SCOR WG157

MetaZooGene

Population genetic diversity, structure, and connectivity of Euphausiacea based on COI barcodes: Implications for biodiversity and biogeography

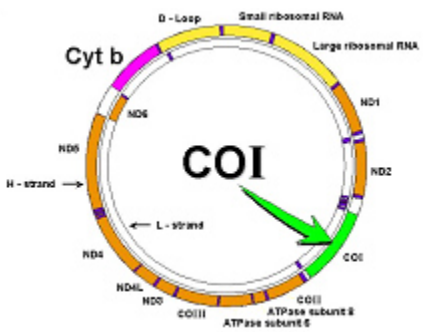
Ann Bucklin[1], Paola-Batta-Lona[1], Jennifer M. Questel[2], Mary Reid[3], Vicki You[1], Peter H. Wiebe[4]

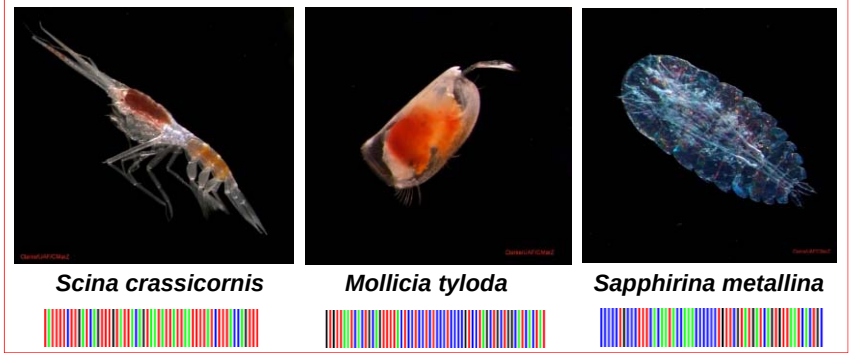
[1]University of Connecticut, [2]University of Alaska, Fairbanks, [3]Bard College, [4]Woods Hole Oceanographic Institution

SCOR MetaZooGene Symposium

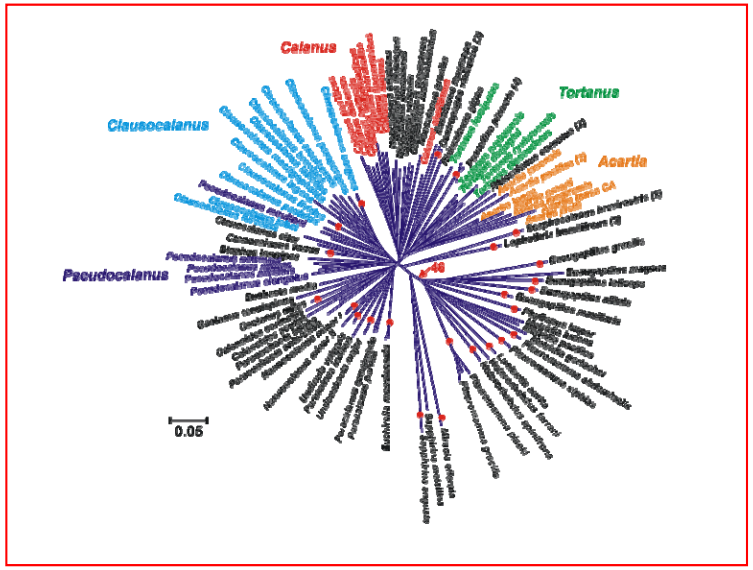
Aviva Stadium, Dublin, Ireland - September 23, 2022

COI Barcoding of Zooplankton Diversity

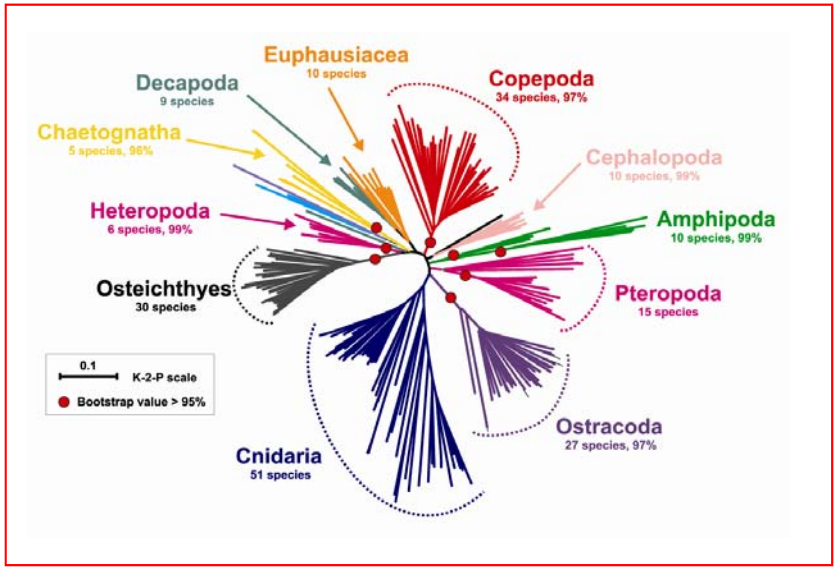




- COI barcodes identify and discriminate species
- Metabarcoding with COI allows species-level analysis of biodiversity
- COI reference barcode database needed to identify species



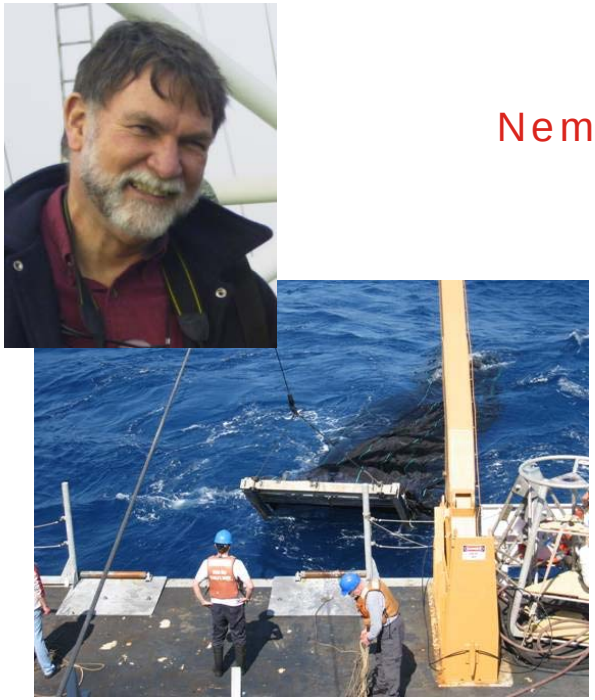
Barcode gene tree for copepods
Blanco-Bercial et al. (2014) PLoS Currents



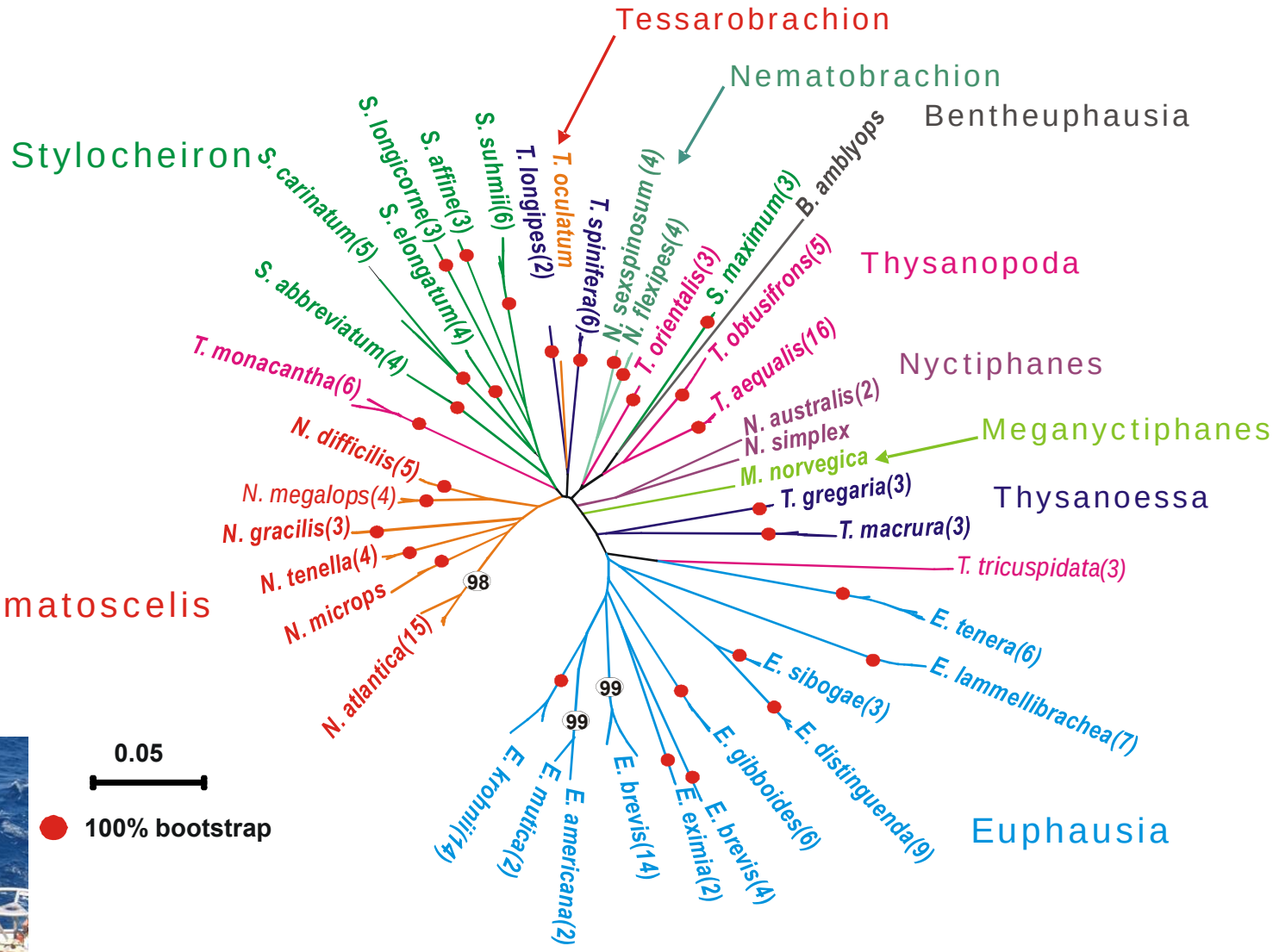
COI "Rosetta Stone" for Sargasso Sea zooplankton
Bucklin et al. (2010) Deep-Sea Res.

Barcoding Euphausiids

Bucklin, Wiebe, et al. (2007) J. Plankton Res.



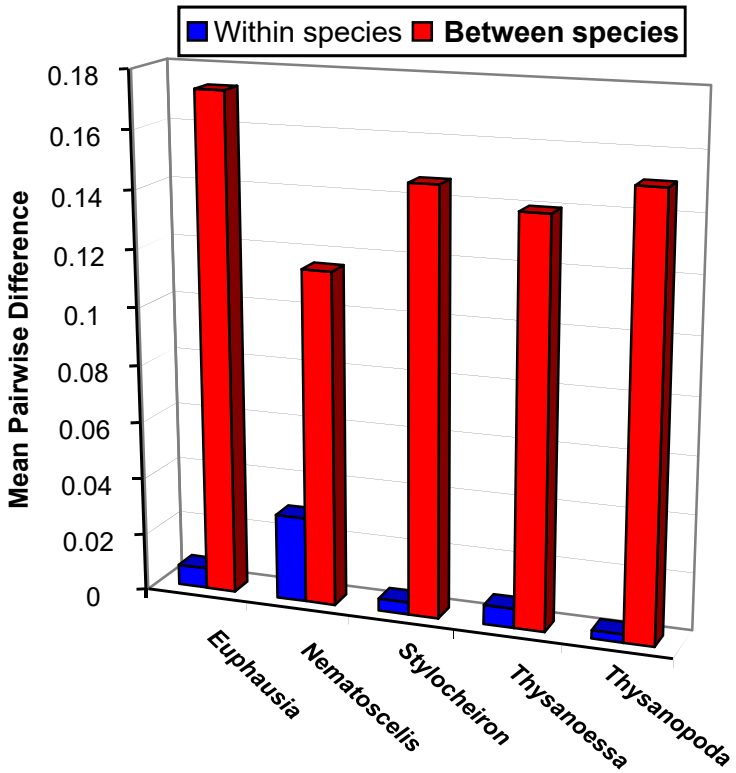
Peter Wiebe (WHOI); 10-m MOCNESS



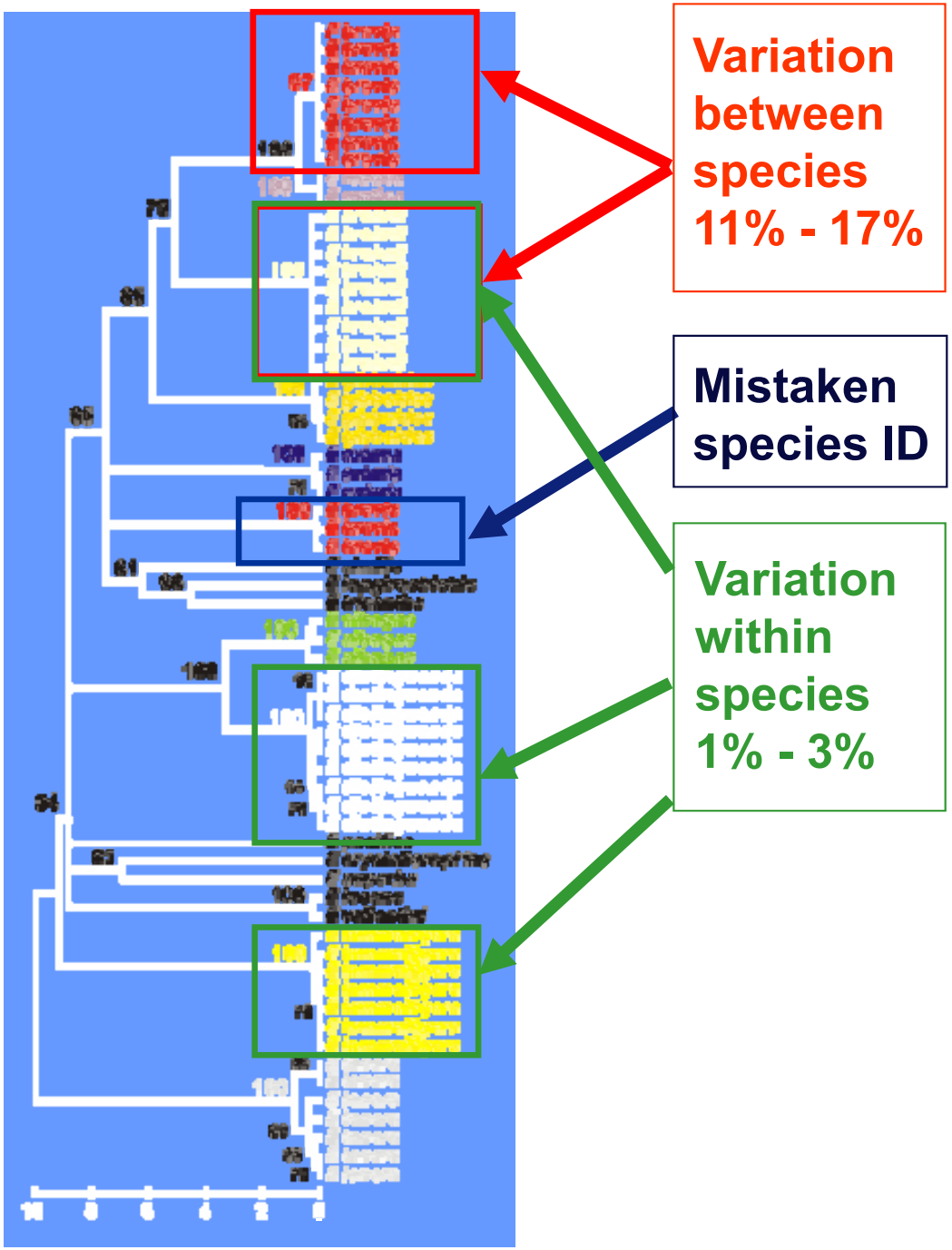
Barcodes for 193 individuals of 40 species

Barcoding Euphausiids

Bucklin, Wiebe et al. (2007) J. Plankton Res.



- **Barcodes for >70 species.**
- **COI discriminates species**
- **Reveals cryptic variation in widespread taxa**



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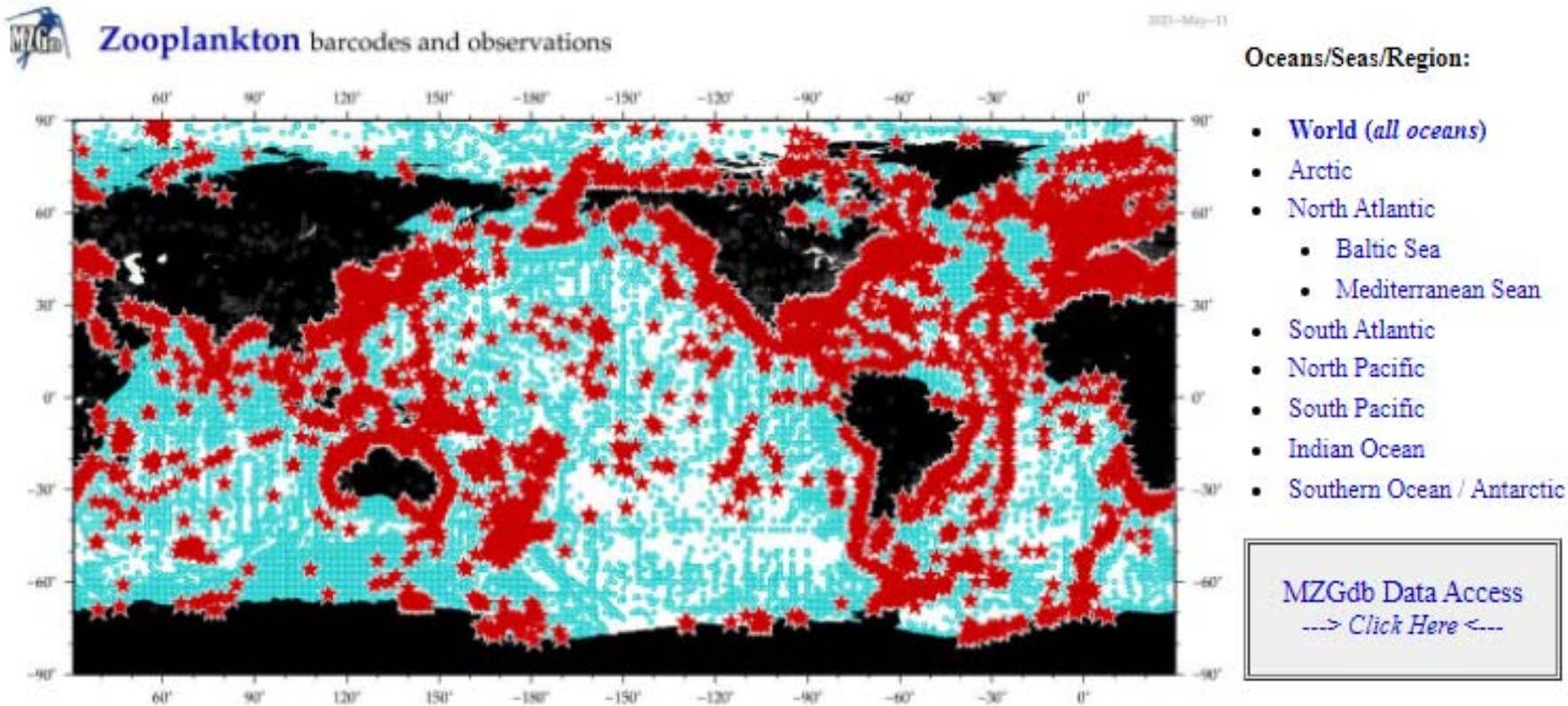
MetaZooGene

MetaZooGene Barcode Atlas & Database (MZGdb)

Todd O'Brien, NOAA Fisheries (USA)

- **Over 218,299 COI sequences for 11,356 species of marine zooplankton**
- **MZGdb expanded to include 18S rRNA & other gene regions; adding fish & protists**
- **Data from NCBI GenBank & BOLD (duplicates removed)**
- **Searchable by taxonomic group and ocean region**



http://metazoogene.org/atlas

Toward a global reference database of COI barcodes for marine zooplankton. Marine Biology (2021)

https://doi.org/10.1007/s00227-021-03887-y

Ann Bucklin, Todd D. O'Brien & MetaZooGene (SCOR WG157) members

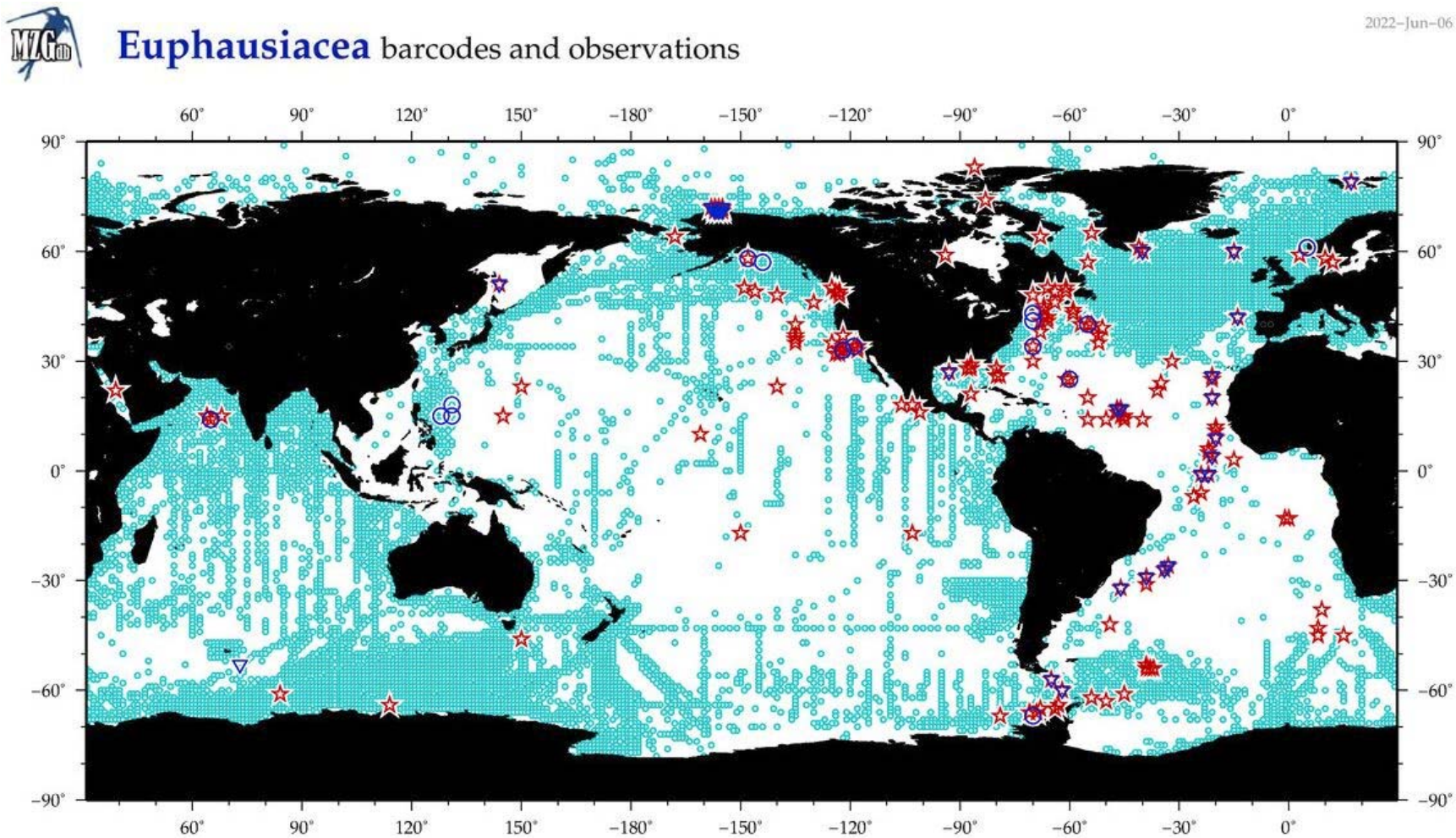
- **Introduce, explain and promote MZGdb: https://metazoogene.org/MZGdb**
- **Acknowledge: MetaZooGene (SCOR WG157) and ICES WGIMT**

Photos by R.R. Hopcroft and C. Clarke (UAF) and L.P. Madin (WHOI); see http://www.cmarz.org/galleries.html

COI Barcodes for Euphausiids (Krill)

MetaZooGene Barcode Atlas & Database (MZGdb)

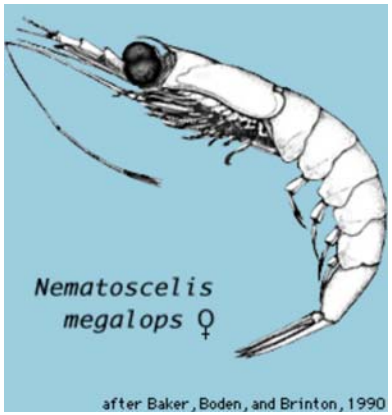
- **83 described / accepted species of euphausiids**
- **65 (78%) with COI barcodes; 3003 COI sequences**
- **28 species (33%) with 18S rRNA barcodes**

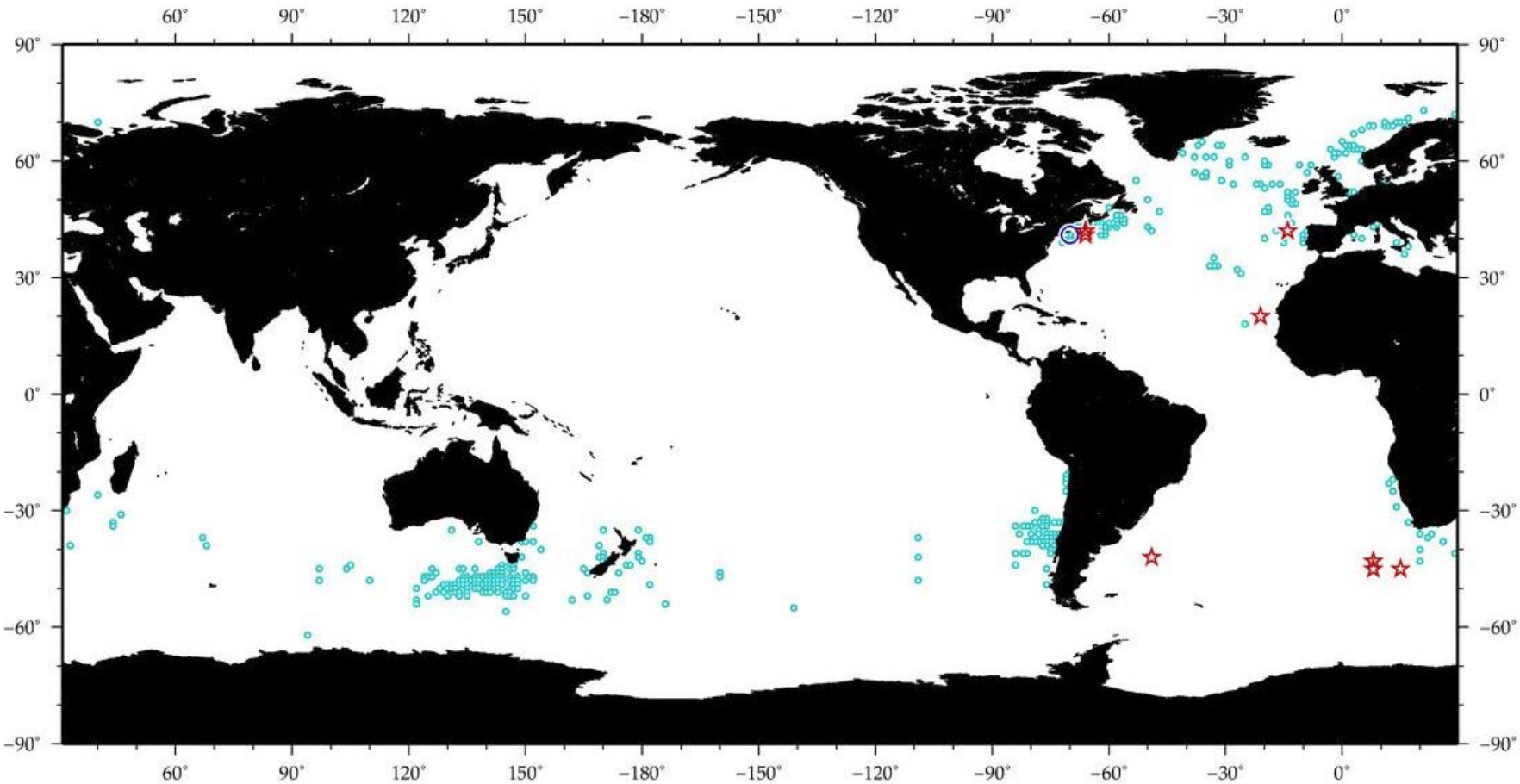


Blue dots: Species collection records; Red stars: barcoded specimens; http://metazoogene.org/atlas

Nematoscelis megalops

Barcode records with georeferencing:
COI = 28; mt 16S = 2; 18S rRNA = 1; 28S = 2

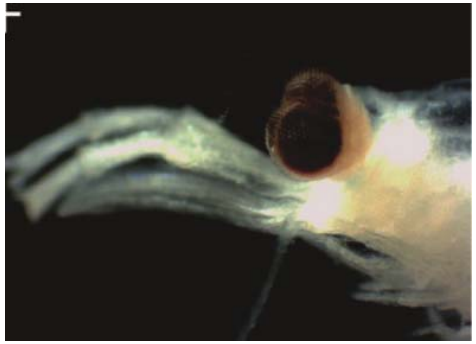




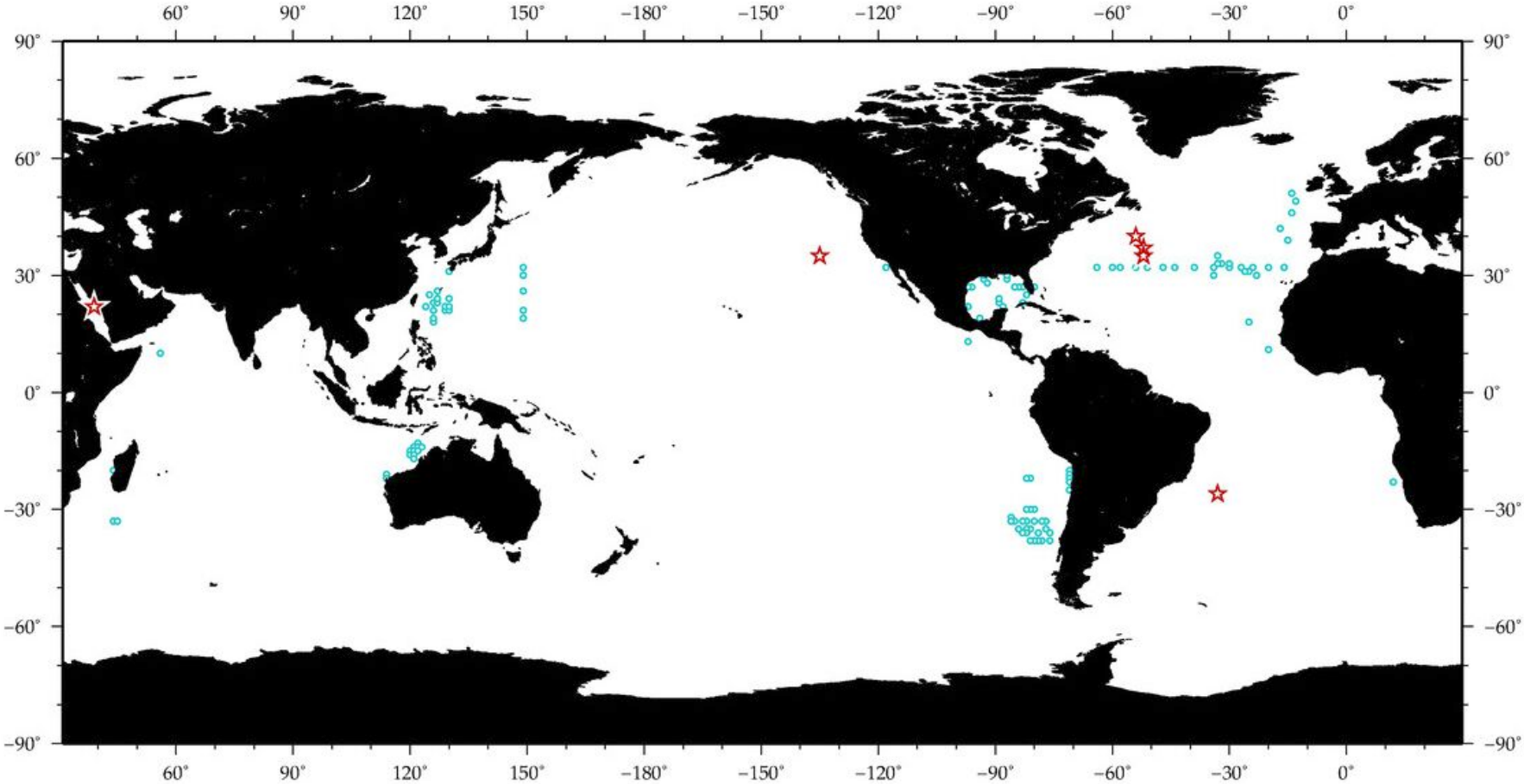
http://metazoogene.org/atlas

Styocheiron affine

Barcode records with georeferencing:
COI = 17; mt 16S rRNA = 1; 18S rRNA = 1



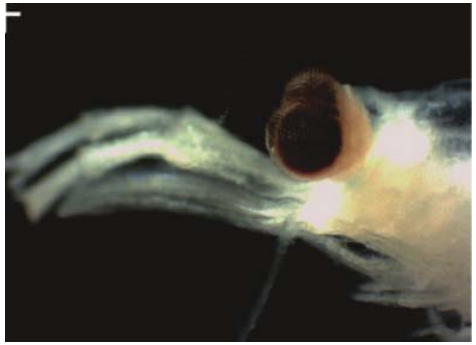
Azofeifa-Solano et al. (2021)



http://metazoogene.org/atlas

Stylocheiron affine in the Red Sea

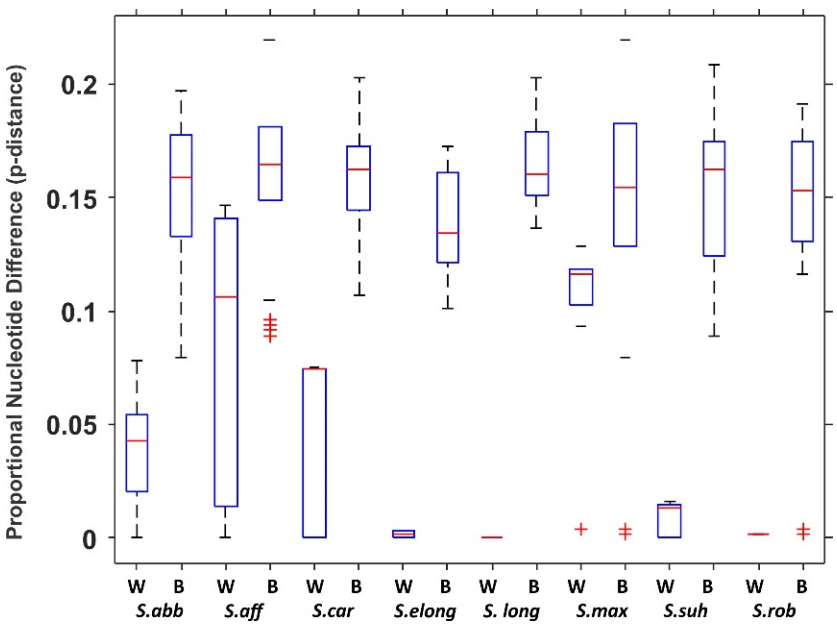
Wiebe, Bucklin et al. (2016) J. Plankton Res.
Bucklin et al. (2021) ICES J. Mar. Sci.

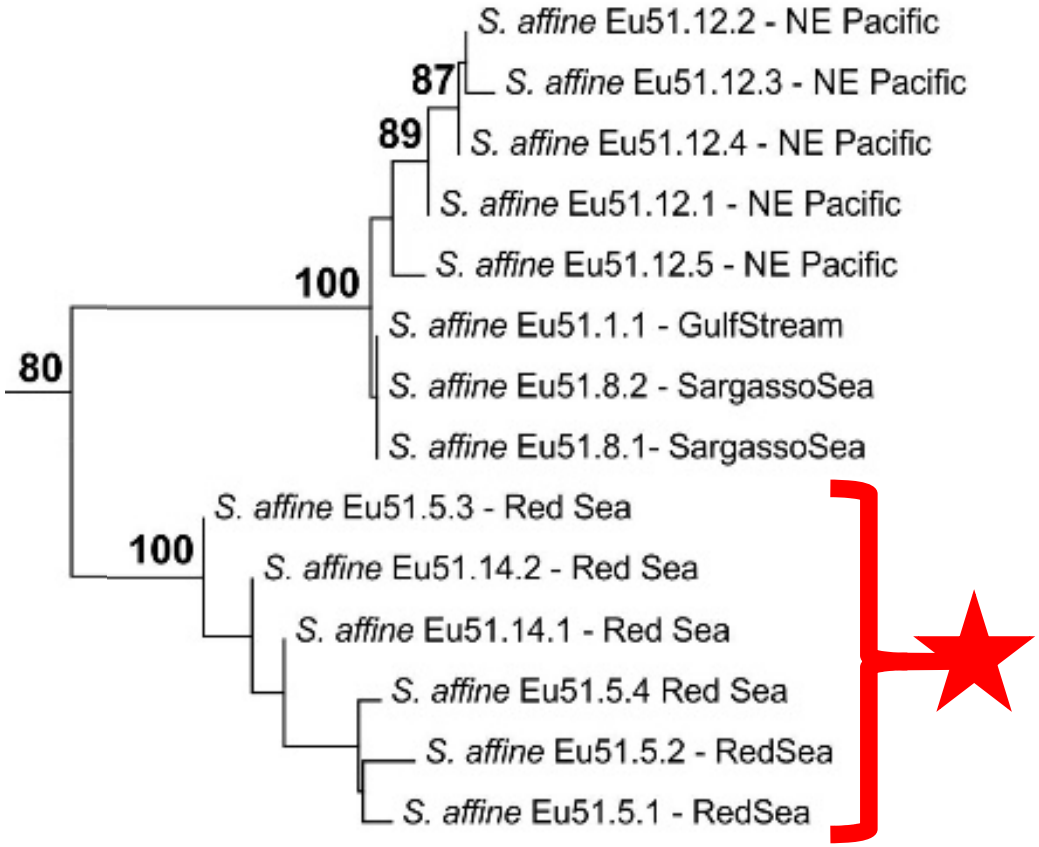


Azofeifa-Solano et al. (2021)

COI variation

- **Within species = 2.8% (SD 3.1%)**
- **Between species = 16.6% (SD 0.7%)**
- **S. affine from Red Sea differed 14% from Atlantic & Pacific**
- **Possible Red Sea cryptic species**

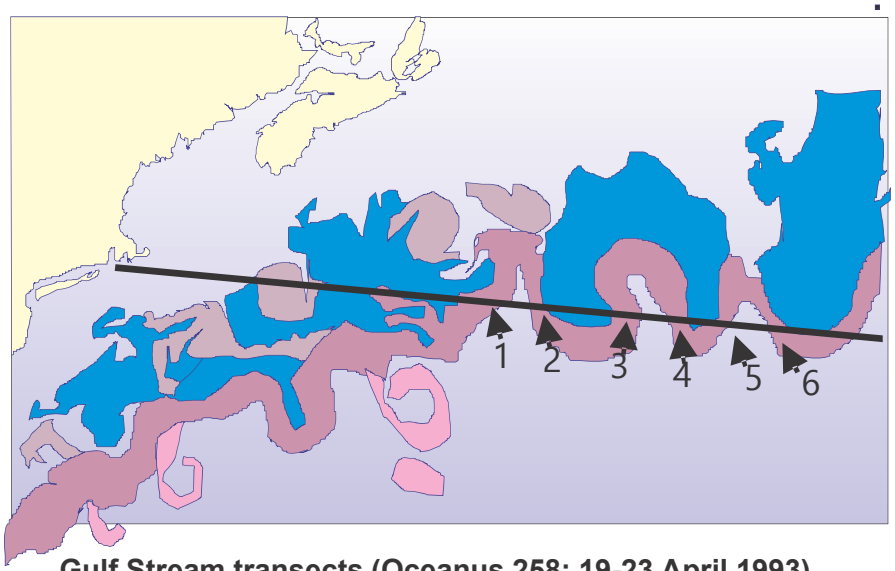




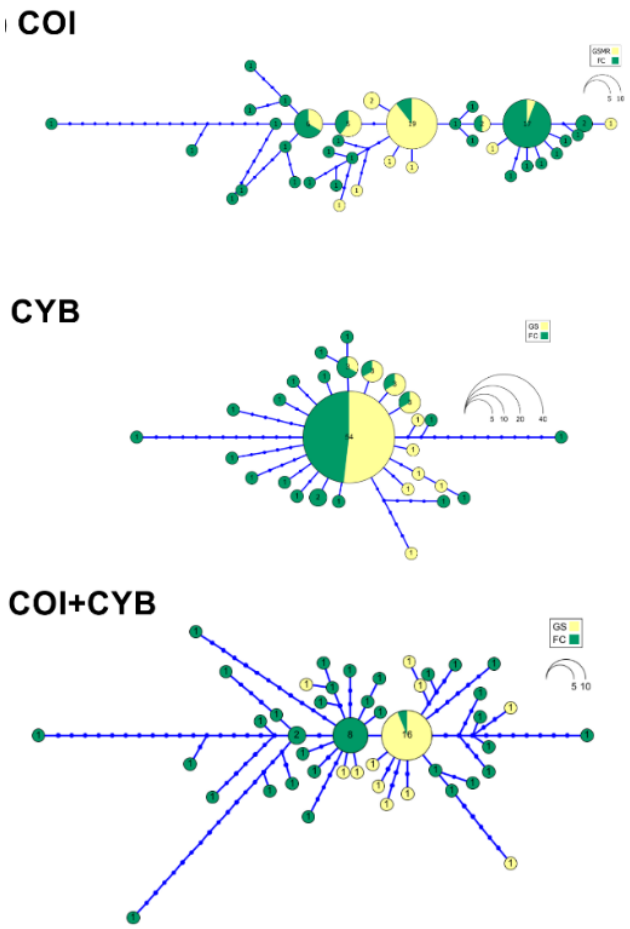
Stylocheiron elongatum in Gulf Stream System

Bucklin et al. (2021) ICES J. Mar. Sci.

- ***Stylocheiron*** **species show low COI variation; little or no population structure.**
- ***S. elongatum*** **showed <1% COI variation across all ocean basins, but significant differentiation in NW Atlantic Ocean.**
- **Position-keeping by deep-living, non-migrating species may prevents mixing along Gulf Stream.**

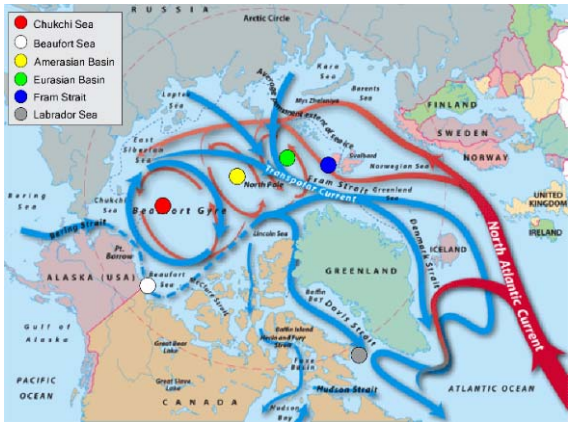


Gulf Stream transects (Oceanus 258; 19-23 April 1993)

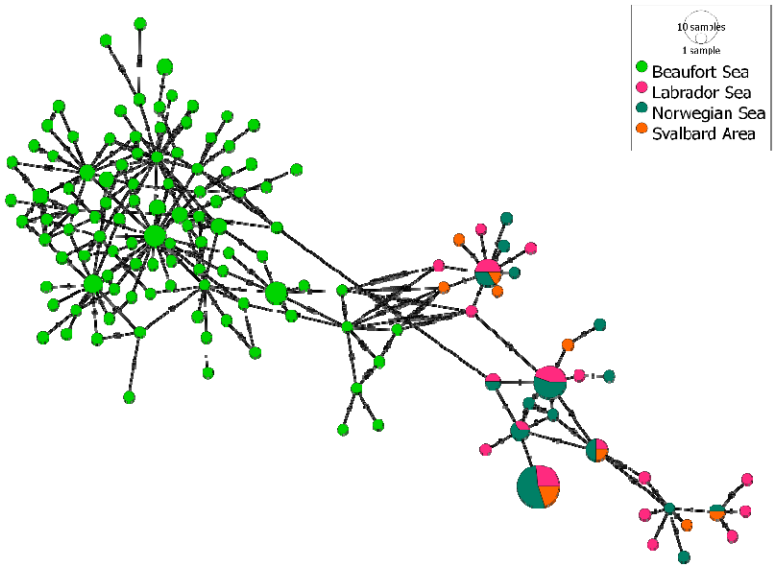


Thysanoessa inermis & *T. raschii*

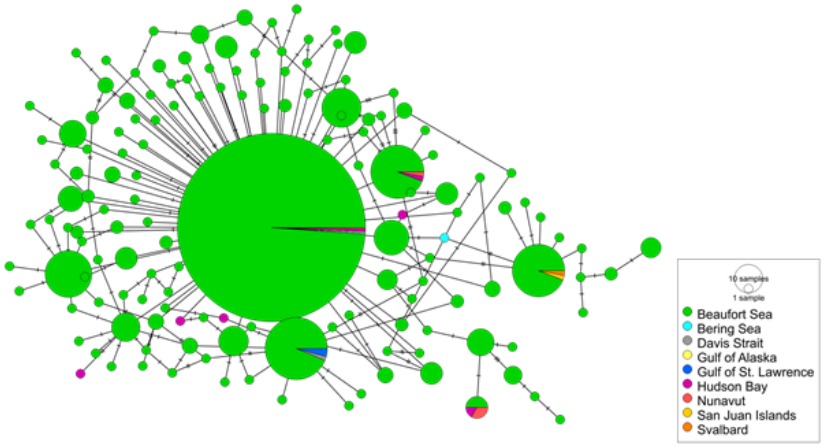
Atlantic – Arctic Divergence



***T. inermis*: Arctic & Atlantic divergence**



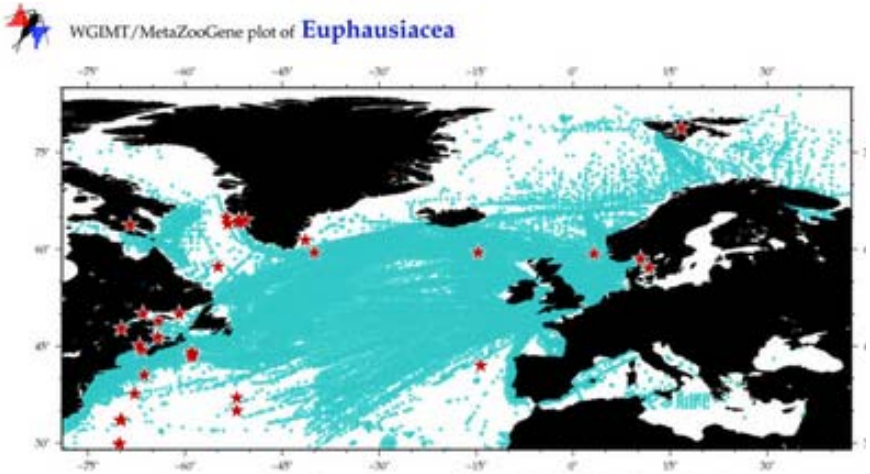
***T. raschii*: no population structure**



COI barcode variation (p-distance): *T. inermis* = 0.003 vs *T. raschii* = 0.025

Euphausiid Barcodes for North Atlantic
MetaZooGene / ICES WGIMT Barcode Atlas

Todd O'Brien (NOAA Fisheries, USA)



Crustacea-Euphausiacea of the ICES North Atlantic

- 42 species from North Atlantic
- 41 species with COI barcodes from "any ocean"; total 1,622
- 21 species with COI barcodes from N Atlantic; total 112
- Collaborative effort:
  - SCOR WG157 MetaZooGene
  - ICES WGIMT and WGZE
  - NOAA COPEPOD

https://metazoogene.org/database

SCOR WG157 MetaZooGene

ICES Working Group on Integrated Morphological & Molecular Taxonomy
WGIMT.net

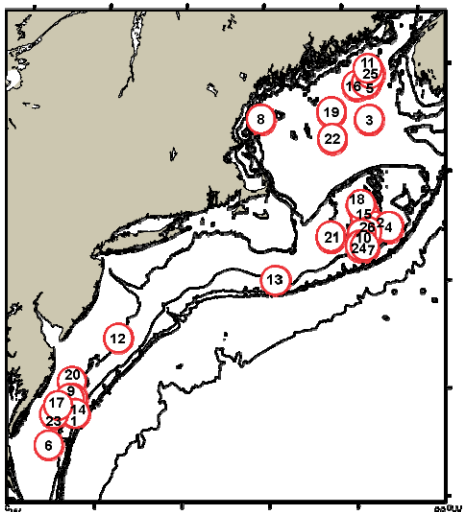
COPEPOD

ICES CIEM

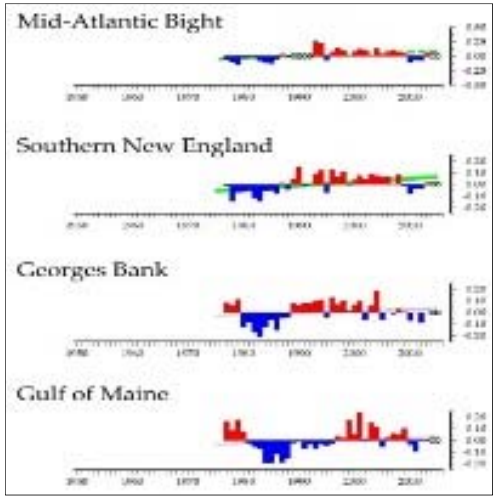
NEFSC Ecosystem Monitoring (EcoMon) NW Atlantic Continental Shelf

NW Atlantic Continental Shelf Regions

Bongo net samples



Station locations 2002-2012



Zooplankton displ. vol. O'Brien et al. (2013)

- **Time-series sampling: NOAA NMFS Ecosystem Monitoring (EcoMon) Surveys**
- **Taxonomic data from EcoMon: zooplankton species counts, biomass**
- **Spring cruises 2002-2012; 3 regions; total 26 samples**

Bucklin, A., H.D. Yeh, J.M. Questel, D.E. Richardson, B. Reese, N.J. Copley, P.H. Wiebe (2019) Time-series metabarcoding analysis of zooplankton diversity of the NW Atlantic continental shelf. ICES J. Marine Sci. doi:10.1093/icesjms/fsz021

Bucklin, A., P.G. Batta-Lona, J.M. Questel, P.H. Wiebe, D.E. Richardson, N.J. Copley, T.D. O'Brien (2022) COI metabarcoding of zooplankton species diversity for time-series monitoring of the NW Atlantic continental shelf. Front. Mar. Sci. 9:867893. doi:10.3389/fmars.2022.867893

ICES Journal of Marine Science

COI Barcodes to Monitor Euphausiid Diversity NEFSC EcoMon Time-Series Surveys

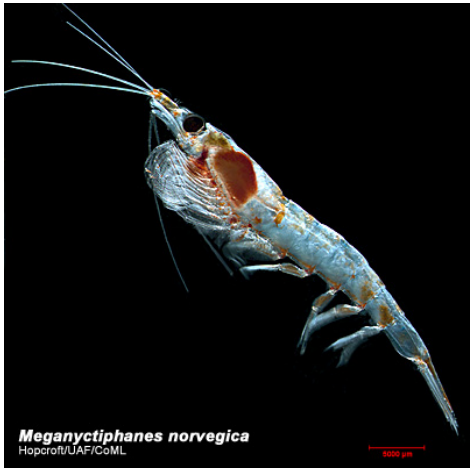
Time-series records of euphausiid species:

- Listed in EcoMon records & detected by both counts & COI
- EcoMon listed but not detected by counts or COI
- Detected only by COI metabarcoding

Species	EcoMon List	Counts >1% FO	COI seqs All	COI Seqs>50
Euphausia americana	X			
Euphausia krohnii	X	X	X	
Euphausia_tenera			X	X
Meganyctiphanes norvegica	X	X	X	X
Nematobrachion boopis	X			
Nematoscelis megalops	X	X	X	X
Stylocheiron_affine			X	
Stylocheiron_carinatum			X	
Stylocheiron elongatum	X			
Thysanoessa gregaria	X	X	X	X
Thysanoessa inermis	X		X	X
Thysanoessa longicaudata	X	X	X	X
Thysanoessa raschii	X			
Thysanoessa spinifera	X			
Thysanopoda acutifrons	X			
Thysanopoda aequalis	X			
Total # Species	13	5	9	6

Tracing Mesopelagic Food Chain

Identification of euphausiid prey species reveals sources of productivity: surface vs deep



Mesopelagic Fish Predators

Argyropelecus aculeatus
Silver hatchet fish

Sigmops elongatus
Bristlemouth

	Fish Species					
Prey Species by Group	**Aa**	**Cs**	**Hh**	**Ns**	**Sb**	**Se**
Euphausiacea						
Euphausia_americana	0.14	-	63.81	-	-	-
Euphausia_krohnii	92.79	35.71	13.00	-	-	1565.60
Meganyctiphanes_norvegica	274.29	74.29	0.05	-	-	617.80
Nematoscelis_megalops	1398.07	58.82	768.57	0.17	0.14	1.00

Photos: Paul Caiger (WHOI)

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Population genetic diversity, structure, and connectivity of Euphausiacea based on COI barcodes: Implications for biodiversity and biogeography

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Acknowledgements

Scientific Committee for Oceanic Research (SCOR)
- SCOR WG157 MetaZooGene
International Council for the Exploration of the Sea (ICES)
- ICES WG for Integrative Morphological and Molecular Taxonomy (WGIMT)
NOAA COPEPOD: Coastal and Oceanic Plankton Ecology, Production, and Observation Database
NOAA Northeast Fisheries Science Center (Narragansett RI, USA)
- Ecosystem Monitoring (EcoMon) Program
University of Connecticut, Institute for System Genomics
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- NOAA Office of Ocean Exploration
- NSF Biological Oceanography Program