Photo: Ove Hoegh-Guldberg

Censusing the Sea in the 21st Century

Nancy Knowlton
&
Matthieu Leray

Smithsonian's
National Museum
of Natural History

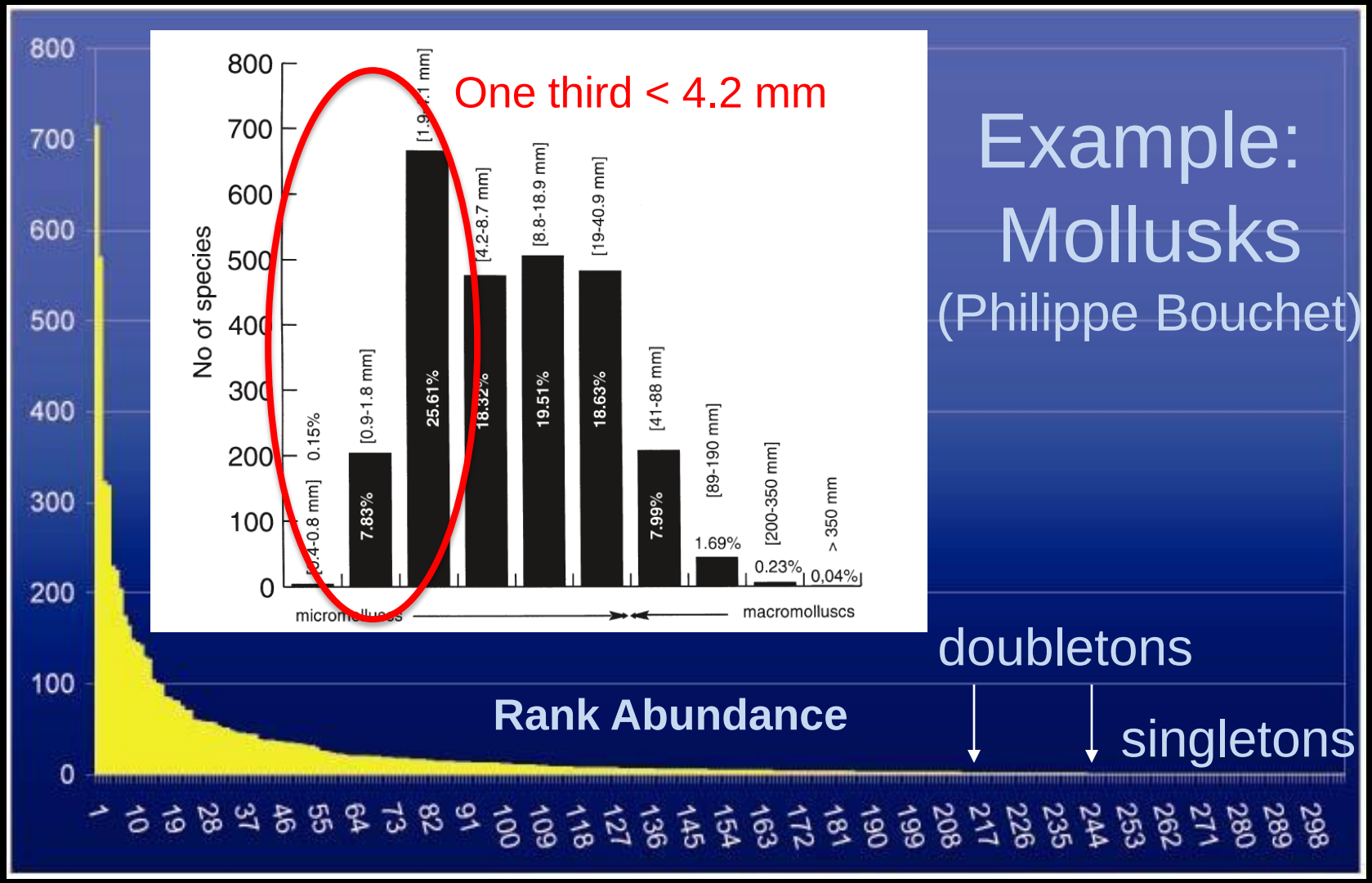
Estimates of Marine/Reef Species Numbers (Millions)

Marine Habitat	Global Ocean	Data Type	Author, Date
10 deep sea	—	box cores, 21 m^2	Grassle & Maciolek, 1992
0.6-9.5 coral reefs	**1.9-30.6***	tropical forests, species-area	Reaka-Kudla, 1997
1.7-3.2 coral reefs	**5.5-10.3***	5 m^2 reef samples, species-area	Small et al., 1998
0.4-0.5* Coral reefs	**1.4-1.6**	European brachyuran crabs	Bouchet, 2006
0.7* coral reefs	**2.2**	ratios of taxa	Mora et al., 2011
0.2-0.3* coral reefs	**0.7-1.0**	expert opinion	Appeltans et al., 2012
0.5-1.3 coral reefs	**1.6-2.4***	expert opinion	Fisher et al. 2015

*Assumes 31% of marine species live on reefs

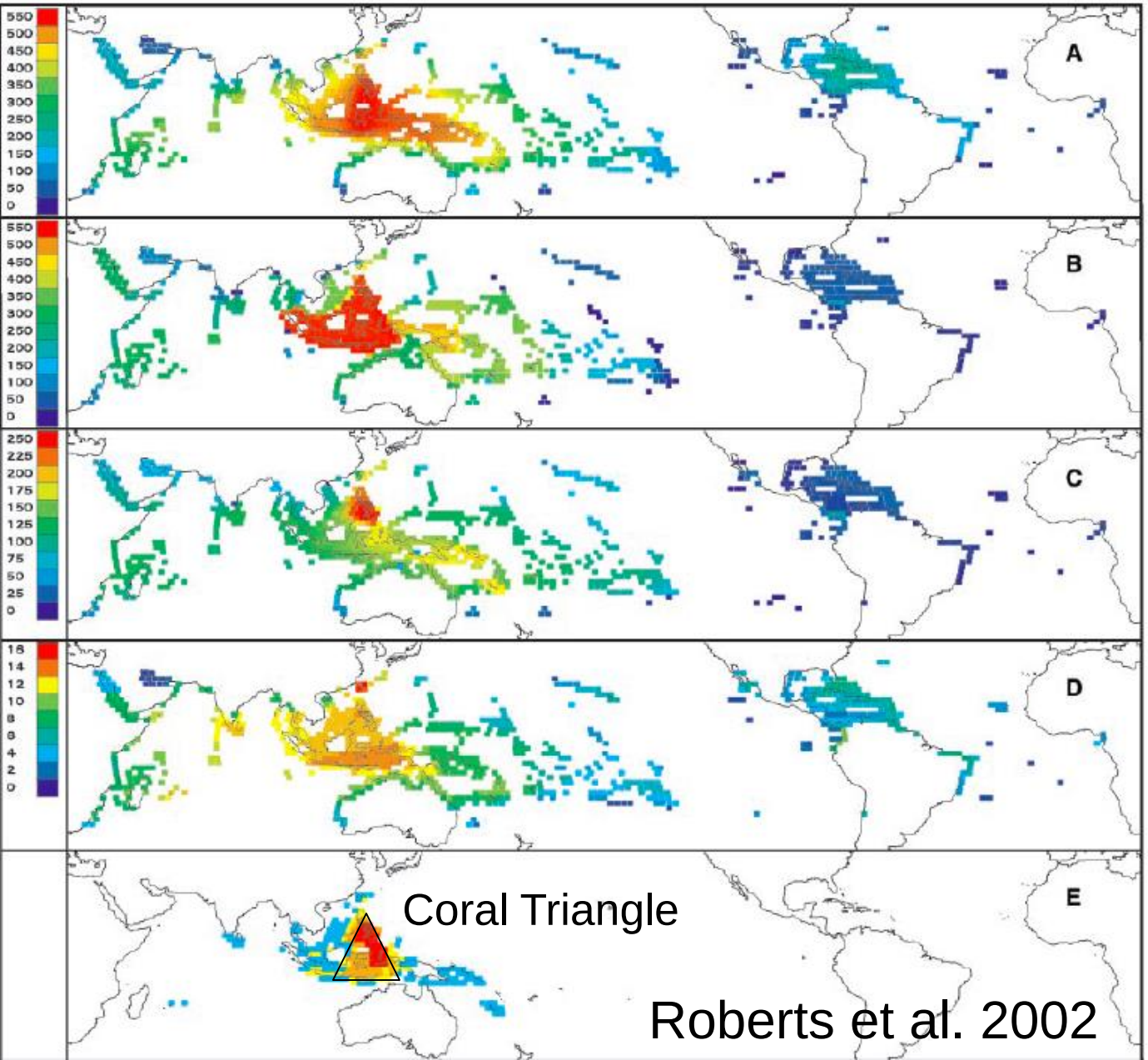
Why so hard?

Most marine species are small and rare



33-91% of all marine species still to be named

Global analyses ignore almost all biodiversity



Some fish
1700 spp

Corals
804 spp

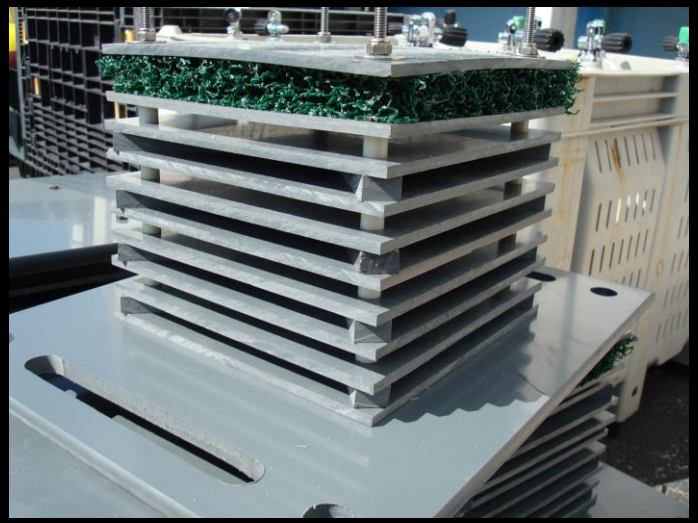
Some snails
662 spp

Lobsters
69 spp

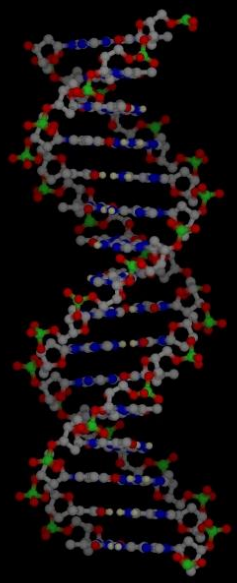
All???
3235 spp
(~250,000 descr.)

Census of Marine Life - CReefs

Artificial Surfaces (ARMS)



DNA



Natural Surfaces (dead heads)

Standardization -

Allows results of different studies to be compared

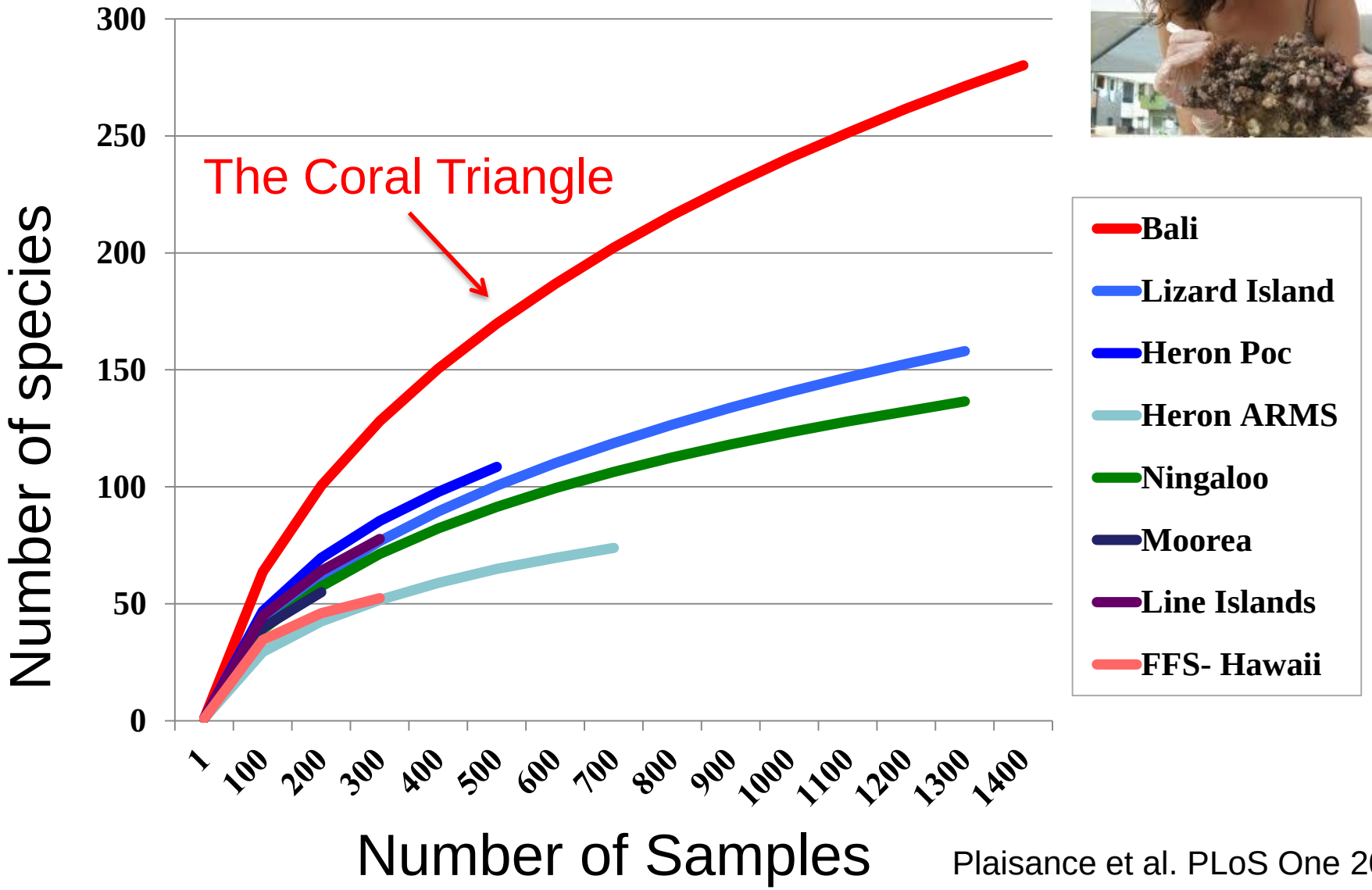
Automation -

Identify species using genetics rather than names

Scalability -

World-wide sampling strategy is feasible

First Studies: Barcoding Crustaceans

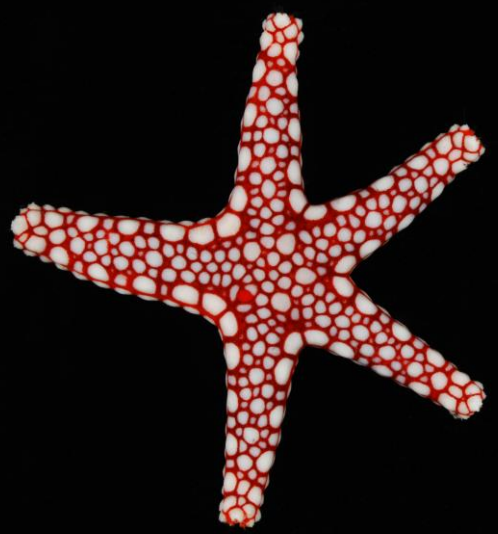


Plaisance et al. PLoS One 2011
Unpublished data

Put Another Way….

Just 6.3 m^2 contained the equivalent of 80% of the described crab diversity of European seas!

Barcoding works well for the charismatic microfauna

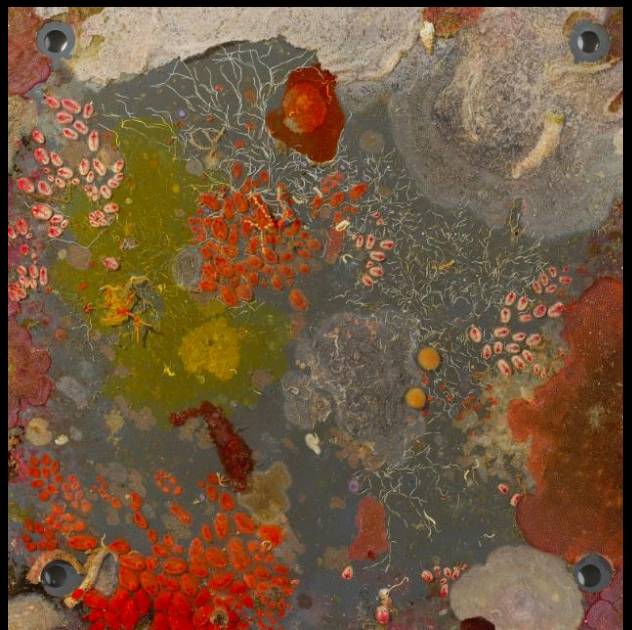


Photos: Matthieu Leray

What about the sessile stuff?

Indonesia (Photos: David Littschwager)



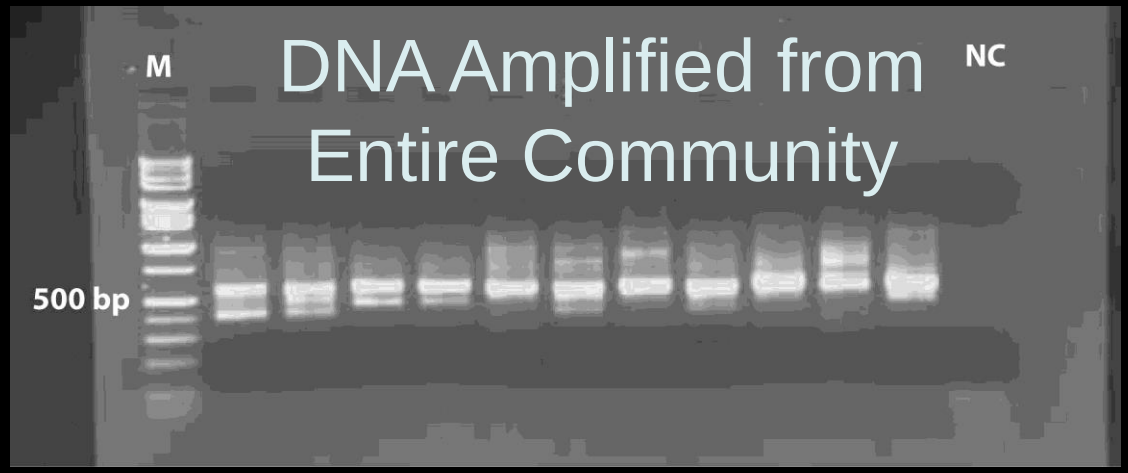
Or the fairly small stuff?

(<2mm)

Photos: Matthieu Leray

From Barcoding to Metabarcoding

Bulk Sample



DNA Amplified from Entire Community

Next-Gen Metabarcodes

(easier said than done)

4 Fractions
(+ vouchers)

1) sessile

COI Metabarcode

2) > 2mm

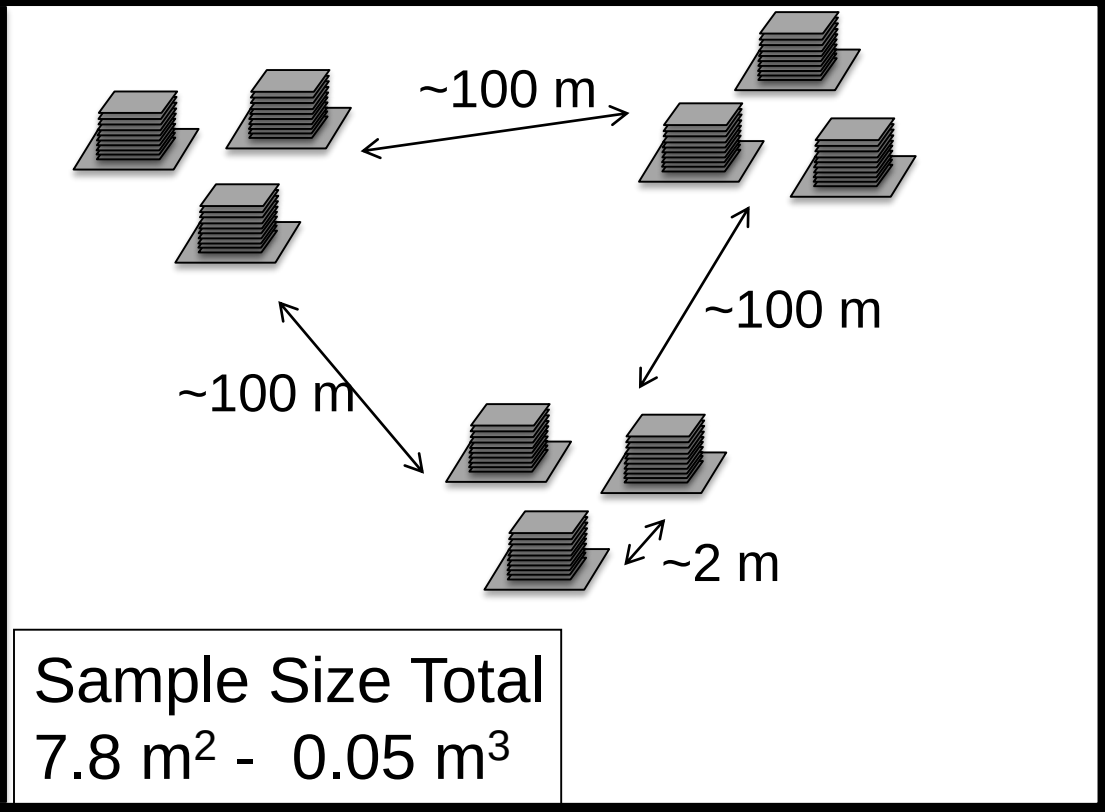
COI barcode

4) 500–106 µm

3) 2mm–500 µm

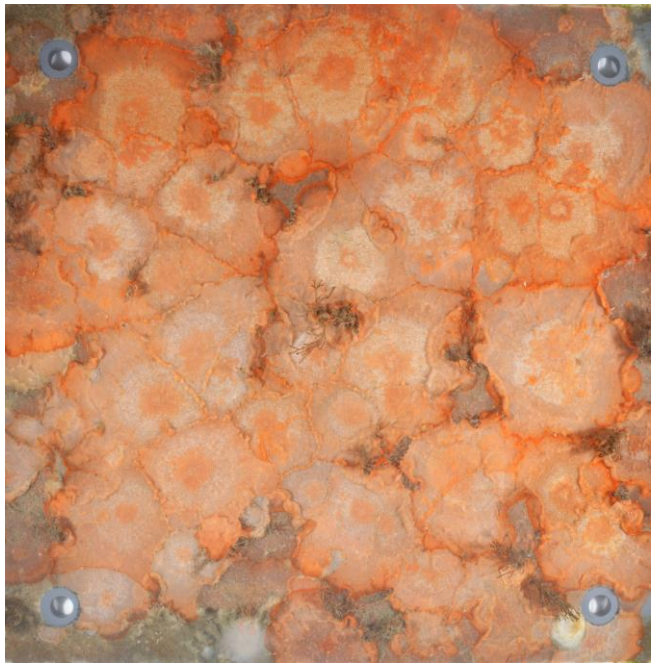
Oyster reefs (6-month deployment)

Leray & Knowlton, PNAS 2015



At what geographic scale are communities different?

Chesapeake Bay, Virginia (9 ARMS)



SHARED

4%

barcode

21%

meta

-barcode

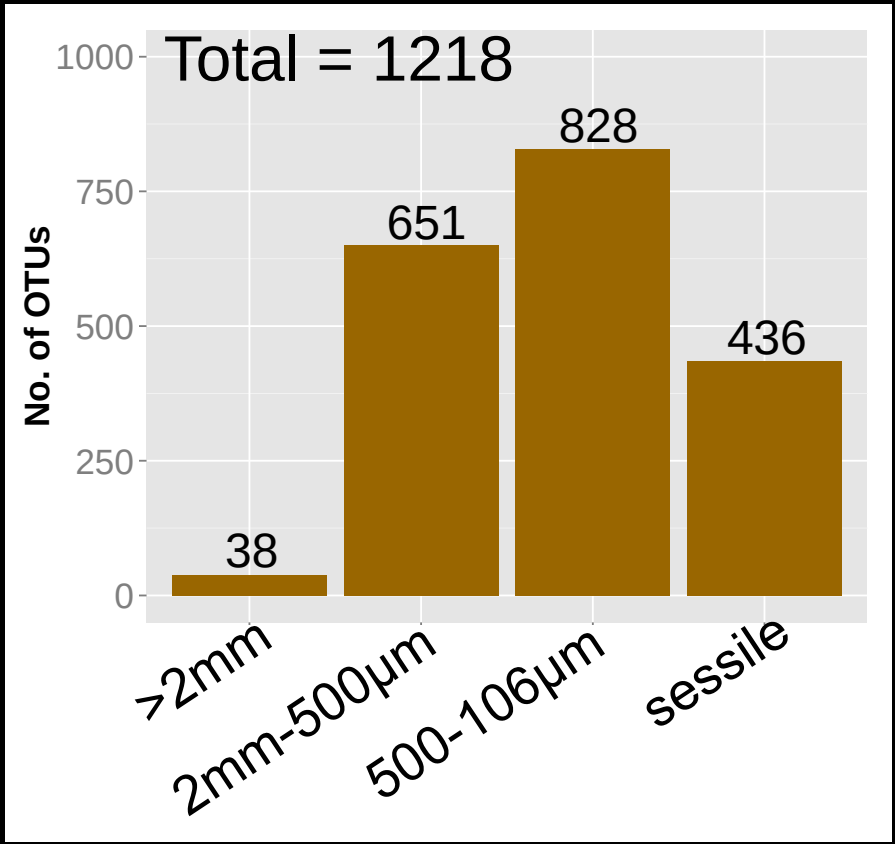
Ft. Pierce, Florida (9 ARMS)

#sequences:	572,290	409,613
% matched:	10.2	11.9
% unknown:	40.9	28.3
% singletons:	34.8	31.1

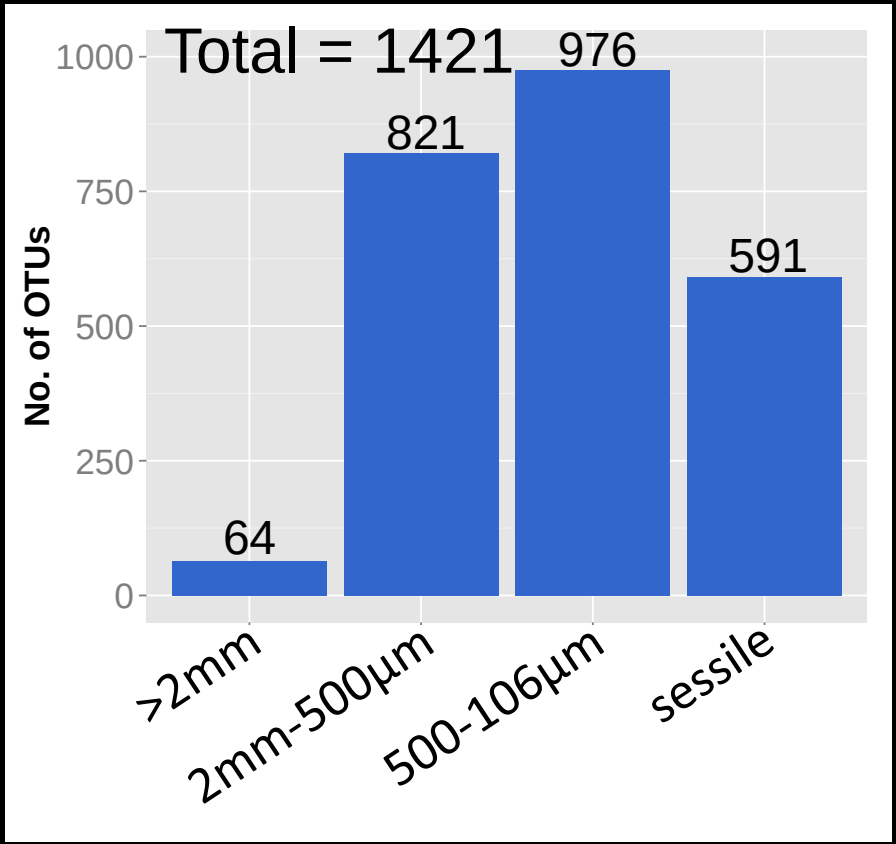
Leray & Knowlton, PNAS 2015

Diversity

Virginia



Florida

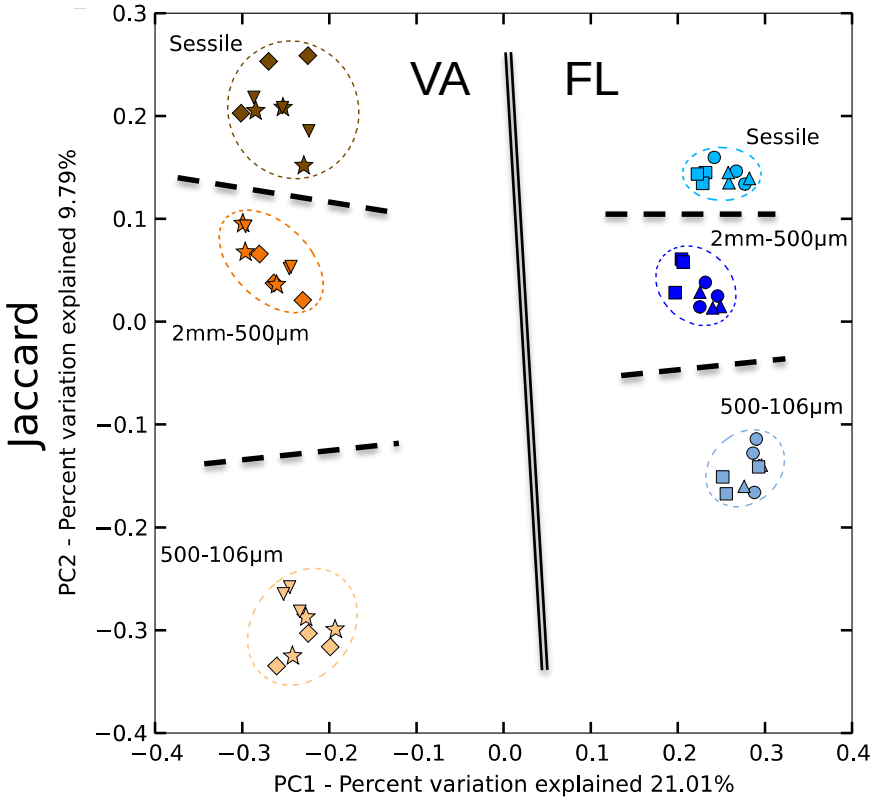


Sub-tropical Florida is more diverse

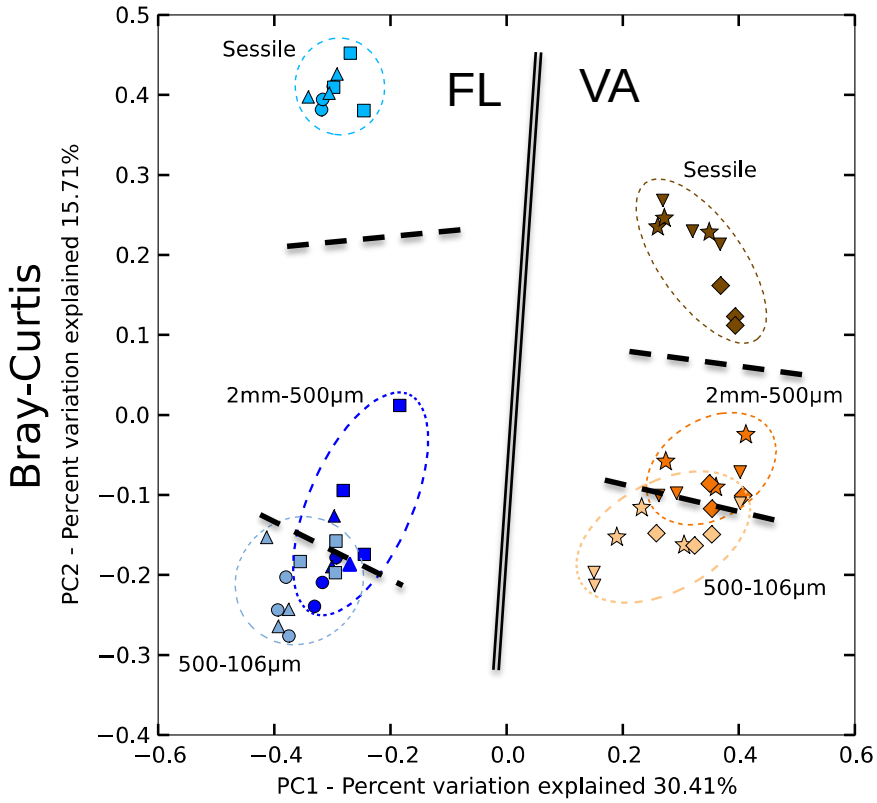
2/3 of diversity is < 500µm

Community similarity

Presence-absence



Relative abundance

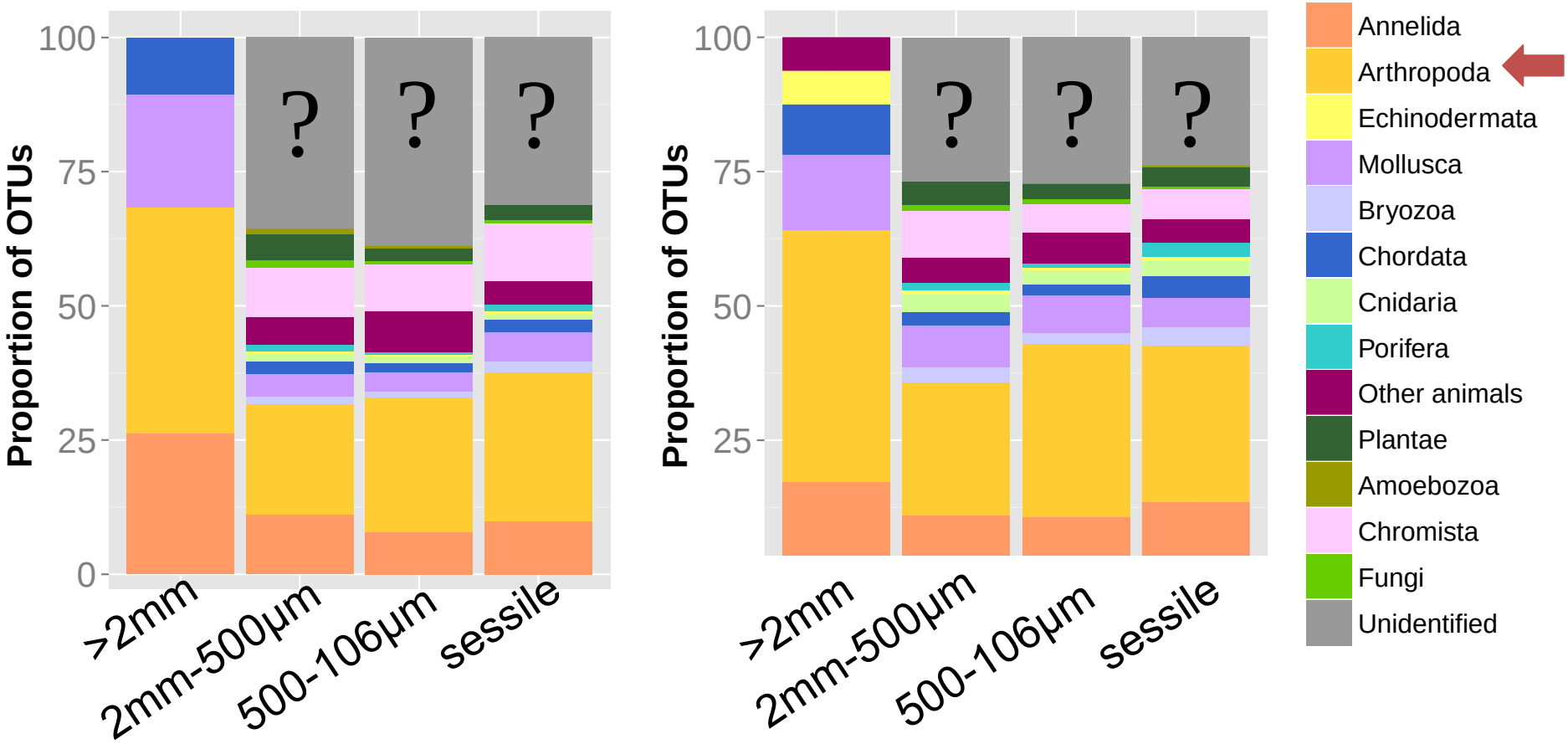


Different locations and metabarcoding communities are distinct

Taxonomic composition

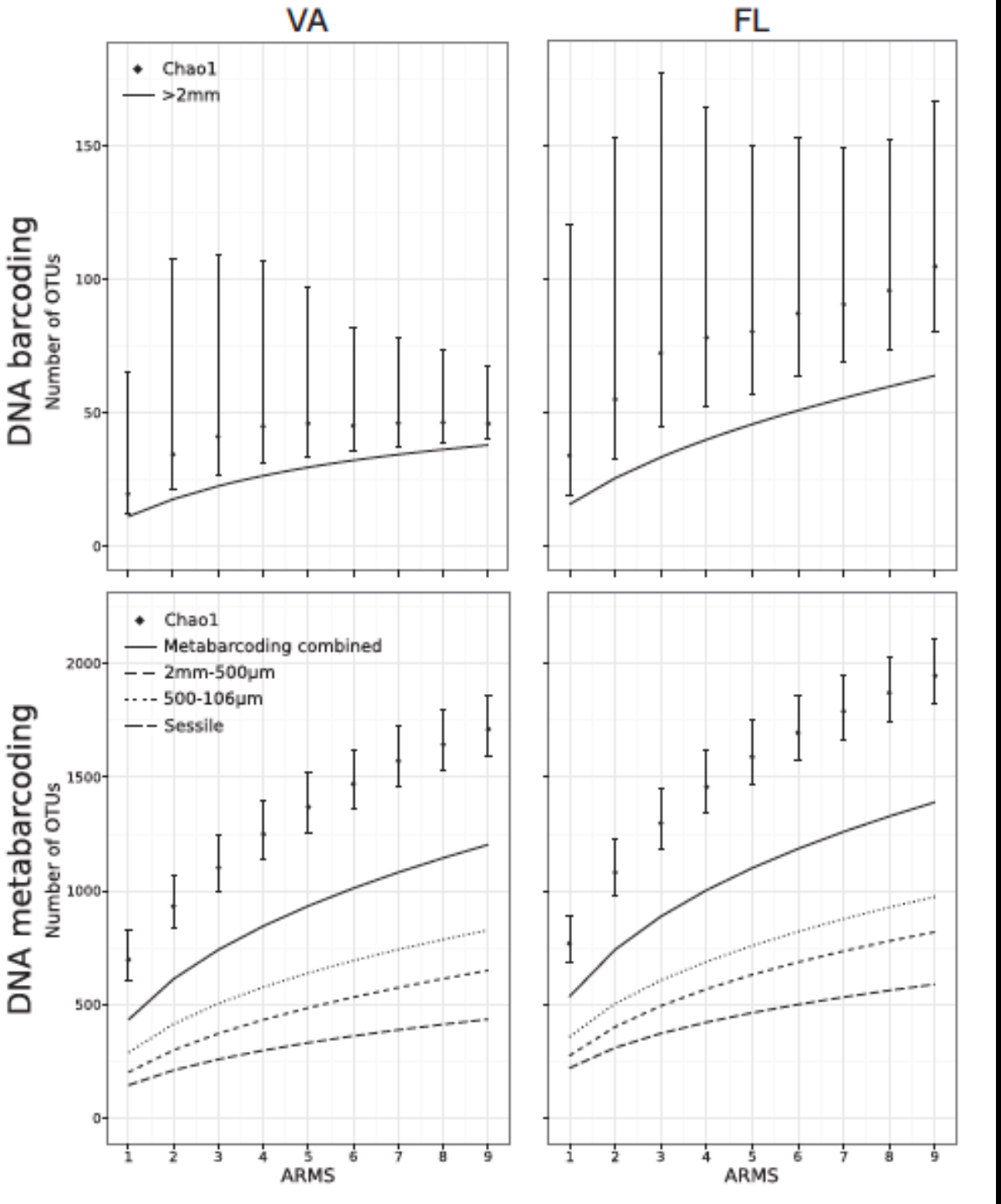
Virginia

Florida



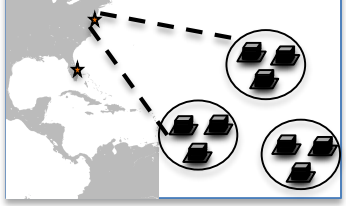
Leray & Knowlton, PNAS 2015

22 animal phyla - Arthropods most diverse



More Sampling Needed

(similar pattern for sampling effort measured by # sequences)



Jackknifed UPGMA tree based on relative abundance

Site 1
Site 2
Site 3
Virginia

Site 1
Site 2
Site 3
Florida

75-100%
50-75%
25-50%
0-25%

VA

FL

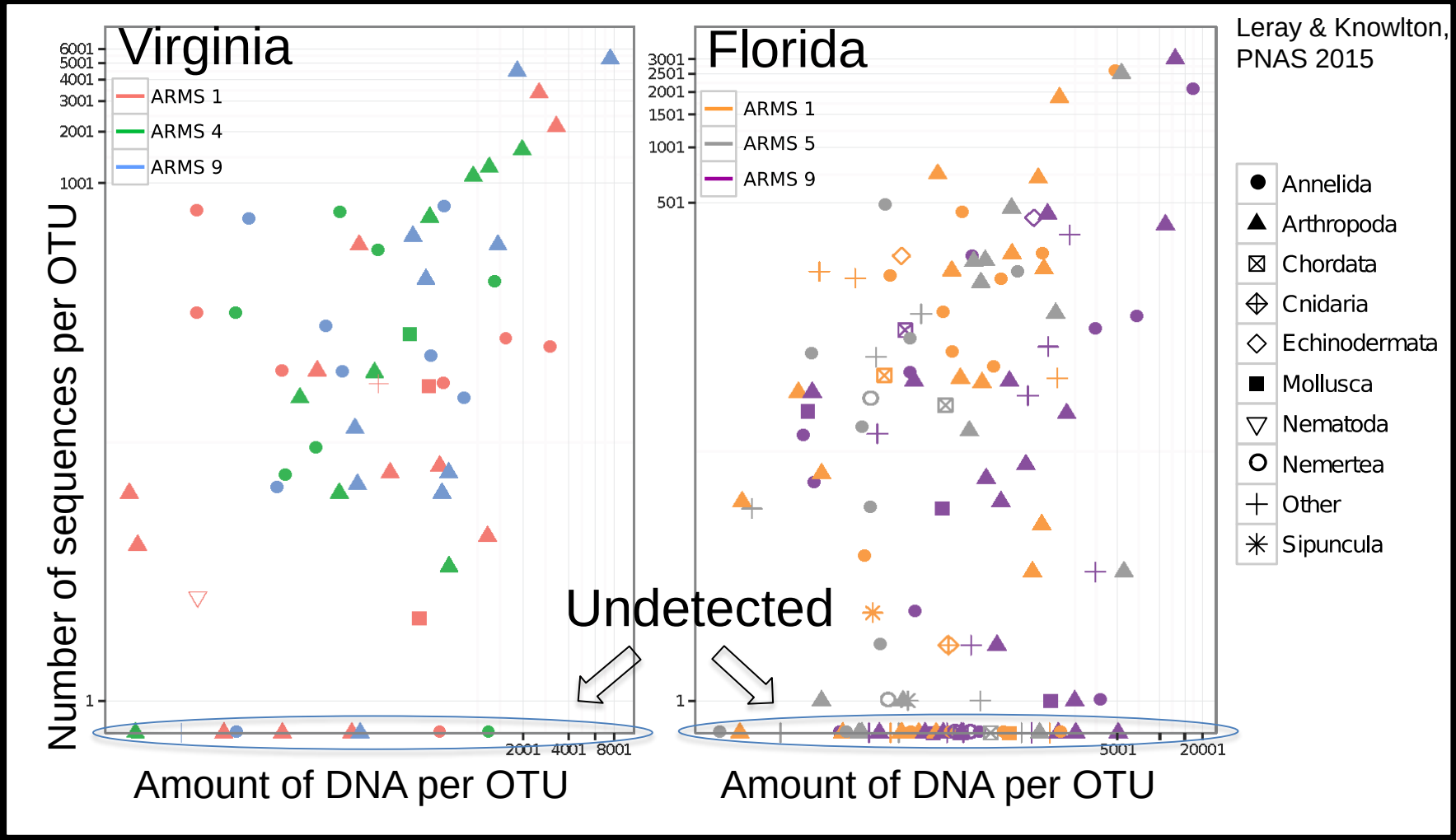
0.1

Fine-scale geographic structuring

Adjacent samples cluster together at the meter scale

Leray & Knowlton, PNAS 2015

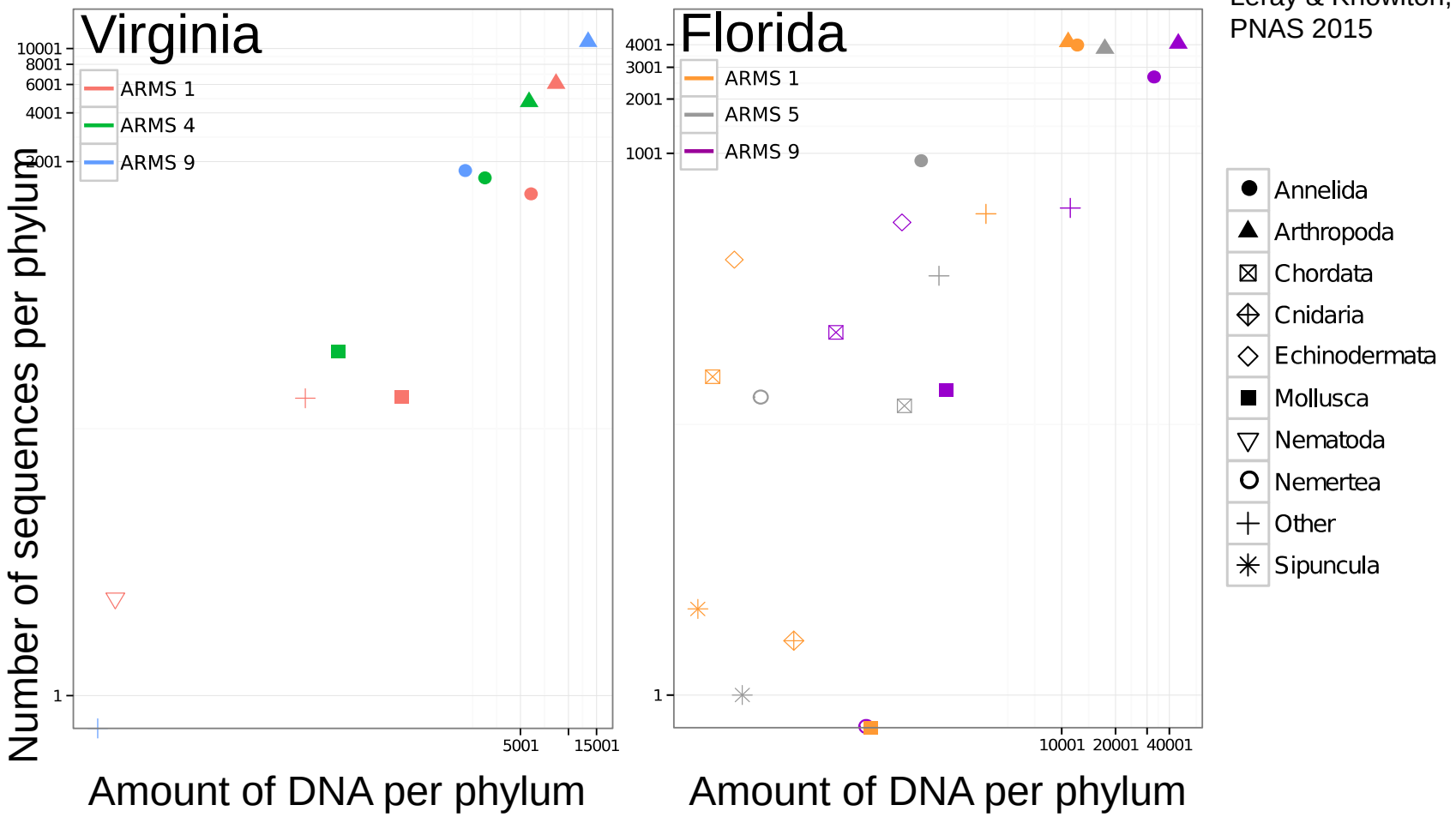
Abundance information as well as presence-absence



65.3% to 91.7% of OTUs successfully recovered per sample

Linear relationship between number of reads and amount of DNA

Even stronger relationship for functional groups



Similar results for sessile community calibrated by % cover

Not Just an Abstract Exercise
Marine Biodiversity in the Anthropocene

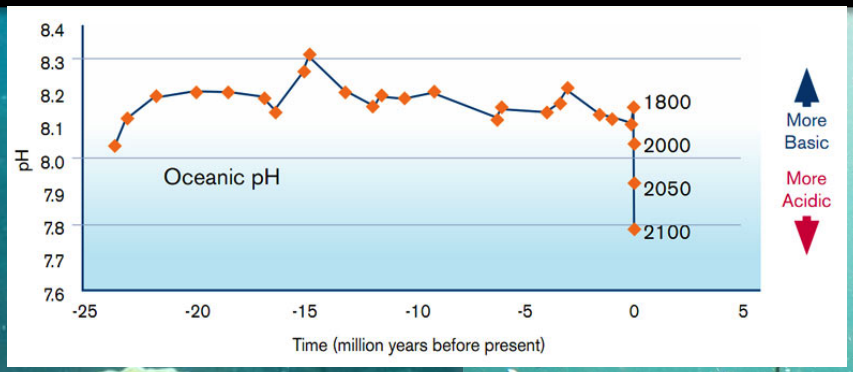
Marine defaunation: Animal loss in the global ocean

Douglas J. McCauley[1,*], Malin L. Pinsky[2], Stephen R. Palumbi[3], James A. Estes[4], Francis H. Joyce[1], Robert R. Warner[1]

Science 16 January 2015: Vol. 347 no. 6219

Example: Effects of Ocean Acidification

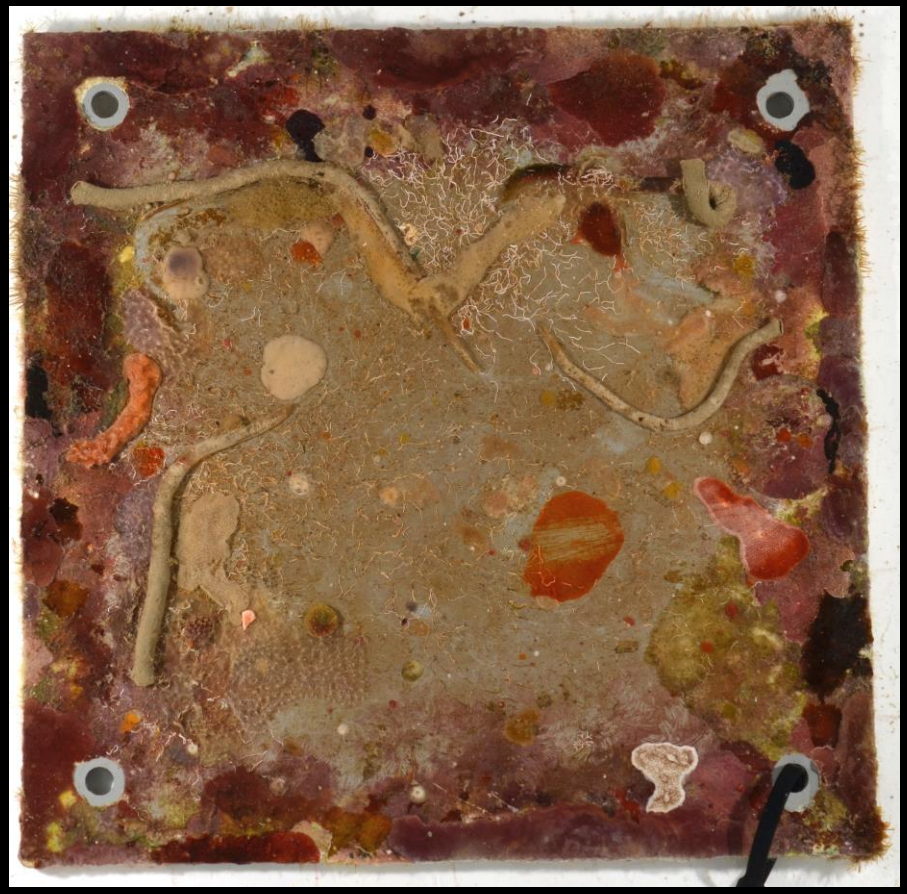
Biodiversity sampling from PNG CO_2 seeps



Photos: Laetitia Plaisance

Example: Effects of Ocean Acidification

Normal (pH 8.0)

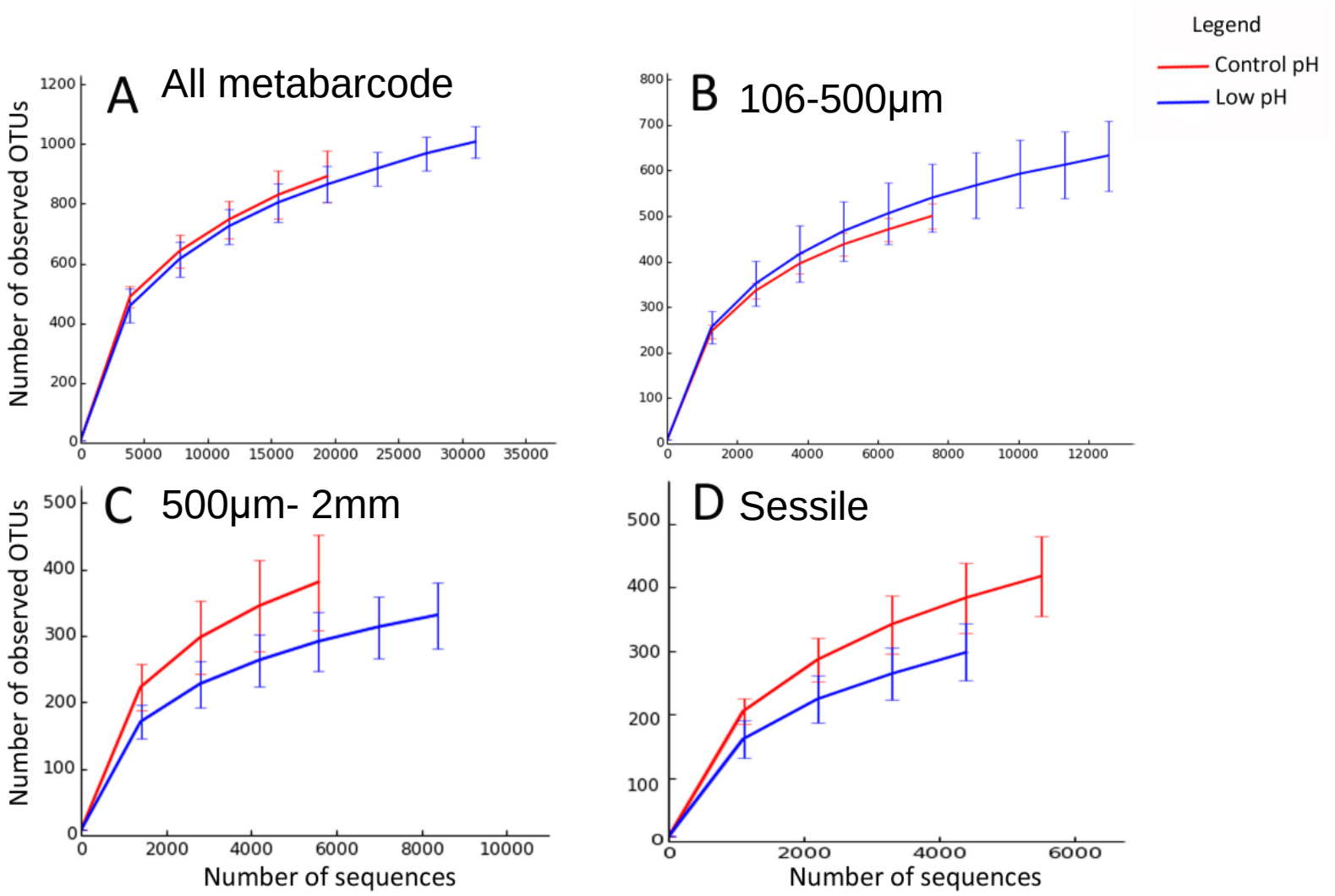


284 individuals >2mm
82 OTUs

Low (pH 7.7)

114 individuals >2mm
43 OTUs

Smallest Fraction Less Sensitive to Acidification?



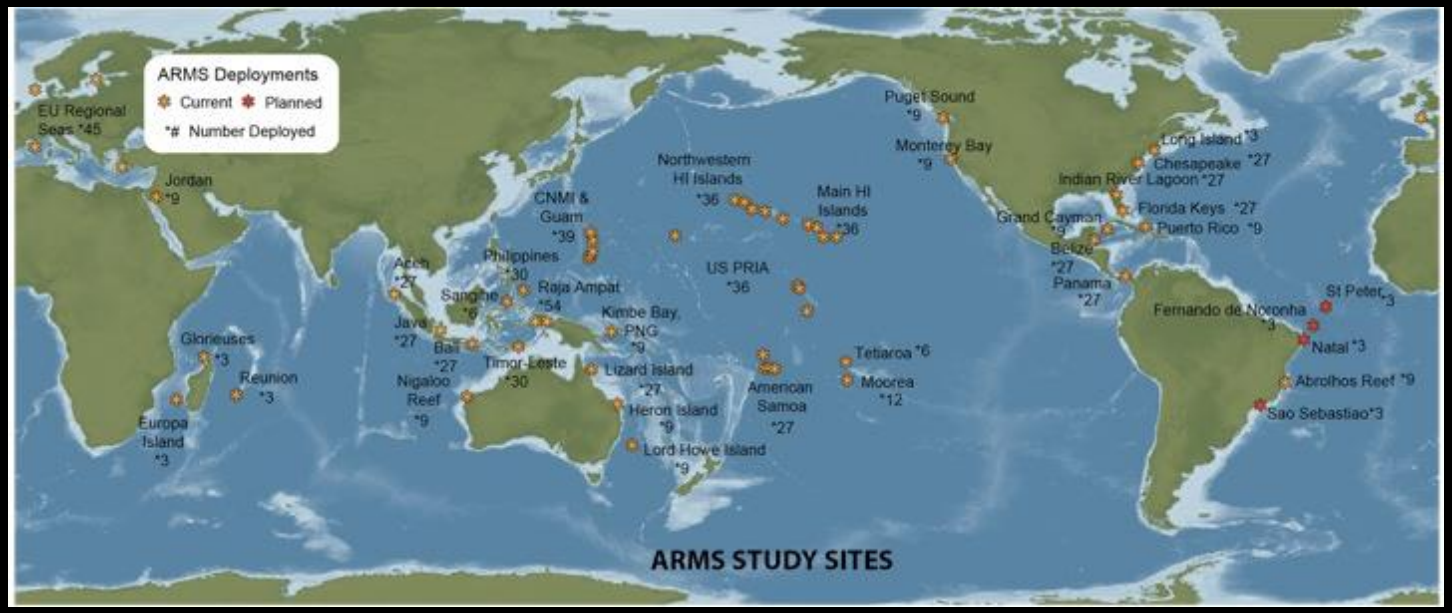
Plaisance, unpubl.

Looking Forward

Multi-gene PCR-based to increase taxonomic coverage

Shotgun metagenomics approach to
- avoid PCR bias
- capture metabolic genes and look at local adaptation

Global deployments and analyses: MarineGEO/PBM?



What are some big questions/challenges?

What are the really dark taxa?
(need branches, not twigs)

How does biodiversity scale geographically
by taxonomic group?
by body size?
as a function of location?

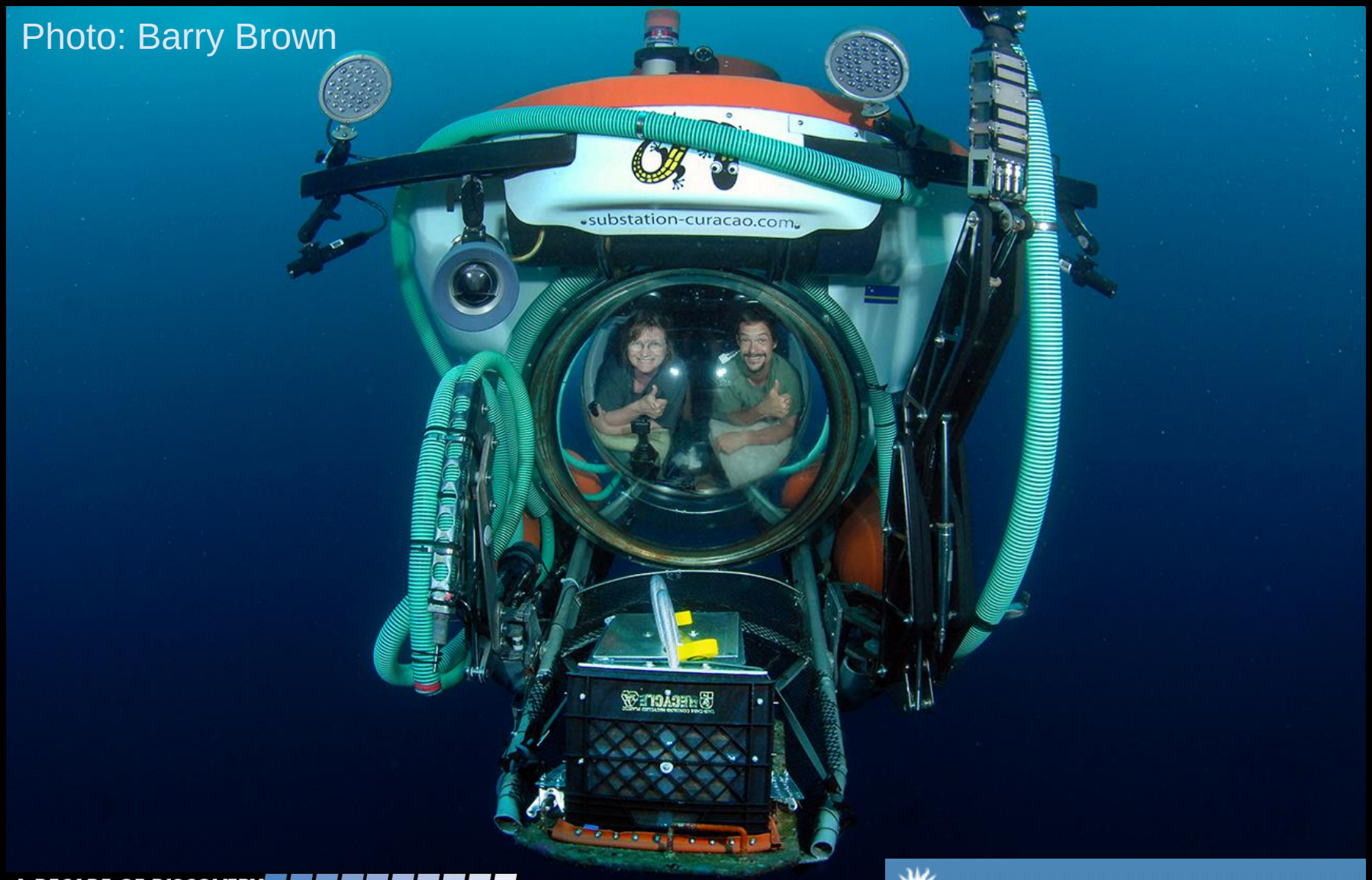
What is the nature of rarity?

Are there biodiversity collapse thresholds?

How is biodiversity changing?
(need community vouchers)

What lives in the sea (or even a bay)?

Thanks – Questions?



A DECADE OF DISCOVERY
CENSUS OF MARINE LIFE 2010

Smithsonian
National Museum of Natural History

Bioinformatics pipeline