

Conference on Coral Reefs, Climate, & Coral Bleaching  
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# Coral reef conservation in a changing climate: Risk minimization and MPAs

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# Climate Change and Coral Bleaching

## A Focus Areas for US CRTF



a. Land-based Sources of Pollution

b. Overfishing

c. Lack of Public Awareness

d. Recreational Overuse and Misuse

e-1. Climate Change and Coral Bleaching

e-2. Disease

# The changing climate of coral reefs

temperatures (2 - 4°C hotter)

sea level  
(0.1 - 0.4 m higher)

atmospheric carbon dioxide  
(3 x more)

cyclone regimes  
(more extreme)

**IPCC Predictions for this Century**

# US Coral Reef Task Force: The National Action Plan

➤ calls to strengthen the effectiveness of existing MPAs, and establish new MPAs where appropriate

- Do MPAs have a role in mitigating the effects of climate change?
- Where are the most appropriate places in a warming world?

# ICRI believes MPAs do have a vital role as a measure to mitigate regional impacts of climate change

*Recommendations from ITMEMS 2 March 2003*

- Factor risk of bleaching impacts into management...

**Try to pick winners or simply spread the risk?**

- Support resilience of coral reefs through:
  - good MPA design,
  - MPA networks and,
  - reducing threats within management control.

**Design for a purpose....resilience**

# Impacts of hotter seas



Decades



Years



Weeks

Very low impact

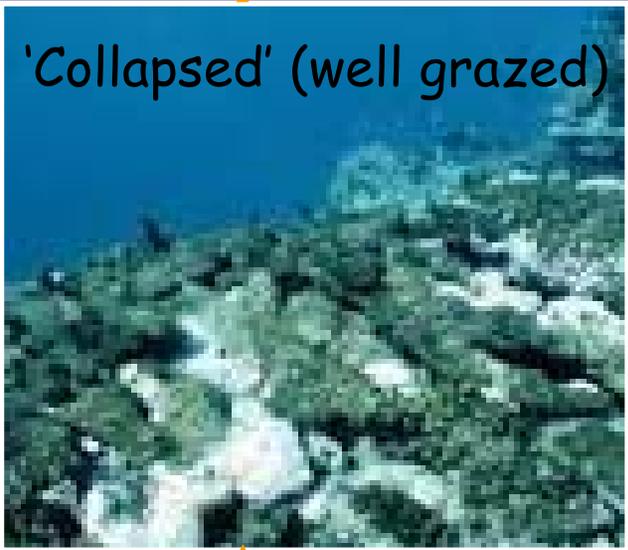


Poor Recovery

Recovery



'Collapsed' (well grazed)



Dead



'Bleached' (alive)



Catastrophic impact



Weeks

Medium impact





**Very low impact**



**'Bleached' (alive)**

**Medium impact**



**Dead**

**Catastrophic impact**



**'Collapsed'**



# Resilience - physiological and ecological

Decades

Settlement and growth of reef-builders

WEAK

STRONG

Poor Recovery

Recovery



Physiologically Resilient



Not Resilient



Months

Ecologically Resilient

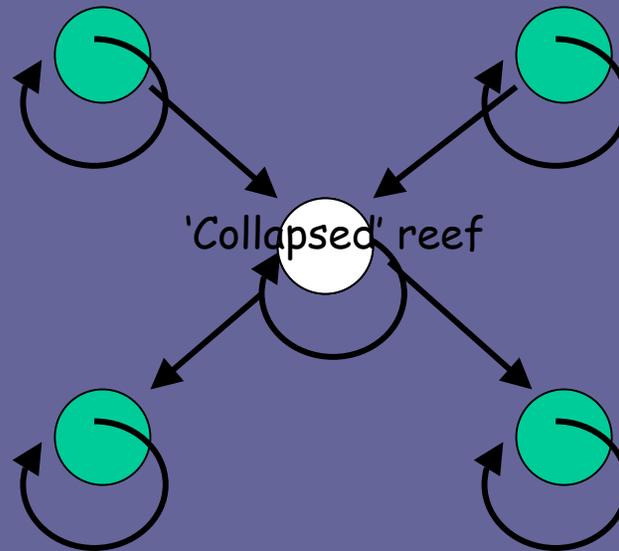
Good MPA design and management

Good Settlement and growth of reef-builders

Ecological Resilience

Settlement

Good MPA design means collapsed reefs can rely on neighbors for reef-building larvae



An MPA network

Growth

Good management provides good environment for settlement and growth of reef builders

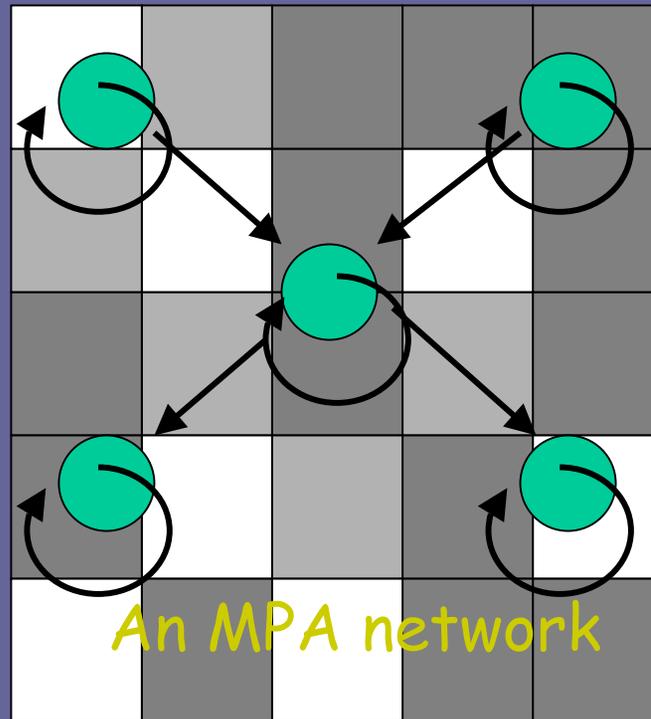
may require local threat reduction

→ Source of reef building larvae

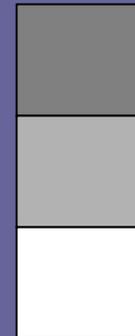
# Try to pick winners or simply spread the risk?

Pattern of risk well known

Pattern of risk poorly known



Risk of major Bleaching



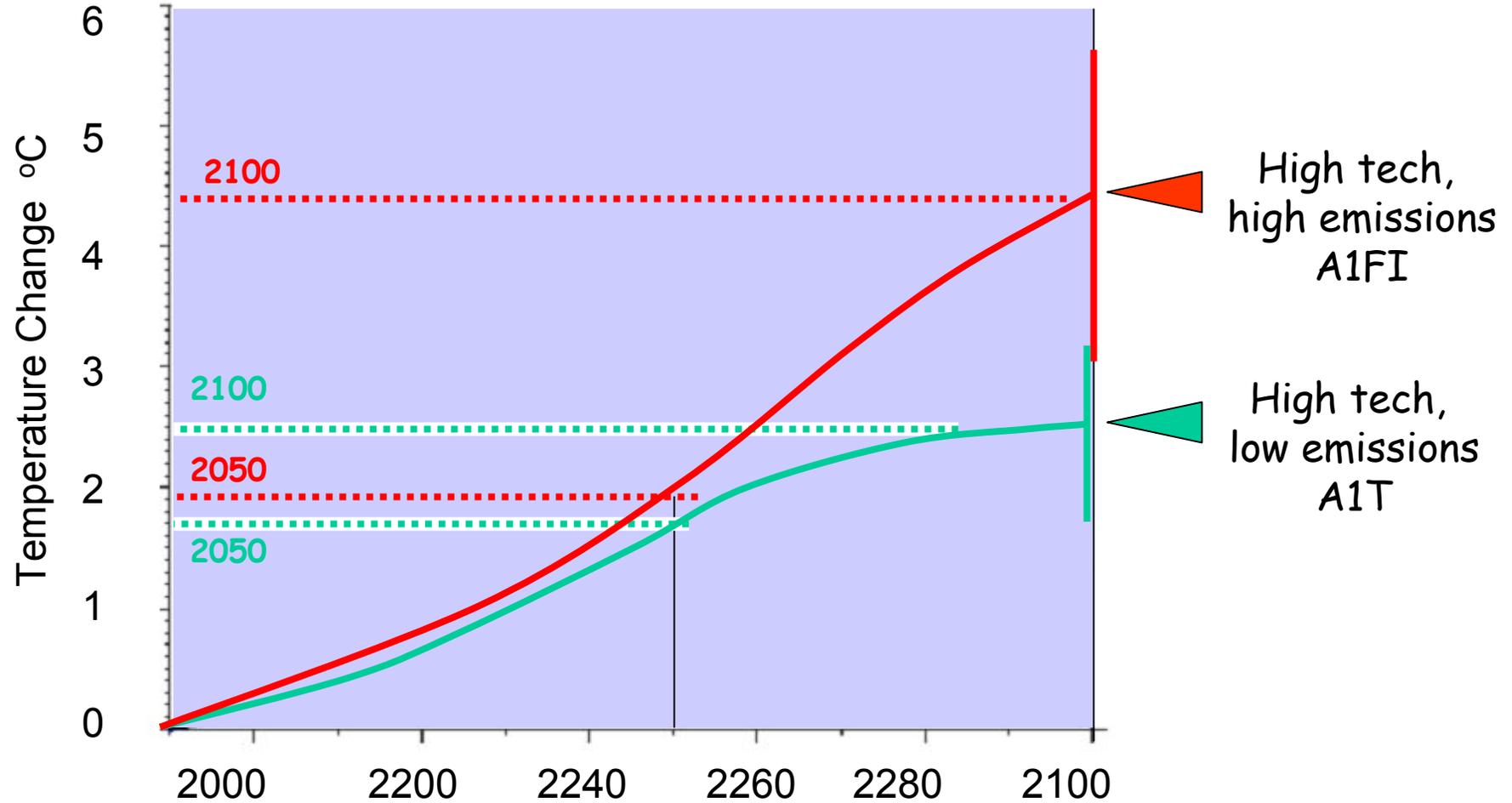
High

Medium

Low

# 'Buying time' for our reefs

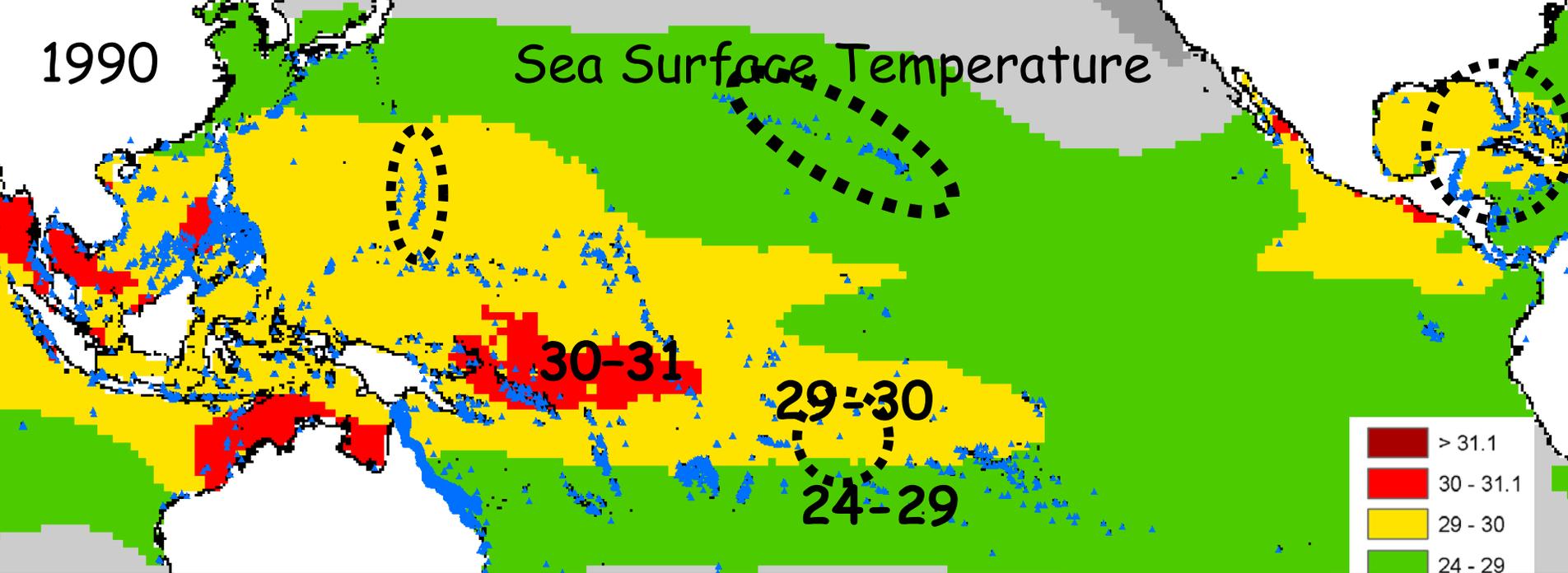
Average global air temperature



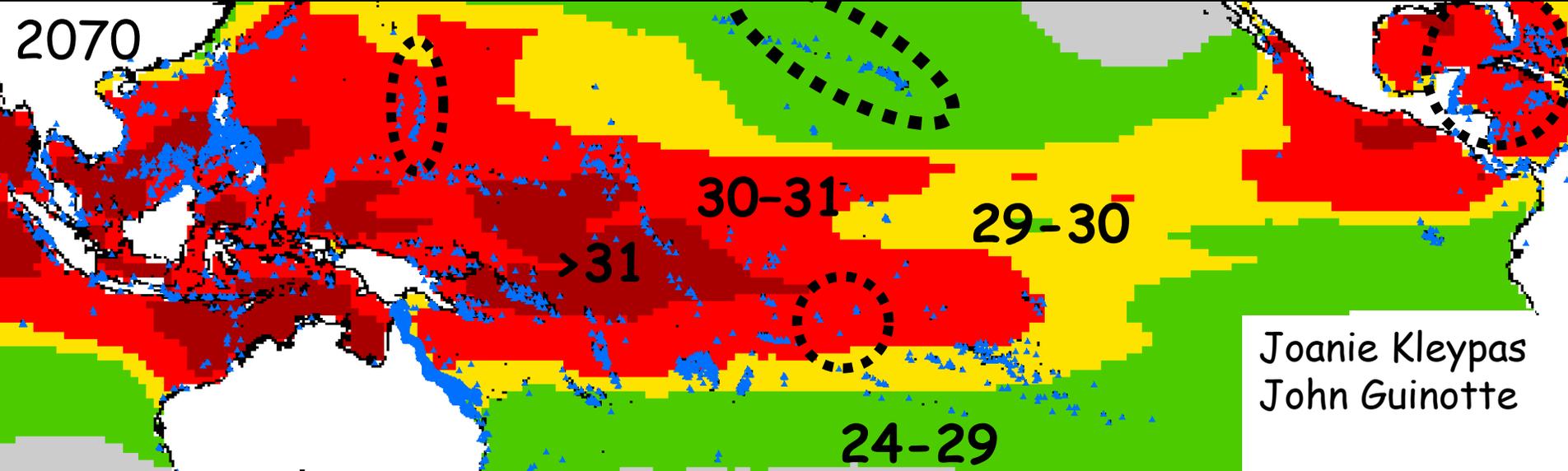
Implications for coral reefs - depend on where

1990

# Sea Surface Temperature

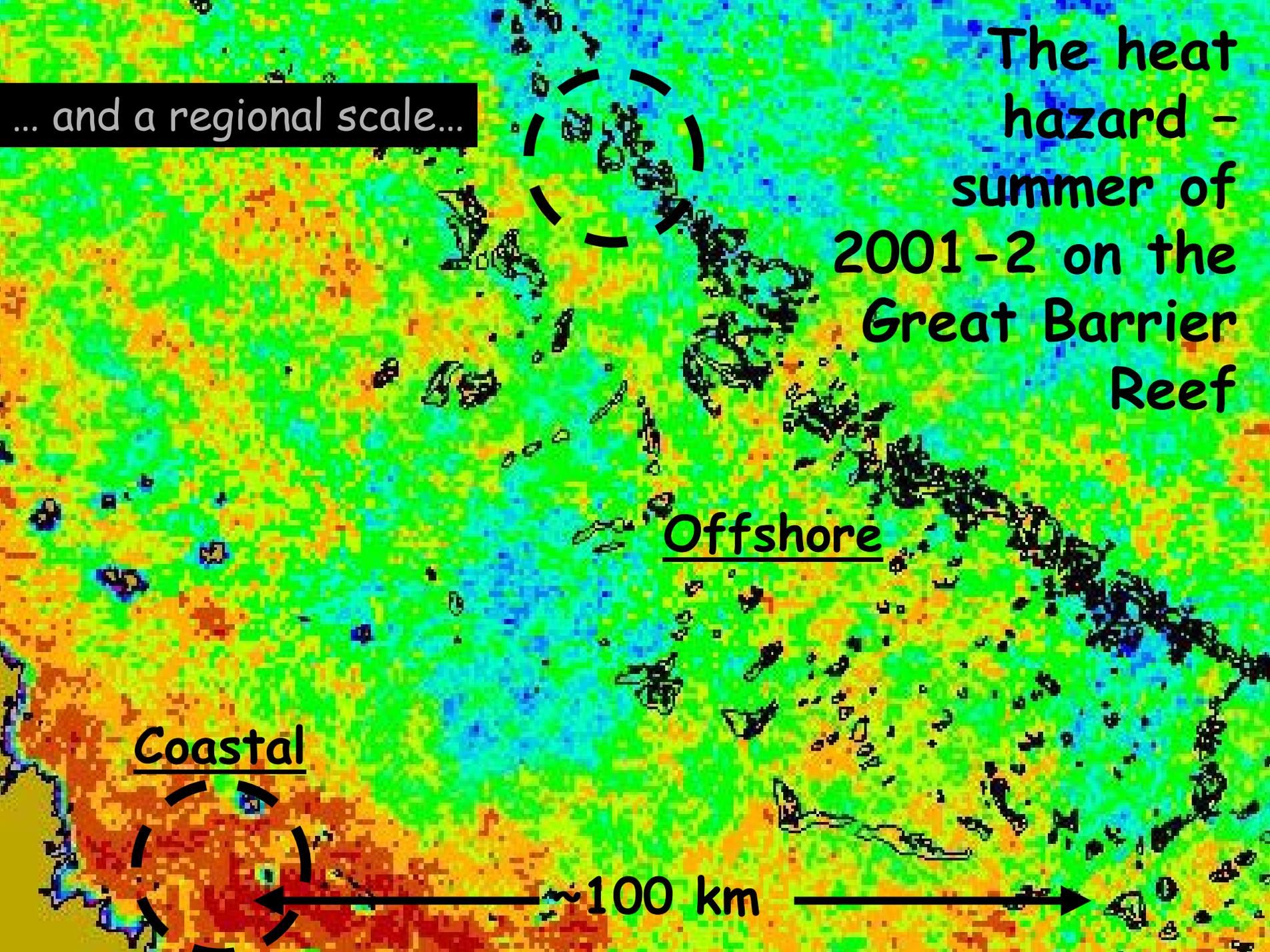


... at a global scale...



... and a regional scale...

The heat hazard - summer of 2001-2 on the Great Barrier Reef



Offshore

Coastal

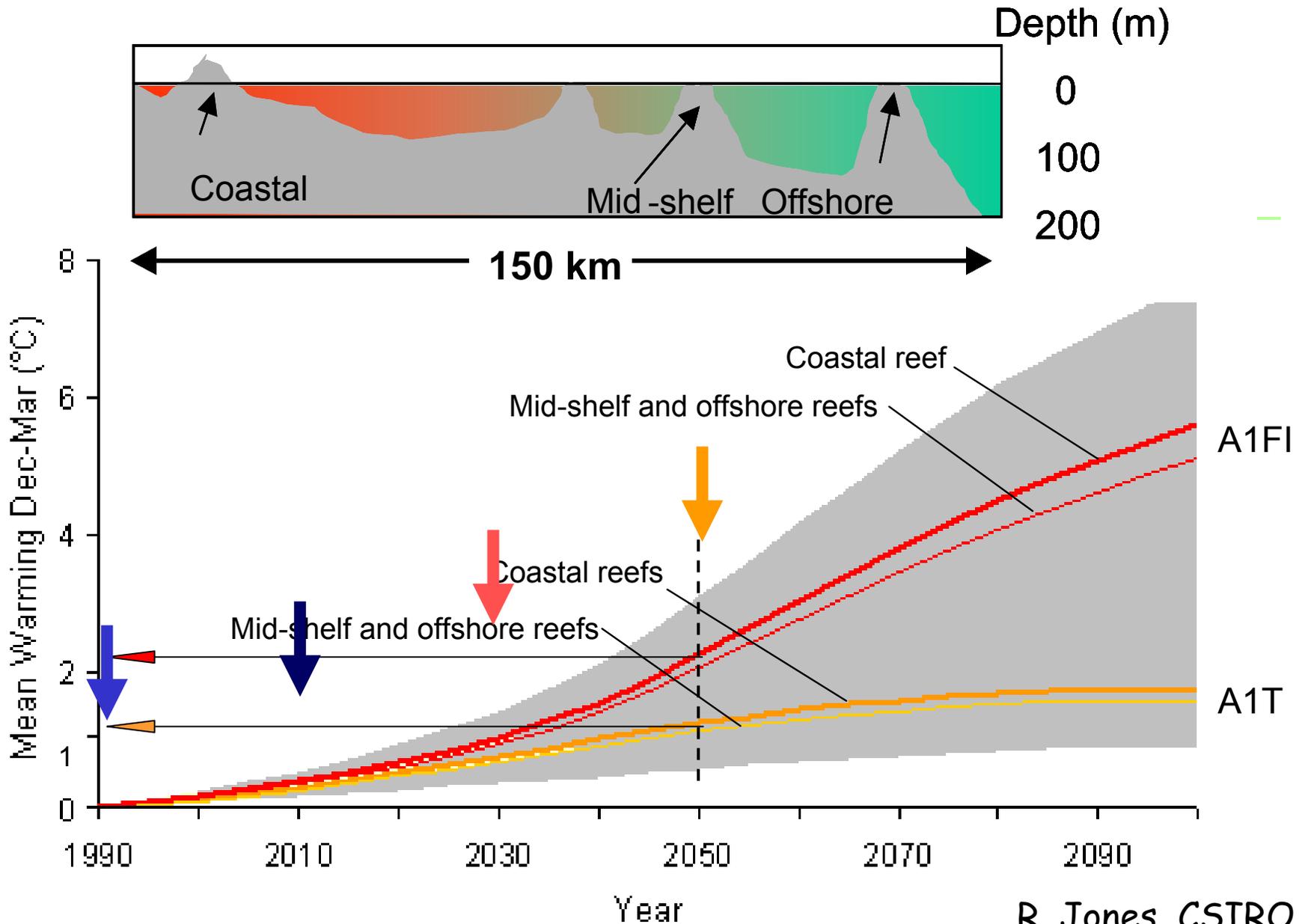
~100 km

... and a local scale...

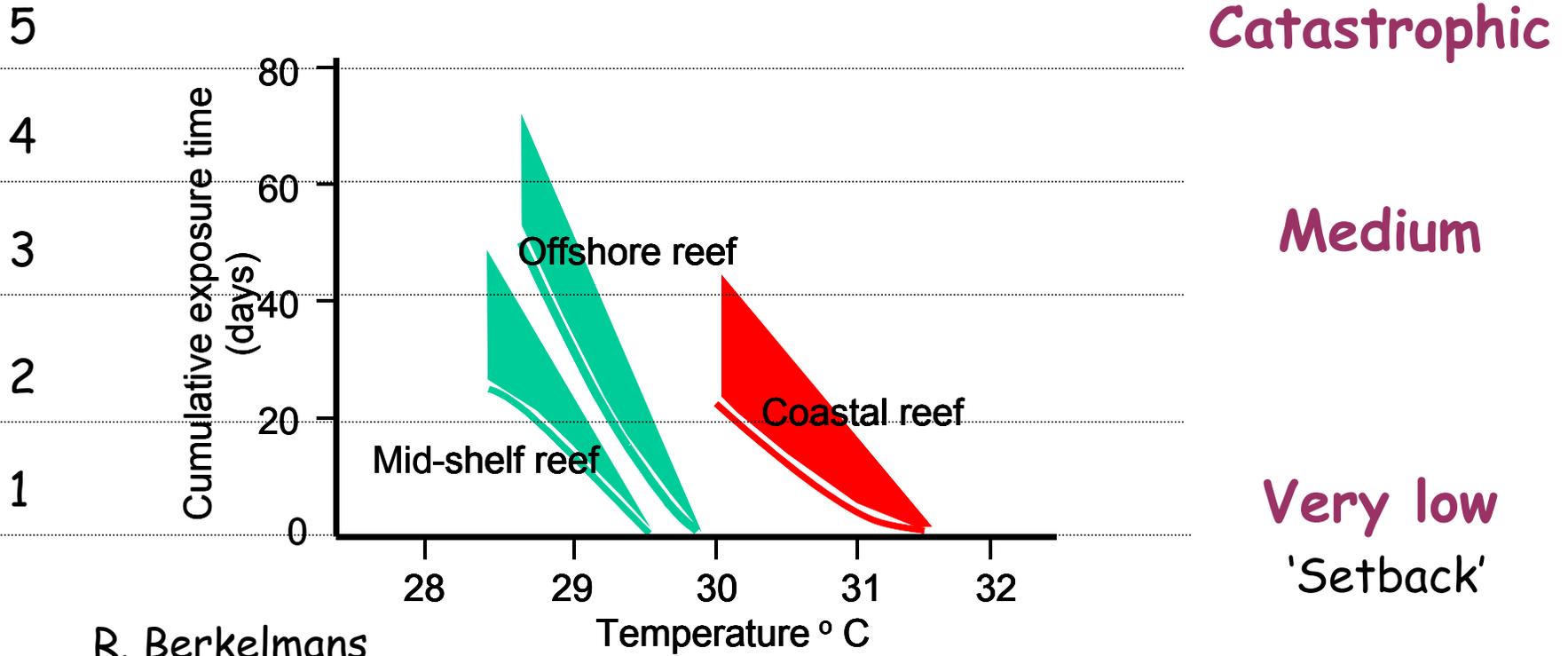
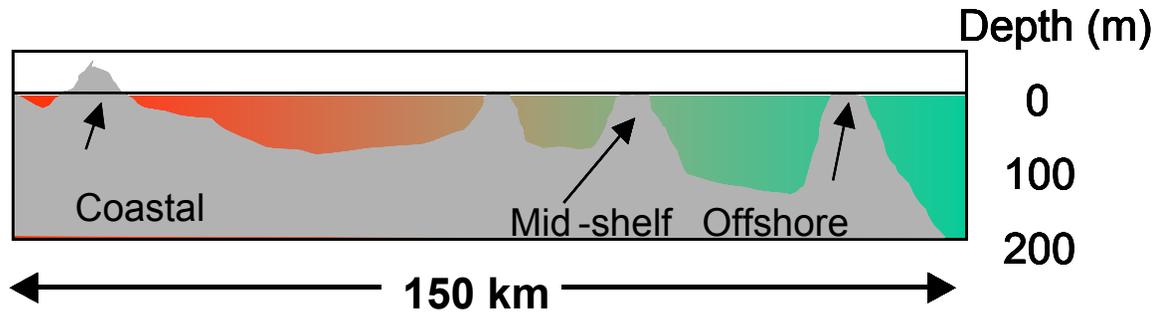
The heat hazard -  
summer of  
2001-2



# Different places have different level of future hazard



# That was the hazard - what about the impacts?



.....depends on the reef's location, type and experience

Risk = hazard x negative consequences

Therefore there are two risk minimizing strategies

1. Minimize the hazard
2. Minimize the negative consequences

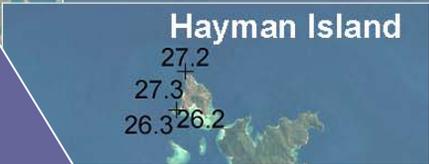
Risks to coral reefs - depends on  
where they are  
(both hazard and vulnerability  
vary in space)

Risk - is changing as climate  
changes

Risk = probability of an unmanageable impact that negates  
management objectives

# Risk - depends on where you are

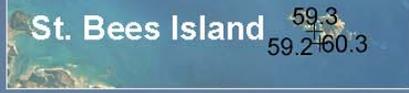
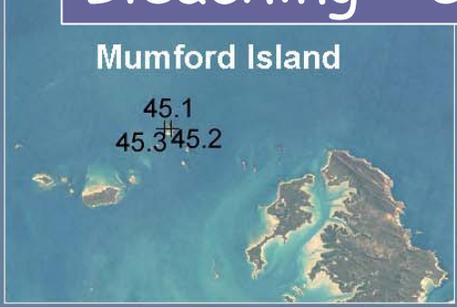
1990s



Flood - every 5 y  
COTS\* - 'never'  
Cyclone - every 15 y  
Bleaching - every 5 y



Flood 'never'  
COTS - 'never'  
Cyclone - every 15 y  
Bleaching - 'never'



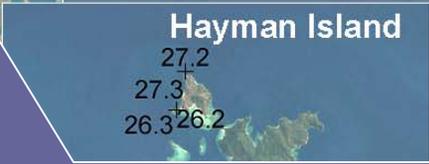
Flood - every 30 y  
COTS - every 15 y  
Cyclone - every 15 y  
Bleaching every 10 y

COTS\*  
Crown of  
Thorns Starfish

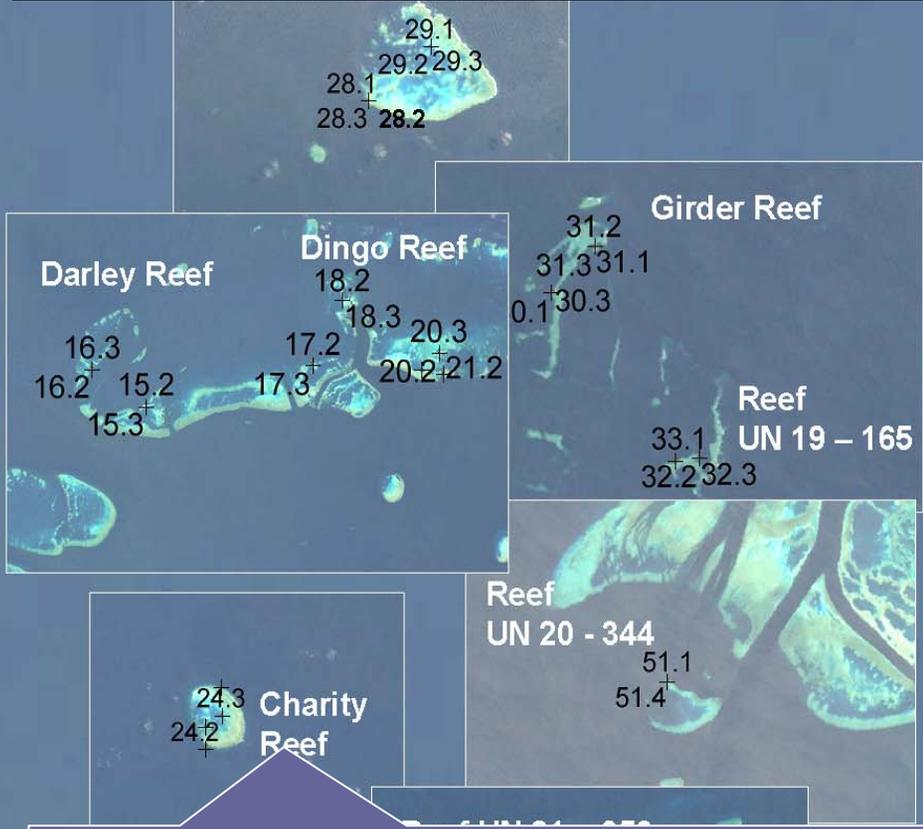


# Risk - changing with climate

1990s (2040s)

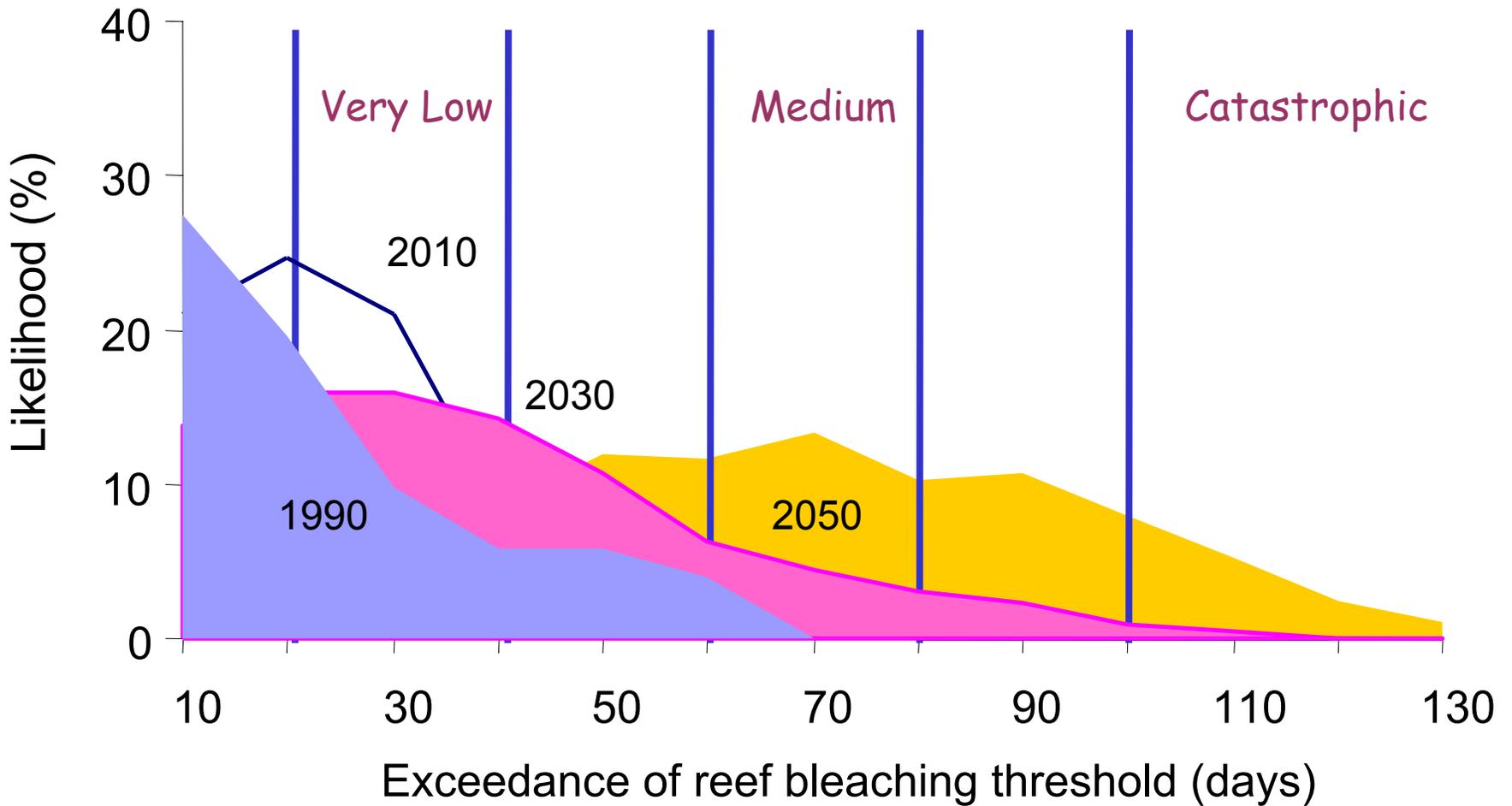


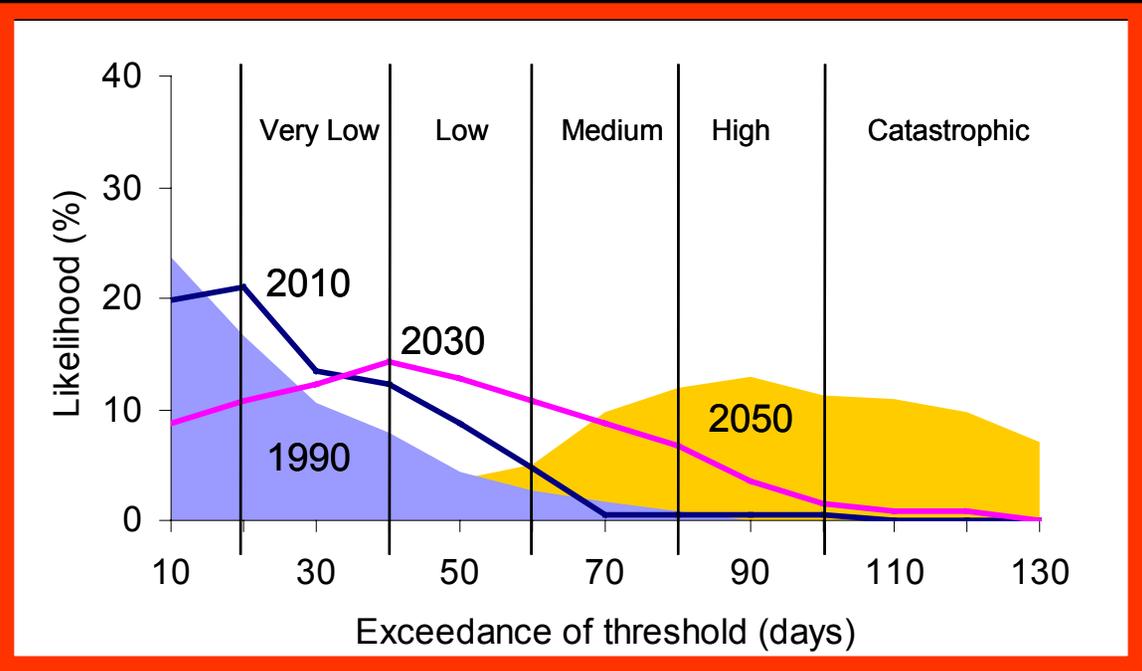
Flood - every 5 y (?)  
 COTS - 'never' (?)  
 Cyclone - every 15 y (10 y)  
 Bleaching - every 5 y (1 y)



Flood - every 30 y (15 y)  
 COTS - every 15 y (?)  
 Cyclone - every 15 y (10y)  
 Bleaching every 10 y (3y)

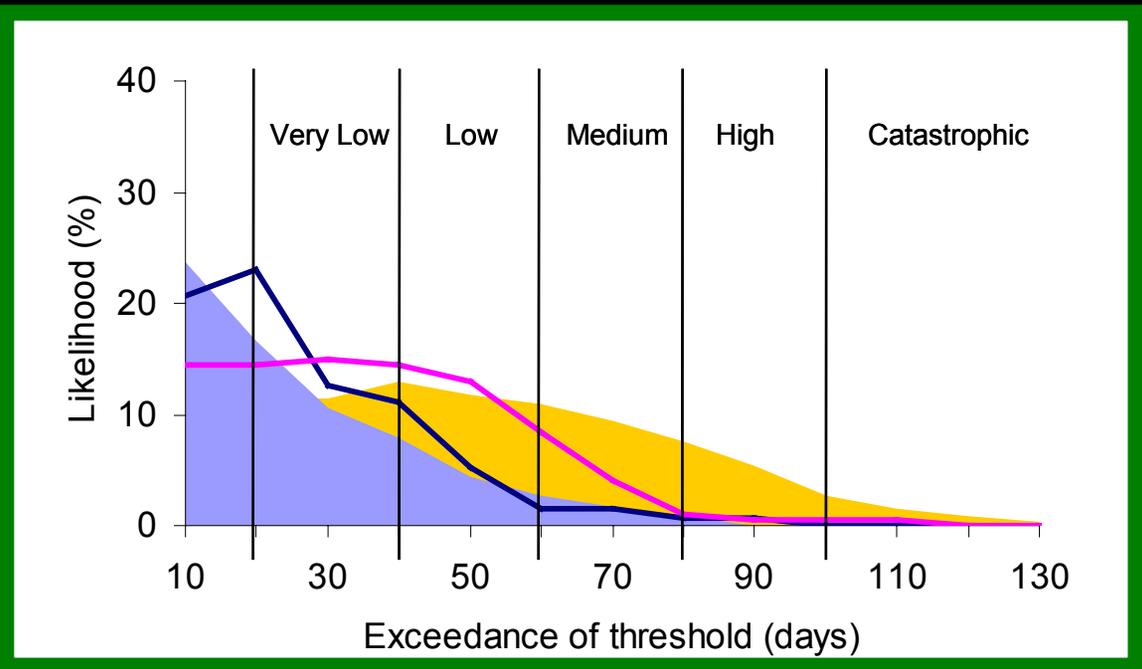
# Simulating probable future risks





Consequences  
of a high tech  
future

... fossil fuel  
intensive



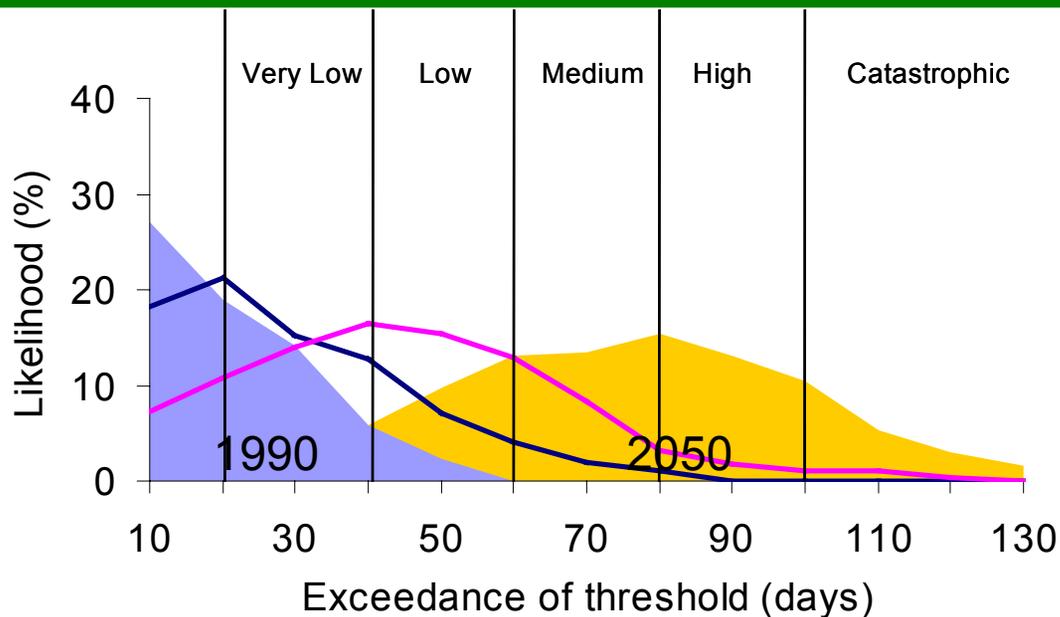
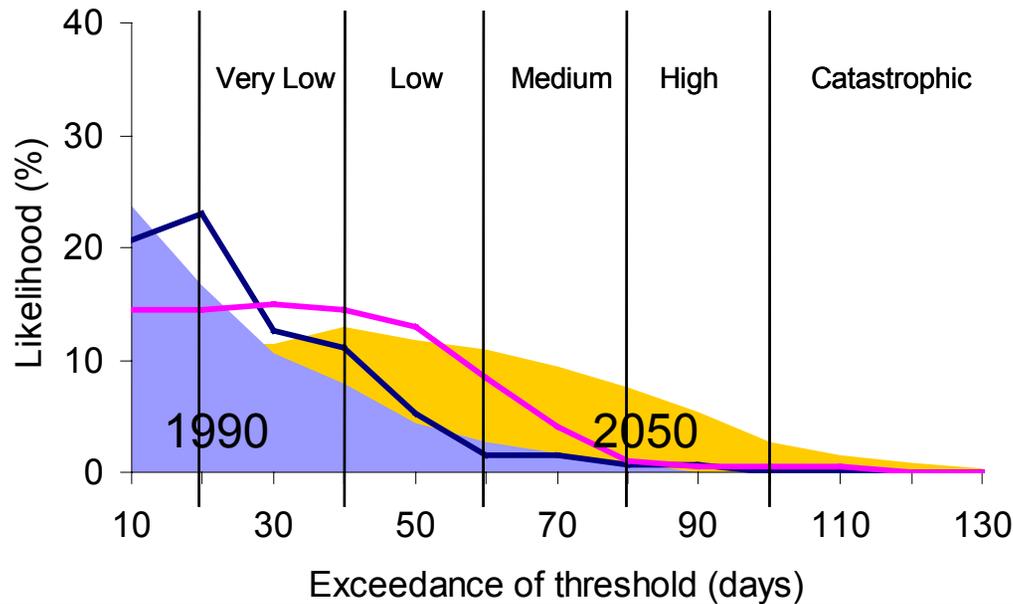
... transition to  
low emissions

Coastal reef

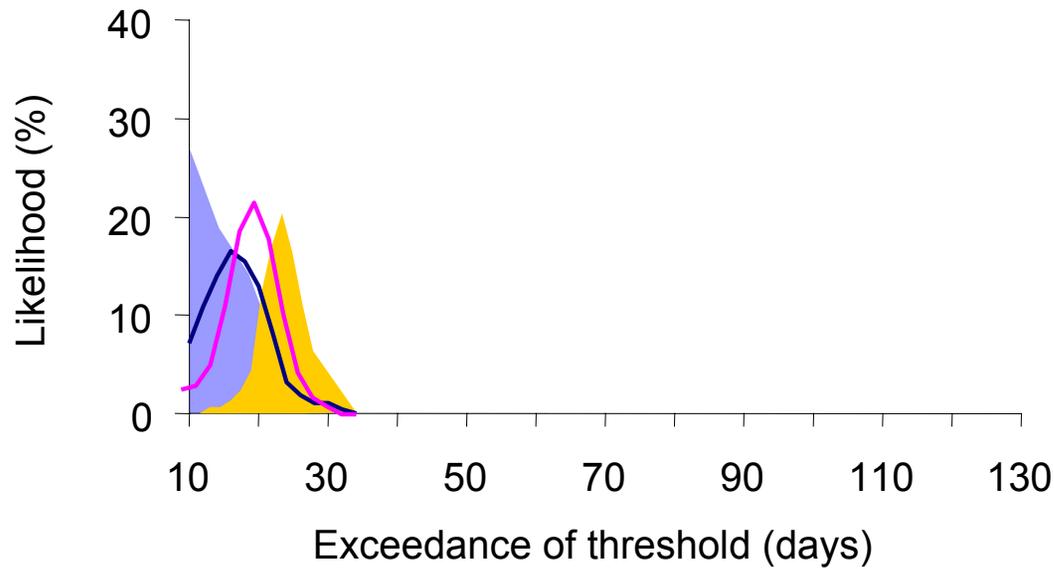
*Different places - same emissions*

... low emissions future

Coastal reef



Offshore reef



### Tools and data requirements:

- CSIRO ReefClim model
- Daily(?) sea temperature (~ 10y)
- local bleaching thresholds

*Are some global regions and/or local reefs at lower risk?*

*Global climate change would be less of an issue at this place - do they exist?*

Your reef?



What do increasing bleaching days per summer mean for coral communities? Appearance? Ecology?

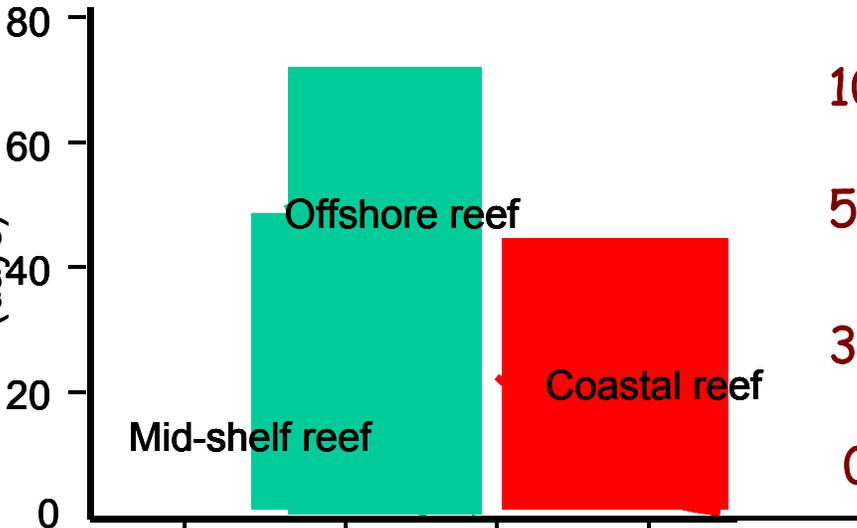


Decades



# 'Setbacks'

Cumulative exposure time (days)



20 y 10 y

10 y 5 y

5 y 1 y

3 y .5 y

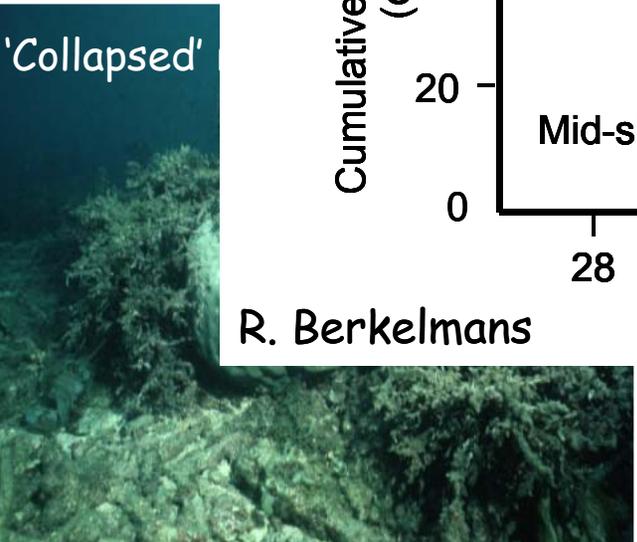
0 y 0 y

Ecology Appearance  
'Setback'

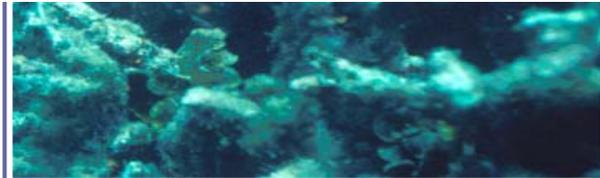
Weeks



'Collapsed'



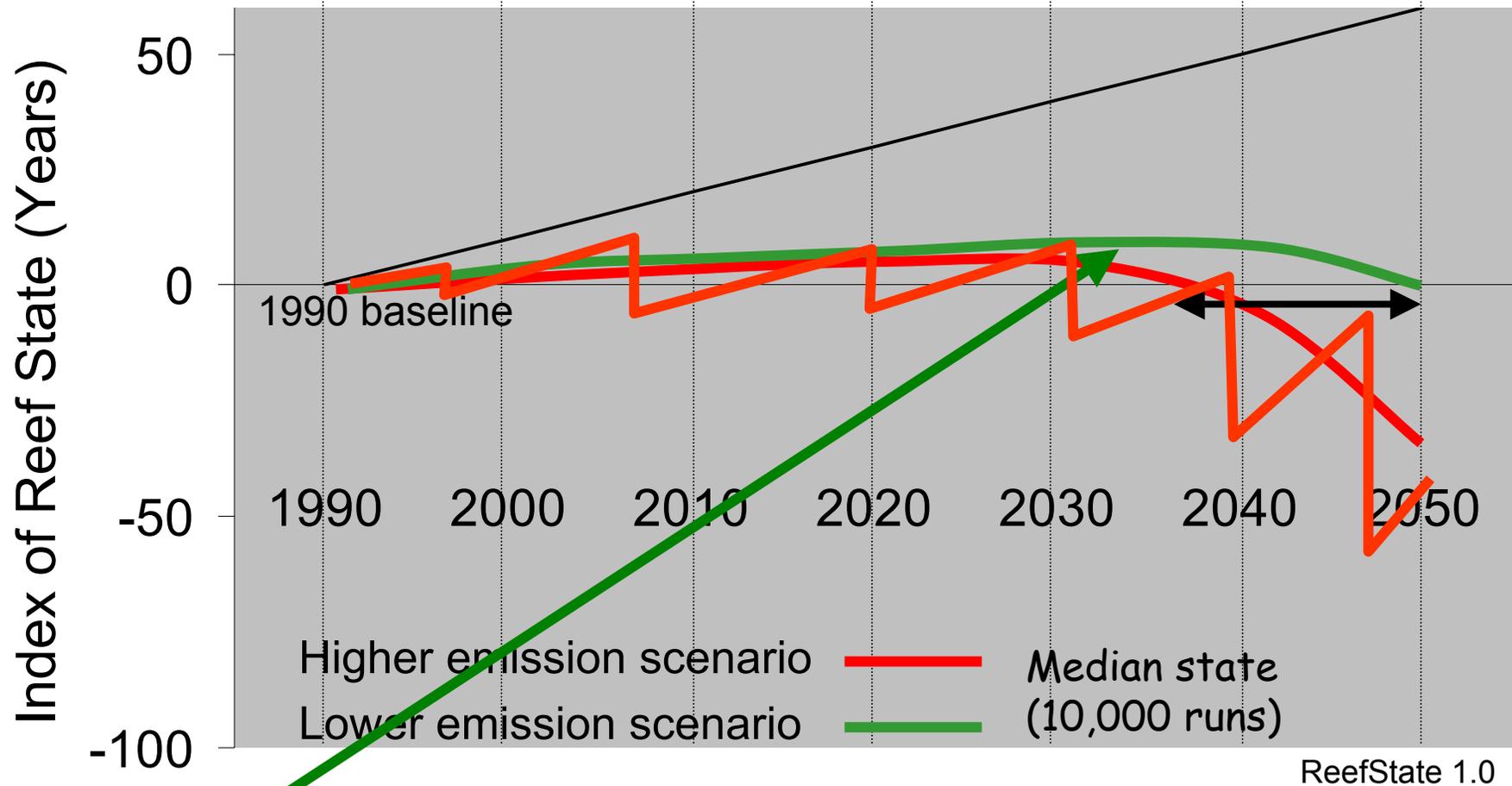
R. Berkelmans



Months



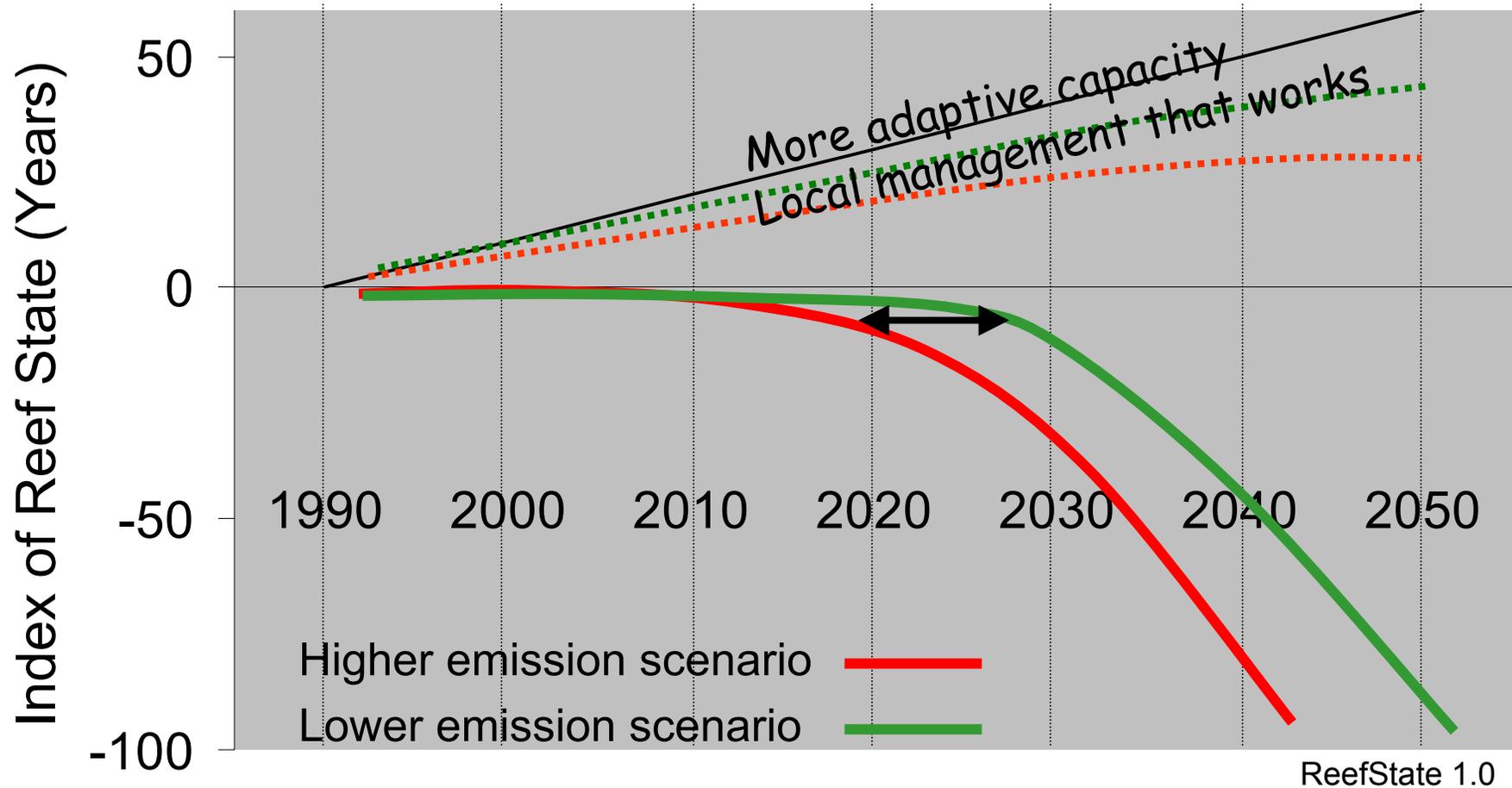
# 'Appearance' (~coral cover)



This global greenhouse gas emissions policy buys some time for this reef

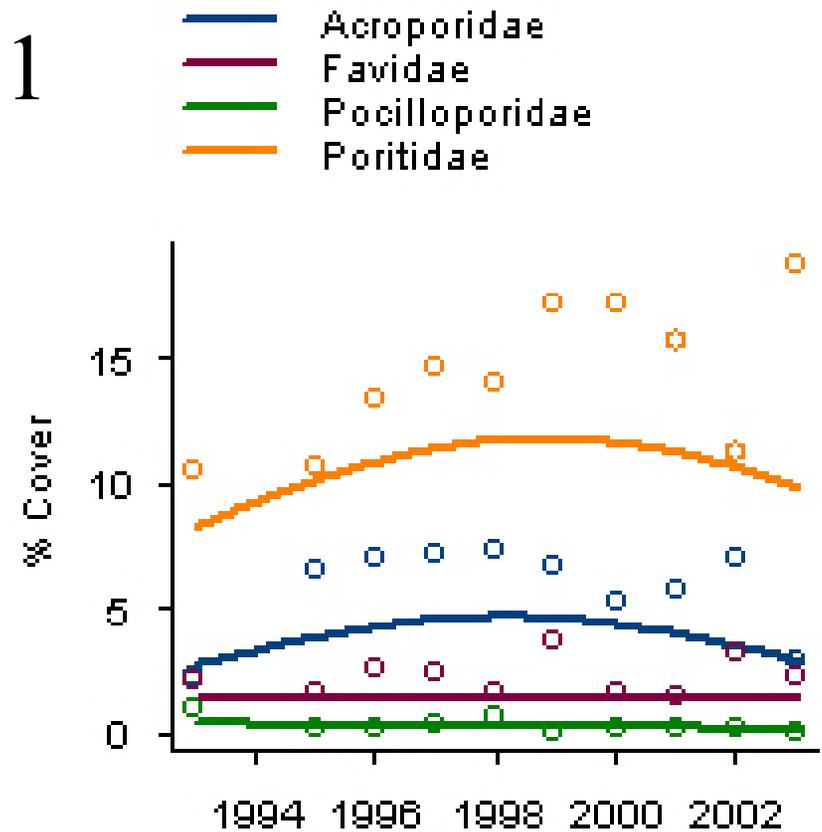
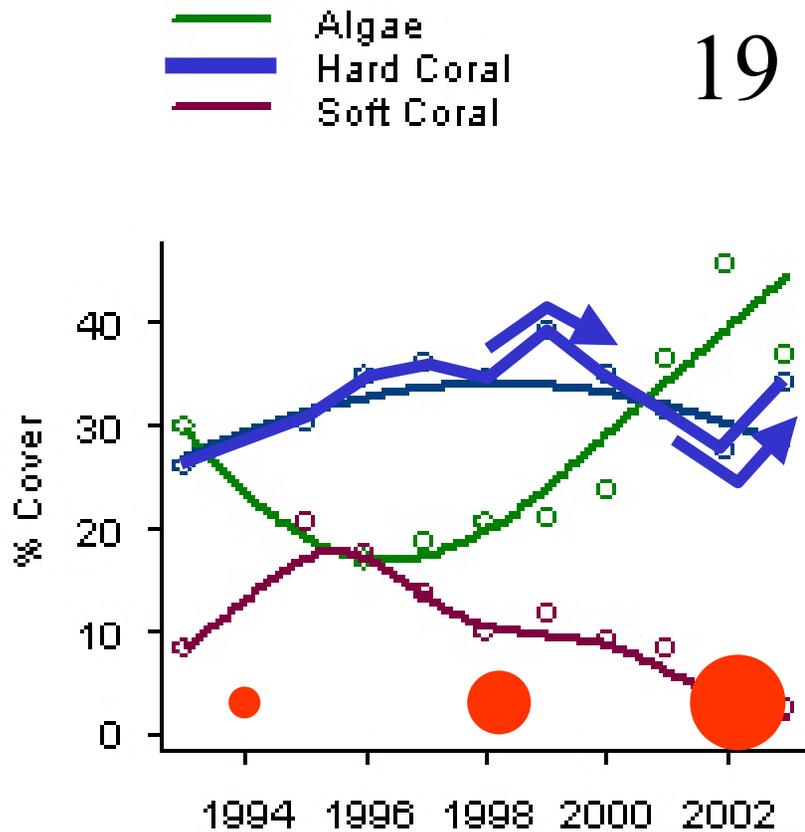
# 'Ecology' (coral cover + composition and size structure)

*Same place, same scenarios*

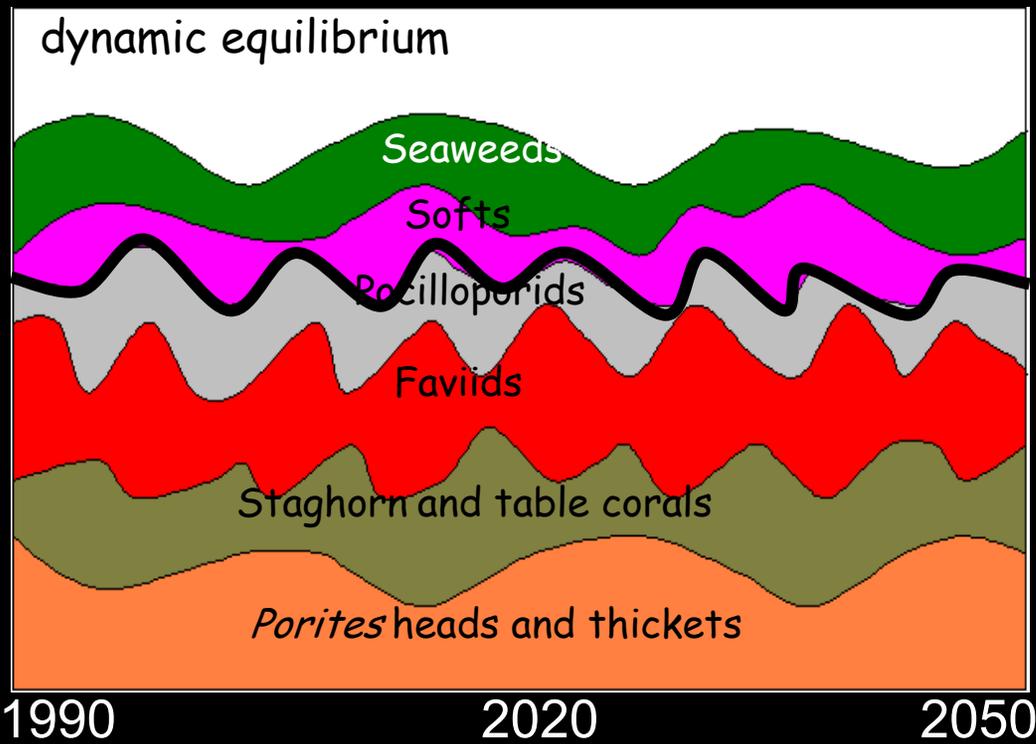


Needed: local management that works to foster resilience (I.e. effective MPAs and threat reduction)

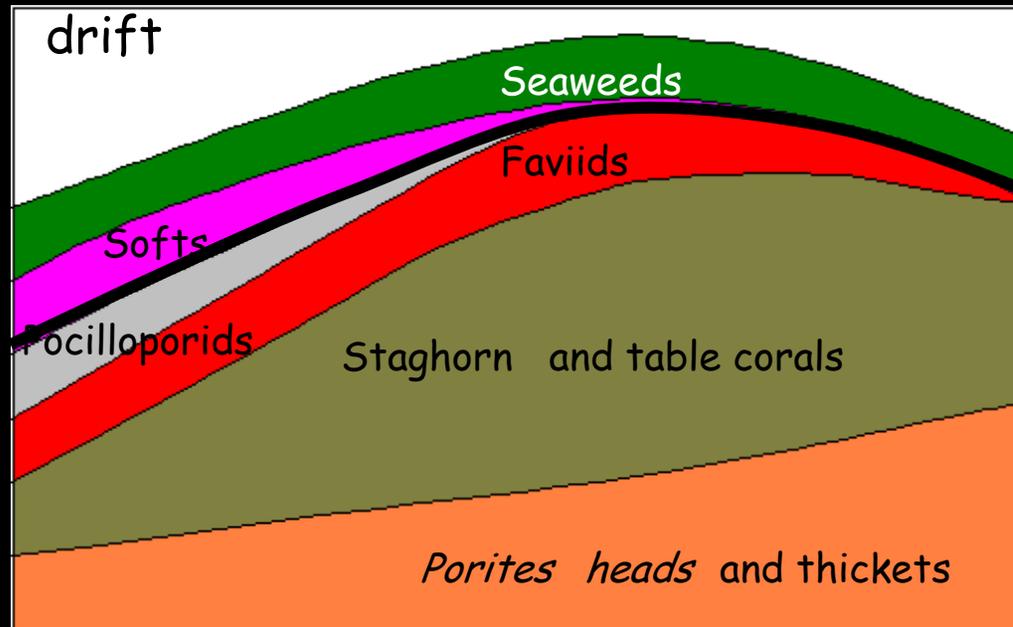
# The models match observations so far... reefs have tracked the 1990s' baseline



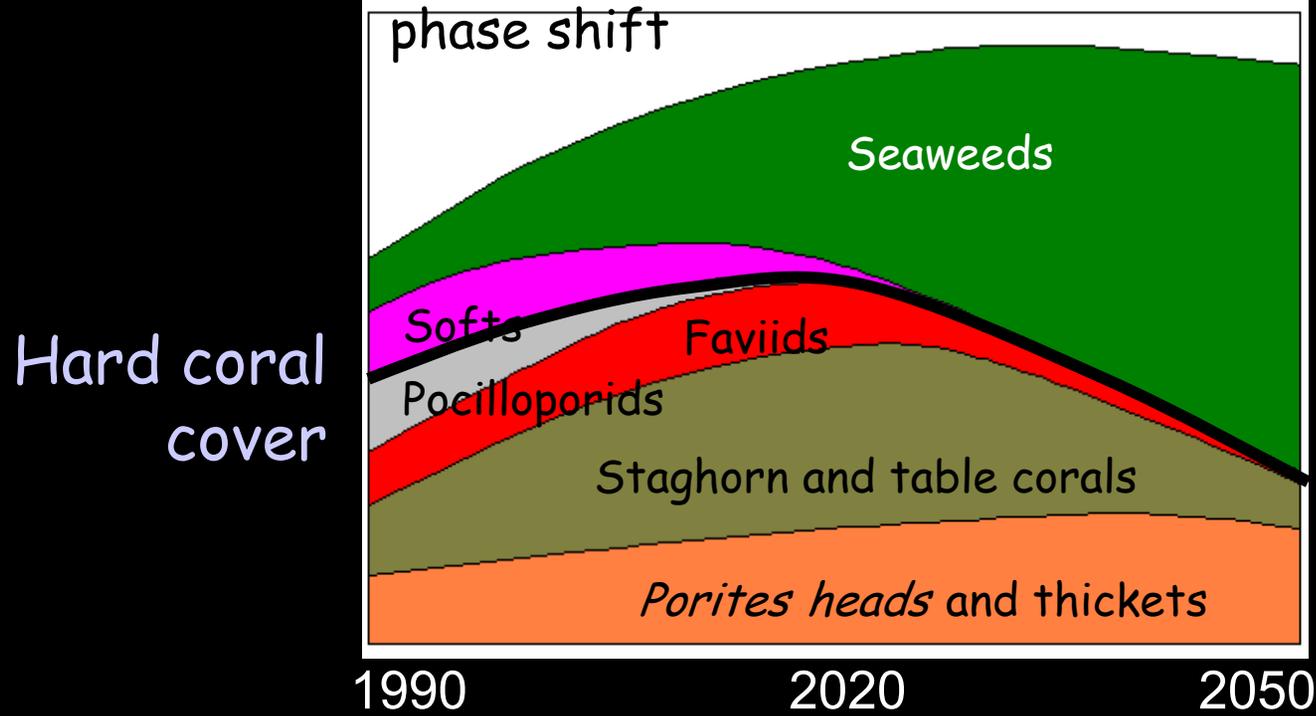
Hard coral cover



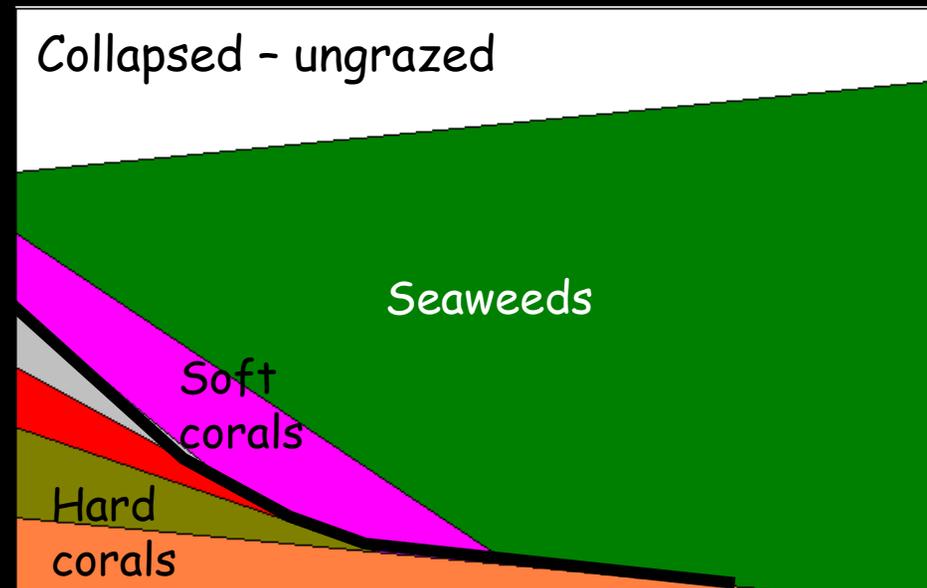
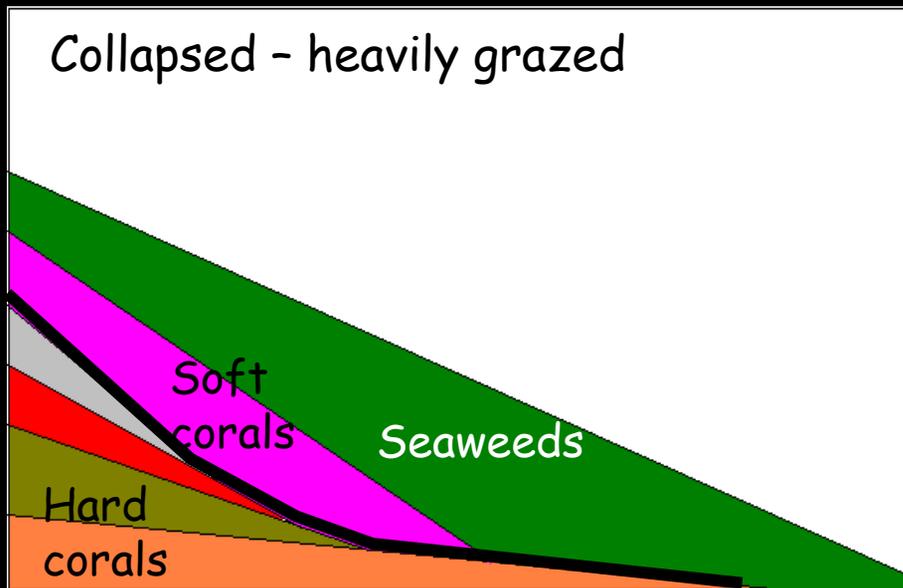
Management that has worked



(Benefit of hindsight!)



Management that has not worked

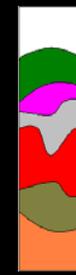


The challenge: without the benefit of hindsight..

Picking winners (*lower cost, higher risk strategy*)

Pick these

Avoid these



Monitoring alone will not give you the answer!

# Needed to pick places that will be winners:

1. Identifying places with low hazard.

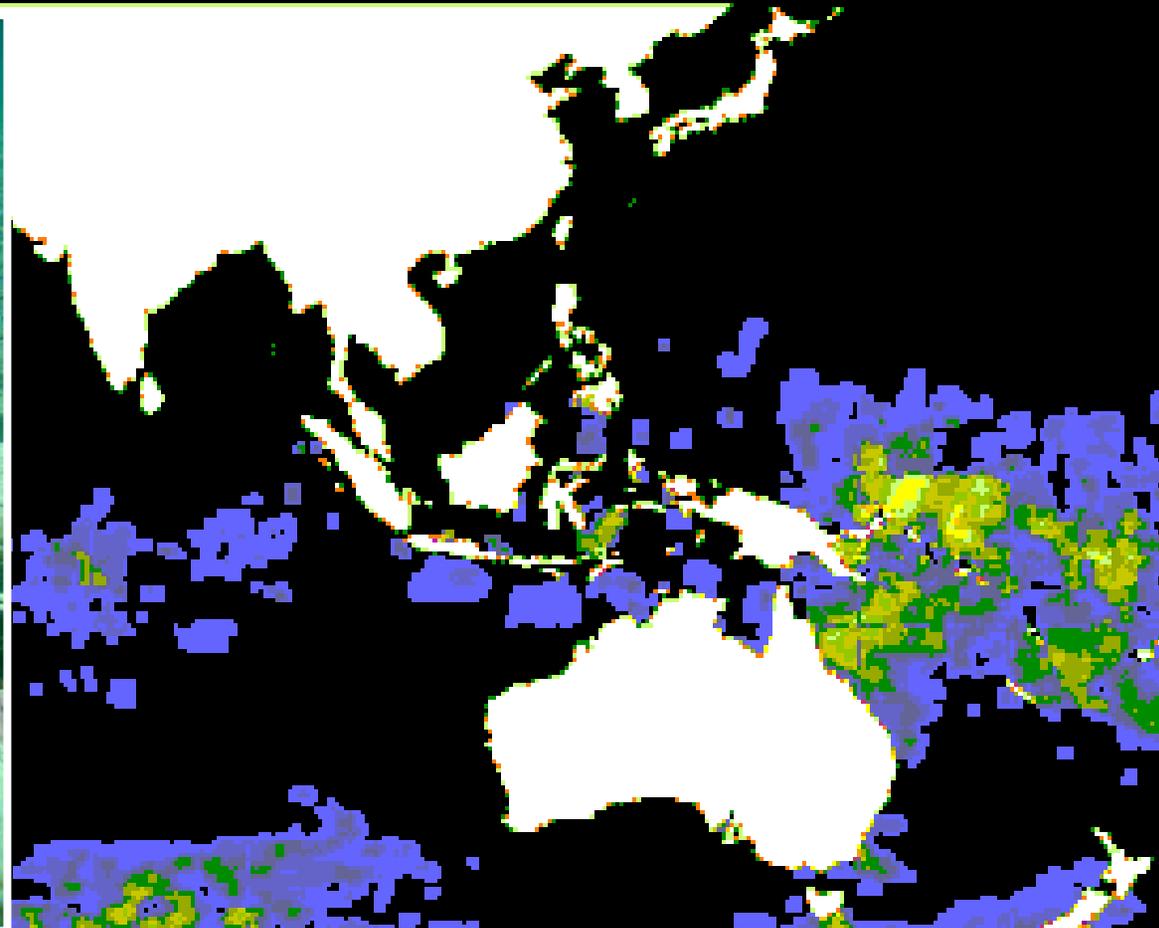
2. A realistic basis for using local ecological knowledge to rate individual reefs according to their likelihood of desirable versus undesirable future reef trajectories

- dynamic equilibrium
- change in coral composition only (drift)
- phase shift
- collapse

....using local ecological knowledge

## How post-bleaching impact surveys can help us pick winners

Degree Heating Weeks for last 90 days - 1/29/2002



# Thanks to...

Al Strong (NOAA)  
William Skirving (NOAA)  
John Guinotte (KU/JCU)  
Rod Salm (TNC)  
Paul Marshall (GBRMPA)  
Roger Jones (CSIRO)  
Peter Whetton (CSIRO)

## AIMS and CRC Reef

Janice Lough  
Craig Steinberg  
Mike Mahoney  
Mary Wakeford  
Emre Turak  
Ray Berkelmans  
Stuart Kininmonth  
Mary Wakeford  
Madeliene Van Oppen  
Glenn De'ath  
Scott Wooldridge



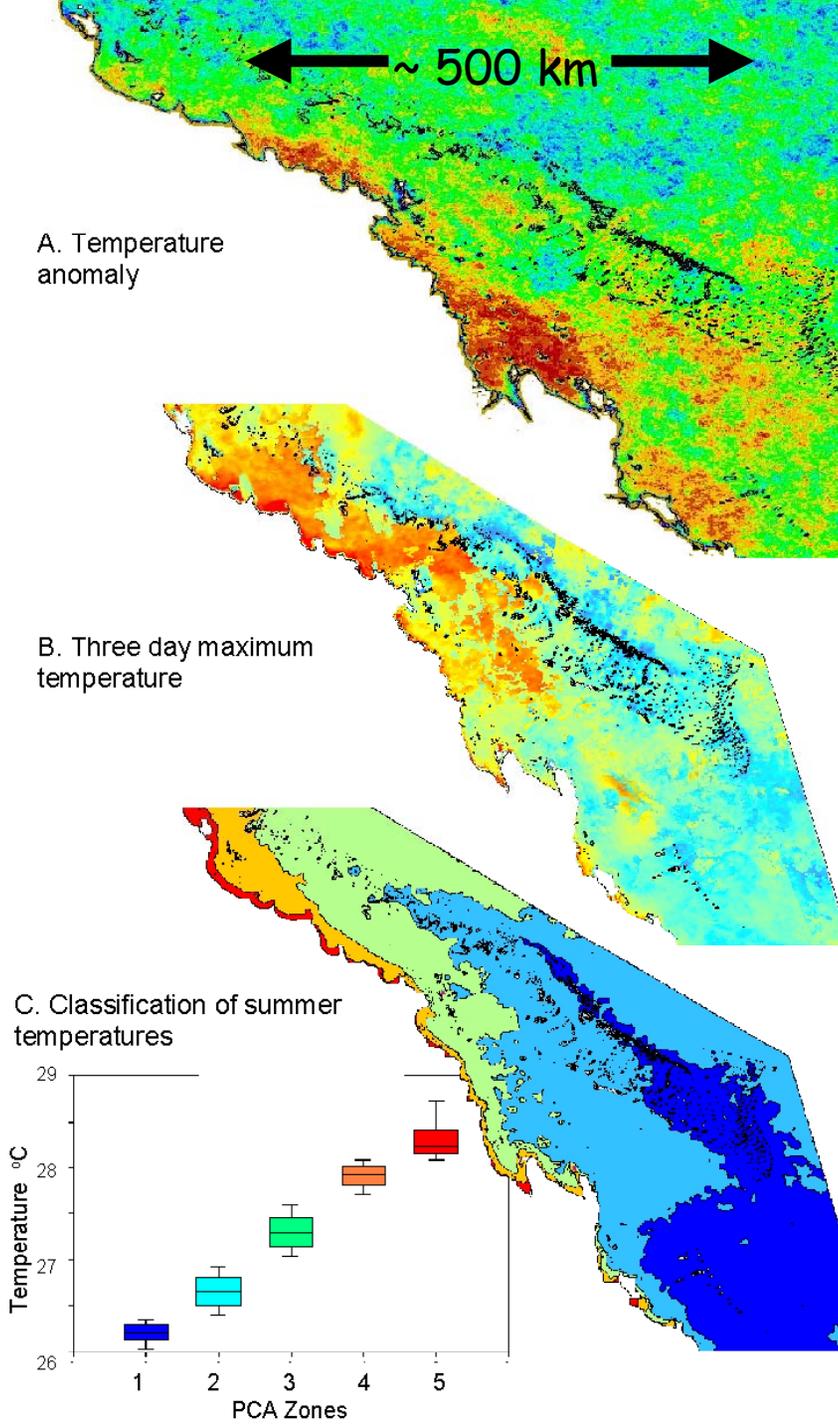
**The Nature  
Conservancy**

Field access to GIS with high resolution SST maps and 10 year satellite archive were invaluable to post-bleaching impact assessment

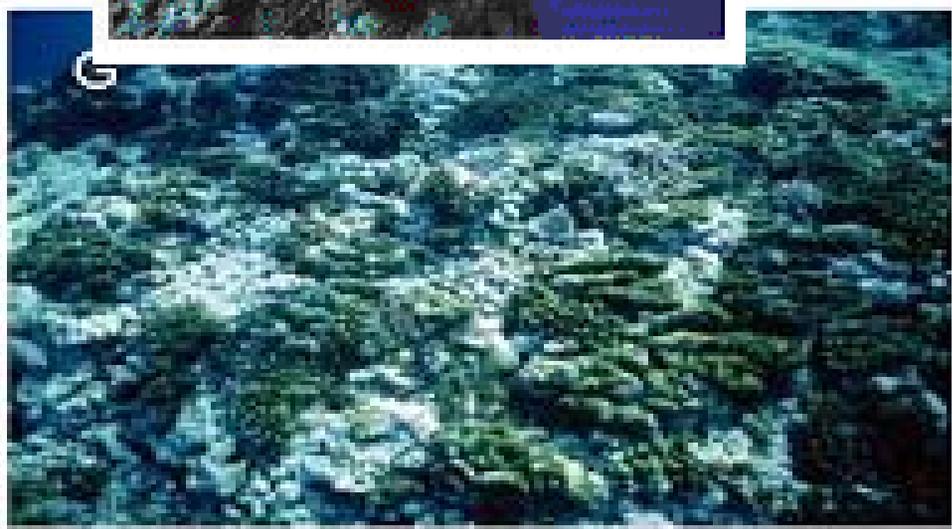
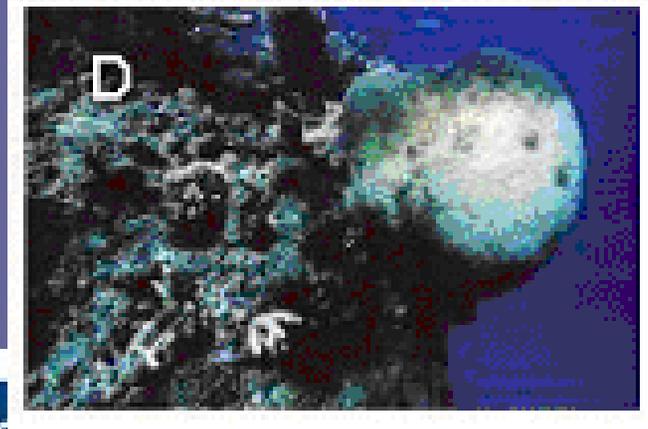
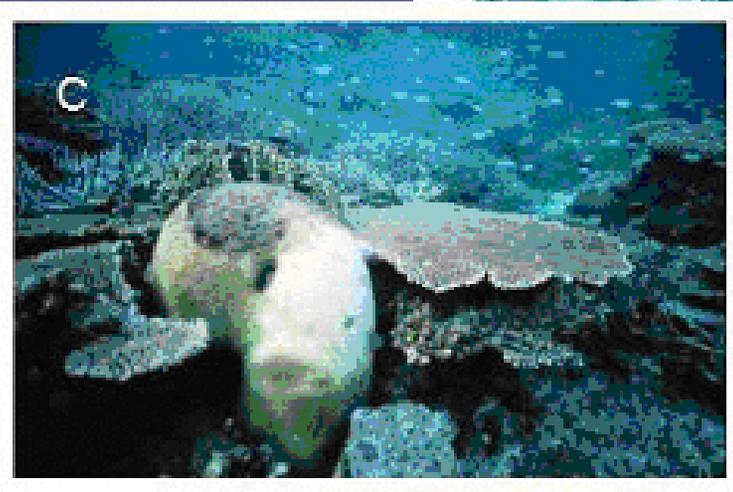
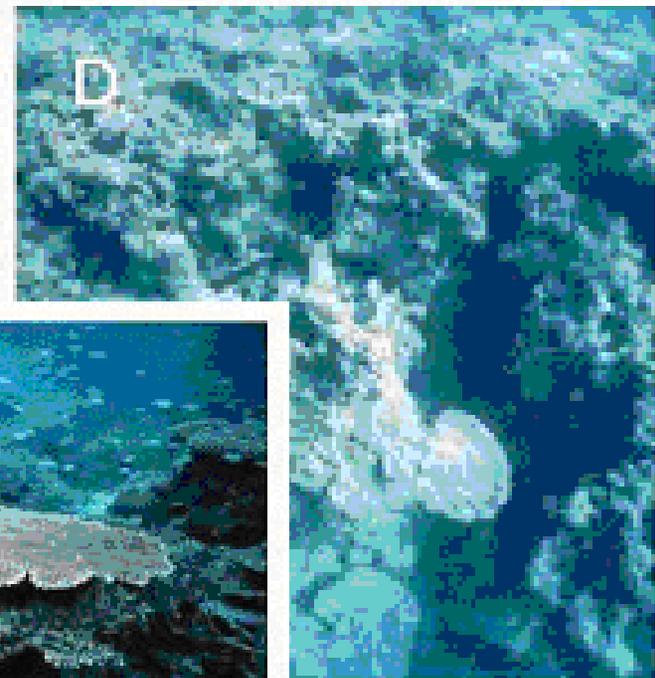
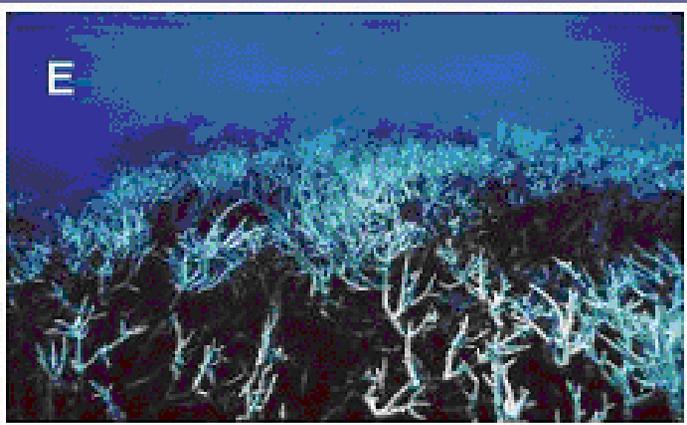
Cumulative heat stress summer 2001-2

Maximum heat stress summer 2001-2

Acclimatization regime 1990s

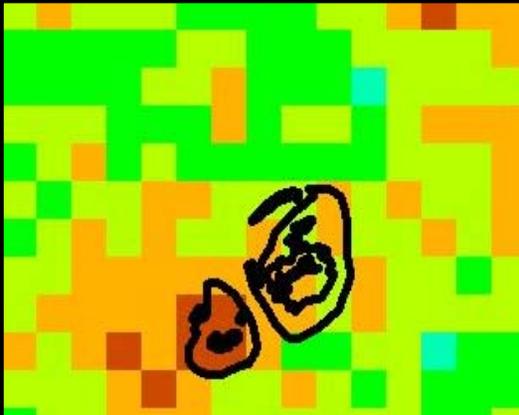
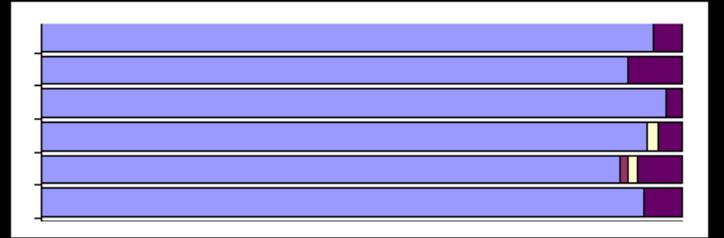
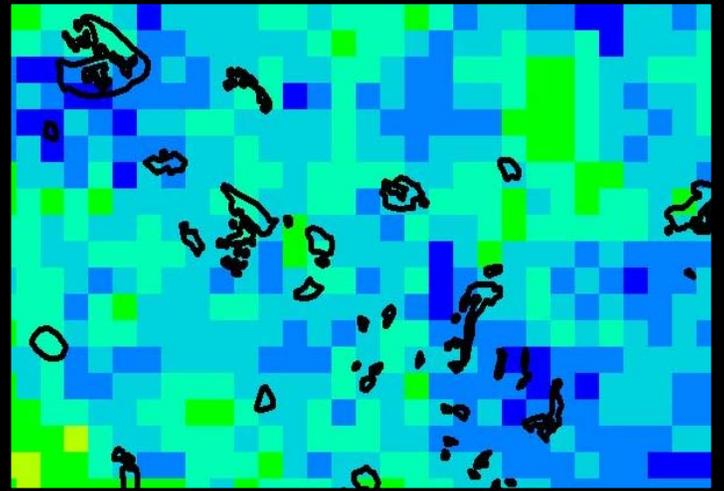
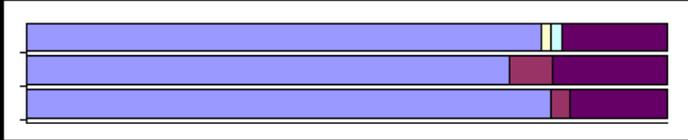
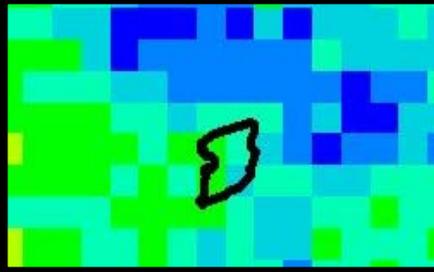




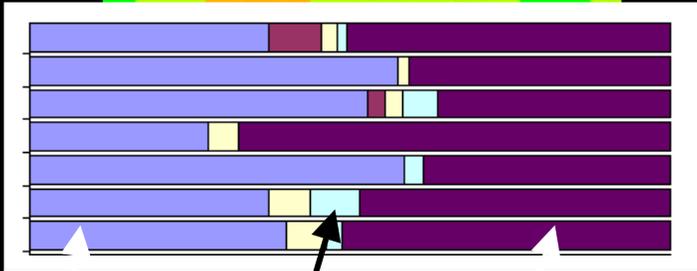


1 km pixels

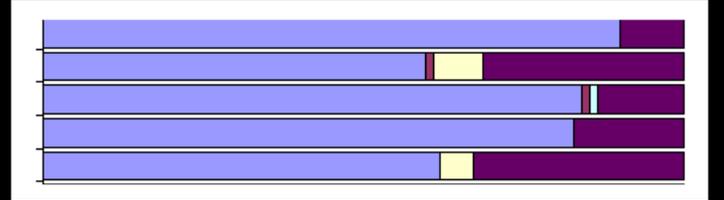
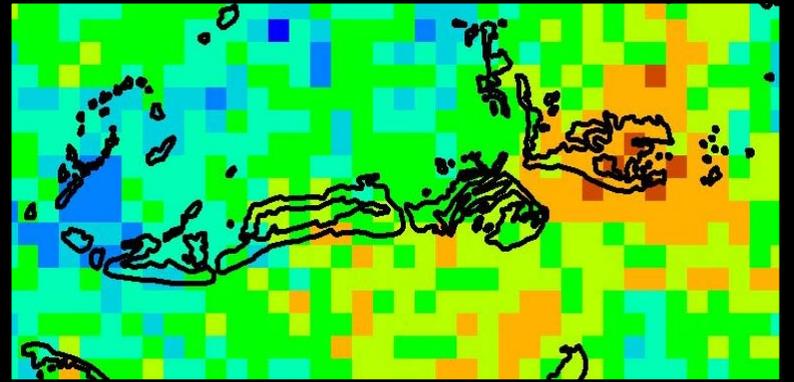
Index of summer heat



GIS was created for selection of assessment sites

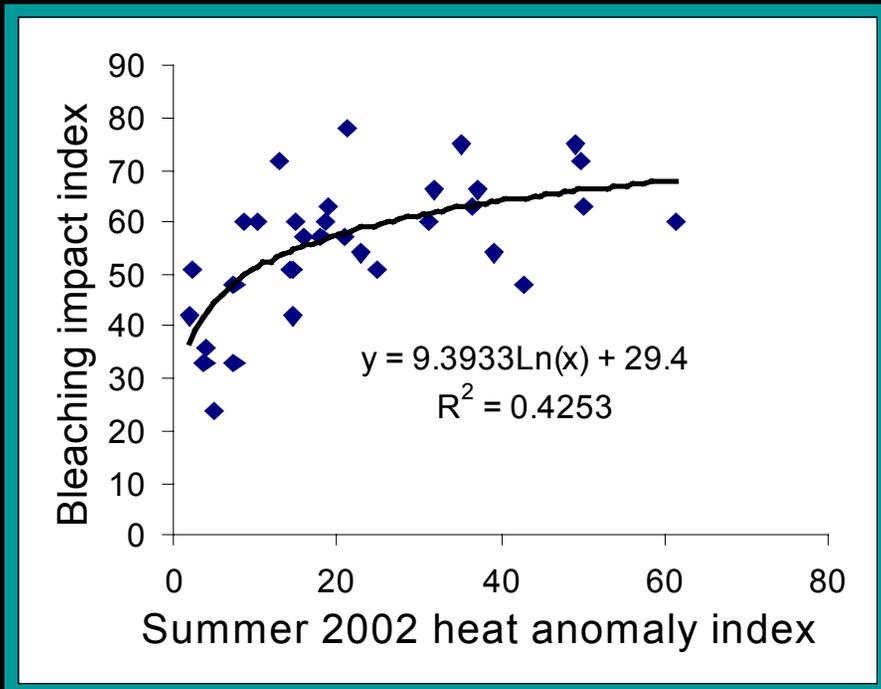


Normal    Bleached    Dead



Field assessments of sites  
*One bar per site*

# Did the 2002 index of hazard (heat anomaly) explain the bleaching impact?

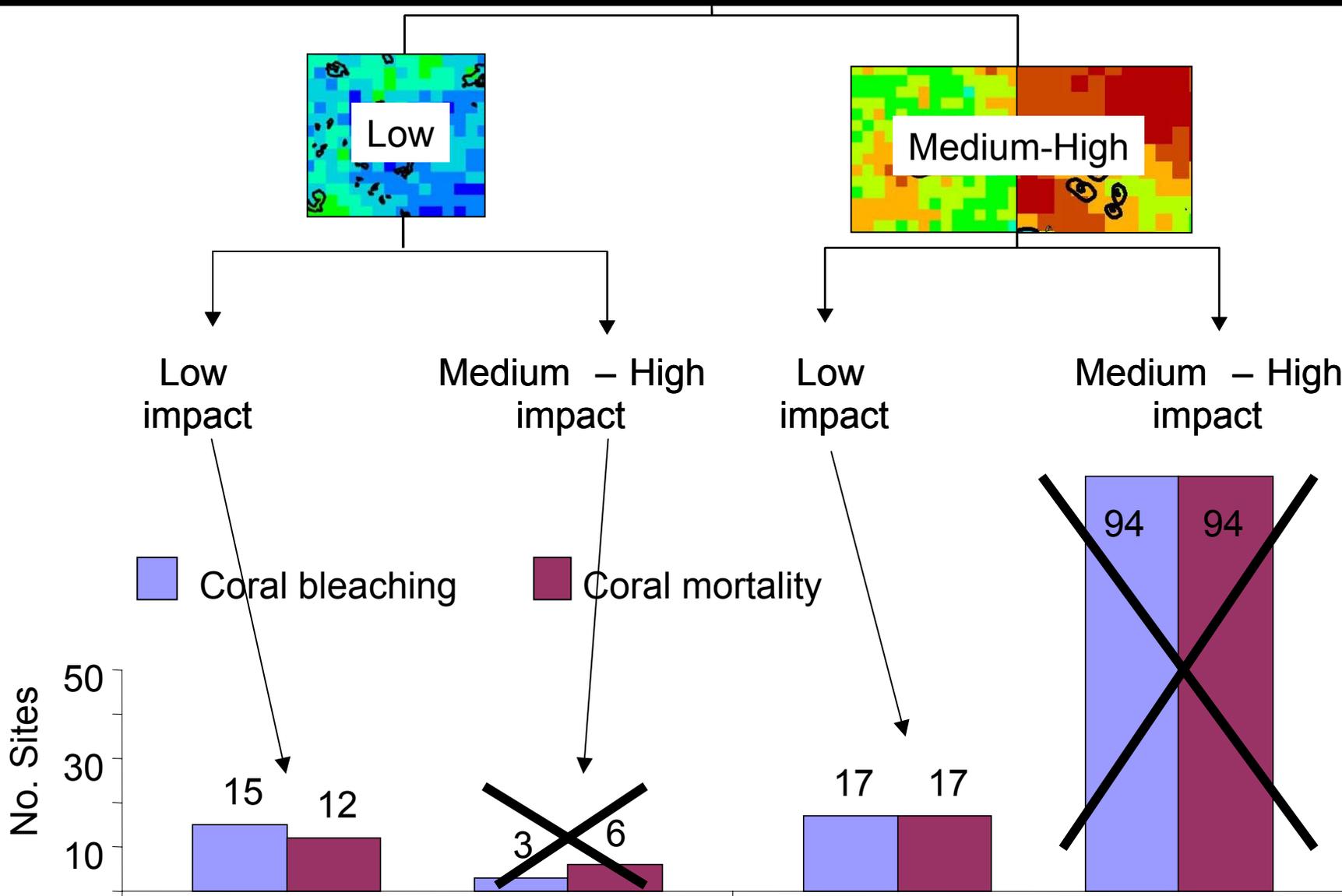


No: there were...

- Interactions and conditional dependencies with other causative factors
- Inaccuracies in SST
- Not the best index of SST
- Not the best index of bleaching impact
- Differences in vulnerability of coral species and communities

Acclimatization regime? ←

# Which locations passed the test of summer 2001-2?



resistant to climate-related coral bleaching?

# What made those reefs resistant? Were they exposed to an anomaly?



**Reason**

**Coral survival**

**Good Luck**

**Good Oceanography**

**High**

**Low**

**A. May be overheated next time**

**B. Unlikely to be overheated**

**C. Well Adapted**

**D. Poorly Adapted**

Places with reliable mixing with cool waters ———  
 Places with deep sediment shading ———  
 Deep reefs ———

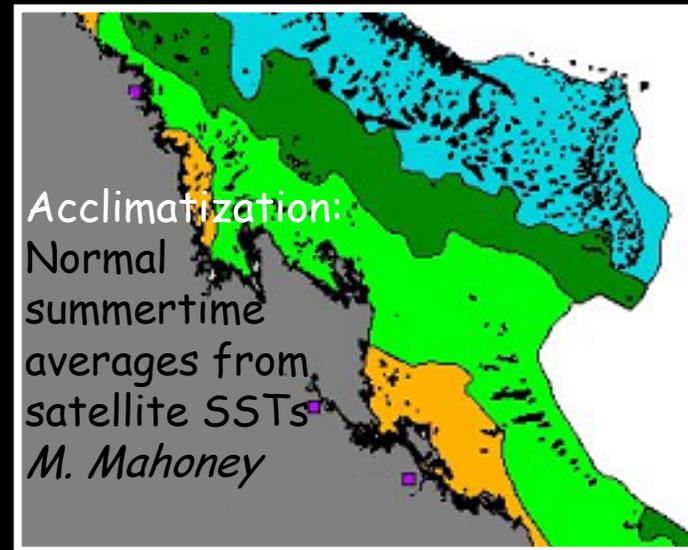
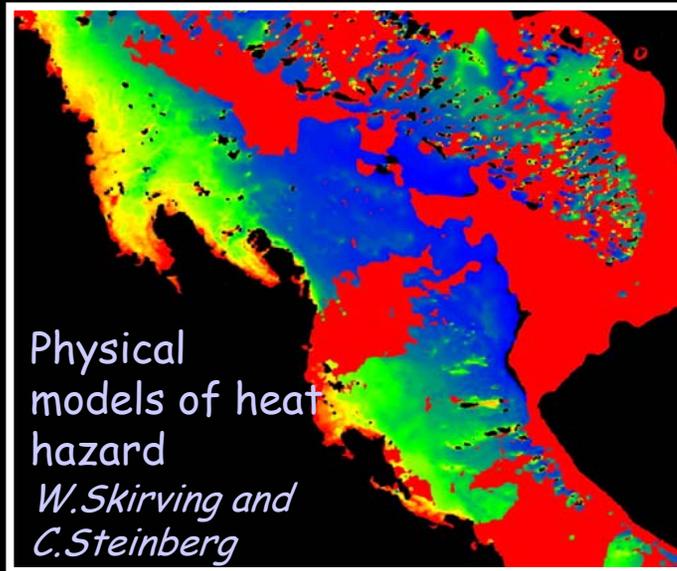
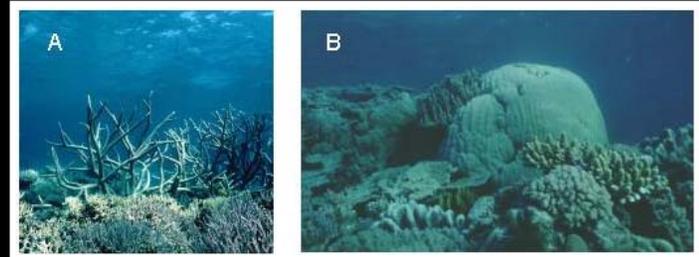
**Synergistic effects - location, type, history**

'Right' history ———  
 Prevalence of heat resistant zooxanthellae genotypes ———  
 Communities present ———

## Turbid water reefs



## Clear water reefs



Places with reliable mixing with cool waters

Places where strong flows resuspend sediments and increase shading

Deep reefs

'Right' history of acclimatization  
'Tough' coral communities present  
Prevalence of heat resistant zooxanthellae genotypes

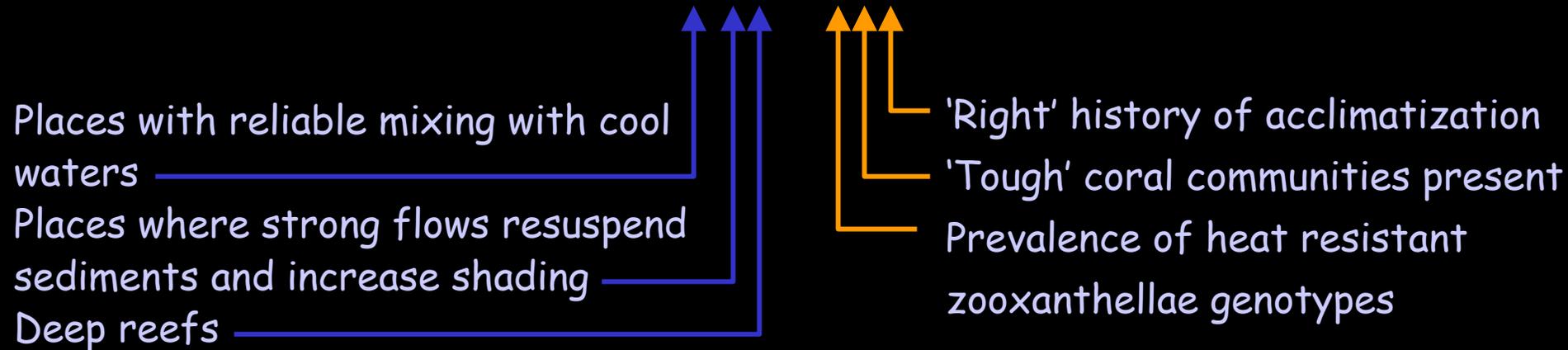
Better explanatory power used in combination than when tested singly

Promising insights using a Bayesian approach



GIS proxies for mixing, cooling and acclimatization

Categories of coral community types and habitats



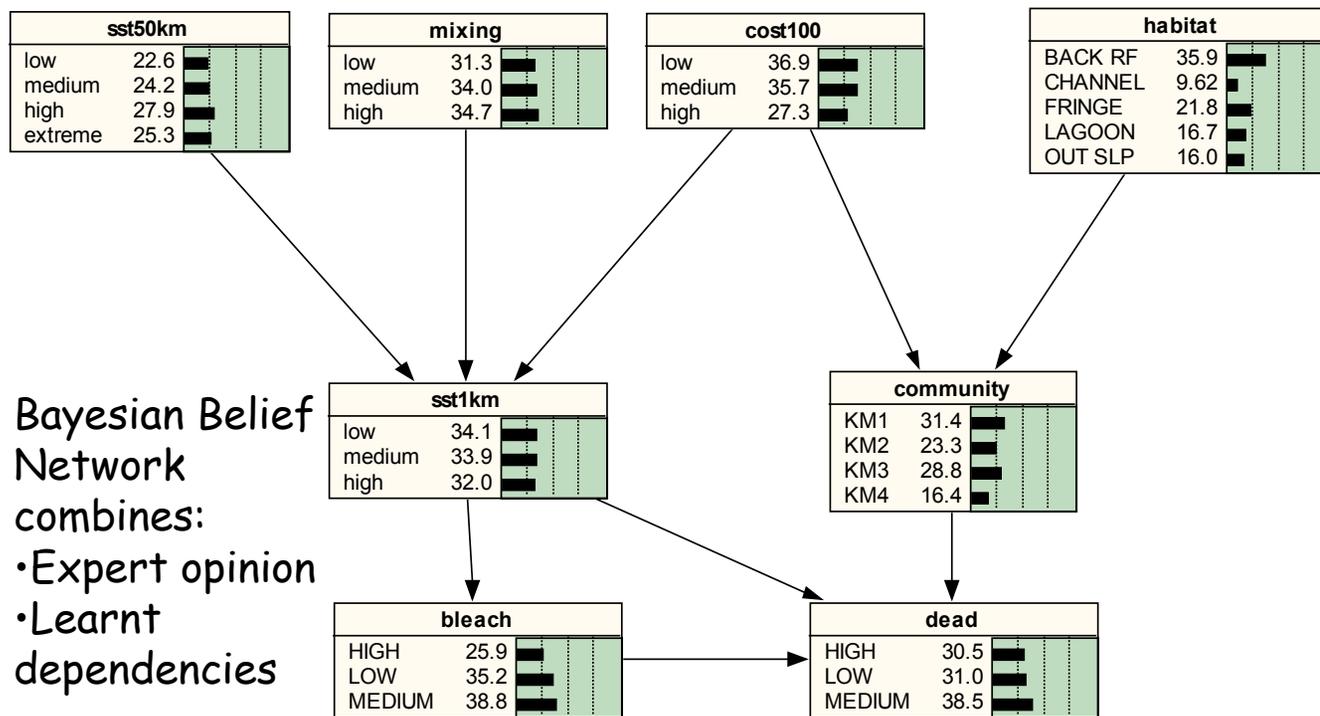
NOAA 50 km products  
hotspots,  
Degree heating weeks

A Mixing index using current vectors depth model

An Index for ease of mixing with cool water from 100 m

Index for Acclimatization regime

Categories of reef habitat and community type



What combination of information best explained places where mortality was low

AIMS 1 km SST products

Index of bleaching for 'sites'

Index of mortality for 'sites'

1. Ecology and post-bleaching impact surveys

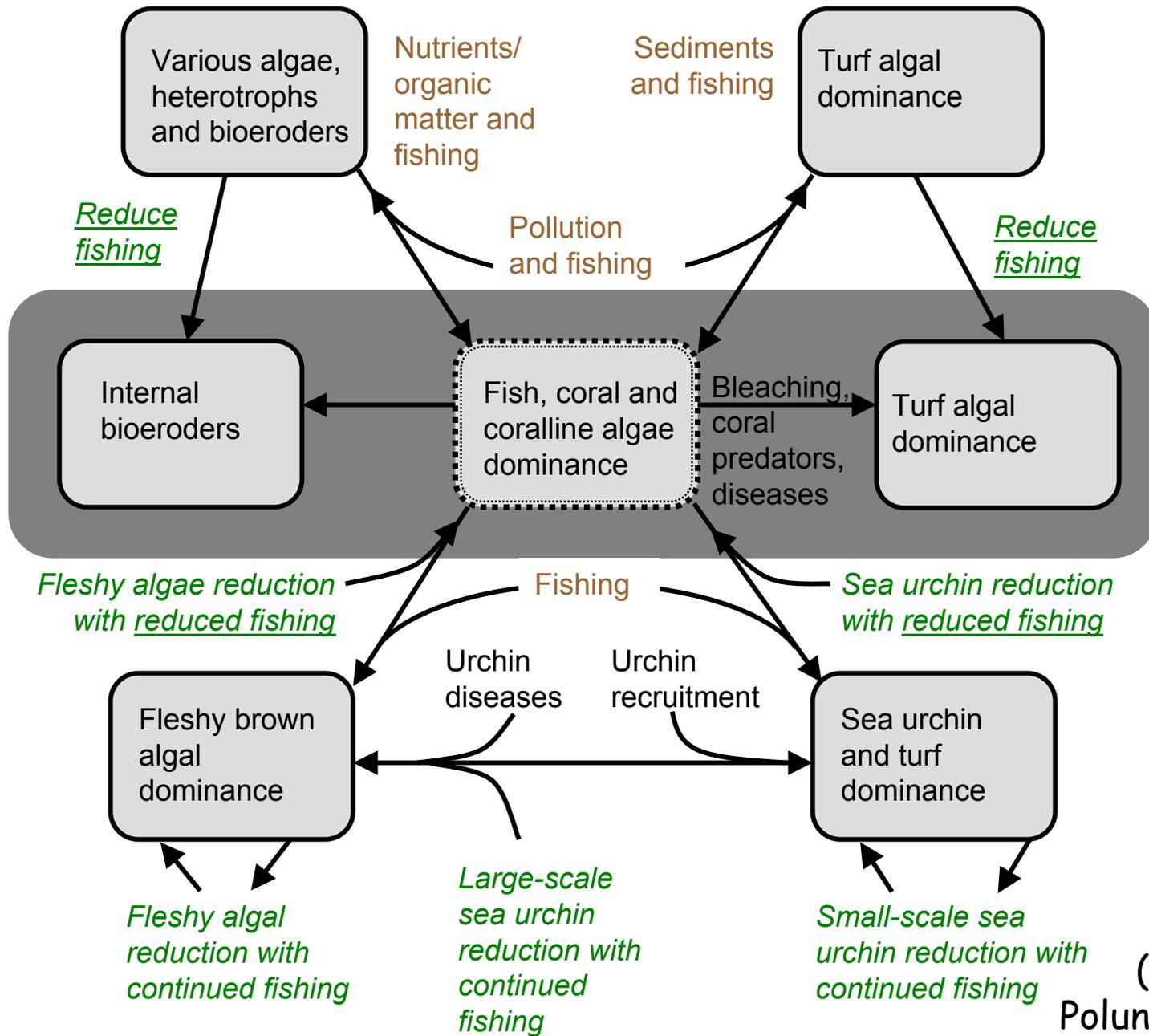
- '...reefs are deteriorating from coral bleaching and mortality due to warming seas....'
- '...counteract these trends by adopting a number of risk minimising strategies.'

Statement from

Second International Marine Ecosystem  
Management Symposium,  
Manila, Philippines, March 24-27 2003

Thank you

# Local conservation actions



(McClanahan, Polunin and Done)