
The Role of Seaweed-Coral Competition and Phenotype-Environment Mismatch in the Coral Reef Death Spiral
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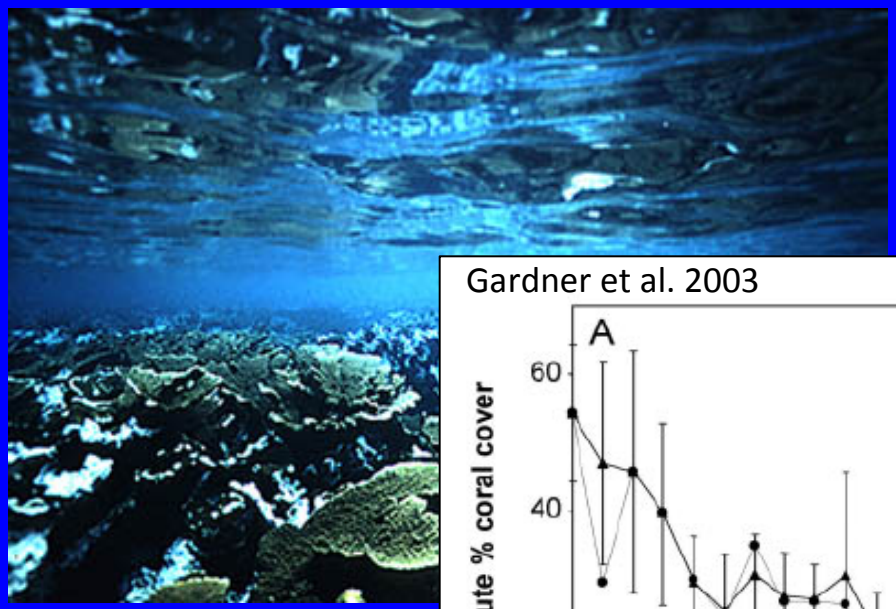
Some Challenges:

- Reef ARE in trouble
- We know many stressors but what we don't know may be our greatest challenge (CoT, then Global Warming, now Ocean Acidification… what next year? – we don't know how to predict *Diadema* disease, Dutch-elm disease, etc.)
- We won't save corals by focusing on corals, ecosystem function needs fixing, not just the corals.

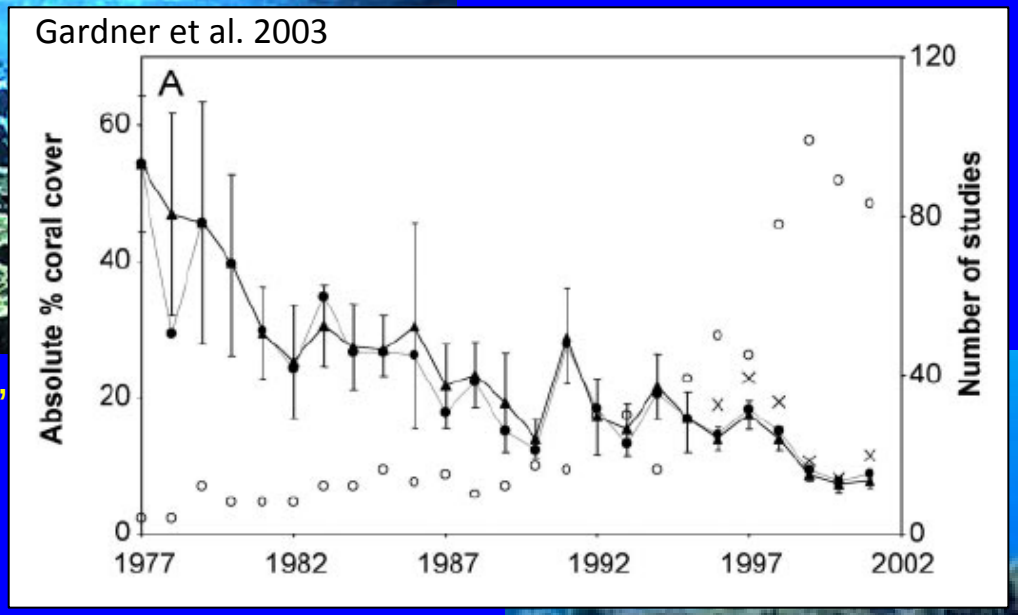
Dramatic Changes in the Caribbean

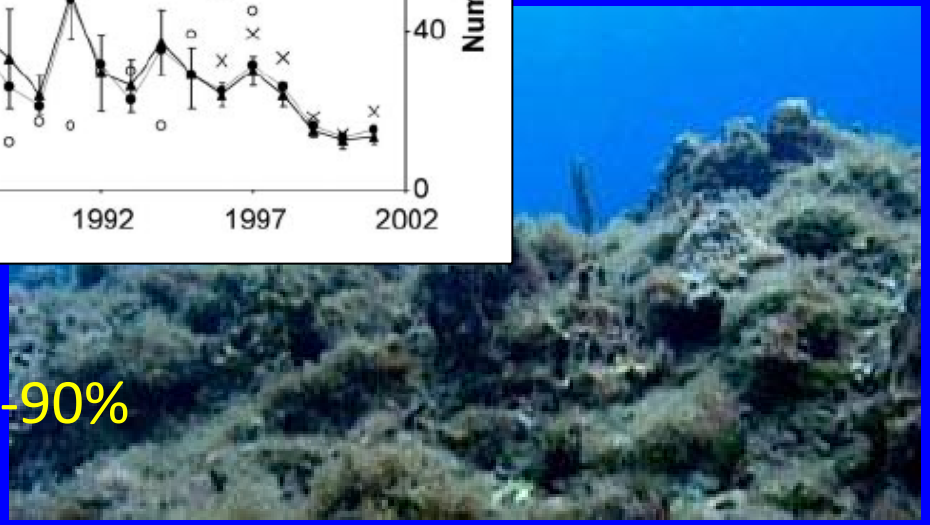
("reefs" are now algal-covered meadows)



1970'

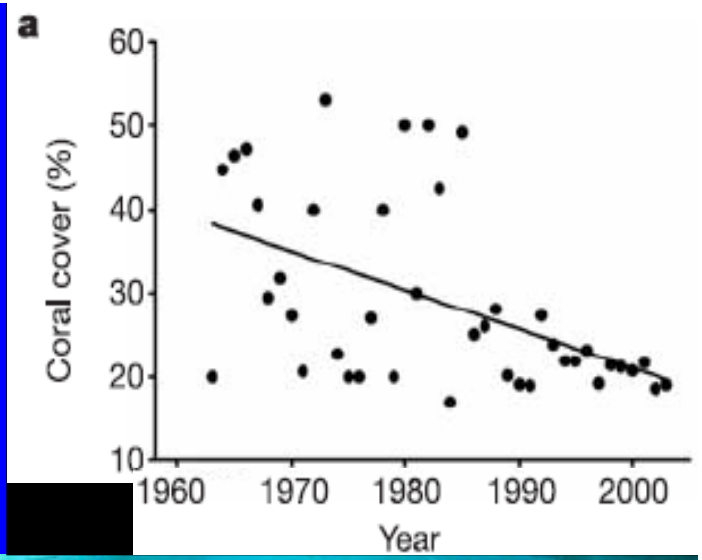
Gardner et al. 2003

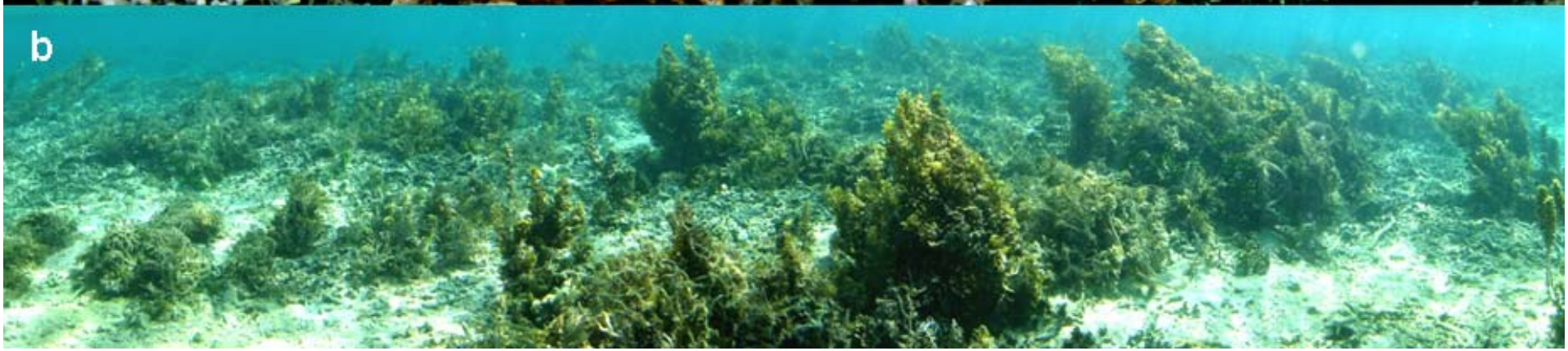




Live coral cover has declined by 80-90%

- The Pacific may be following the Caribbean pattern –
- Coral decline of ~50% along the GBR since 1980
- Is the Caribbean an indicator of the future or an unusual outlier?





Fights about Causes of Coral Loss (= coral necrophilia?)

- Global change
- Herbivore loss
- Nutrient addition
- Disease…..

Are seaweeds a cause or a consequence of coral decline? YES, but what is happening on modern reefs?

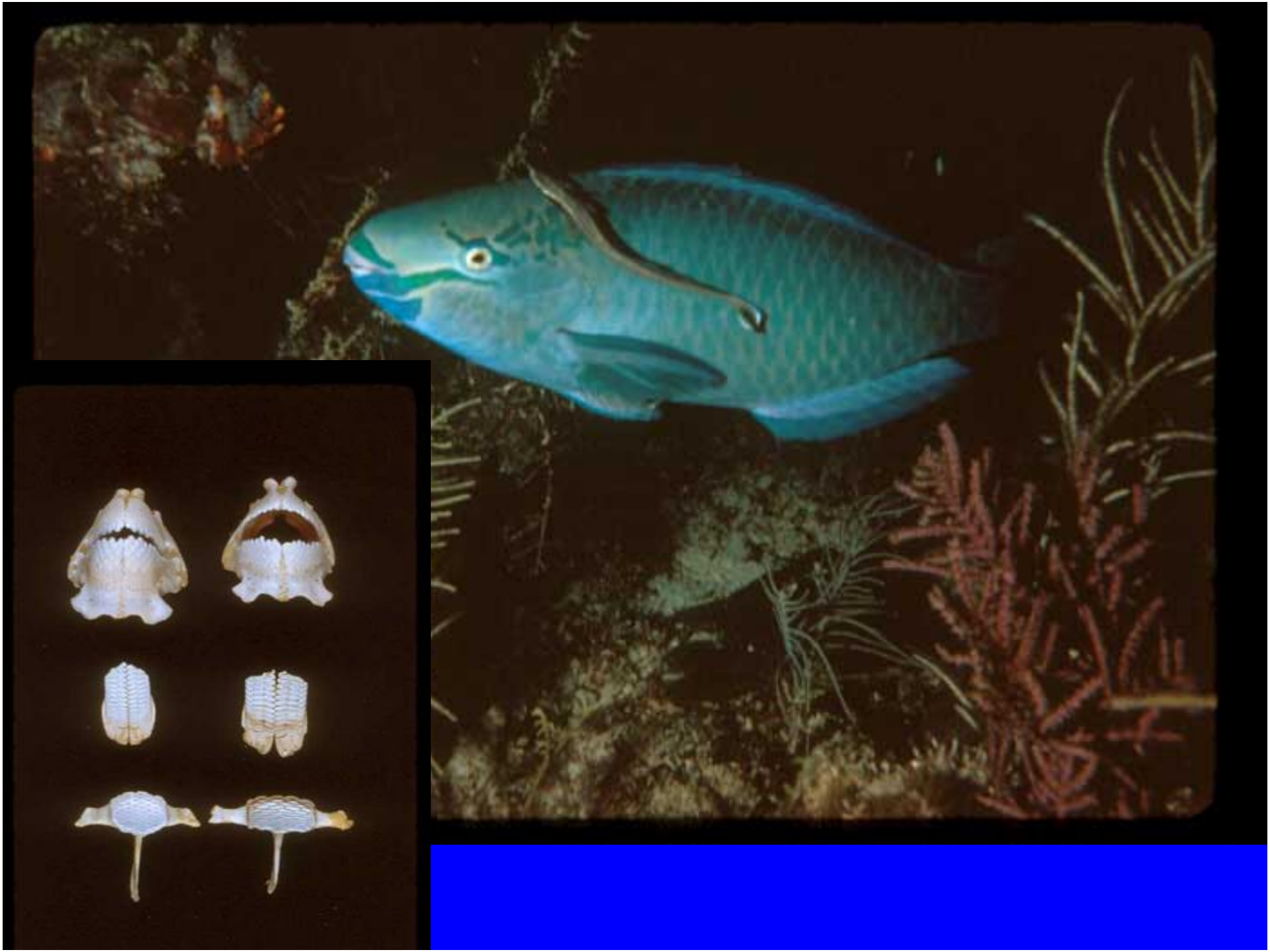
What to do?

- Can manage locally (fishing, nutrients, runoff)
- Locals can't affect global stresses (global warming, ocean acidification, etc.)
- Can local efforts be useful in the face of global stresses?

- If coral-algal competition is important then…..
- local management (MPAs) may be effective in the face of global stressors (elevated sea surface temperatures, ocean acidification, etc.)? At lease for a while.
- Are we asking “low carbon use” people to conserve so that “we” don’t have to?

Votua Village
Fiji

Atlanta



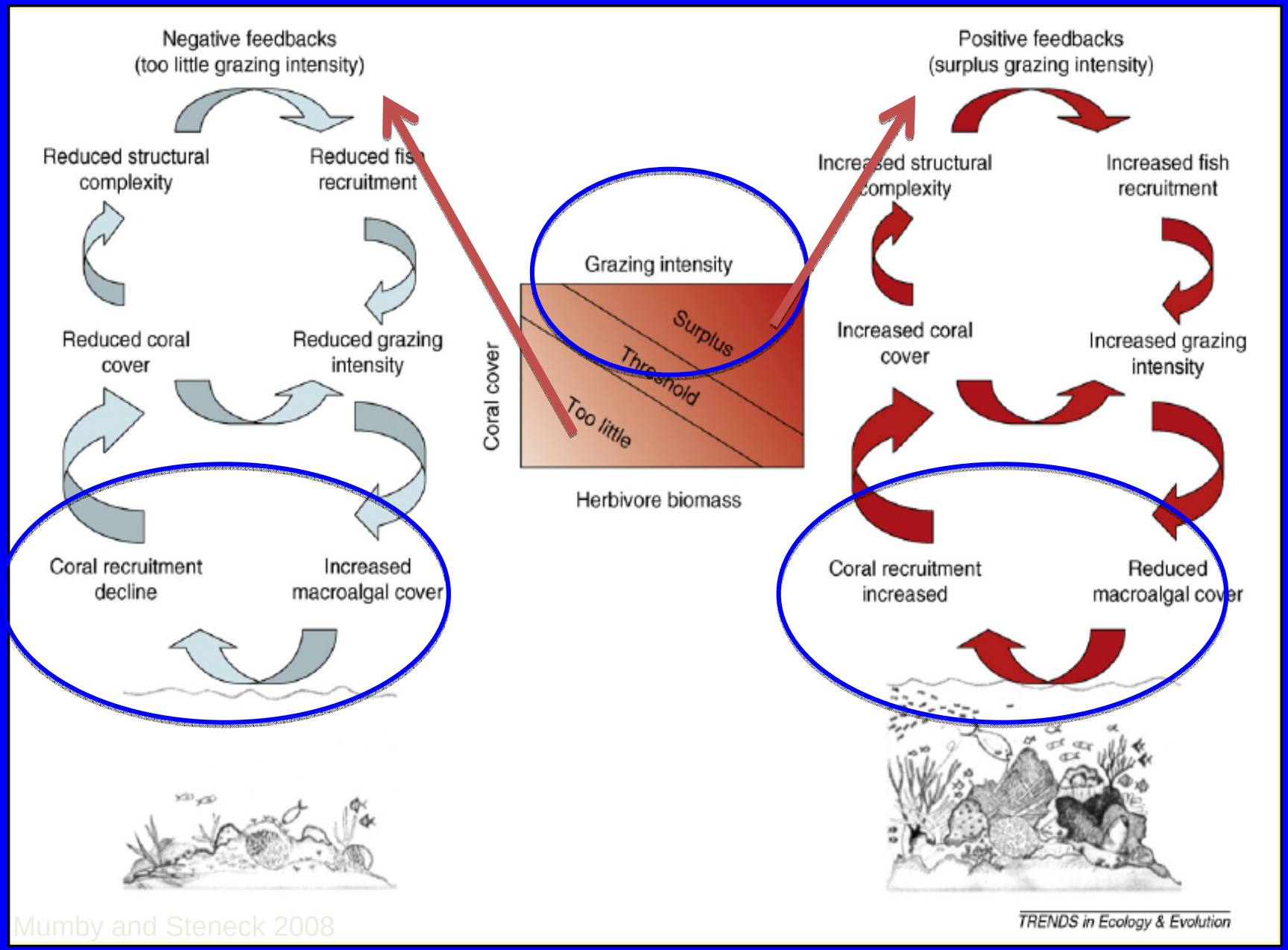

Fishing versus Nutrients? (Both play a role, but the herbivore removal effect is ~3x > than nutrient addition effect)

Fishing is like a global caging experiment

Herbivores are in decline

Subsistence harvest

Suva city market



Mumby and Steeck TREE 2008

Experimental Outcomes

- Excluding herbivores causes > seaweeds and < corals (so seaweeds somehow damage corals?)
- Considerable coral loss form bleaching, disease
- More seaweeds < settlement and survivorship of coral larvae
- THE RELATIVE IMPORTANCE OF SEAWEEDS KILLING CORALS VERSUS ONLY COLONIZING OPPORTUNISTICLY AFTER THEIR DEMISE? (a cause or a symptom? If the former, are some seaweeds more damaging than others?)

Porites cylindrica

Montipora digitata

Acropora millepora

Pocillopora damicornis

Sargassum polycystum

Turbinaria conoides

Padina boryana

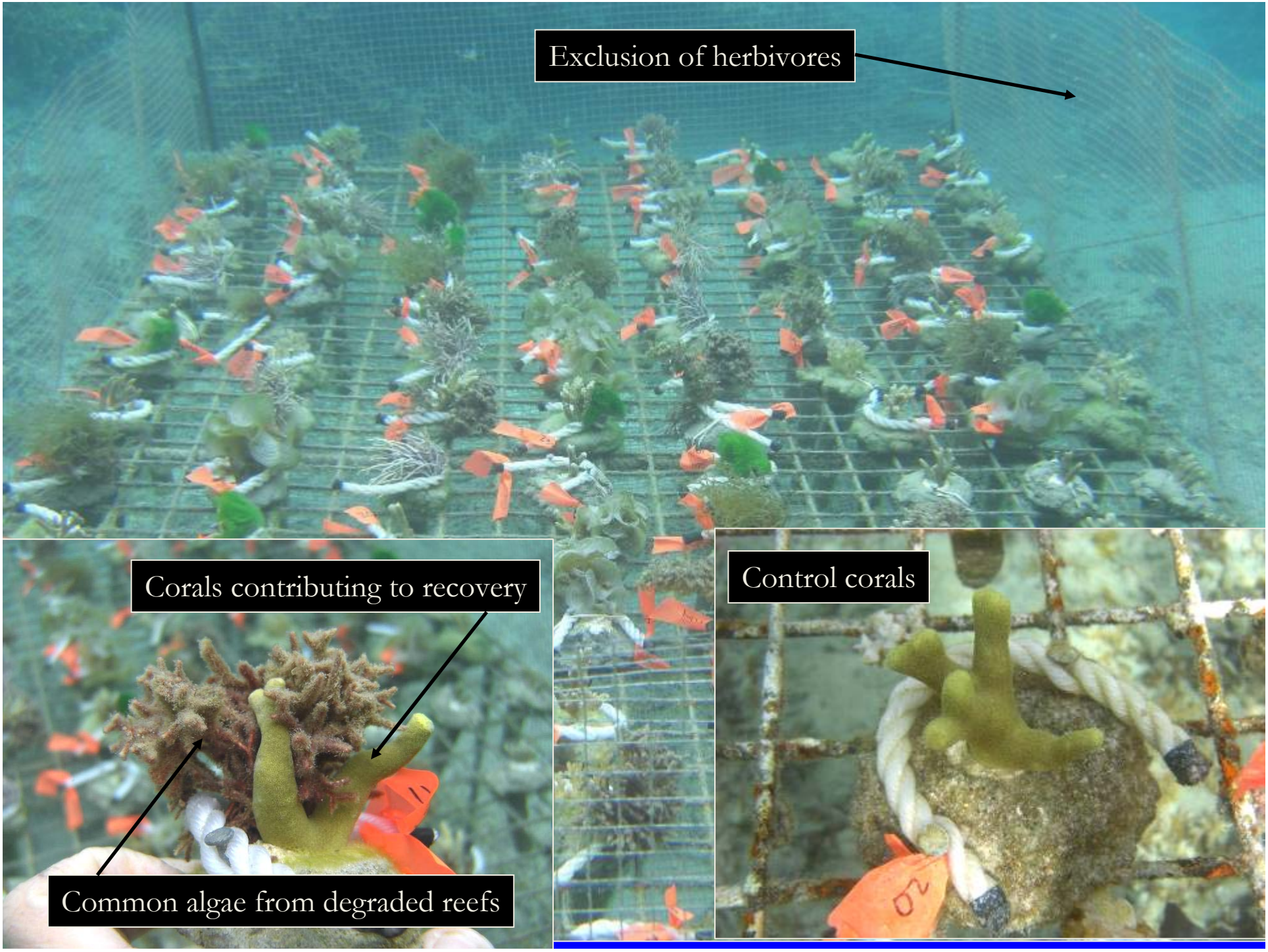
Dictyota bartayresiana

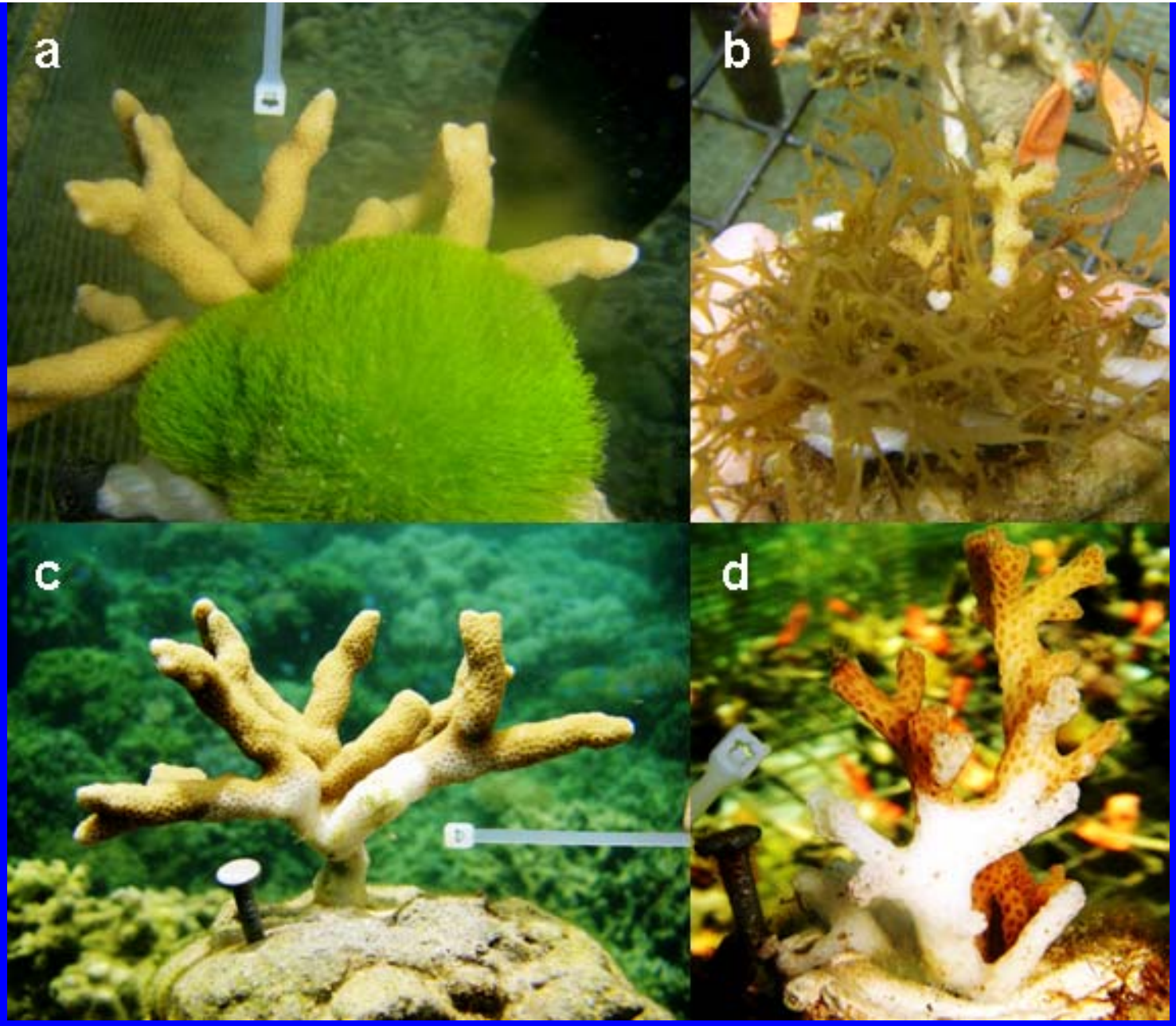
Amphiroa crassa

Galaxaura filamentosa

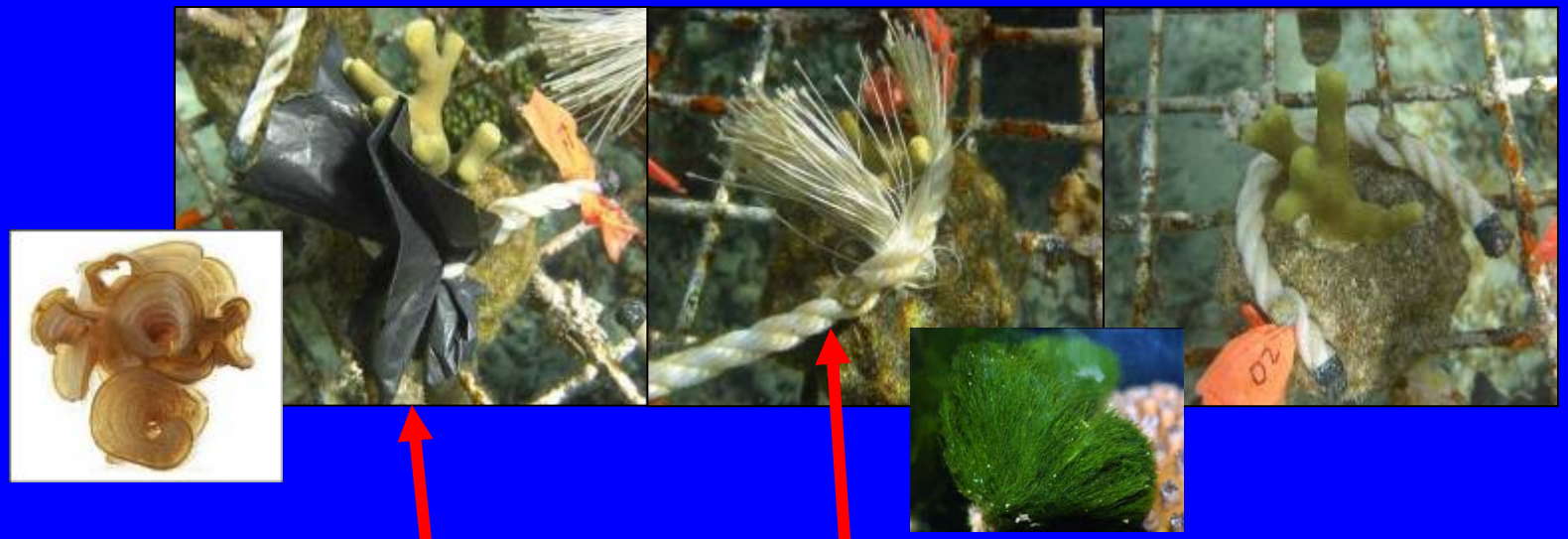
Liagora sp.

Chlorodesmis fastigiata.

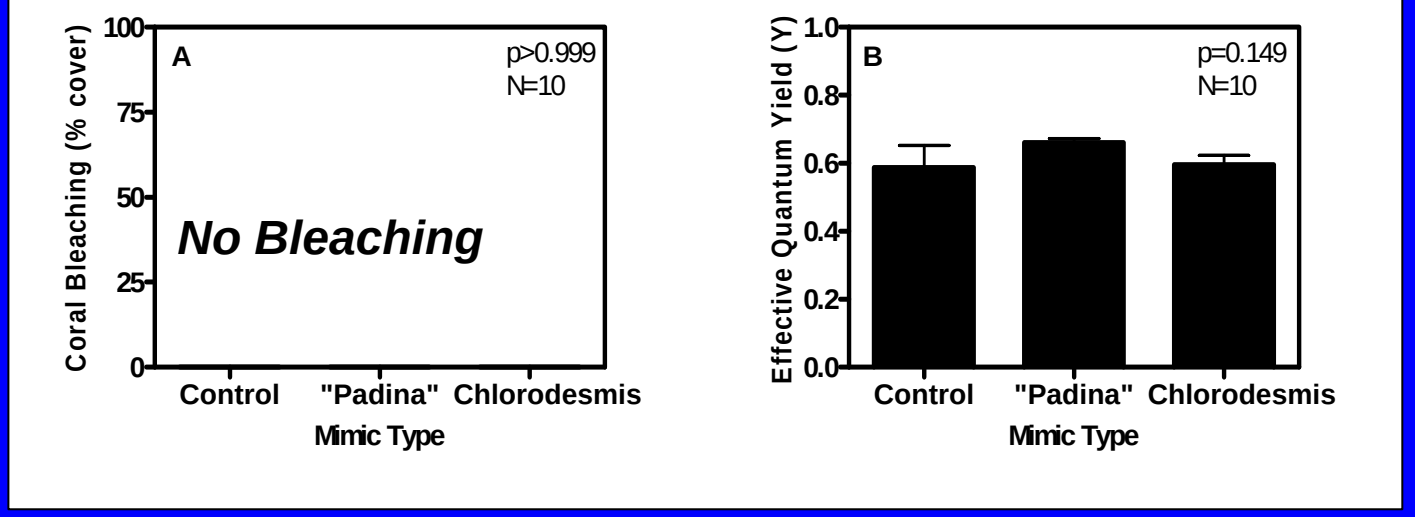

Exclusion of herbivores
Corals contributing to recovery
Common algae from degraded reefs
Control corals



Damage primarily in areas of contact.
Allelopathy or shading and abrasion?

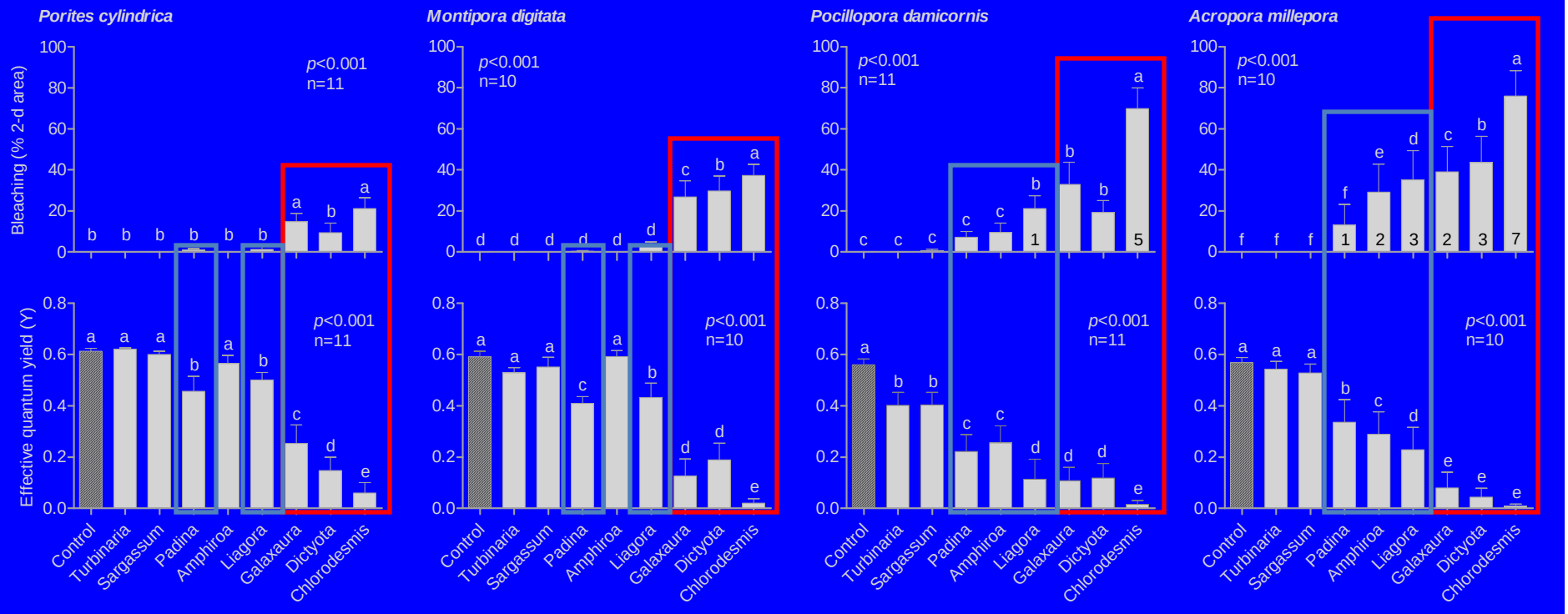


Inert "*Padina*" and "*Chlorodesmis*"



No effects of shading or abrasion

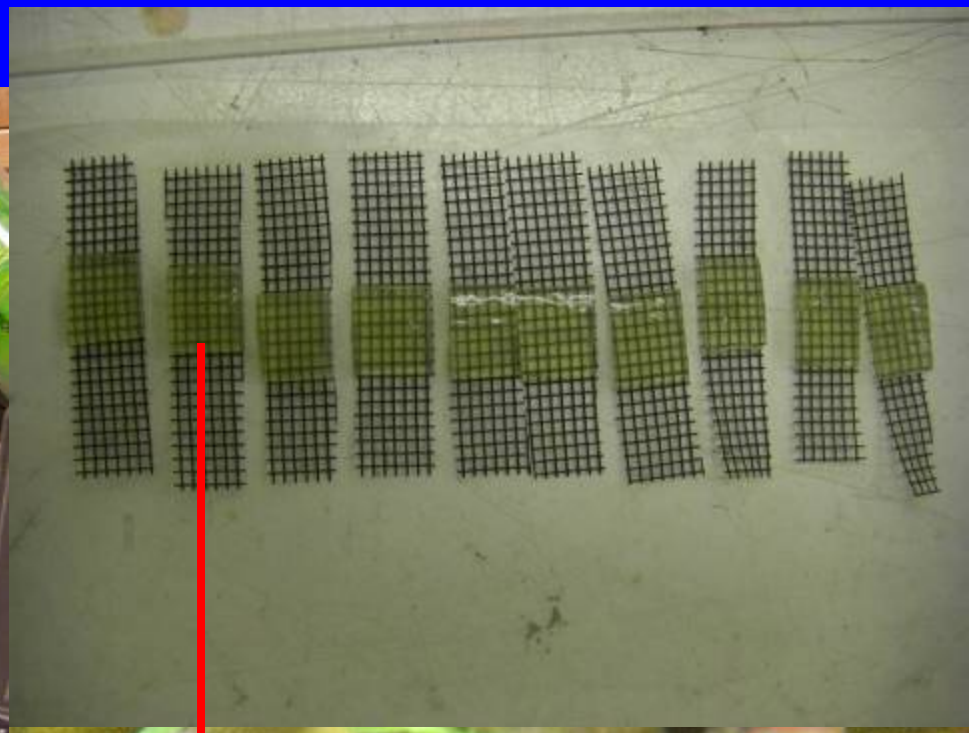
Visual coral bleaching

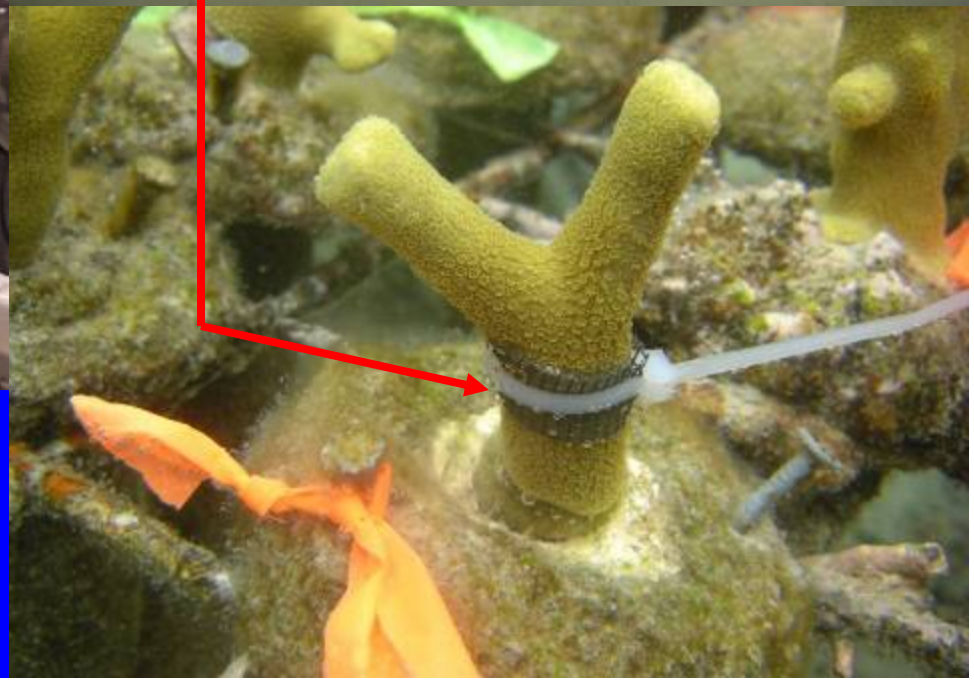


Quantum Yield

Coral sensitivity to algal contact

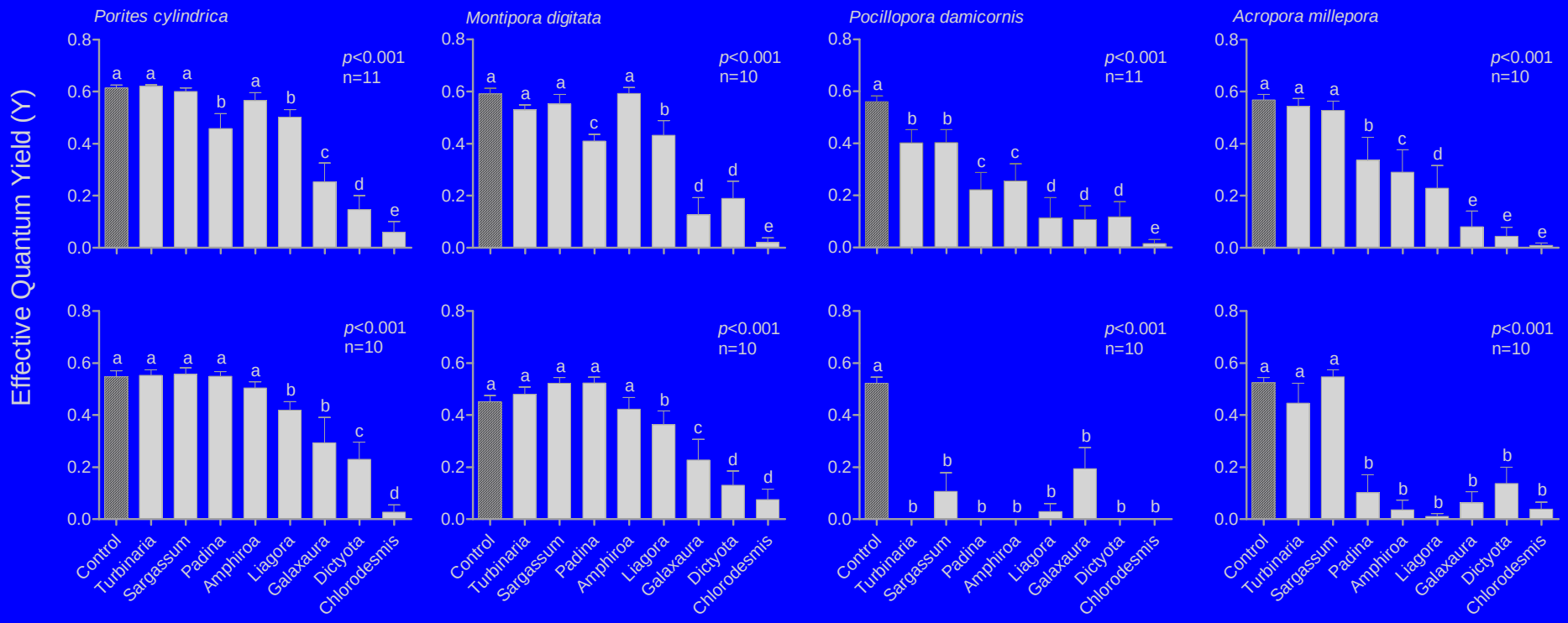
Rasher and Hay 2010 *PNAS*
Rasher et al. 2011 *PNAS*





Direct tests of allelopathy

Contact with seaweed for 20 days

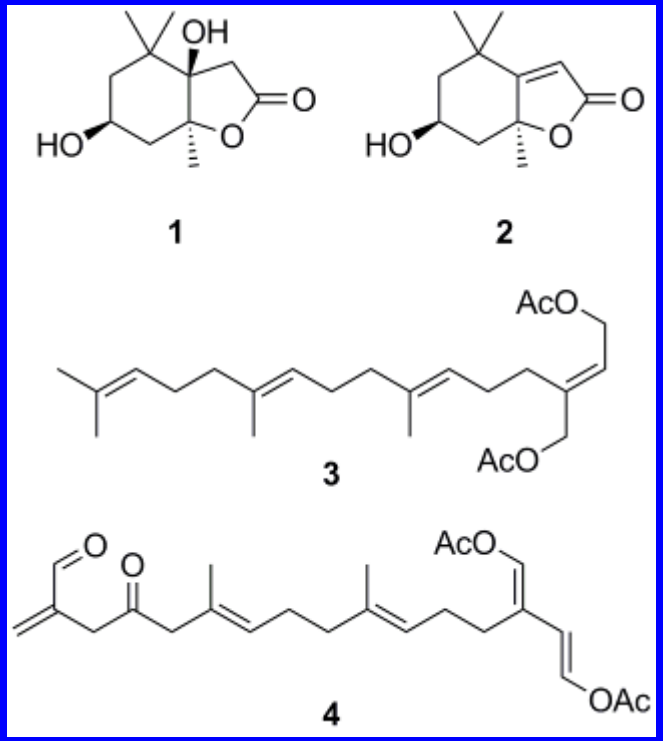


Contact with extract only for 24 hours

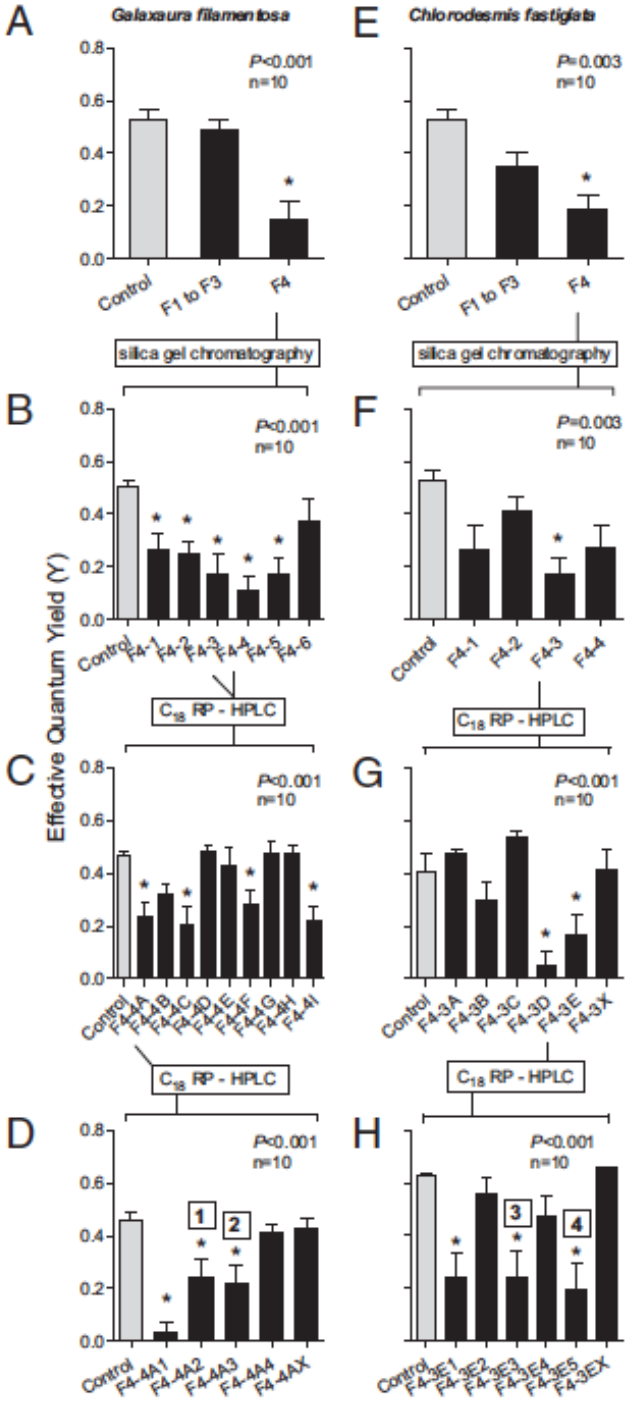
Equivalent effects of surface only extracts

Compound isolation

Galaxaura filamentosa



Chlorodesmis fastigiata.



Rasher et al. 2011

Conclusions : Algal-coral competition

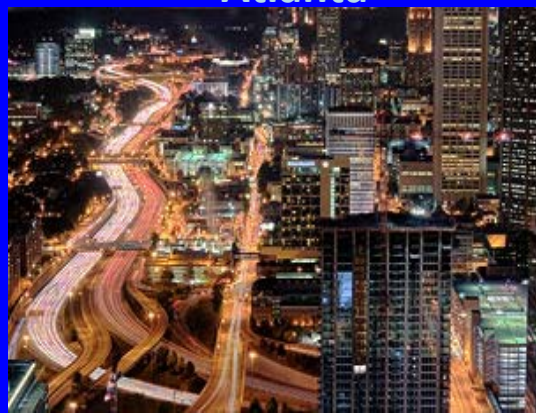
- Allelopathy is common (~75% of the 32 contrasts we investigated)
  - Potent, hydrophobic molecules transferred from algal to coral surfaces

- Algal-coral interactions are species-specific
  - Seaweeds vary in potency
  - Corals vary in susceptibility
  - There is a general trend for which seaweeds are most potent and which corals are most susceptible.

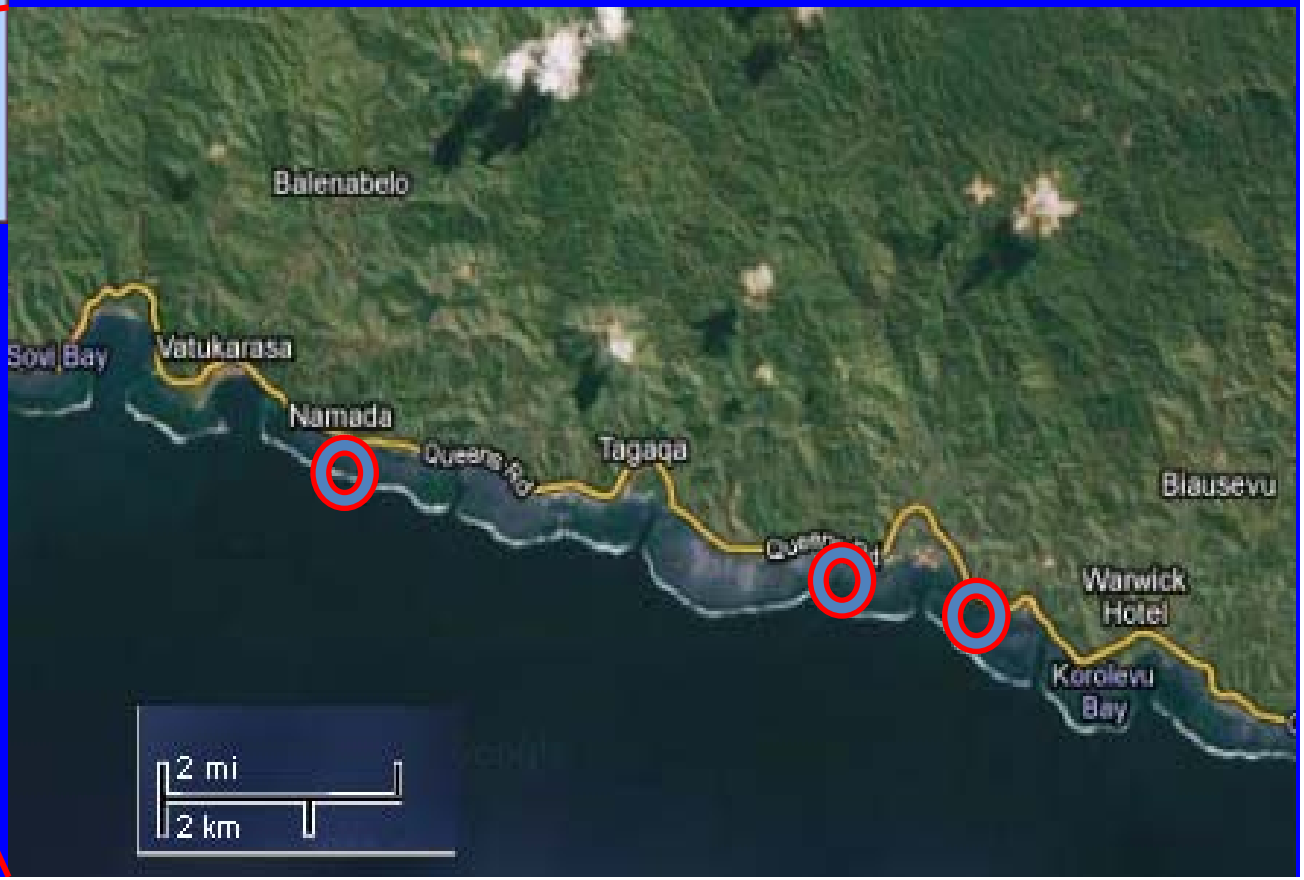
- Can local management (MPAs) may be effective in the face of global stressors?
- Are we asking “low carbon use” people to conserve so that “we” don’t have to?

Votua Village
Fiji

Atlanta

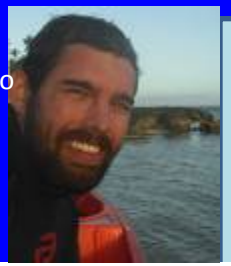


Three paired MPAs and Fished Areas on the Coral Coast

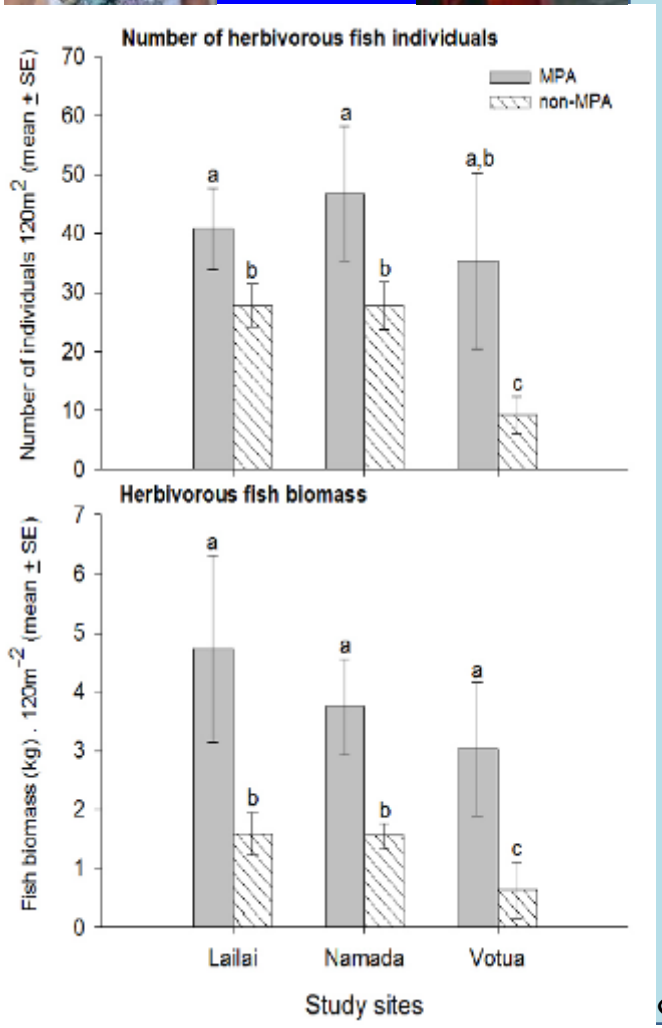


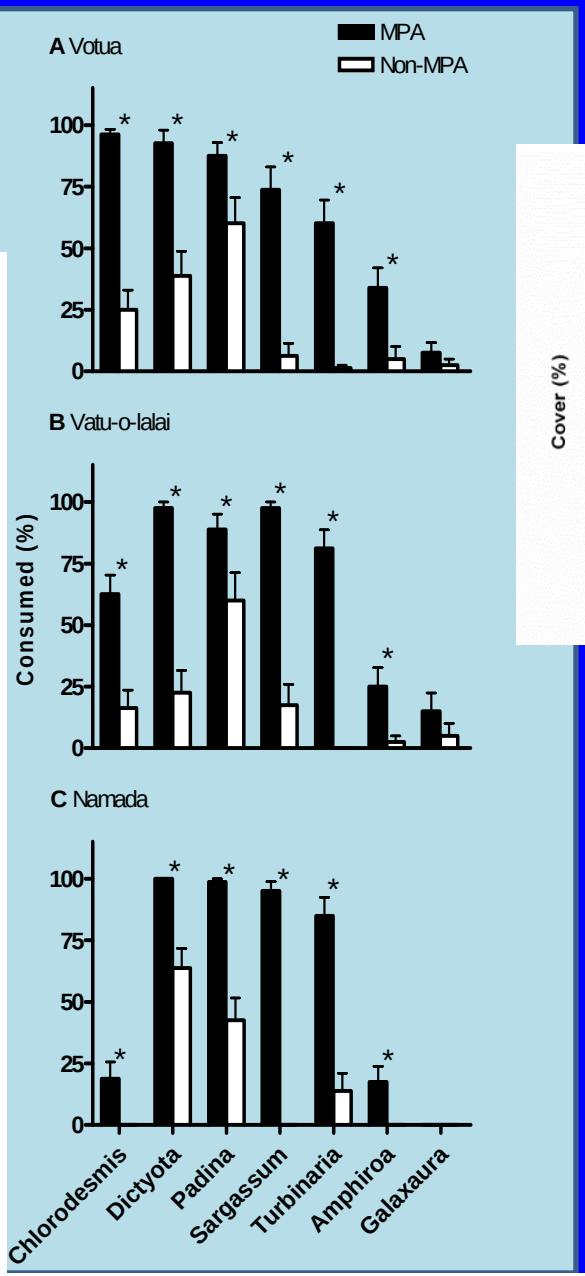
3, Paired MPA and Adjacent Fished Areas

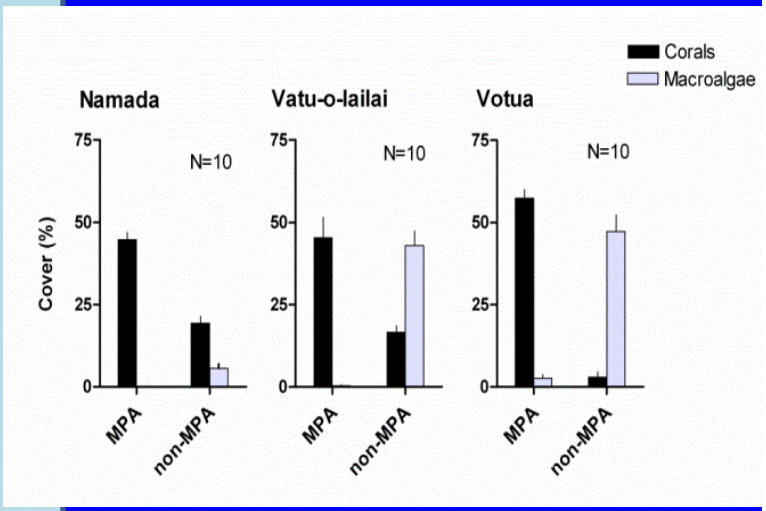
Roberta Bonaldo



Doug Rasher





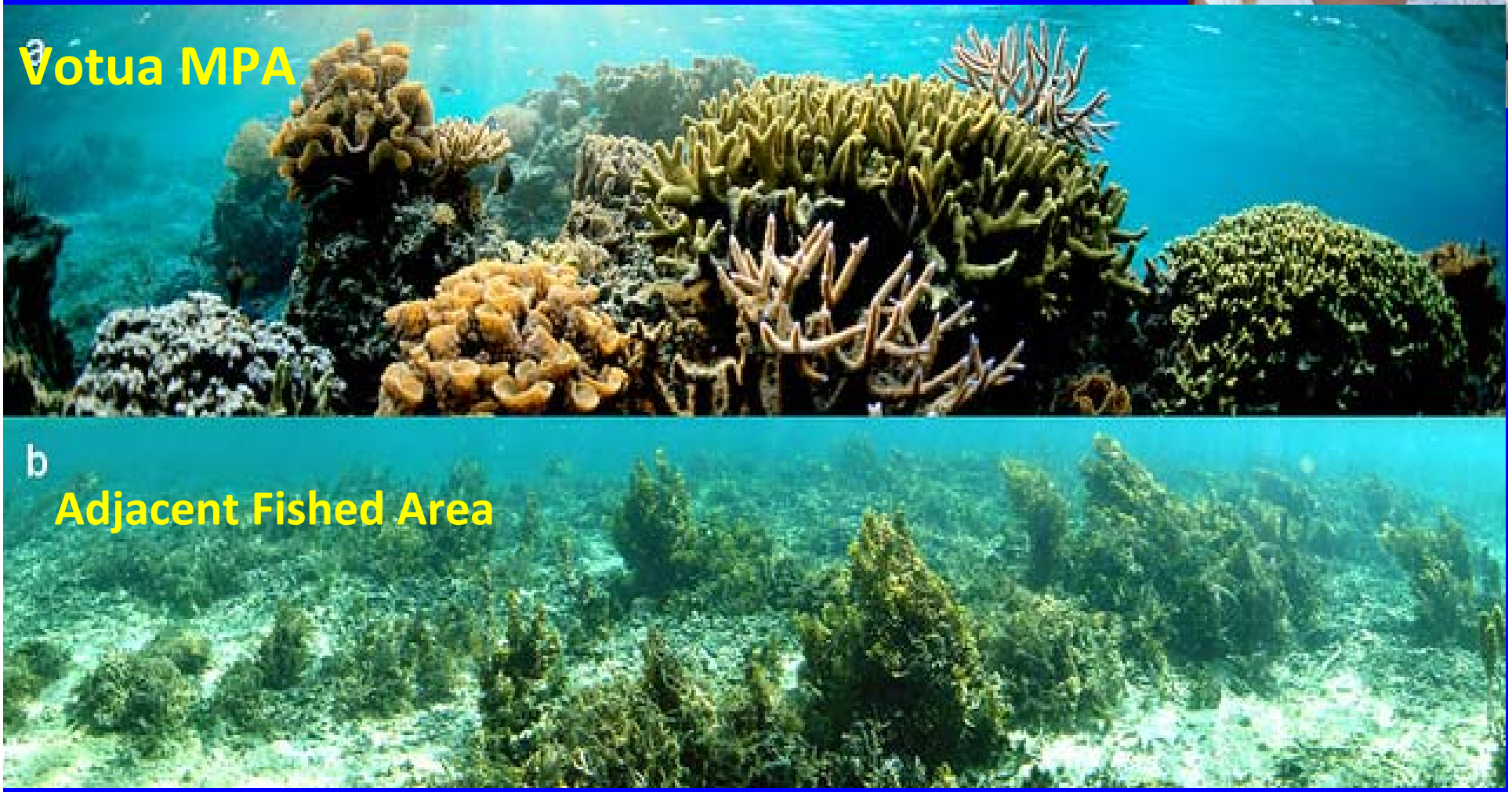


MPA to non-MPA contrast:

- 170-380% more herbivore mass
- 250-360% faster consumption of macrophytes
- 130-1800% more coral cover
- 94-100% less seaweed cover

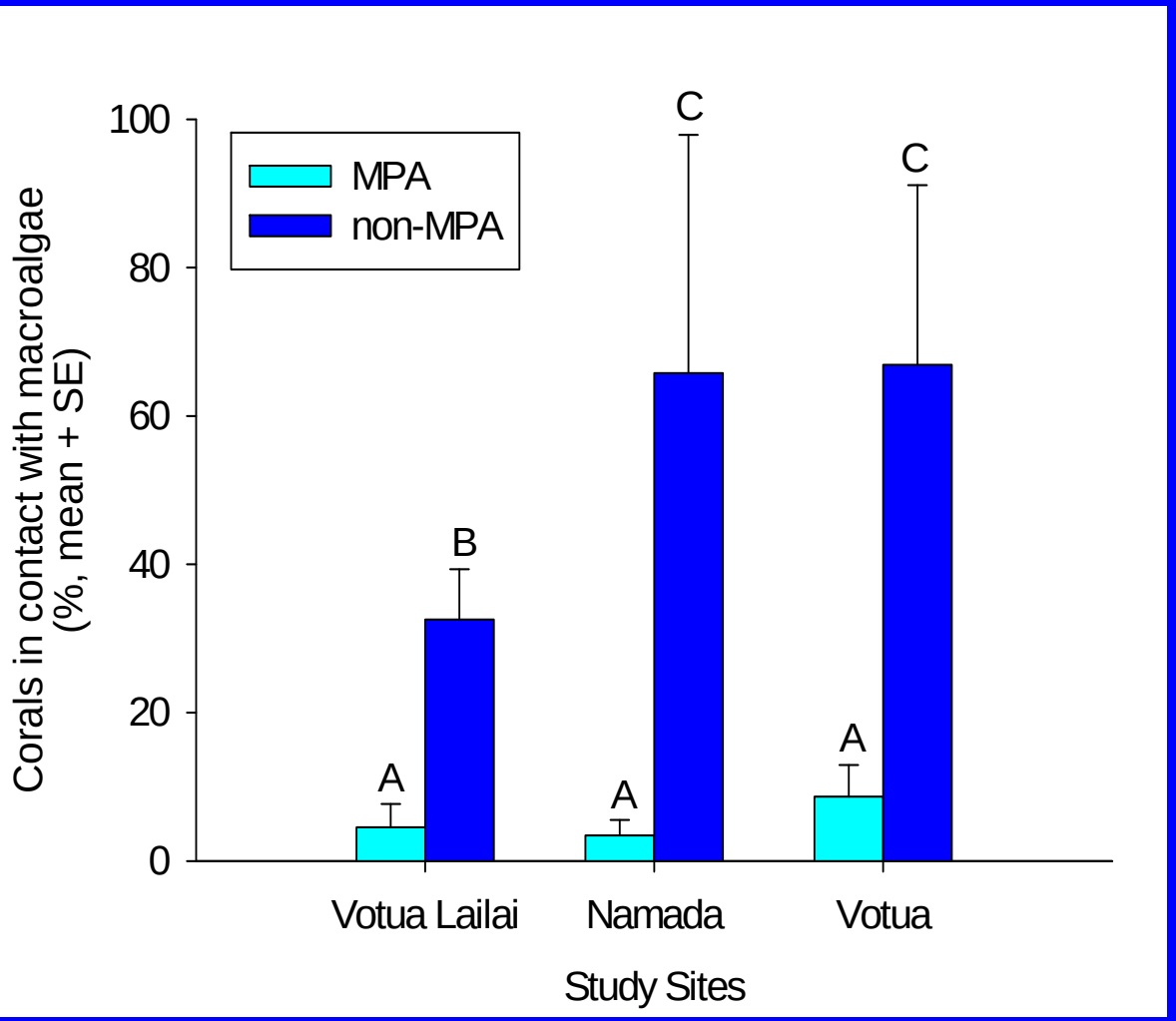
Dr. Roberta Bonaldo

Coral-algal interactions in fished vs protected areas?

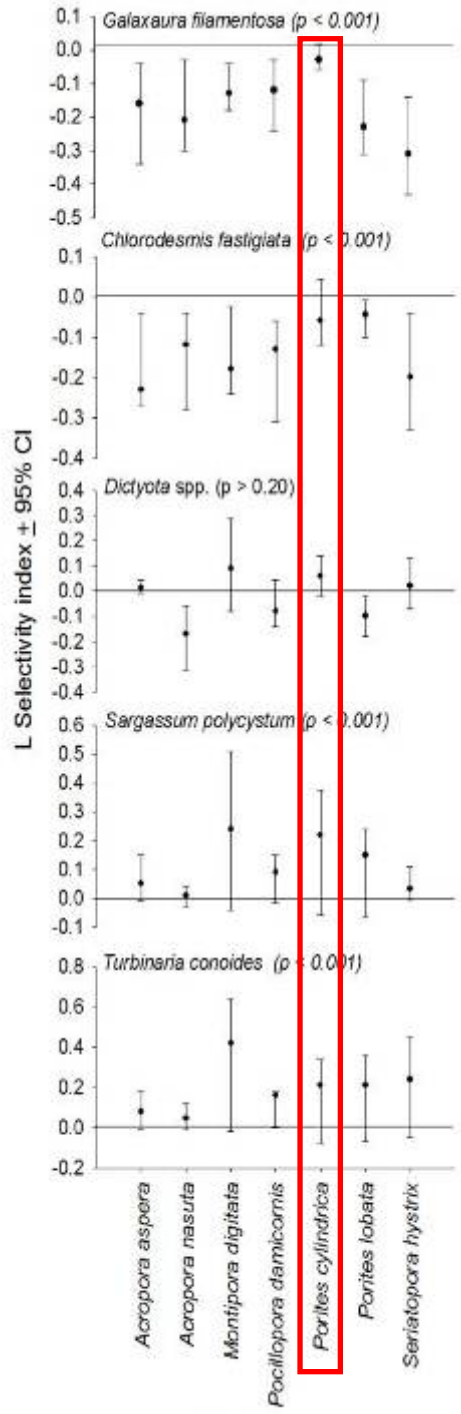


180 transects (30x4m) with 54,000 points to get % cover and frequency of coral-seaweed contacts

% coral colonies with macroalgal contacts



5-15x more contacts in the non-MPA areas



*

*

*

No association

Positive association

Negative association

* = allelopathic in previous assays

Feeding experiments

Sargassum polycystum

Turbinaria conoides

Padina boryana

Dictyota bartayresiana

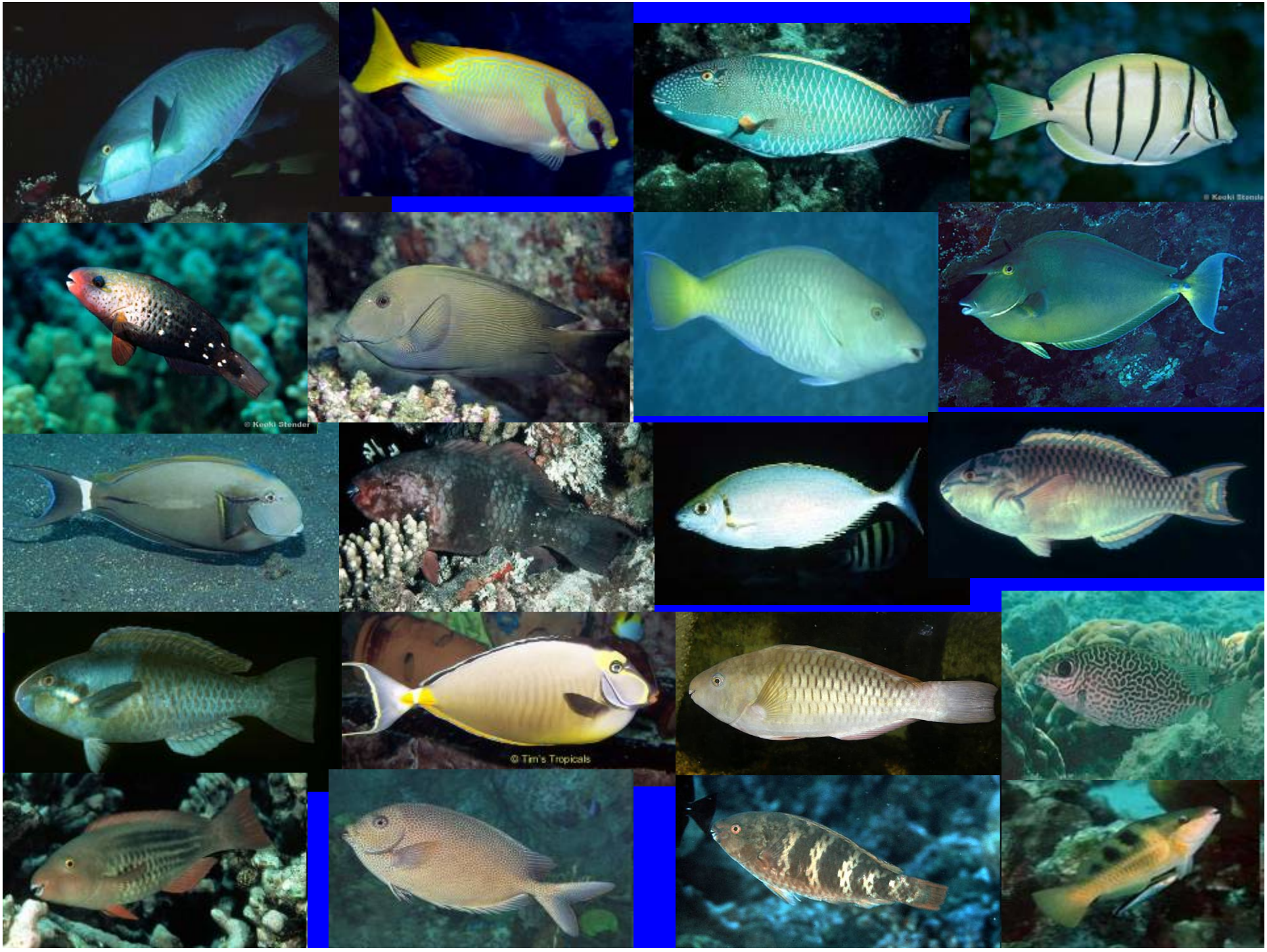
Amphiroa crassa

Galaxaura filamentosa

Liagora sp.

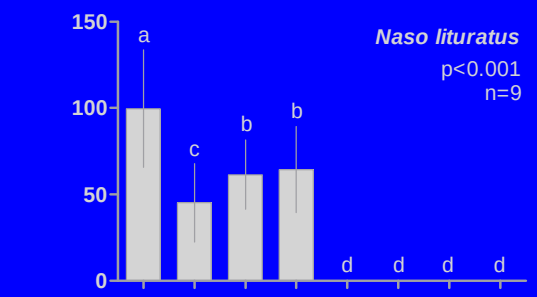
Chlorodesmis fastigiata.

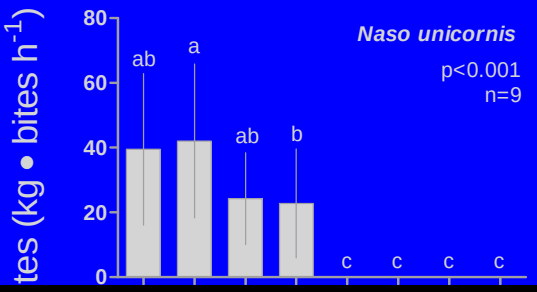
Ephemeral

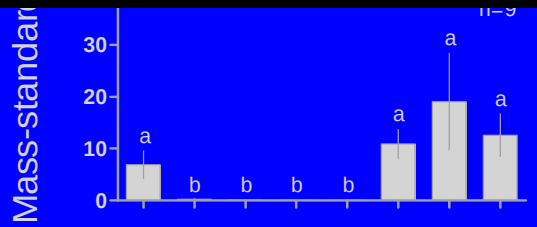

© Keoki Stender
© Tim's Tropicals

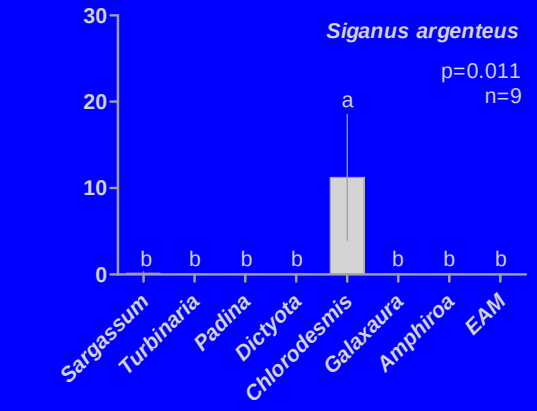

3 reserves
N=3 sites reserve-1
5 days site-1
Scored identity, size, # bites/alga
Standardized bites by mass

Macroalgal browsers









19,757 bites

97% bites from only 4 SPECIES

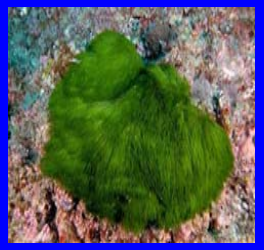
H_A: Complementarity is driven by differential herbivore tolerances to algal defenses

Eat

Avoid

Amphiroa crassa

Galaxaura filamentosa



Chlorodesmis fastigiata

Extract

Extract

Extract

Coat

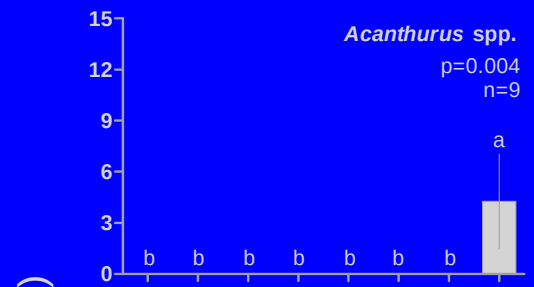
Vs.

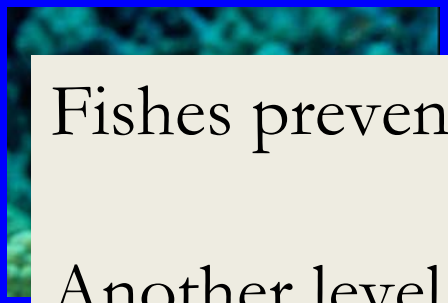
Solvent + extract

Solvent only

Differential effects of chemical defenses explained much of the among-herbivore variance in feeding

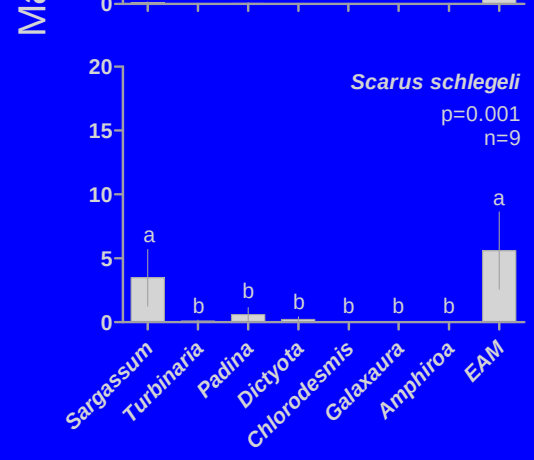
Substratum grazers





Fishes preventing vs. reversing phase-shifts are different

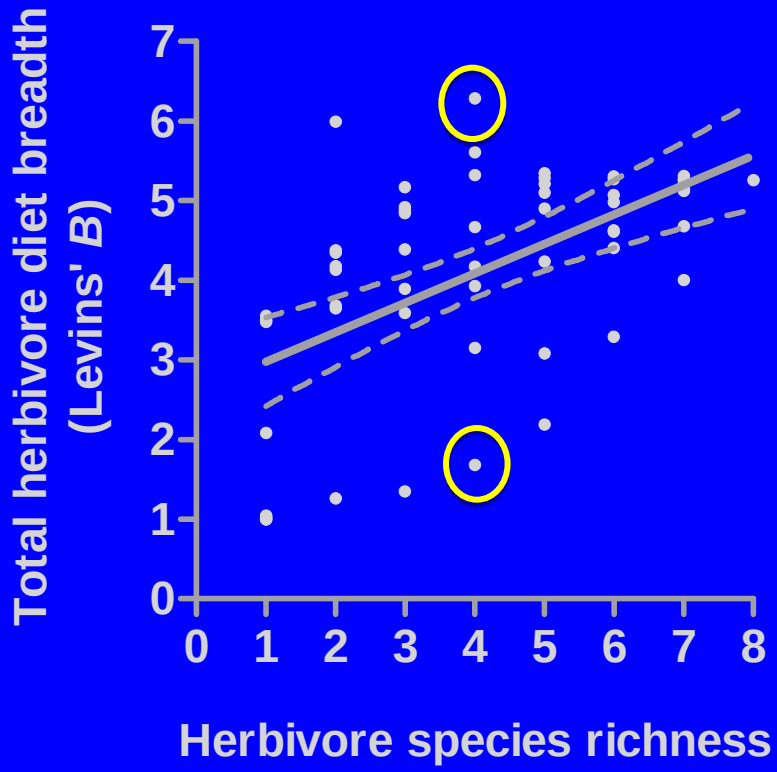
Another level of complementarity



4,999 bites on substratum

98% bites from only 5 SPECIES

Why is herbivore diversity *per se* important?



Why might some MPAs recover and others fail?

Increasing diversity ⟶
increasing # species with complementary feeding ⟶
increasing control of algae with differing defenses

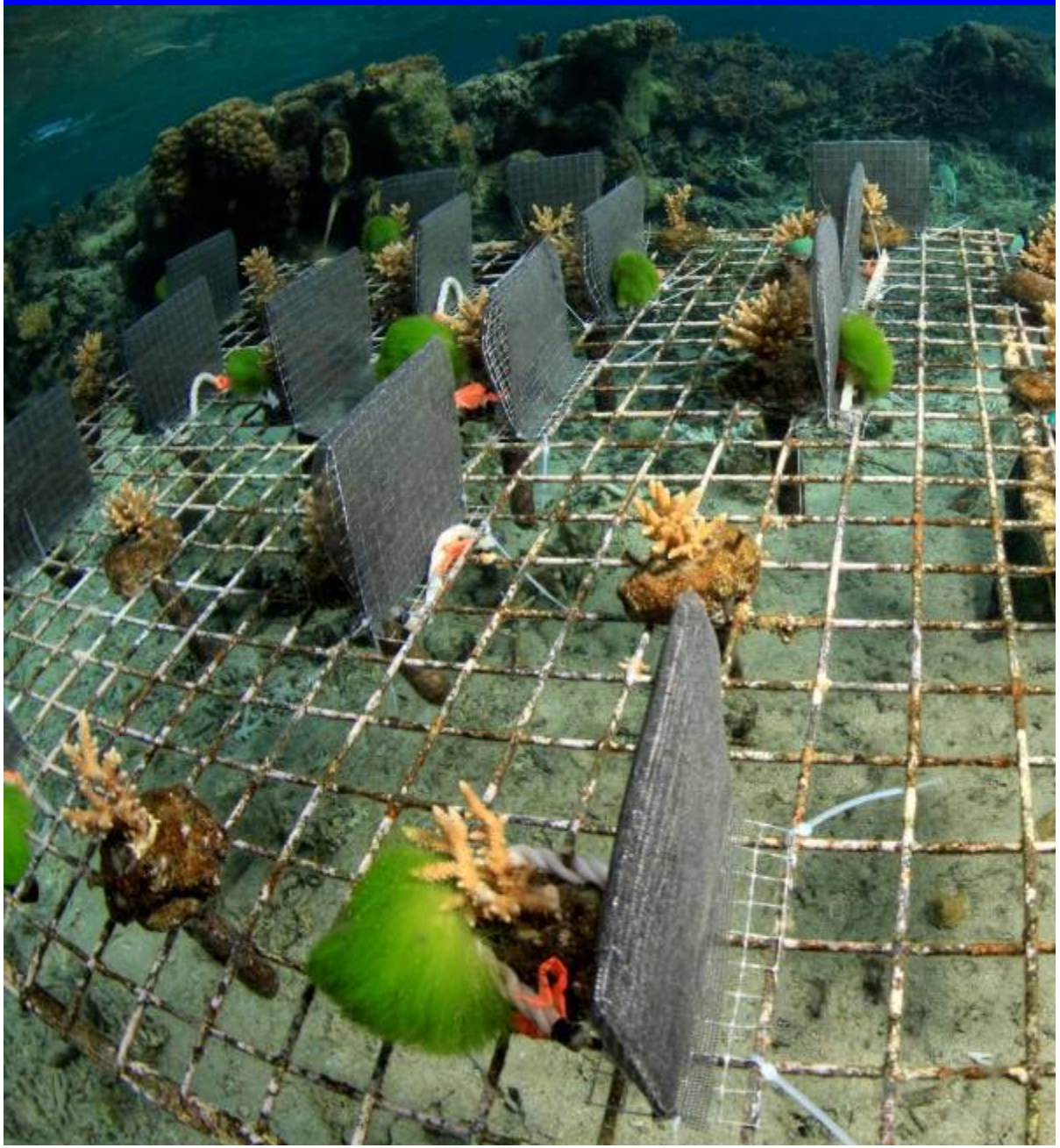
The Role of Herbivory

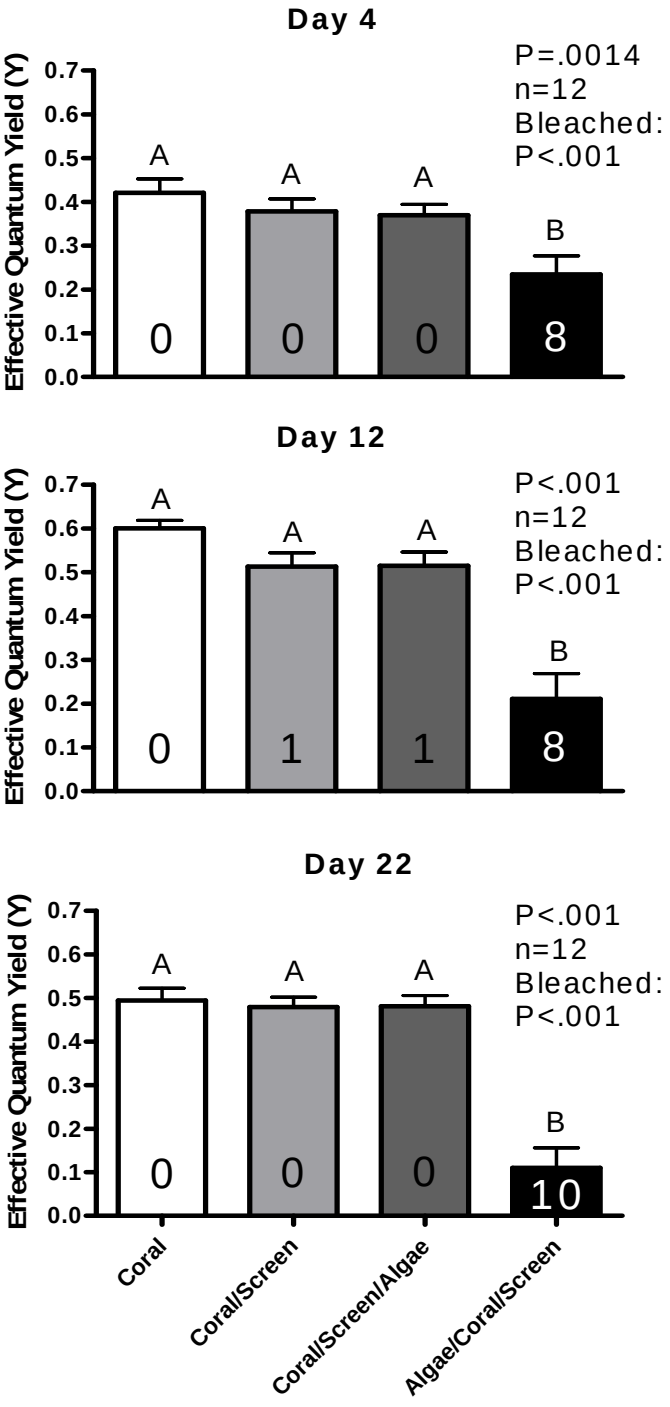
- Herbivores consumed all macrophytes, even chemically-rich, allelopathic species
- But, relatively few herbivores played key roles in this process
  - Some allelopathic algae consumed by only one species
- Algae vary in defenses against herbivores
- Herbivores vary in tolerances to differing algal defenses
- **Interaction between defenses and tolerances makes herbivore diversity *per se* essential to the suppression of macroalgae and reversal of phase-shifts**

Overall

- Allelopathy could reinforce phase-shifts on degraded coral reefs
- Herbivore functional diversity is required to suppress macroalgal effects on coral
- Secondary chemistry plays a key role in ecological processes that affect coral reef resilience (now, more about the compounds and their traits)

Damage ONLY on contact

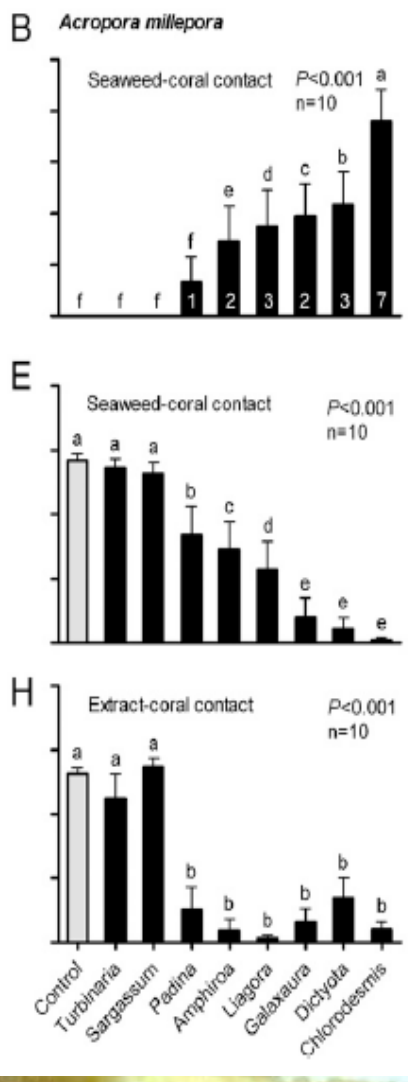




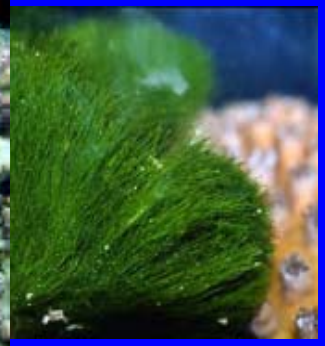
Can Corals Fight-Back?

- Induce resistance? (to some but not others)
- Corals induce seaweed susceptibility to herbivores? (to some but not others)
- **Recruit protective symbionts to "guard" the coral? (coral goby)

Dr. Danielle Dixson


B
Acropora millepora
Seaweed-coral contact
P<0.001
n=10
f f f 1 2 3 2 3 7
a b c d e f
E
Seaweed-coral contact
P<0.001
n=10
a a a b c d e e e
H
Extract-coral contact
P<0.001
n=10
a a a b b b b b b
Control
Turbinaria
Sargassum
Padina
Amphiroa
Liagora
Galaxaura
Dictyota
Chlorodesmis

Put Coral (*Acropora nasuta*) and *Chlorodesmis* together w/ and w/o symbionts



Impact of symbionts on the interaction?

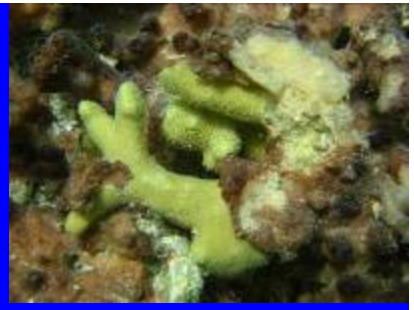
Water Column control

- Control
- Juncture
- Juncture w/ seaweed removed for 20 min
- Seaweed

- Fish reaction?

- Gobies defend their host by removing allelopathic seaweed
- The coral sends a signal to the goby to initiate defense based on chemical recognition of the seaweed (an evolved response based on an historic problem?)
- It does this within 5-15 minutes of contacting the seaweed chemistry
- Gobies are effective in reducing seaweed contact with the coral and thus damage to the coral.
- Gobies and corals = marine ant-plants

Overall



- Seaweed allelopathy to corals is common (probably not evolved for this function – antimicrobial defenses?)
- Allelopathy is due to lipid-soluble metabolites on seaweed surfaces – contact is required
- MPAs can advantage corals over seaweeds
- Herbivory by fishes can suppress seaweed-coral contact and advantage corals (this depends on herbivore diversity at a reef scale and symbiotic relationships at a colony scale - the gobies)
- MPAs are unlikely to be “enough”
- Fished areas need to be managed to enhance their receptivity to larvae from MPAs and to enhance spill-over possibilities

Phenotype-Environment Mismatch

Rescue effects of MPAs seem unlikely because larvae selected for A are unlikely to be adapted well for B. Fished areas need to be managed to enhance their receptivity to larvae from MPAs and to enhance spill-over possibilities.

The End