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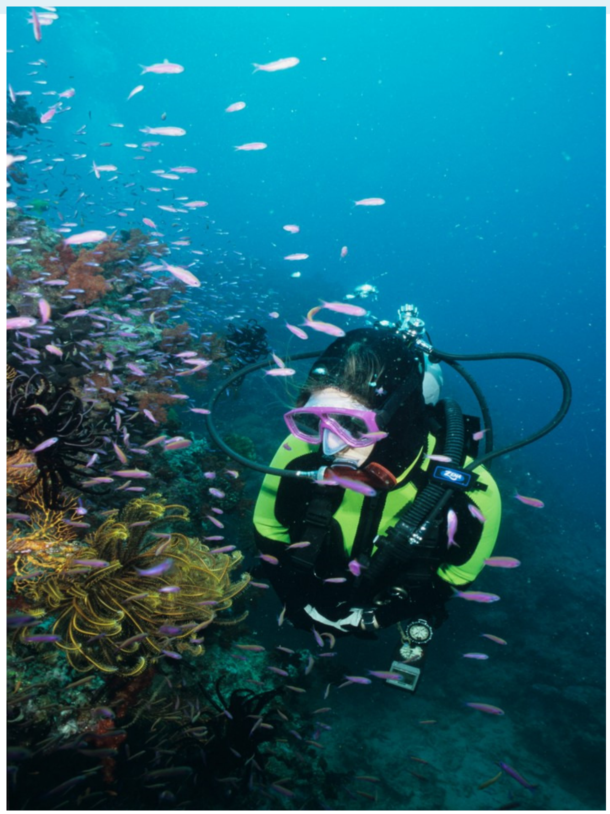
Dynamical seasonal forecasting for decision support in marine fisheries and aquaculture

Claire Spillman, Alistair Hobday, Paige Eveson, Jason Hartog & Grant Smith

NOAA Science Seminar, 9 February 2017, Silver Spring, MD, USA



Warming oceans

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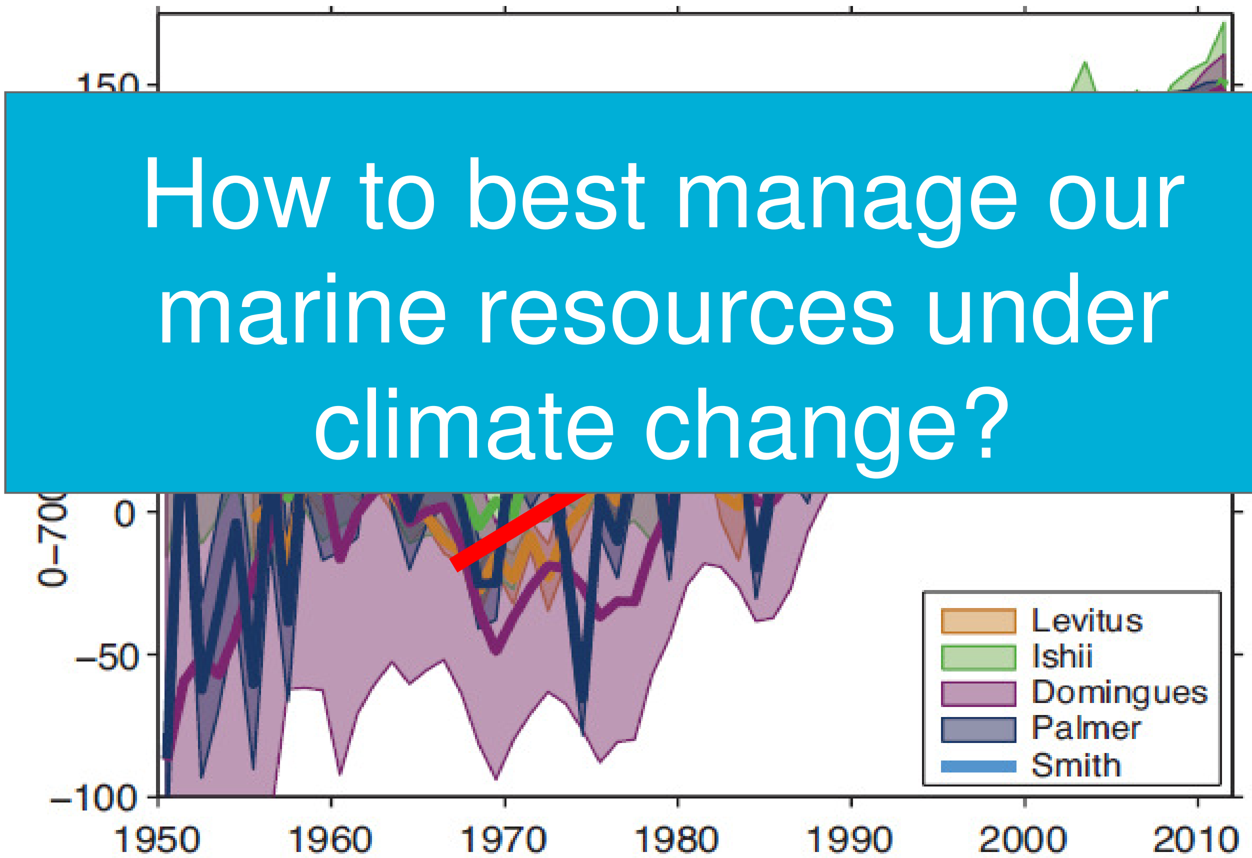
Observation-based estimates of annual global mean upper ocean heat content



How to best manage our marine resources under climate change?

Fig 3.2 in Rhein et al 2013. Climate Change 2013:
The Physical Science Basis. WG1 IPCC AR5

Recent marine heatwave

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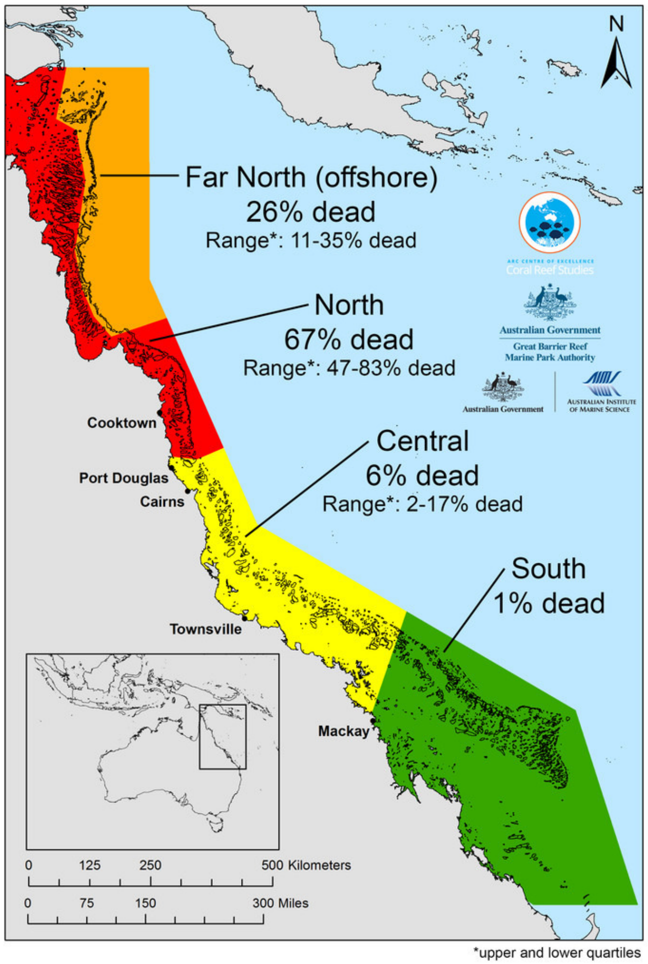
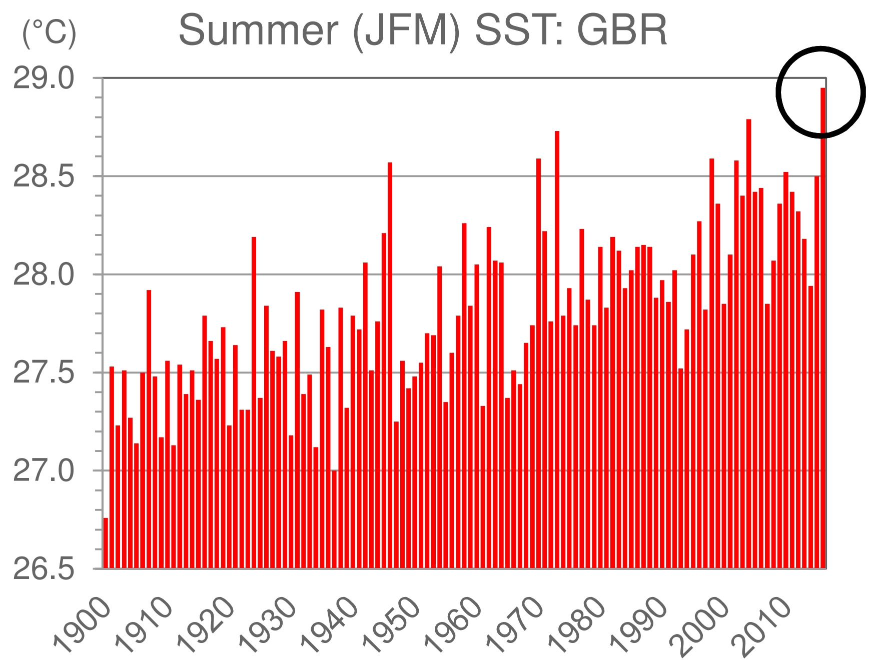


- Highest SST on record for JFM 2016 for GBR & Tasmania



ERSSTv4 SST data: 1961-1990 climatology   Hughes et al 2016: The Conversation

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Climate variability vs climate change

In marine industries, coping with climate variability is "business as usual" to many…

Coping with climate variability is **<u>responsive</u>** adaptation

Cost effective?

Does it allow for "opportunity" to be recognised?

Climate change is a new factor for a range of businesses

Can it just be managed as for climate variability?

Anticipating climate variability & change is **<u>proactive</u>** adaptation

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Management decision timescales

Time

Weather timescales: 1-7 days

Minimal warning time

Reactive management

Seasonal timescales: 2 weeks-9 months

Early window for implementation of strategies to minimise impacts

Climate forecasting: 10 – 100s years

Long term planning

Seasonal timescale most useful for proactive management. Business performance and industry resilience could be improved with predictions about future conditions.

Seasonal forecasting

Surveying bleached corals

- Seasonal timescale most useful for marine managers
- Provides an early window for implementation of management strategies to minimise impacts
- Dynamical models can incorporate climate change signals unlike statistical models
- Better managed marine resources have improved resilience under climate change

Spillman & Alves 2009, Spillman 2011
Image Commonwealth of Australia (GBRMPA)

When is seasonal forecasting useful?

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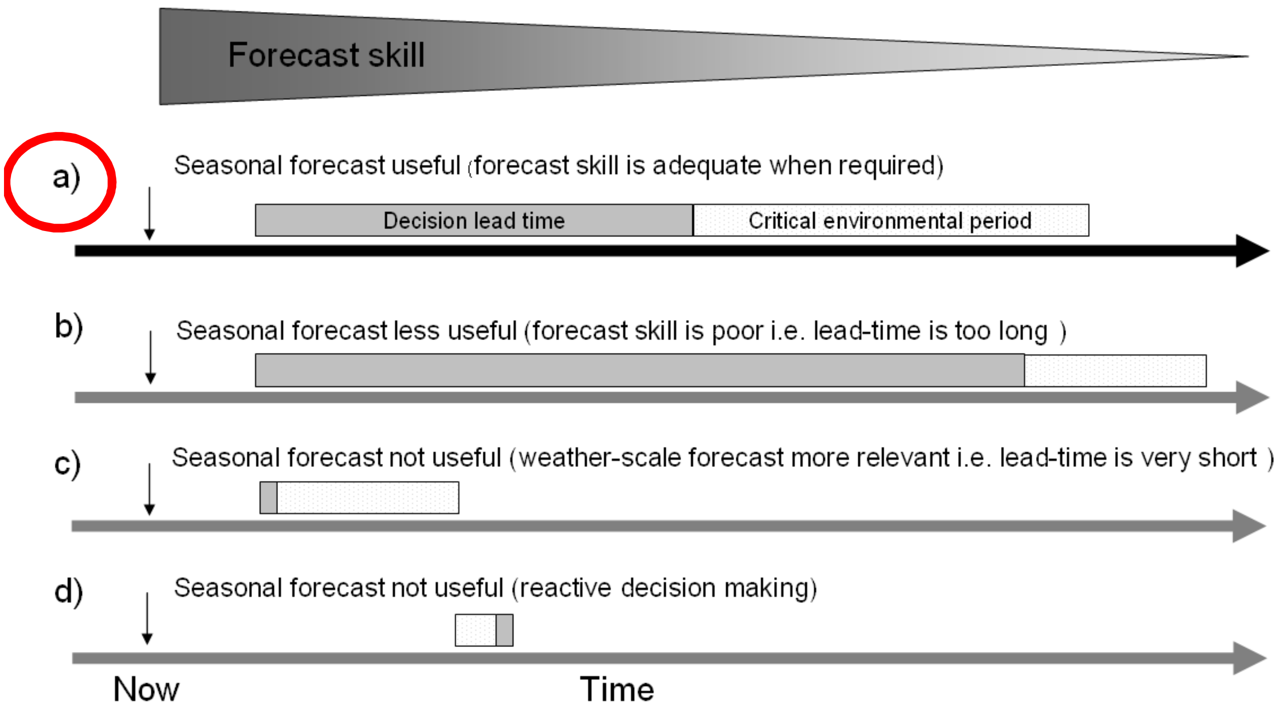

Usefulness depends on the timing of both the **management decision** to be made and that of the **critical environmental period** affecting the decision, together with **forecast accuracy** at that time.

When the lead-time required to make a decision is such that the forecast skill for the critical environmental period is adequate, a seasonal forecast may be useful (a).

Hobday et al 2016

POAMA

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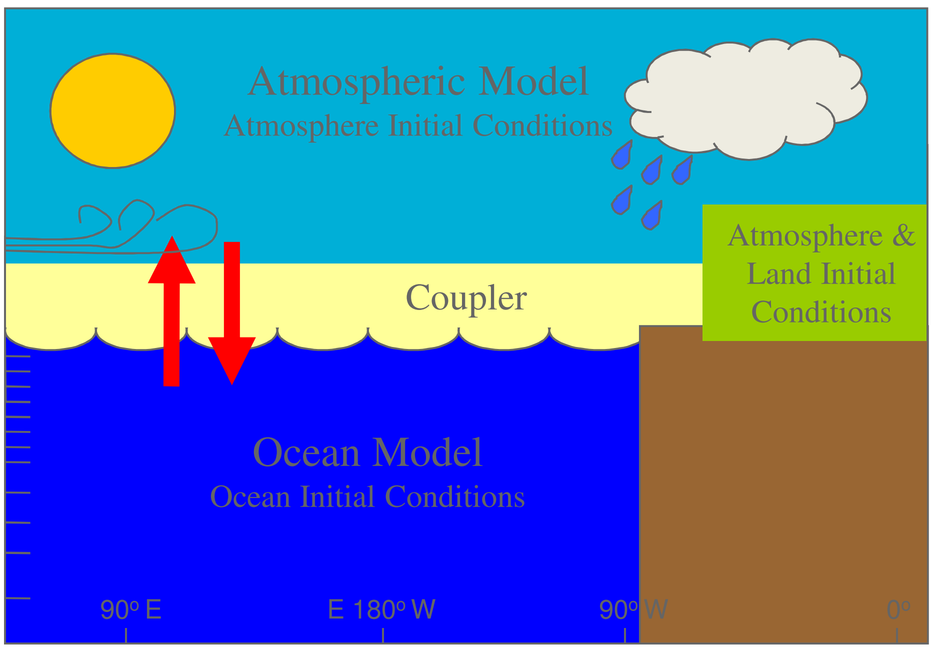
Predictive **O**cean **A**tmosphere **M**odel for **A**ustralia

The Bureau of Meteorology's global dynamical coupled ocean-atmosphere seasonal prediction system



- Forecast out to 9 months
- Run operationally in real time twice a week
- Atmospheric grid: ~250 km
- Ocean grid: 0.5-1.5° x 2°
- Temperature, sea level, salinity, currents & atmospheric variables

http://poama.bom.gov.au

Spillman & Alves 2009, Spillman 2011

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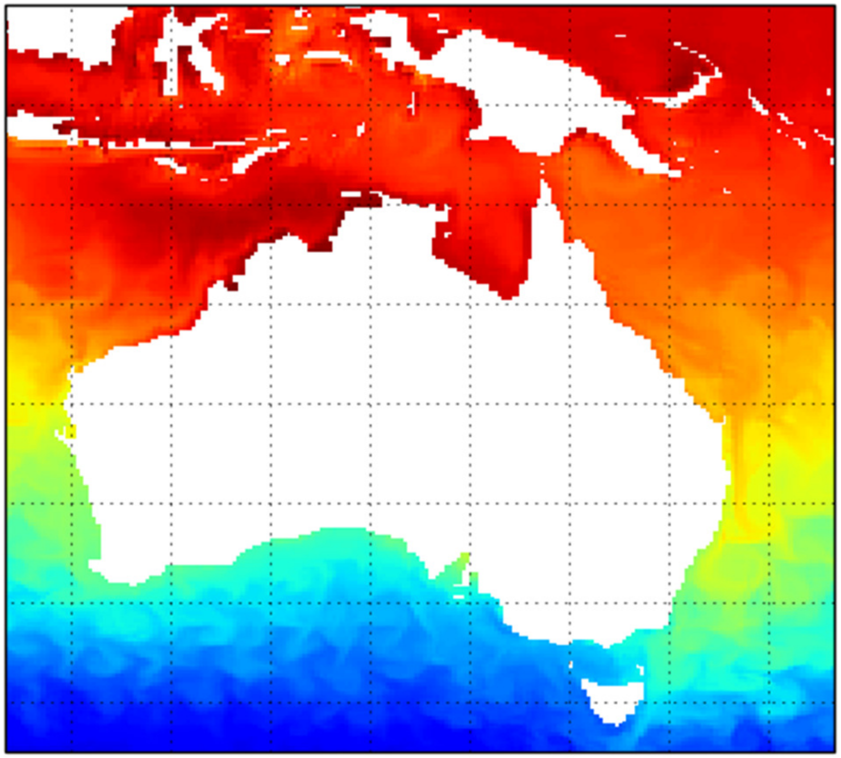
ACCESS-S

Australian **C**ommunity **C**limate & **E**arth **S**ystem **S**imulator



- ACCESS-S1 to replace POAMA as Bureau operational system in 2017
- Global coupled model
- UKMO collaboration
- S1 operational in 2017
- S2 operational in 2018-19
- Run daily in real-time

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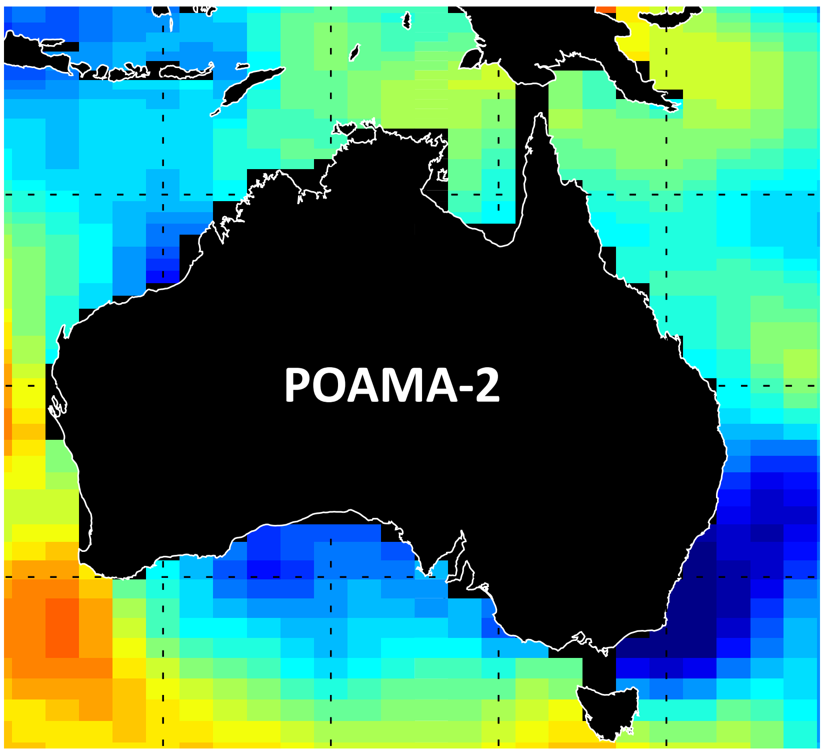
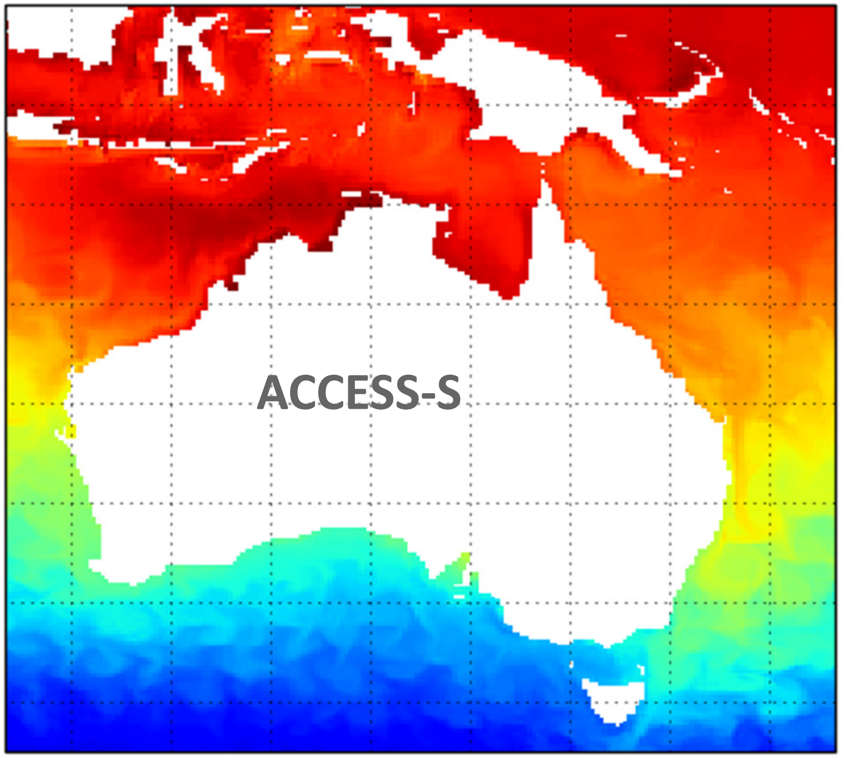
POAMA vs ACCESS-S

	POAMA-2	ACCESS-S1
Atmospheric model	Bureau BAM (~10 years old)	Latest UKMO atmospheric model (GC2)
Atmospheric resolution	Horizontal: 250 km (T47) Vertical: 17 levels	Horizontal: **60 km** in the mid latitudes (N216) Vertical: **85 levels**
Ocean model	MOM version 2 (~13 years old)	Latest European ocean model NEMO
Ocean resolution	Horizontal: ~200 km x 100 km Vertical: 15- 1000 m levels	Horizontal: **25 km (eddy permitting)** Vertical: **1-200 m** levels
Land surface model	Simple bucket model	State-of-the-art land surface model JULES
Sea ice model	No sea ice model	Latest sea ice model CICE (UK & USA)
Hindcast set	1982-2010 (33 ensembles)	1990-2012 (11 ensembles)

Ocean model resolution





Seasonal forecast tool development

A. Assess needs

Define management or industry need

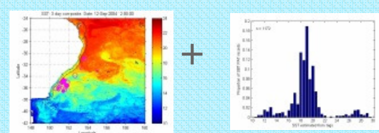
Determine critical variables & decision timescales

Verification data

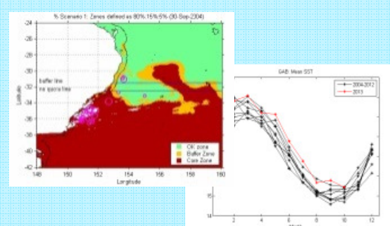
B. Development

Assess seasonal model skill

Produce habitat distribution forecast

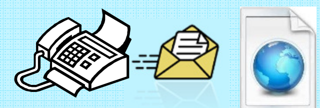


Forecast products



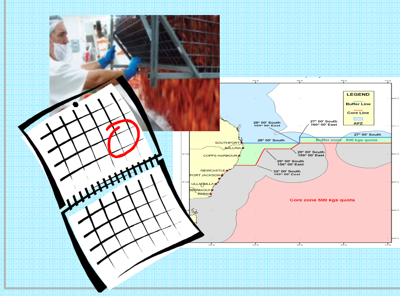
C. Implementation

Forecast delivery



Support & education

End user decision



User feedback

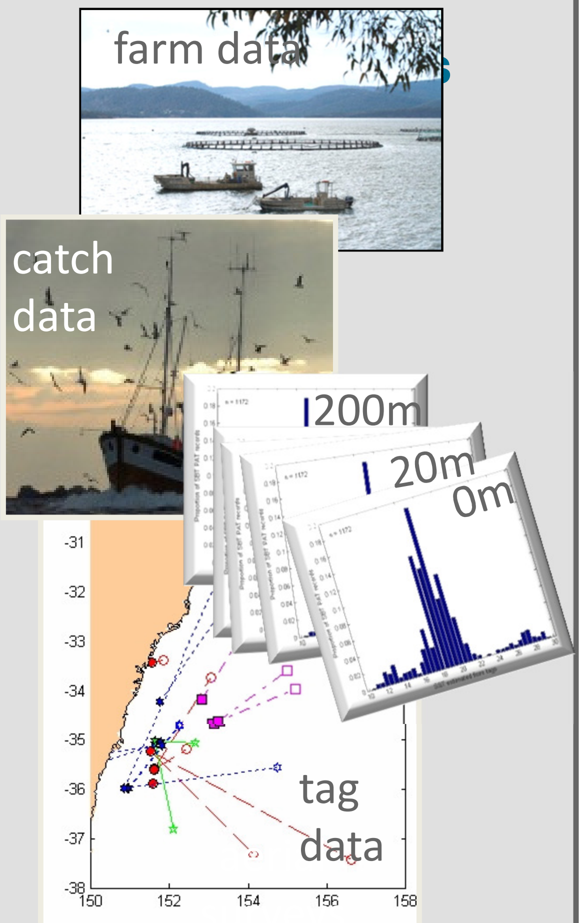
Hobday et al 2016

A. Assess needs

- Define management need
  - What is the management issue?
  - What management decisions are made and when?
  - Which thresholds trigger management action?
- What forecast information is needed?
  - Variable of interest?
  - Spatial and temporal resolution?
  - Lead time required?
  - Minimum skill?
- What validation data is available?

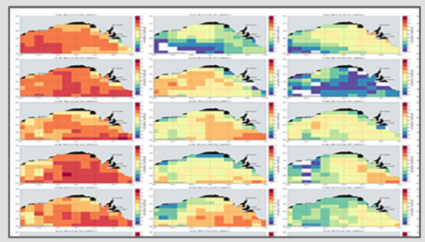
B. Development

Observations



Model skill

lead, location, season



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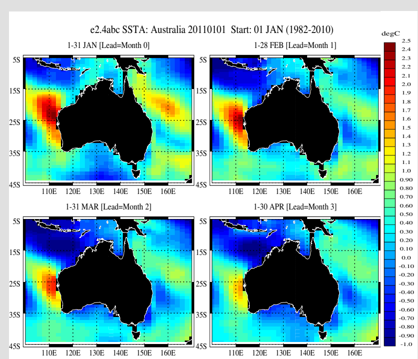
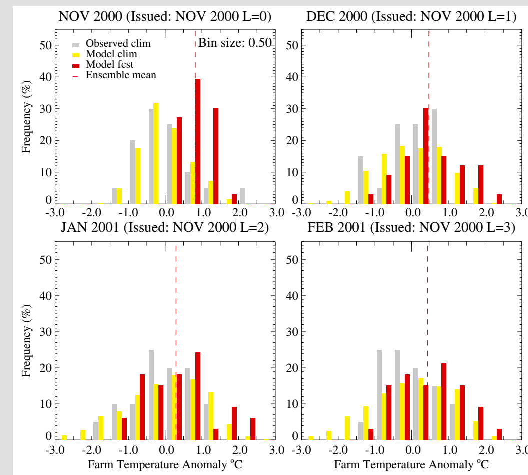
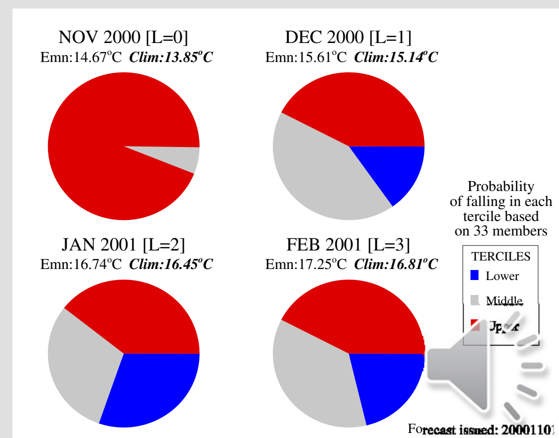
Realtime Forecasts



Forecast products





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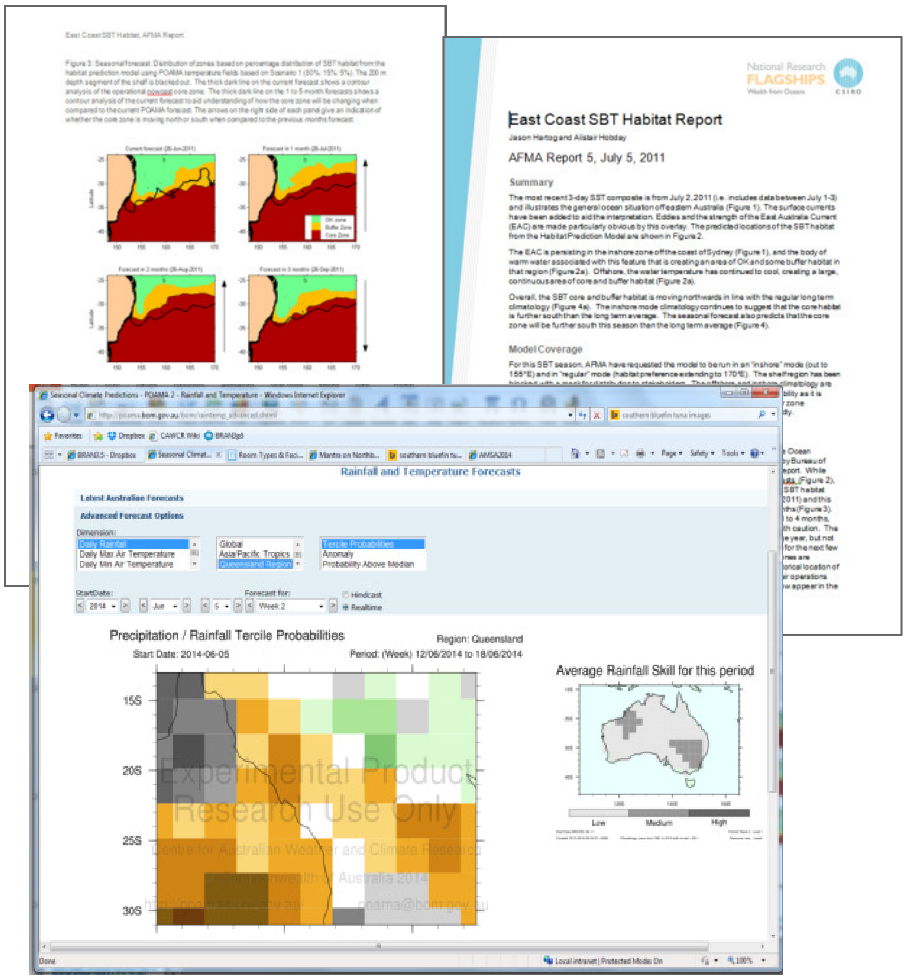
C. Implementation



- Online forecast delivery
- Emailed reports
- Meetings & presentations
- Support & education
- Industry feedback
- Farm visits very successful
- Industry award

Matt West, Australian Prawn Farms

Hobday et al 2011, Spillman & Hobday 2014, Spillman et al 2015, Eveson et al 2015

Lessons learned

Essential ingredients:	Very useful ingredients:
• Strong industry engagement • Clear understanding of end user skills & requirements • Skilful model forecasts • Appropriate forecast delivery • Industry feedback	• Industry advocate • Face-to-face user meetings

Critical information:	Very useful information:
• Relevant spatial & temporal scales? • Minimum skill level required? • Types of management decisions made?	• Which threshold initiates management actions? • The economic cost/benefit value of forecasts to industry?

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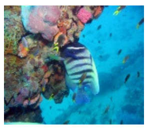
Seasonal marine applications

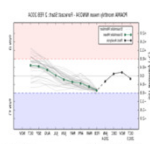

Coral bleaching risk


Commercial wild fisheries


Aquaculture


Sea level extremes


Heatwaves


ENSO

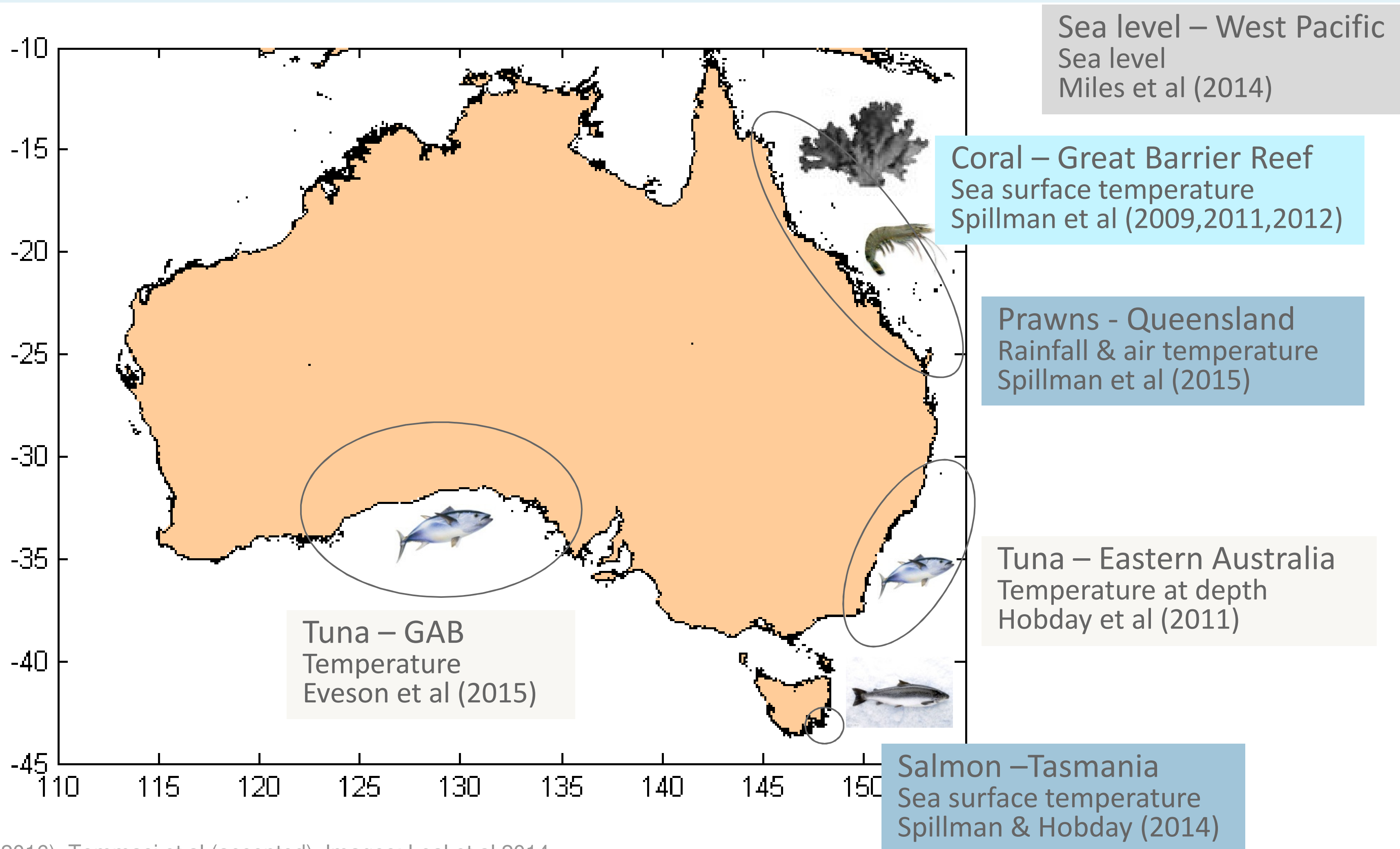
Use forecasts of seasonal ocean temperature and sea level anomalies up to 6 months ahead

Operational & experimental products

Images: Commonwealth of Australia, www.discoverwest.com.au, National Geographic, ABC

Spillman (2011), Spillman & Hobday (2014), Hobday et al (2012),
Eveson et al. (2015), Miles et al (2014), Alves et al (2011), Shi et al (2012)

Marine seasonal forecasting case studies



Hobday et al (2016), Tommasi et al (accepted). Images: Leal et al 2014

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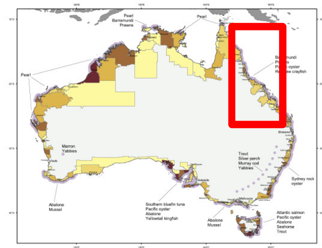
1. Coral bleaching



Great Barrier Reef
A$6B

Great Barrier Reef Marine Park Authority (GBRMPA)

Extreme ocean temps for bleaching

Inform management activities

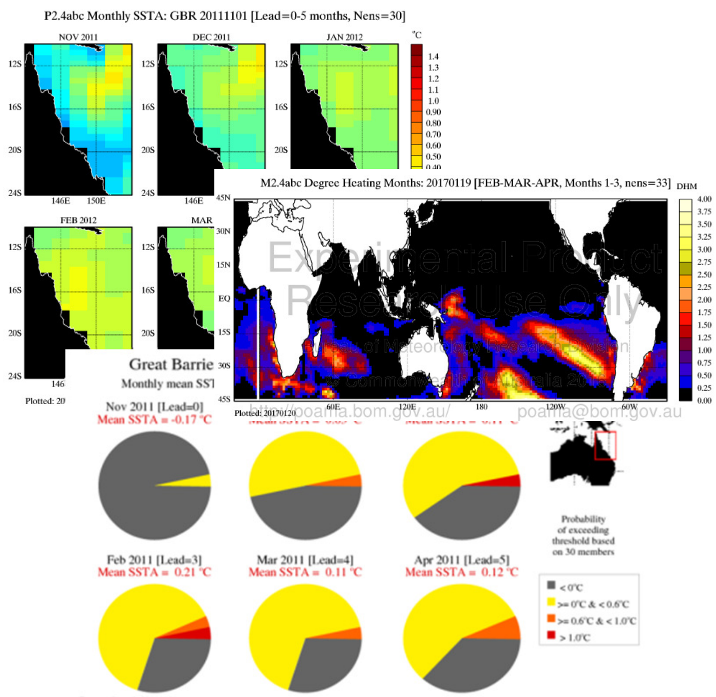
Information 2 weeks to 6 months ahead

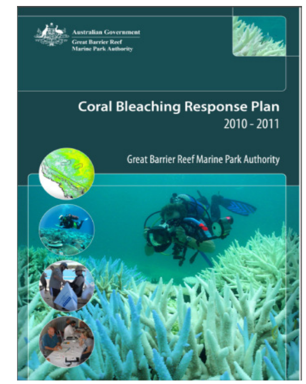
Summer SST though year round

Spillman et al (2009, 2011, 2012)

Real-time forecast products

- Spatial maps of multiweek SSTA
- GBR index based on mean SSTA
- Probabilistic SSTA forecasts > thresholds
- Degree Heating Months





- First operational dynamical seasonal forecasts for coral bleaching risk
- Component of GBRMPA Early Warning System
- Brief government, tourist operators, general public
- 3 year project to upgrade bleaching risk product suite to ACCESS-S ($510K)

2a. Southern bluefin tuna

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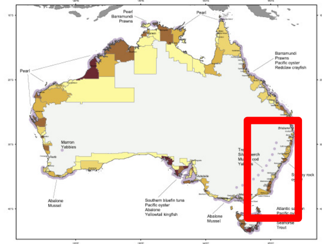


Eastern Australia SBT A$40M

Australian Fisheries Management Authority (AFMA)

Reduce non-quota capture

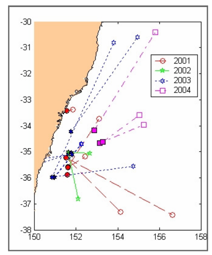
Inform spatial zoning to regulate access

Information 2 weeks to 6 months ahead

Winter ocean temp (0-200m)

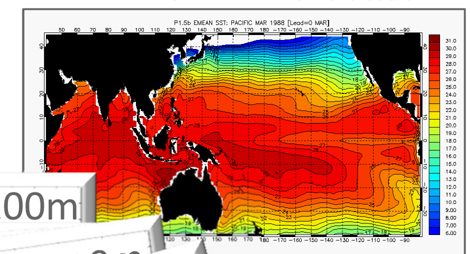
Hobday et al (2011)

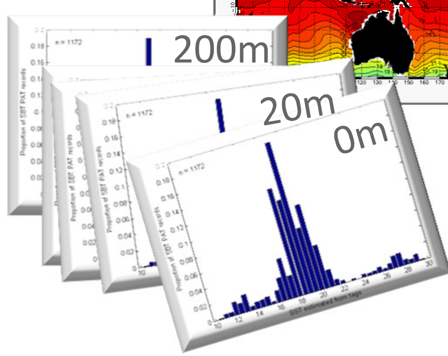
SBT habitat forecast products



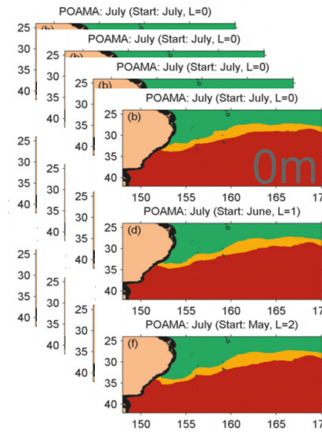
Catch data
Tuna tags

POAMA forecast



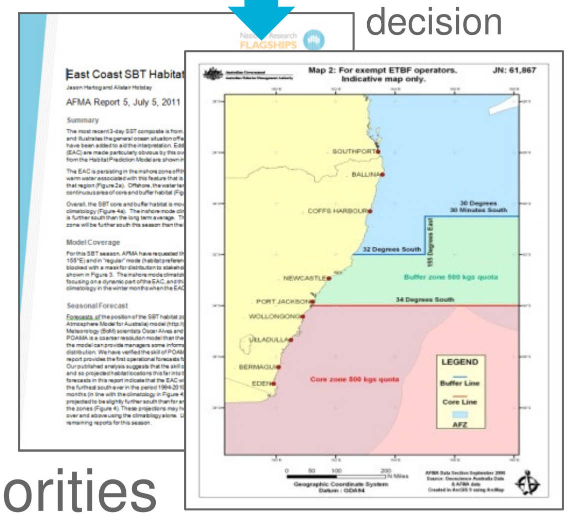


Observed temperature preference by depth



Probability maps across depth

Management decision



Information to allow authorities to set management zones

2b. Southern bluefin tuna

Australian Government
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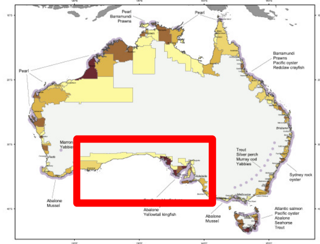

Great Australian Bight SBT A$60M

- Peak industry body and fishers
- Changing SBT distributions
- Improve industry efficiency
- Information up to 1-2 months ahead
- Summer SST

Eveson et al (2015)

http://www.cmar.csiro.au/gab-forecasts/index.html

SBT habitat distribution forecast products

SBT data for habitat model

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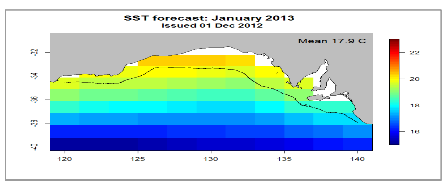
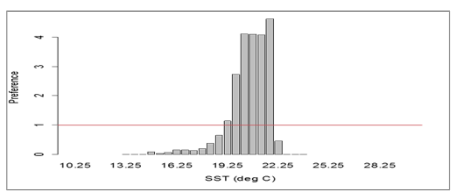
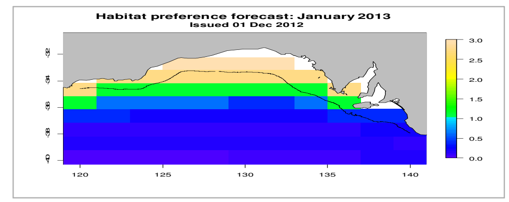
POAMA ocean forecasts





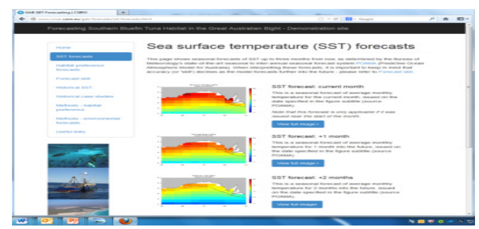
Habitat distribution model

Habitat distribution forecasts



Meetings & education
Industry feedback

Forecasts online



Forecasts were skilful 2 months ahead in the fishing season (Dec-Mar). Information about future habitat distributions in upcoming months allows fishers to better plan their port departures and operational activities.

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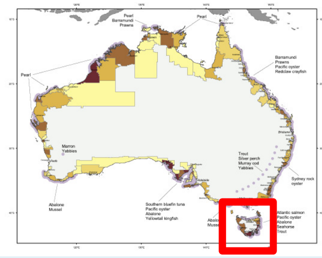
3. Salmon aquaculture



Tasmanian Salmon A$500M
Salmon Growers Association
Salmon grown towards upper thermal limit
Reduce vulnerability to temp extremes
Information 1 month to a season ahead
Summer SST

Spillman & Hobday (2014)

Tailored salmon farm forecast products

Farm temp data & monthly climatologies

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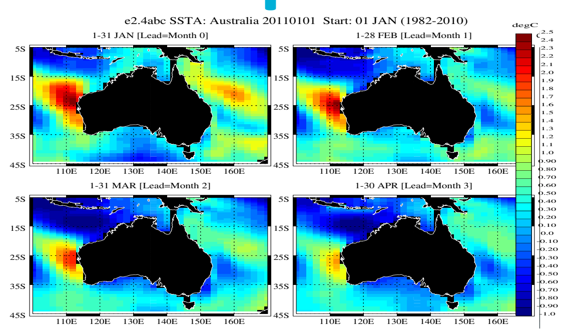
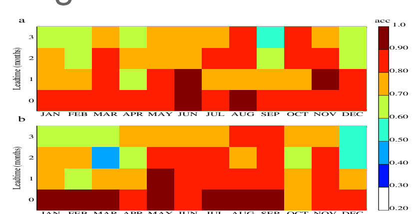


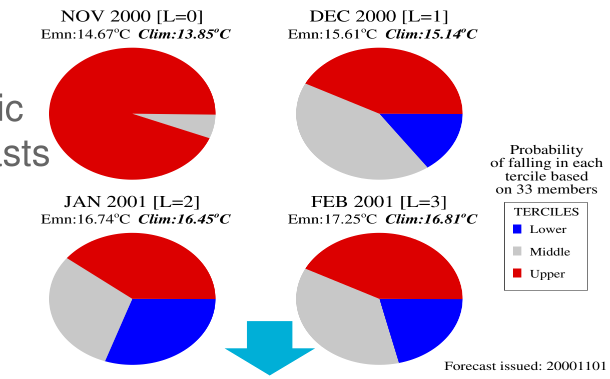
Regional ocean forecasts



Forecast accuracy information

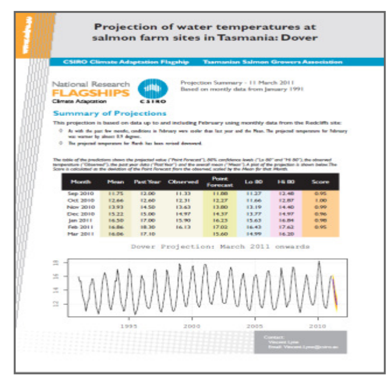
Forecasts were skilful up to 3 months ahead in summer months

Farm specific forecasts

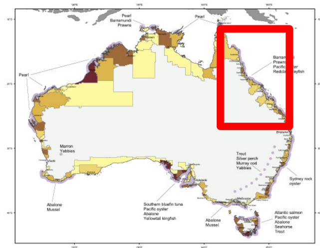


Monthly forecast reports

Meetings & education
Industry feedback



4. Prawn aquaculture

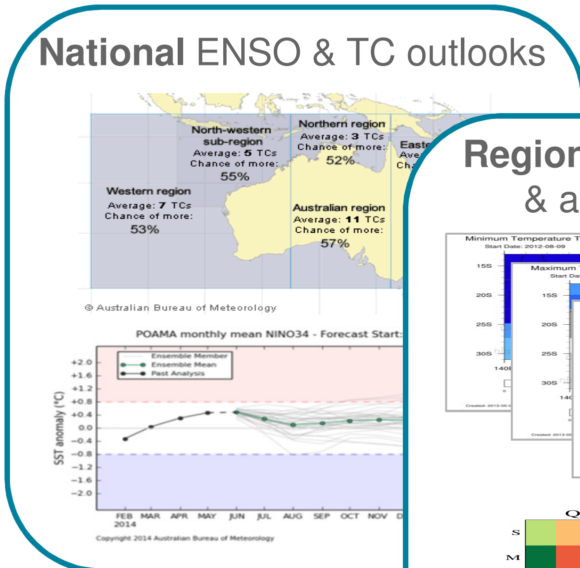


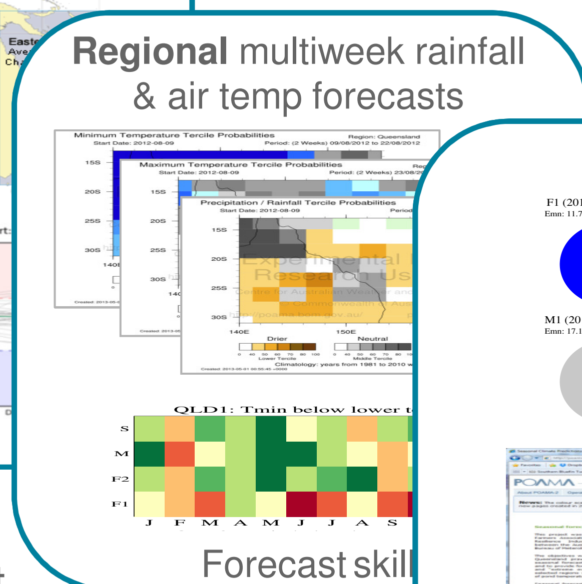
Queensland prawns A$70M

- Australian Prawn Farmers Association and individual farms
- Optimize prawn growth & yield; target markets
- Reduce vulnerability to temp & rainfall extremes
- Information 2 weeks to a season ahead
- Air temperature & rainfall year round

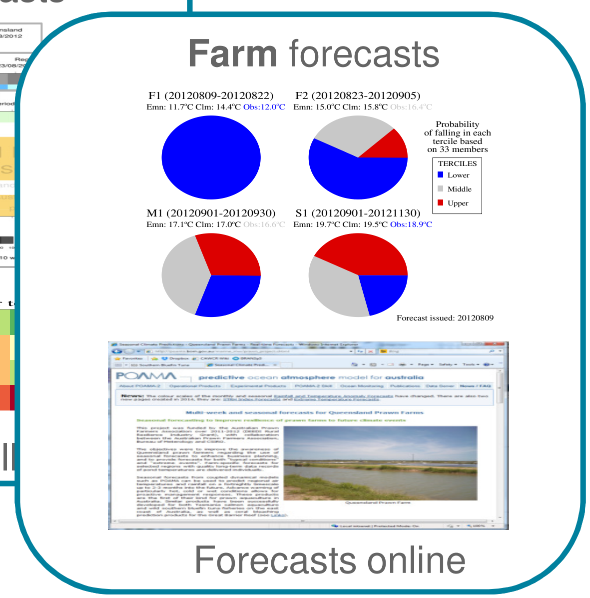
Spillman et al (2015)

Tailored prawn farm forecast packages





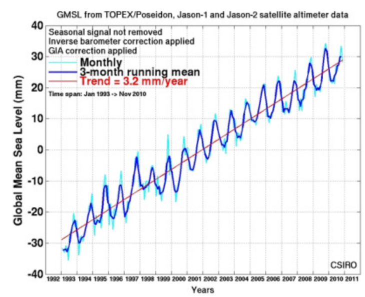
Farm visits
Industry feedback



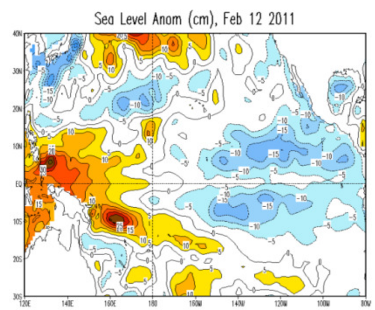
Seasonal forecast information allows farm managers to implement strategies to optimise prawn growth, whilst reducing vulnerability to climate extremes.

5. Sea level extremes

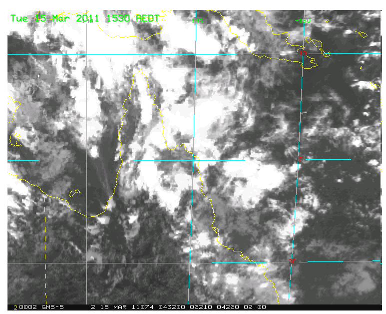
- Seasonal sea level anomaly forecasts provided to Pacific Island Nations
- First dynamical sea level forecasts
- Assist planning and improve resilience under climate change in Western Pacific
- NOAA collaboration MME experiment



Seasonal variability
+
Global SL rise



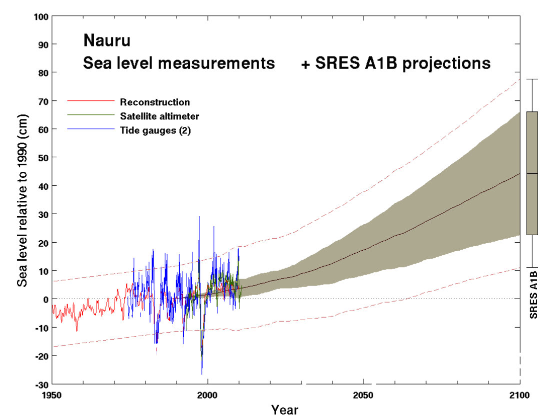
Regional variability



Weather
+
Tides

Tuvalu

Fiji



Future projections..

Miles et al. 2014, Mcintosh et al. 2015. Images: http://news.com.au
Pacific-Australia Climate Change Science Adaptation Program

Australian Government
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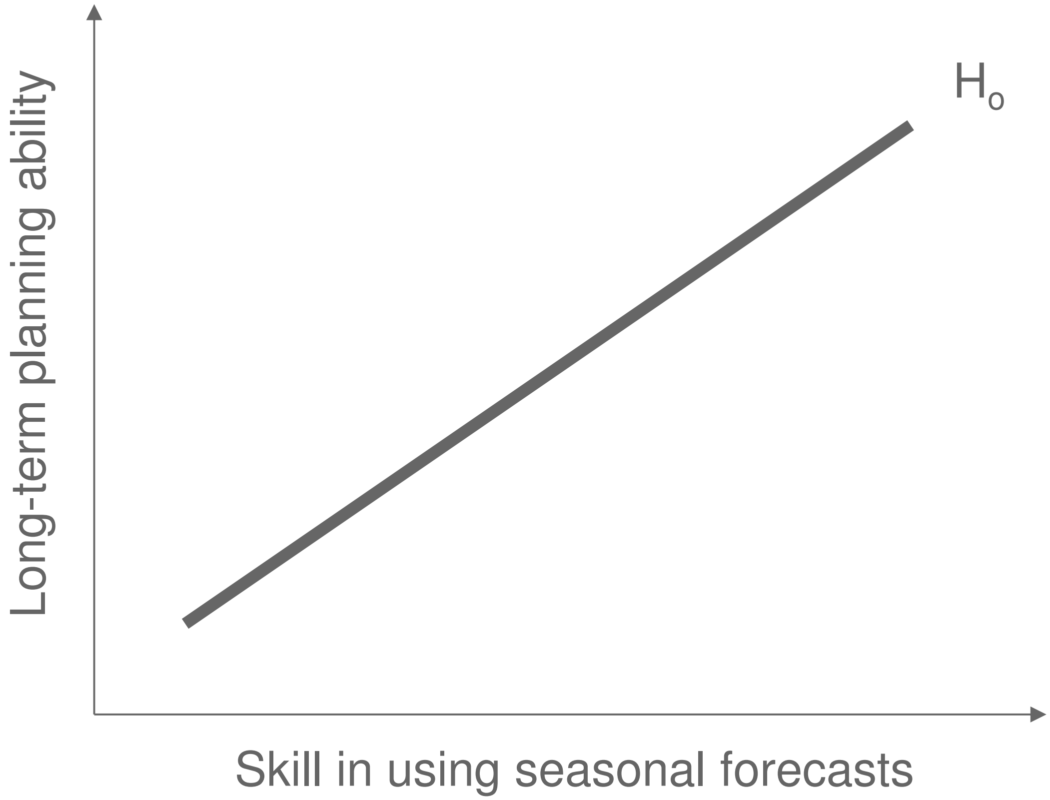
Engaging at a relevant timescale…

Does thinking more about the future lead to better long term skills?



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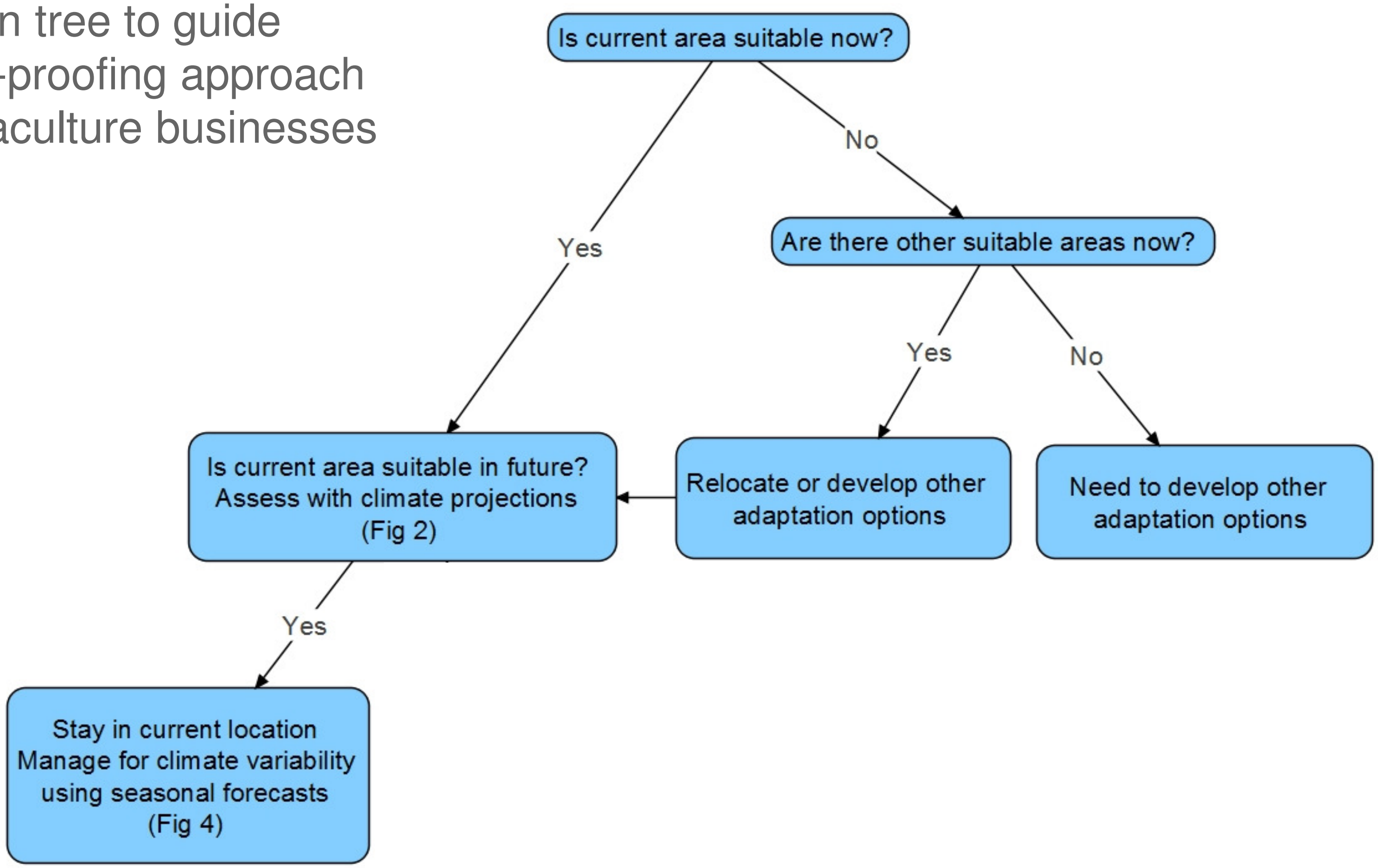
Climate proofing

- A risk-based management strategy that can be used by industries exposed to both short-term environmental variability and long-term change.
- Long–term climate projections provide insight into when current locations may no longer be suitable for industry.
- In the meantime, seasonal forecasting can be beneficial in helping plan ahead to reduce impacts in poor years & maximise opportunities in good years.
- Use of seasonal forecasting could extend the period of time in which industry can cope in a location as environmental suitability declines due to climate change.

Decision tree

Decision tree to guide climate-proofing approach by aquaculture businesses



Hobday et al. submitted

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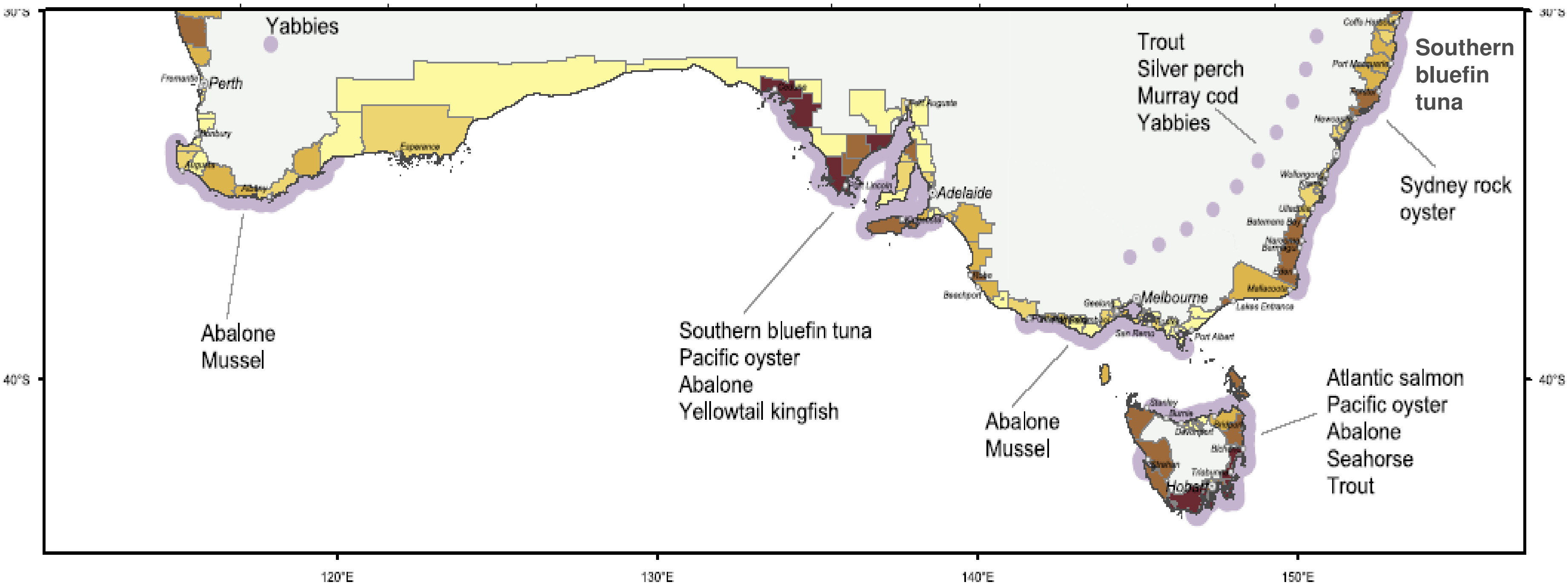
Case study: Southern Australia



Marine industries in southern Australia

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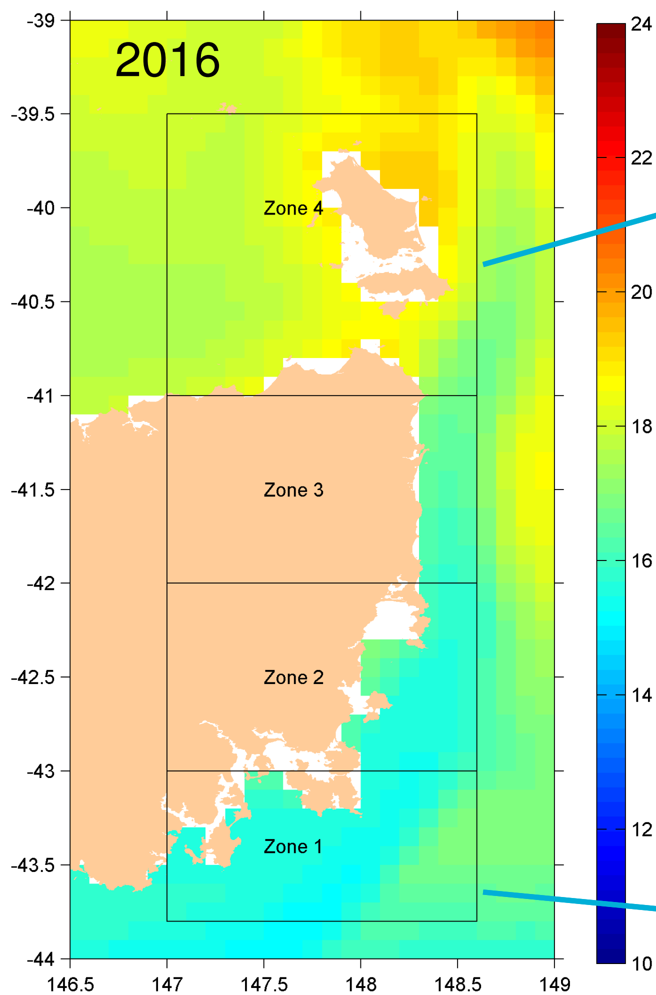
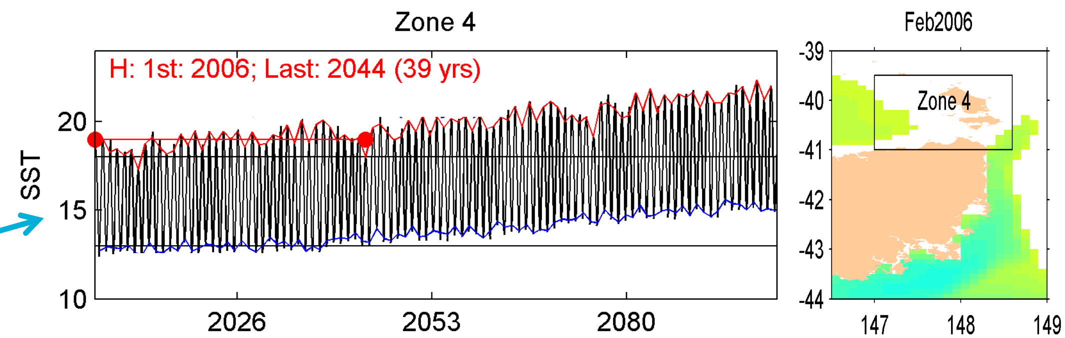
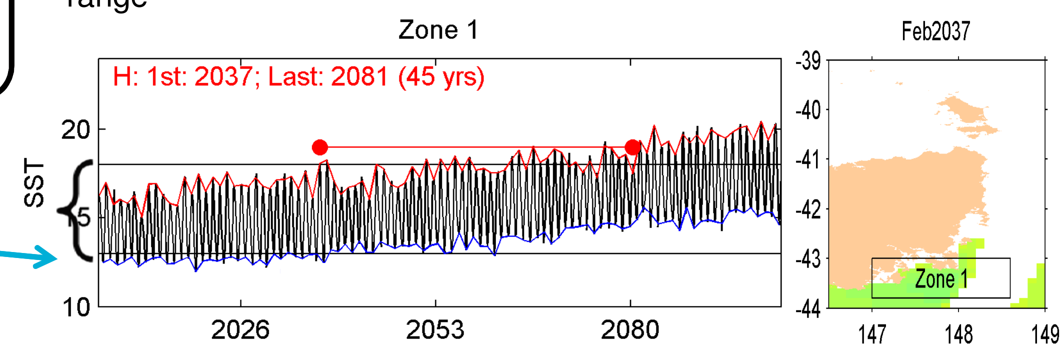
Case study: How long do we have?





Example ideal SST range

- First and permanent emergence times for summer (red dots)
- February SST maps for the year of first exceedance; summer SST below the threshold values are shaded.



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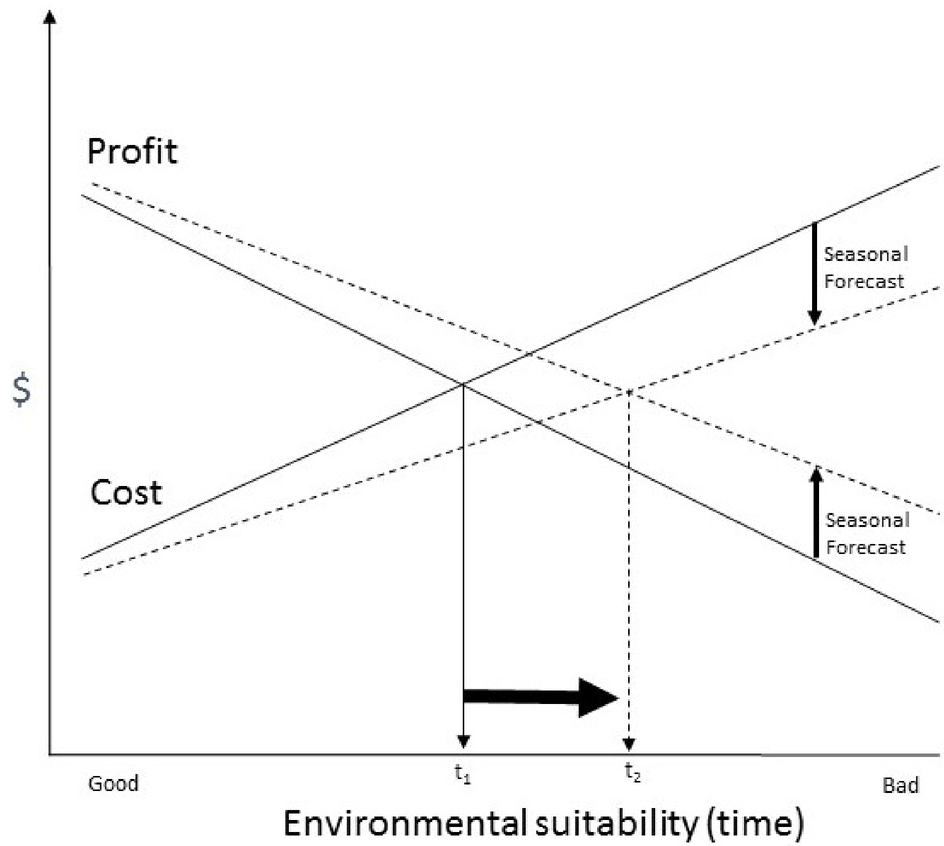
Benefit of seasonal forecasting



Using seasonal forecasts to provide information on future conditions, businesses should be able to reduce costs and increase profits, relative to no forecast such that they can remain profitable under less suitable environmental conditions for longer (until t_2).

Beyond this point, conditions are such that relocation (or another adaptation option) is necessary.

Hobday et al. submitted

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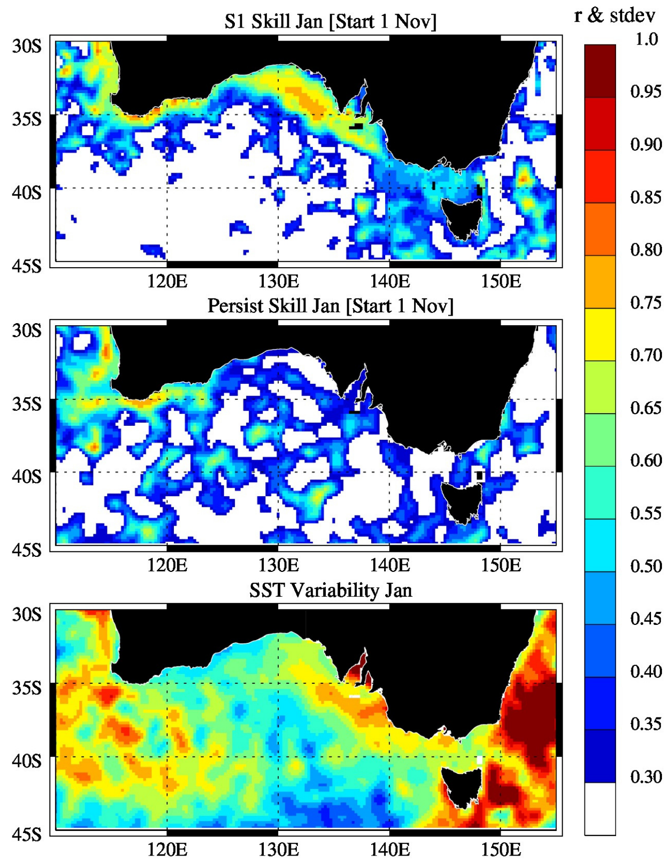
Managing environmental variability approaches



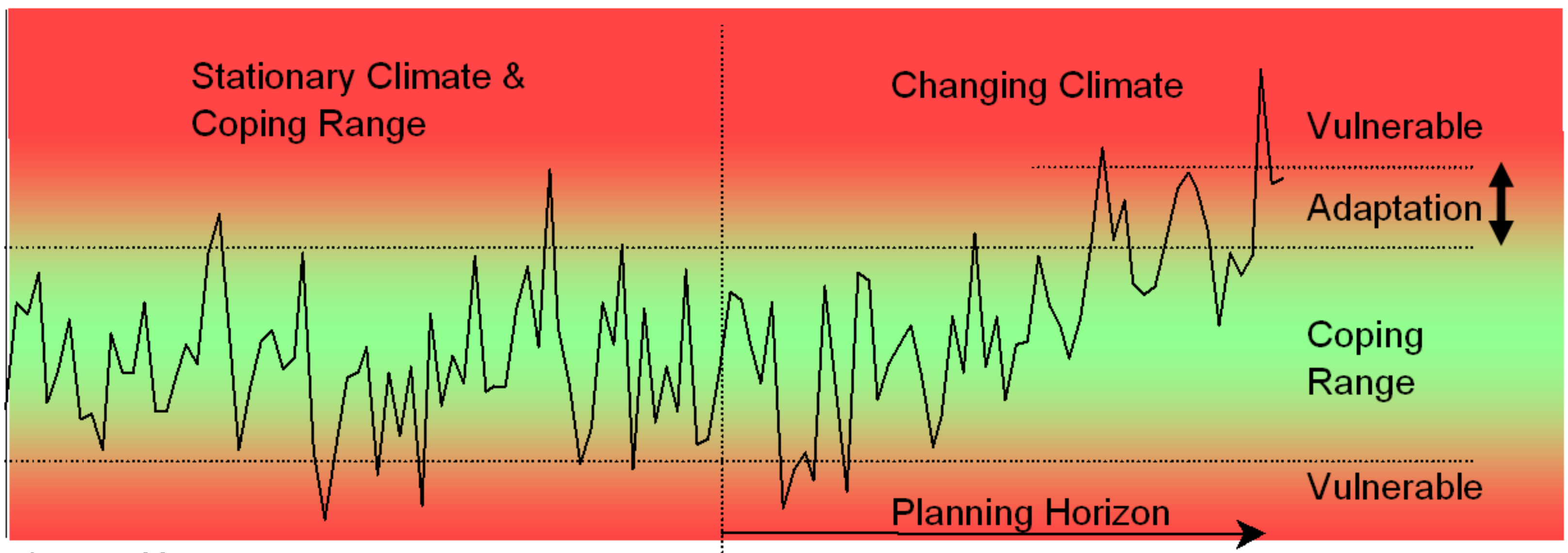
	Inter-annual SST variability	Persist skill	Model skill	Best approach at this time	Climate-proof?
1	Low	NR	NR	Climatology	No
2	High	Low	Low	Difficult – uncertain environment for business	No
3	Low/High	High	Low	Use real-time obs.	No
4	Low/High	Low	High	Dynamic model forecast.	Yes
5	Low/High	High	High	Dynamic model or persistence forecast.	Yes

Only dynamical model forecasts provide a viable option for managing environmental risk where climate change is reducing environmental suitability

Hobday et al. submitted

The future will be different..

- Climate change is leading to a future where past experience is of reduced value – outside coping range?
- Need to make reasonable decisions even if the details change, based on the best information available at the time
- Risk management approach



Jones & Mearns 2005

Looking ahead

- Dynamical seasonal forecast products valuable tools for proactive marine management
- Probabilistic forecasts important for risk analysis & management
- Potential for a variety of marine and climate applications
- Improves efficiency and enhances resilience of industry to climate variability and change
- Adoption takes time…. need to be in it for the long run!

Image courtesy of Michele Benoy-Westmorland (www.photomediaonline.com)

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Thank you

Dr Claire Spillman
Senior Research Scientist

+61 3 9669 8105
claire.spillman@bom.gov.au
www.bom.gov.au/research

- **POAMA:** http://poama.bom.gov.au

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Front image courtesy of Commonwealth of Australia (GRBMPA)