# Adaptation to climate change in coastal systems

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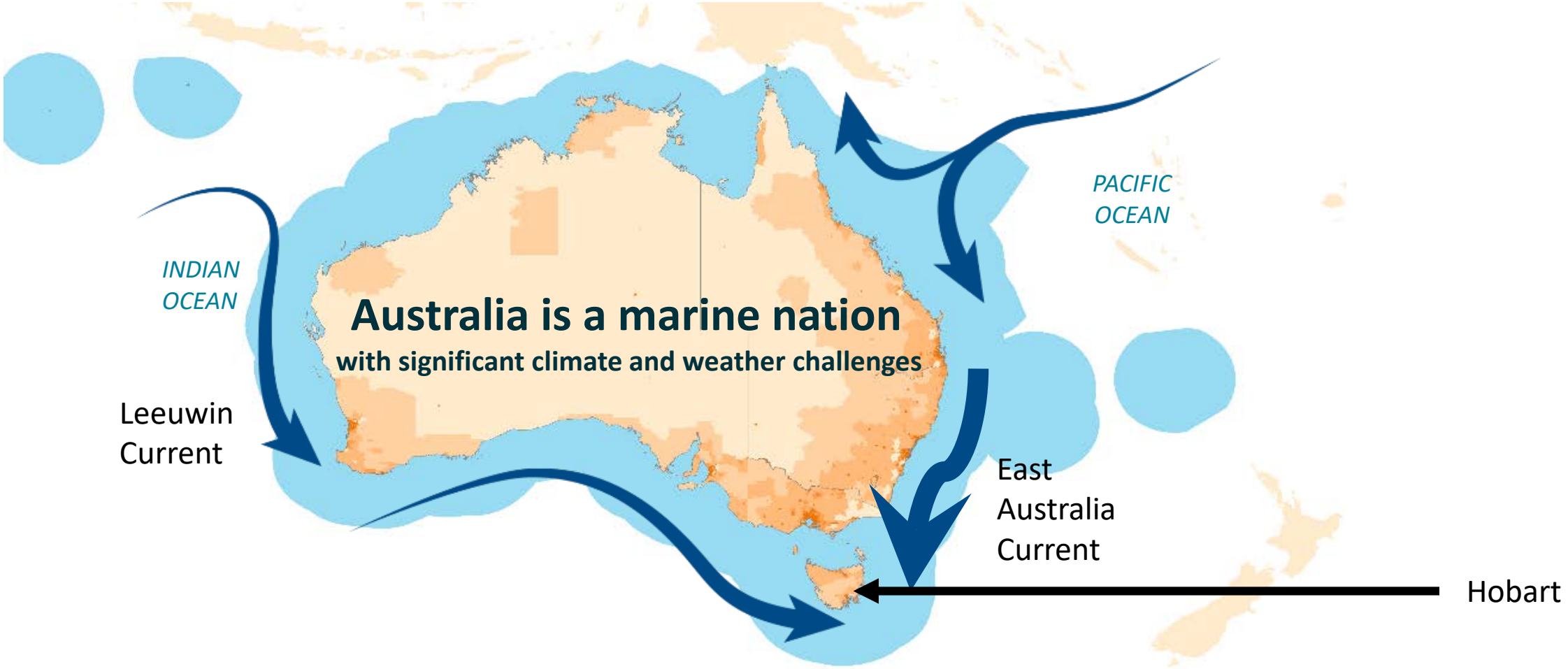
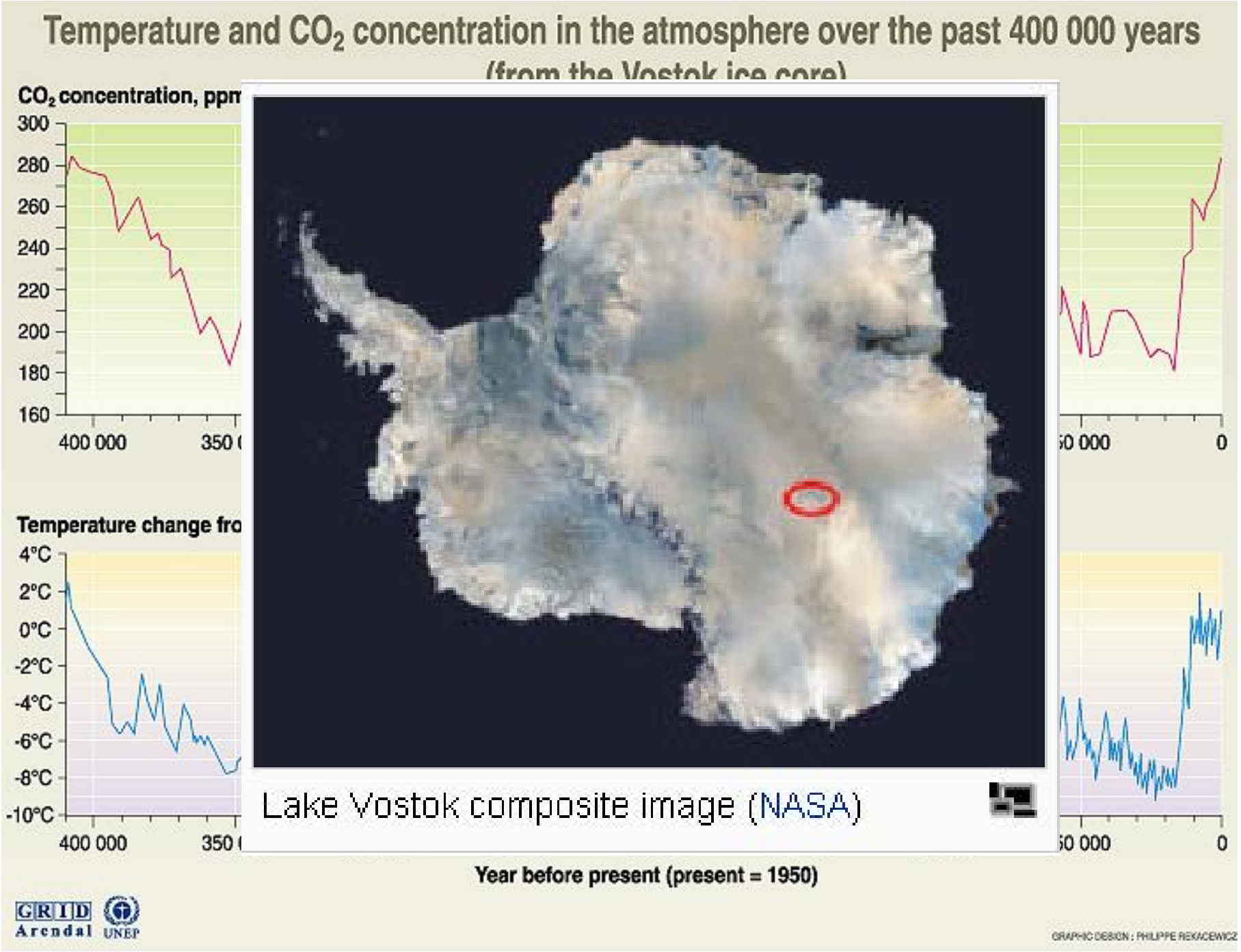
Hobart, Australia

# CSIRO – Oceans and Atmosphere Division

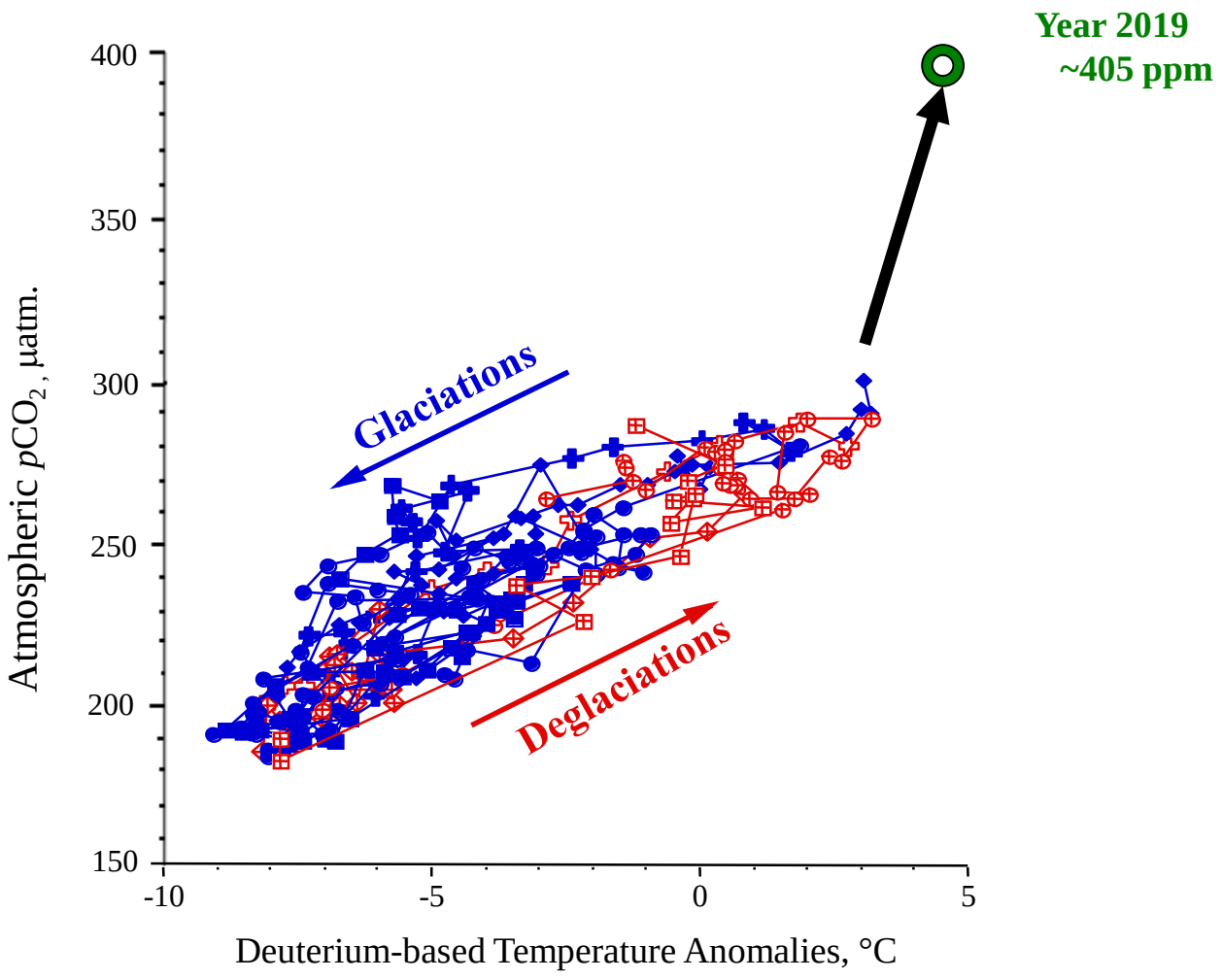





Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

# $CO_2$ & Temperature (~800,000 Years)

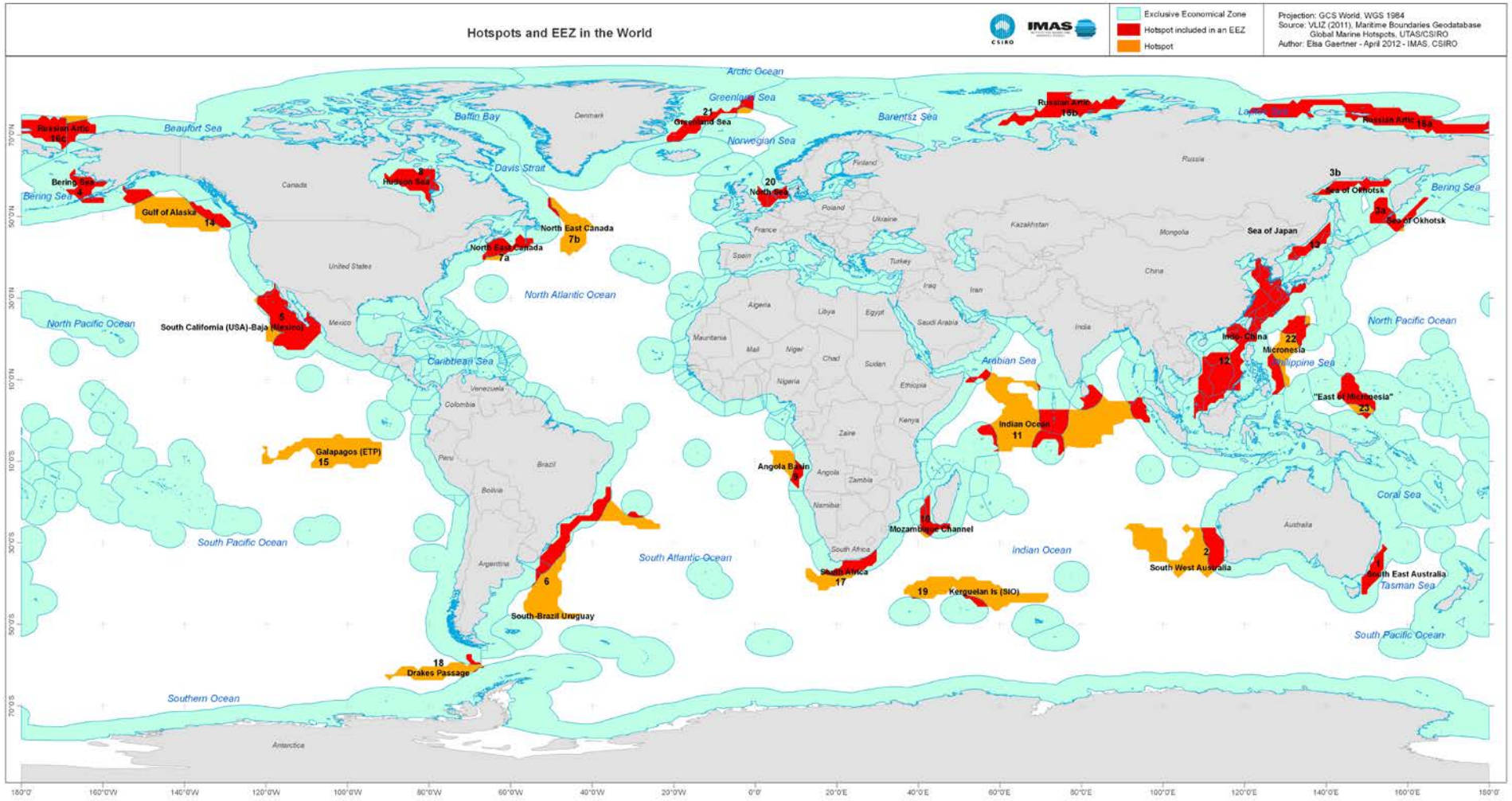
Vostok Ice Core Data




*IGBP 2000*

Courtesy David Ugalde, DCC

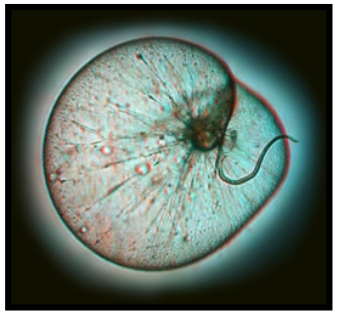
# Oceans are rapidly warming



# Biological changes in south-east Australia – now well documented

14/29 intertidal species have moved further south in Tasmania over last 50 years *(Pitt et al 2010)*

Expansion of sea urchins native to NSW causing loss of kelp forests in Tasmania *(Ling et al 2009)*

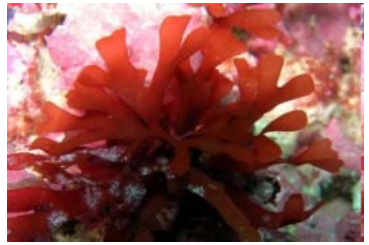


Changing composition of phytoplankton blooms off Tasmania– increased tropical species and red tides *(Thompson et al 2009)*

Rock lobster recruitment, catch and distribution correlated with regional SST changes *(Pecl et al 2009)*

Some 45 coastal fish species have exhibited major distributional changes in Tasmania *(Last et al 2011)*

Seaweeds: 85% further south on east coast and 56% on the west coast from 1940 *(Wernberg et al 2011)*



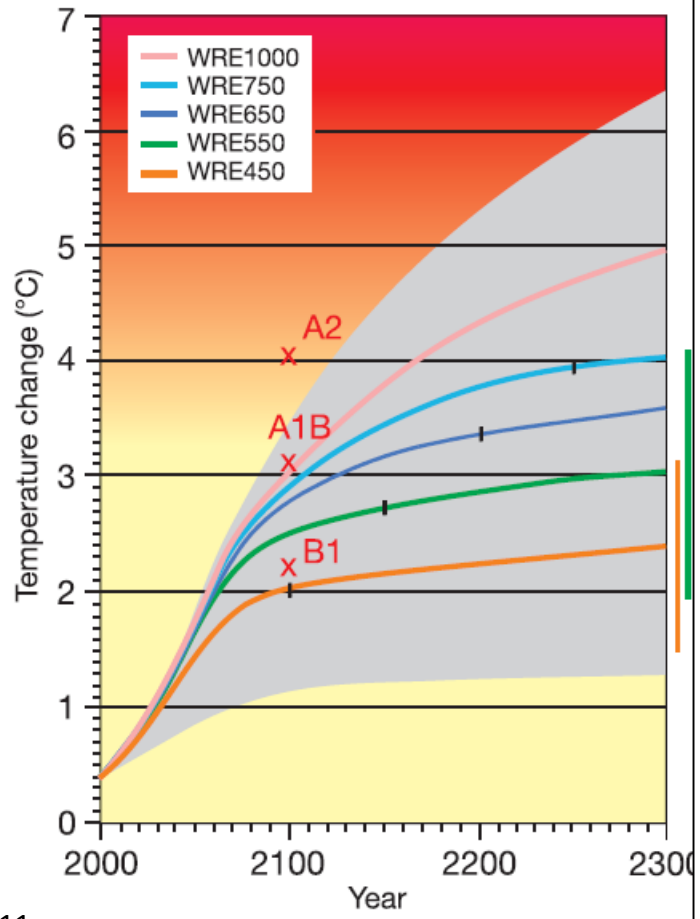
# What to do? Mitigation vs Adaptation

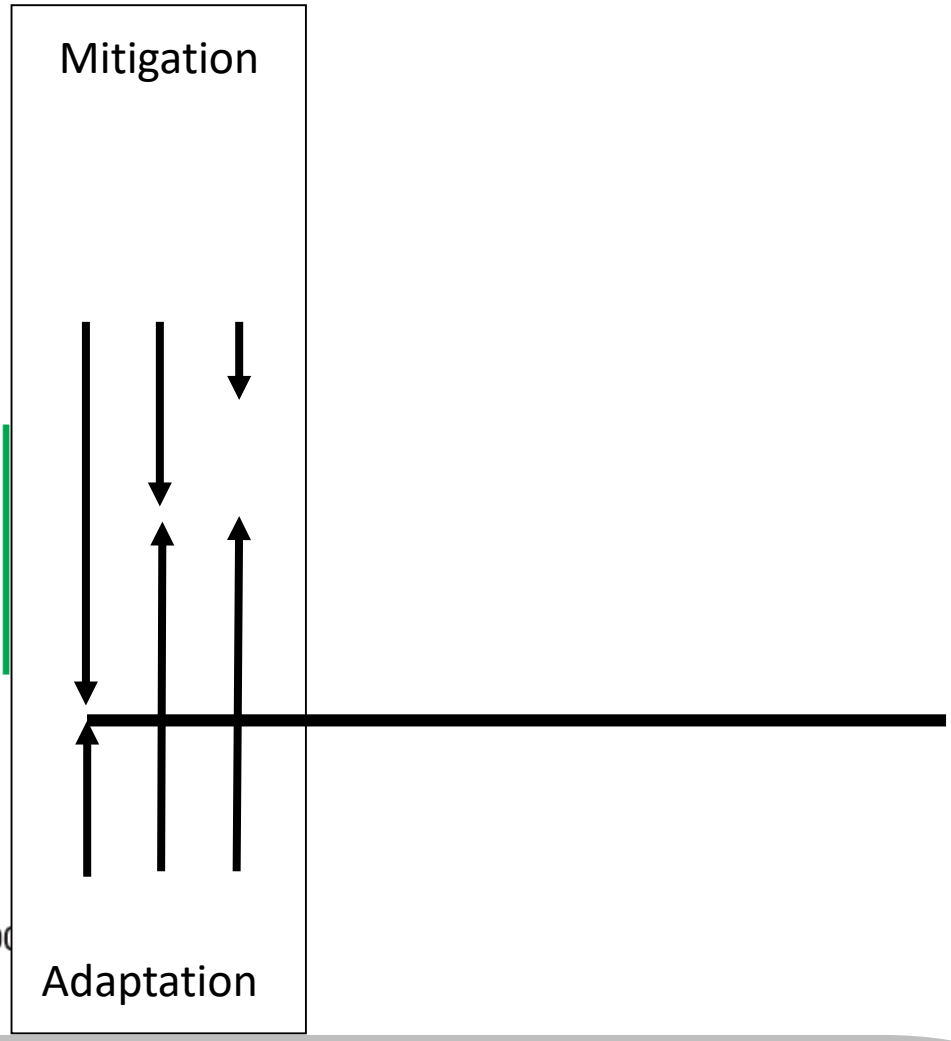
- Mitigation: usually considered with regard to the climate system ("global", e.g. reduce greenhouse gas emission)

- Adaptation: usually local in scale, to address local impacts of climate change (+/-)

  - Adaptation strategies should aim to increase the flexibility in management of vulnerable ecosystems (Hulme 2005)

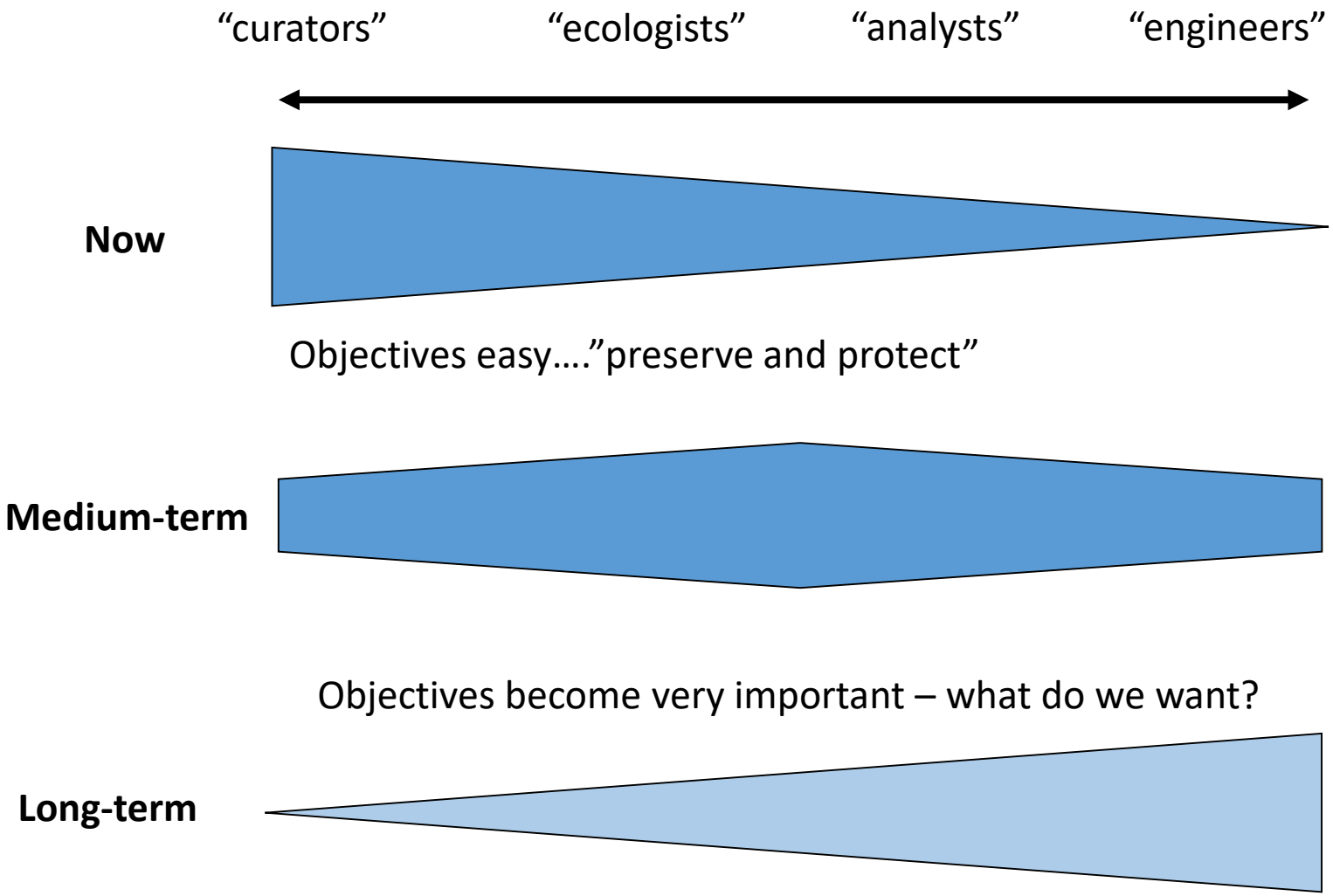
# Climate change is already disrupting natural systems




IPCC 2007, WG II, Ch 11

# Natural systems & managers – confronting rapid change



# Is a useful manager one…

A. with no tools?

B. with a list?

C. with tools and a list, but no experience?

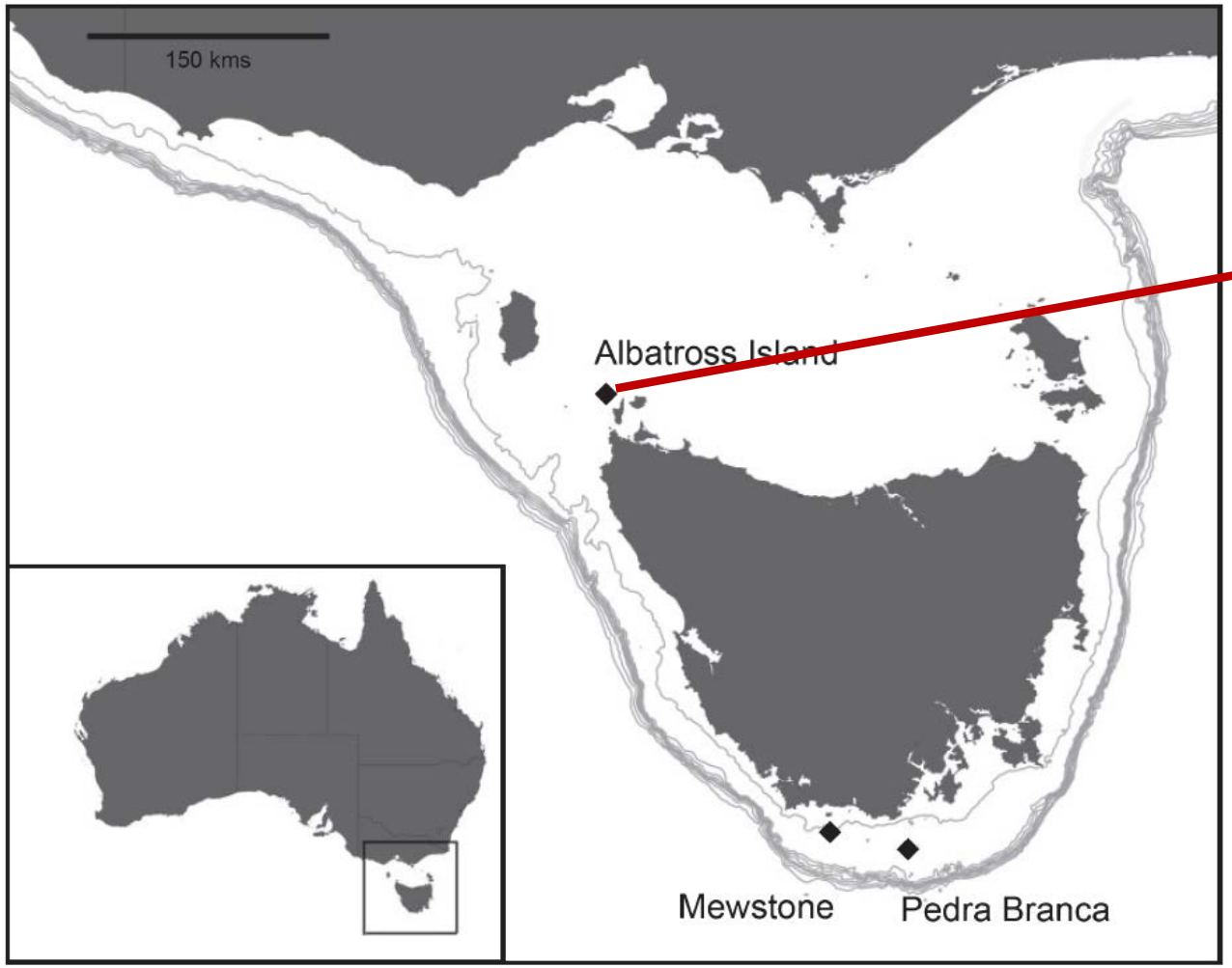
D. with tools and a list, and experience?

# Adaptation Pathways: the process of practice

1. Develop adaptation options: with partners
2. Rate options: expert cost-benefit-risk scoring
3. Test best options
   (a) In the field
   (b) In a model
4. Compare outcomes: performance indicators
   (eg Numbers of Breeding Pairs)
5. Develop an adaptation pathway
6. Inform management and research: refine

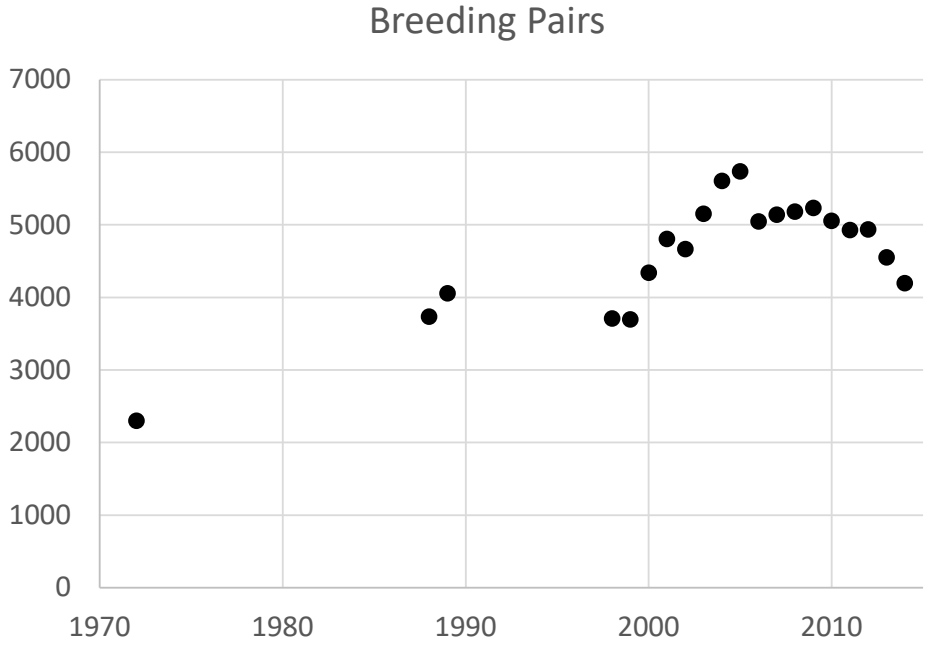
# Adaptation for scientists, managers and seabirds

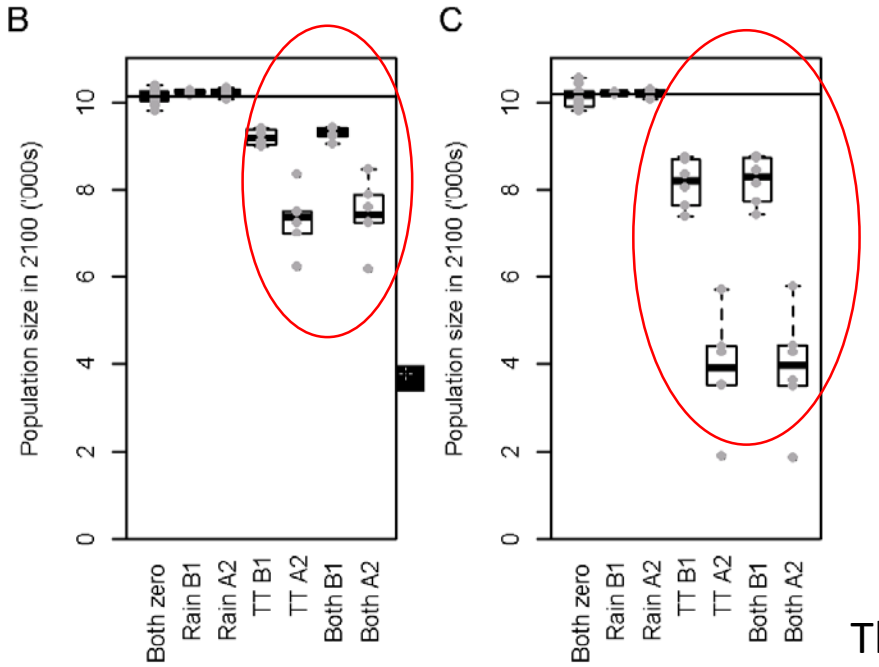
# Shy Albatross




# Shy Albatross

- Signal in population – declining numbers
- Climate signal (breeding success ↓ with ↑ temp)
- Projections of continued poor population status
- Business as usual will not offset losses




Thomson et al 2015

# Generate and evaluate adaptation options – rapid assessment

| **Implementation of successful adaptation requires options that are** | **“Responsible” group** | **Tools to assess options** |
|---|---|---|
| Generate options | Scientists and managers | 1. Vulnerability framework |
| Technically appropriate (k) | Scientists and managers | 2. Cost-benefit-risk |
| Institutionally possible (r) | ‘Policy & management” | 3. Barriers analysis |
| Socially acceptable (v) | Citizens | 4. Social acceptability |

Hobday et al. 2015

# Option: Egg replacement

# Option: Drainage

# Option: Nest enhancement

# Option:
# Bird rescue

# Option: Bird rescue

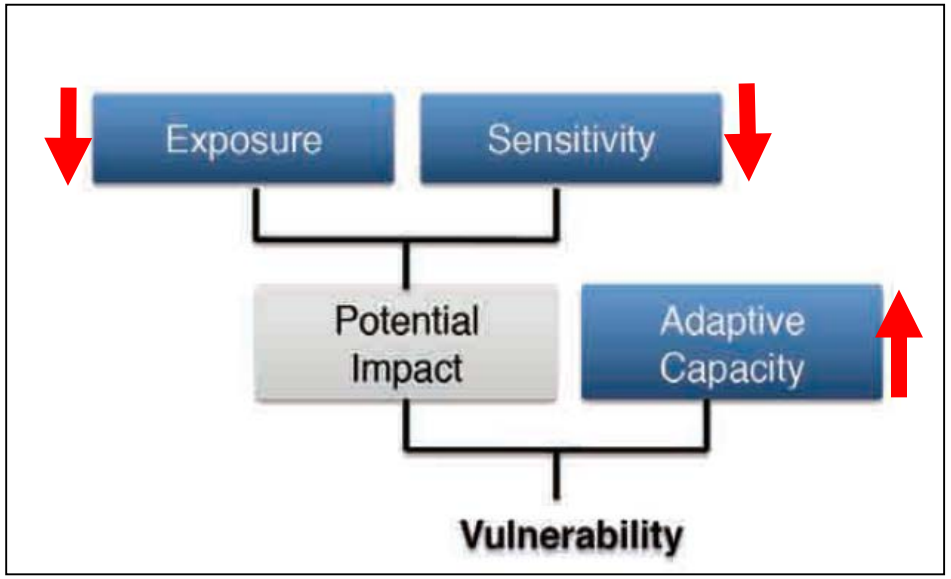
# Option

- Remove competitor

# Option: disease treatment

# Adaptation options: reduce vulnerability

<u>Reduce exposure</u>
(avoid climate)
- Translocation
- Habitat modification
- Shading
- Engineering

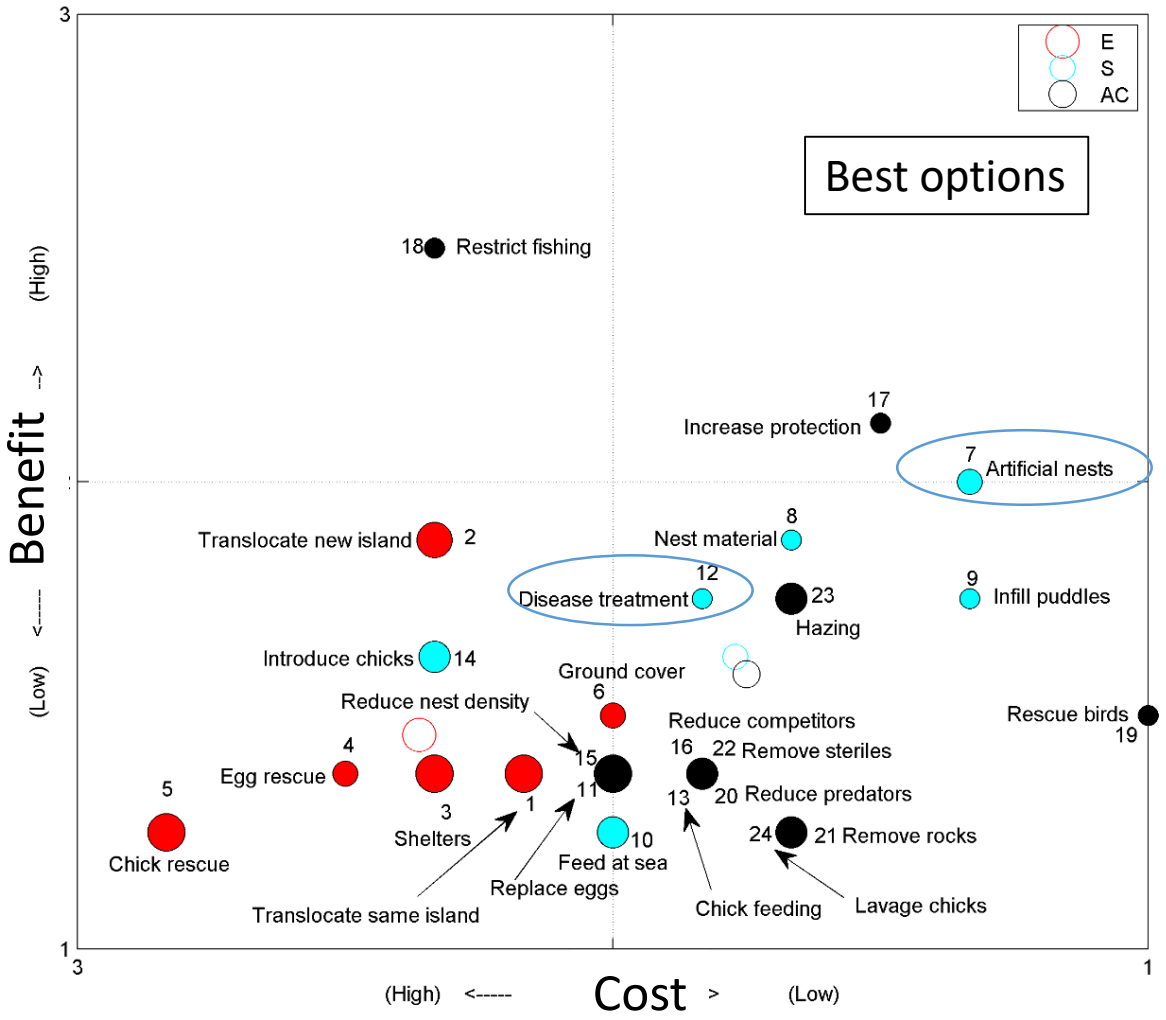


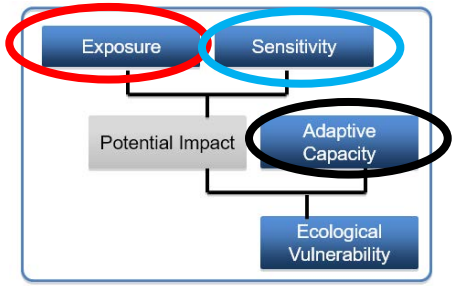

<u>Reduce sensitivity</u>
(improve condition)
- Supplemental feeding
- Habitat modification
- Disease treatment

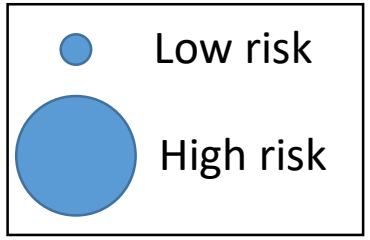
<u>Increase adaptive capacity</u>
(reduce other stressors)
- Reduce bycatch
- Pest eradication
- Predator management

Hobday et al. 2013

# Rate the adaptation options

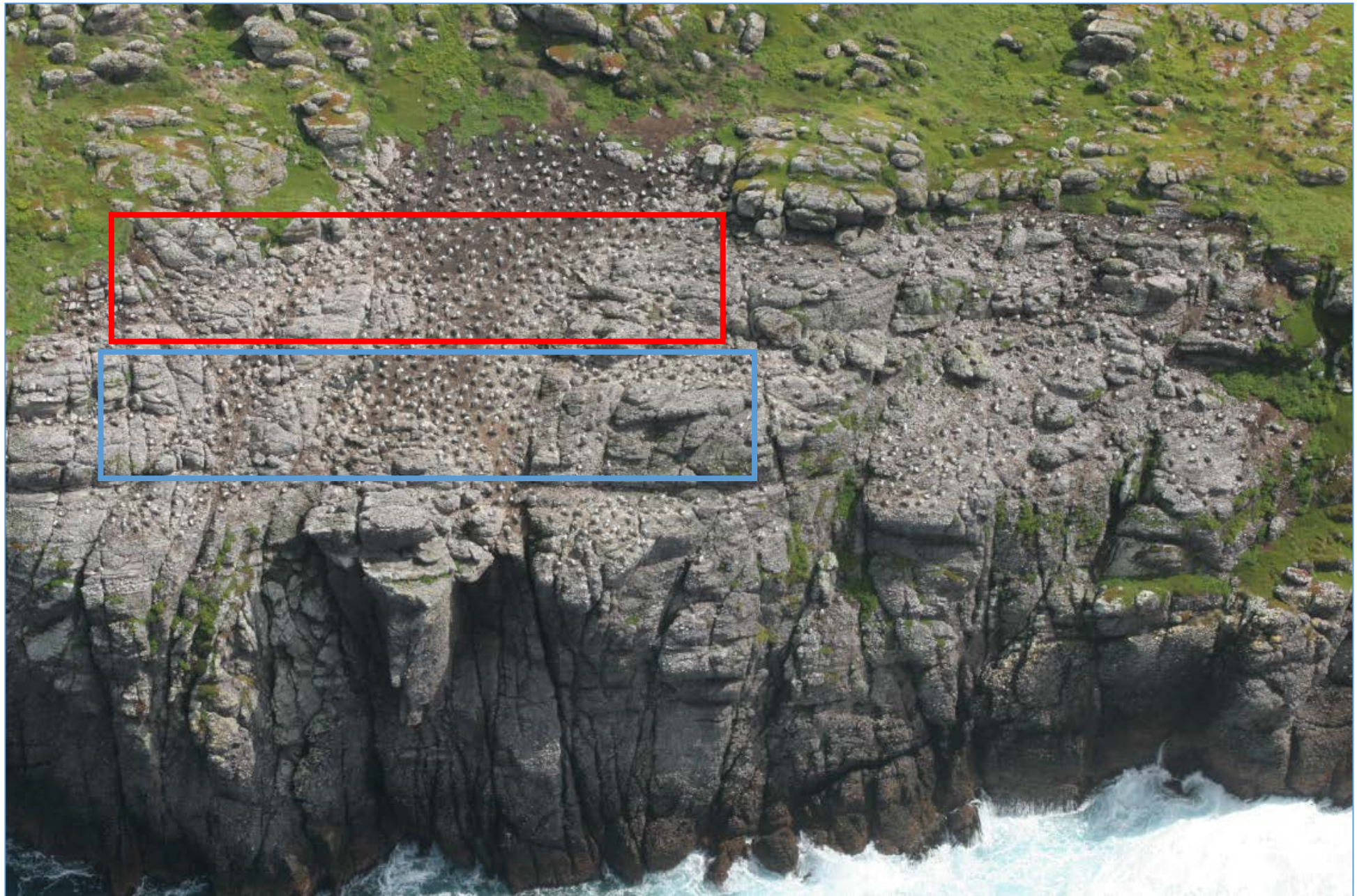


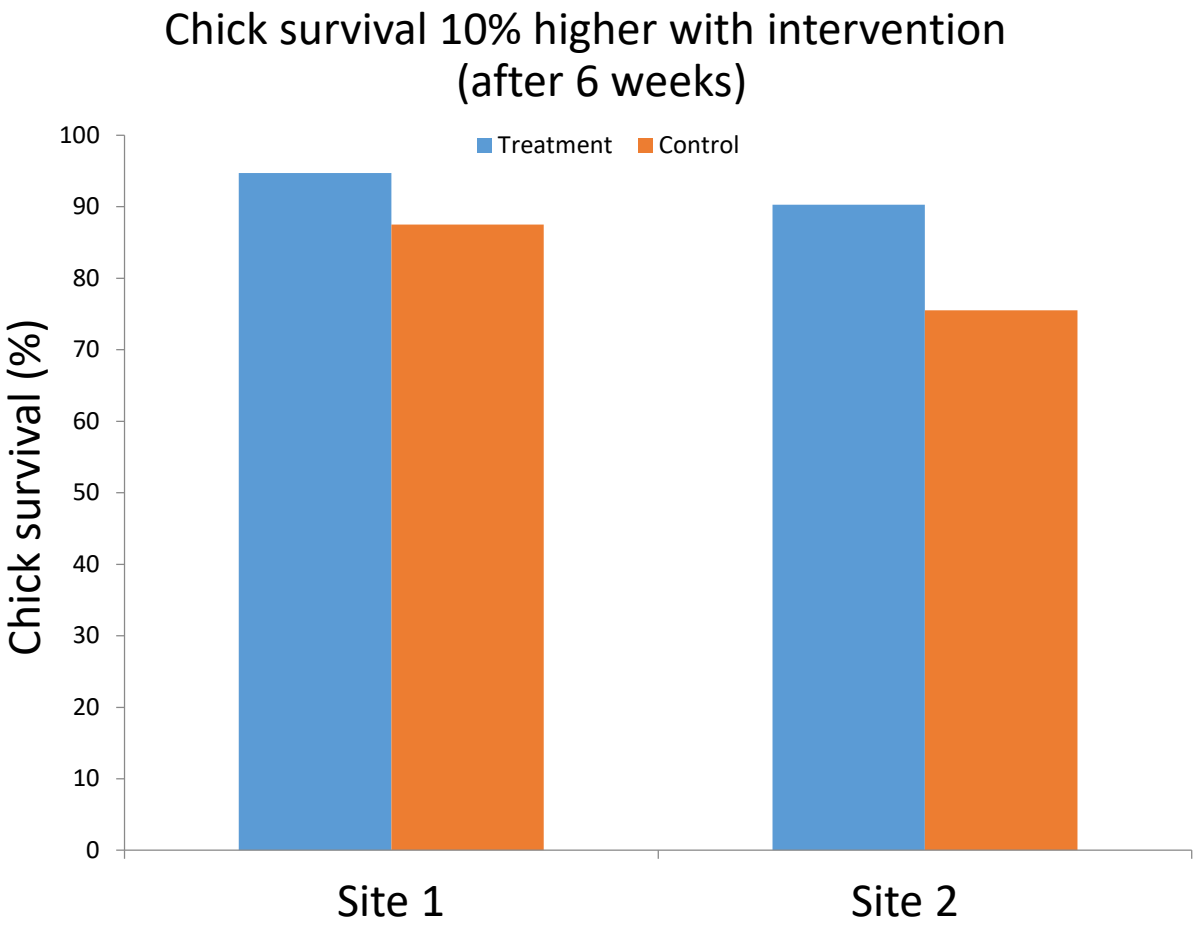




Alderman & Hobday 2017

# Adaptation Experiment 1: Disease treatment



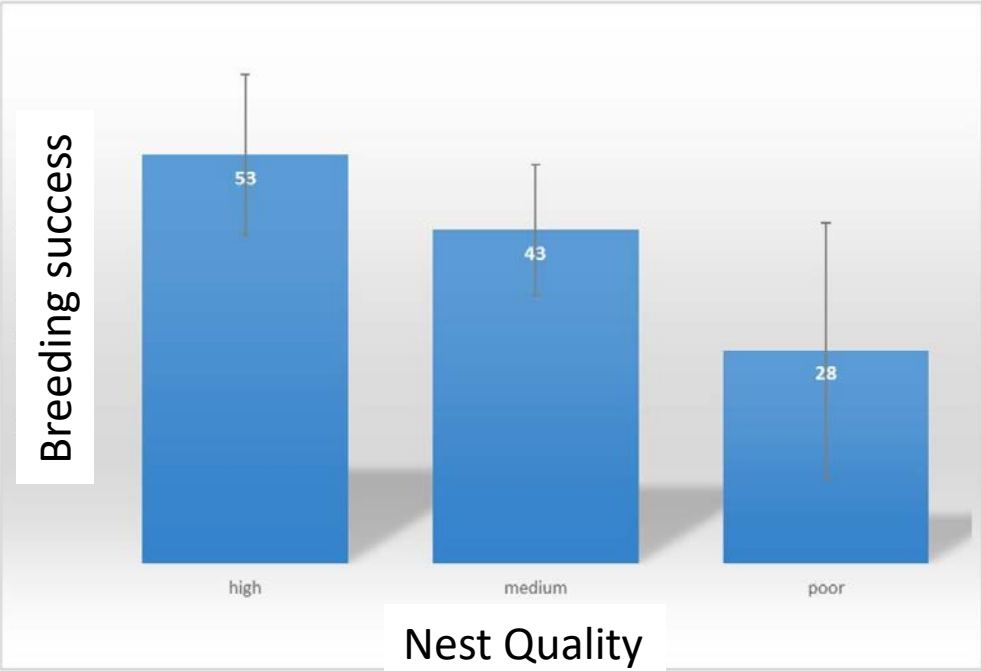
# Adaptation experiment 1: Disease treatment




Alderman and Hobday (2017)

# Adaptation experiment 2: Nest enhancement

Sept 2017 - present




Good nest

poor nest

# Breeding success

Adults used nests

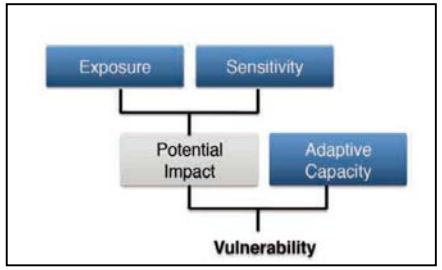
Laid eggs and chicks hatched

Chicks fledged

Breeding success tripled on artificial nests

# Adaptation pathway for albatross

Leadtime for development and social acceptability means staging options




**Adaptive capacity**

Protection status

Bycatch reduction

Pest control

Doing before

Implemented now

Easy

**Sensitivity**

Disease treatment

Nest enhancement

Hazing

Supplemental feeding

Testing now

Costly now

Moderate

**Exposure**

Egg rescue

Chick rescue

Translocation

Hard

present

2050

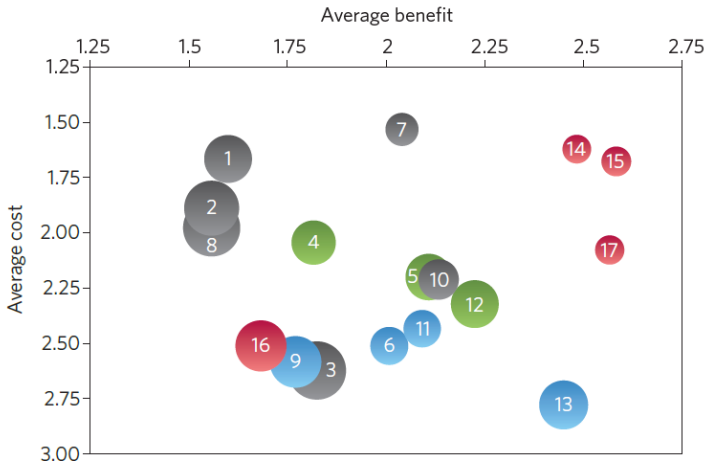
2100

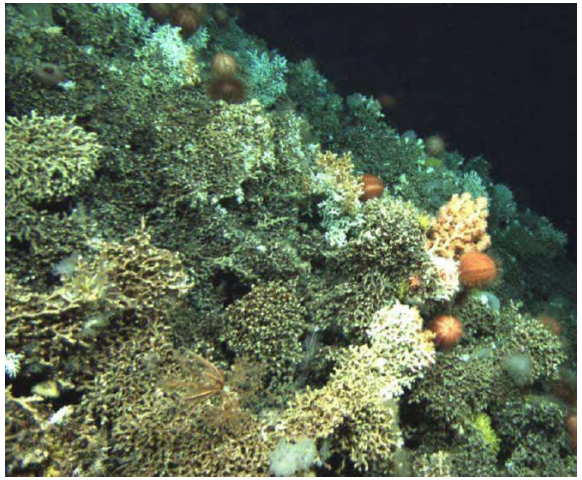
Is the ‘world’ ready?

# Adaptation options: marine species & habitats

- Options developed and prioritised for:
  - Seabirds (Hobday et al 2015)
  - Marine mammals (Hobday et al 2015)
  - Deep reefs (Thresher et al 2015)
  - Coral Trout (Pratchett et al. 2017)
  - Albatross (Alderman & Hobday 2017)
  - Great Barrier Reef (Condie et al. in rejection)

- Tested options with
  - Albatross

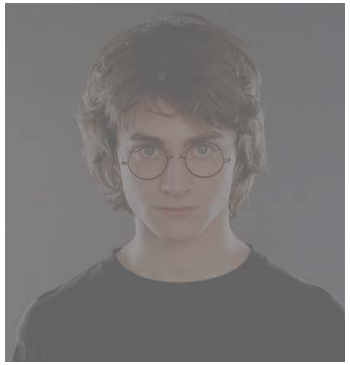


Thresher et al 2015

# Career progression

| Impacts | Attribution | Adaptation |
|---|---|---|
| “see” | “why” | “what to do” |



Science → Management/Policy

<40 yrs.

40-60 yrs

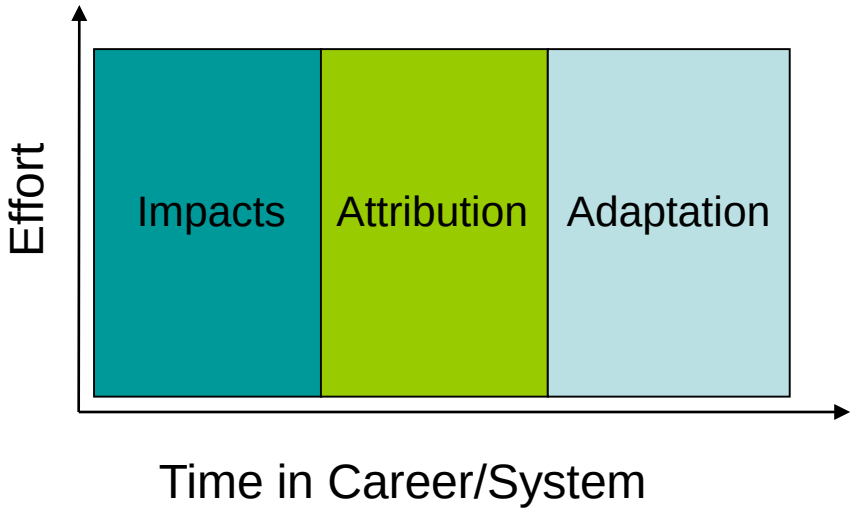
50-65 yrs.

Few years left….

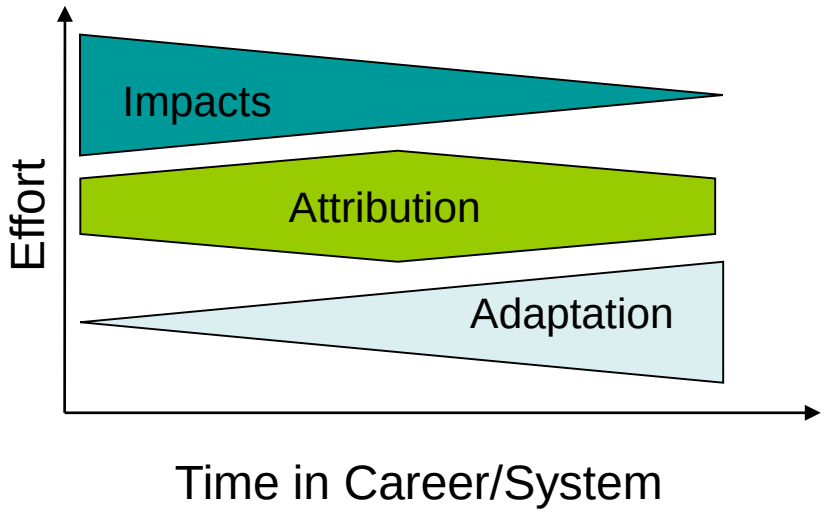
How can we speed this up?

# What kind of scientist will be useful under climate change?

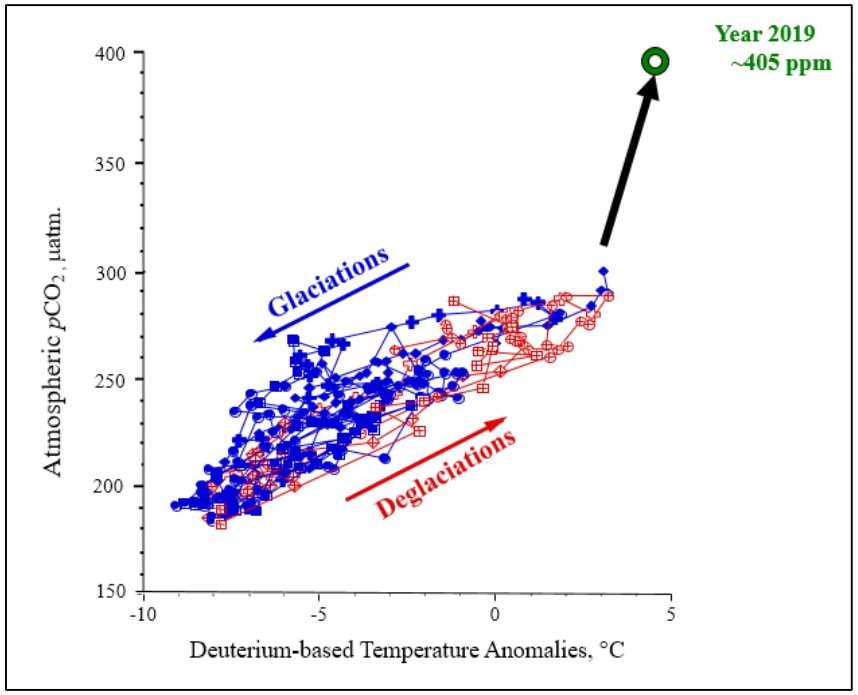
**Scientist 1**

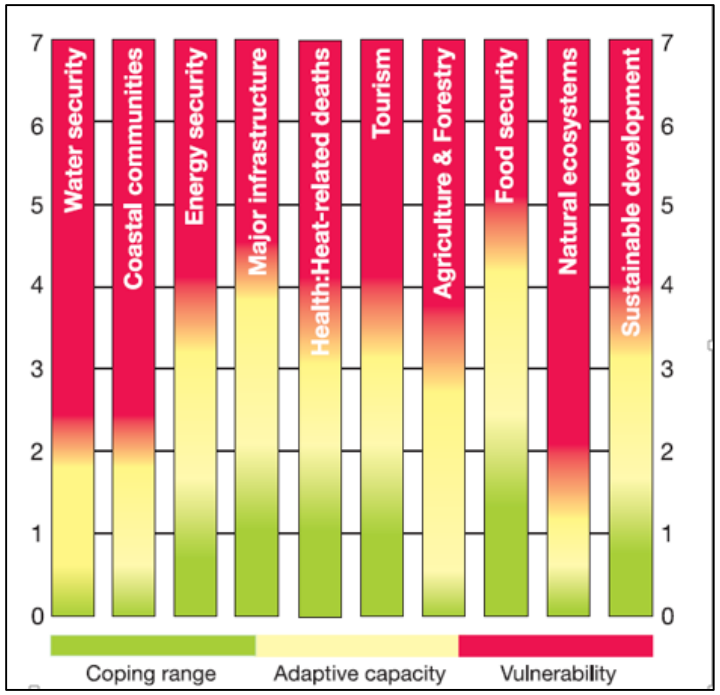


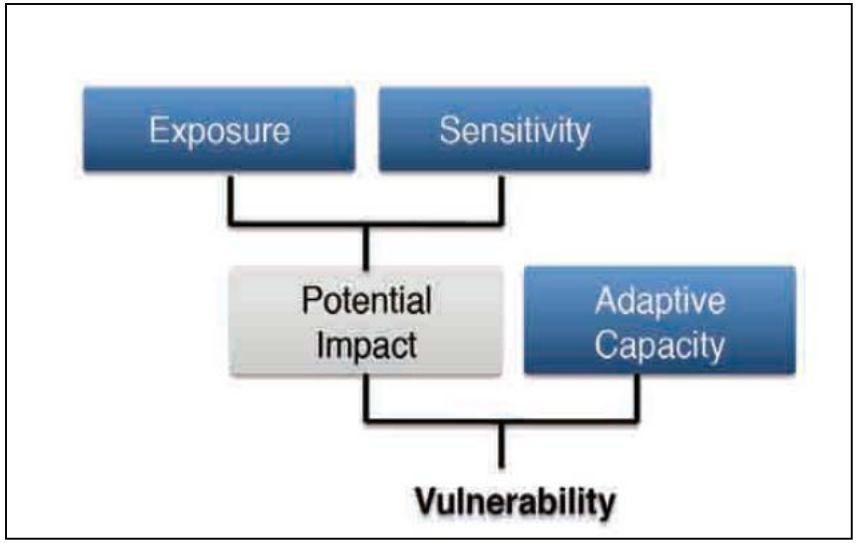

**Scientist 2**

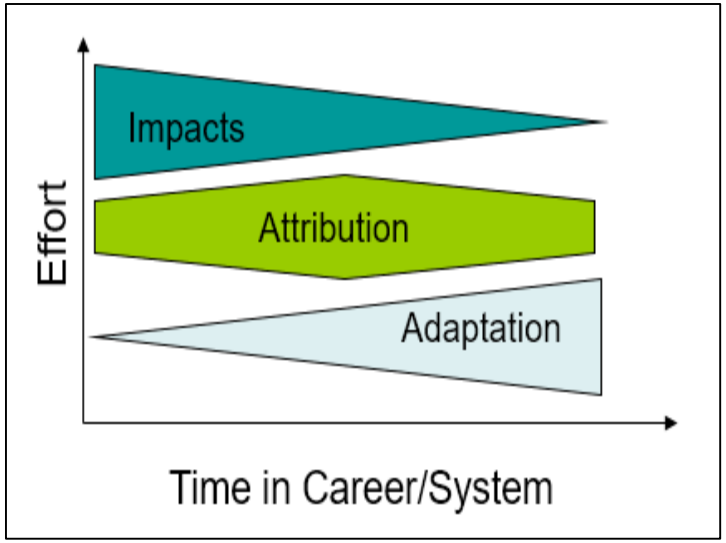



Alderman & Hobday 2017


Year 2019
~405 ppm
Glaciations
Deglaciations
Atmospheric $pCO_2$, µatm.
400
350
300
250
200
150
-10
-5
0
5
Deuterium-based Temperature Anomalies, °C


Water security
Coastal communities
Energy security
Major infrastructure
Health:Heat-related deaths
Tourism
Agriculture & Forestry
Food security
Natural ecosystems
Sustainable development
0
1
2
3
4
5
6
7
Coping range
Adaptive capacity
Vulnerability


Exposure
Sensitivity
Potential Impact
Adaptive Capacity
Vulnerability


Impacts
Attribution
Adaptation
Effort
Time in Career/System

# Some proposed adaptation options will be “novel”

COMMENT

## Bring elephants to Australia?

There’s a solution to the continent’s rampant fires and feral animals, says **David Bowman** — introduce large mammals and increase hunting pressure.

Three years ago this week, Australia was burning. On 7 February 2009 — now known as Black Saturday — a massive firestorm consumed more than 400,000 hectares in southern Australia. At least 173 people died trying to outrun the fires, defend their homes or seek shelter.

That blaze was unusually fierce, but fires are a constant source of anxiety for Australia. The continent is extremely fire-prone, with a distinctive signature of oscillating fire activity that begins in the north during the winter, then moves south during the summer. Lately, the fires have been more intense and widespread, perhaps as a result of climate change — last year, around 5% of the continent was burnt.

If only fires were Australia’s sole environmental concern. The continent is also overrun by invasive species. They fill holes created by a mass extinction event that occurred around 50,000 years ago during the Pleistocene, when the arrival of the first Australians coincided with a collapse in the continent’s megafauna, namely giant marsupials (some as large as hippopotamuses), reptiles and birds[1]. The precise causes of that event are unclear, but the resulting gap in the food web has been filled by populations of pigs, goats, cattle, horses, donkeys, camels, buffalo and deer[2]. These animals are reconstructing ecosystems, a trend amplified by the introduction of alien plants, particularly

I accept that this is a radical way of thinking; we would have to weigh the various options. For example, we could stop poisoning the Australian wolf (dingo). Poisoning disrupts their social structure, and research suggests that dingoes in packs act as top predators of smaller predators such as introduced foxes[5]. More dingoes could also help to control other feral animals, such as

pigs. Alternatively, we could introduce

control gamba grass involve using chemicals or physically clearing the land, which would destroy the habitat. Using mega-herbivores may ultimately be more practical and cost-effective, and it would help to conserve animals that are threatened by poaching in their native environments. This potential solution is not limited to Australia — it has been suggested that elephants could be used as part of a project to ‘rewild’, or return North American ecosystems to their prehuman state[9].

I realize that there are major risks associated with what I am proposing. It would be essential to proceed cautiously, with well-designed studies to monitor the effects. The greatest challenge would be managing the density of herbivore populations so that their demand on resources does not degrade the ecosystem. Here, we could adopt management methods from game parks and reserves, such as building fences, regulating the availability of water and food, and controlling breeding and hunting.

Of course, introducing large mammals cannot solve all of Australia’s ecological-management conundrums. And I am mindful that the proposal could be used to justify commercial grazing in fragile ecosystems, an ongoing controversy[10]. But the usual approaches to managing these issues aren’t working. The full spectrum of options needs to be canvassed in an open and honest way. ■

A. BRAMELLI/ALAMY

CORRESPONDENCE COMMENT

BEST CONTROL

### Sugar: a problem of developed countries

The contribution of sugar towards chronic disease is more relevant to developed countries than to the developing world (*Nature* 482, 27–29; 2012). In Asia, for example, up to 10% of the population is obese and/or diabetic (see go.nature.com/qnumdq). Although the data [illegible] from fewer than 83 [illegible] less than 83 [illegible] person. It is more [illegible] a high consumption [illegible] in-based foods [illegible] statistic (see [illegible] consumption [illegible]).

Overall, [illegible] foods that have a high glycaemic index (that trigger a rapid and sharp increase in blood glucose), such as wheat, potatoes and certain types of rice, also contribute to obesity and diabetes. Emphasis on sugar alone is therefore to a narrow a basis for devising policies to curb these problems.

Christiani Jeyakumar Henry, Viren Ranawana *Clinical Nutrition Research Centre, Singapore Institute for Clinical Sciences, Singapore*
*jeya_henry@sics.a-star.edu.sg*

### Sugar: other ‘toxic’ factors play a part

Regulating products based on a scientific risk analysis is a worthy goal, but I contend that Robert Lustig and colleagues oversimplify the ‘toxic’ truth about refined carbohydrates (*Nature* 482, 27–29; 2012). Rather than demonizing sugar, the authors would have better served public health with recommendations to manage a balanced diet with exercise.

The authors also downplay other complex factors that could contribute to non-communicable disease burdens. These include relatively recent [illegible] and pollutants [illegible] affect [illegible] factors [illegible] history [illegible] tobacco [illegible] not [illegible] nutrition, nor do they have the second-hand proximity impact of tobacco smoking — key factors in their regulation.

Saleem H. Ali *University of Vermont, Burlington, USA.*
*saleem.ali@uvm.edu*

### Australia: small steps to control invasives

We believe that there are more obvious and less destructive options for controlling gamba grass and other invasive weeds in Australia than introducing mega-herbivores such as elephants (*Nature* 482, 30; 2012).

Biological control using carefully screened host-specific arthropods or pathogens, combined with quarantine and spread-prevention measures, is a more balanced approach, and one with which Australia has considerable experience.

The world is littered with examples of generalist vertebrate species (cane toads, foxes, myna, mosquito fish and so on) that were introduced in the misguided hope of controlling a pest species, only to have a substantial unintended impact on native biodiversity.

Credible solutions to these [illegible] are many [illegible] rather than [illegible] or [illegible] animals.

Bruce I. [illegible] Rapid [illegible] *Australia; and University of Western Australia, Australia.*
*bruce.webb@csiro.au*

### Australia: better solutions to wildfires

Among David Bowman’s more outlandish suggestions for dealing with Australia’s massive problems of wildfires, feral animals and weeds, there are some workable ideas (*Nature* 482, 30; 2012).

Some of these are already being implemented, such as the reintroduction of Aboriginal fire management in the north of the country. The Australian Wildlife Conservancy’s prescribed-burn programme in the Kimberley region is having great success.

These innovations are radical, but they are based on a sound ecological understanding.

Richard J. Hobbs *University of Western Australia, Crawley, Australia.*
*richard.hobbs@uwa.edu.au*

### Australia: a case for Aboriginal rangers

David Bowman makes a strong case for employing Aboriginal people to manage their own land and to reinstate traditional fire practices in Australia (*Nature* 482, 30; 2012). This strategy could form the basis of a coordinated, long-term conservation service.

It would also provide desperately needed employment for landowners, as well as supplying them with a reliable source of profits from hunting feral animals (N. Collar *et al. Hum. Ecol.* 39, 155–164; 2011).

In addition, the Aboriginal people, who have a deep spiritual connection to land, would be able to remain on their traditional territories and so maintain close functional relationships with their ancestors.

Clive R. McMahon [illegible] *University, [illegible] Australia.*

### Australia: a price on [illegible] risk

David Bowman proposes that elephants should be introduced into Australia as a cost-effective way to control invasive gamba grass, a major source of wildfire fuel (*Nature* 482, 30; 2012). But managing the elephants could be more expensive than, say, launching a fleet of harvesters every year to reduce fire risk. We should start by asking what is likely to work best, regardless of the cost.

To combat the problems caused by invasive aliens, we should implement ecologically sound control mechanisms that have a reasonable probability of success. We can worry about the bill later.

B. J. Nico de Bruyn, Andrew B. Davies *University of Pretoria, Hatfield, South Africa.*
*pjadebruyn@zoology.up.ac.za*

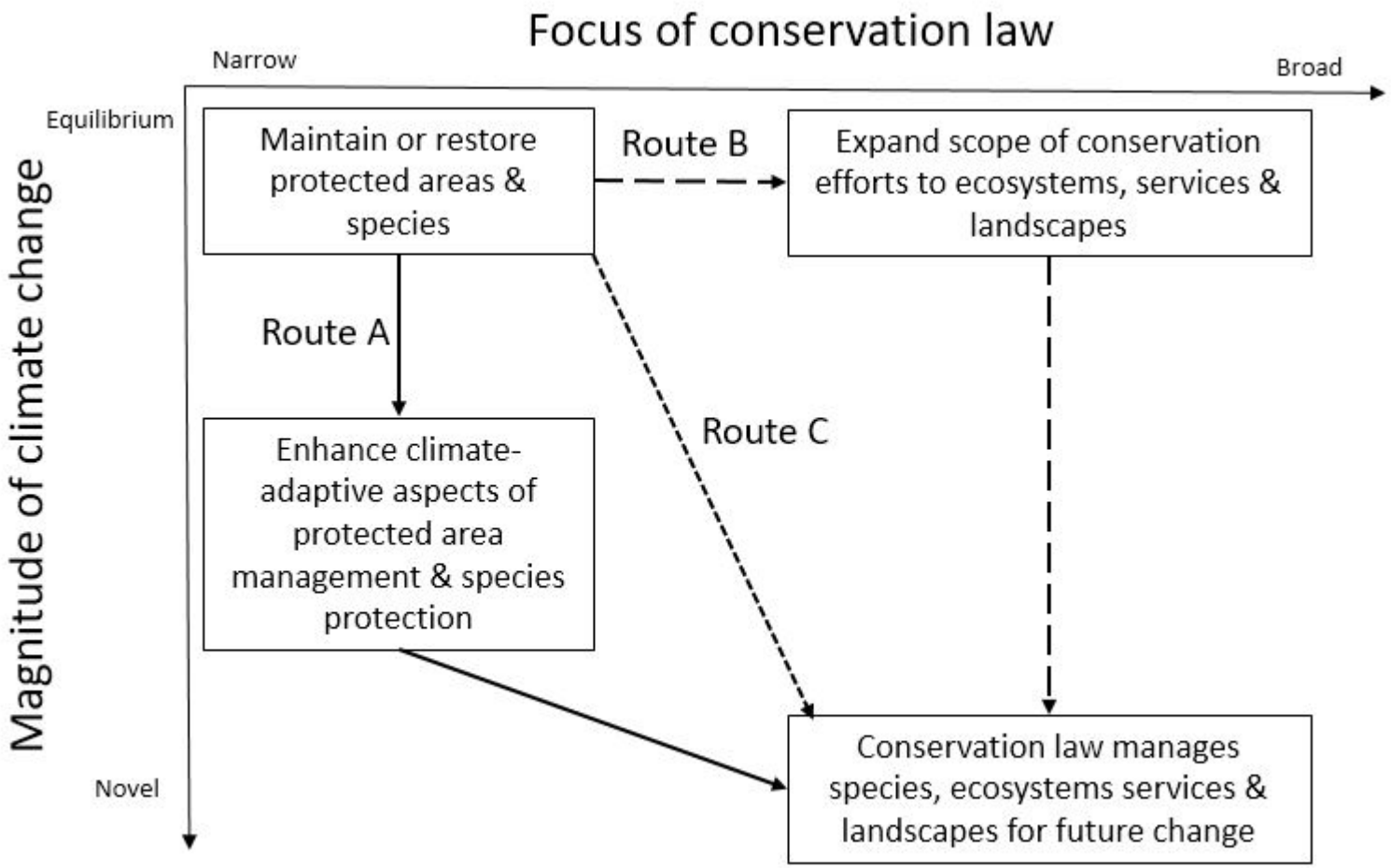




Outrage!

But, novel conversations are important….need maturity to have them

# Conservation laws for the future




McDonald et al. 2019

# Explore options…

- Reframing conservation actions with climate interventions
- Link actions to reference points
  - A “Harvest Strategy” approach
- Targets and objectives for intervention
  - How many birds is enough?

## Investigating adaptation options for iconic species – shy albatross

Evidence of population declines as a result of climate change is particularly concerning for threatened and endangered species, which may already be at risk. Iconic marine species will continue to attract conservation attention, and under climate change, intervention may be required to help populations persist. Developing adaptation options for iconic species will be challenging, and so much effort has been devoted to reducing non-climate stressors. In some cases, this will be insufficient, and so intervention is the only alternative to extinction. Recent work suggests the shy albatross (*Thalassarche cauta*) will be adversely affected by projected changes in environmental conditions under plausible climate change scenarios. This tool allows exploration of a range of intervention options, and demonstrates the effect on population size. The "Management Reference Level" is a minimum level of population abundance chosen by managers below which some action may be taken to improve population status. The reference level shown here is for illustration purposes only and has not been agreed by managers of this population.

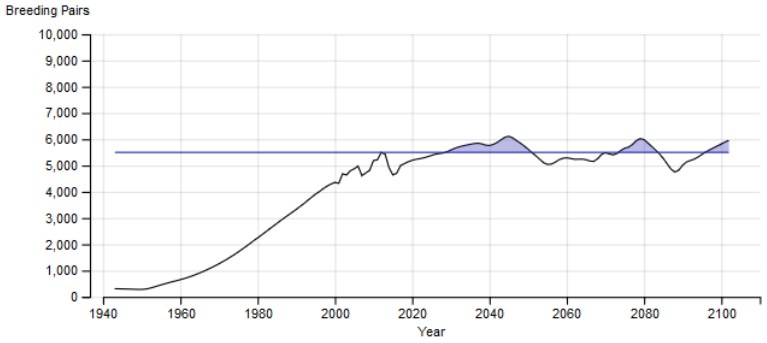
### Adaptation Options

- No Environmental Influence
- With Environment: No Adaptation
- Reduce Chick Mortality
- + Improve Juvenile Survival
- + Improve Chick Production
- Delay 5 Years
- Adult Survival Delay
- Improve Adult Survival

### Pathway Result

In the **+ Improve Chick Production** scenario, our model predicts the Albatross population will have **39** years above the Management Reference Level.

In this path, there are an average of **294** breeding pairs above the nominated Management Reference Level.




### Resources

Enabling Adaptation Pathways

### Contacts

Alistair Hobday, Oceans & Atmosphere (alistair.hobday@csiro.au)

Xavier Ho, Information Management & Technology (xavier.ho@csiro.au)

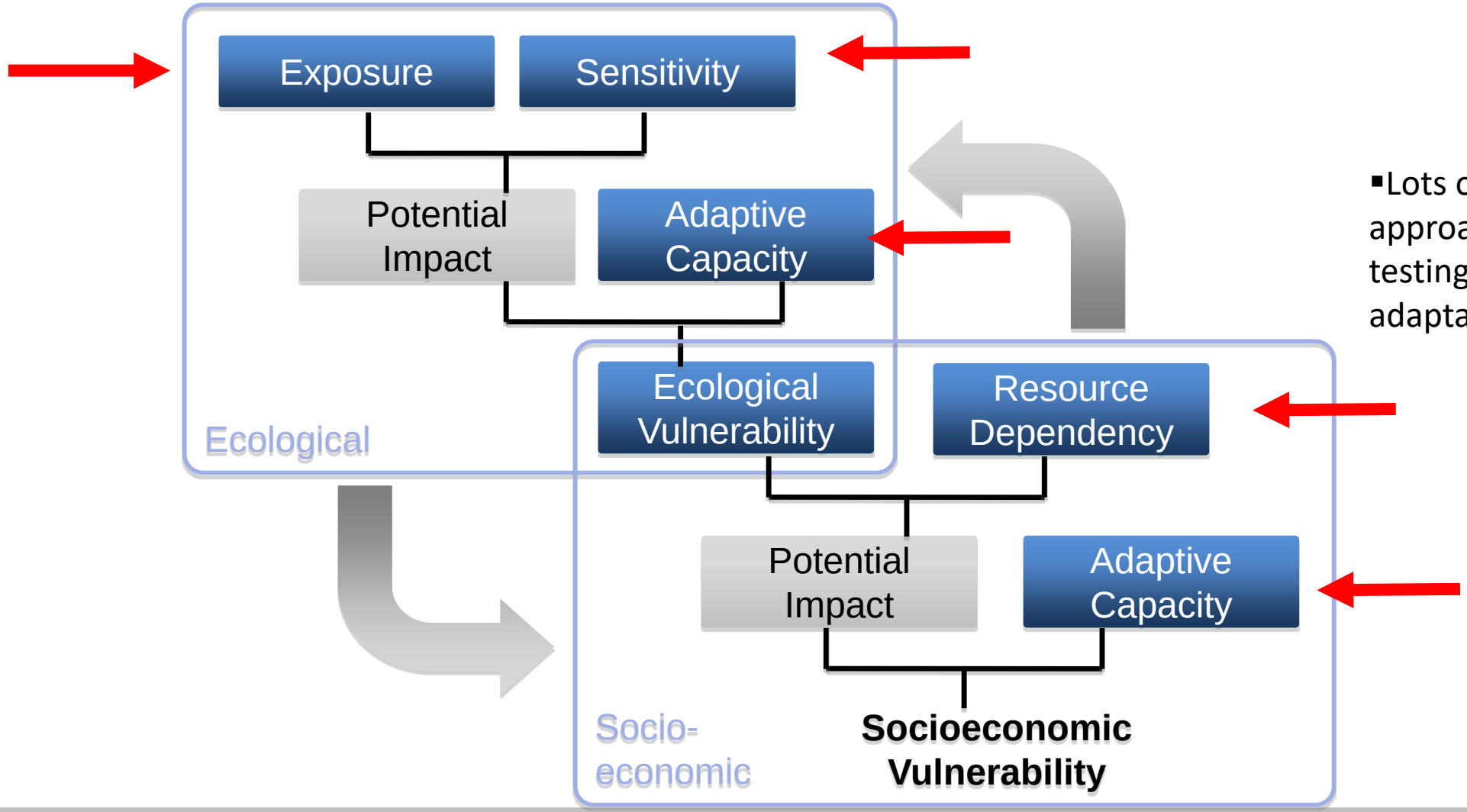
**+ Improve Chick Production**
If more chicks can be produced, as might occur if adults could be encouraged by intervention to breed every year, then population recovery also occurs for a short time.

# Research to support fishers and managers

1. Historical analysis
   - This fish/fishery has moved, declined, changed

- 2. Future projections
  - This species is sensitive to climate change
  - This fish/fishery will move elsewhere

# Adaptation options

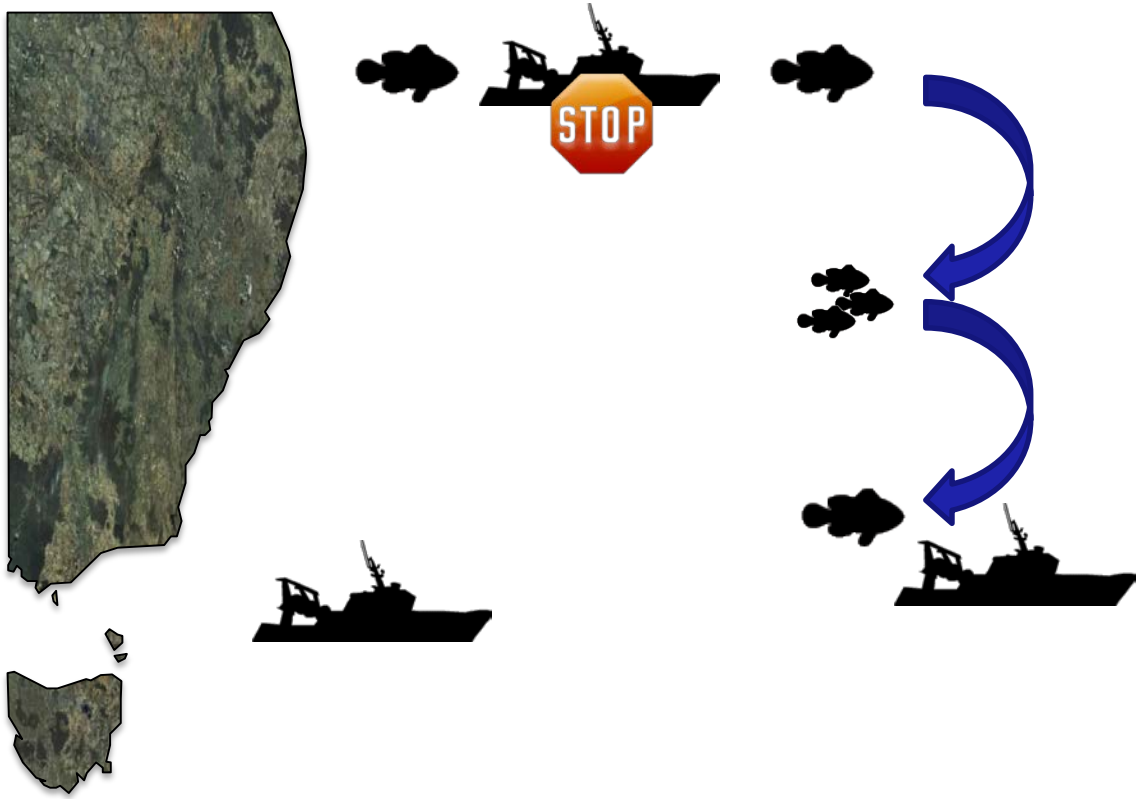



- Lots of options and approaches for generating, testing, and evaluating adaptation options

*Marshall, Hobday, Marshall, 2013 (Ecosystems)*

# Management adaptation to climate change

- New tools needed (e.g. interventions; differential management rules)
- Flexible regulations & non-static assessments
- Fisheries forecasts (short & long term)
- Cross-jurisdiction management coordination
- Plans for differential outcomes



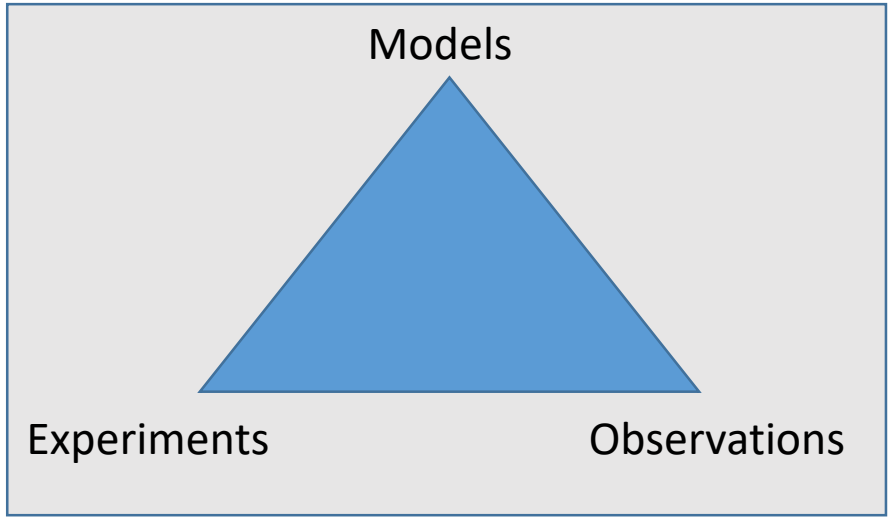
# How can we learn faster?

When we can test, or observe, cause-and-effect

1. Models – process and mechanism limited…
   - Projections (at short time scales) – not 2100!

2. Experiments – scale and factors limited….

3. Observations – replication limited….
   - Local studies – in situ process understanding
   - Spatial contrasts – fast warming areas
   - Temporal contrasts – extremes



# Research papers

- Hobday, A. J., C. M. Spillman, P. Eveson, J. R. Hartog, X. Zhang and S. Brodie (2018). A Framework for Combining Seasonal Forecasts and Climate Projections to Aid Risk Management for Fisheries and Aquaculture. Frontiers in Marine Science: https://doi.org/10.3389/fmars.2018.00137.
  - Environmental variability affects the performance of coastal fisheries and aquaculture. This paper describes how decision makers need future climate information at a range of time scales, including seasonal (next 1-4 months) and long term (decades) to plan all sorts of activities (where to fish, what to fish, where to locate an aquaculture business). The current research challenge is to improve these forecasts so fishers, aquaculture, and even conservation managers, can make better decisions. What sorts of decisions might be better made if we could provide reliable forecasts?
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- Alderman, R. and A. J. Hobday (2017). Developing a climate adaptation strategy for vulnerable seabirds based on prioritisation of intervention options. Deep Sea Research II **140**: 290-297.
  - A range of species living in coastal environments are vulnerable to climate change impacts, which may directly cause mortality (e.g. heat stress) or indirectly (e.g. reduced prey availability). Conservation managers might need to try new options to help species cope with climate change. This paper describes an approach to develop, screen and then test options on a seabird species. Think about what options you think are acceptable, and unacceptable, and why.