Climate impacts in Australian waters

Alistair Hobday
Thomas Kunz, Tom Okey, Elvira Poloczanska, Anthony Richardson

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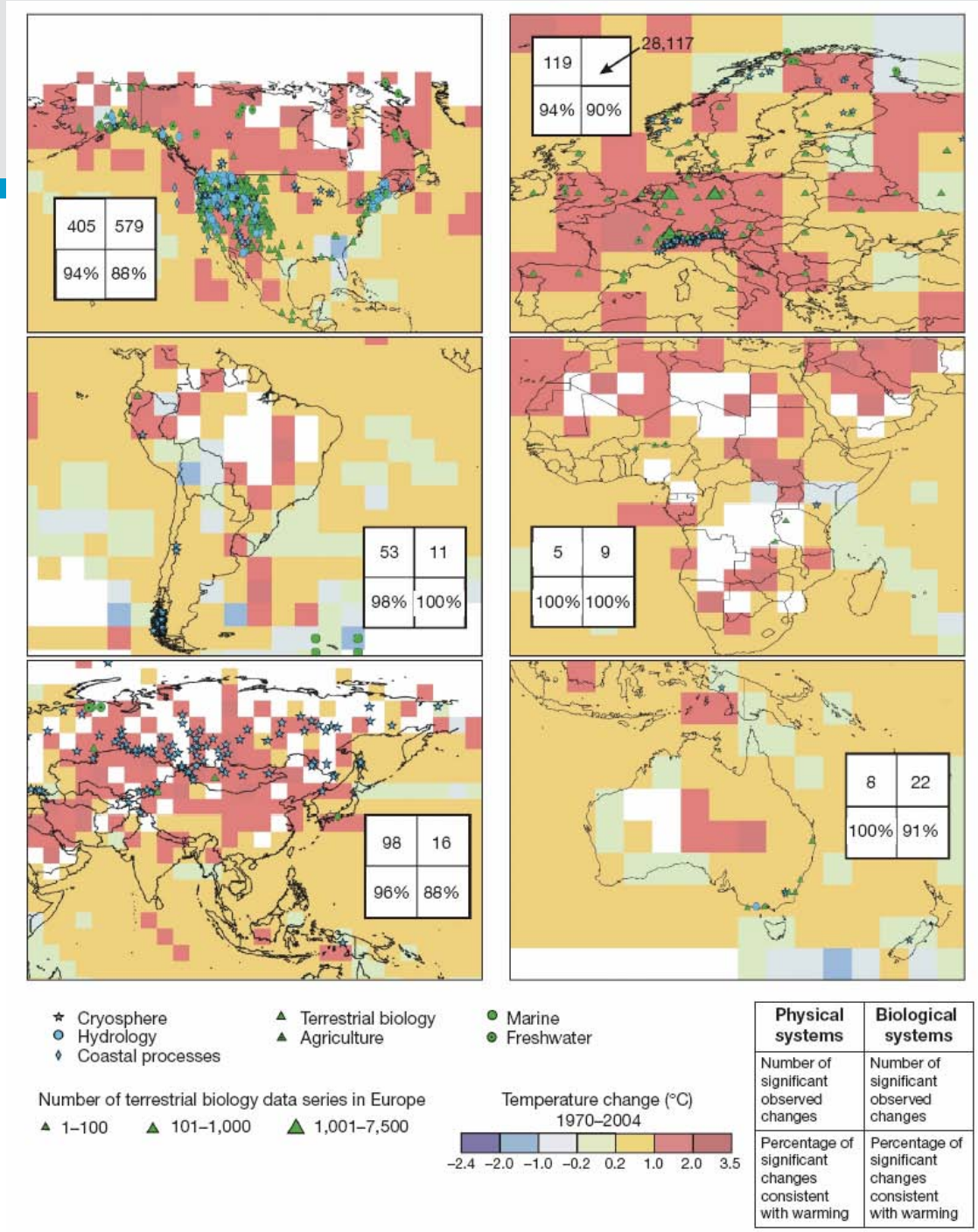
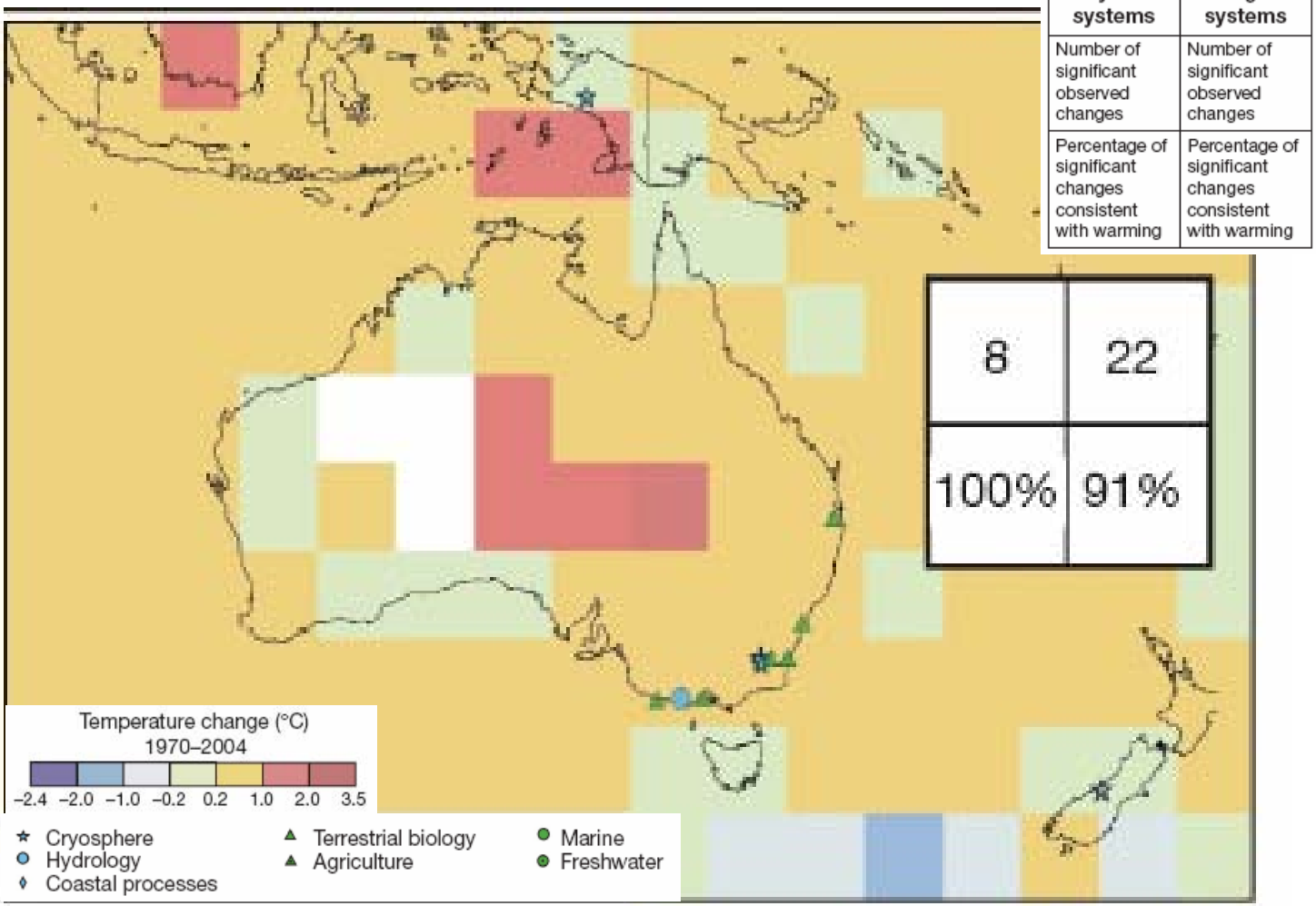
- Time series approach to detecting climate change signal
- Statistical support in a wide range of taxa and locations



Rosenzweig et al 2008

Limited time-series data from Australia



Rosenzweig et al 2008

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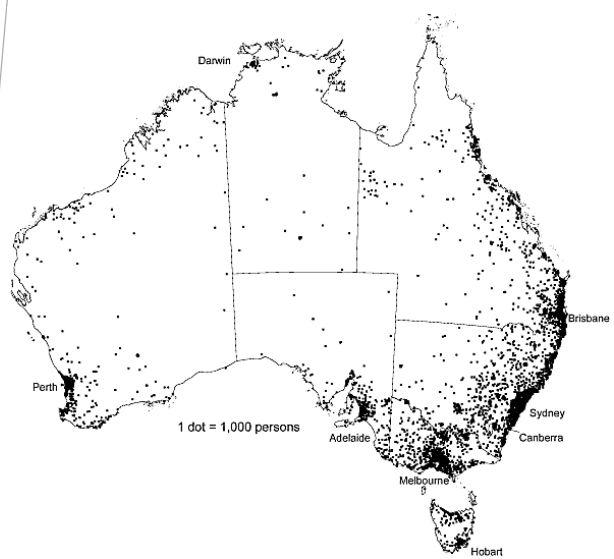
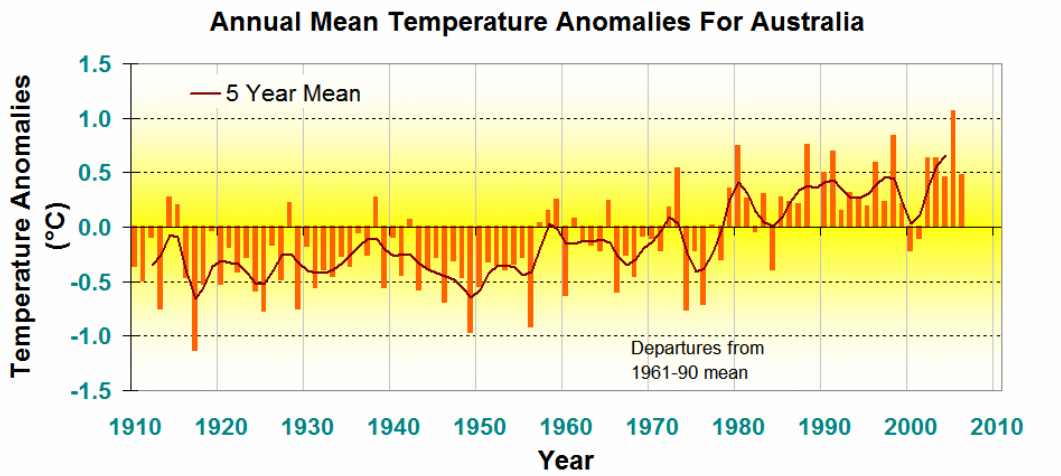
Australian monitoring

Why so few Australian observations?

- Large area/small population? (sovereign rights ~ 8.1 million km^2 ocean, land area 7.1 million km^2, population ~ 20 million)
- Different history/lack of natural studies compared to Europe? poor historical monitoring
- Climate change not yet affecting Australian biological systems?



Population Distribution 2003
(Australian Bureau of Statistics)



Bureau of Meteorology

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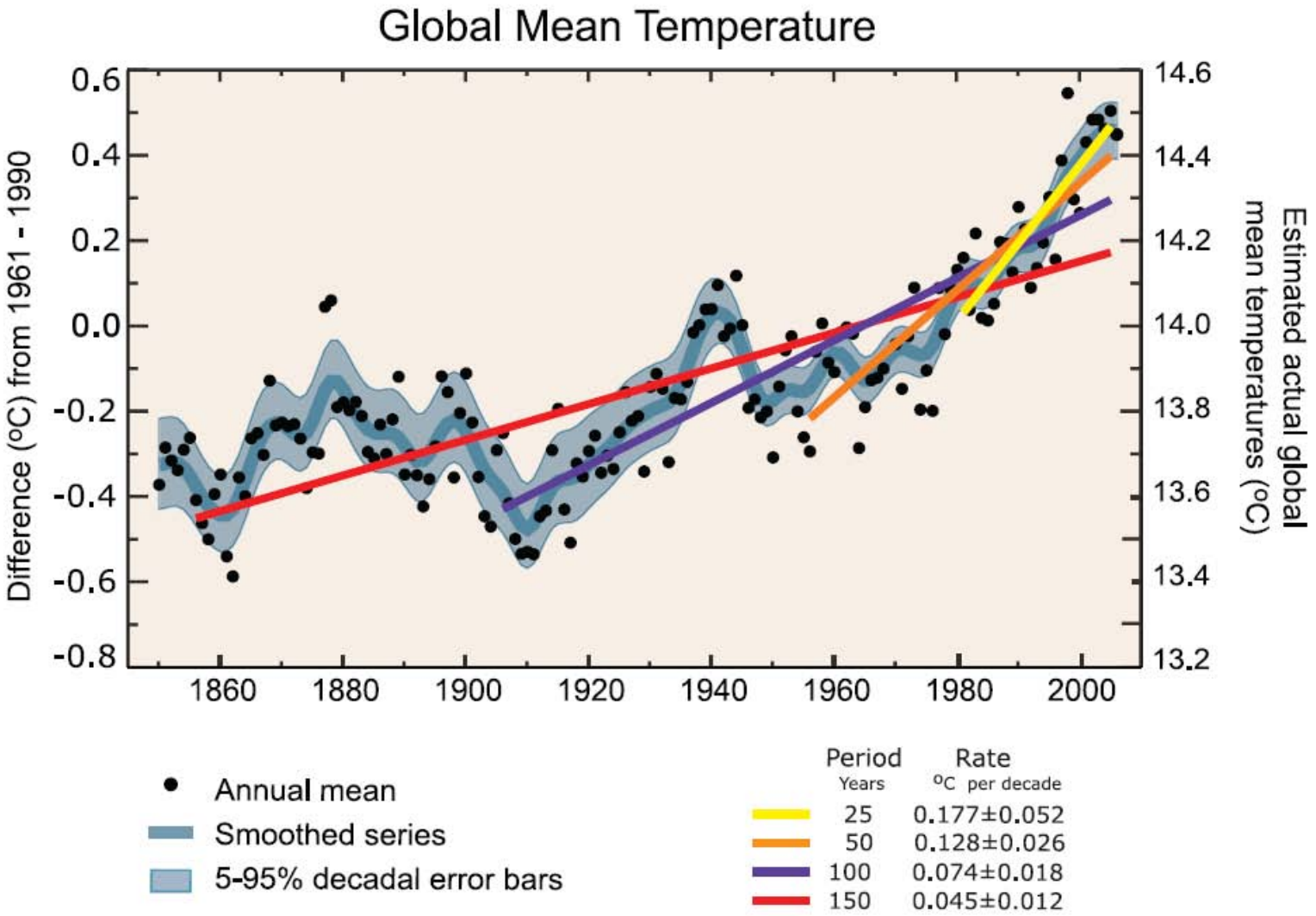
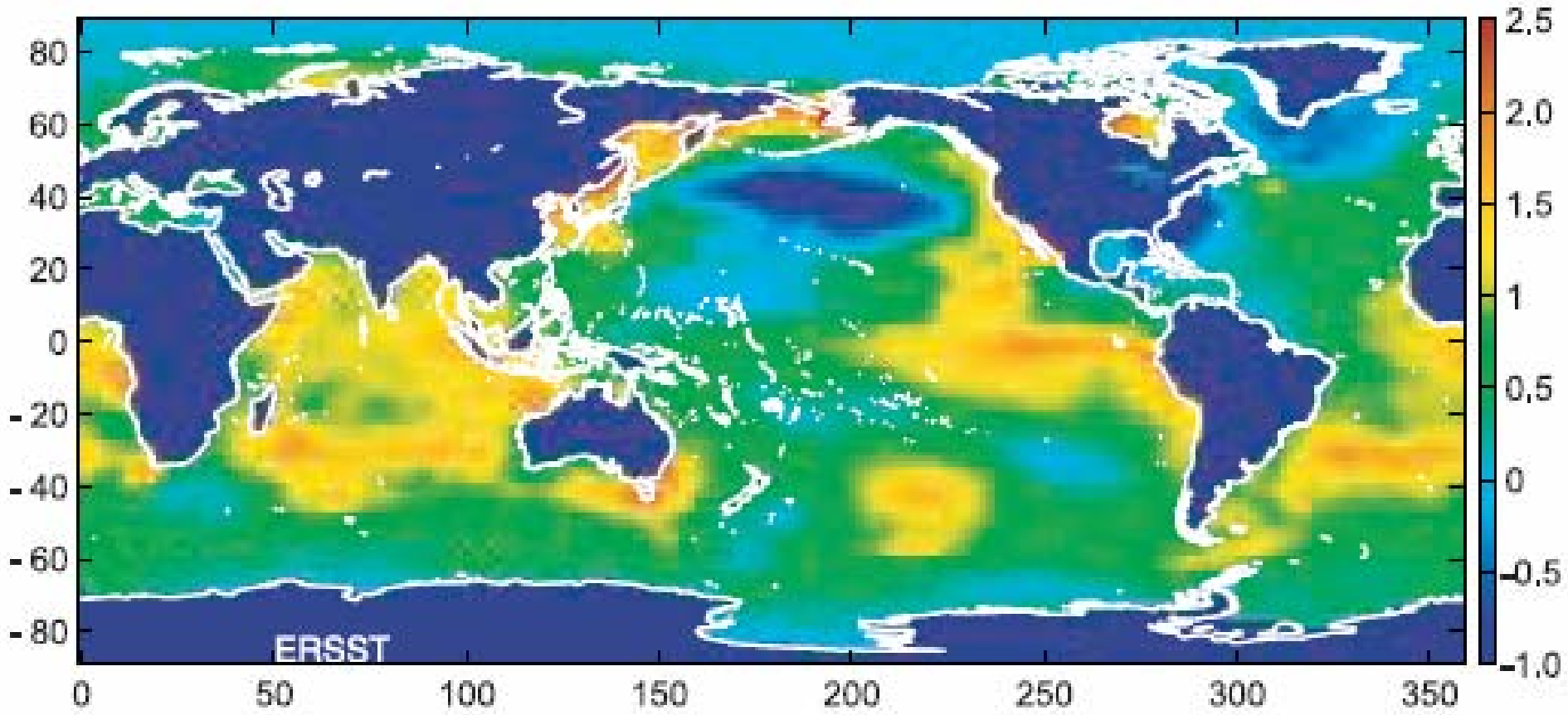
Annual global mean observed temperatures with linear trend fits to last 150 – 25 years (IPCC 2007)



IPCC 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report

Trend in Sea Surface Temperature: 1944-2005

- It’s not getting hotter everywhere….



Ridgway 2007

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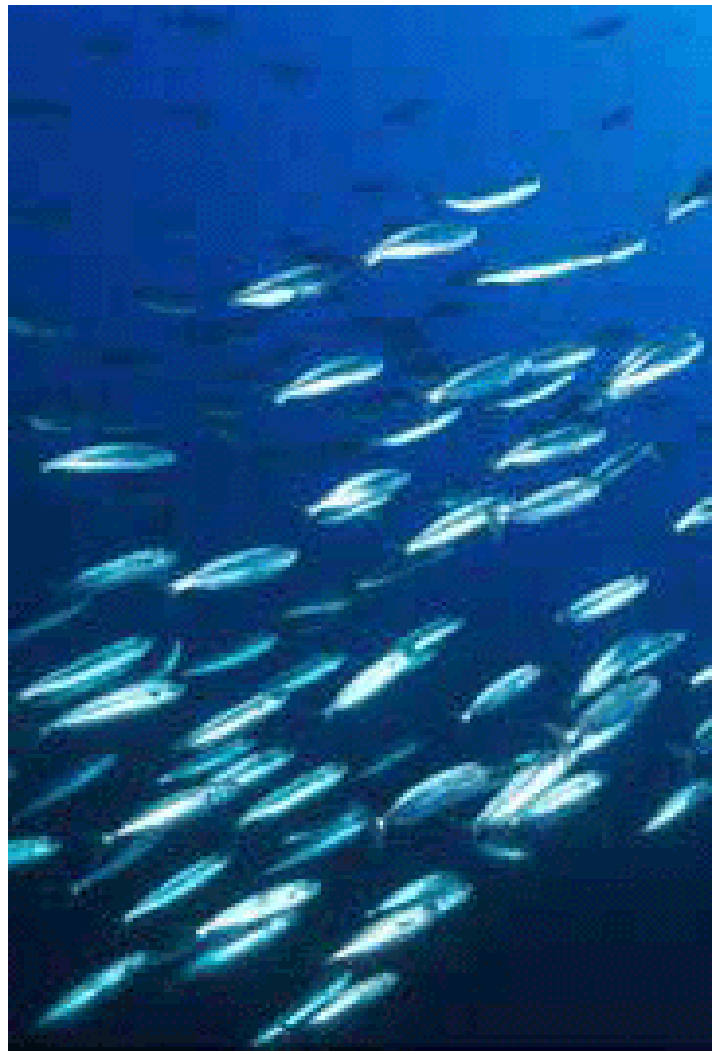
Eastern Australia – getting warmer

- Greatest warming this century in the Southern Hemisphere is expected in south-east Australian waters
- East Australia Current: projected to strengthen and increase southward flow in coming decades
- SST: warming by 1-2°C by 2030's



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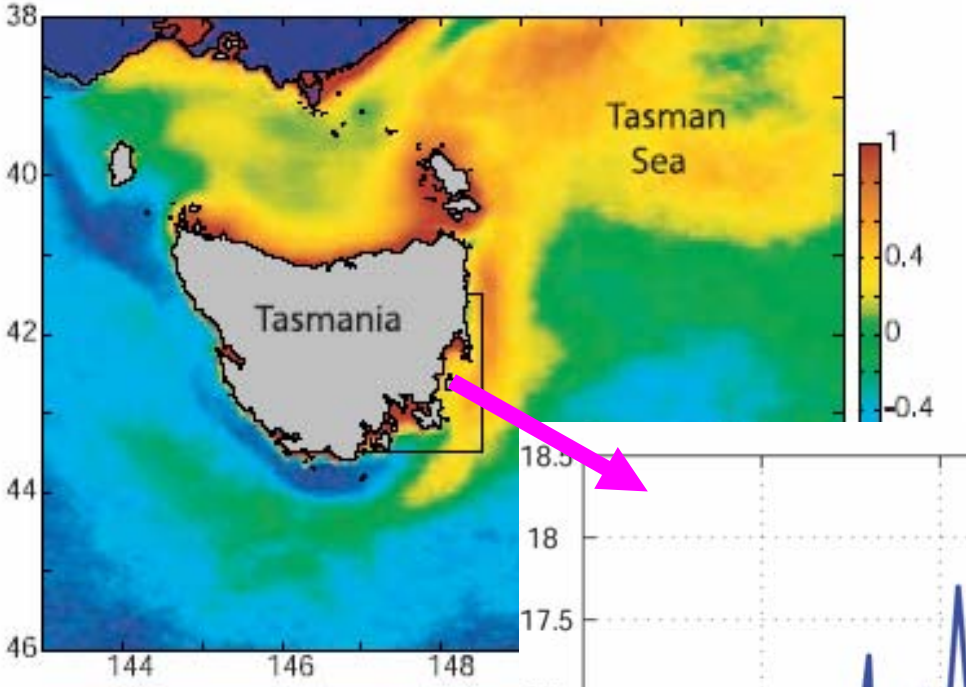
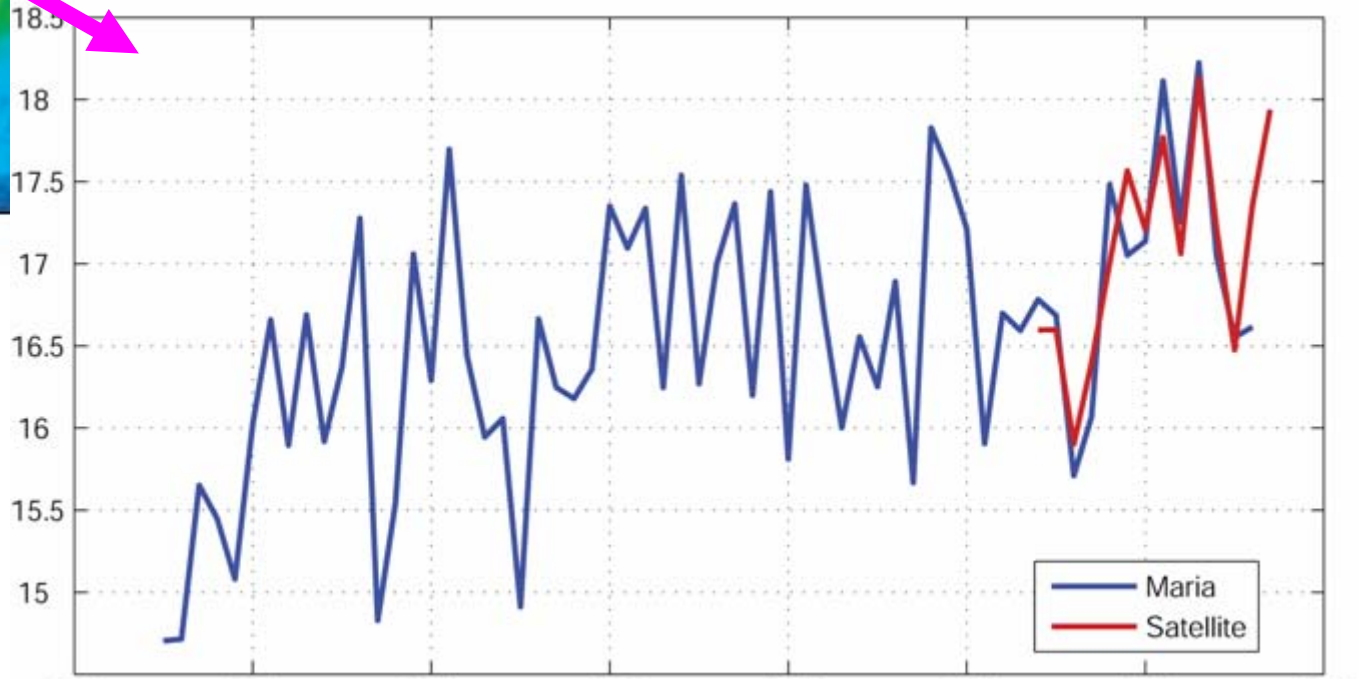
Changes at Maria Island, Tasmania



- Summer SST (Jan-Mar)
  - 350 km movement

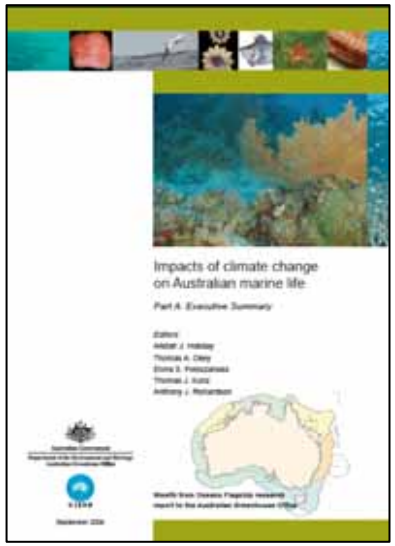


Ridgway 2007

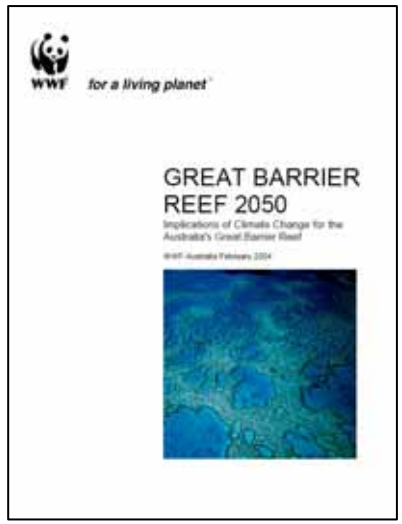
Recent Reviews of Climate Change Impacts on Australian Fauna and Flora

Hobday A.J. & Matear R. (eds.) 2006 Review of Climate Impacts on Australian Fisheries and Aquaculture

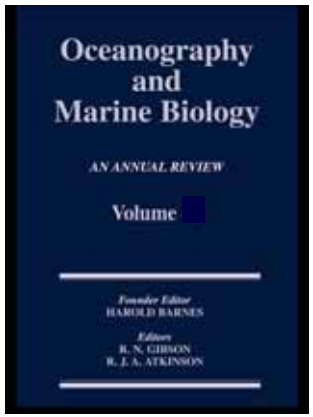
Hobday et al (eds.) 2007 Impacts of Climate Change on Australian Marine Life.



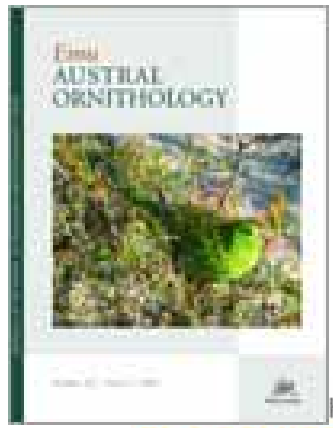
WWF-Australia 2004 Implications of Climate Change for Australia's Great Barrier Reef



Voice et al (2006). Vulnerability to climate change of Australia's coastal zone



Poloczanska et al 2007 Climate Change and Australian Marine Life



Chambers et al 2005 Climate change and its impact on Australia's avifauna

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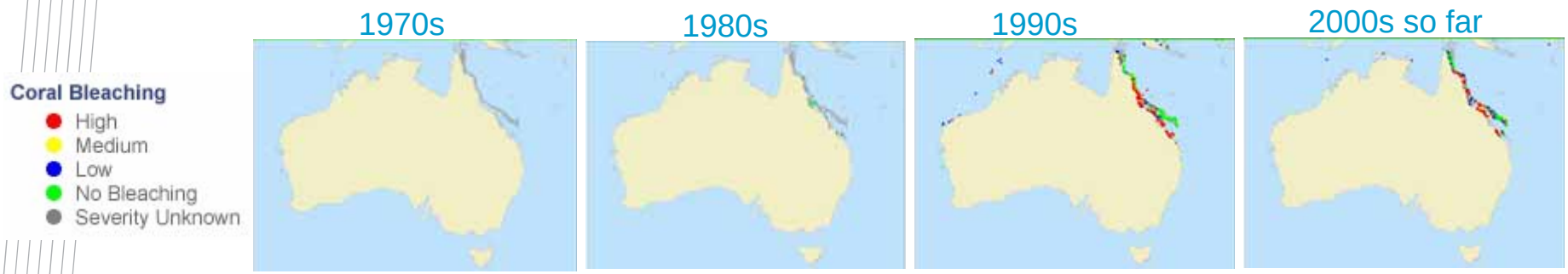
Historical data – plugging the gap

- Time series
  - ‘Natural’ variability vs climate change
  - Restart if appropriate
- Broadscale surveys (one-off or over a number of years)
  - Identify key biotic and abiotic factors influencing distributions (statistical analysis)
  - Resurvey if appropriate

    Baseline for measuring future change
- Inform modelling, laboratory and field studies
  - Population modelling (time series)
  - Biogeographic modelling (broadscale surveys)
- Inform monitoring programmes
  - Indicator species, vulnerable species, ‘hot-spots’ of change

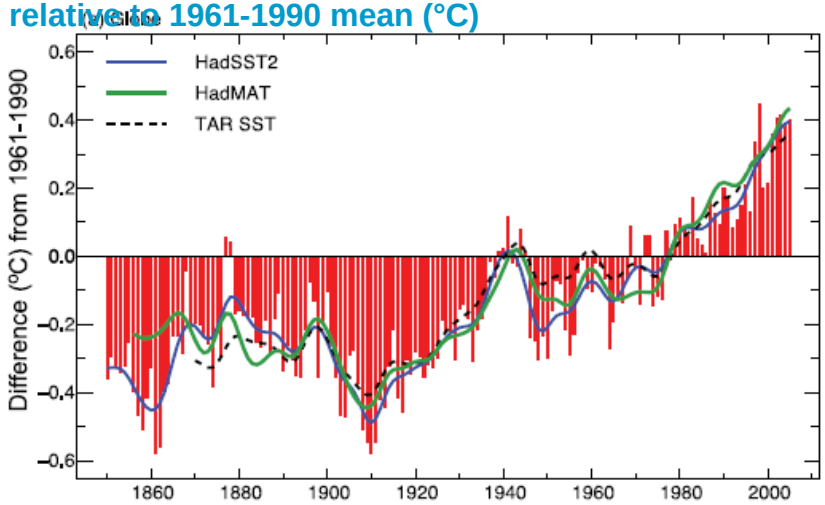
Evidence climate change *is* already impacting tropical Australian marine systems

Bleaching events on tropical coral reefs



www.reefbase.org

Annual anomalies of global SST 1850-2005, relative to 1961-1990 mean (°C)



IPCC 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report

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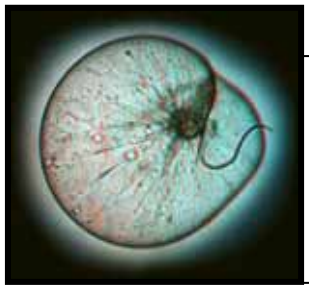
Climate change *is* already impacting temperate SE Australian marine systems

Southward expansion of ~50% of Tasmanian intertidal fauna over 50 years *(E. Poloczanska)*

Southward expansion of sea urchins contributing to loss of kelp forests in off eastern Tasmania *(C. Johnson)*



Changing composition of phytoplankton blooms off Tasmania– increased tropical species and red tides *(S. Blackburn)*

Rock lobster catch and distribution correlated with regional SST changes around Tasman Sea *(S. Frusher)*

In last decade 34 fish species have exhibited major distributional changes: either newly established south of Bass strait, or show significant range extensions. *(P. Last)*

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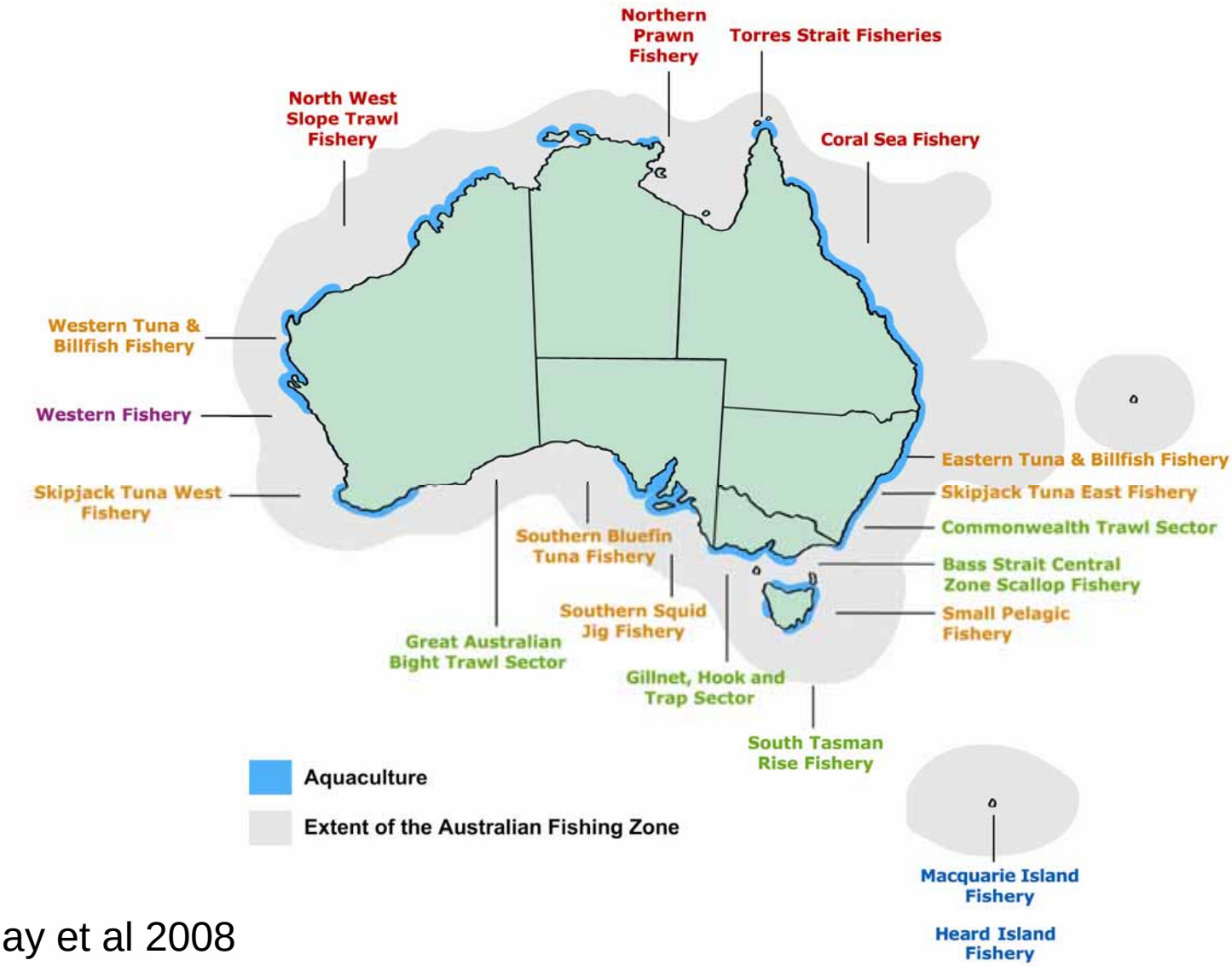
Climate change impacts – fishing and aquaculture



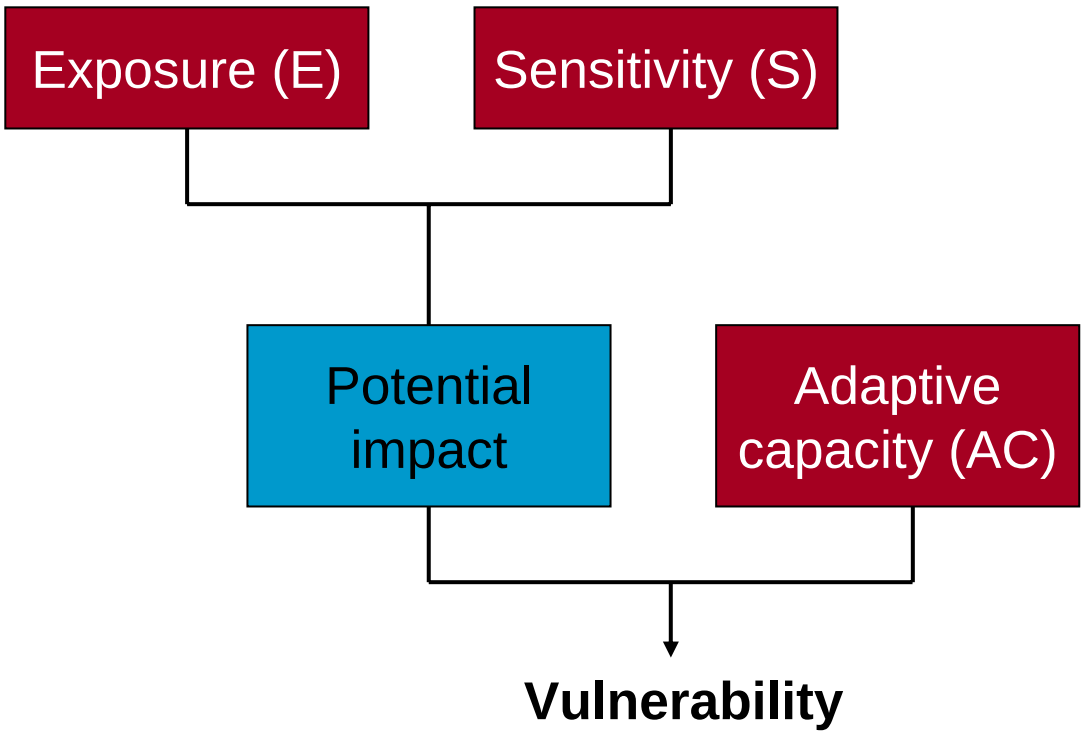
Hobday et al 2008

Australian fisheries: (+) & (-) impacts

- Range changes
  - Species move south (east coast) (+ / -)
- Abundance changes
  - ↑ growth and recruitment (e.g. prawns)
- Productivity changes
  - ↑ upwelling in southern Australia
- Extreme events
  - ↑ storms (freshwater, turbidity) => aquaculture impacts

Do we have the management structure to take opportunities and reduce impact?

Estimating future impacts: Vulnerability Indices

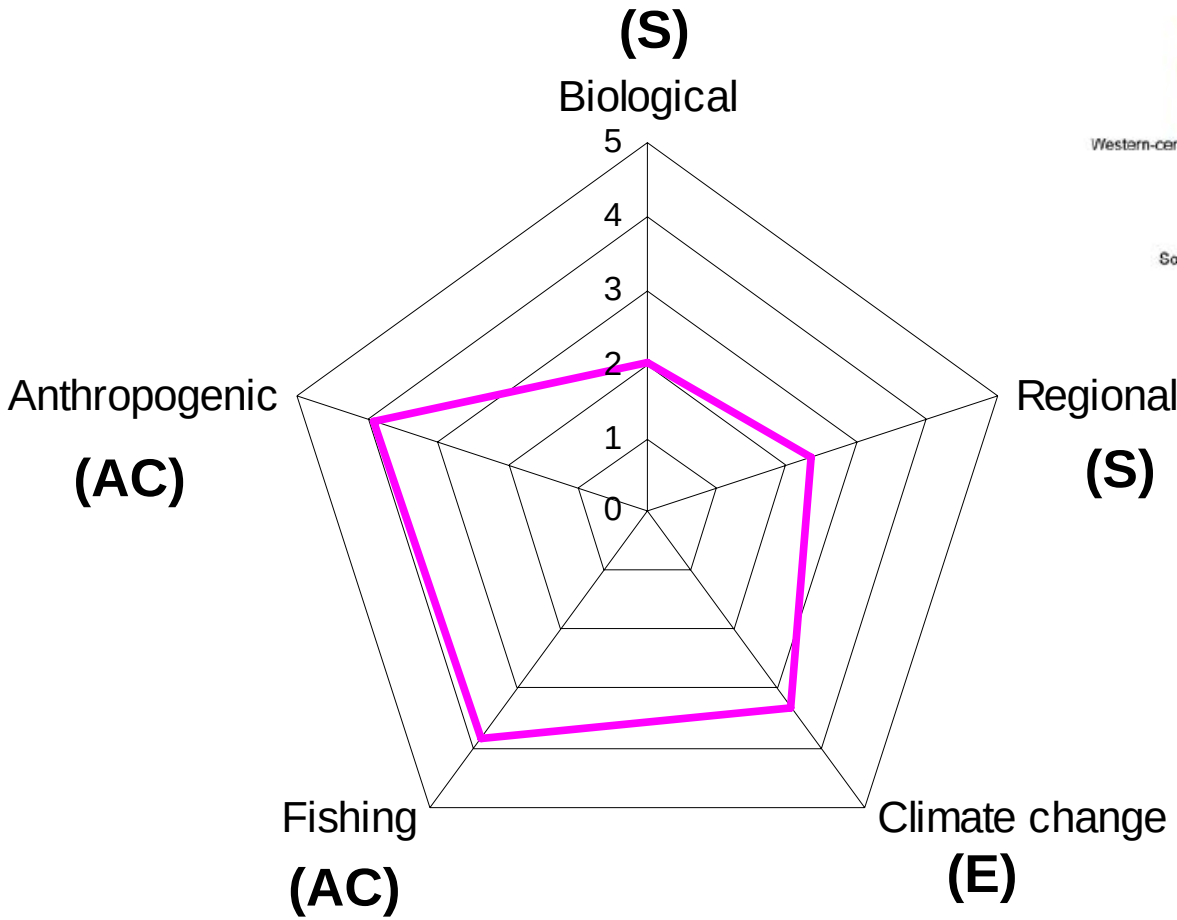


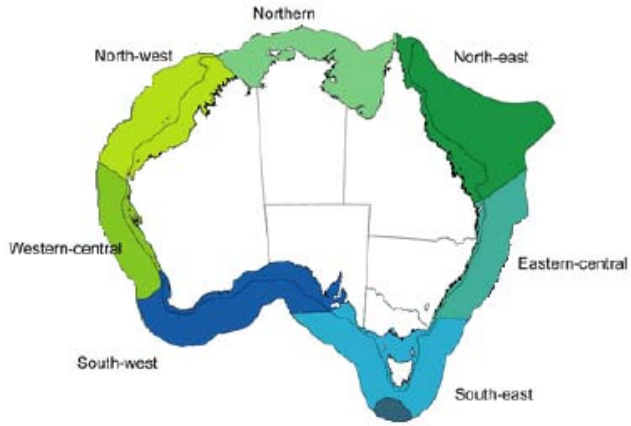
(Allen Report 2005)

Vulnerability: *Potential to be damaged, altered or to resist change*

'The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change' (IPCC 2001)

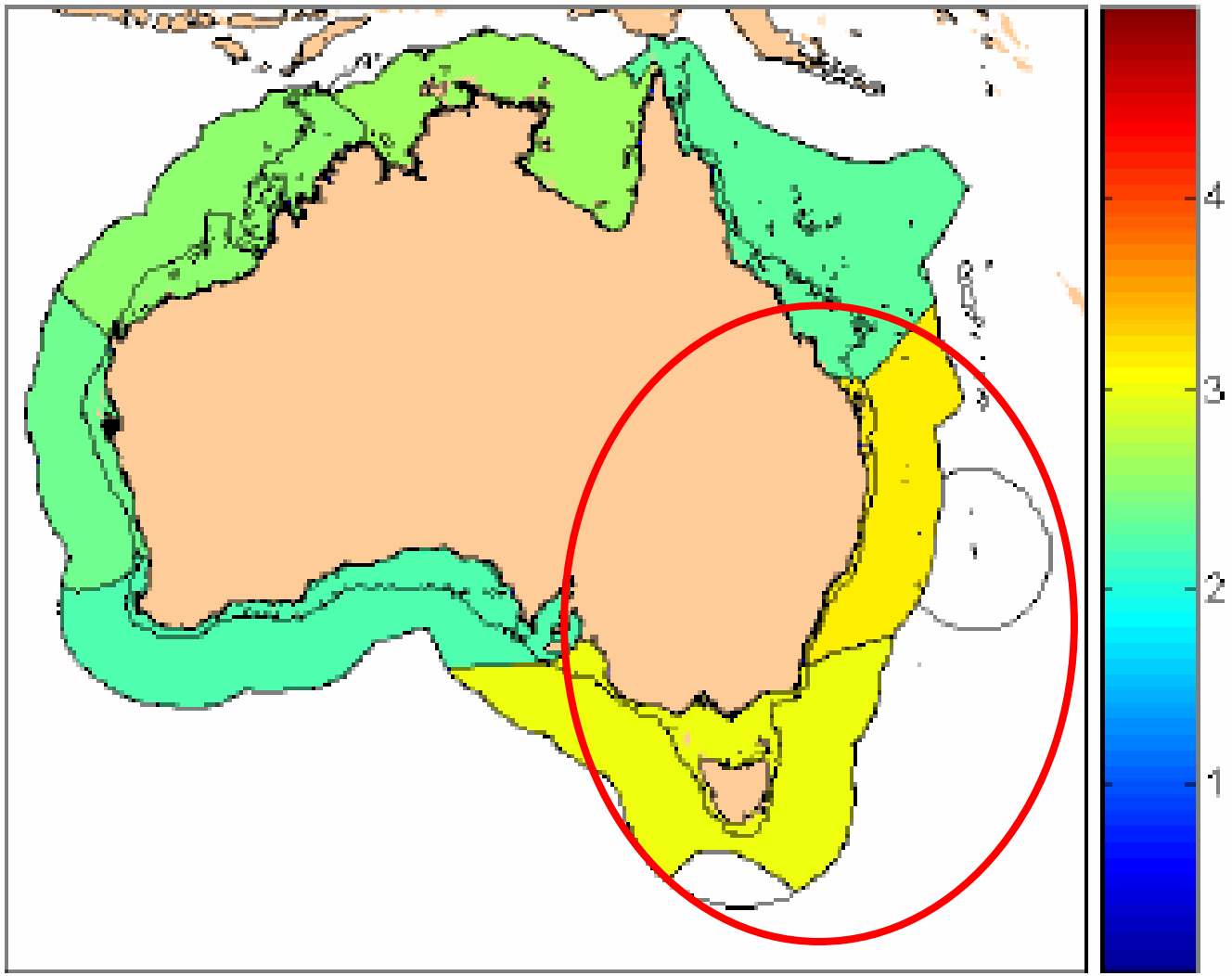
Estimating Vulnerability – regional focus





Dimension	*Indicator*	*Vulnerability Component*
Biological	Threatened, endangered and protected (TEP) species	S
	Number of endemic demersal slope fish	S
	% introduced species per port	S
	TEP uniqueness	S
Regional	Area (square degrees)	S
	Foundational area (% < 50 m depth)	S
	Poleward boundedness	S
Climate	% change in sea surface temperature	E
Change	% change in temperature at 500 m depth	E
	% change in mixed layer depth	E
	% change in incident solar radiation	E
	% change in surface currents	E
	% change in surface winds	E
Fishing	Fisheries gear impact – habitat	AC
	Fisheries gear impact – bycatch	AC
	Overexploited fisheries	AC
	Number of fisheries hours	AC
	Number of AFMA fisheries	AC
	Recreational fishing index (1000 days per degree)	AC
Other	Population within 200km of coast (1996)	AC
Anthropogenic	Organic compounds	AC
	Chemical compounds	AC
	Heavy metals	AC
	Chemical dumps	AC
	Ship visits	AC
	Oil and gas wells	AC
	Seismic surveys	AC

Overall vulnerability – regional identification



Hobday et al (2007)

Future impacts: fisheries in eastern Australia

- Range changes
- Abundance
- Physiology/Phenology

Hobday (in review)

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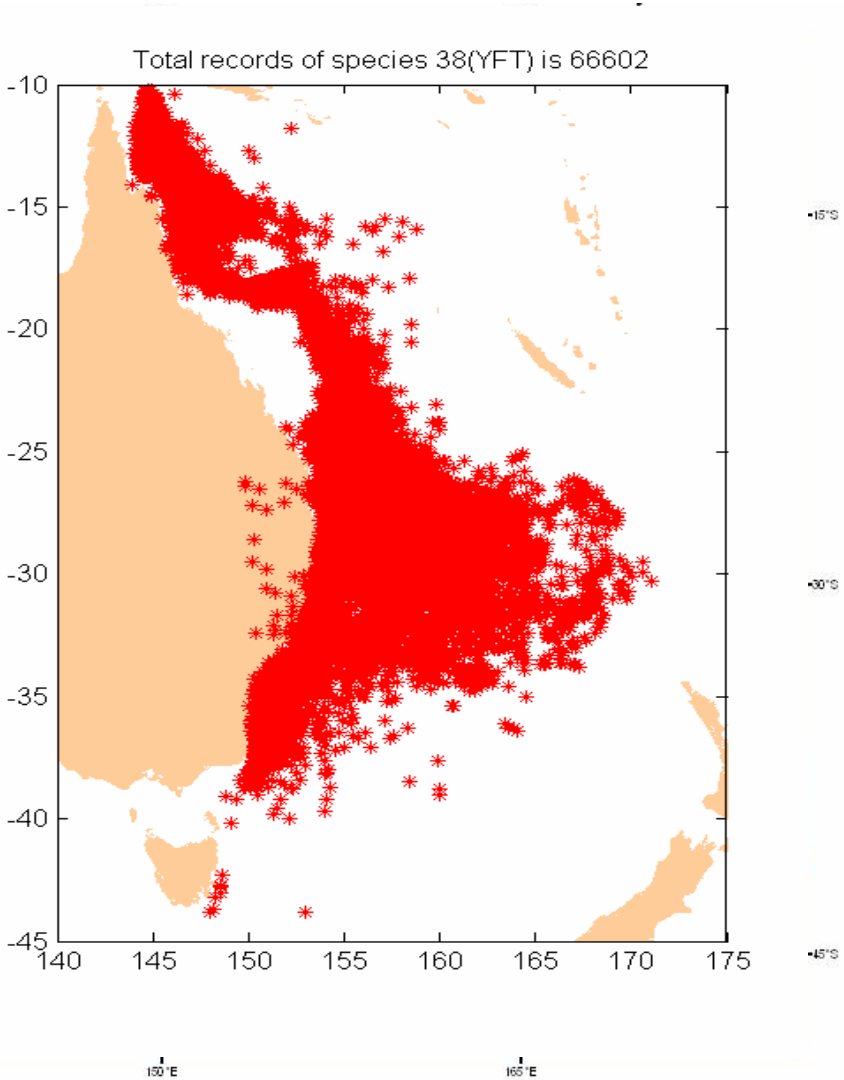
Pelagic species - longline fishery



14 top species, 1997-2005, 375,000 records (logbook data)

Tuna
- Yellowfin Tuna (YFT)
- Southern Bluefin Tuna (SBT)
- Albacore Tuna
- Bigeye Tuna
- Wahoo

Billfish
- Broad Billed Swordfish
- Striped Marlin

Sharks
- Shortfin Mako
- Bronze Whaler
- Blue Shark
- Oceanic Whitetip Shark

Other teleosts
- Rudderfish
- Dolphinfish
- Ray's Bream

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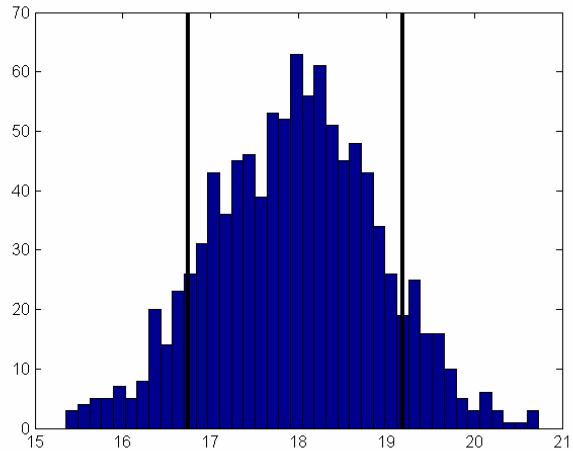
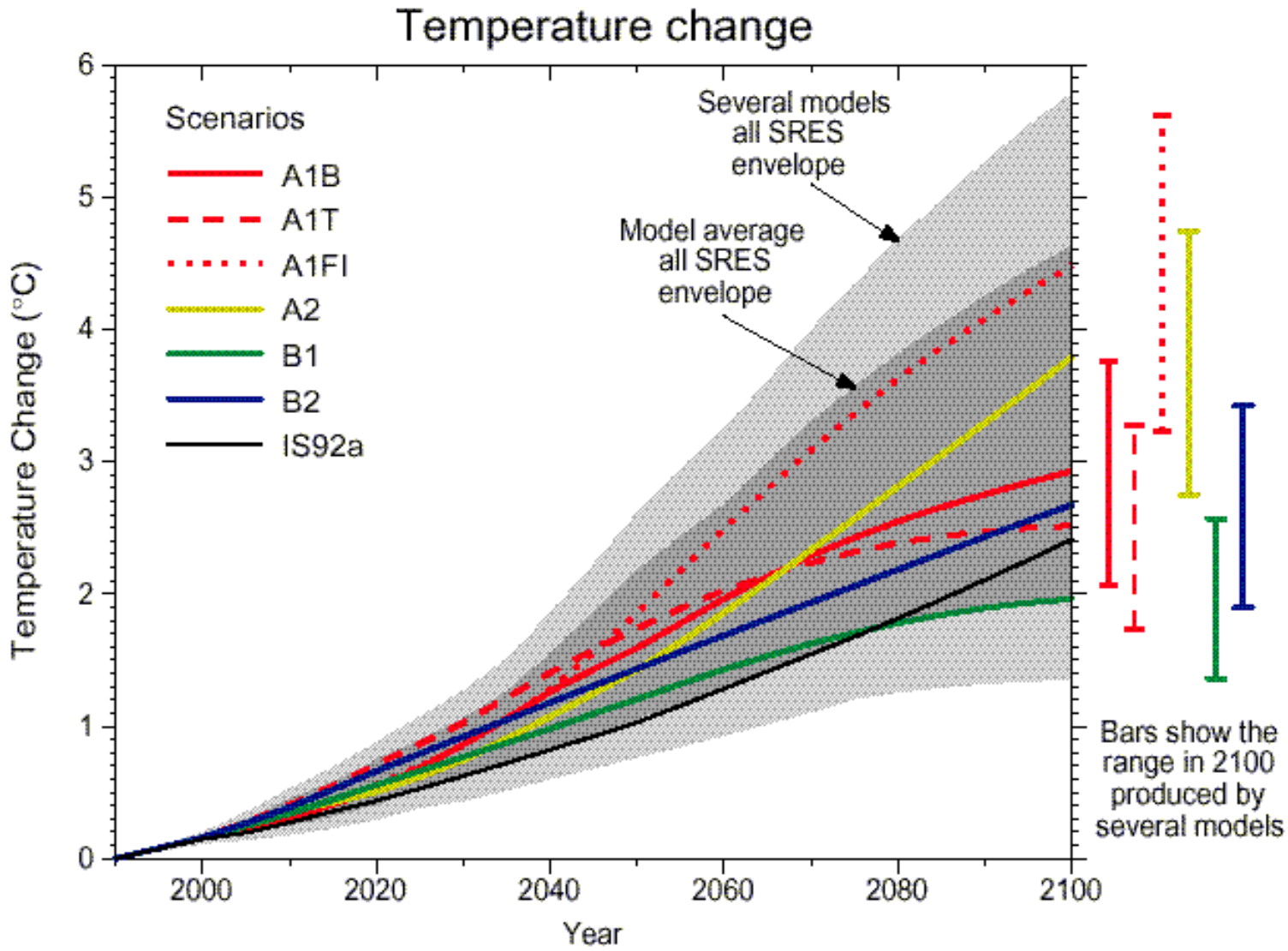
Preliminary Habitat Description

(Species Temperature Distribution)

- Temperature where species caught
  - Get upper and lower SST limits ("suitable temperature")
- Where is this habitat in future?
  - North or south?
  - Expanding or contracting?
- Assumptions: Bioclimatic analyses
  - Present distribution indicates environmental preference
  - No adaptation in future

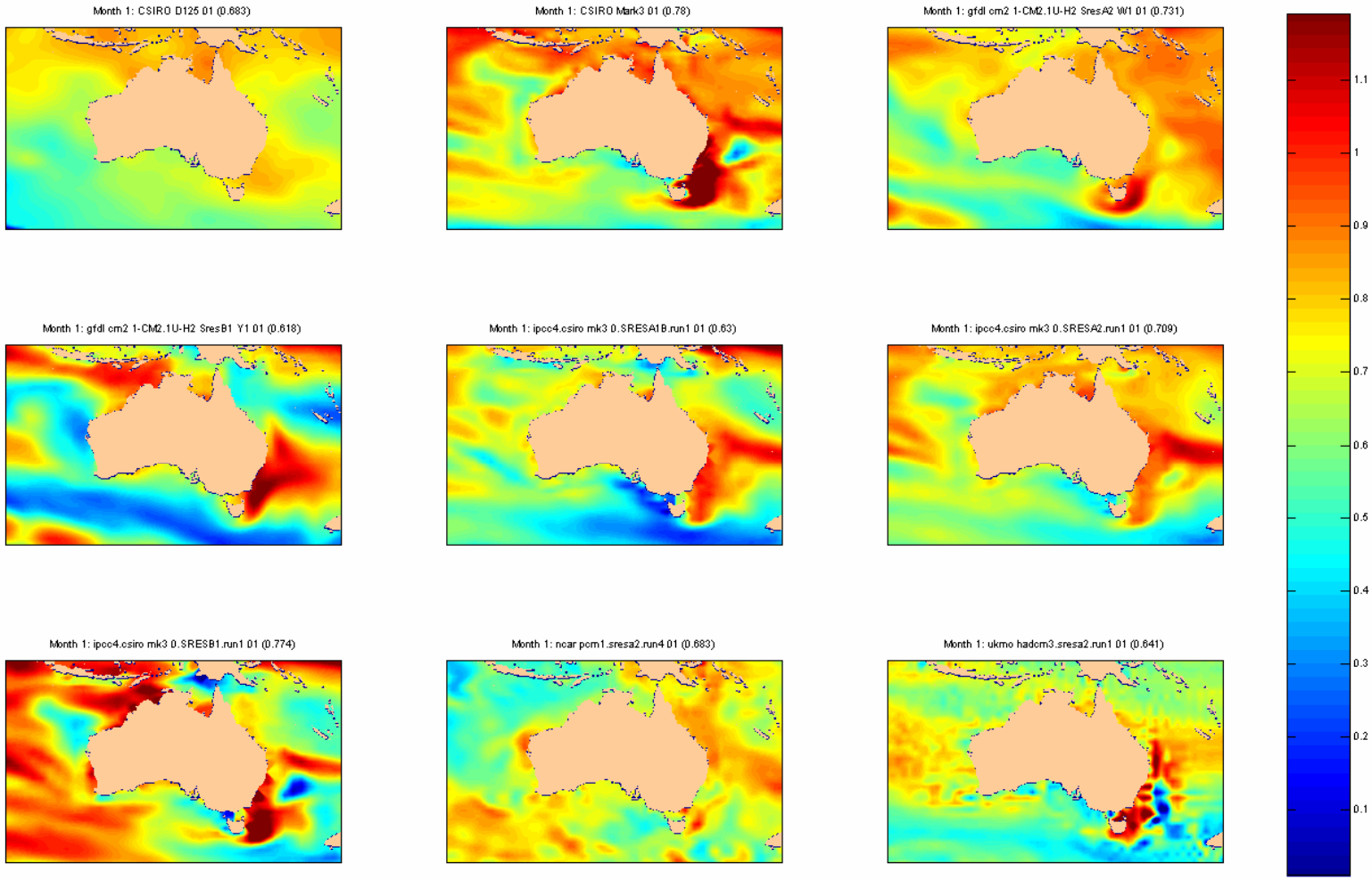


Projected temperature increase - scenarios



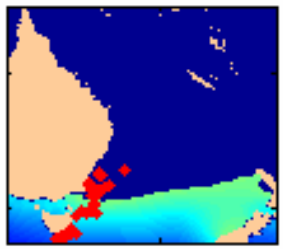
Variable predictions among models

January 9 different models

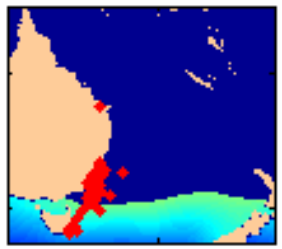


Present: SBT, CSIRO Mk3.5

Month 1



Month 2



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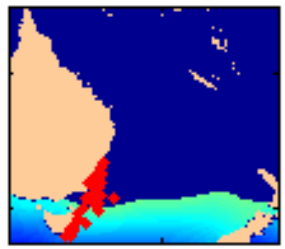

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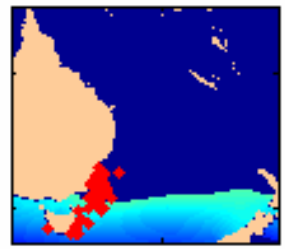

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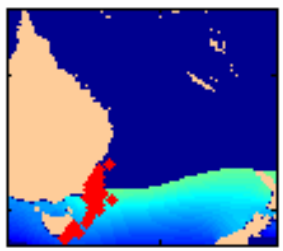

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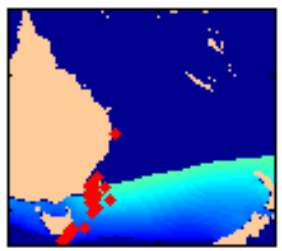

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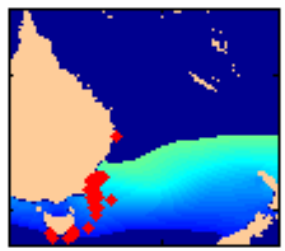

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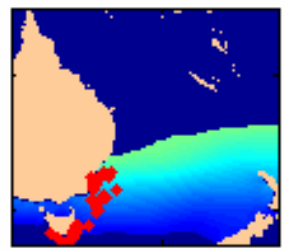

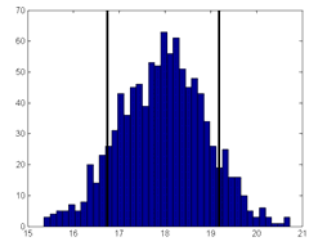

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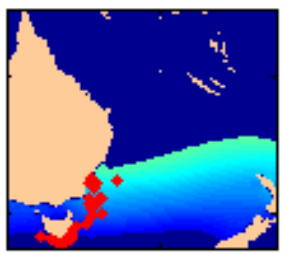

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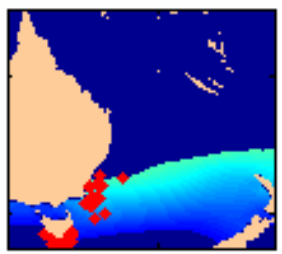

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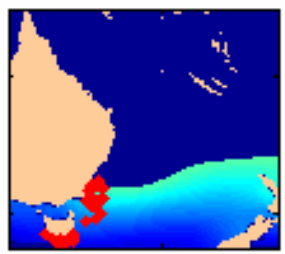

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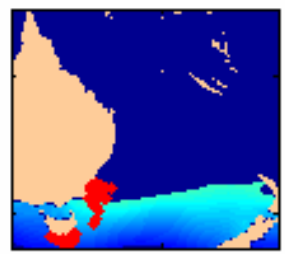

2100: SBT, CSIRO Mk3.5

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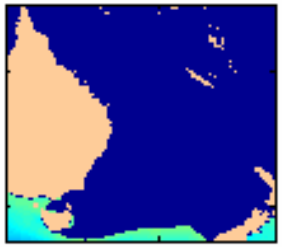

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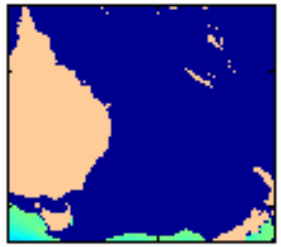

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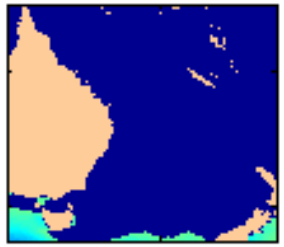

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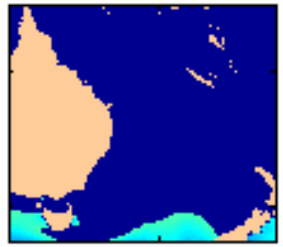

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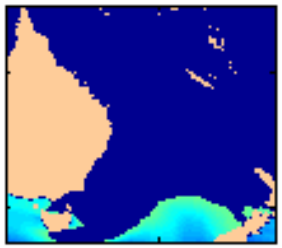

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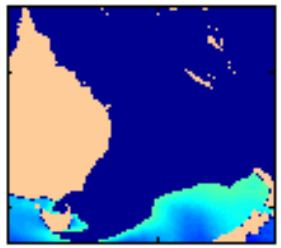

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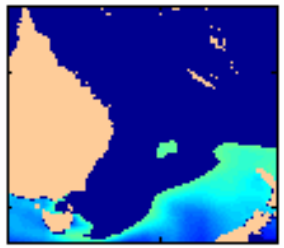

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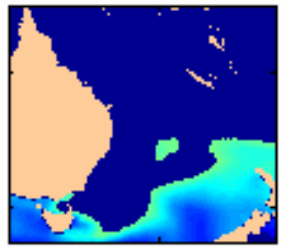

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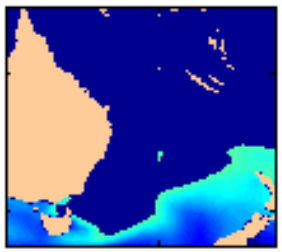

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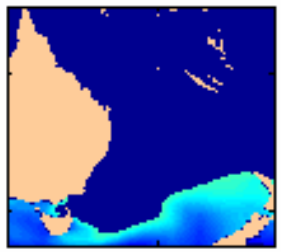
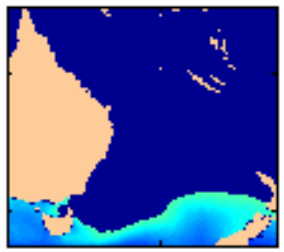
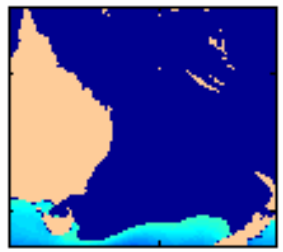


Month 11

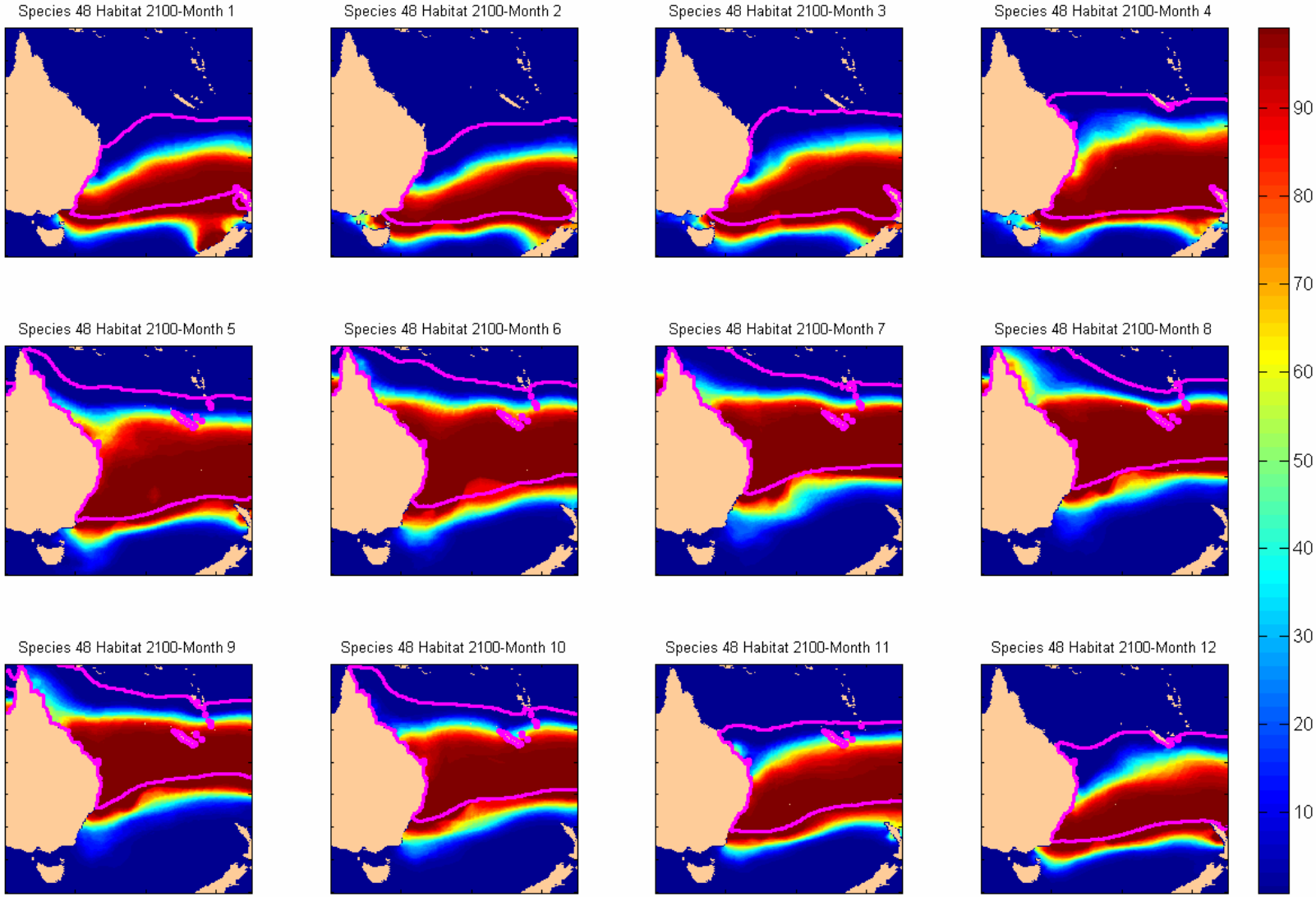


Month 12



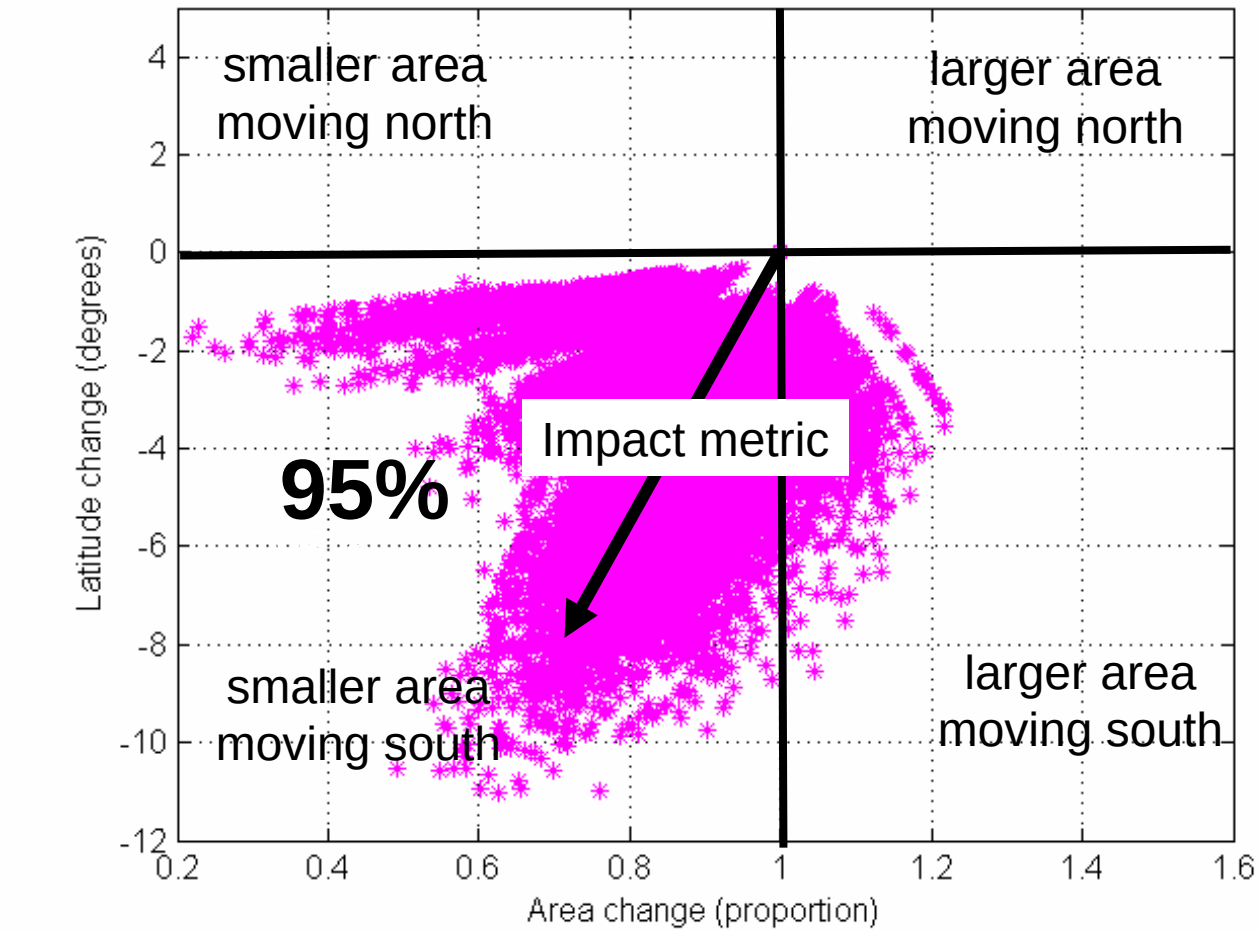
CSIRO

Broadbill swordfish (225 futures)



Overall change in species distribution

(14 species, 12 months, 9 models, 25 scenarios = 37,800 futures)



Hobday (in review)

National Research FLAGSHIPS Climate Adaptation CSIRO

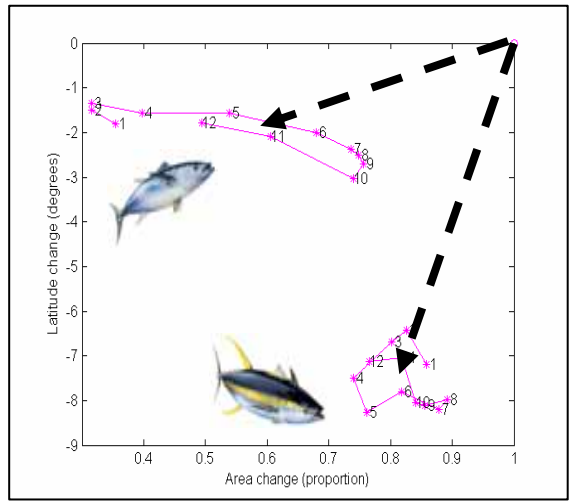
Eastern Australia Climate Impact Metric (SST)

(mean change per species, n=2700)

High impact

Low impact

Bigeye Tuna	4.60 ± 1.40
Dolphinfish	4.59 ± 1.54
Broad Billed Swordfish	4.57 ± 1.31
Yellowfin Tuna	4.54 ± 1.41
Oceanic Whitetip Shark	4.54 ± 1.41
Wahoo	4.51 ± 1.54
Bronze Whaler	4.45 ± 1.36
Albacore Tuna	4.39 ± 1.20
Rudderfish	4.39 ± 1.26
Striped Marlin	4.33 ± 1.22
Shortfin Mako	3.62 ± 1.14
Blue Shark	3.12 ± 0.88
Ray's Bream	2.80 ± 0.84
Southern Bluefin Tuna	2.70 ± 0.89



Hobday (in review)

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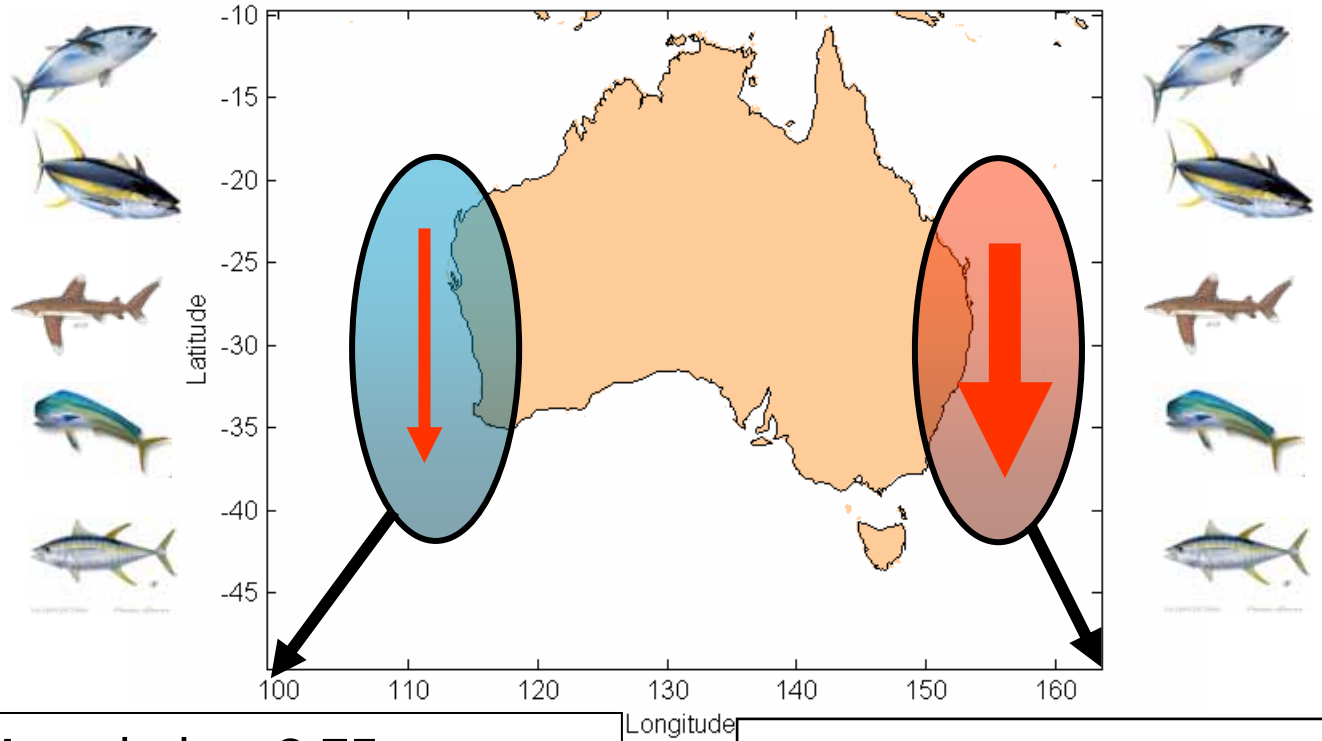
Regional Impact for Fisheries

11 species in longline fisheries



West: Mean index: 3.75

- Mean latitude change: 3.58°S
- Mean area change: 0.95

East: Mean index: 4.28

- Mean latitude change: 4.08 °S
- Mean area change: 0.88

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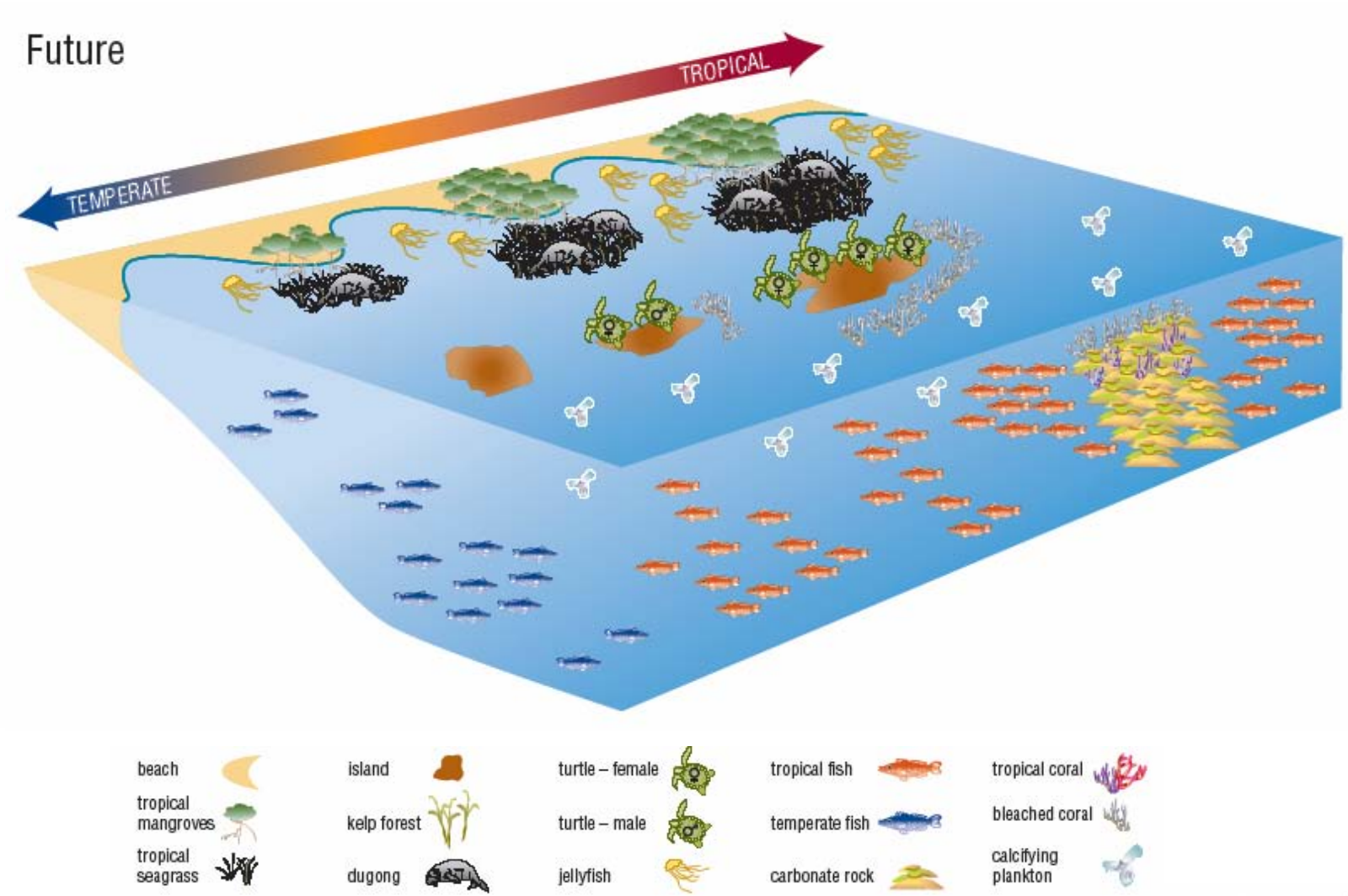
Future impacts for Australia

- CC will impact physical and biological elements of the coast (structures, ocean life, people)
- Australia is data poor => smart research strategy
- Cumulative interactions with climate change
  - Exploitation
  - Coastal development
  - Pollution / eutrophication / riverflow modifications
  - Mining and oil extraction

- Capacity and knowledge to address these issues exists
  - Understand changes, identify opportunities (minimize costs)



Poloczanksa et al (2007)

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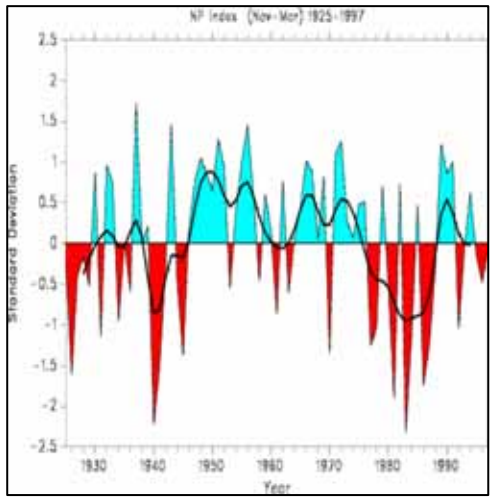
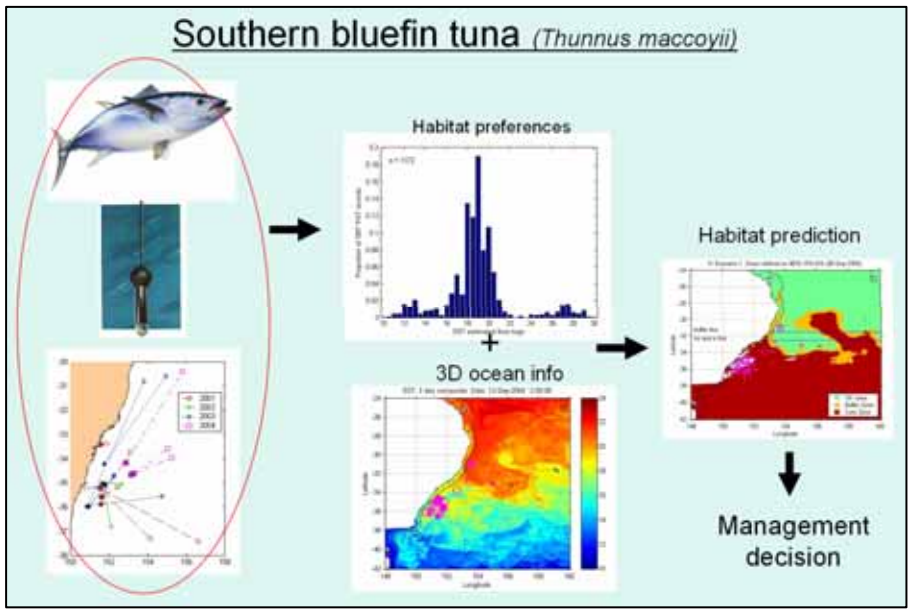
Management Strategies – Environment

- Examples - around the world
  - Anticipatory strategies
  - Proportional catch rate strategies
  - Environment-based catch control rule
  - Dynamic spatial strategies (Australia)

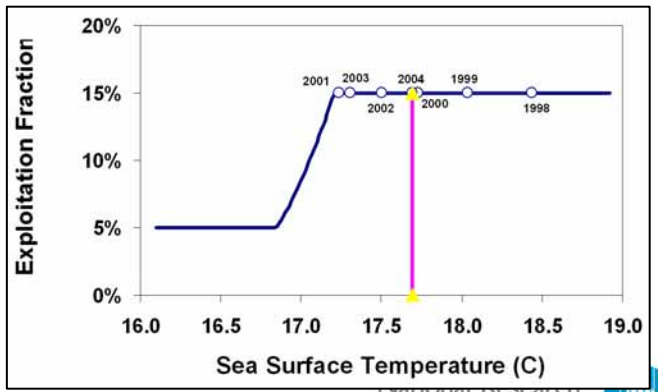


Hobday & Hartmann (2006)

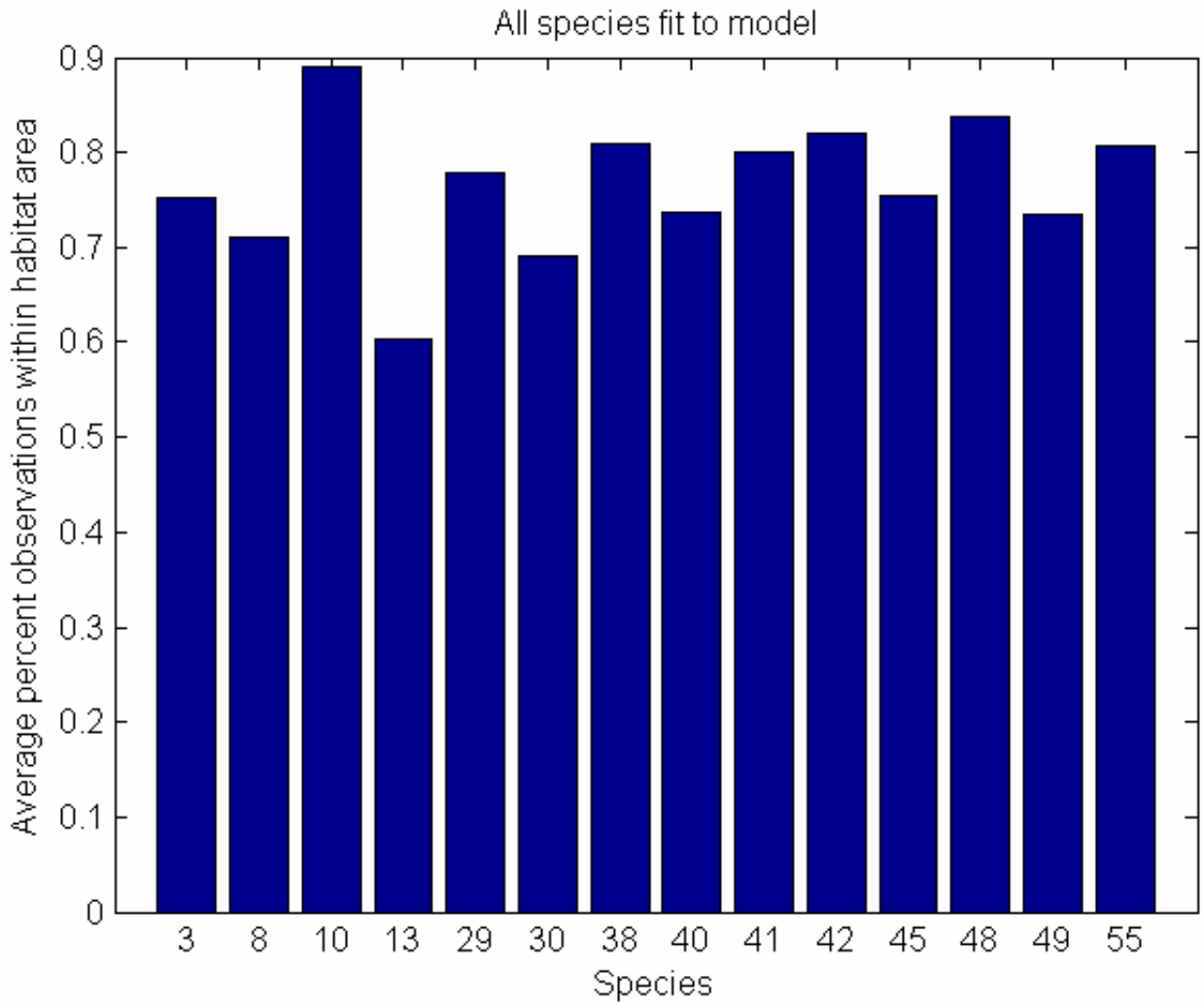


HG_{2005} = (Stock biomass$_{2004}$ – Cutoff) · Fraction · USA distribution

Fraction represents a bounded function of temperature and used as a proxy for 'F_{MSY}'



Fit to model by all species based on real observations



Biological Impacts of Climate Change

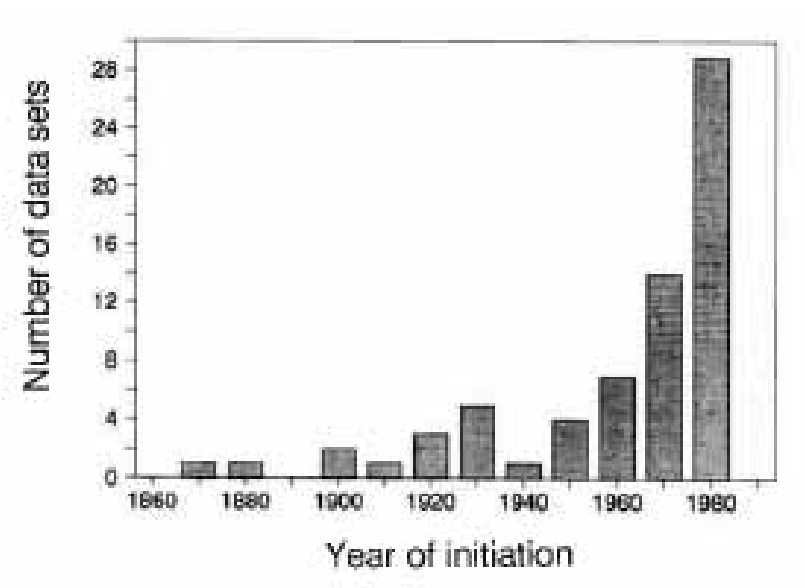
- Distributional Changes
  - Shift towards poles
  - Shift towards higher altitudes
- Phenological Changes
  - Advancement of spring events such as egg-laying, migrations
  - Lengthening of growing season
- Community Alteration
  - Shifts in species composition
  - Invasions and extinctions (local and global)

- Direct impacts of anthropogenic climate change have been documented on every continent, in every ocean and in most major taxonomic groups (Parmesan 2006).

Marine ecosystem monitoring

Why so few marine biological observations?

- End in 1990 or later, and span at least 20 years



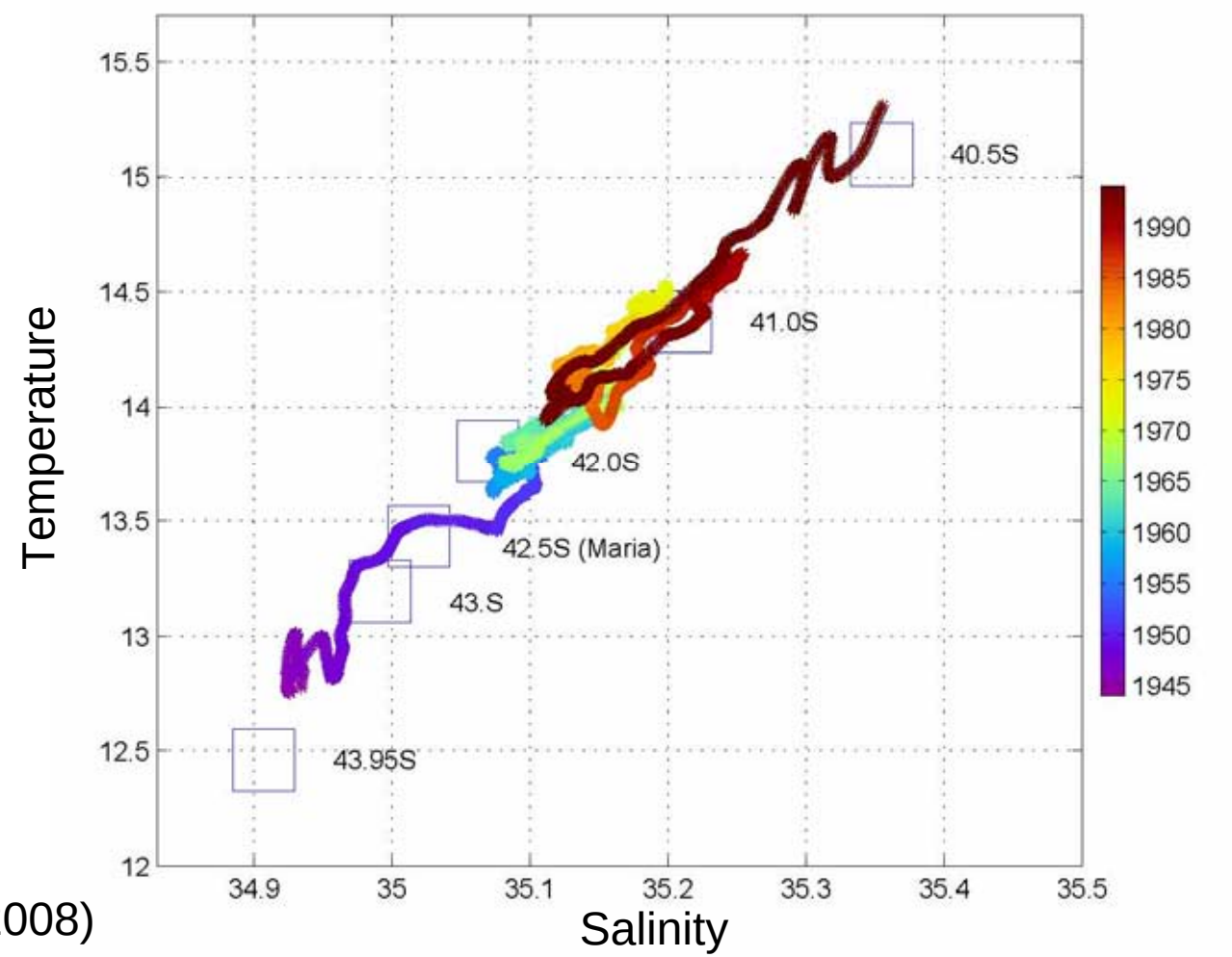
Duarte et al 1992

- Increase in initiation of long-term programmes at European marine stations from 1940 (Duarte et al. 1992)
- 55% terminated by 1992, 40% terminated in late 1980s
- Few marine biological monitoring programmes > 20 years

Sampling the oceans is expensive and difficult compared to many terrestrial systems

East Australian Current – poleward extension

- Change in water masses and hence species and ecosystems?



Hill et al (2008)