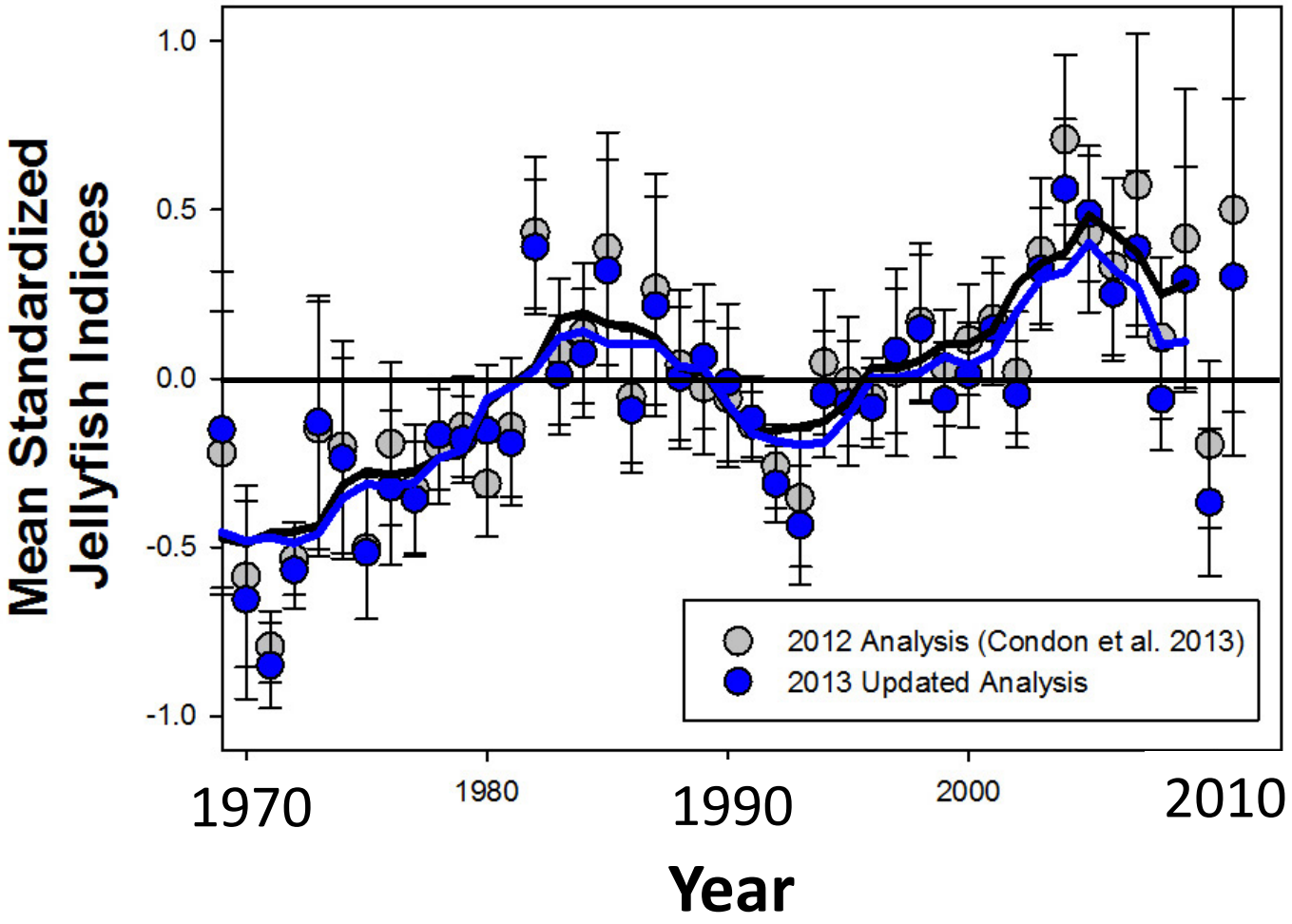
Interpretation might alias the data

Runs Test: p = 0.001*

Condon et al., *PNAS* 2013

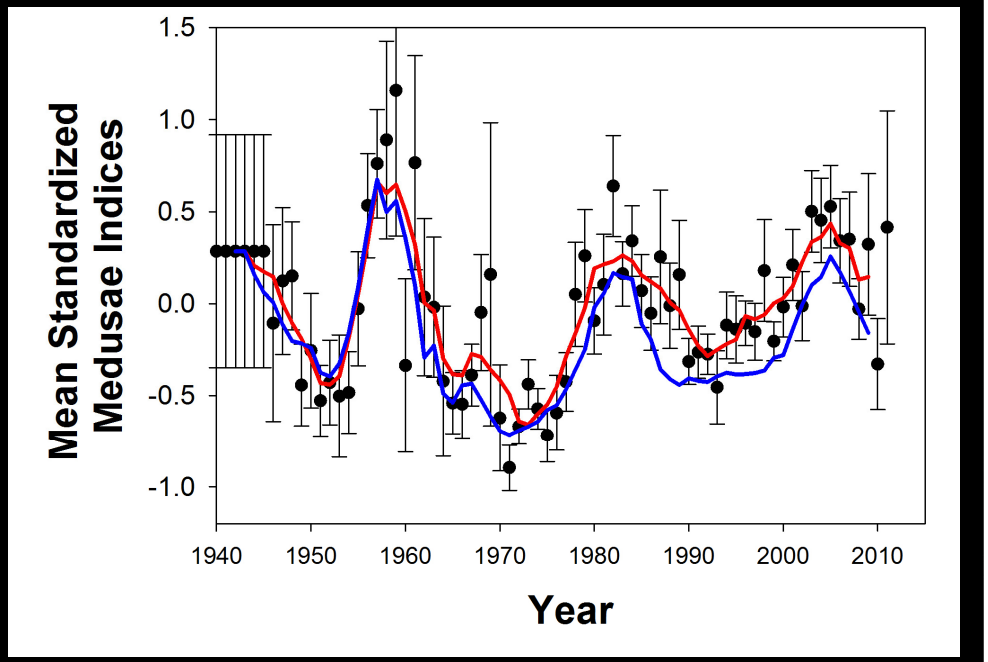
The Latest Update…..

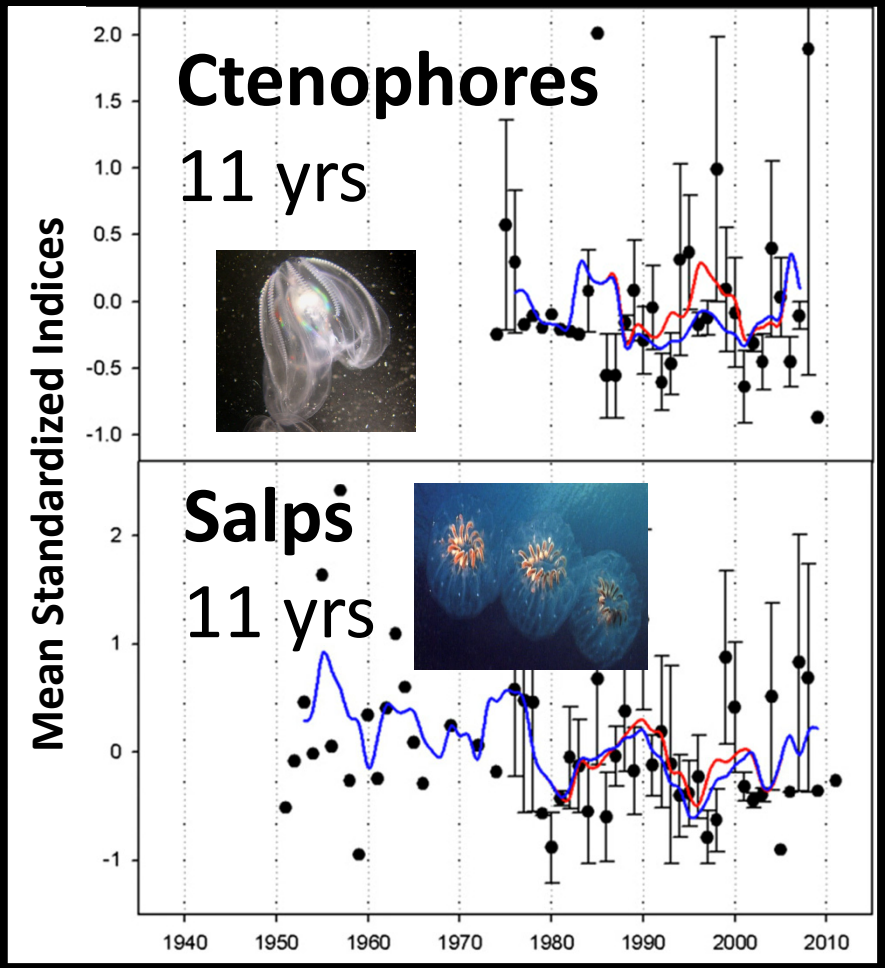
1970-2011



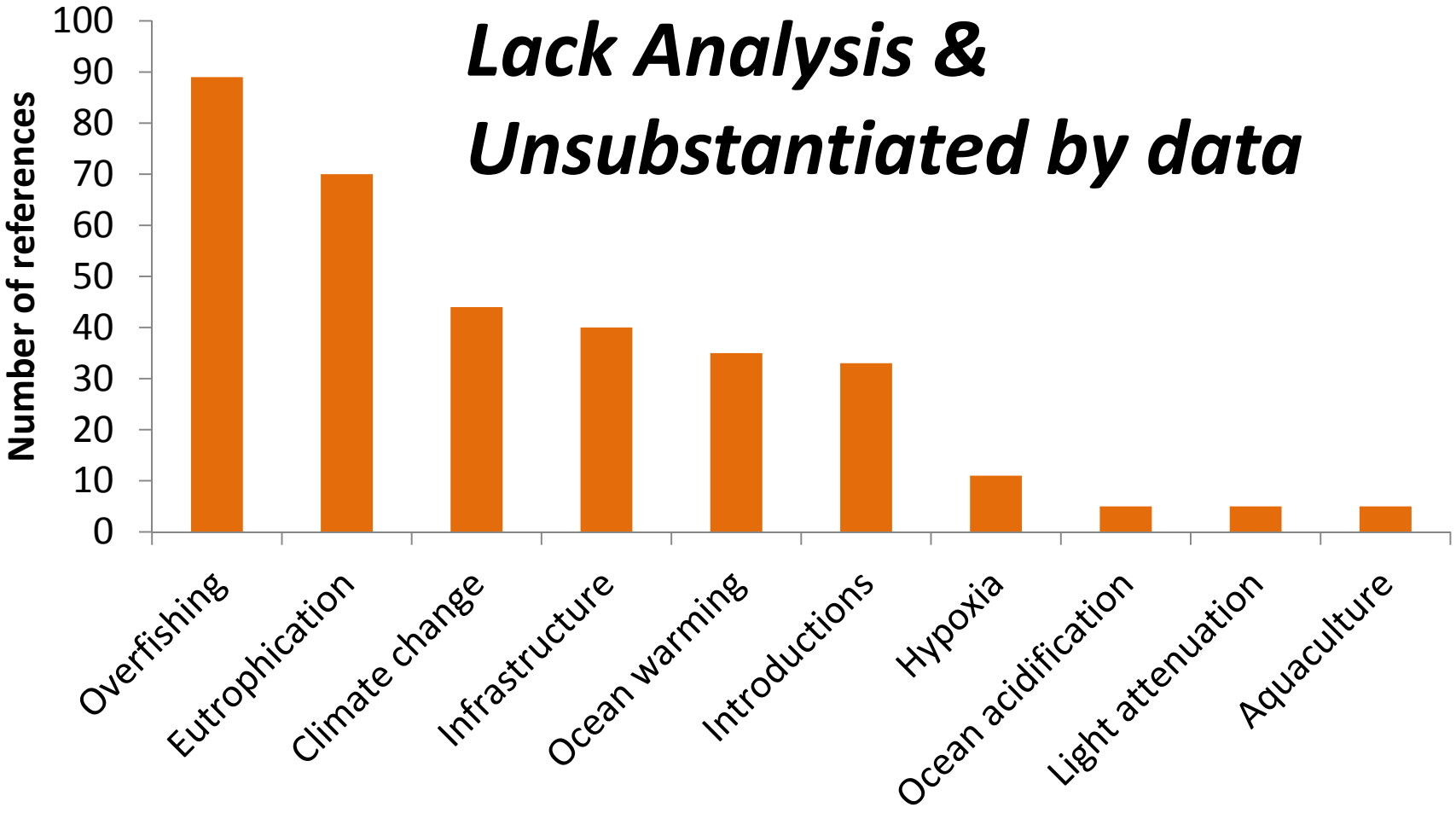
Trend Varies Between Jelly Groups

Cnidarians
22 yrs





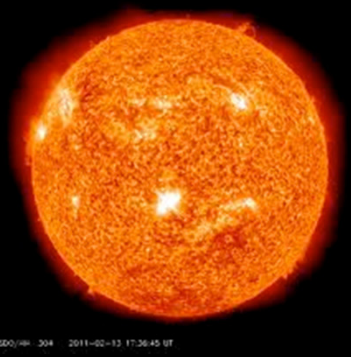
Overfishing and eutrophication are the most commonly cited causes of jellyfish blooms



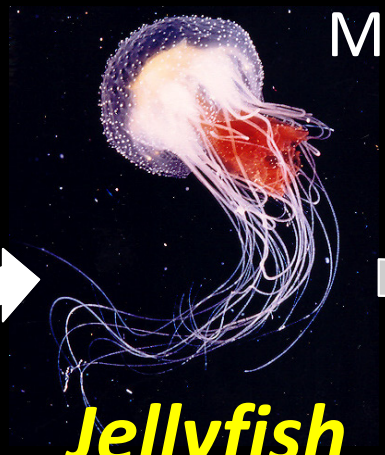
Pitt et al. Submitted, Duarte et al. 2012

Natural vs. Human Global Drivers?

Solar Activity

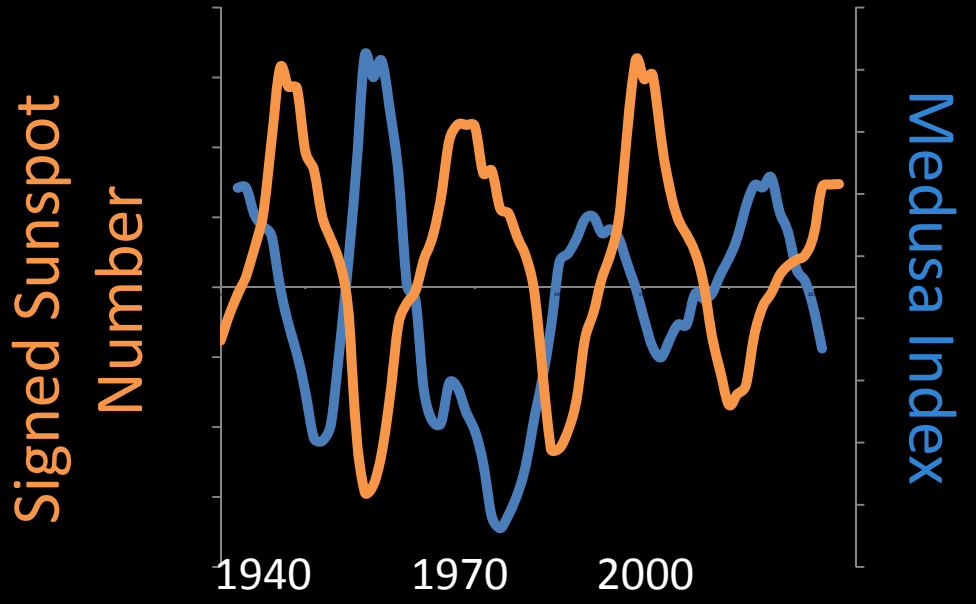


UV
Heat

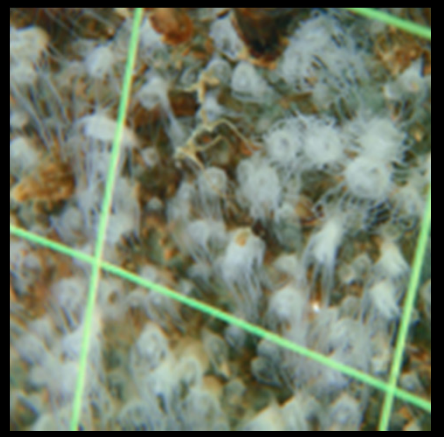


Medusa

Jellyfish
Life Cycle

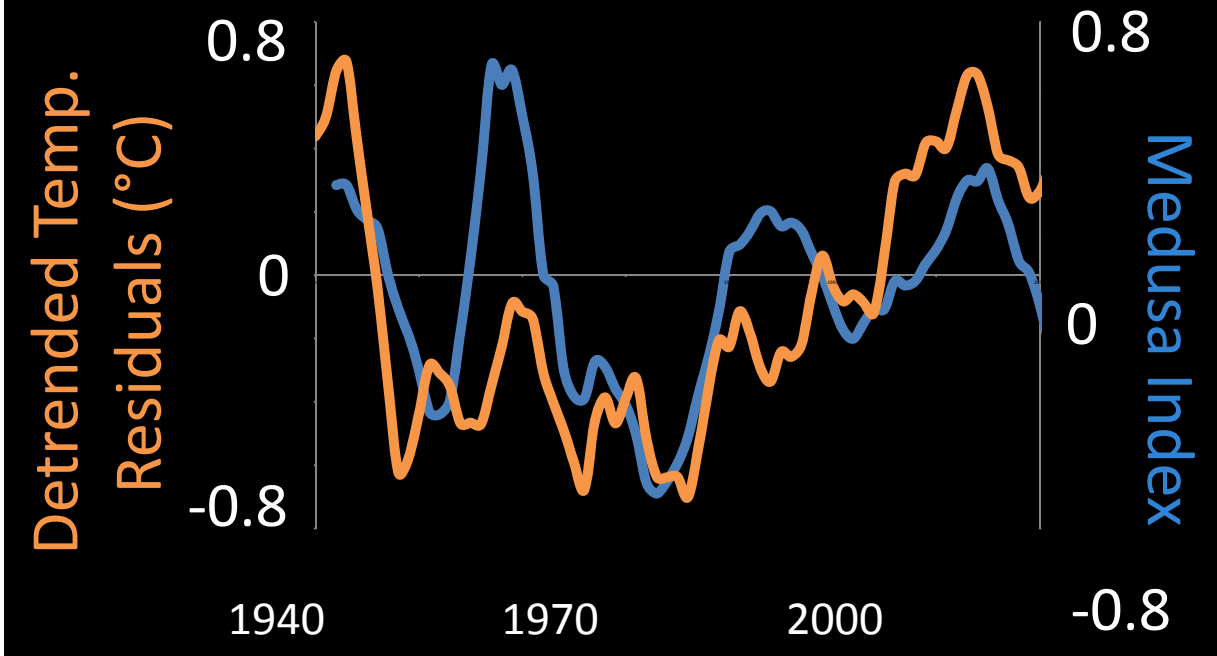


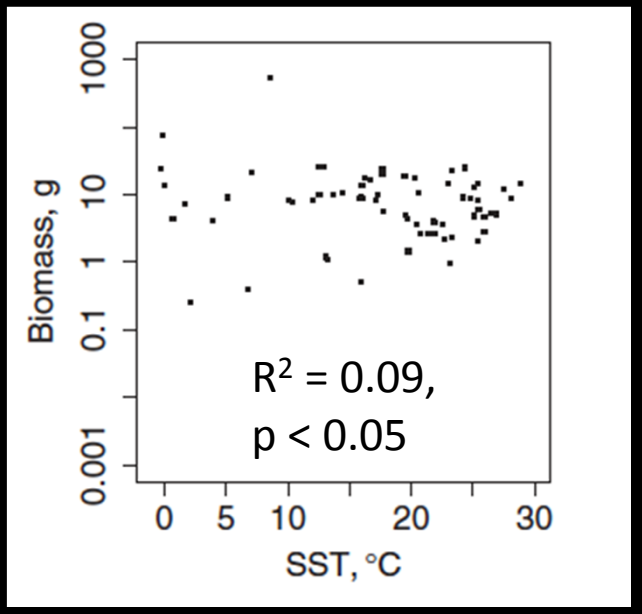
Polyp
1-2mm

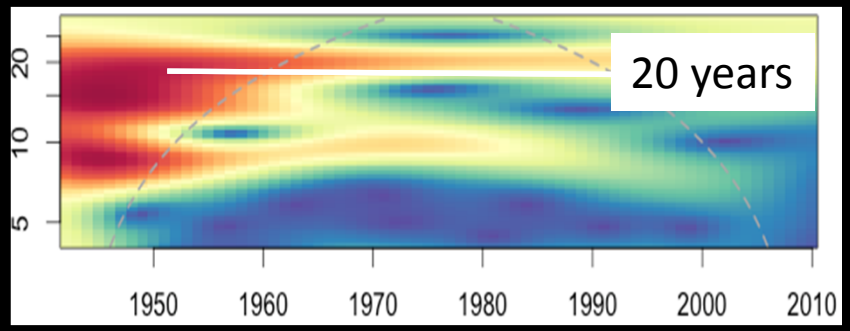


Sun Spot Drivers: Temperature

Global Sea Surface Temperature



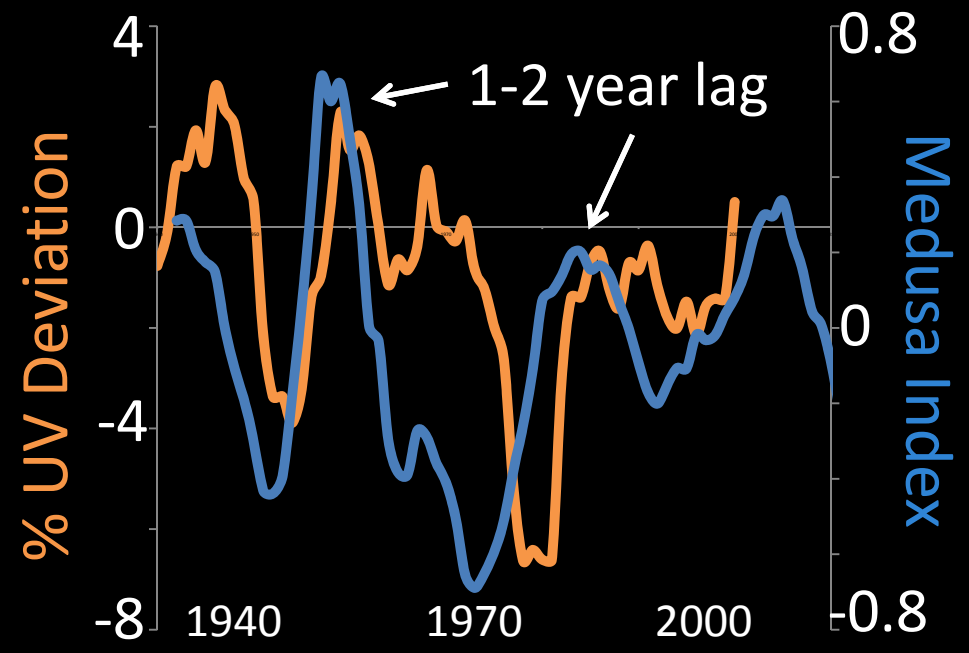




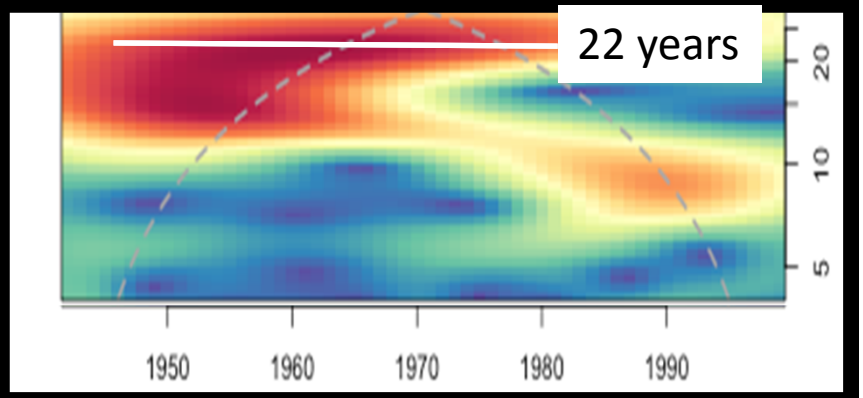
Lucas et al. 2014

Sun Spot Drivers: UV-B

Stratospheric UV



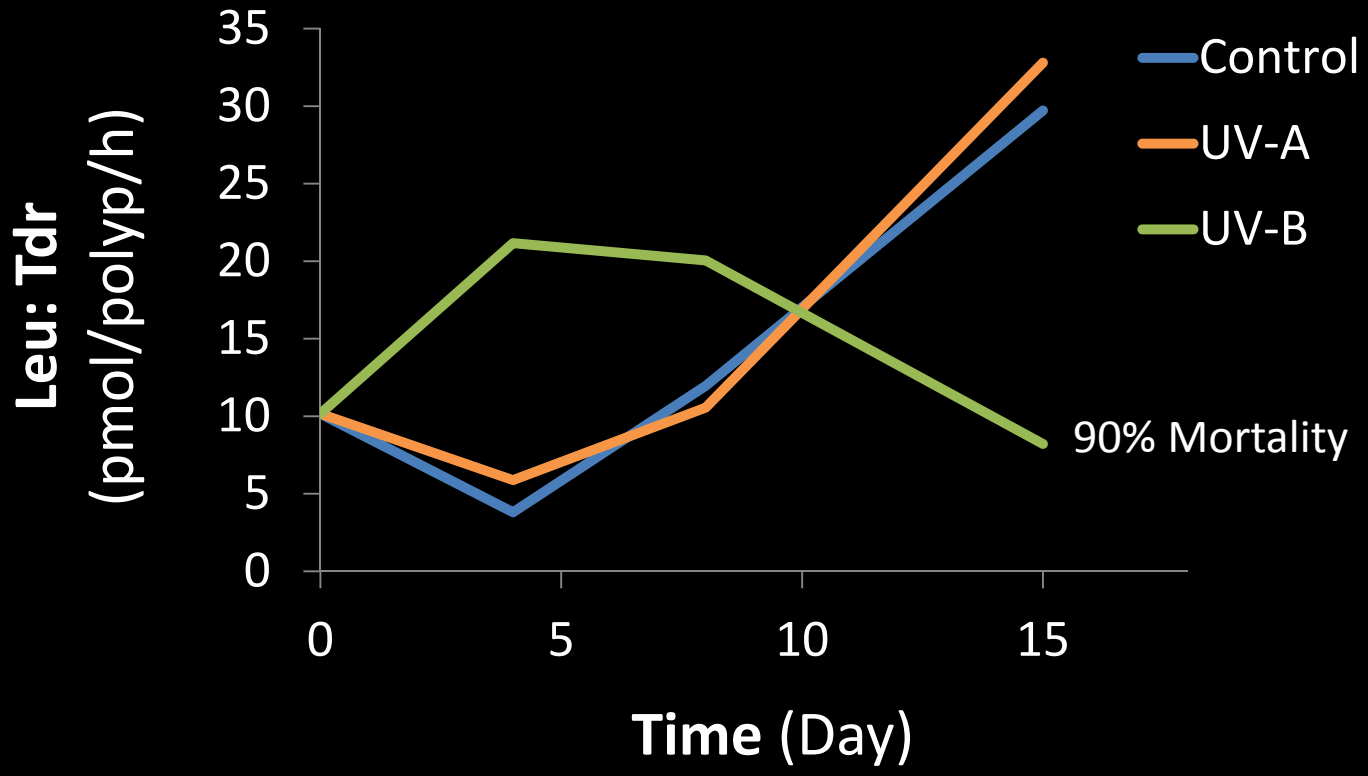
Wavelet Analysis



UV data extracted from Lindfors & Vuelleumier *J. Geoph. Res.* 2005

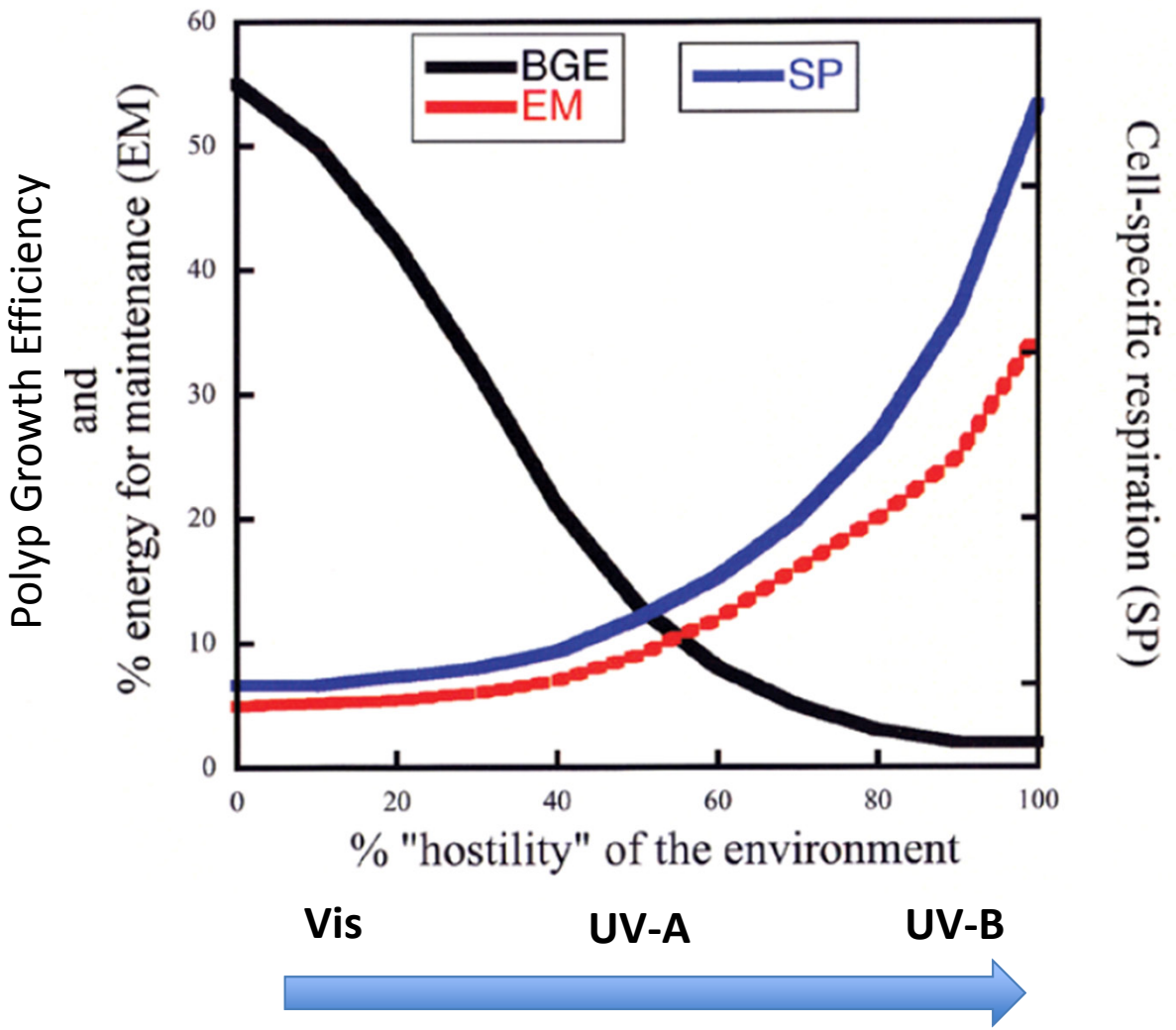
Polyp Response to UV-B Stressors

Polyp Production: ^{3}H-Leucine vs Thymidine



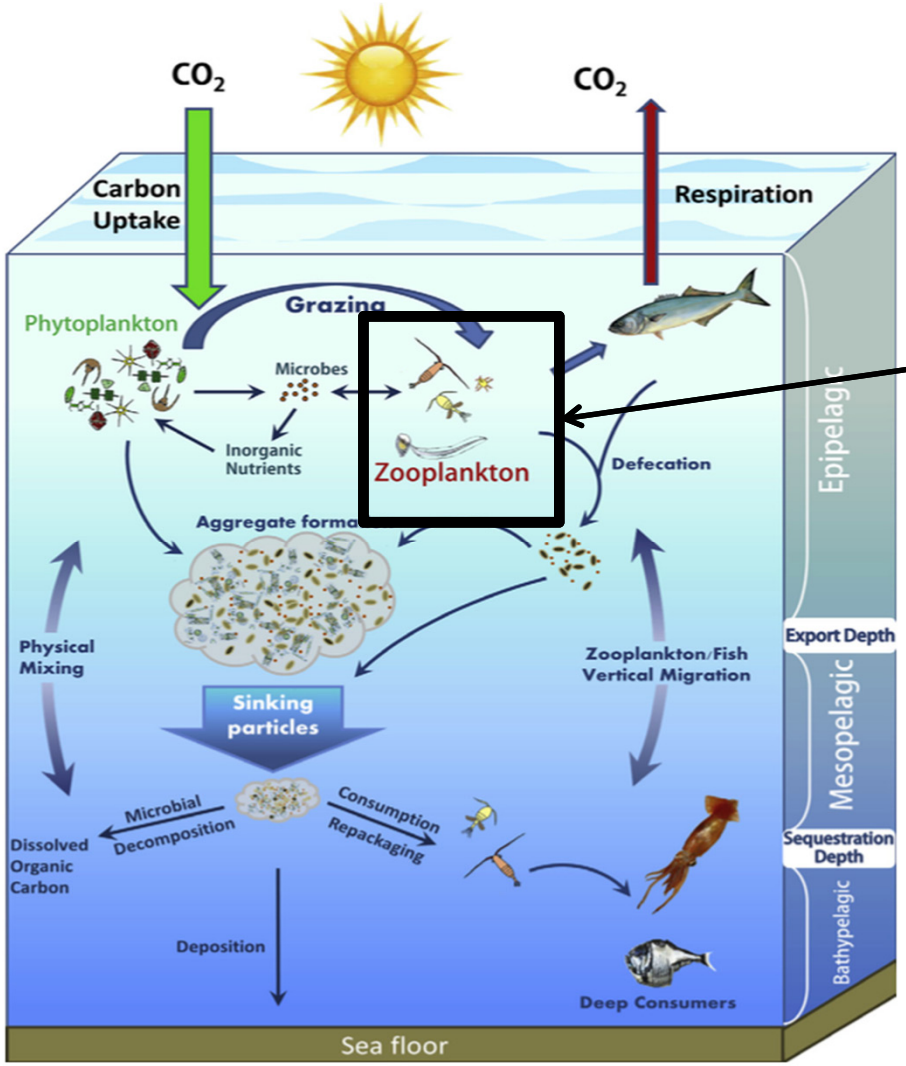
Treible, Condon et al. In Prep

Environmental Hostility Model



Adapted from Carlson et al. *Oceanography* (2007)

Biological Pump



Zooplankton "lumped" together

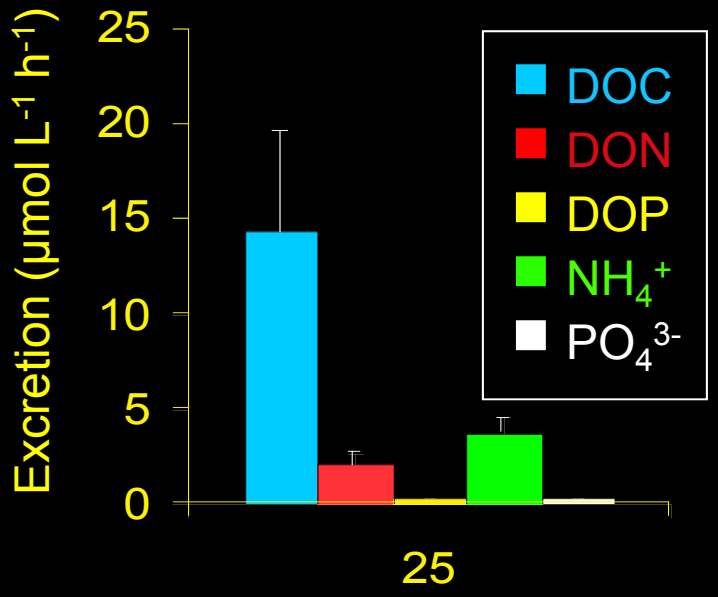
Highlight 2 processes

- Jelly Carbon Shunt
- Sinking of dead carcasses

Turner *Prog. Oceanogr*. 2015

Nutrient Regeneration by Jellies

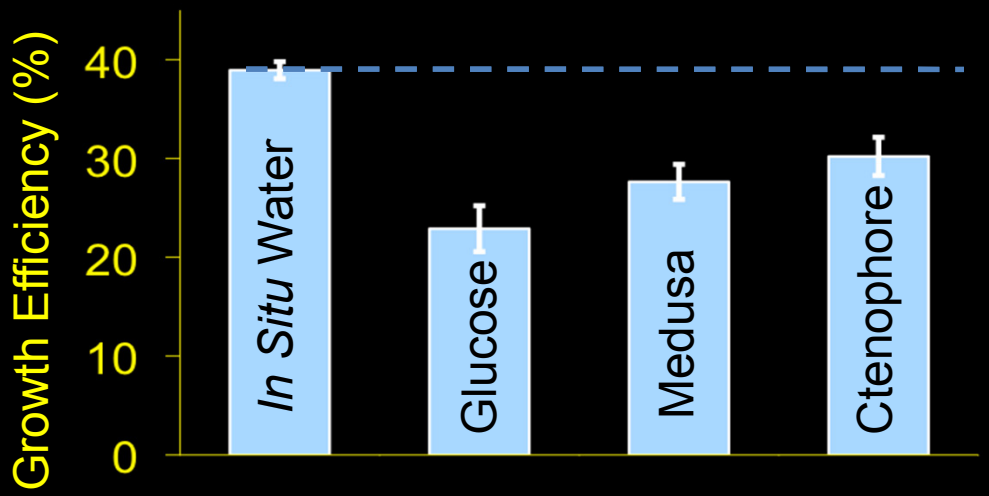
Jelly-DOM Excretion



- Bacteria rapidly consume ‘jelly-DOM’ for their respiration

- 55-80% of total excretion is ‘jelly-DOM’
- C-rich DOM contributes 20-30 % to labile DOC pools

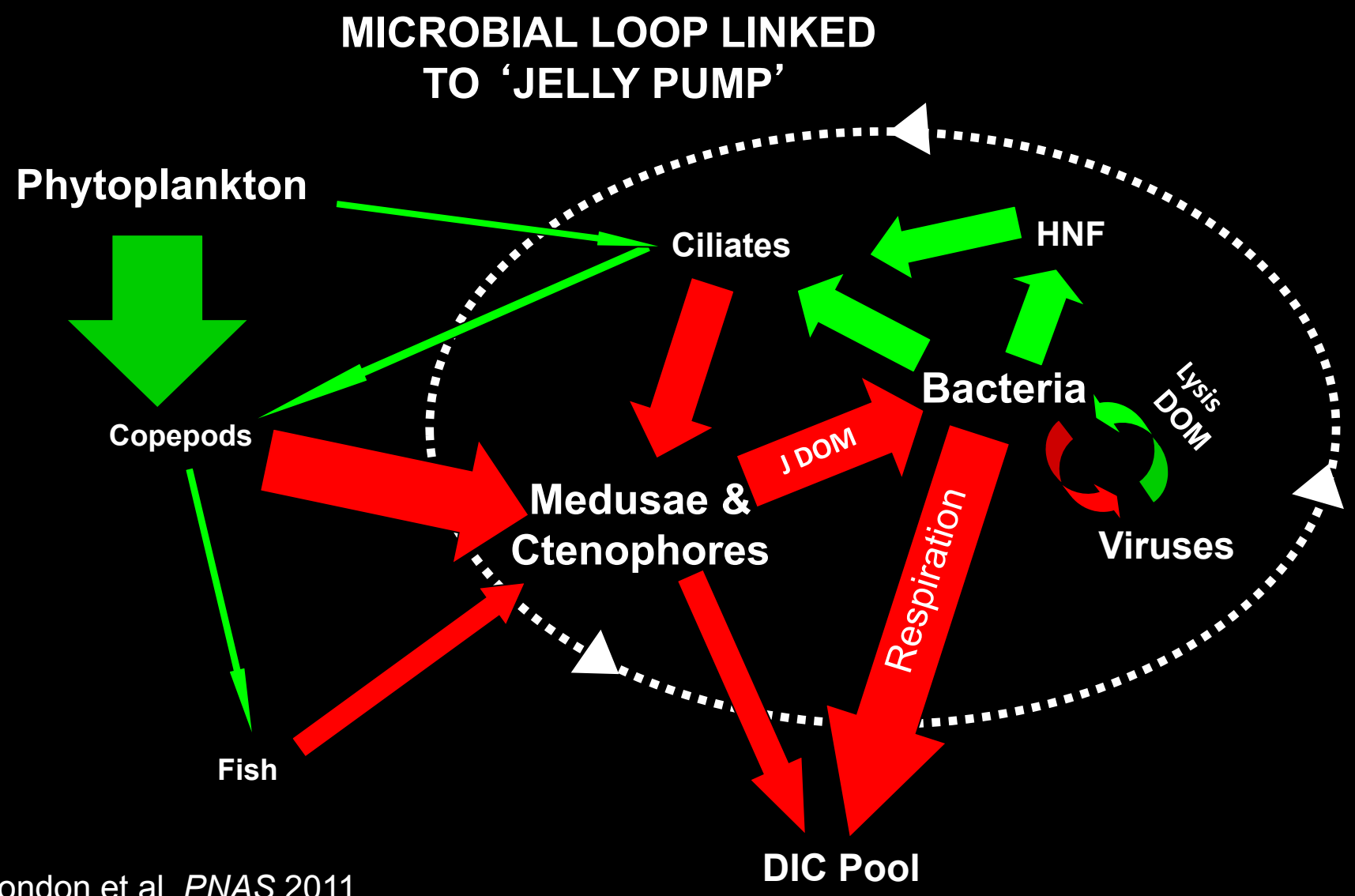
Bacterial Metabolism



Condon et al. *PNAS* 2011

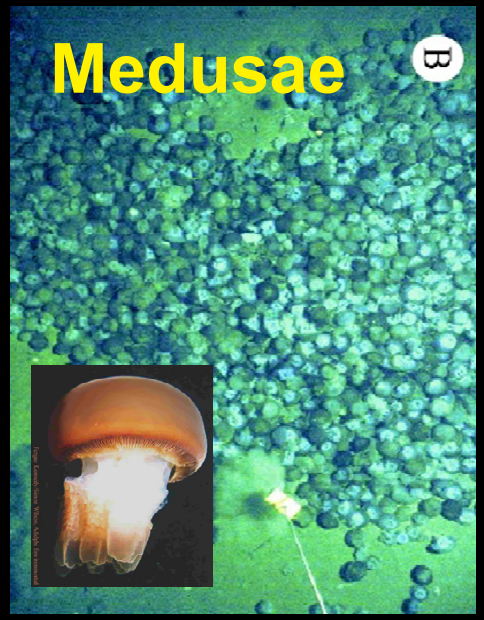
* = $p < 0.05$

Jelly Carbon Shunt

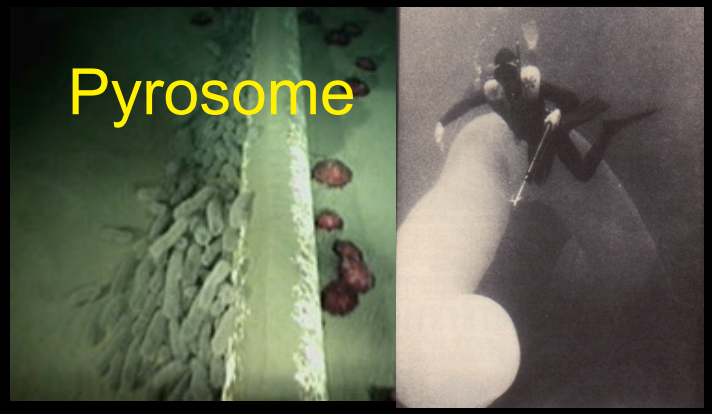


Condon et al. *PNAS* 2011

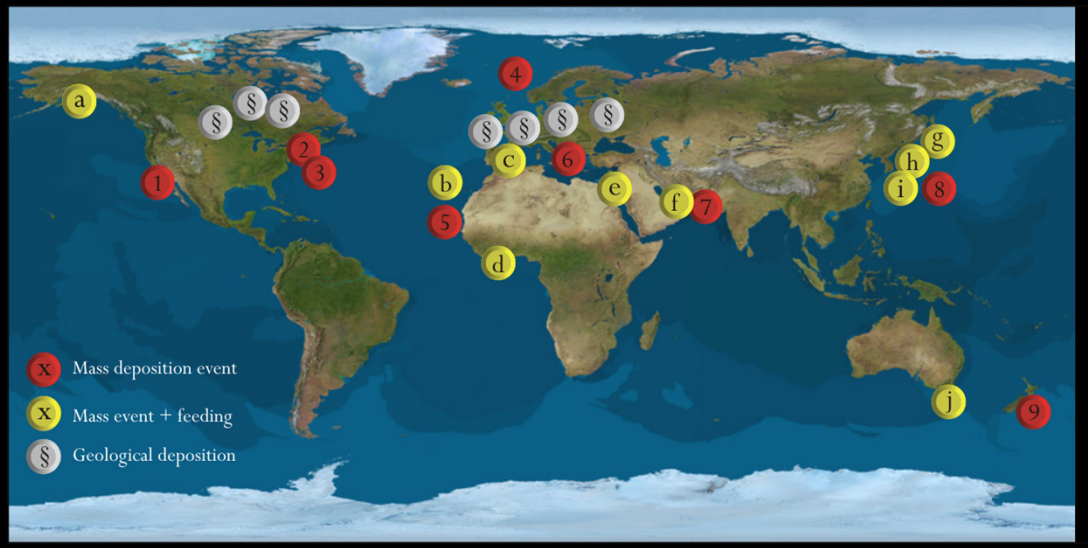
Fate of Jellyfish: “Jelly-Falls”



- Geological & current timescales
- Dead jellyfish improves Biological Carbon Pump
  - > 10 times more C than total annual flux
  - ‘Gelatinous bricks’ - sink fast
  - Implications for benthic communities

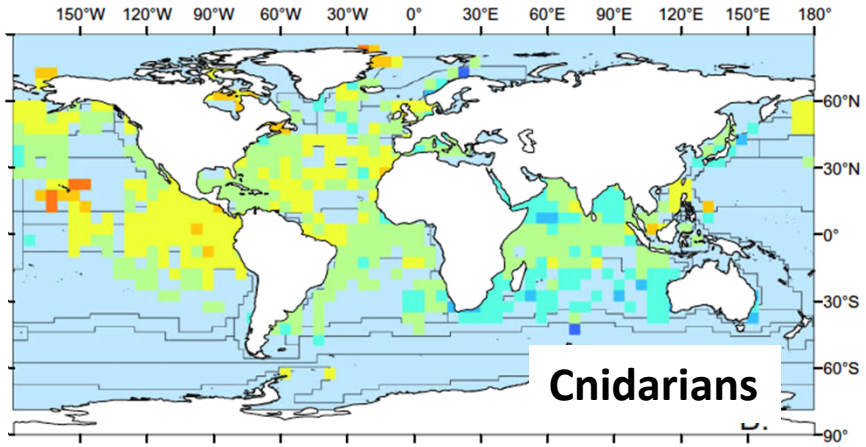


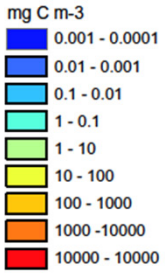
(Billet et al 2005; Lebrato et al. 2009)



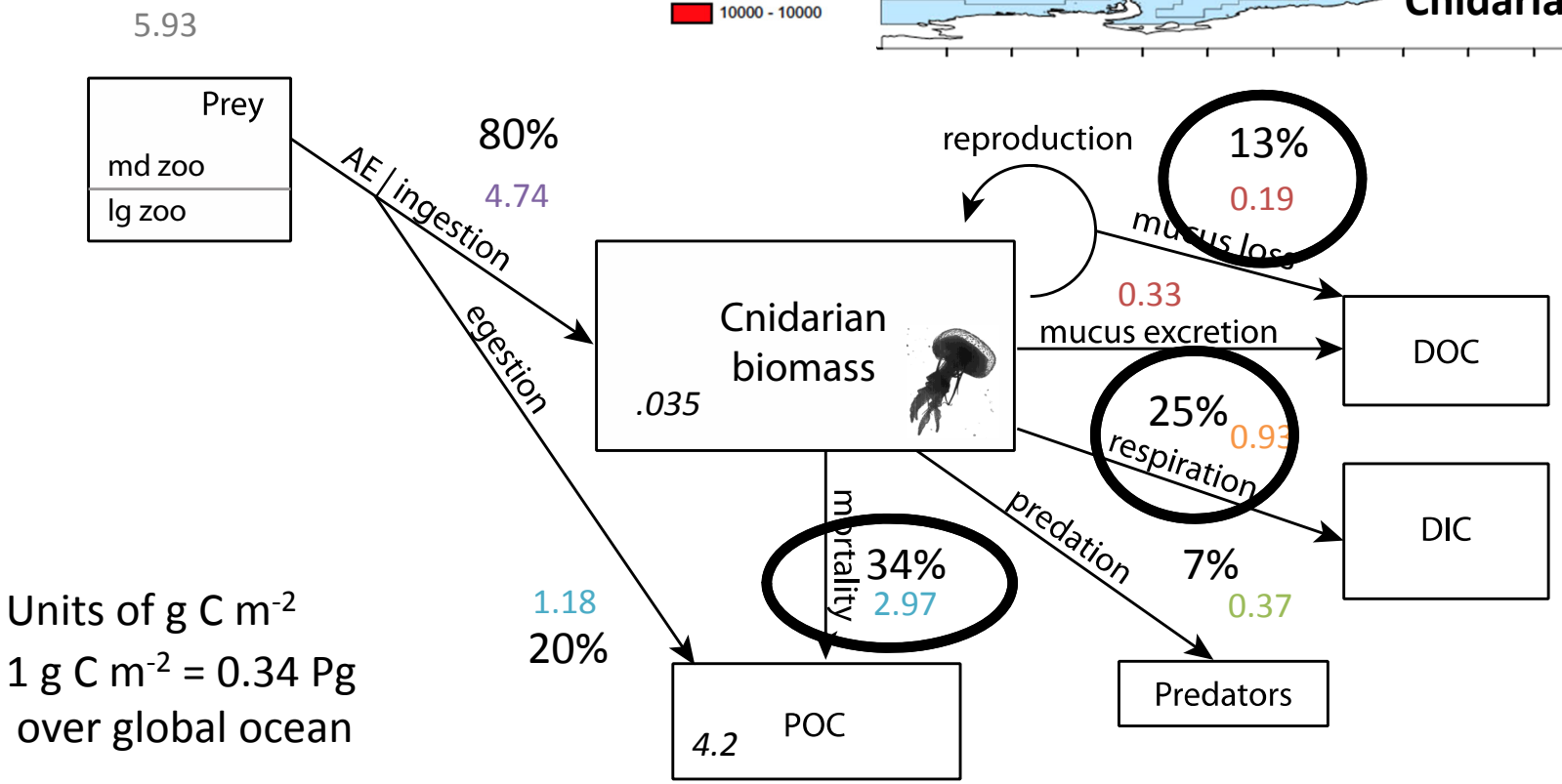
(Lebrato et al. 2013)

Cnidarians: global flux at baseline





Bioenergetic Carbon Model

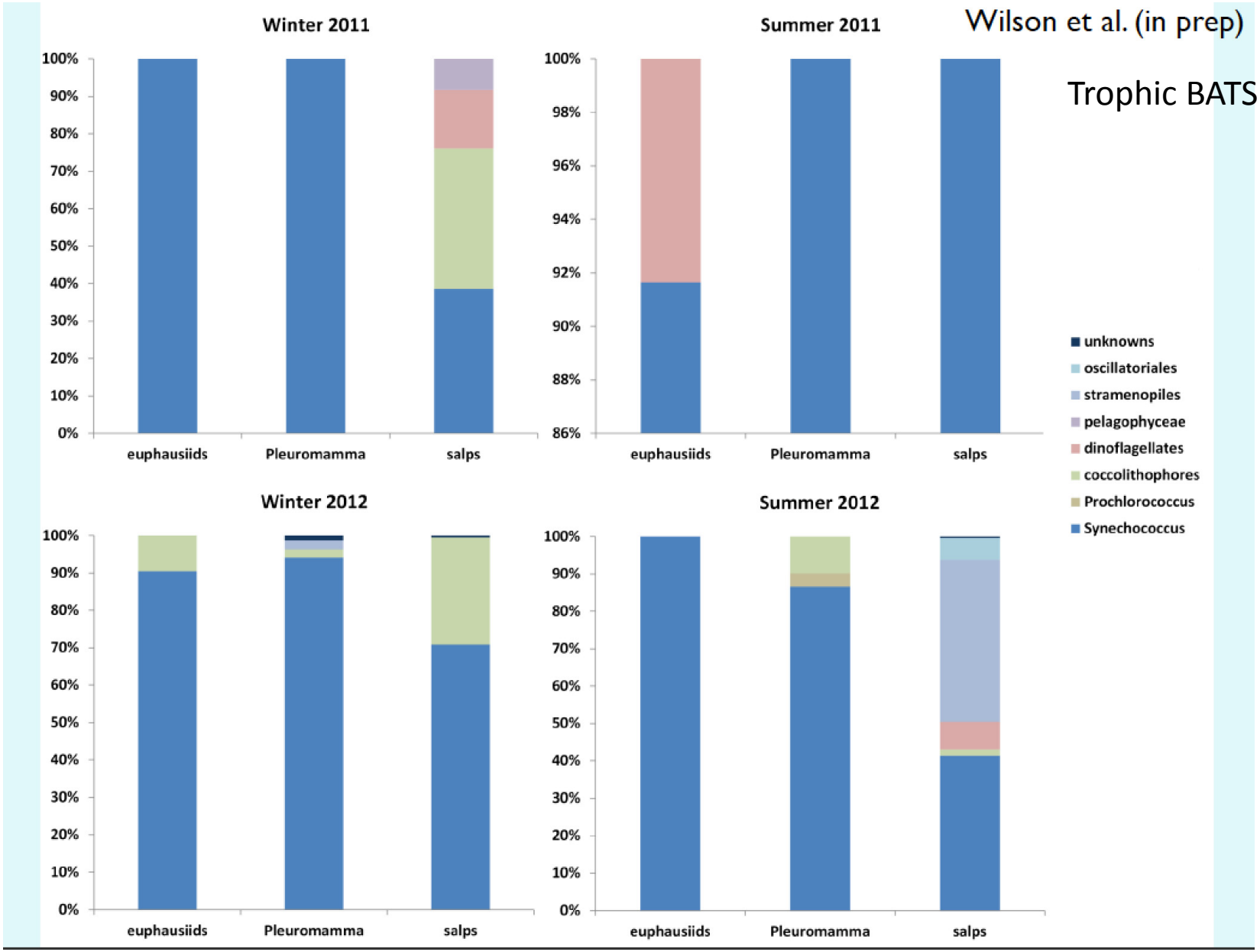


Units of g C m^{-2}

1 g C m^{-2} = 0.34 Pg over global ocean

Luo et al. In Prep

How Much Carbon Is Assimilated?

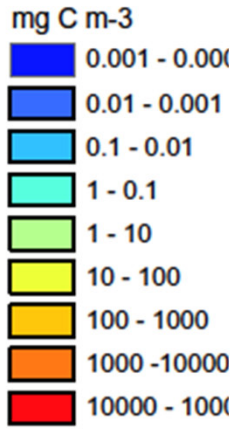


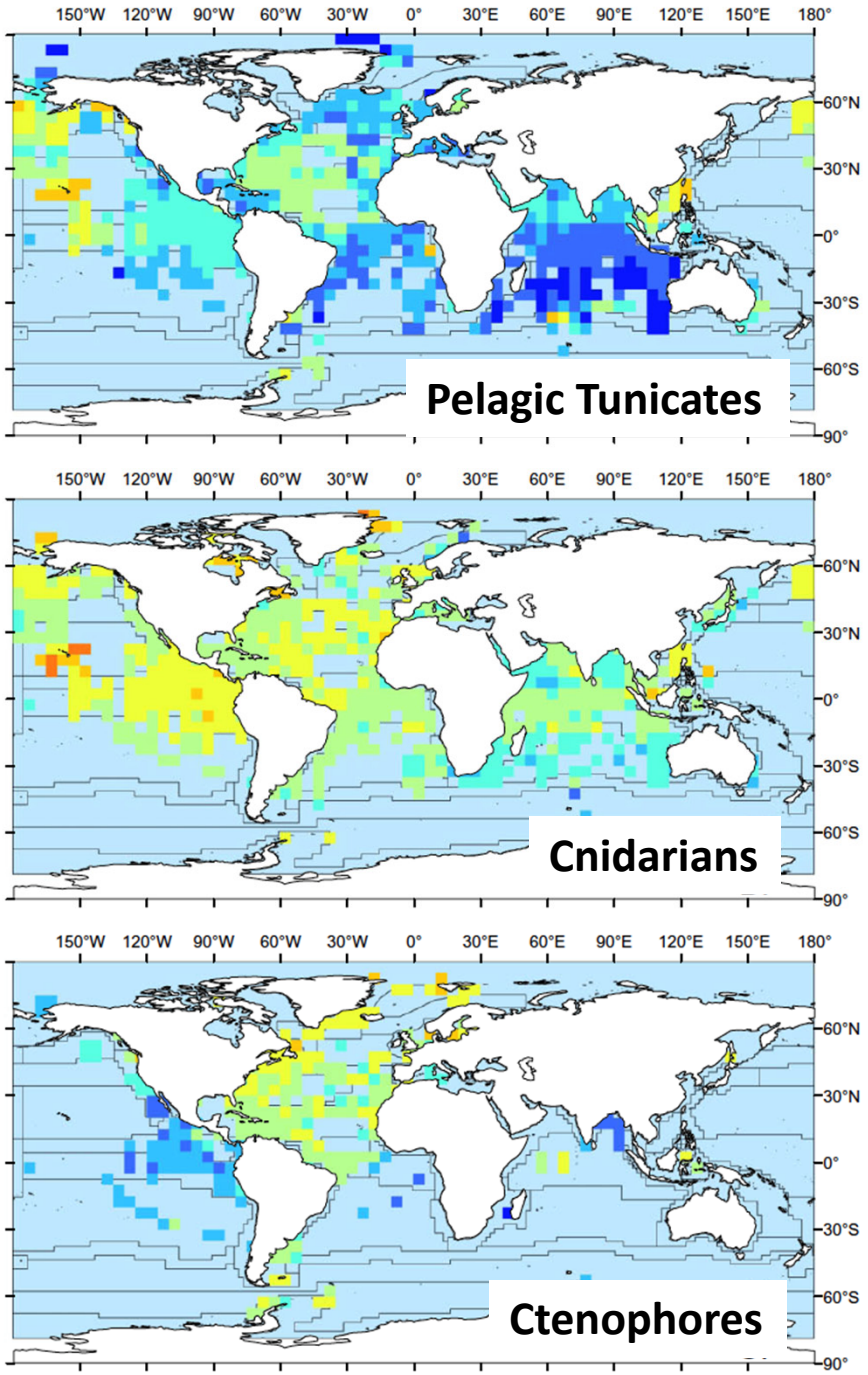
Concluding Thoughts

- Trends in GZ & roles in carbon cycles need to analyzed on appropriate space & time scales, and validated with hypothesis based tests
- Identifying the true environmental stressors & mechanisms involved in the dynamics of GZ cycles to fully understand roles in biogeochemical cycles
- Next 20 years are key to achieving these goals:
  - Inclusion in time-series programs
  - Focus on rate measurements
  - Inclusion of JeDI in climate forecasting models

Gelatinous Biomass By Group

- Similar high biomass in cnidarians & pelagic tunicates
- Ctenophores low biomass but severely underestimated
- Challenge for community, need to include technology
  - ROV, AUV, ISIS





In Situ Ichthyoplankton Imaging System (ISIIS)

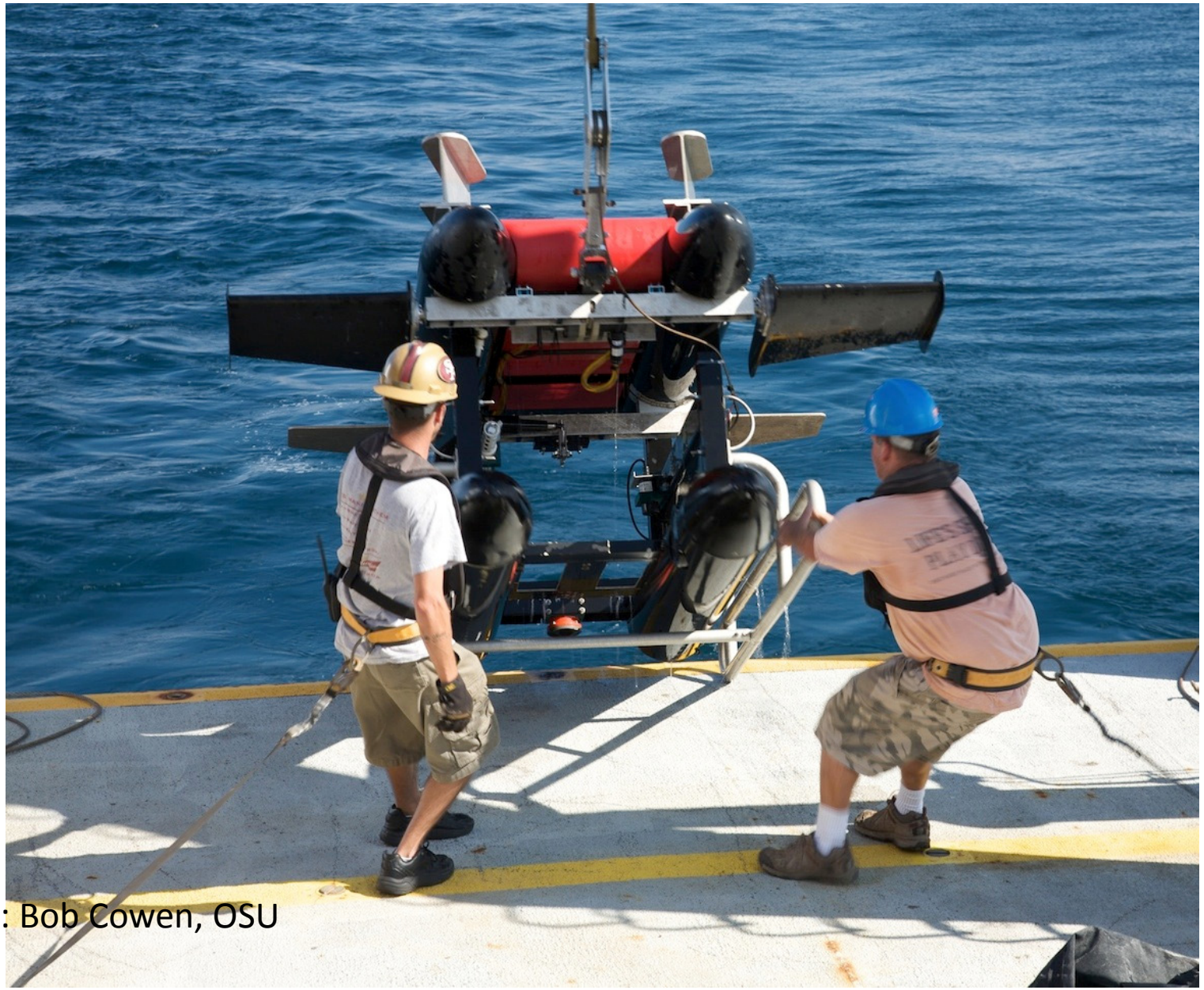
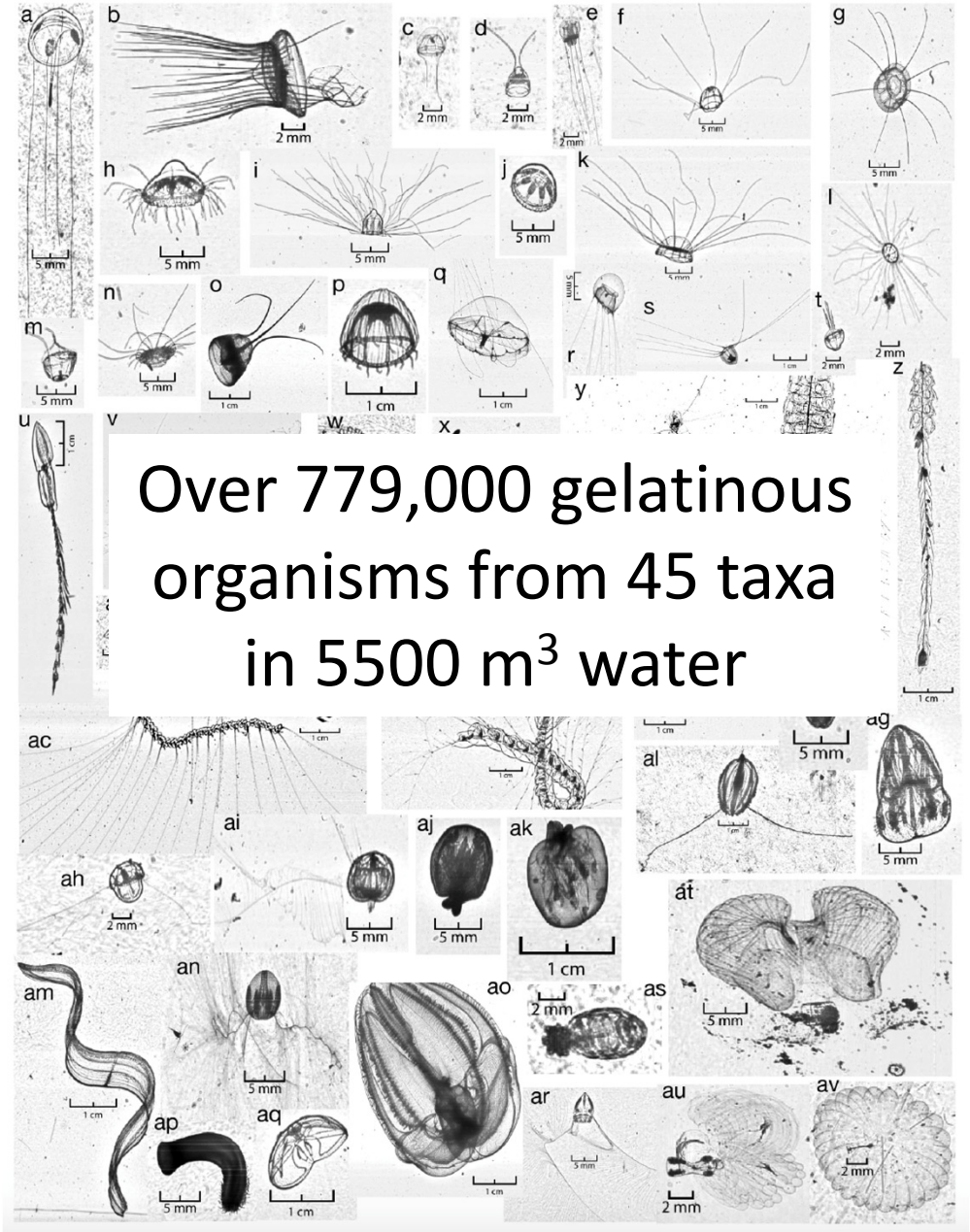
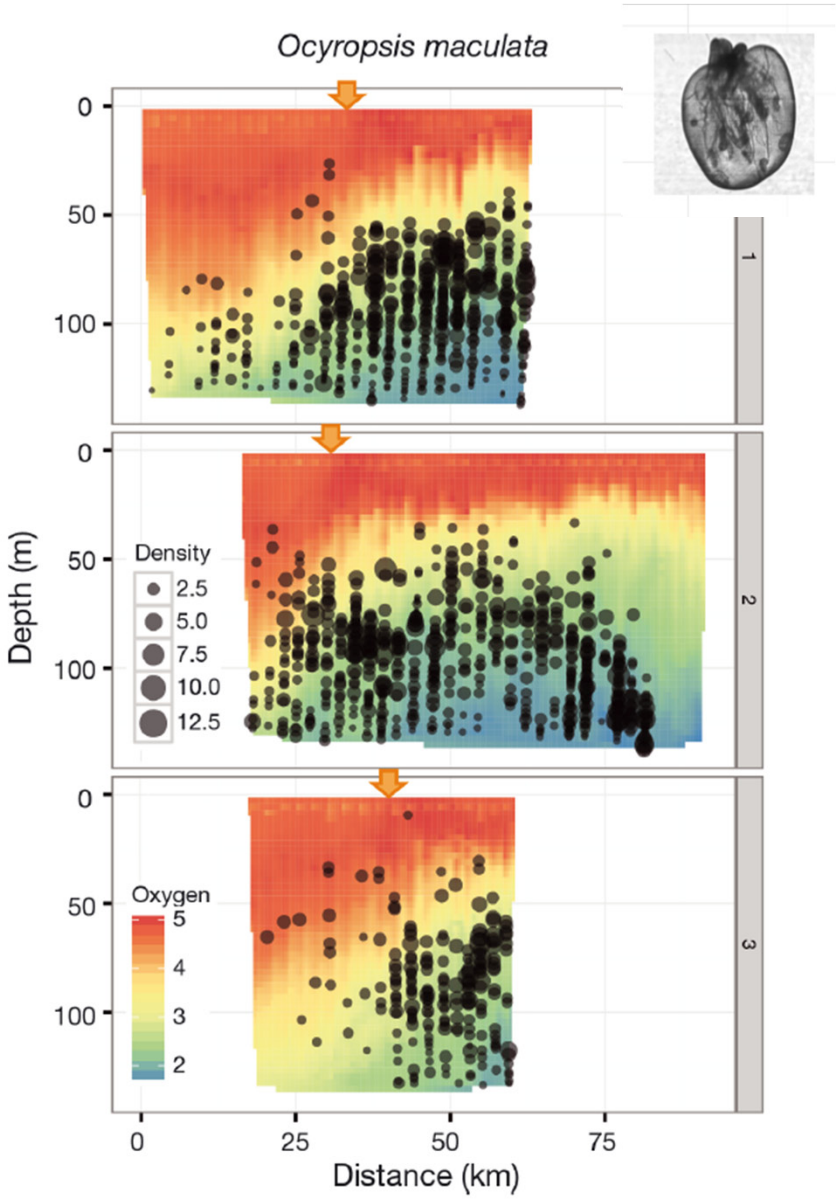


Photo: Bob Cowen, OSU



Over 779,000 gelatinous organisms from 45 taxa in 5500 m^3 water

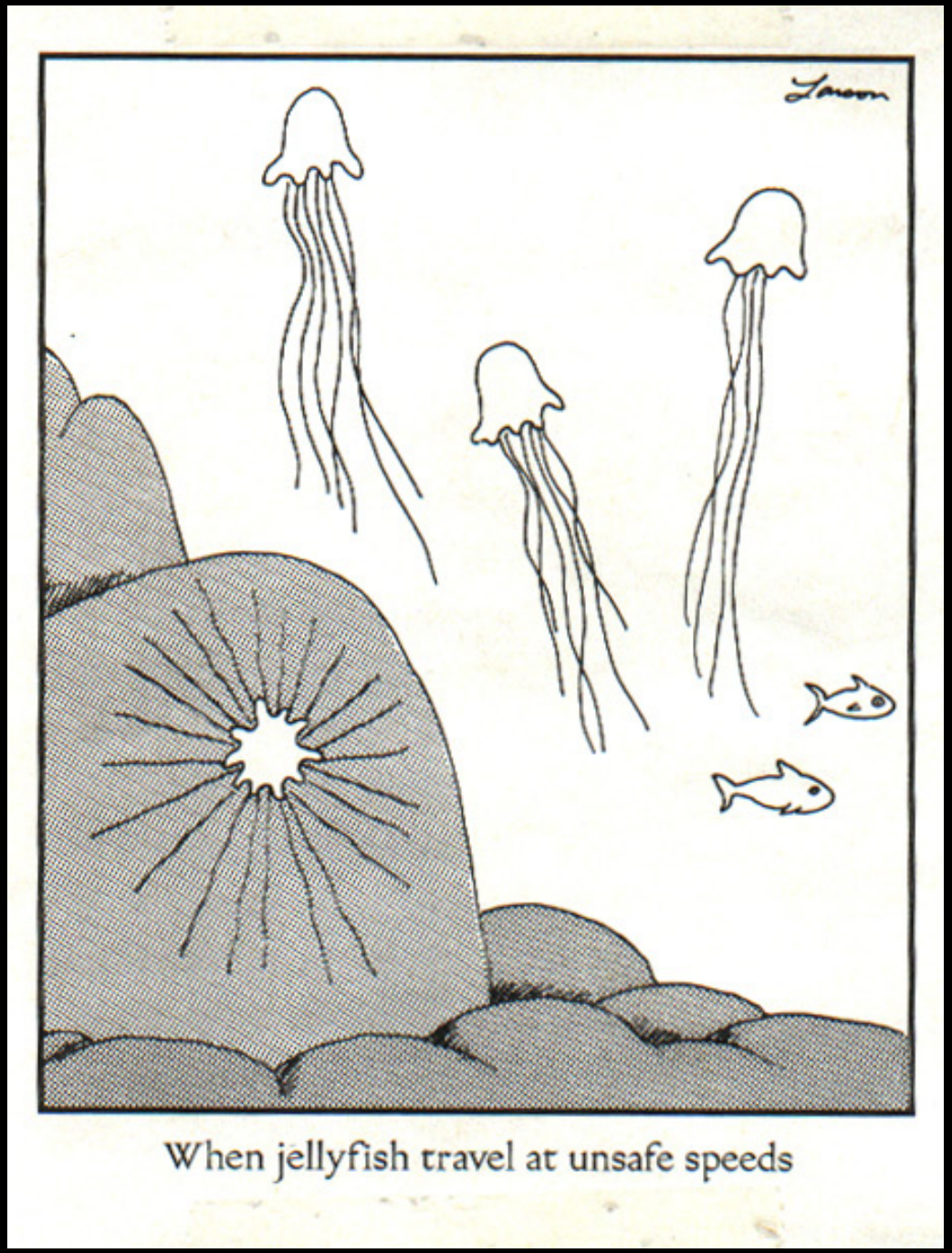


Luo et al. *MEPS* 2014

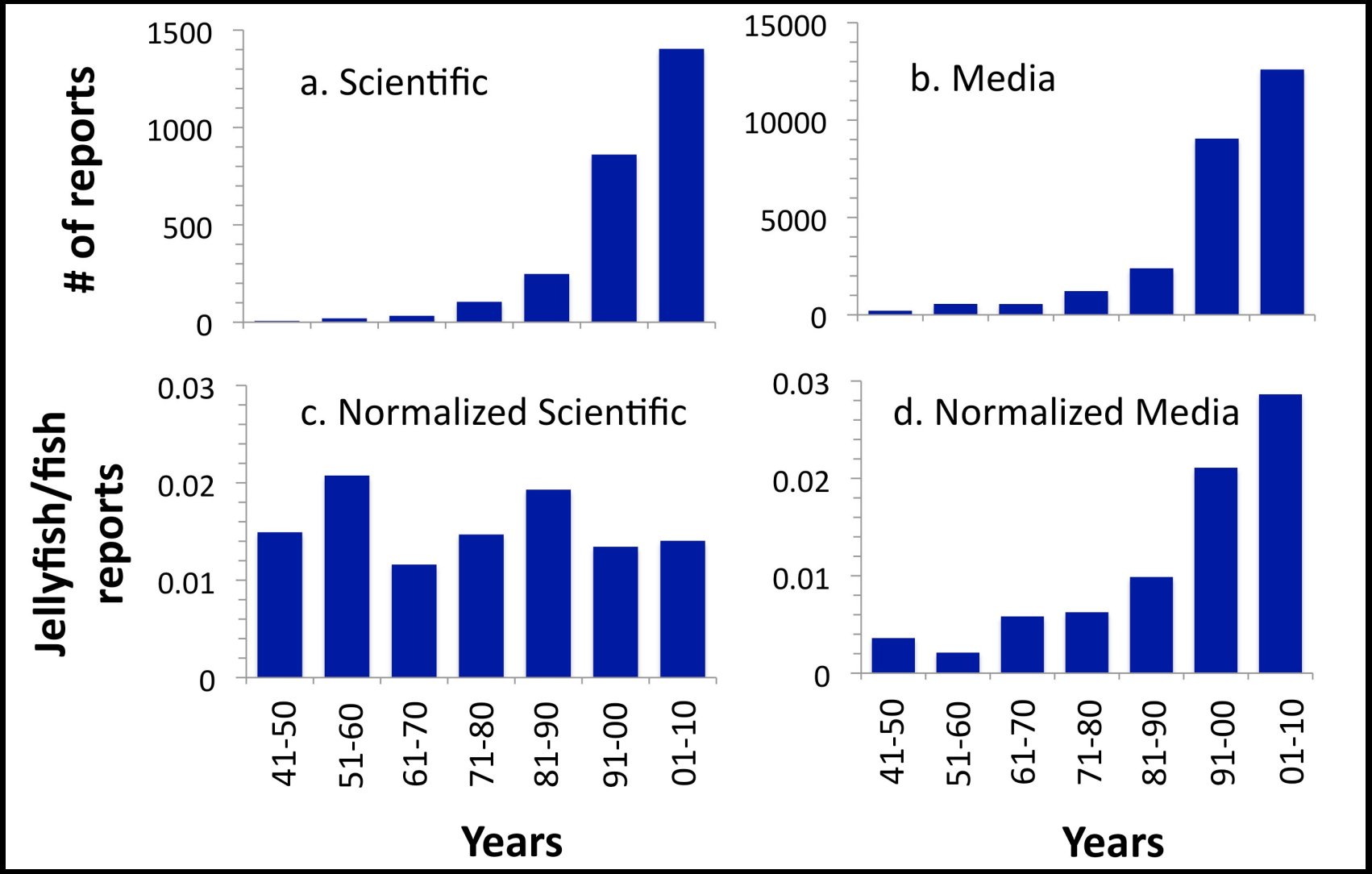
Acknowledgements

- Global Jellyfish Group, including over 25 participants from around the world, and also colleagues in the wider scientific community
- NSF OCE: 1030149 (Condon) & 0934727 (Decker)
- NCEAS: NSF-DEB 94-21535

Questions?



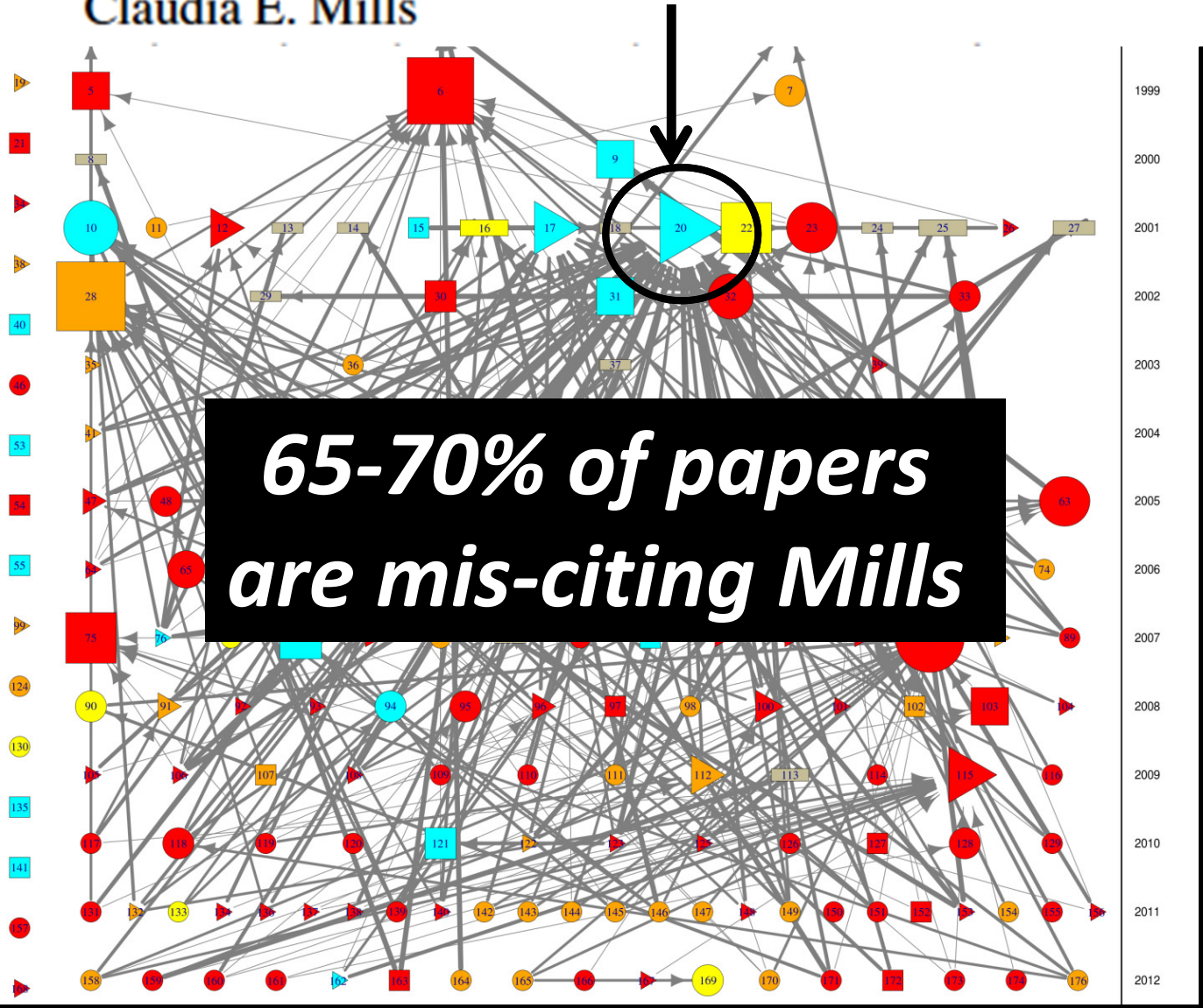
Increased Public & Media Attention



(Condon et al., *BioScience,* 2012)

Jellyfish blooms: are populations increasing globally in response to changing ocean conditions?

Claudia E. Mills



65-70% of papers are mis-citing Mills

Colour = Affirmation

- Are
- Maybe
- Unclear
- Variable
- No trend

Shape = Scale

- Global
- Multiple regions
- Regional
- No trend