A Molecular Perspective on Galatheoid Biodiversity at Deep-Sea Coral and Cold Seep Habitats in the Northwest Atlantic Ocean

Martha S. Nizinski
NOAA/NMFS Systematics Lab, Smithsonian Institution

Cheryl L. Morrison
USGS Leetown Science Center

Molecular Perspective = Phylogeny

Phylogenetics is a tool to help us understand community structure.

- Diversity
  - Among sites
  - Within sites
- Identify phylogenetic lineages
  - Are all species that occur at seep sites more closely related to each other?
  - Are lineages that occur at these sites unique to these kinds of environments? OR
  - Are these lineages representative of deep-sea taxa occurring in other environments?

Genetics vs Morphology

- Genetic approaches may reveal underlying diversity that is not evident due to morphological conservatism
- Genetic approaches provide an independent assessment of diversity from that of morphology
- Genetic approaches provide a finer scale of resolution to determine immediate ancestory and parental lineages that morphology can’t address

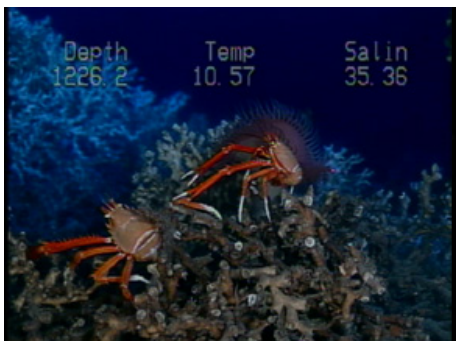
Underlying Questions

- Within-site diversity
- Uniqueness of taxa
- Genetic connectiveness
- Uniqueness of lineages at sites

Only through phylogenetic reconstruction can we frame these questions in an evolutionary context.

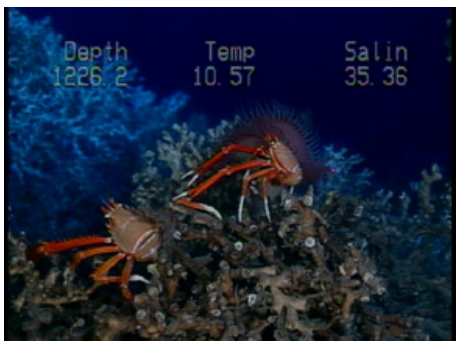
Galatheoids 101

- Abundant, speciose, worldwide distribution
  - 3 Families
    - Galatheidae
    - Chirostylidae
    - Kiwaidae
  - 42 Genera
  - 870 Species
- All marine habitats and depths
- Primarily in temperate and tropical latitudes




Galatheoids 101 (continued)

- Known from cold seep sites since the discovery of these habitats
- Dominant members of assemblage of associated fauna at seep and deep-sea coral habitats
- Main contributor to scavenging/predatory fauna in seep and deep-sea coral habitats
- Potential vector for export of organic carbon to surrounding deep-sea communities
- Many species similar in appearance; observations numerous but vague




Trends in Galatheoid Biodiversity NW Atlantic Reefs and Seeps

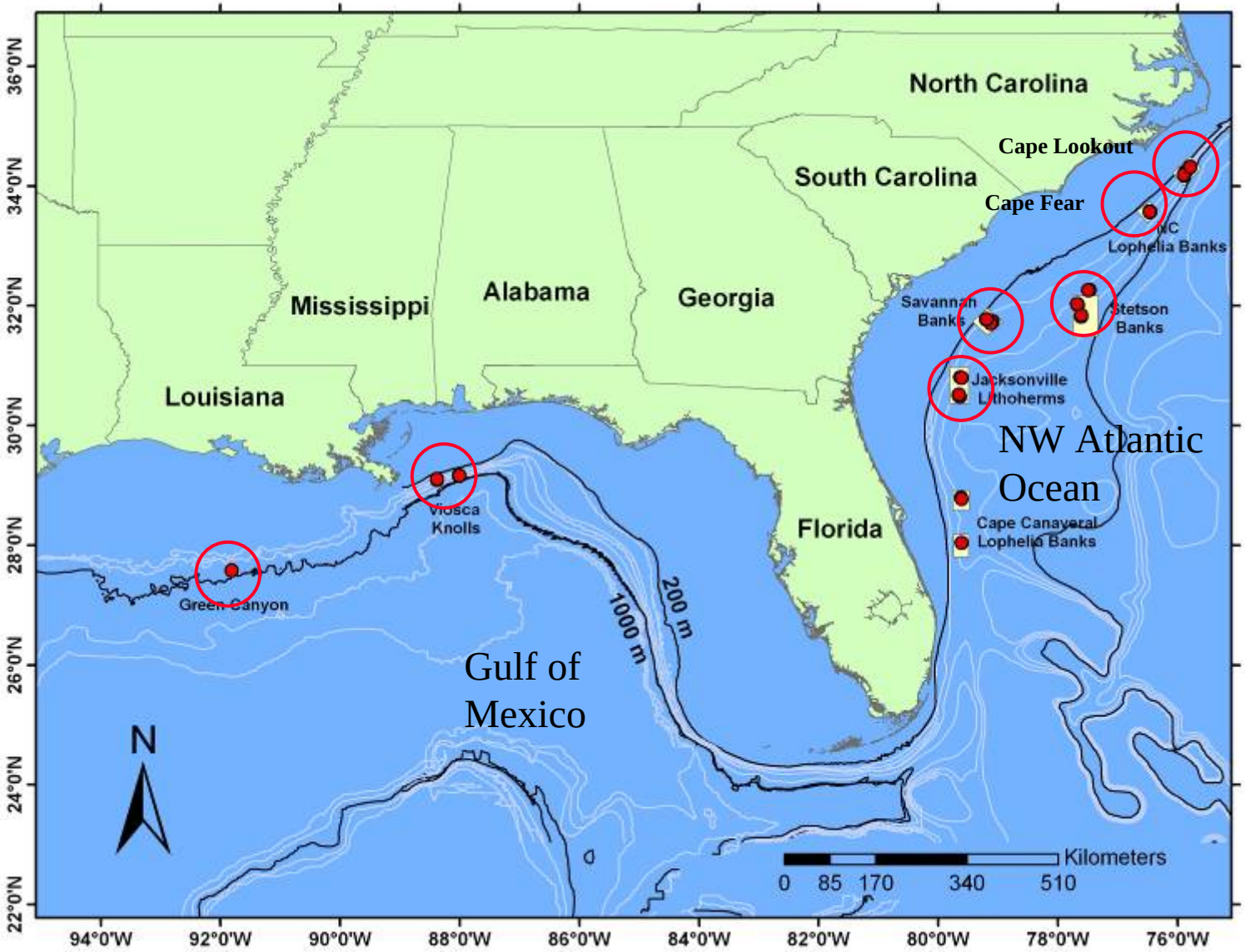
- Diverse assemblages associated with these habitats

- Assemblages may be habitat specific
  - Coral vs seep
  - Depth: faunal transition between upper and lower slope species (e.g. Cordes et al. 2007)

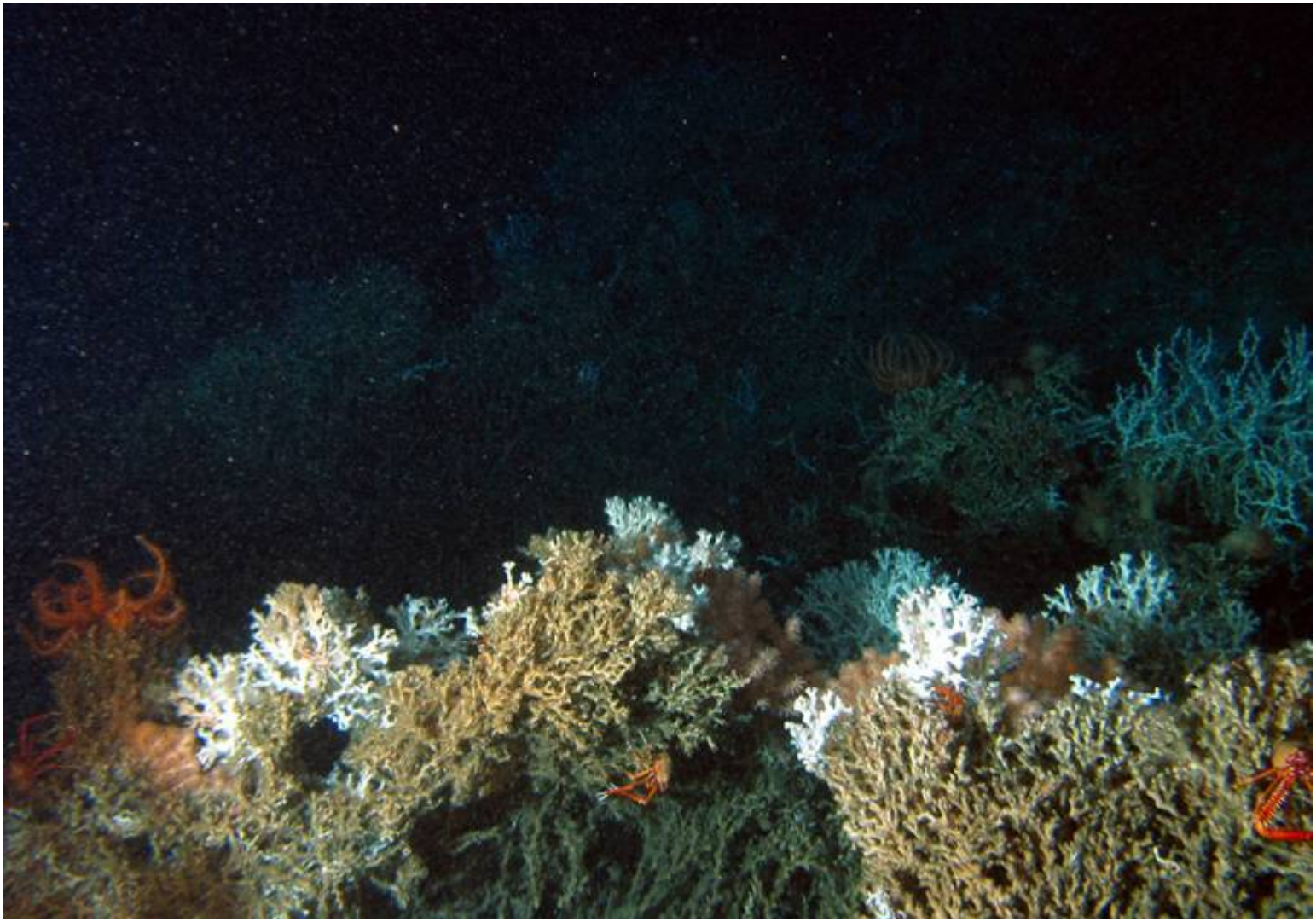
Objectives

- Examine phylogenetic relationships among NW Atlantic galatheoid species using DNA sequence data
- Put relationships into context with better characterized Pacific species
- Provide a framework for ongoing taxonomic and ecological studies

Upper Continental Slope Collection Sites (<1,000m)

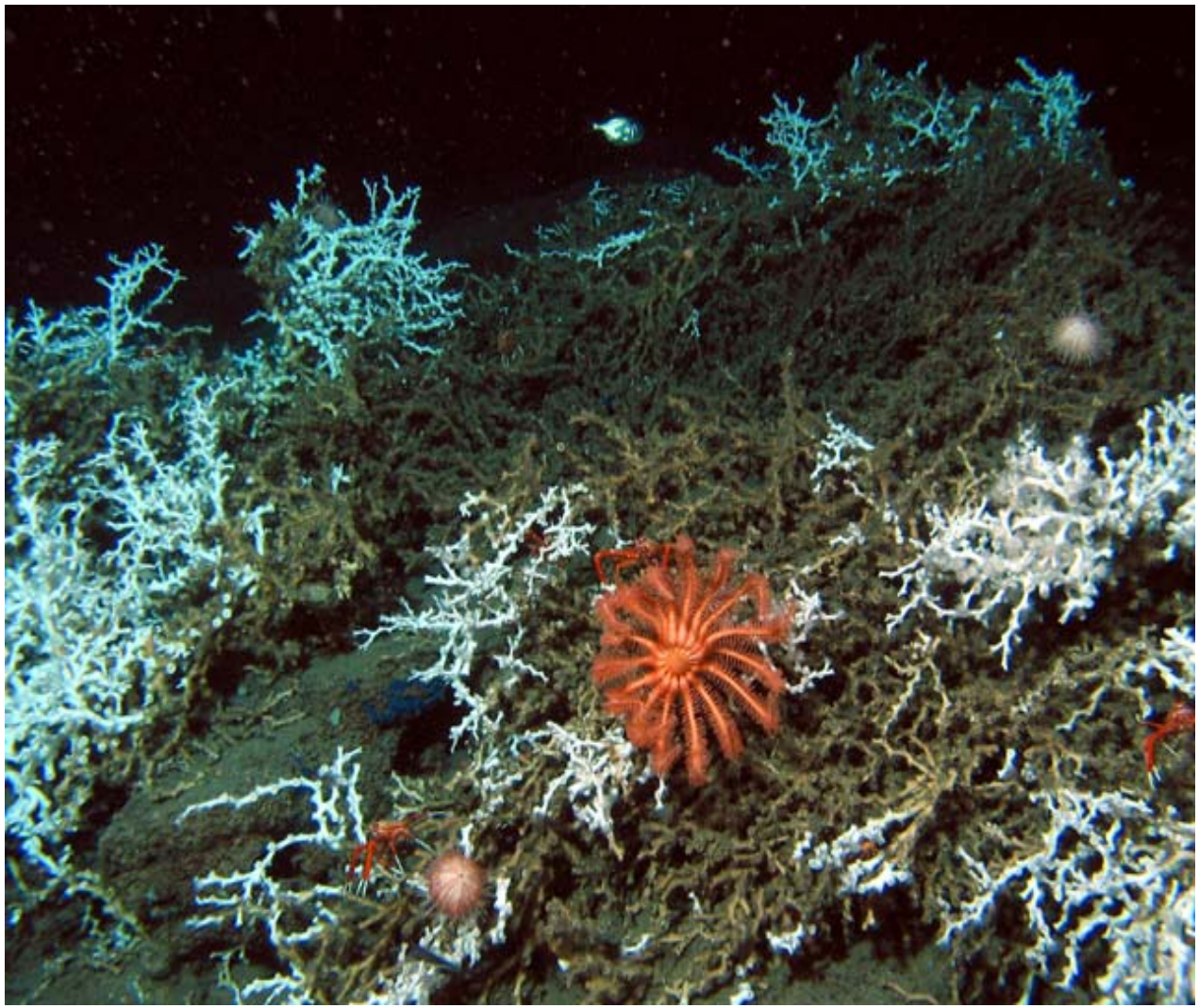


Upper Continental Slope Deep-sea Coral Habitat, *Lophelia pertusa*



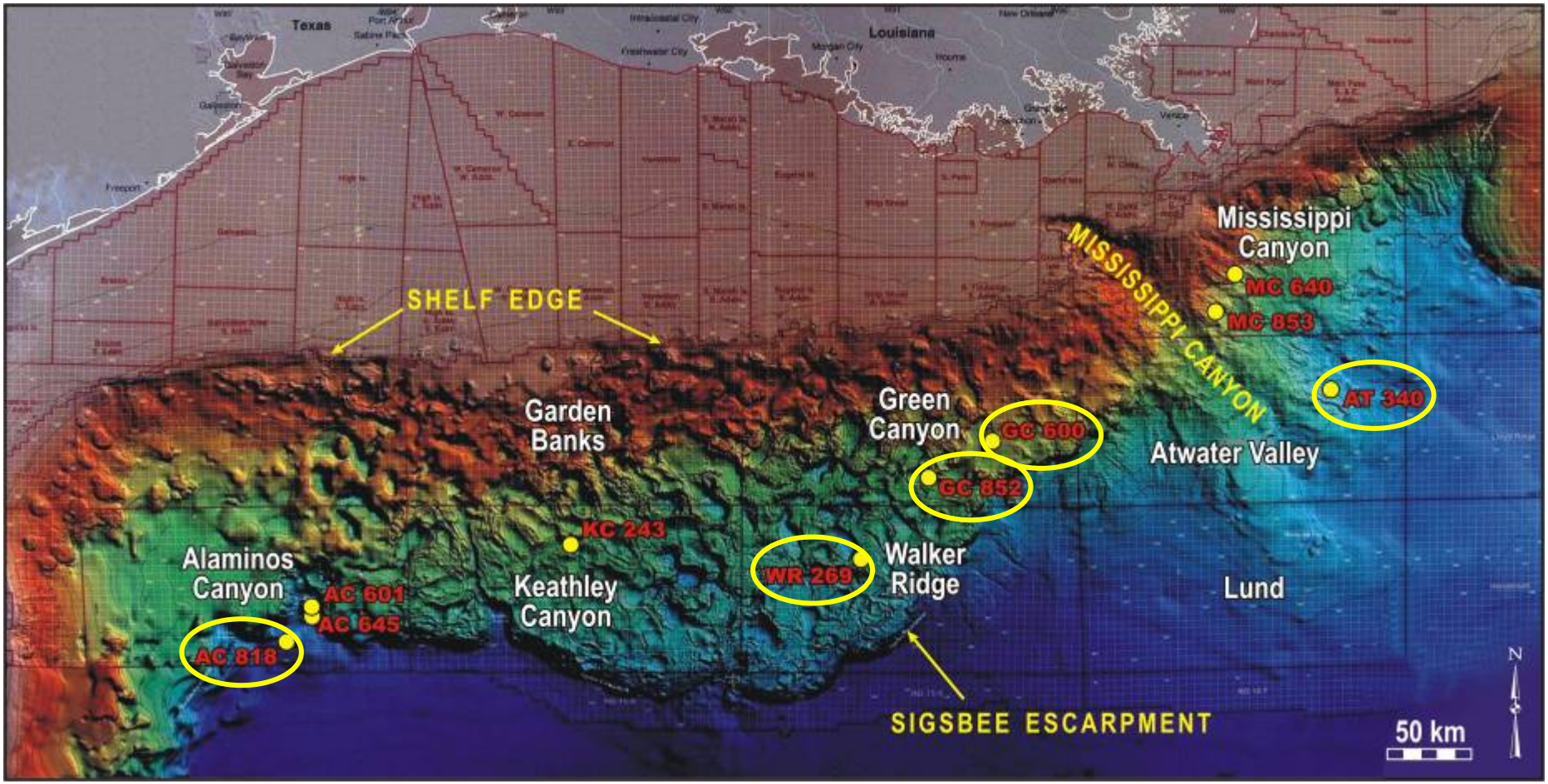
NW Atlantic Ocean, off Cape Lookout, NC, 440 m

Upper Continental Slope Deep-sea Coral Habitat, *Lophelia pertusa*



Gulf of Mexico, Viosca Knoll 826, 480 m

Lower Continental Slope Collection Sites
Gulf of Mexico Cold Seep Habitats (> 1,000m)

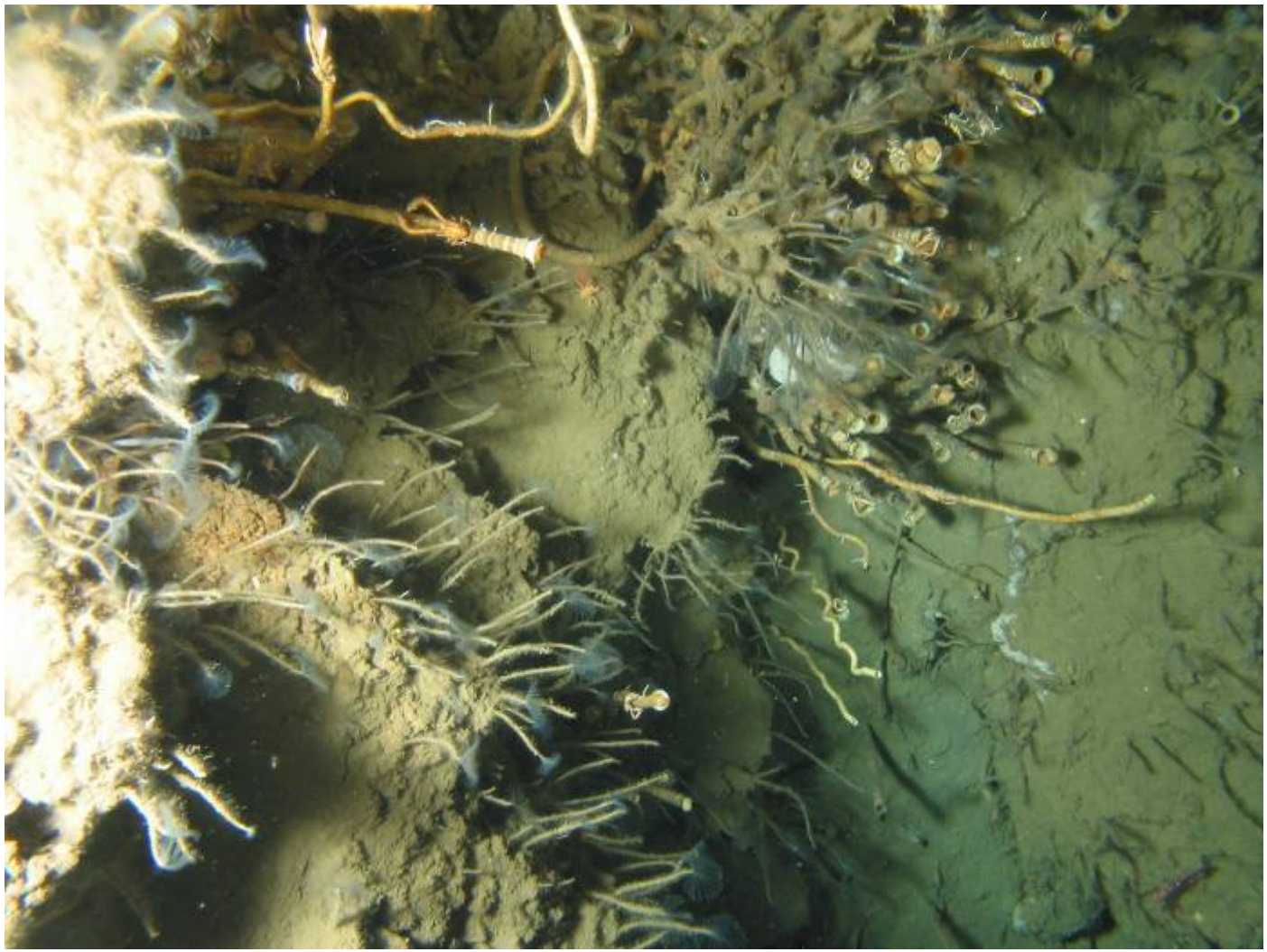


Roberts et al. 2007.

Lower Continental Slope Deep Coral Habitat

Green Canyon 852, 1,440 m

Upper Continental Slope Cold Seep-Chemosynthetic Community Habitat



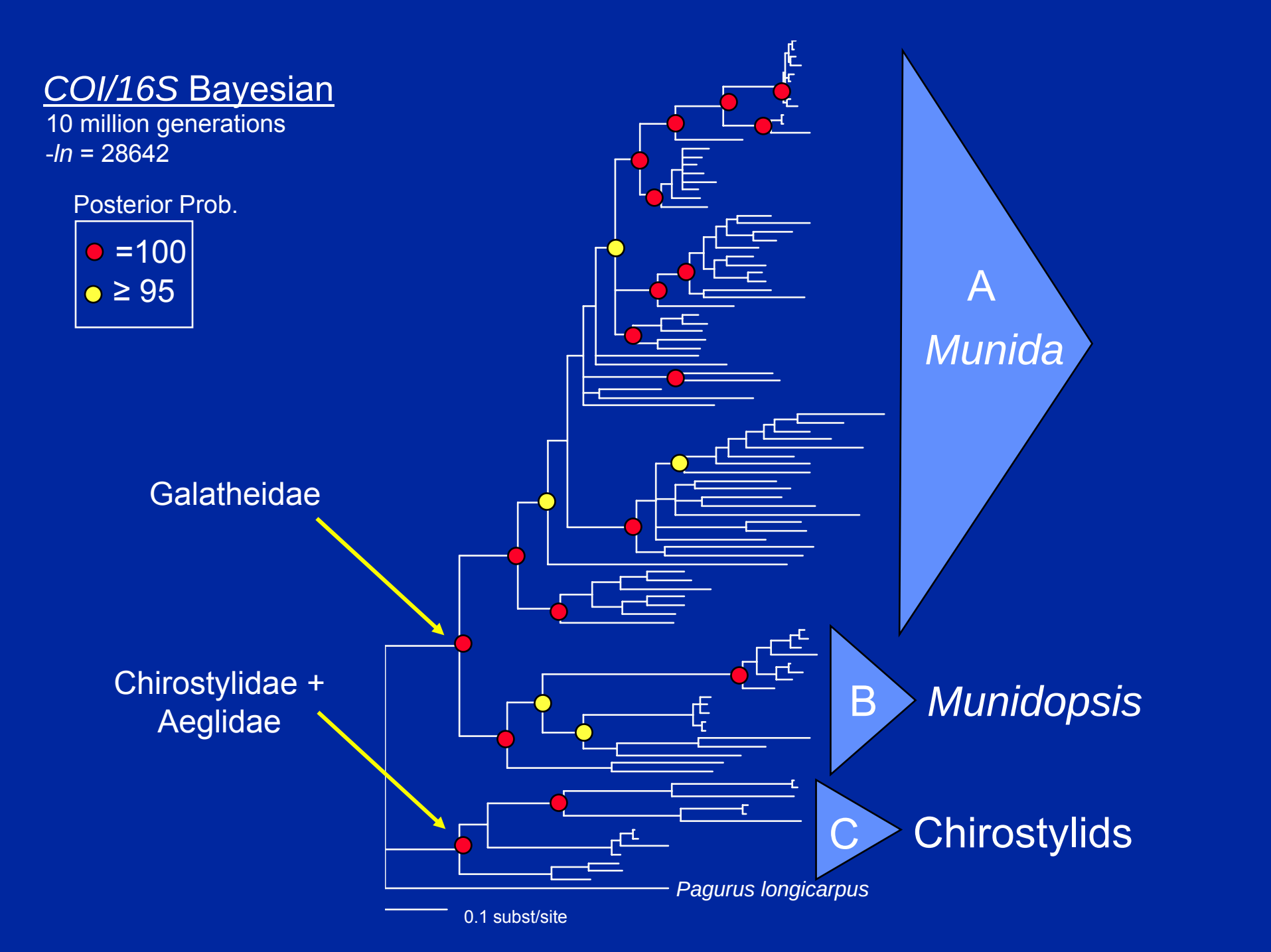
Gulf of Mexico, Green Canyon 354, 562 m

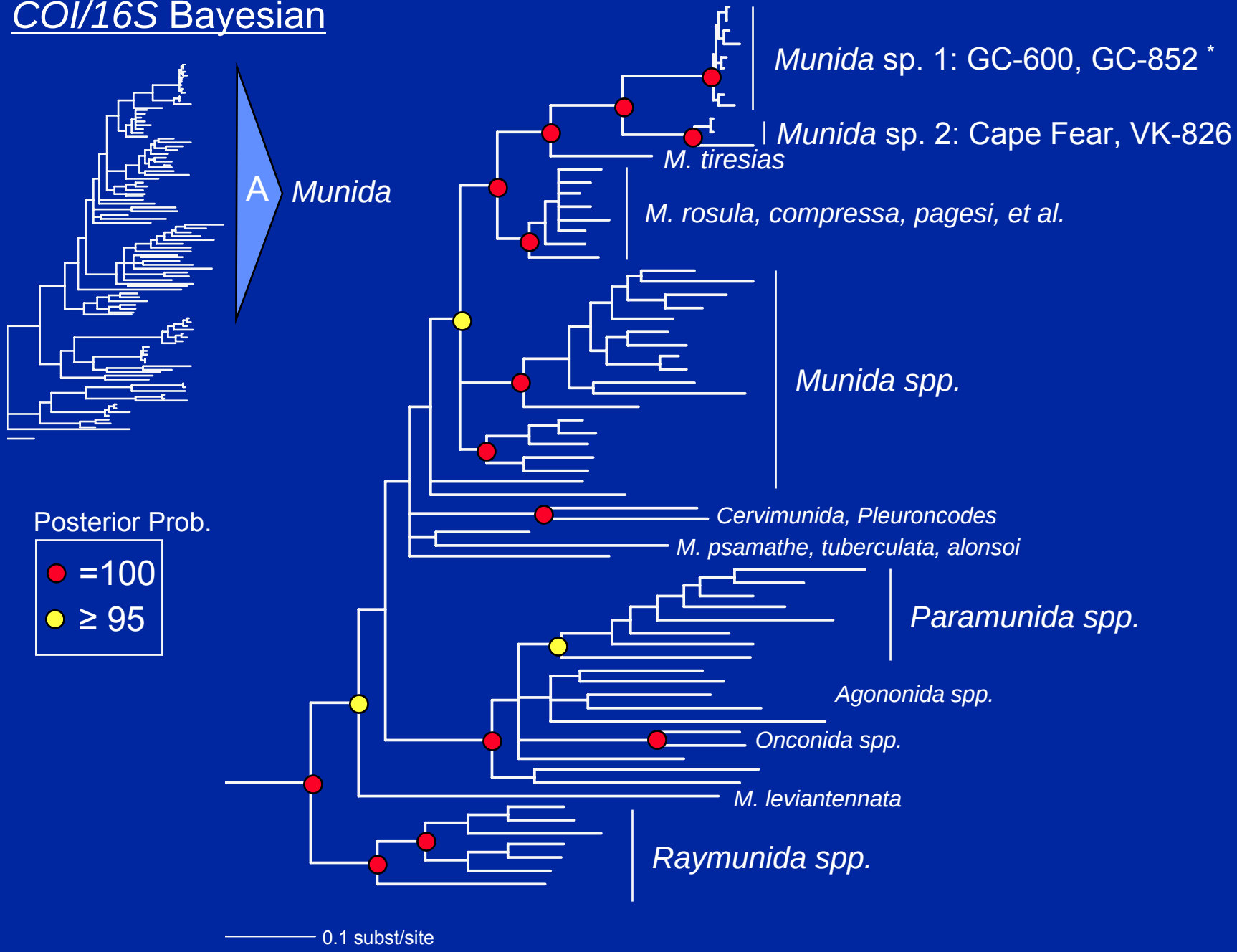
Lower Continental Slope Cold Seep-Chemosynthetic Community Habitat

Gulf of Mexico, Alaminos Canyon 645, 2,226 m

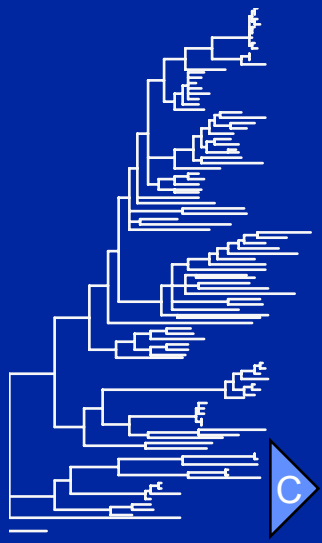

DNA Methods

- Specimens stored in 70–95% ETOH, vouchered at Smithsonian
- Partial mtDNA 16S gene sequenced
  - 42 new sequences, ~610 bp aligned
  - 76 GenBank species:
    - Machordom & Macpherson 2004
- Partial mtDNA COI gene sequenced
  - 34 new sequences,~500–650 bp
  - 80 Genbank species:
    - Machordom & Macpherson 2004
    - Jones & Macpherson 2007
- Bayesian phylogenetic analyses performed on combined 16S/COI and COI datasets


COI/16S Bayesian
10 million generations
-ln = 28642
Posterior Prob.
=100
≥ 95
A
Munida
Galatheidae
Chirostylidae +
Aeglidae
B
Munidopsis
C
Chirostylids
Pagurus longicarpus
0.1 subst/site


COI/16S Bayesian
A
Munida
Posterior Prob.
=100
≥ 95
Munida sp. 1: GC-600, GC-852 *
Munida sp. 2: Cape Fear, VK-826
M. tiresias
M. rosula, compressa, pagesi, et al.
Munida spp.
Cervimunida, Pleuroncodes
M. psamathe, tuberculata, alonsoi
Paramunida spp.
Agononida spp.
Onconida spp.
M. leviantennata
Raymunida spp.
0.1 subst/site

COI/16S Bayesian



Gastroptychus spinifer

Uroptychus spp.: JAX, STS

Uroptychus parvulus

Gastroptychus spinifer: VK-826, SAV

Gastroptychus affinis: GC-852 *

Posterior Prob.

=100

Aegla spp.

E. sternomaculata

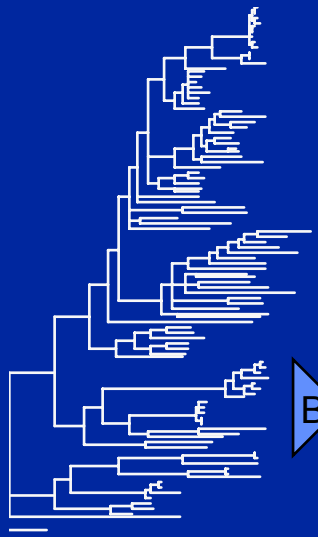
E. picta: CLO

E. annulosa

0.1 subst/site

Eumunida picta

COI/16S Bayesian



B *Munidopsis*

Posterior Prob.

- =100
- ≥ 95

Munidopsis sp. 3: AC-818

M. recta

Munidopsis sp. 2: AC-818

M. similis-like: AT-340, GC-852 *

Munidopsis sp. 1: AC-818

Munidopsis n. sp.
JAX, VK-826, GC-354

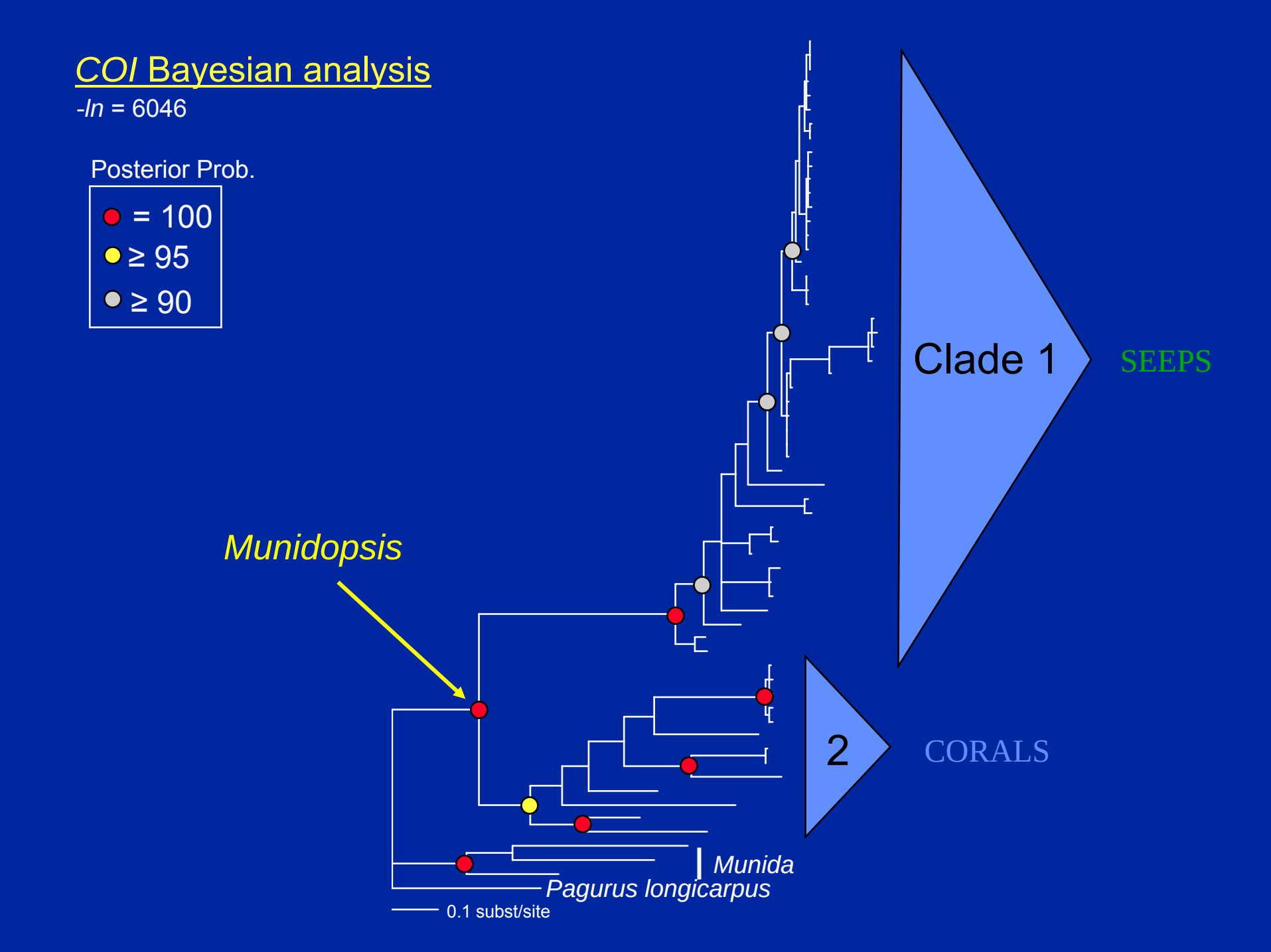
M. spinoculata? CLO

Munidopsis sp. 4: VK-826

M. curvirostra: WR-269

Leiogalathea laevirostris

Leiogalathea agassizii: CLO


COI Bayesian analysis
-ln = 6046
Posterior Prob.
= 100
≥ 95
≥ 90
Clade 1
SEEPS
Munidopsis
2
CORALS
Munida
Pagurus longicarpus
0.1 subst/site

COI Bayesian analysis

Munidopsis

1

SEEPS

M. bracteosa

Munidopsis sp. 3: AC-818

M. recta

M. exuta (MAR)

M. scotti

1%

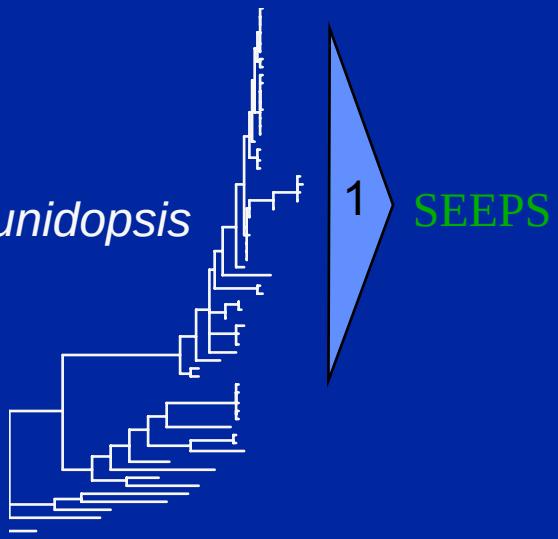
East Pacific Rise
'Rapid Diversification'

Posterior Prob.

- = 100
- ≥ 95
- ≥ 90

0.1 subst/site

COI Bayesian analysis



Posterior Prob.

- = 100
- ≥ 95
- ≥ 90

M. bracteosa

M. recta

M. kensmithi

M. verrucosus

M. antonii

M. segonzaci

Munidopsis sp. 2: AC-818

M. albatrossae/aries

M. similis-like: AT-340, GC-852 *

M. vrijenhoeki

M. tiburon

M. hirtella

M. cascadia

Munidopsis sp. 1: AC-818

0.1 subst/site

COI Bayesian analysis

Posterior Prob.

= 100

≥ 95

Munidopsis n. sp.

JAX, VK-826, GC-354

M. curvirostra: WR-269, pogonophorans

Munidopsis sp. 4: VK-826

M. spinoculata? CLO

M. polymorpha

Munidopsis quadrata

Leiogalathea agassizii: CLO

Leiogalathea laevirostris

0.1 subst/site

Preliminary Conclusions

- Habitat Specificity
  - Depth an important factor shaping species composition
  - Species separated into clades corresponding to upper vs lower slope habitats
  - Habitat type- difficult to determine, unknown degree of overlap
  - Samples confounded since most deep sites are Chemo sites and most 'shallower' sites coral sites
- *Munidopsis* = most diverse
  - Upper slope species-
    - Genetically differentiated (not a species complex)
    - *Leiogalathea* spp. basal
    - New species = widespread: Coral habitats in NW Atlantic + Gulf
  - Lower slope seep species:
    - Belong to complex of eastern Pacific species
    - Suggests faunal connections
    - Ability to inhabit variety of habitats? Long-distance dispersers?

Acknowledgments

- Funding
  - USGS-BRD Outer Continental Shelf Ecosystem Program and sponsored by Minerals Management Service
  - NOAA Ocean Exploration
- Logistics
  - Harbor Branch Oceanographic Institute, *JSL* Sub Crew
  - Woods Hole Oceanographic Institute, Alvin and *Jason* crews
  - USGS Deep Coral Ecology Team: S. Ross, K. Sulak, G. Brewer
  - TDI Brooks 'Chemo III' Team: C. Fisher, H. Roberts, I. MacDonald, R. Carney, E. Cordes
- Lab work: R. Johnson
- Samples: E. Cordes, C. Fisher
- Photos: A. Howard, I. MacDonald, J. Caruso, C. Kellogg, E. Cordes

References

Cordes, E.E., S.L. Carney, S. Hourdez, R.S. Carney, J.M. Brooks, and C.R. Fisher. 2007. Cold seeps of the deep Gulf of Mexico: Community structure and biogeographic comparisons to Atlantic equatorial belt seep communities. Deep Sea Research I 54:637–653.

Jones, W.J. and E. Macpherson. 2007. Molecular phylogeny of the East Pacific squat lobsters of the genus *Munidopsis* (Decapoda: Galatheidae) with the descriptions of seven new species. Journal of Crustacean Biology 27:477–501.

Machordom, A. and E. Macpherson. 2004. Rapid radiation and cryptic speciation in squat lobsters of the genus *Munida* (Crustacea, Decapoda) and related genera in the South West Pacific: Molecular and morphological evidence. Molecular Phylogenetics and Evolution 33:259–279.

Roberts, H.H., C.R. Fisher, B. Bernard, J.M. Brooks, M. Bright, R.S. Carney, E.E. Cordes, S. Hourdez, J.L. Hunt, S.B. Joye, and others. 2007. ALVIN explores the deep northern Gulf of Mexico Slope. EOS Transactions, American Geophysical Union 88:341–342.