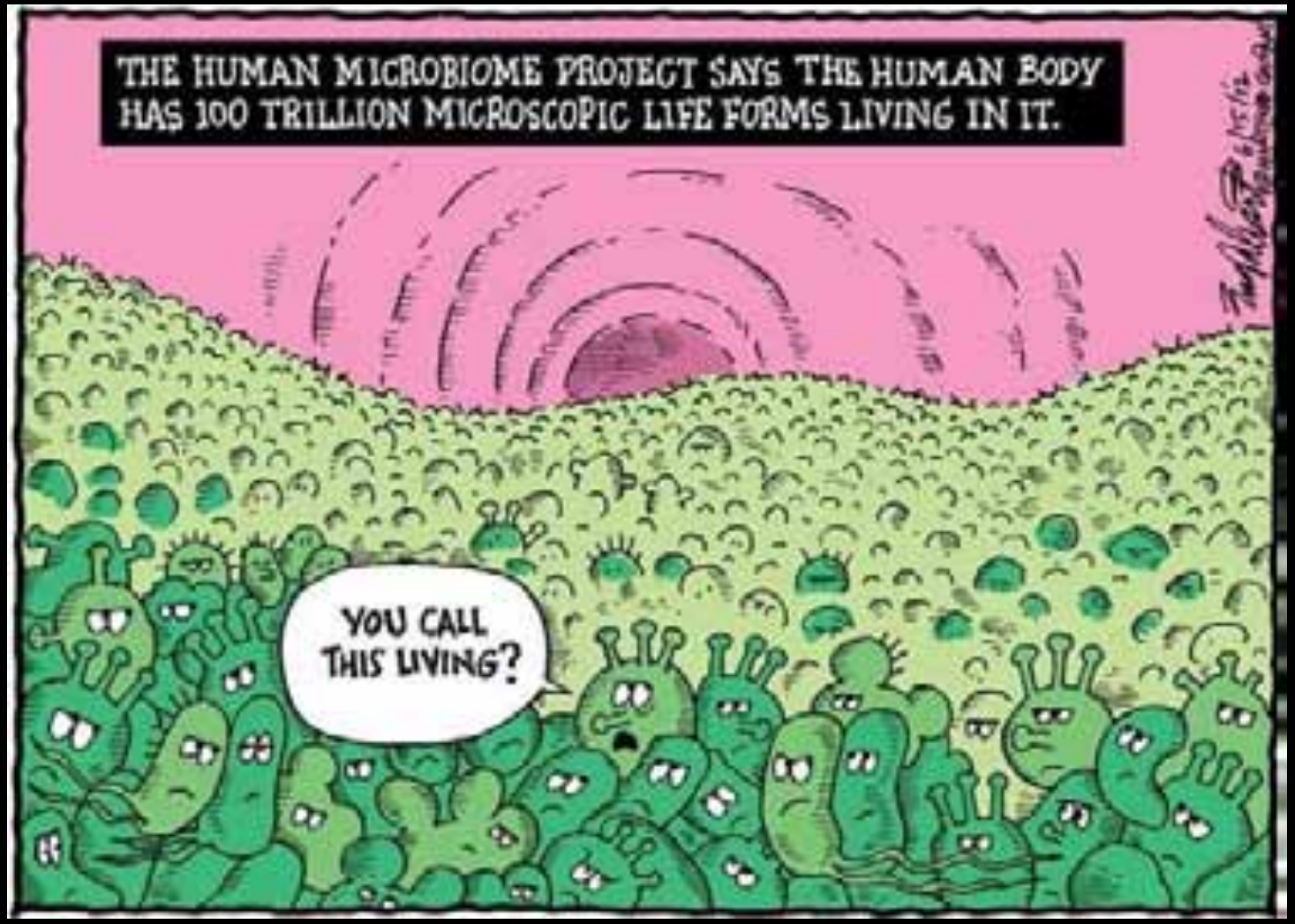
Honors Enrichment Seminar: Survey of Biological Research
HON 120 Guest Lecture • November 18, 2013

Friends, Foes and Freeloaders: Microbial Symbionts in Marine Invertebrates

PATRICK M. ERWIN

Introduction

Your Symbionts…



Introduction

Your Symbionts…

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Introduction

Symbiosis

Mutualism Commensalism Parasitism

"The living together of unlike organisms."

Anton de Bary

Introduction

Symbiosis

Mutualism Commensalism Parasitism

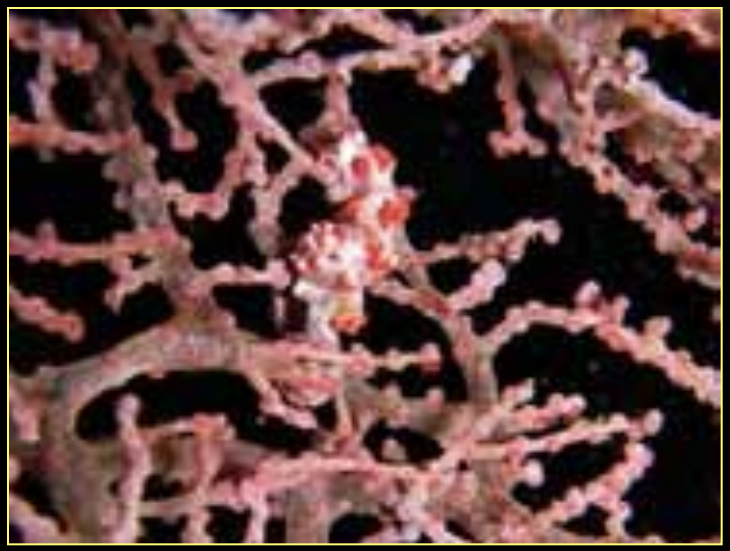
+/+

Introduction

Symbiosis

Mutualism Commensalism Parasitism

+/o



Introduction

Symbiosis

Mutualism Commensalism Parasitism

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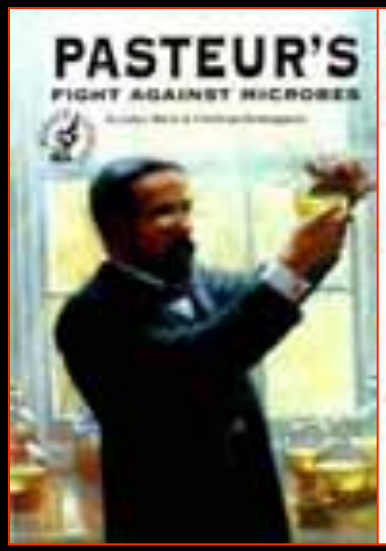


Introduction

Beneficial Microbes

Bobtail Squid

↓

Bioluminescence

Camouflage

Stony Corals

↓

Photosynthesis

Nutrition

Marine Sponges

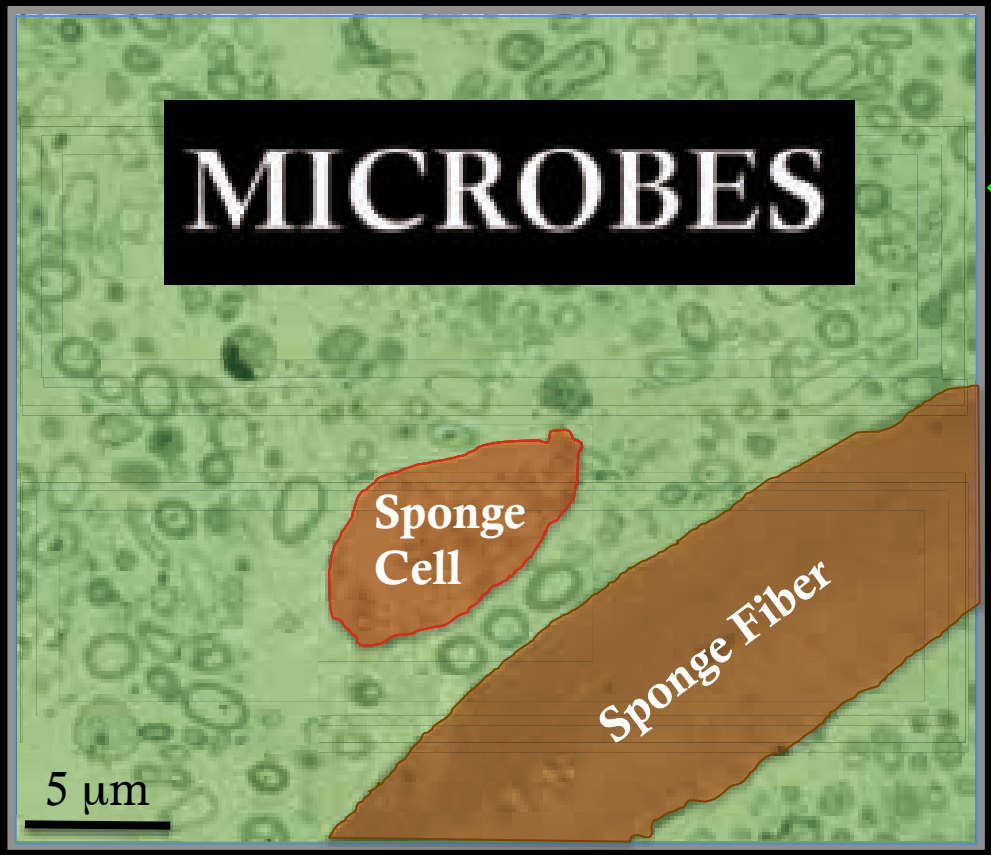
↓

Physiology

Function

Introduction

Beneficial Microbes?



Marine Sponges

Physiology

Function

TAYLOR ET AL. 2007

Introduction

Marine Sponges

Fermentation of the sea's scum… certaine matter wrought together, of the fome and froth of the sea, which we call spunges [sic]

GERARDE 1597 – *THE HERBALL OR GENERALL HISTORIE OF PLANTES*

Introduction

Marine Sponges

Ancient Animals

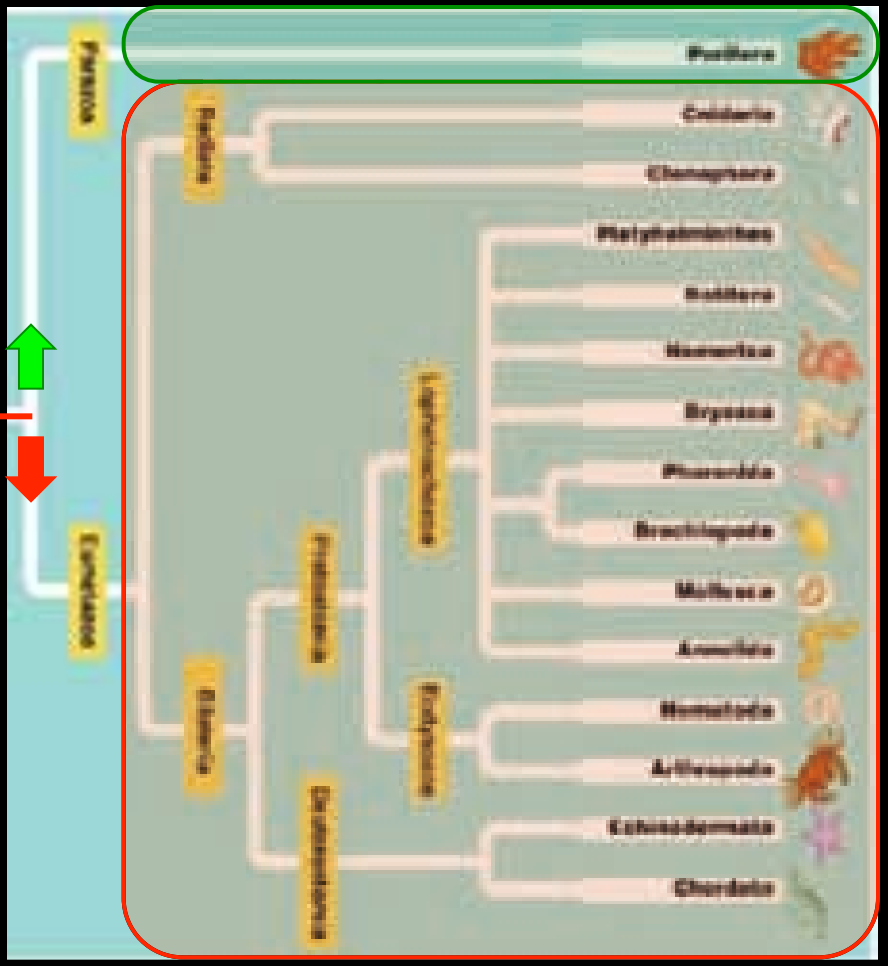
- Evolution

Filter-Feeders

- Ecology

Chemical Factories

- Biotechnology



Introduction

Marine Sponges

Ancient Animals

- Evolution

Filter-Feeders

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Chemical Factories

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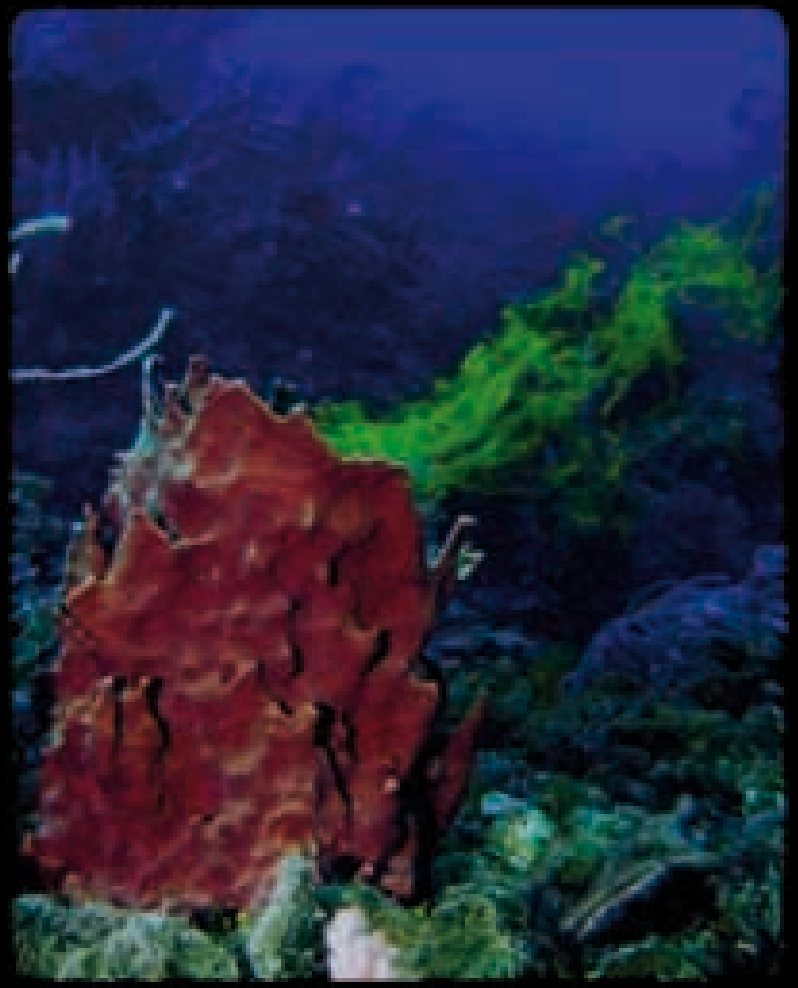


Introduction

Marine Sponges

Ancient Animals

- Evolution

Filter-Feeders

- Ecology

Chemical Factories

- Biotechnology

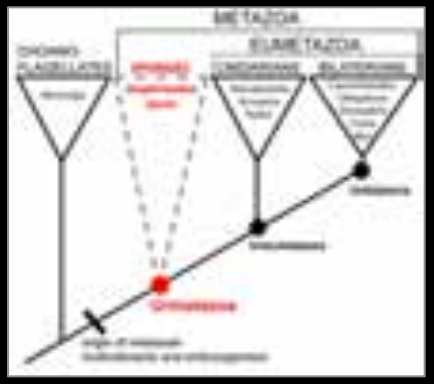
Novel Compounds:
6,605

Anti-Cancer Drugs:
$40 – 200 billion

Erwin et al. 2010 □ *Ecol Econ*

Introduction

Converging on Microbes



Evolution

Physiology

Chemistry

Bacteria-Induced Multicellularity

Photosynthesis Nitrification

Symbiont-Derived Drugs

Introduction

Ecology

Part I: Cyanobacteria

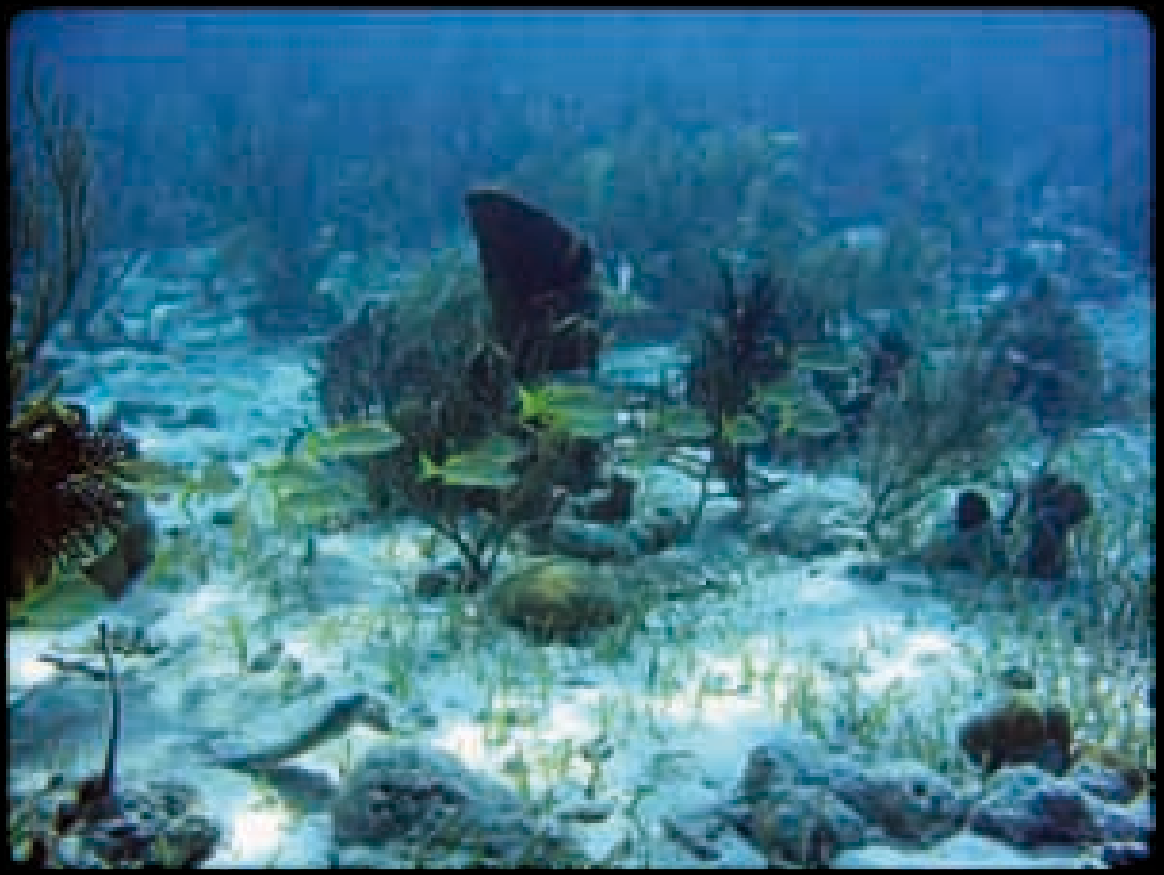
Coral Reef Sponges

Part II: Bacteria

Temperate Sponges

Part III: Future Research

Ongoing Projects



Caribbean Sea

Photosymbionts in Reef Sponges

Part I:

Republic of Panama


Smithsonian Research Station
Isla de los Pajaros
Boca del Drago
ISLA COLON
Playa Drago
Punta Donato
Canal de Bocas del Toro
Punta Toro
Isla Carenero
Bastimentos
Bocas Town
Punta Hospital
ISLA SOLARTE
Bahia Almirante
ISLA BASTIMENTOS
ALMIRANTE
Punta Pond Sock
Punta Coco
Punta Vieja
Cayos Zapatilla
ISLA SAN CRISTOBAL
Punta Galllinazo
Cayo Crawl
ISLA PASTORES
Laguna Bocoatorito
Punta de Pargo
Tierra Oscura
Punta Norte
ISLA POPA
Punta de Nispero
ISLA CAYO AGUA
Punta Limon
ISLA LOMA PARTIDA
Punta Corocital
Punta Laurel

Part I:

Coral Reef Ecosystems

Demanding Environment

- Space-Limited, Oligotrophic

Photosymbionts

- Supplemental Nutrition

Part I:

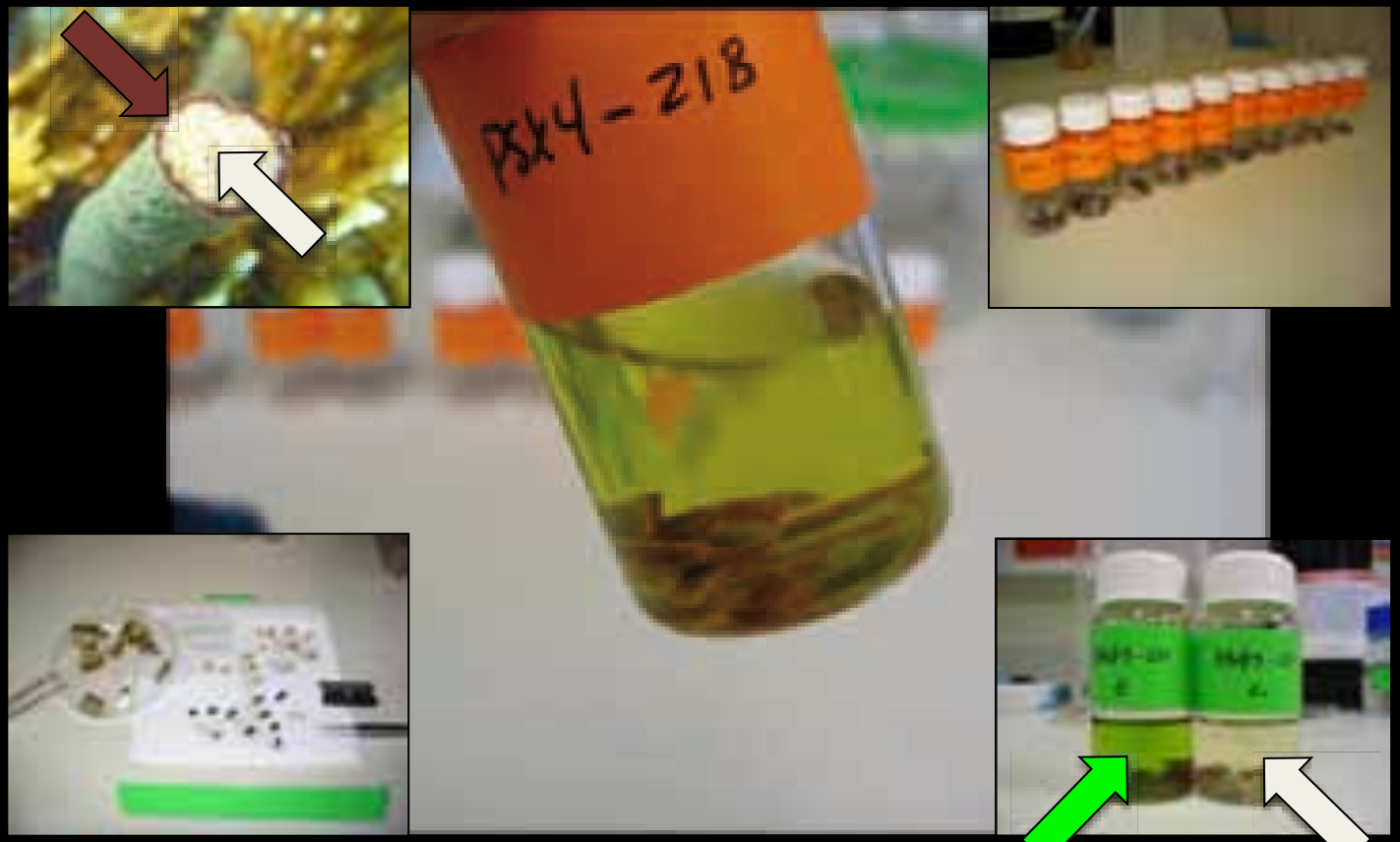
Sponge Photosymbionts

Incidence	Importance	Identity
		
Transects Chlorophyll	Shading Experiments	PCR Screening

Part I:

Incidence

Chlorophyll *a* Quantification

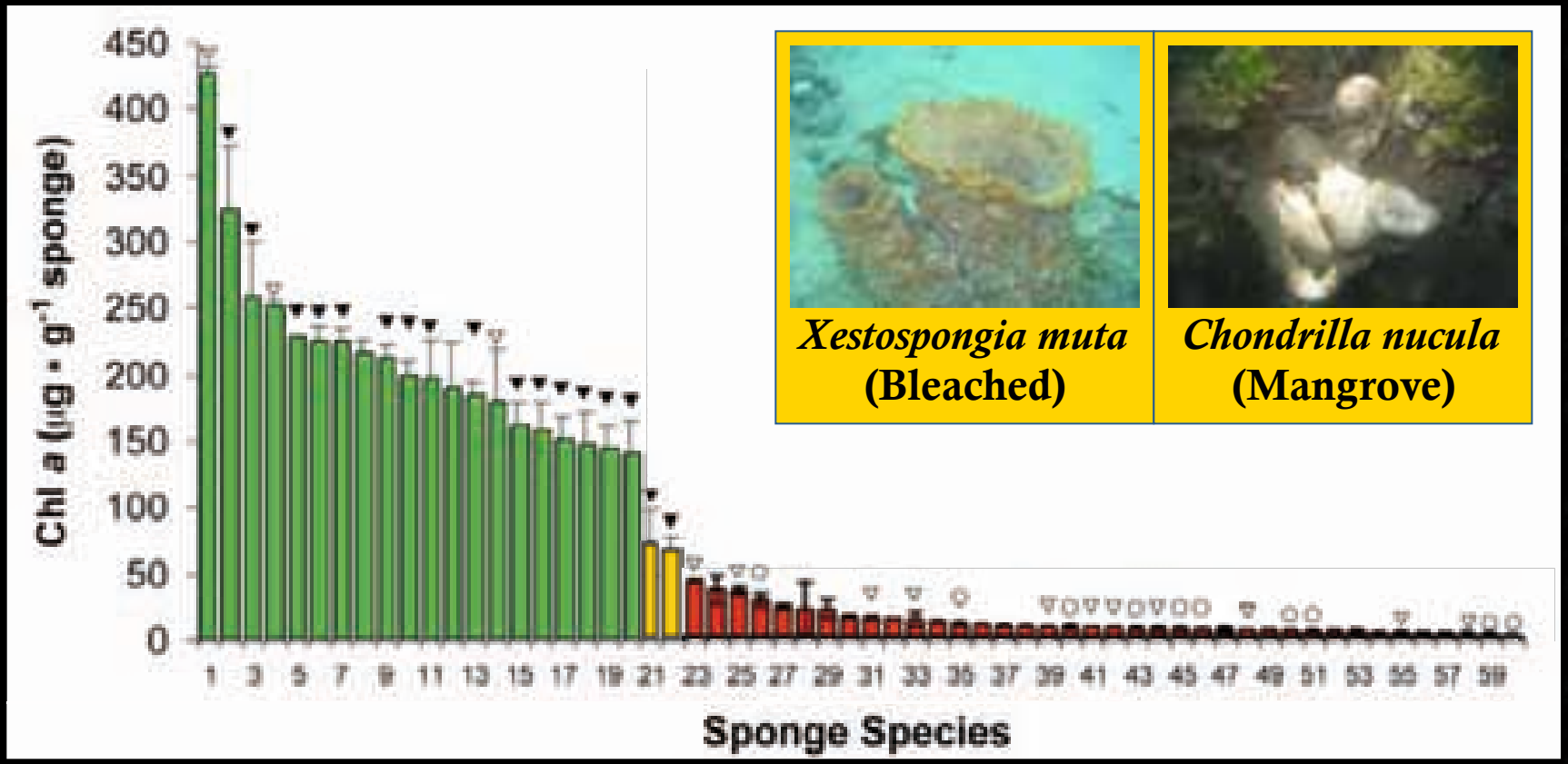


ERWIN & THACKER 2007 *J MAR BIOL ASSOC UK*

Part I:

Incidence

Photosymbionts = 22 spp. No symbionts = 38 spp.

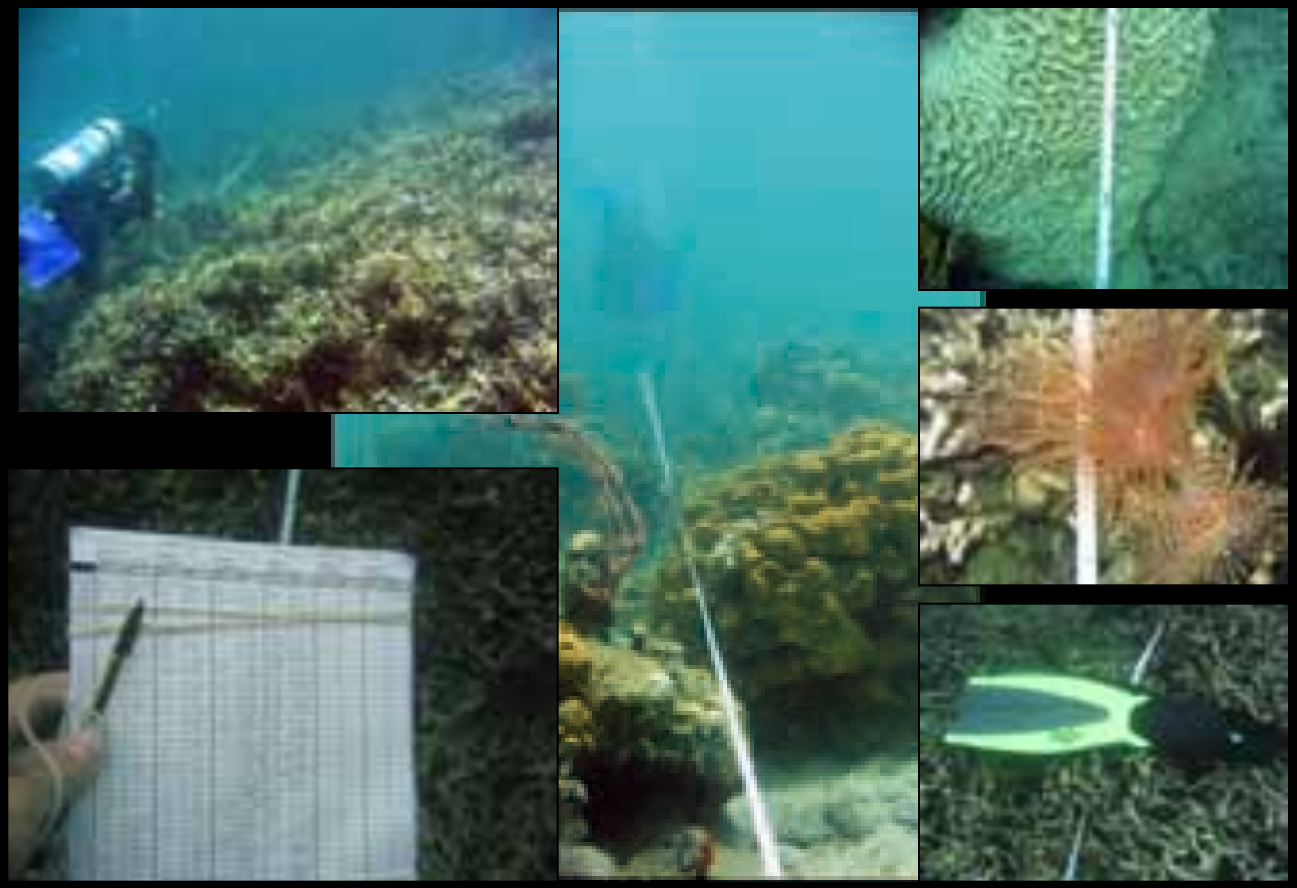


ERWIN & THACKER 2007 ❑ *MAR BIOL ASSOC UK*

Part I:

Abundance

Line-Intercept Transects

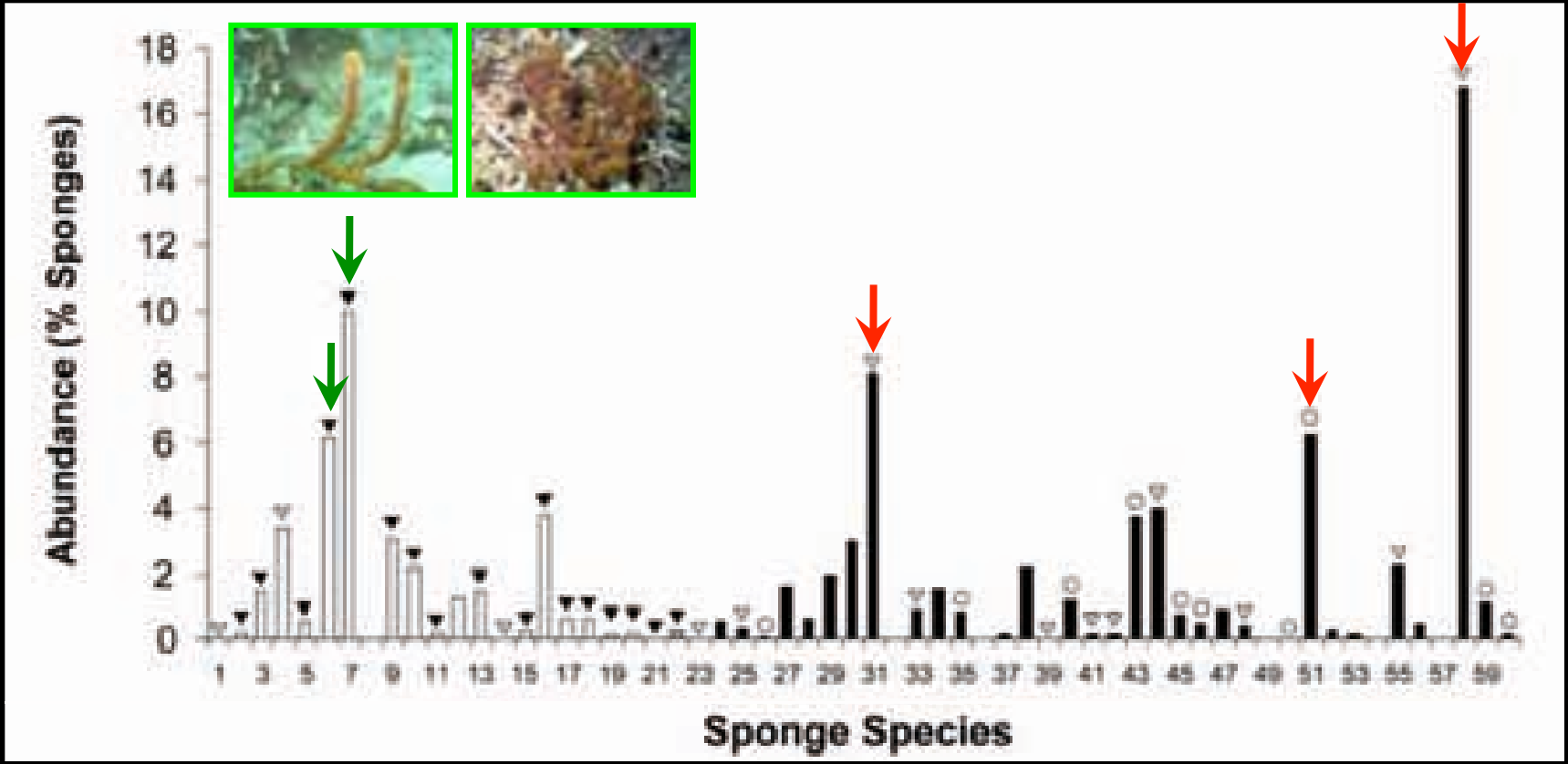


ERWIN & THACKER 2007 ❑ *MAR BIOL ASSOC UK*

Part I:

Abundance

Photosymbionts = 37% No symbionts = 63%



ERWIN & THACKER 2007 ❑ *MAR BIOL ASSOC UK*

Part I:

Importance

Shading Experiment

Aplysina fulva

Host cyanobacterial symbionts

Rope-like or digitate growth form

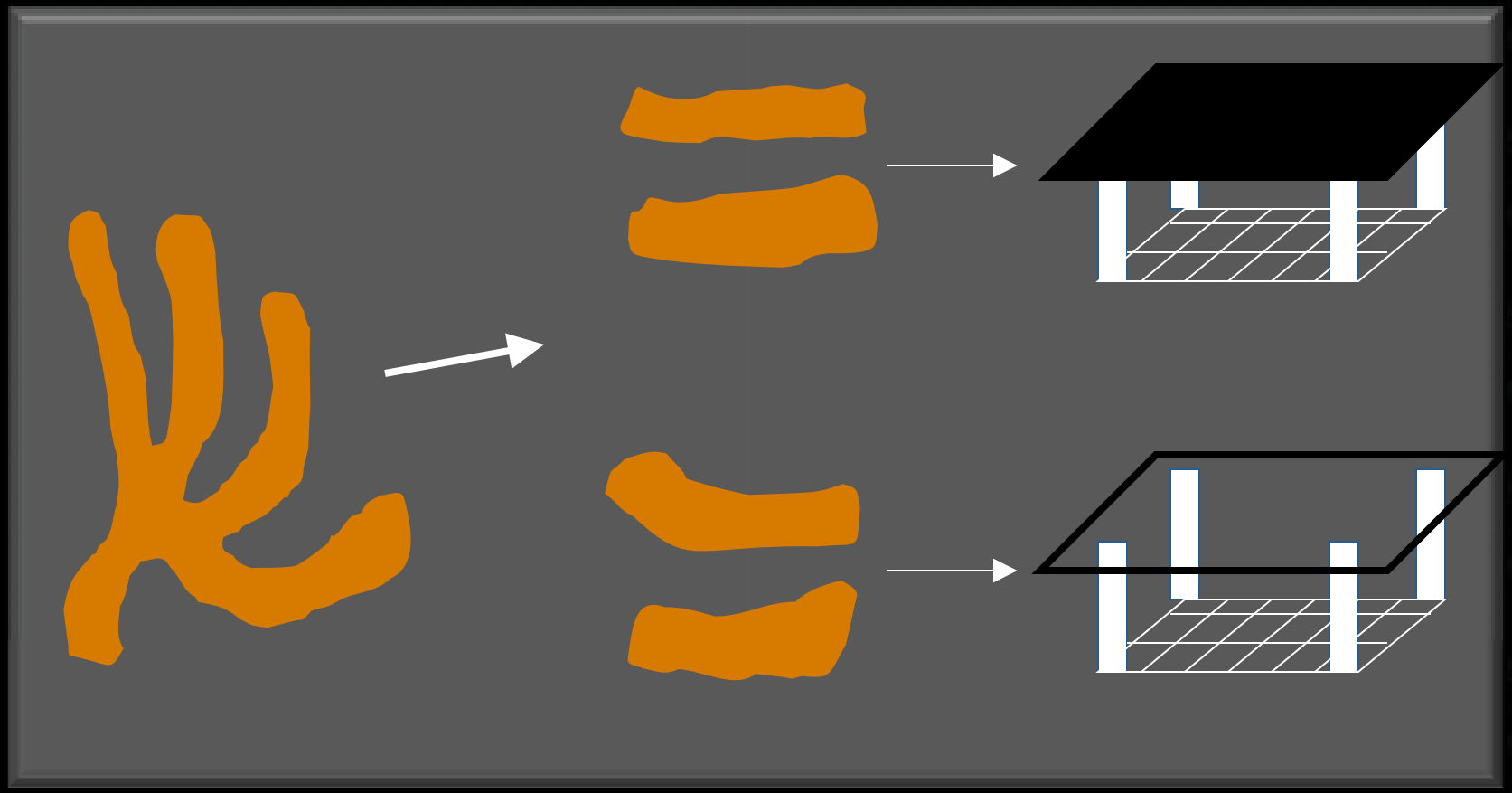
Very common on shallow water reefs

Neopetrosia subtriangularis

Part I:

Importance

Shading Experiment



Part I:

Importance

Shading Experiment

40 Total Sponge Canopies
(10 paired reps per species)

Part I:

Importance

Shading Experiment

Weekly Monitoring

Part I:

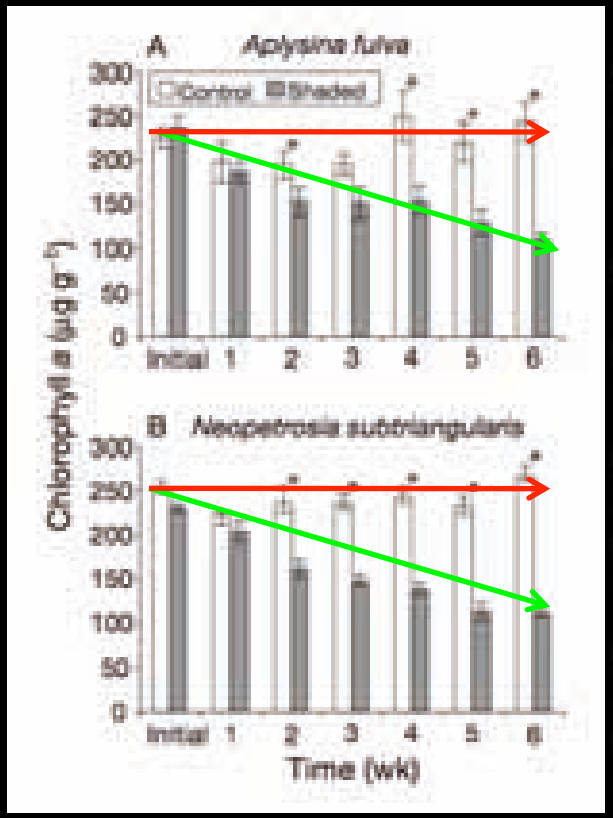
Symbiont Response

Significant reduction (2 wks.)
>50% reduction (6 wks.)

A. fulva

Significant reduction (2 wks.)
>50% reduction (6 wks.)

N. subtriangularis



ERWIN & THACKER 2008A *MAR ECOL PROG SER*

Part I:

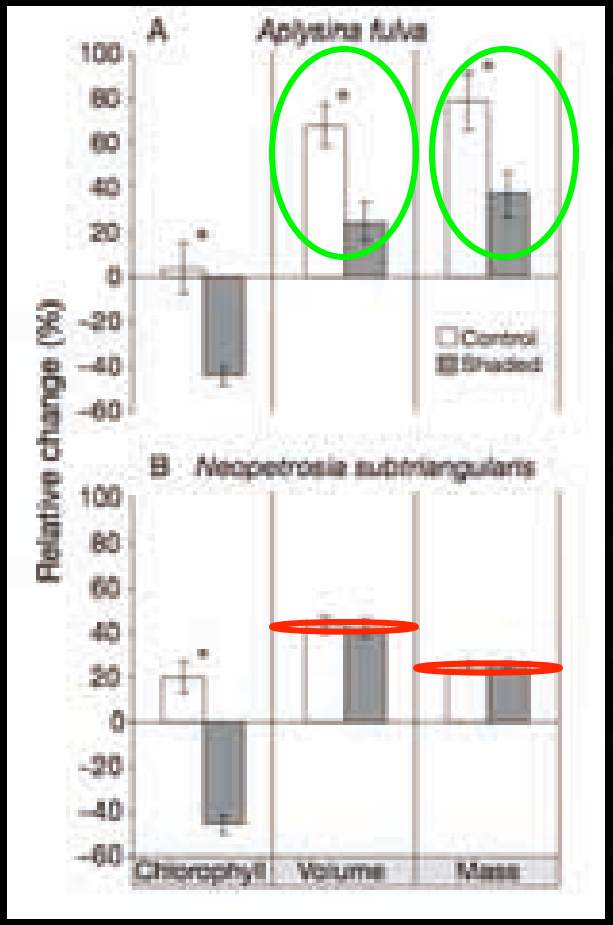
Host Response

Shaded vs. Control
>50% growth reduction

A. fulva

Shaded vs. Control
No difference in growth

N. subtriangularis



ERWIN & THACKER 2008A *MAR ECOL PROG SER*

Part I:

Host Response

Shaded vs. Control
>50% growth reduction

A. fulva

Shaded vs. Control
No difference in growth

N. subtriangularis

ERWIN & THACKER 2008A *MAR ECOL PROG SER*

Part I:

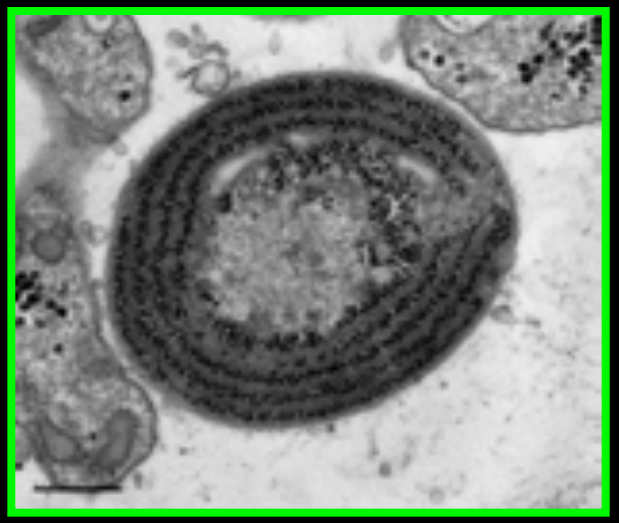
Identity

→ *Synechococcus spongiarum*

A. fulva

→ *Synechococcus spongiarum*

N. subtriangularis

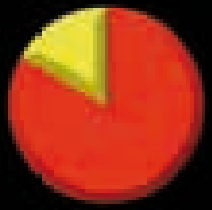


- In 85% of sponges with photosymbionts

ERWIN & THACKER 2008A TAYLOR ET AL. 2007

Part I:

Identity



Clade A

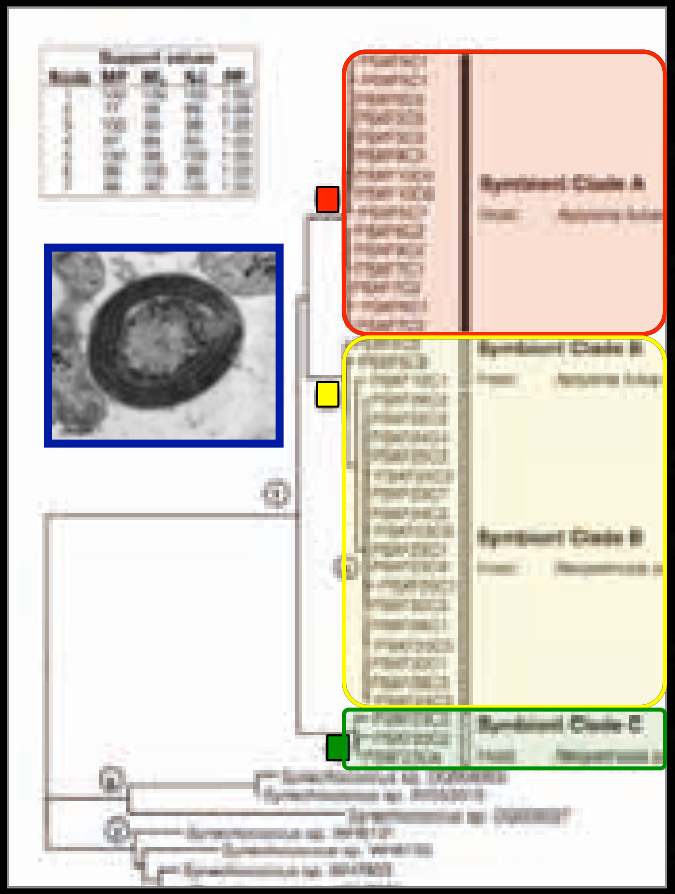
Clade B

A. fulva

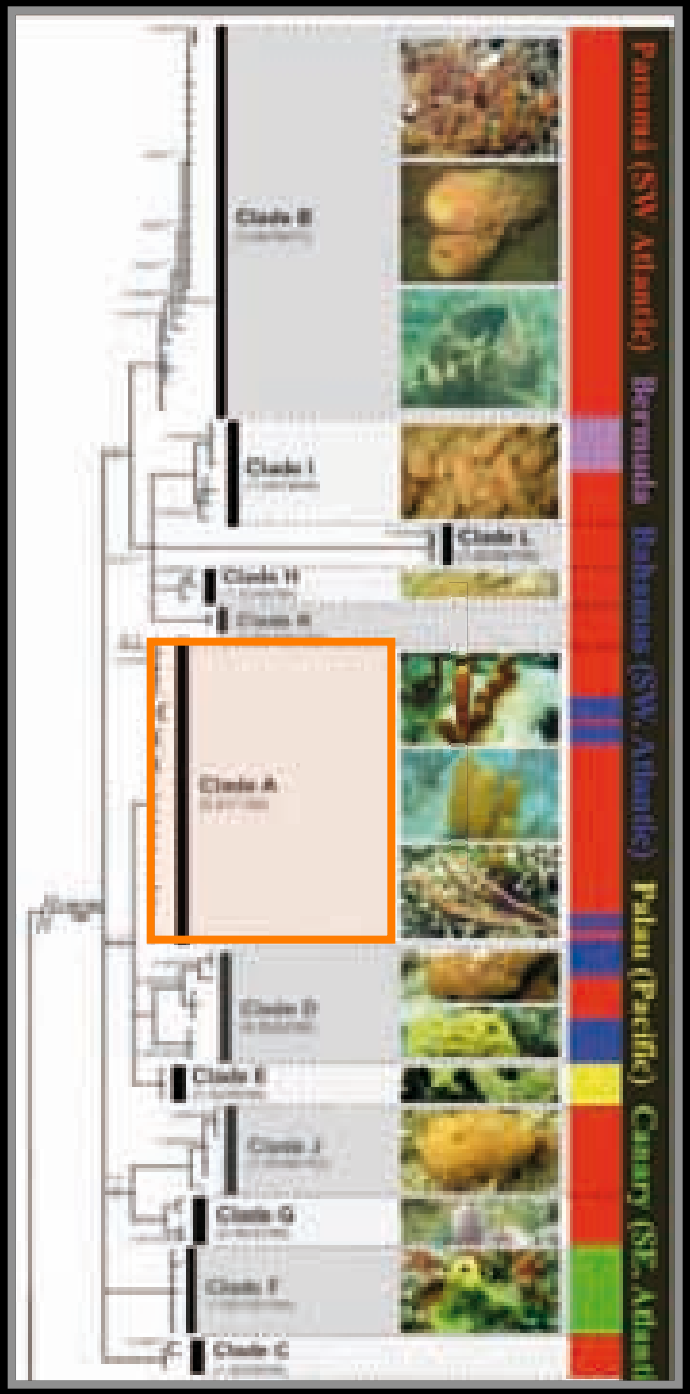
Clade B

Clade C

N. subtriangularis



ERWIN & THACKER 2008A *MAR ECOL PROG SER*



Symbiont Clade A

Specificity

Aplysina (Verongida)

Geography

Panama + Bahamas

A. cauliformis

A. lacunosa

A. fulva

A. fistularis

ERWIN & THACKER 2008B *MOL ECOL*

Part I:

Photosymbionts

Incidence

- 37% host photo-symbionts

Importance

- Enhance host growth (*A. fulva*)

Identity

- 85% host *S. spongiarum* (12 clades)

Mediterranean Sea

Symbiont Specificity and Stability

Part II:

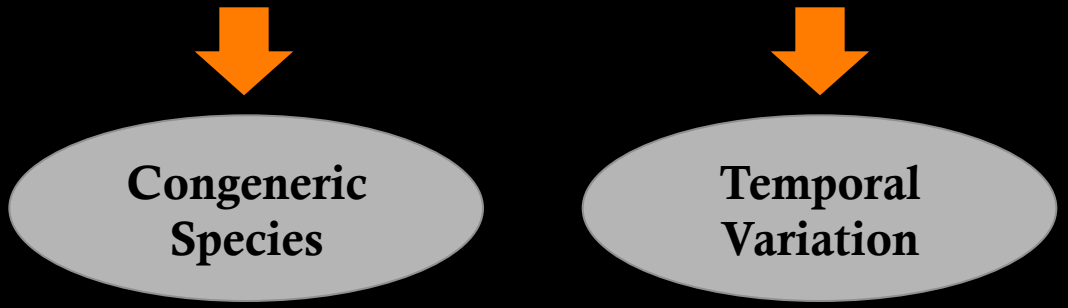
Bacterial Communities

Specificity

- Species-Specific vs. Uniform

Structuring Factors

- Host-Related vs. Environmental



Part II:

Target Species

Genus
Ircinia

I. fasciculata

I. variabilis

I. oros

Supplemental:

Distinct Habitats

- *Ircinia fasciculata*

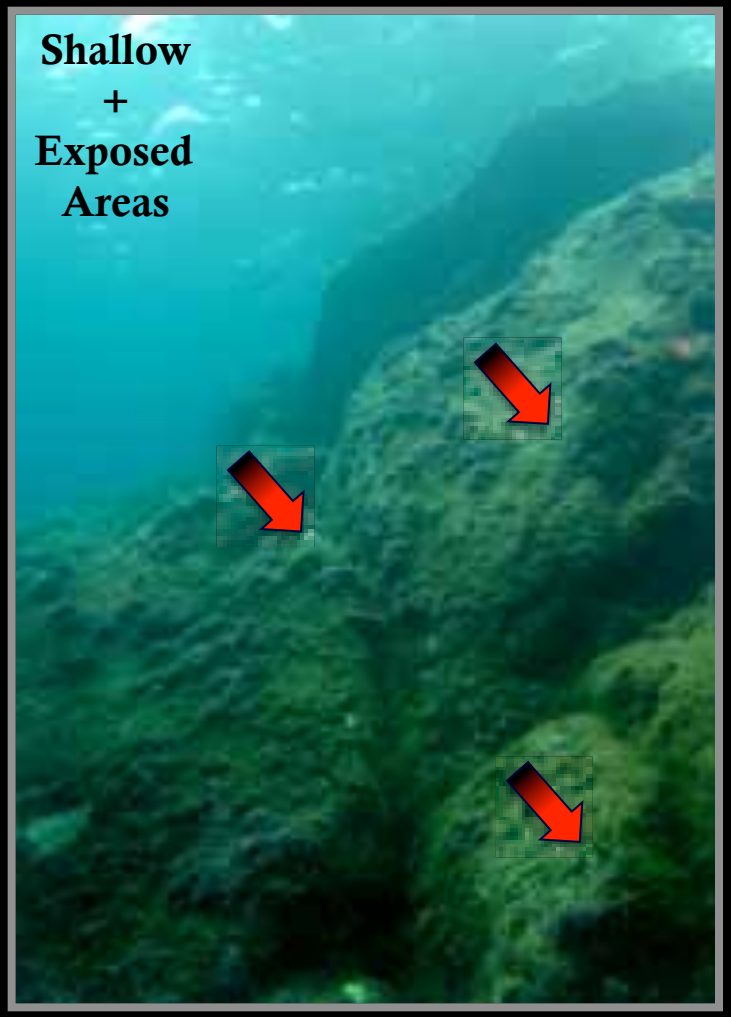
- *Ircinia variabilis*

- *Ircinia oros*

Supplemental:

Distinct Habitats

- *Ircinia fasciculata*
  - high irradiance, algae
  - photosymbionts



Supplemental:

Distinct Habitats

- *Ircinia variabilis*
  - low irradiance, inverts
  - photosymbionts

Supplemental:

Distinct Habitats

- *Ircinia oros*
  - low irradiance, inverts
  - no photosymbionts

Part II:

Host-Related Factors

Specificity

Clone Libraries

Congeneric Hosts

- Triplicate Sponge Samples
- 16S rRNA Clone Libraries
- Statistical Analyses

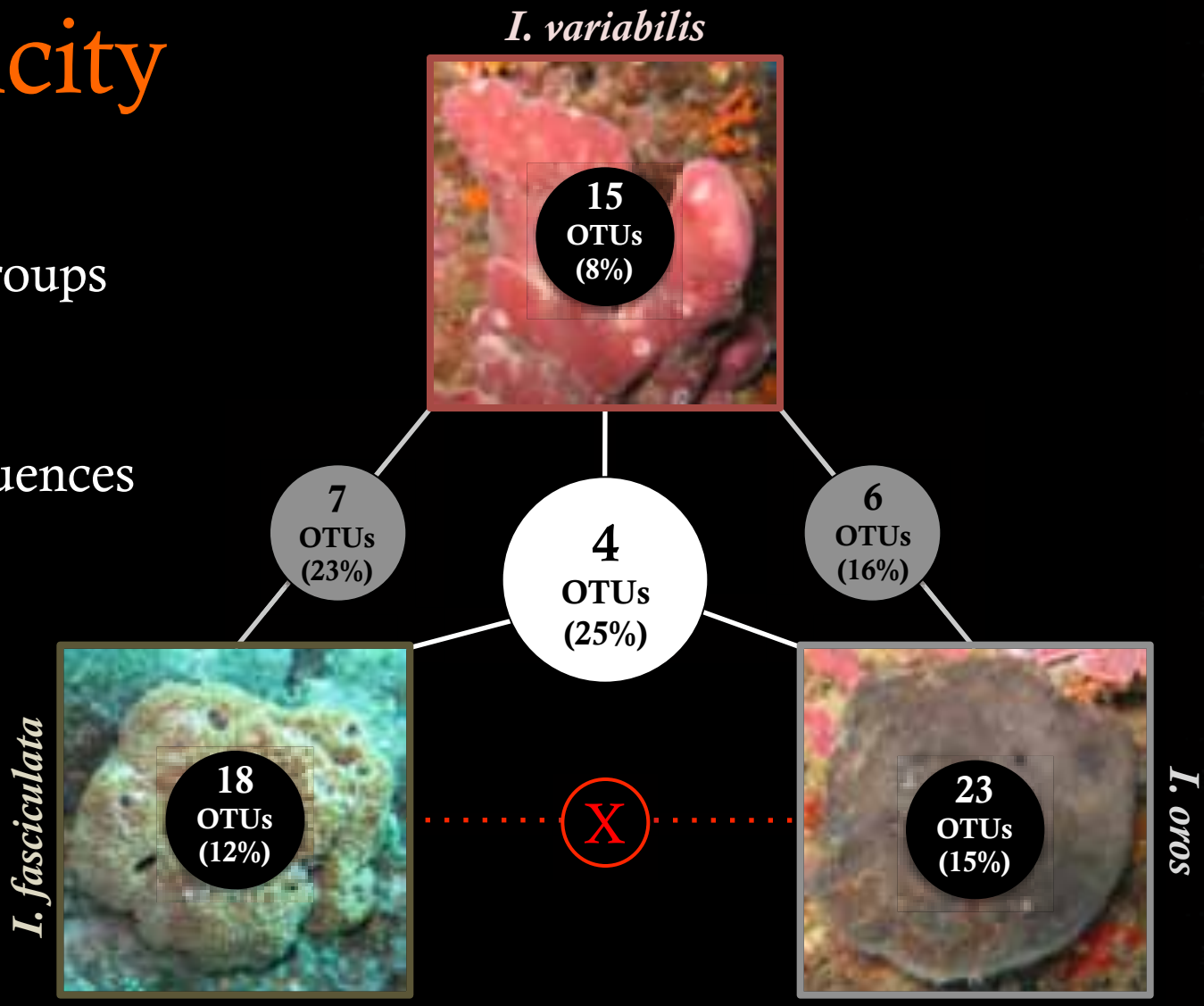
Erwin et al. 2012a *FEMS Microbiol Ecol*

Part II:

Specificity

73
symbiont groups

312
bacterial sequences



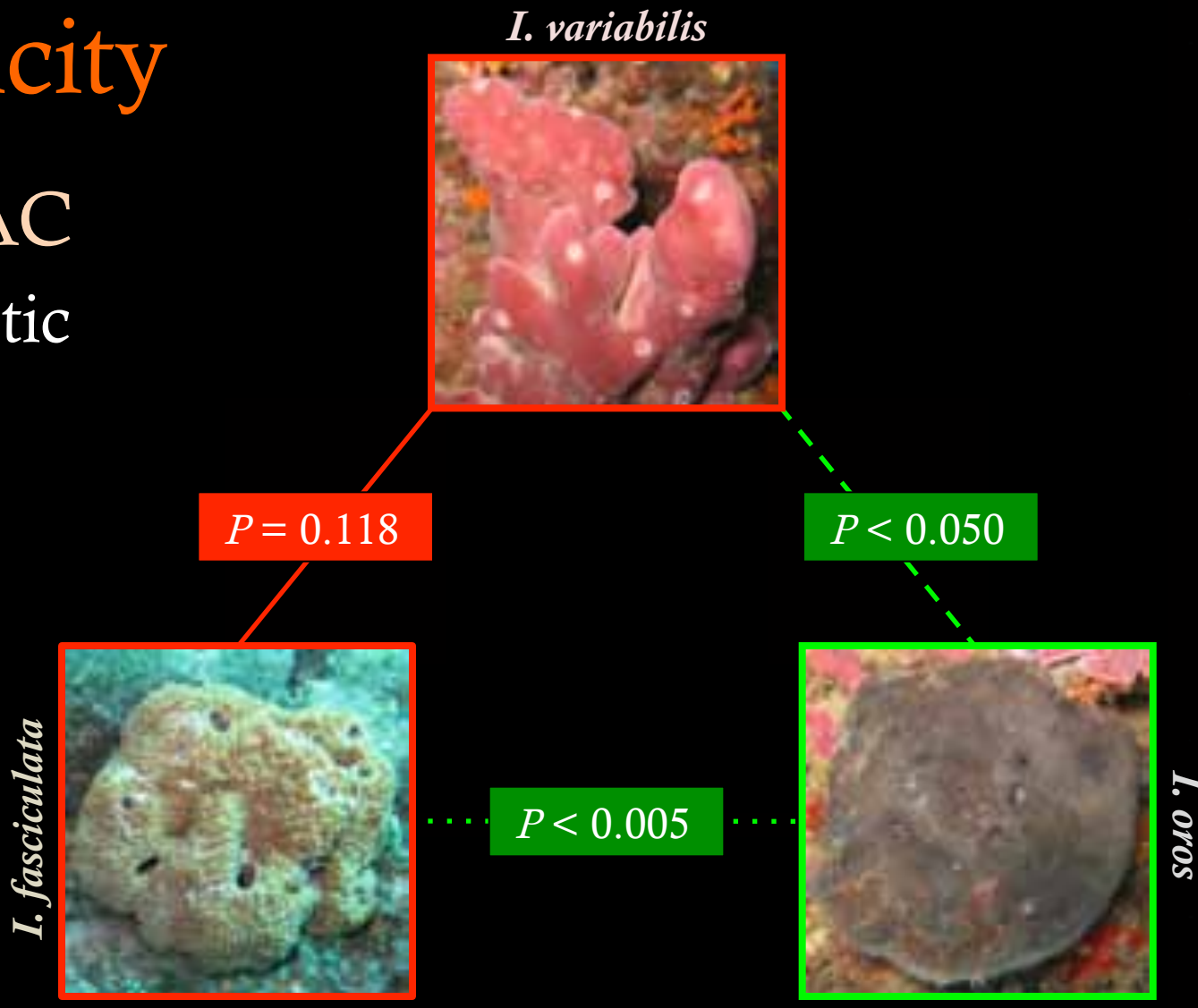
ERWIN ET AL. 2012A *FEMS MICROBIOL ECOL*

Part II:

Specificity

UNIFRAC

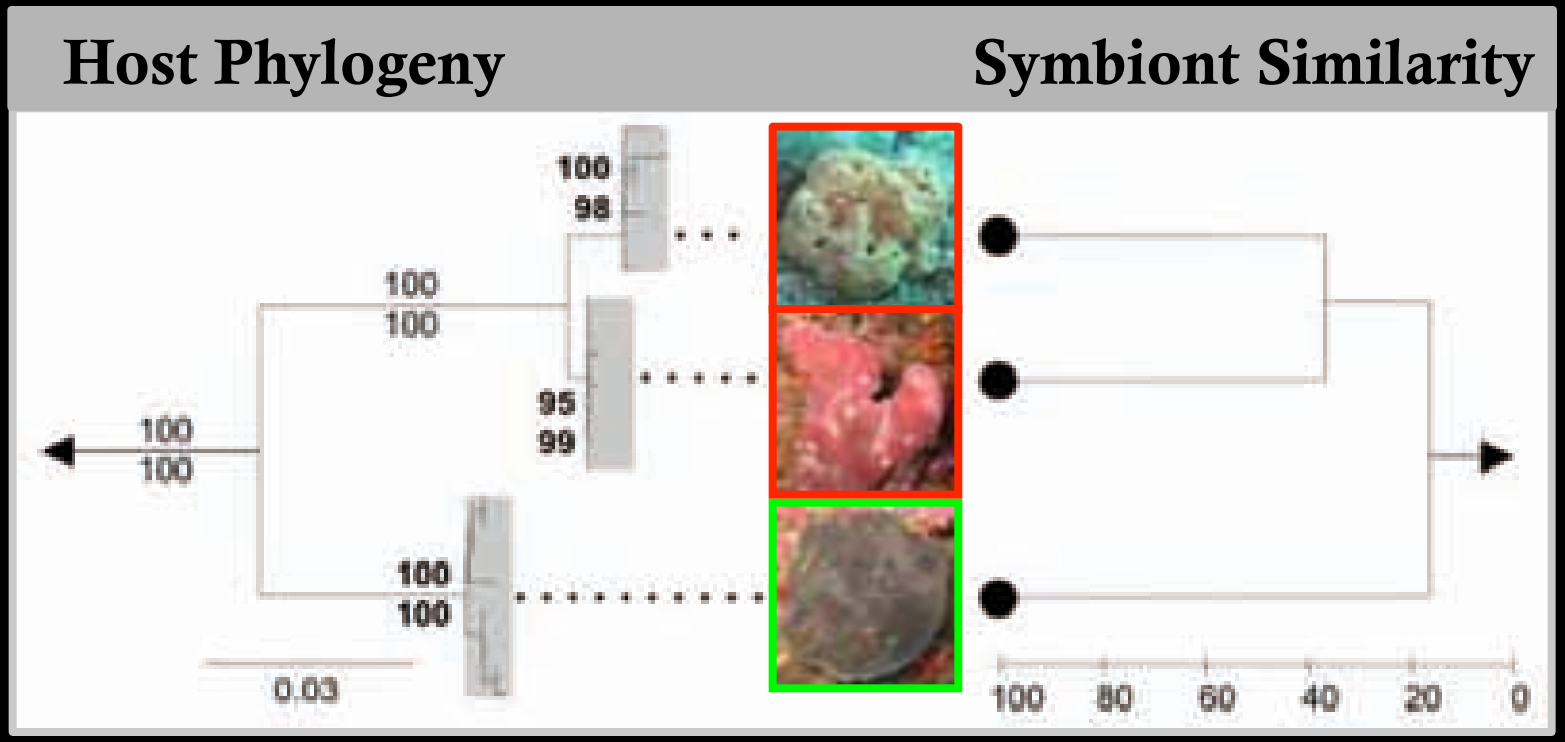
Phylogenetic Structure



Erwin et al. 2012a *FEMS Microbiol Ecol*

Part II:

Specificity



Erwin et al. 2012a *FEMS Microbiol Ecol*

Part II:

Environmental Factors

Stability

T-RFLP Analysis

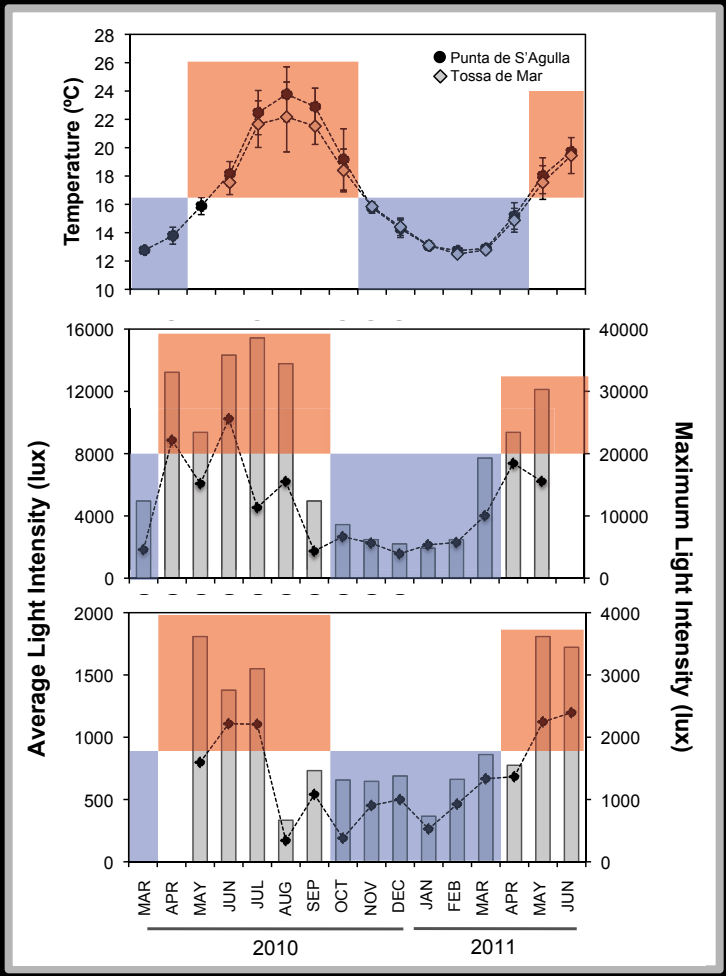
Temporal Variation

- 6 Samples x 6 Time Points
- DNA Fingerprints
- Statistical Analyses

ERWIN ET AL. 2012A ☐ *APPL ENVIRON MICROBIOL*

Part II:

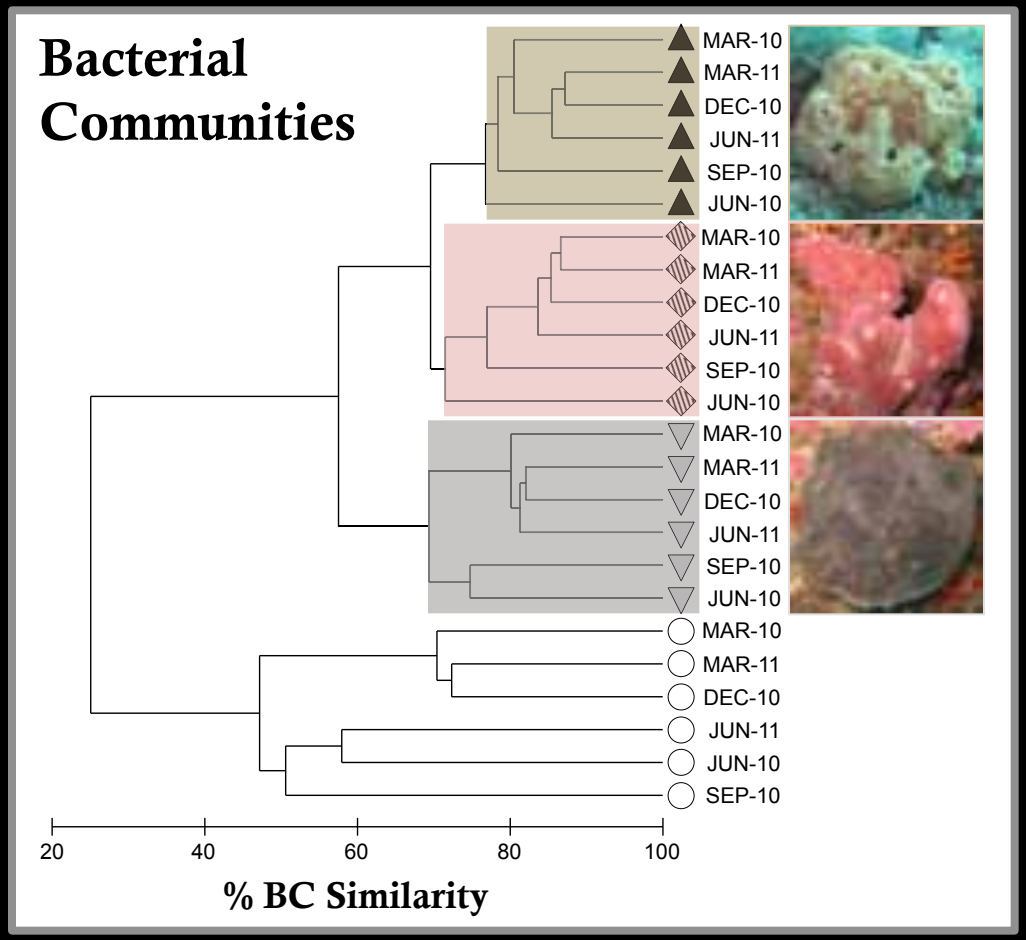
Seasonal Variability



- Temperature
  - Winter · 12 ºC
  - Summer · 24 ºC
- Irradiance
  - Winter · Low
  - Summer · High

Part II:

Host Specifity

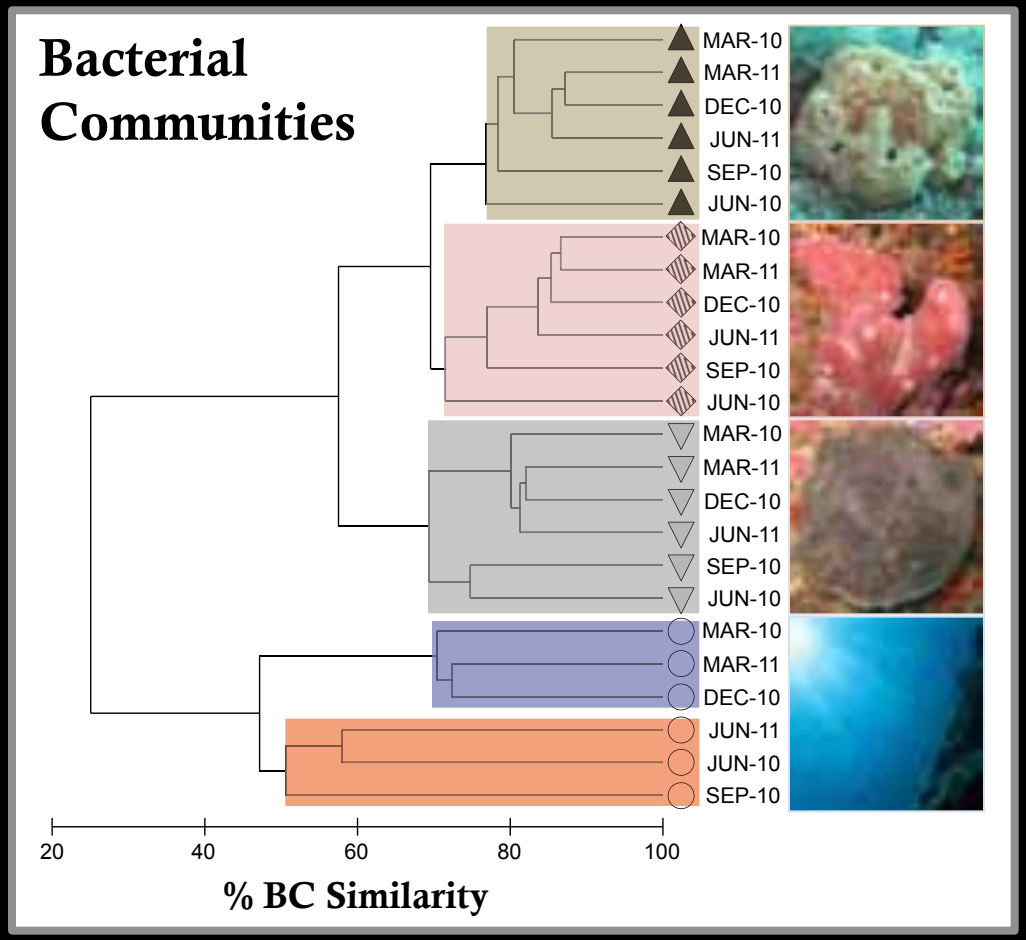


>70% Similarity

ERWIN ET AL. 2012B ☐ *APPL ENVIRON MICROBIOL*

Part II:

Host Specify



>70% Similarity

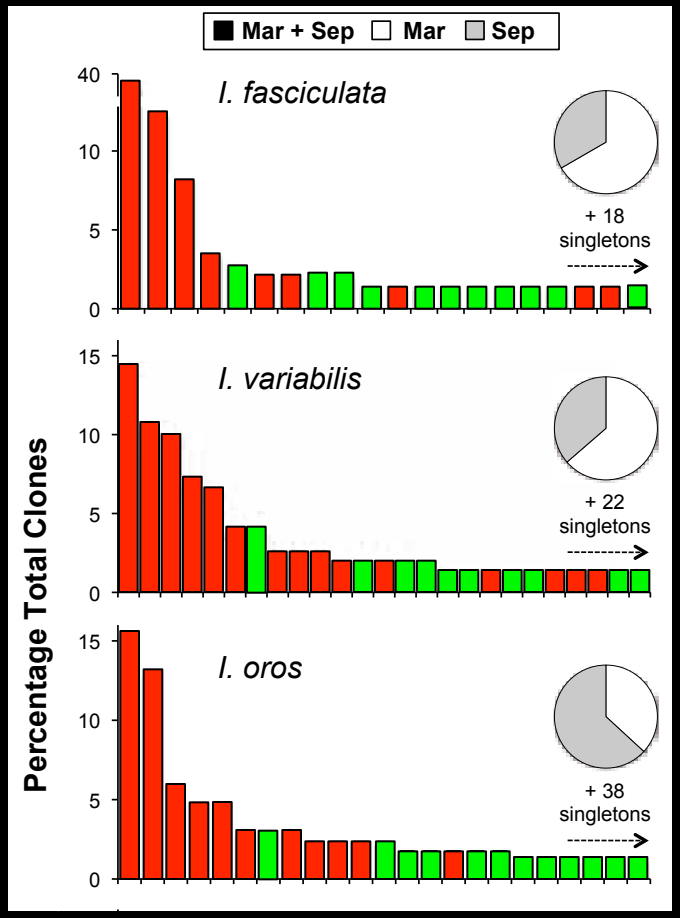
Fall-Winter

Spring-Summer

ERWIN ET AL. 2012B ☐ *APPL ENVIRON MICROBIOL*

Part II:

Symbiont Function



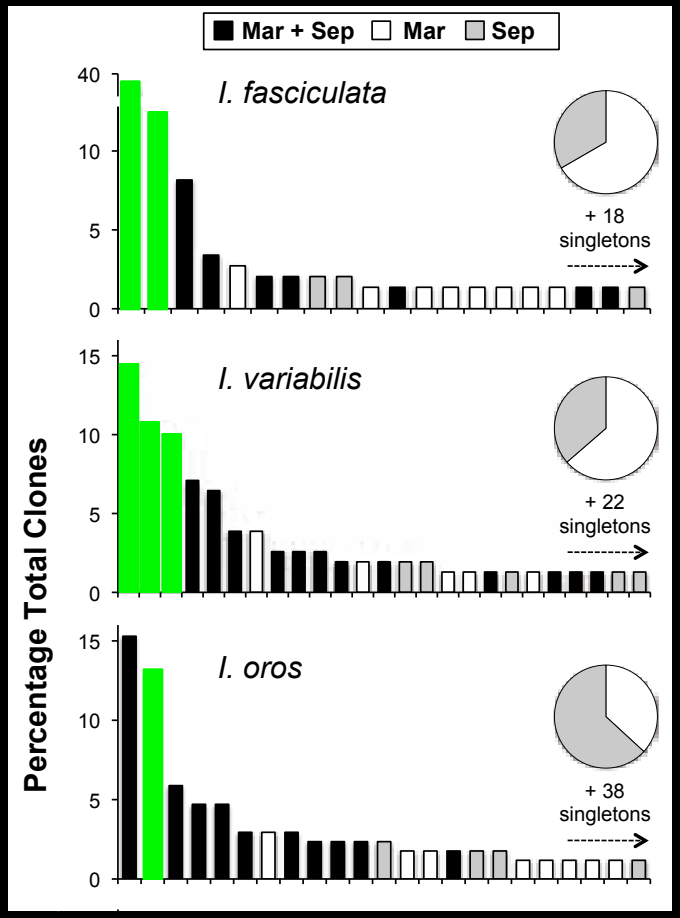
Stable Symbionts
Dominant

Variable Symbionts
Rare

ERWIN ET AL. 2012B ☐ *APPL ENVIRON MICROBIOL*

Part II:

Symbiont Function



Carbon Fixation	Sulfate Reduction	Nitrite Oxidation
✔	✔	–
✔	✔	✔
–	✔	–

Erwin et al. 2012b ☐ *Appl Environ Microbiol*

Conclusions

Sponge-Microbe Symbioses

- Host Specificity
  - Clades to Communities
- High Stability
  - Host > Enviromental
- Functionality
  - Host Ecology

Future Research

Ongoing Projects

Part III:

Future Directions

1. Anthropogenic Impacts
   - Climate change
   - Anthropogenic impacts

Ecological monitoring

2. Nutrient Cycles
   - Keystone Symbionts
   - Sponge Microbiome Project

Metagenomics

3. New Model Systems

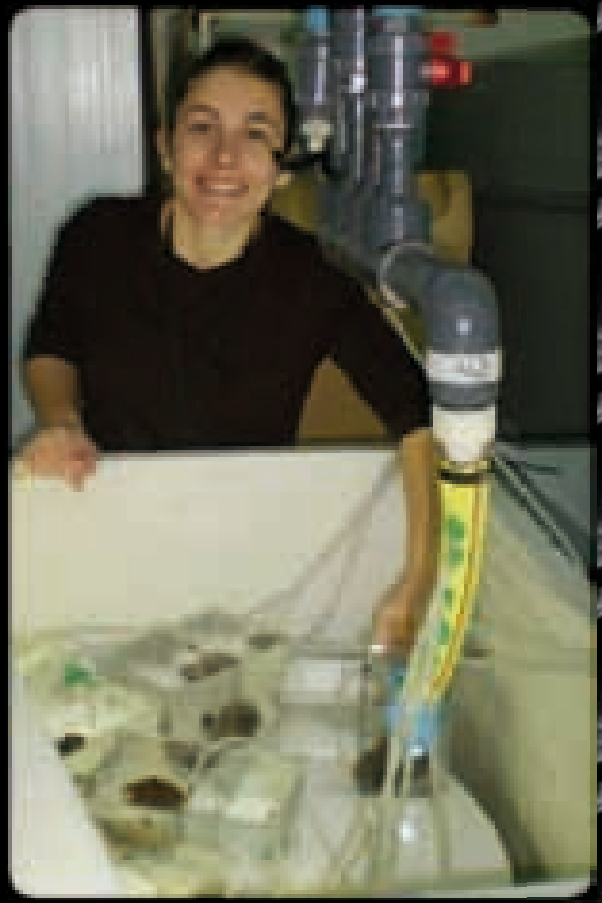
Part III:

(1) Anthropogenic Impacts

Thermal Tolerance of Sponge-Bacteria Symbioses

Aquaria Experimentation

Lucía Pita
PhD Candidate
University of Barcelona



PITA ET AL. 2013 *PLOS ONE*

Part III:

(1) Anthropogenic Impacts

Model Sponges in North Carolina

Pre- and Post-Oil Spill
Natural vs. Artifical Habitats
Spatio-Temporal Scales
Aquaria Experimentation

Low Diversity Symbiont Communities (7 spp.)

ERWIN ET AL. 2011 *PLOS ONE*

Part III:

(2) Nutrient Cycles

Carbon Cycles
"Keystone Symboints"

Target species:

Petrosia ficiformis
Chondrosia reniformis

Collaboration with:

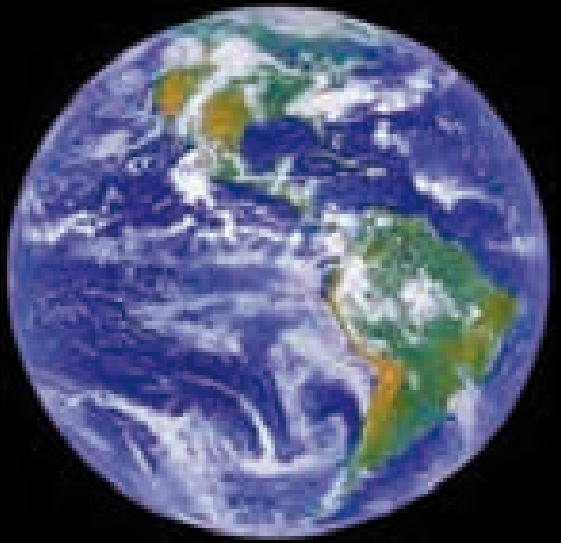
University of Haifa (Israel)

Part III:

(2) Sponge Microbiome Project

Metagenomics:

Carbon/Nitrogen Cycle



Target species:

30 spp. across the world

Collaboration with:

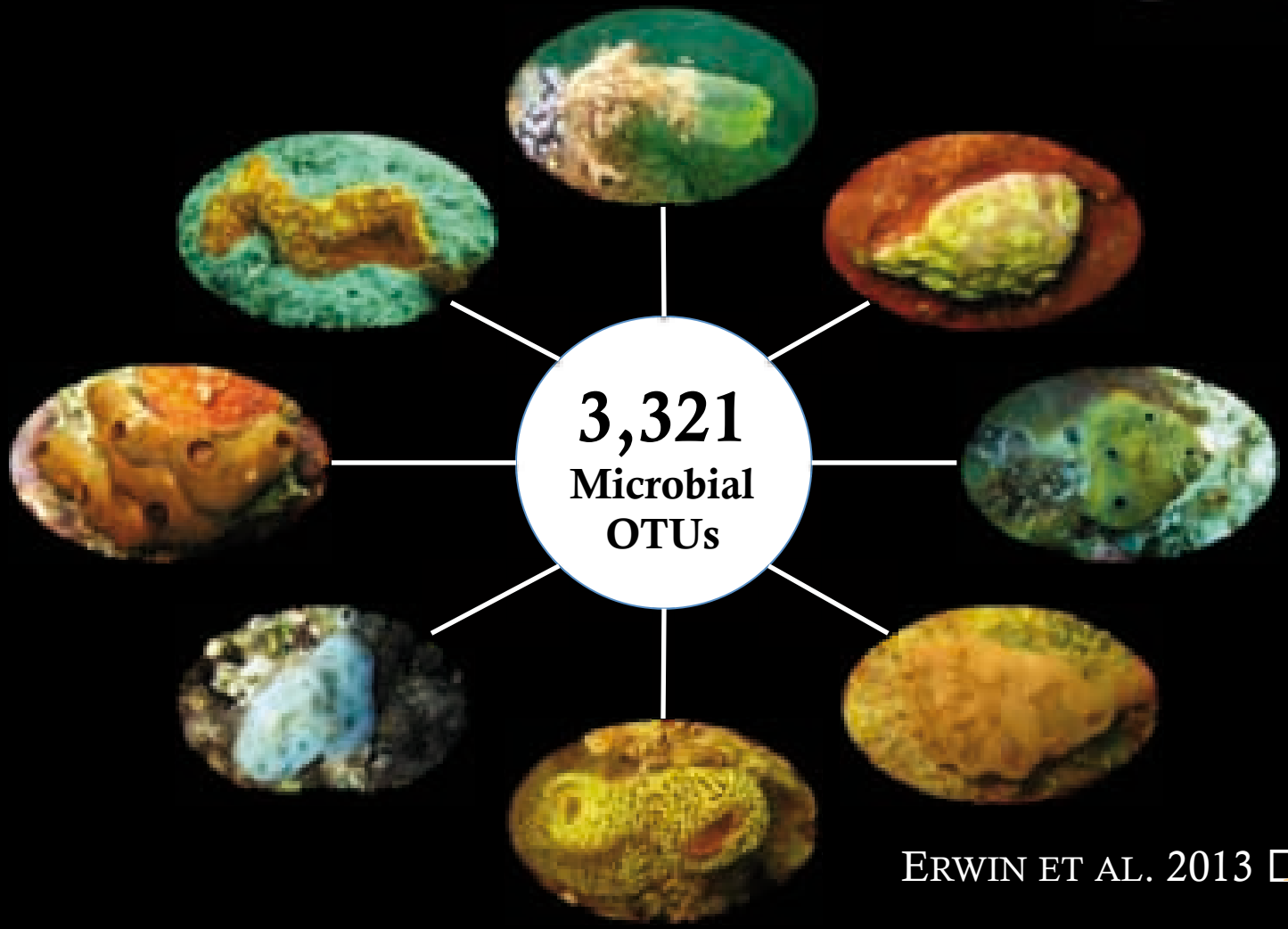
25 researchers, 10 countries

earth microbiome project

First Run Complete (Aug) = 1,052 Samples = 85,000,000 Sequences

Part III:

(3) New Model Systems



ERWIN ET AL. 2013 *ISME J*

Part III:

(3) New Model Systems

Future Work

Conclusion

Acknowledgements

Funding Sources

- National Science Foundation
  NSF-0853089
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  Fellowship
- Sigma Xi Research Society
  Grant-In-Aid-of-Research
- Society Integr. Comp. Biol.
  Grant-In-Aid-of-Research

Host Institutions

- University of Barcelona
- Center Adv. Studies of Blanes
- Univ. Alabama at Birmingham

Collaborators

- Xavier Turon (CEAB)
- Robert W. Thacker (UAB)
- Susanna López-Legentil (UB)

Graduate Students

- Lucía Pita (PhD)
- Anna Garriga Pla (MSc)