Catastrophic Mortality on Inshore Reefs of the Florida Keys: Cold-Water Physiology of Three Common Reef-Building Corals

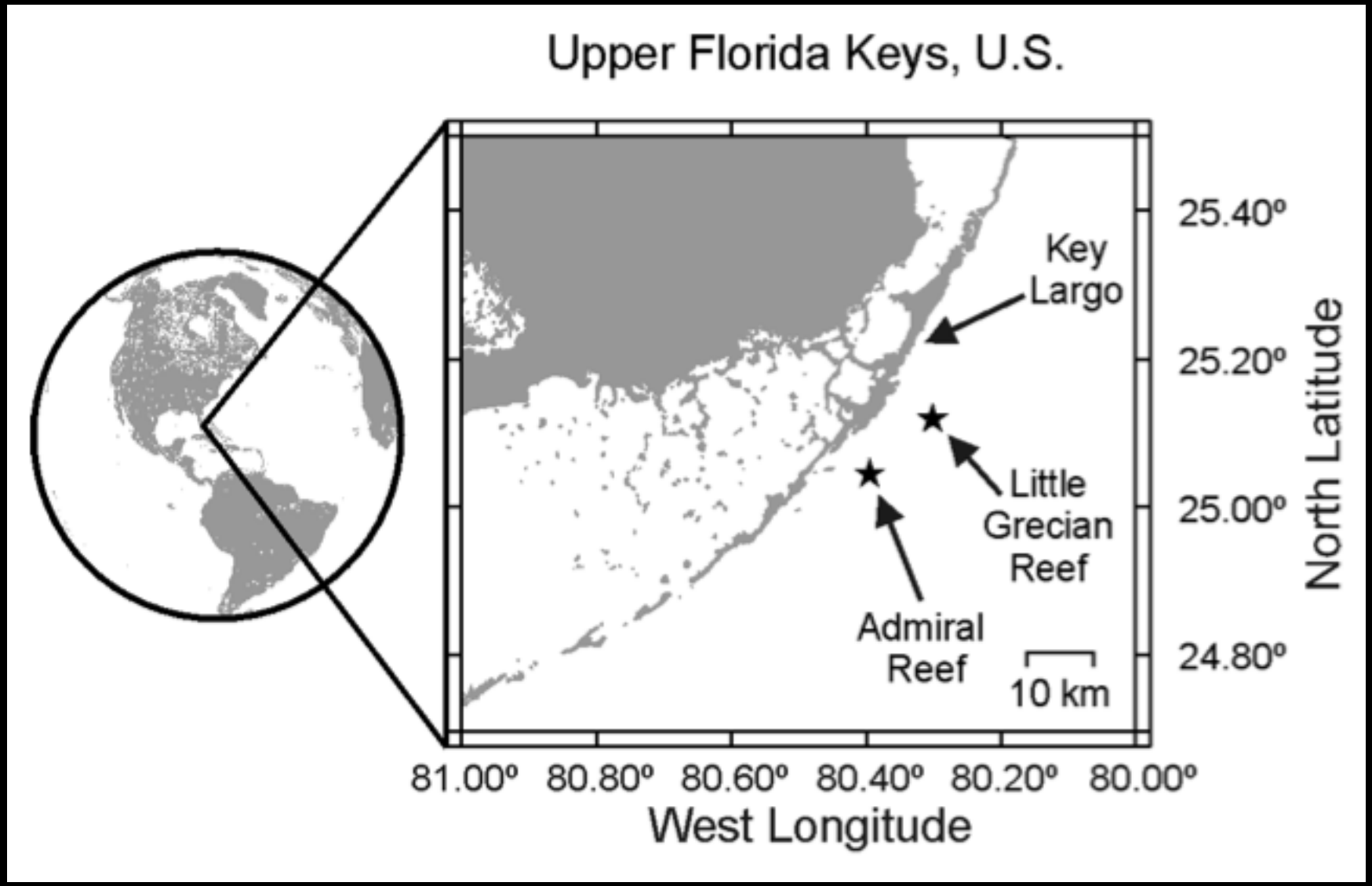
Dustin W. Kemp [1], Clint A. Oakley [2], Daniel Thornhill [3], Gregory W. Schmidt [2], William K. Fitt [1]

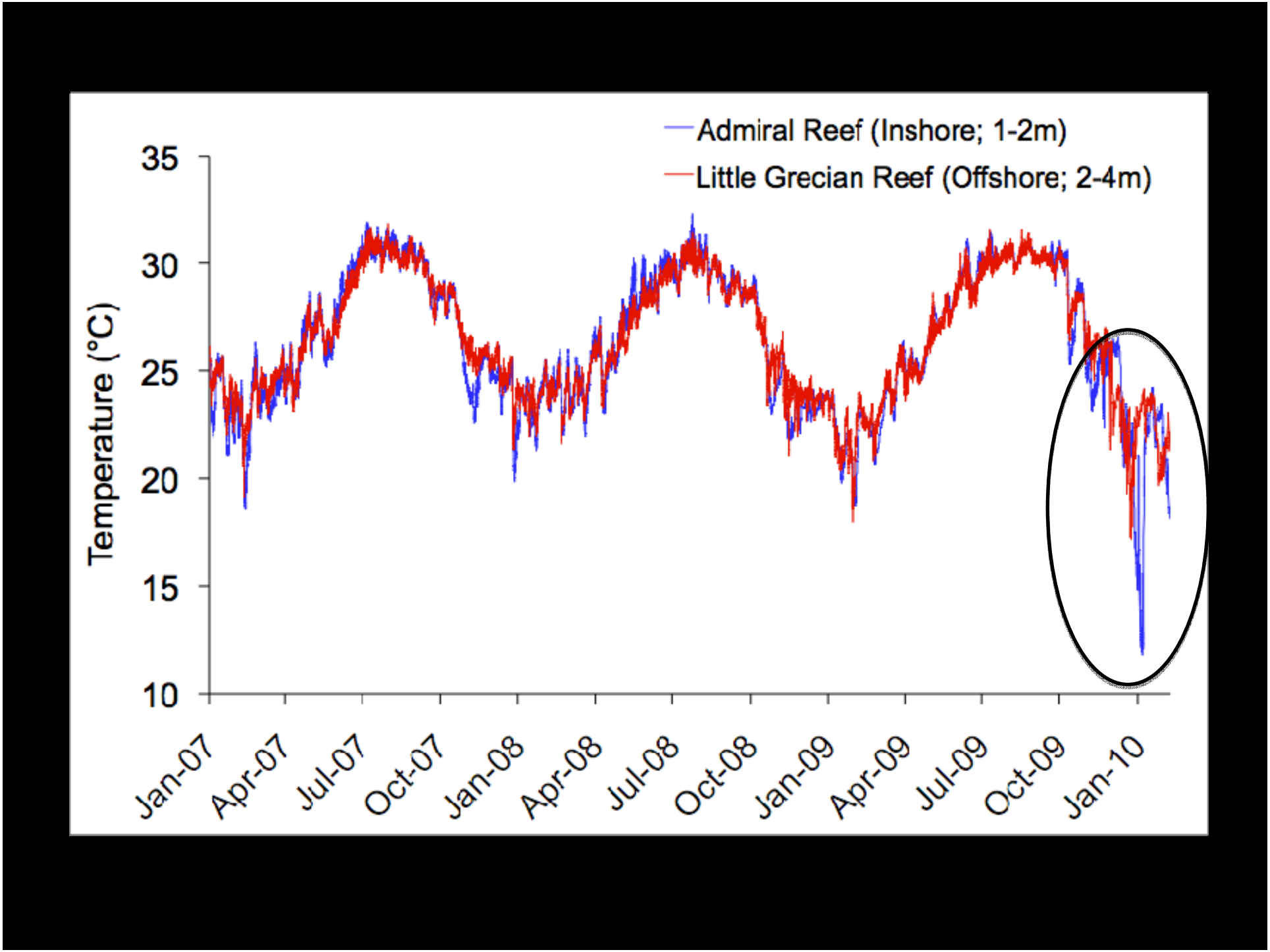
[1] Odum School of Ecology
University of Georgia

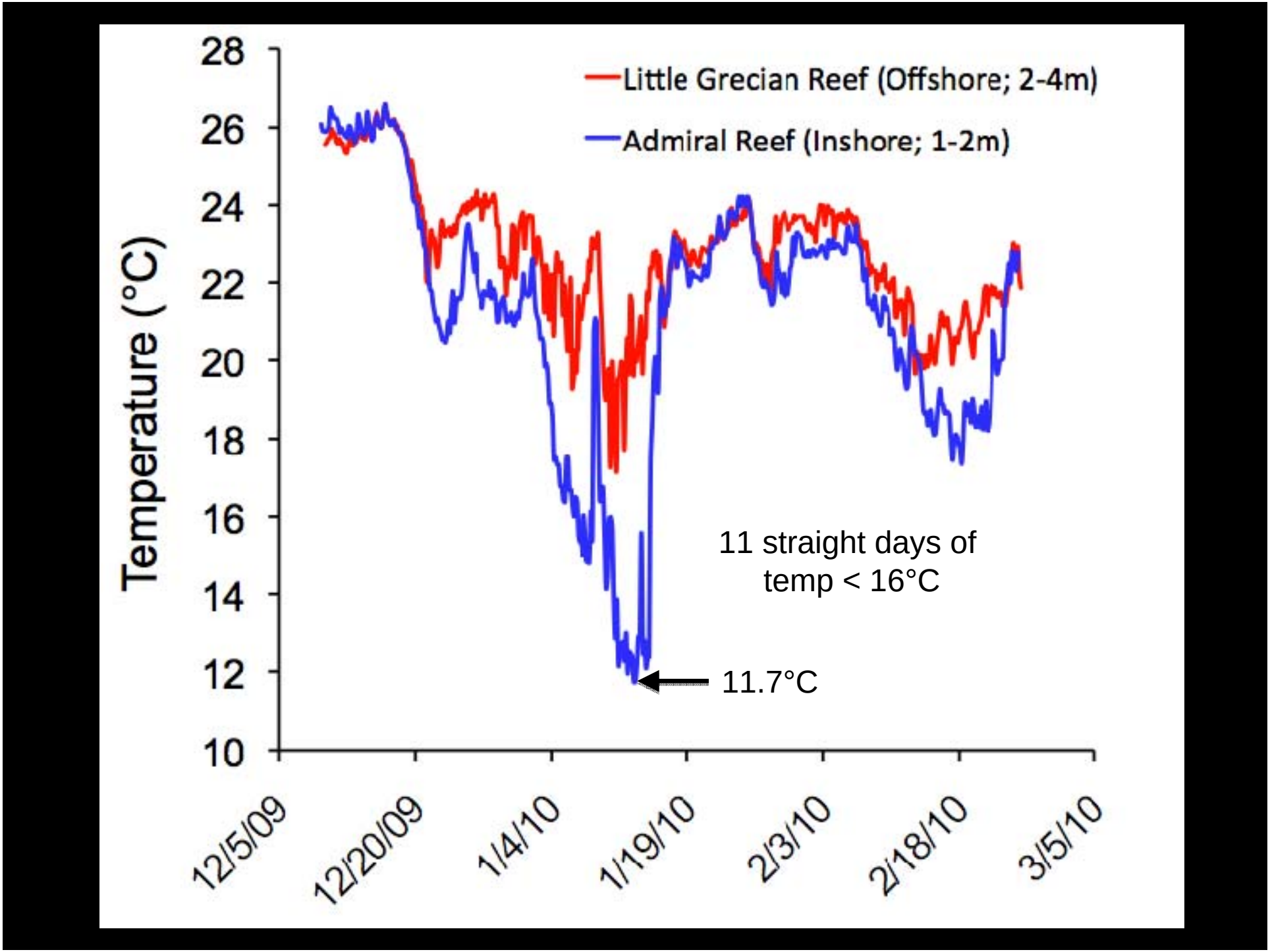
[2] Department of Plant Biology
University of Georgia

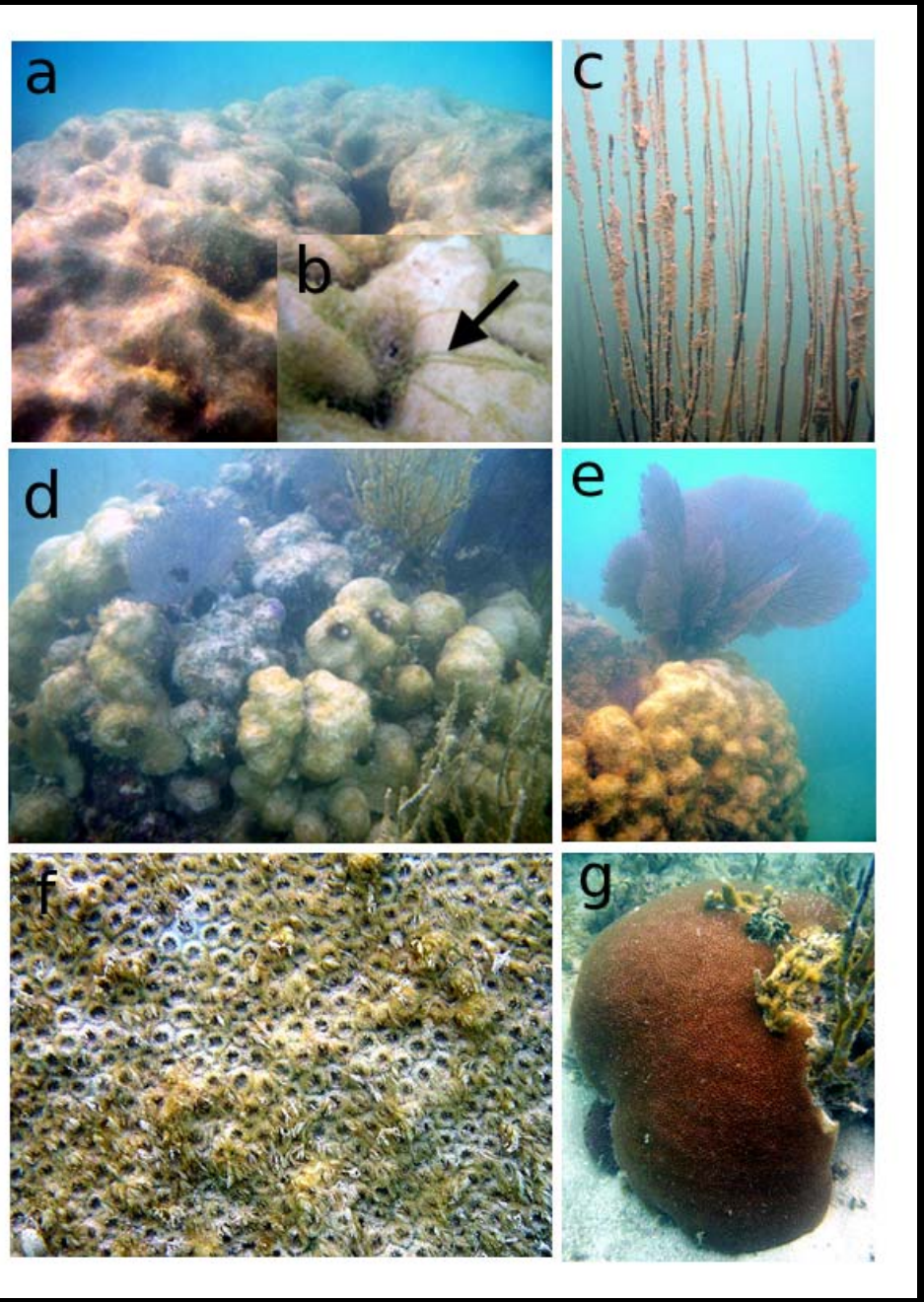
[3] Department of Biology
Bowdin College

DKemp1@uga.edu


Upper Florida Keys, U.S.
Key Largo
Little Grecian Reef
Admiral Reef
10 km
25.40º
25.20º
25.00º
24.80º
North Latitude
81.00º
80.80º
80.60º
80.40º
80.20º
80.00º
West Longitude

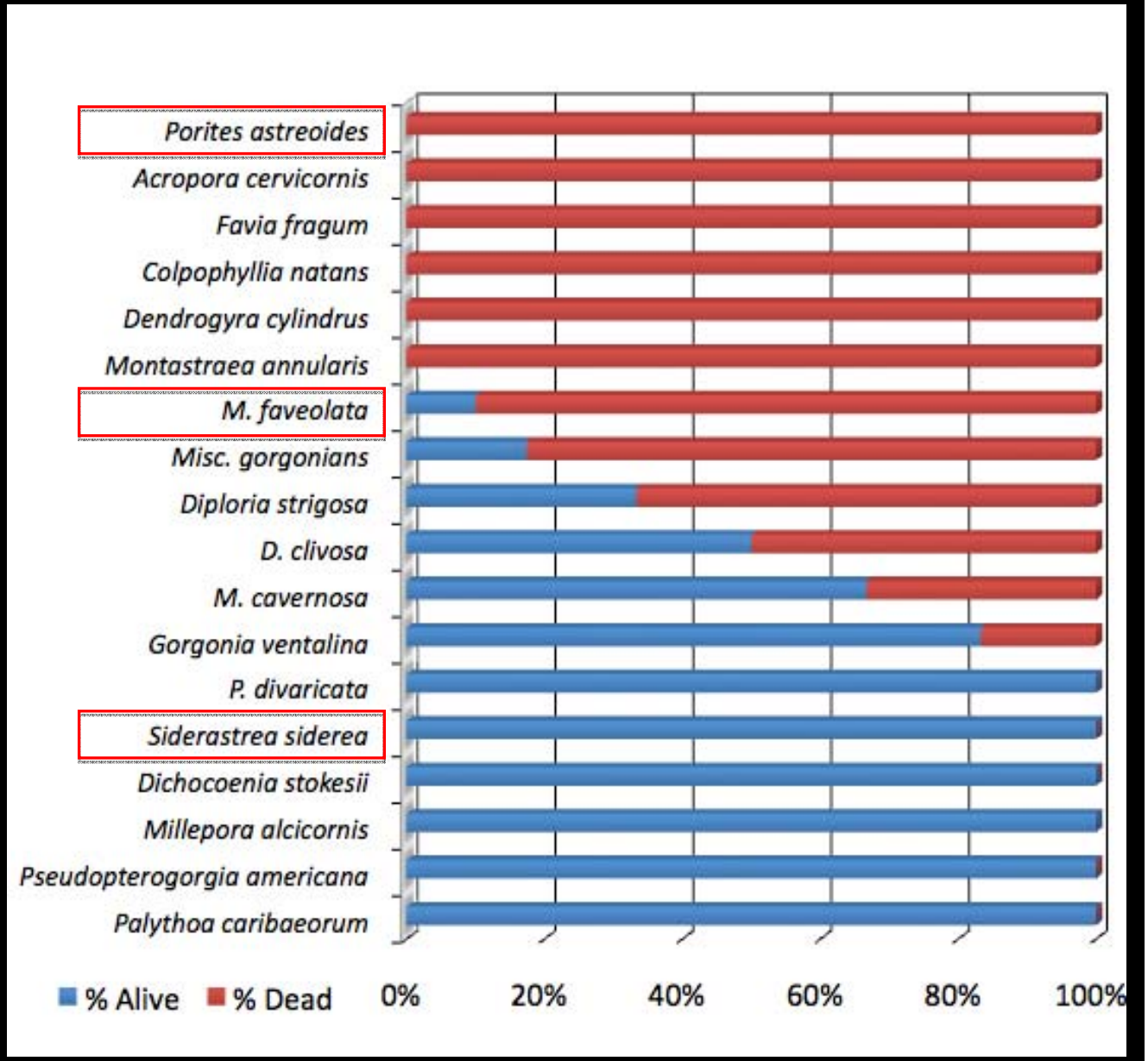

Admiral Reef (Inshore; 1-2m)
Little Grecian Reef (Offshore; 2-4m)
Temperature (°C)
35
30
25
20
15
10
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08
Oct-08
Jan-09
Apr-09
Jul-09
Oct-09
Jan-10


Little Grecian Reef (Offshore; 2-4m)
Admiral Reef (Inshore; 1-2m)
Temperature (°C)
28
26
24
22
20
18
16
14
12
10
11 straight days of
temp < 16°C
11.7°C
12/5/09
12/20/09
1/4/10
1/19/10
2/3/10
2/18/10
3/5/10


a
b
c
d
e
f
g

Admiral Reef Surveys

- Conducted one month after cold-water event
  - *Six 10 m^2 iinear transects
- NO coral mortality detected from offshore reefs (Little Grecian).

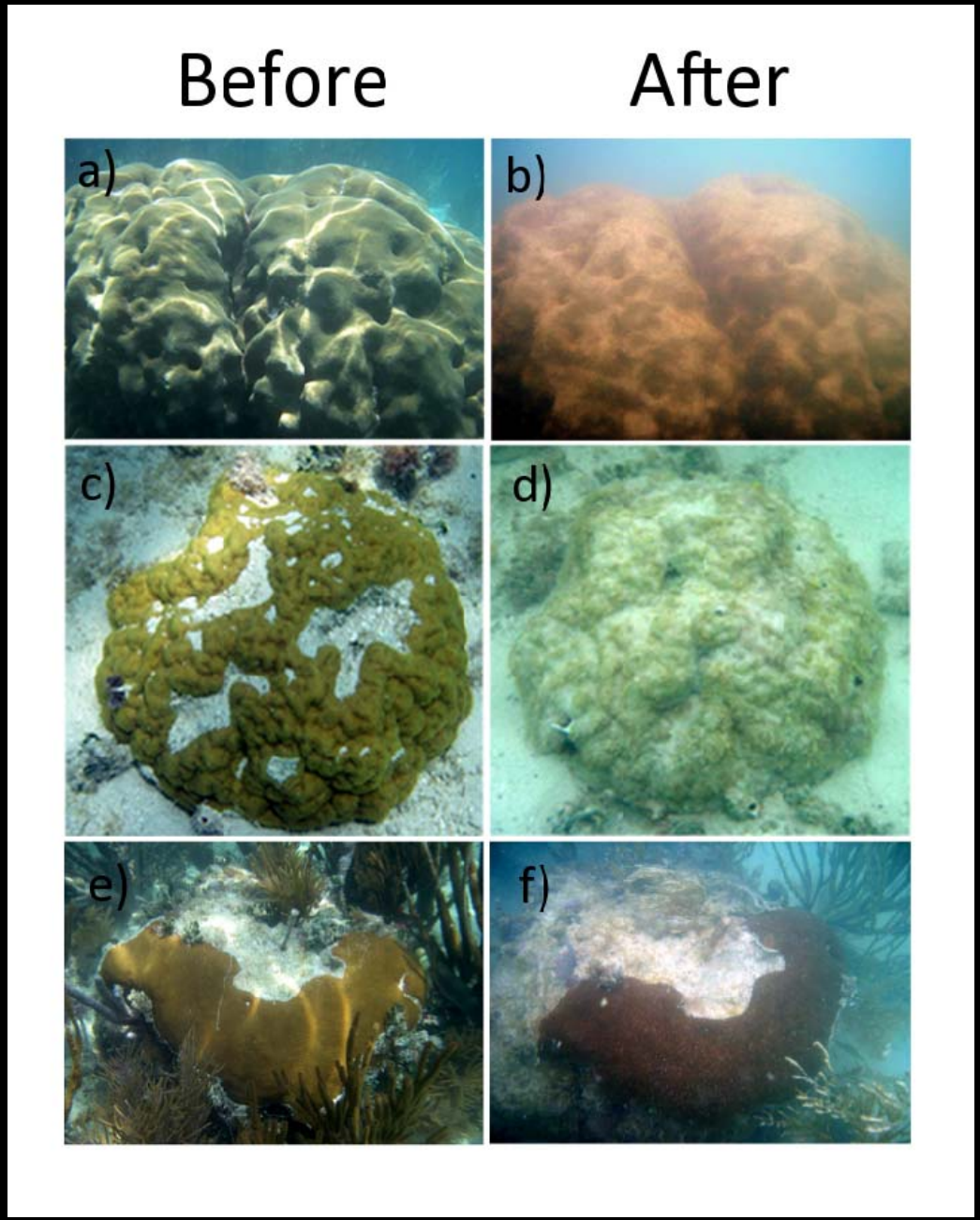


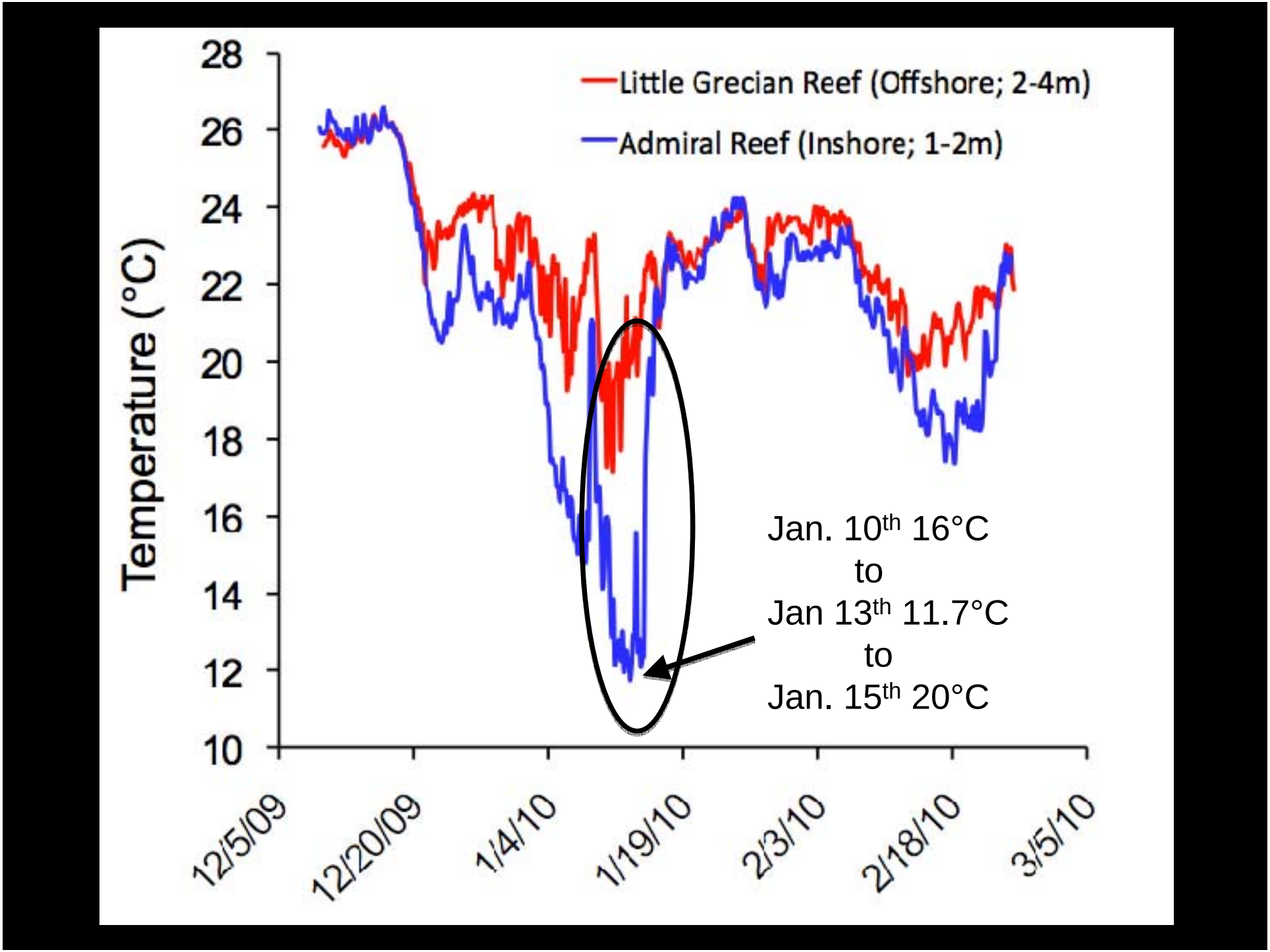
Research Goals:

1)Evaluate the physiology of the “winners” and the “losers”

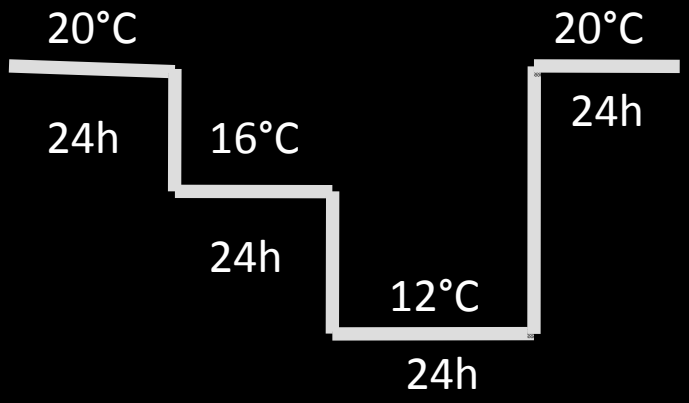
2)Analyze the effect cold stress has on the coral animal and their endosymbiotic algae.

Admiral Reef (Inshore)	Little Grecian Reef (Offshore)
Siderastrea siderea	*Siderastrea siderea*
	Porites astreoides
	Montastraea faveolata




Little Grecian Reef (Offshore; 2-4m)
Admiral Reef (Inshore; 1-2m)
Temperature (°C)
28
26
24
22
20
18
16
14
12
10
12/5/09
12/20/09
1/4/10
1/19/10
2/3/10
2/18/10
3/5/10
Jan. 10th 16°C
to
Jan 13th 11.7°C
to
Jan. 15th 20°C

Physiological Parameters



Coral-Zooxanthellae Parameters

- Zooxanthellae densities (cm^{-2})
- Chlorophyll *a* density (cm^{-2} and $cell^{-1}$)

Zooxanthellae Genetic Identity

- *Symbiodinium* ITS2-type (Denature Gradient Gel Electrophoresis)
- No shift or switch in *Symbiodinium* detected

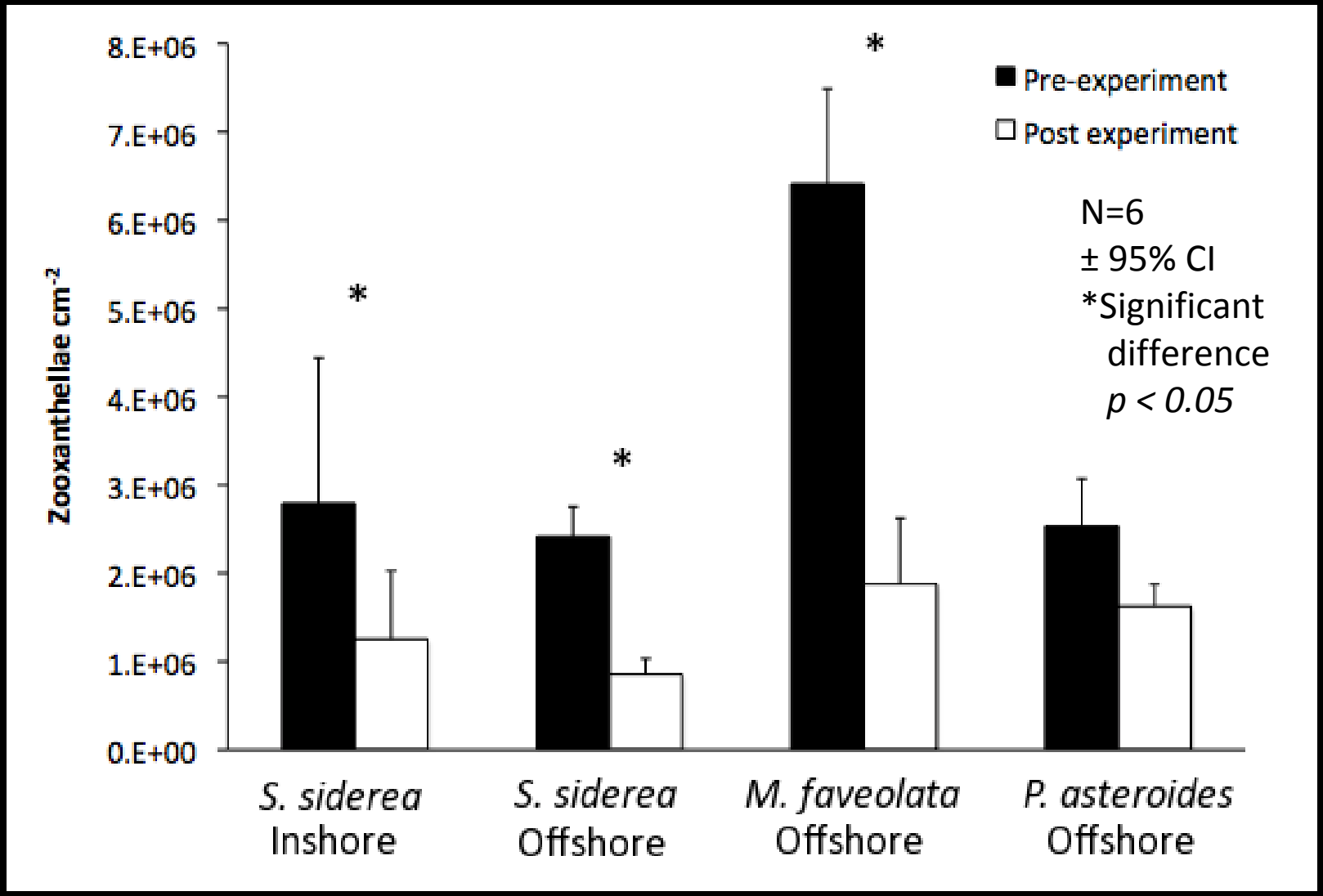
Coral-Zooxanthellae Oxygen Flux

- Gross Photosynthesis (at saturating irradiance)
- Dark Respiration (O_2 consumption)

Maximum Photosynthetic Capacity

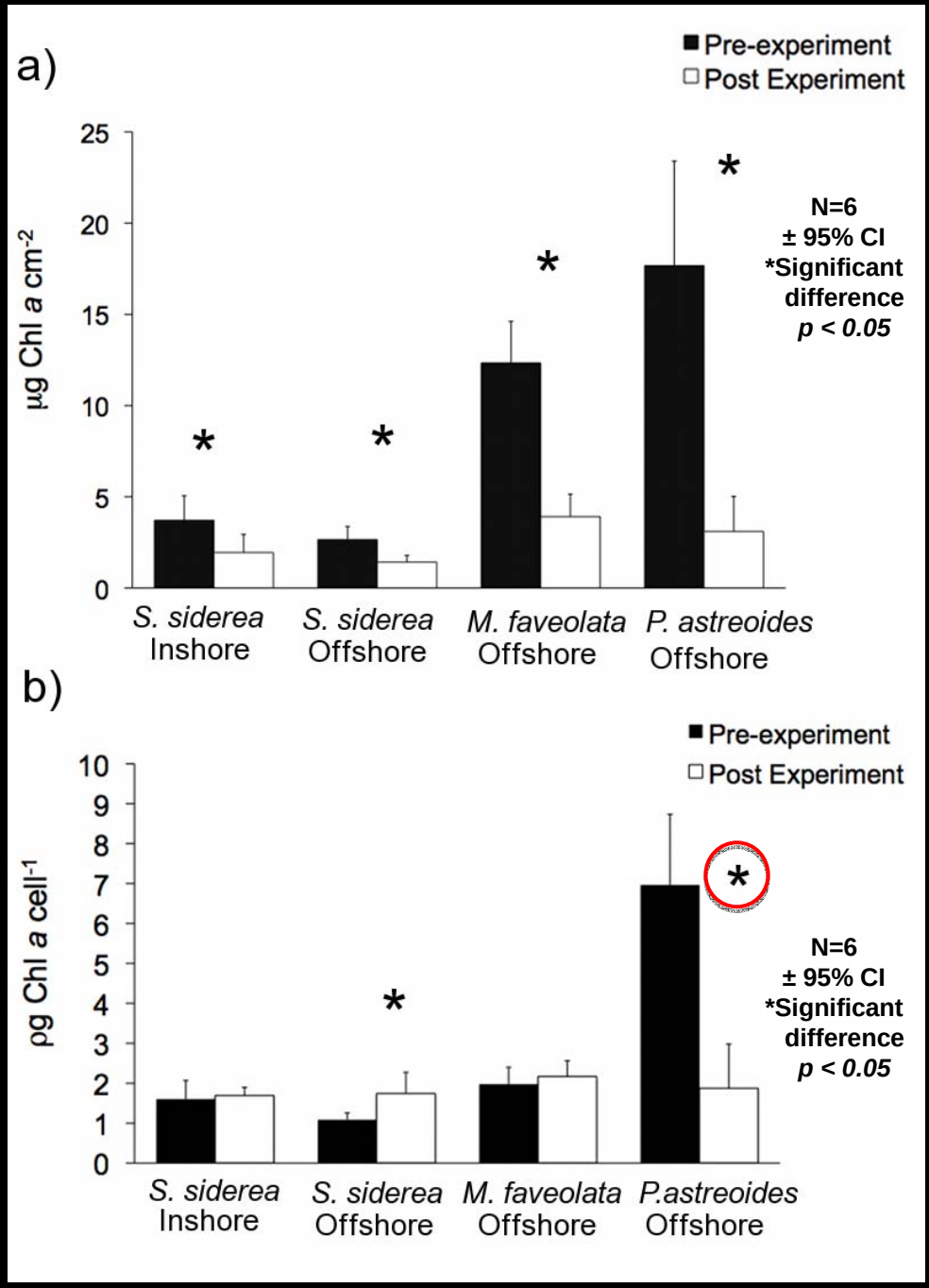
- Dark acclimated photosynthetic yields (Fv/Fm; PAM fluorometry)

Zooxanthellae cell densities

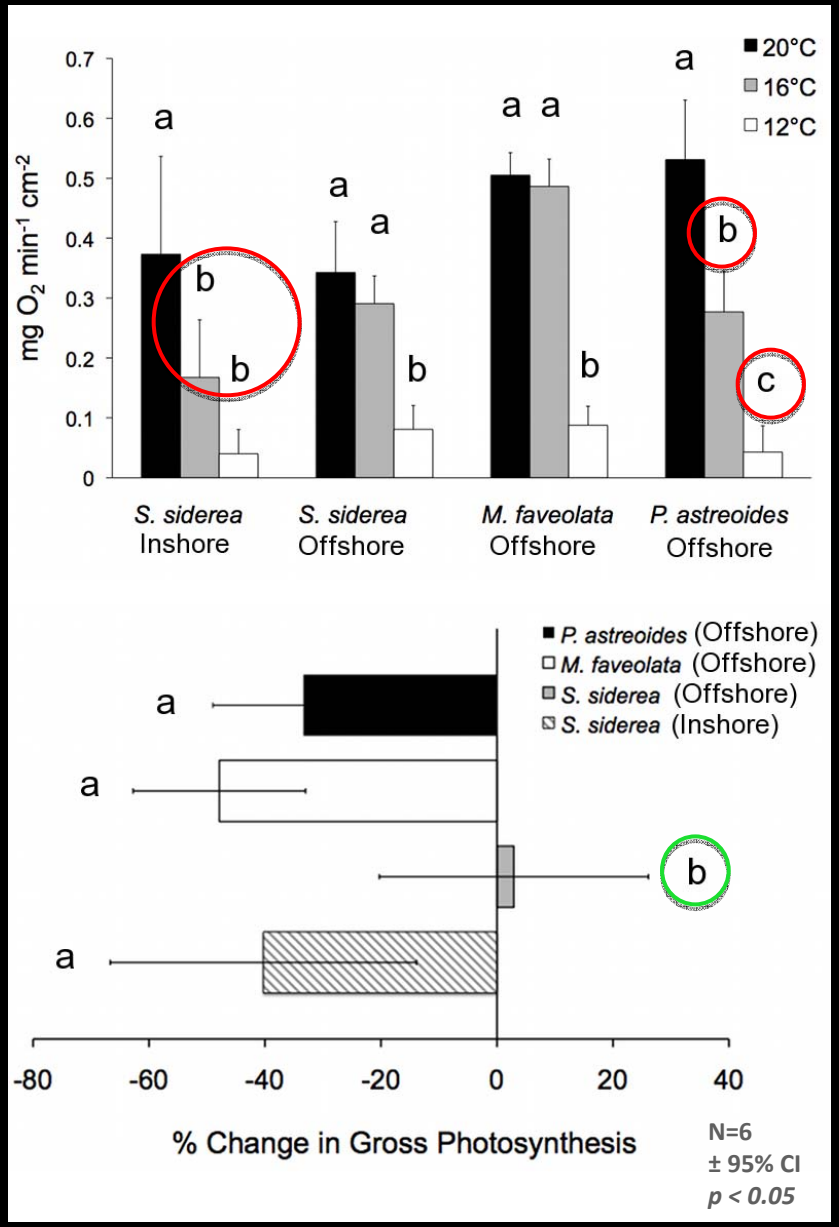


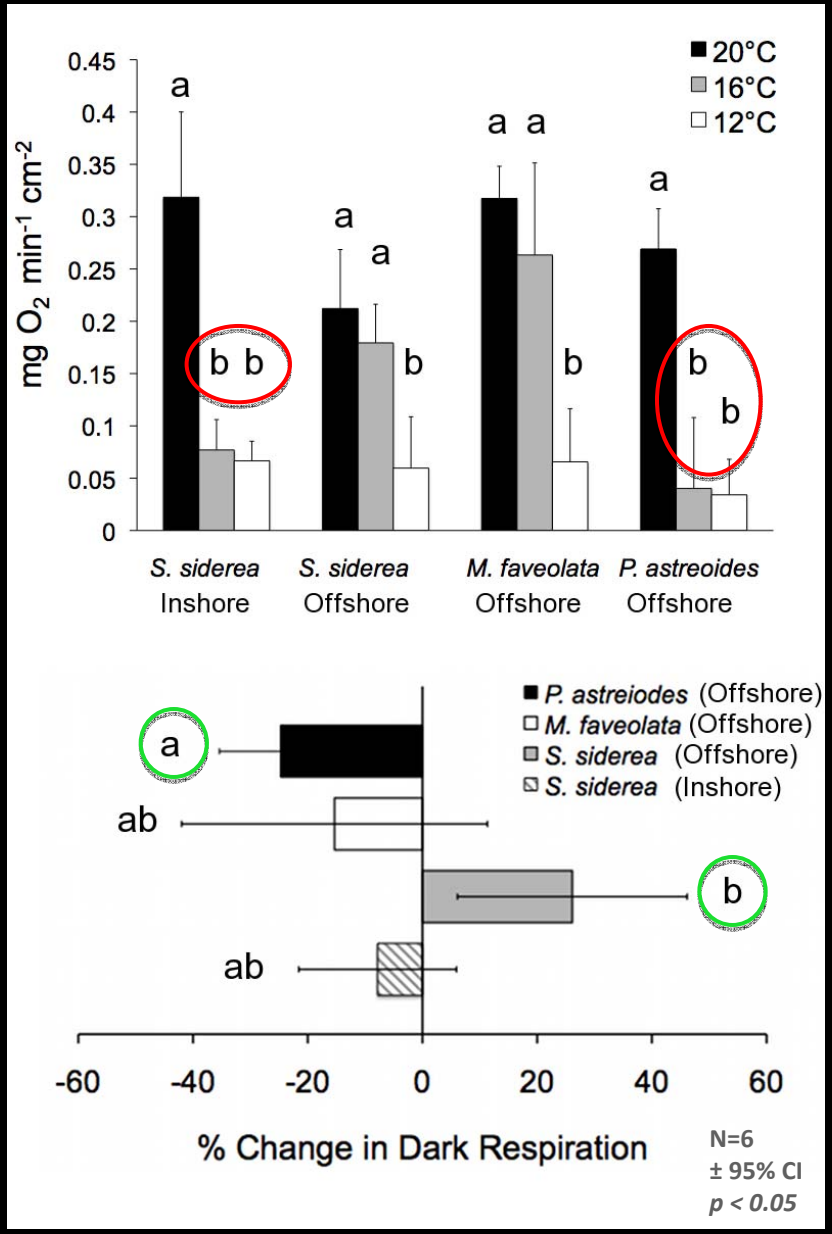
Chlorophyll
Coral surface area (cm^{-2})

Chlorophyll
Zooxanthellae $cell^{-1}$



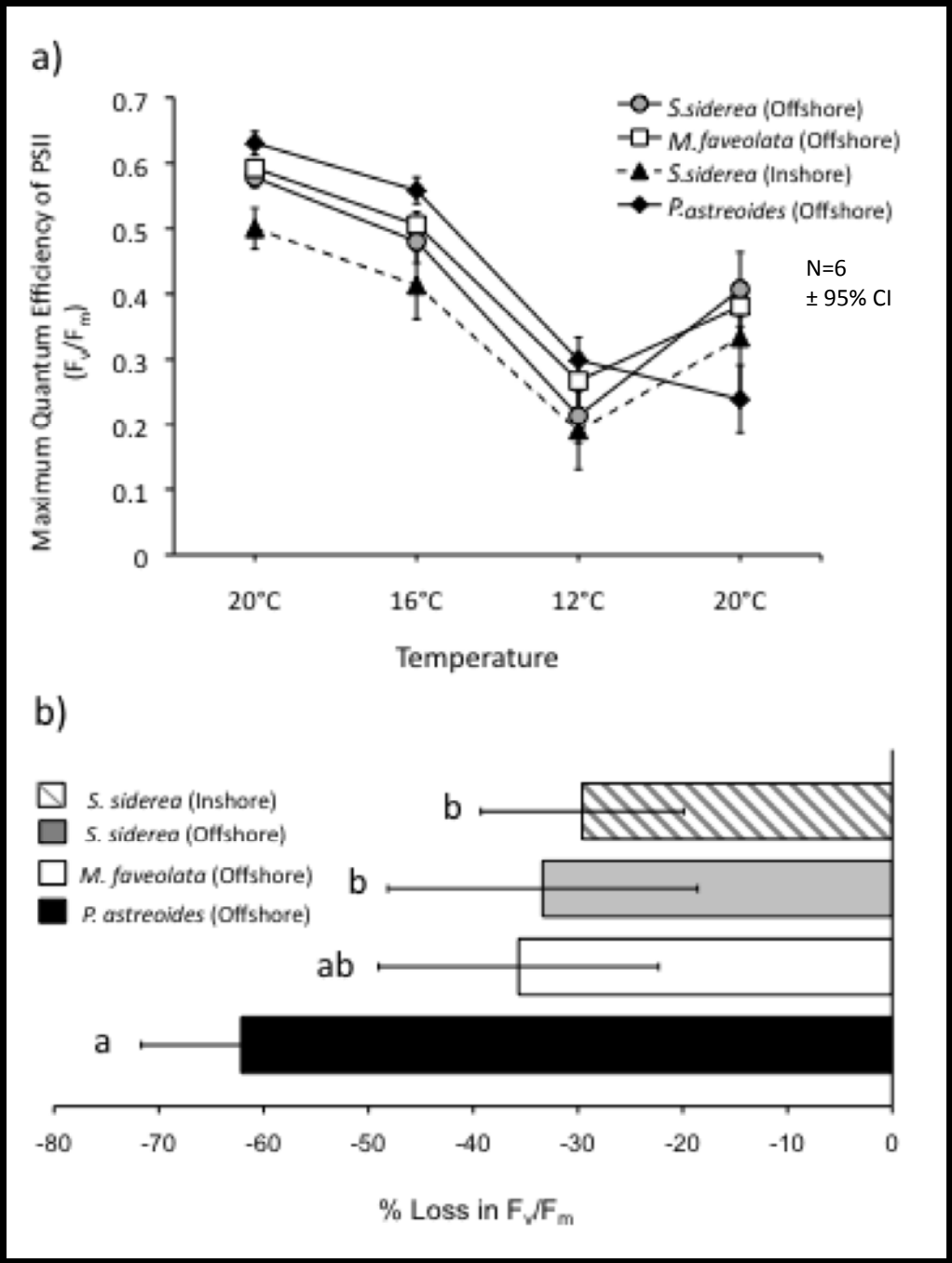
Oxygen Flux


20°C
16°C
12°C
mg O_2 min^{-1} cm^{-2}
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
a
b
b
a
a
b
a a
b
b
a
b
c
S. siderea Inshore
S. siderea Offshore
M. faveolata Offshore
P. astreoides Offshore
P. astreoides (Offshore)
M. faveolata (Offshore)
S. siderea (Offshore)
S. siderea (Inshore)
a
a
b
a
-80
-60
-40
-20
0
20
40
% Change in Gross Photosynthesis
N=6
± 95% CI
p < 0.05


20°C
16°C
12°C
mg O_2 min^{-1} cm^{-2}
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
a
b b
a
a
b
a a
b
a
b
b
S. siderea Inshore
S. siderea Offshore
M. faveolata Offshore
P. astreoides Offshore
P. astreiodes (Offshore)
M. faveolata (Offshore)
S. siderea (Offshore)
S. siderea (Inshore)
a
ab
b
ab
-60
-40
-20
0
20
40
60
% Change in Dark Respiration
N=6
± 95% CI
p < 0.05

Photosynthetic Efficiency of Photosystem II (Fv/Fm)

Pulse Amplitude Modulated Fluorometer
AKA: PAM Fluorometer



Experimental Results

Coral-Zooxanthellae Parameters

- All corals except *P. astreoides* (Offhore) lost significant amounts of zooxanthellae
- All corals lost significant amounts of Chlorophyll *a* cm^{-2}
- Only *P. astreoides* (Offhore) lost significant Chl *a* $cell^{-1}$
- No detectable genetic change in zooxanthellae

Coral-Zooxanthellae Oxygen Flux

- Species-specific response to cold temperature.
  - *P. astreoides* and *S. siderea* (Inshore) where negatively affected at 16°C
  - *S. siderea* (Offshore) and *M. faveolata* (Offshore) were not affected at 16°C

Maximum Photosynthetic Capacity

- All corals showed significant decrease in photosynthetic yield at 12°C.
- All corals showed recovery in photosynthesis EXCEPT *P. asteriodes*

Experimental Results Summary

Coral-Zooxanthellae Parameters (Yes = $p<0.05$)

	S. siderea (Inshore)	*S. siderea* (Offshore)	*M. faveolata* (Offshore)	*P. astreoides* (Offshore)
Zooxanthellae (cm^{-2})	Yes	Yes	Yes	No
Chlorophyll (cm^{-2})	Yes	Yes	Yes	Yes
Chlorophyll ($cell^{-1}$)	No	No	No	Yes

Coral-Zooxanthellae Oxygen Flux from 20°C to 16°C (Yes = $p<0.05$)

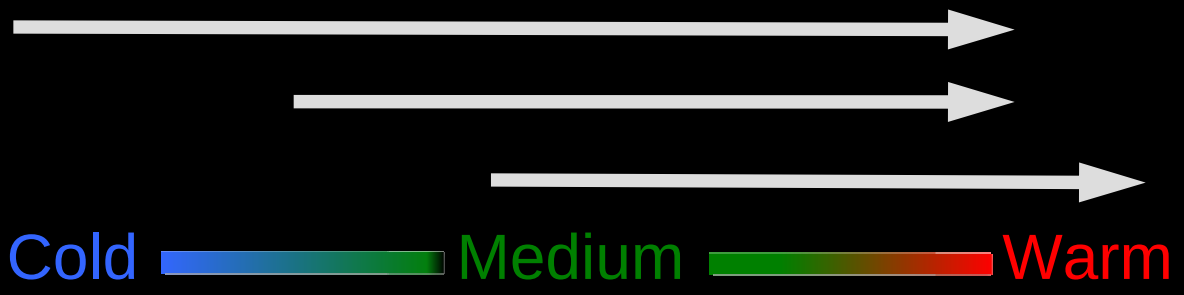
	S. siderea (Inshore)	*S. siderea* (Offshore)	*M. faveolata* (Offshore)	*P. astreoides* (Offshore)
Gross Photosynthesis	Yes	No	No	Yes
Dark Respiration	Yes	No	No	Yes

Siderastrea siderea possible explanations:

1. Already had experienced a cold-water stress
2. Have genetically different zooxanthellae

Hierarchy of thermal tolerance?

S. siderea
M. faveolata
P. astreoides



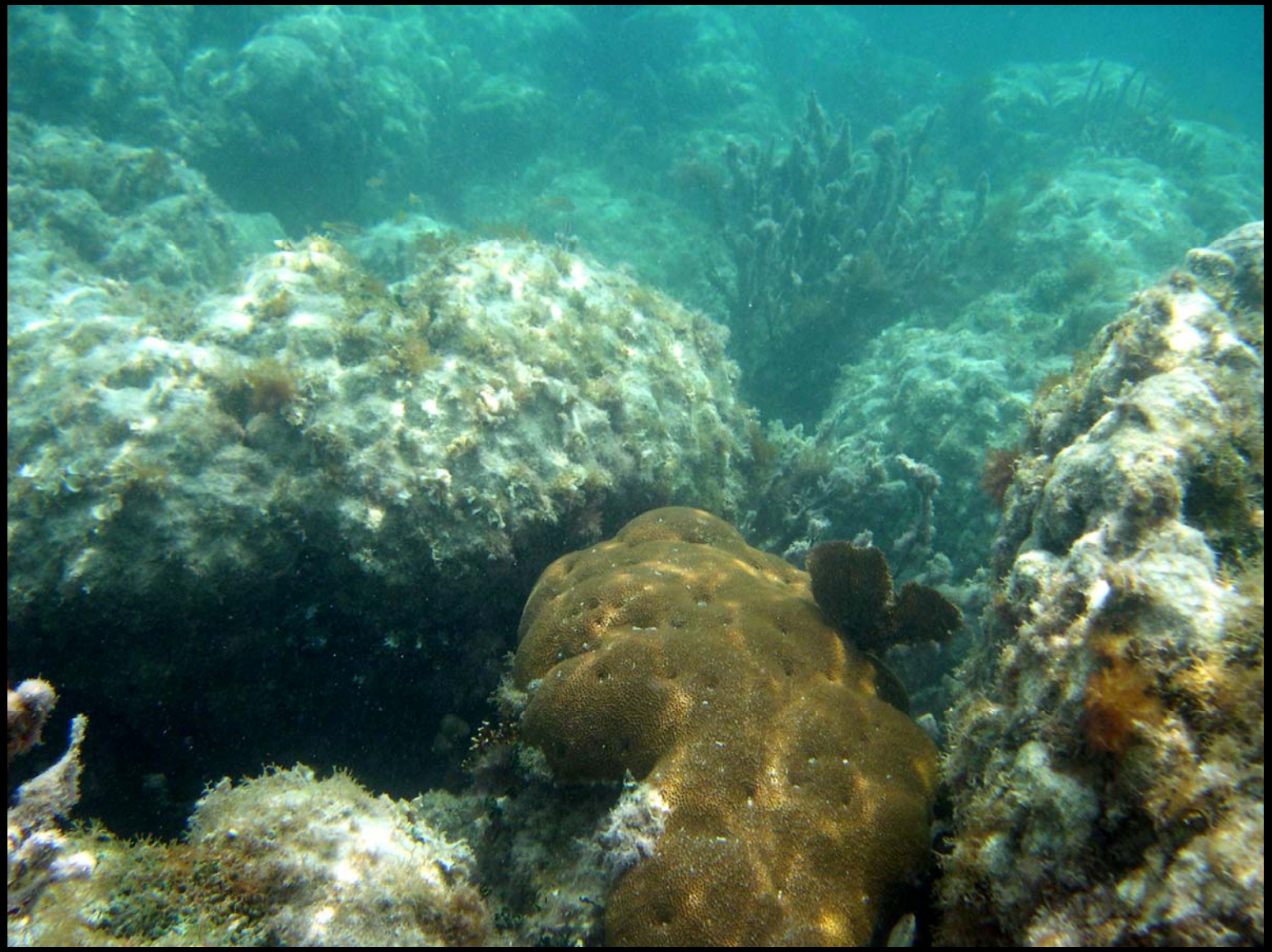
Physiological Mechanisms ?

Is it the animal or the alga?

Probably both…but we clearly document in *P. astreoides*

1) Loss of Chl *a* (cm^{-2} and $cell^{-1}$)
2) Reduction in Photosynthesis
3) Increased Photo-damage
4) ONLY tested coral that has type A4a zooxanthellae

A.G. Mayor



Admiral Reef 2008 = 24% coral coverage*

2010 < 1% coral coverage

*CREMP

Cold water anomaly broader impacts:

Are the “winners” really “winners”?

Duration to the exposed stressor is key to the physiological response and recovery potential of coral

Corals cold-water response are similar to physiological responses to warm-water stressors

- Loss in zooxanthellae
- Loss in Chl *a*
- Loss in photosynthesis
- Photodamage

Not sure if cellular and biochemical responses are similar to warm-water stress …but

Overall outcome is LESS NET CARBON FIXED.

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