Adjusting Harvest Control Rules (HCRs) in changing environments / non-static Maximum Sustainable Yield (MSY)

Éva Plagányi
Finding rules that work under non-equilibrium conditions eg naturally variable stocks, strong environmental influences, changing climates, non-static MSY – plus political and market forces change demand and impacts

Examples:

• (a) highly variable stocks:
  • Torres Strait tropical rock lobster fishery
  • Bêche de mer (sea cucumber) fisheries
  • Australia’s Northern Prawn Fishery
  • Forage fisheries

• (b) impacts and approaches for dealing with changing climate;

• (c) ecosystem and socio-ecological interactions altering sustainable yield reference levels
Summary of Approaches

• designing highly adaptive empirical HCRs
• using tiered approaches
• simulation testing the robustness of HCRs across a broad range of plausible scenarios to bound the uncertainty
• allowing within season adjustments
• simulation testing less conventional management strategies such as spatial rotation strategies
• aligning choice of HCRs with life history and recruitment characteristics
• Testing climate-smart strategies
• Including social, economic and ecosystem factors
Australia’s National Harvest Strategy Guidelines

Harvest Strategy: “a framework that specifies the pre-determined management actions in a fishery necessary to achieve the agreed ecological, economic and/or social management objectives.”

A key principle is that fishery managers, fishers and key stakeholders utilise **pre-agreed (and preferably pre-tested) rules as to how to adjust management recommendations given updates of data and/or model outputs**

Torres Strait tropical lobster *P. ornatus* Example

- **Lobster Catch (t live weight)**
  - 0
  - 500
  - 1000
  - 1500

- **Year**
  - 1971
  - 1973
  - 1975
  - 1977
  - 1979
  - 1981
  - 1983
  - 1985
  - 1987
  - 1989
  - 1991
  - 1993
  - 1995
  - 1997
  - 1999
  - 2001
  - 2003
  - 2005
  - 2007
  - 2009
  - 2011
  - 2013
  - 2015
  - 2017

- **Trawling banned**

- **Population surveys**

- **Lobsters per 2000 sqm**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7

- **Lobster Catch by Method**
  - TRAWL
  - PNGDIVE
  - AUSDIVE

- **Legend**
  - 2+ lobsters
  - 1+ lobsters

- **Years for Population Surveys**
  - 1988
  - 1989
  - 1990
  - 1991
  - 1992
  - 1993
  - 1994
  - 1995
  - 1996
  - 1997
  - 1998
  - 1999
  - 2000
  - 2001
  - 2002
  - 2003
  - 2004
  - 2005
  - 2006
  - 2007
  - 2008
  - 2009
  - 2010
  - 2011
  - 2012
  - 2013
  - 2014

- **Years for Trawling Ban**
  - 2008
  - 2009
  - 2010
  - 2011
  - 2012
  - 2013
  - 2014

- **Years for Population Surveys**
  - 2008
  - 2009
  - 2010
  - 2011
  - 2012
  - 2013
Problem

• Challenging to reliably predict recruitment
• Use Pre-season survey but needs to be as close to start of fishing season as possible
• But not enough time to update and review stock assessment model to set quota

Solution

• Develop empirical harvest control rule that uses survey and fishery CPUE (catch-per-unit-effort) data as inputs
• Pre-tested so quick and transparent to implement
• Use MSE (Management Strategy Evaluation) to simulation test rule

Strong environmental influences on recruitment
User-friendly HCR - Spreadsheet

Torres Strait tropical lobster / Kaiar Panulirus ornatus
Harvest Control Rule Recommended Biological Catch Calculator

A. Instructions

- Cells shaded light yellow can receive entered values. Cells shaded light blue show results, but cannot be changed.
- Enter data updates in the yellow-shaded cells in Section B below. Example values have been entered for 2016. These need to be changed to the real values when these are available. Data will be provided annually.
- Total Catch to be entered = TIB + TVH + PNG catch in tons (live weight).
- Preseason survey indices = the standardised values obtained from the November survey; the last 5 values of each series need to be checked
- CPUE = the standardised values obtained from the analyses run in October; note that if the earlier values change in the standardisation, the last 5 values of each series all need to be updated for the calculations below.
- The resulting 2017 recommended biological catch (RBC) calculated using the Harvest Control Rule is shown in Section C, together with comparative values for the 2015 and 2016 HCR RBCs for comparison. Historical TACs and the 2017 RBC are plotted compared to the historical average TAC.
- Consolidated historical and entered data are summarised in Section D and the Survey and CPUE regressions through the recent data are plotted. Further information on the HCR is provided in Section E.

(Spreadsheet by CSIRO, contact Dr Eva Maganuy-Iloyd: Eva.Plaganyi-lloyd@csiro.au)

B. Data Entry Section

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Catch</th>
<th>Survey indices</th>
<th>CPUE indices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Preseason 0+</td>
<td>Preseason 1+</td>
</tr>
<tr>
<td>2015</td>
<td>539</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
<td></td>
<td></td>
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</table>

C. RBC Calculator

<table>
<thead>
<tr>
<th>Year</th>
<th>RBC</th>
<th>Forecast RBC</th>
<th>RBC-Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>736.8</td>
<td>616.1</td>
<td>62.7</td>
</tr>
<tr>
<td>2016</td>
<td>678.9</td>
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<tr>
<td>2017</td>
<td>#NUM!</td>
<td>#NUM!</td>
<td>HCR</td>
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</table>

D. Consolidated Catch, Indices and RBCs table

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Catch</th>
<th>Survey indices</th>
<th>CPUE indices</th>
<th>TAC / RBC</th>
<th>Average TAC</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Preseason 0+</td>
<td>Preseason 1+</td>
<td>CPUE_TIB</td>
<td>CPUE_TVH</td>
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<tr>
<td>2006</td>
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<td>5.76</td>
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<tr>
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<td>2009</td>
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<td>1.03</td>
<td>1.18</td>
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<td>2011</td>
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<td>2012</td>
<td>712.7</td>
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<td>1.38</td>
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<td>2013</td>
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<td>2014</td>
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<td>0.79</td>
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<td>2017</td>
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<td>#NUM!</td>
<td>HCR</td>
<td>#NUM!</td>
<td></td>
</tr>
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D. Harvest Control Rule Information

Relative weighting of indices in harvest control rule

<table>
<thead>
<tr>
<th>Preseason 0+</th>
<th>Preseason 1+</th>
<th>CPUE_TIB</th>
<th>CPUE_TVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.045</td>
<td>0.039</td>
<td>-0.105</td>
<td>-0.272</td>
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<td>#NUM!</td>
<td>#NUM!</td>
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</table>

Slope of regression line fitted to logs of last 5 points of each series

<table>
<thead>
<tr>
<th>Year</th>
<th>Slope Pre0+</th>
<th>Slope Pre1+</th>
<th>Slope C/E_TIB</th>
<th>Slope C/E TVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>0.045</td>
<td>0.039</td>
<td>-0.105</td>
<td>-0.272</td>
</tr>
<tr>
<td>2016</td>
<td>#NUM!</td>
<td>#NUM!</td>
<td>#NUM!</td>
<td>#NUM!</td>
</tr>
</tbody>
</table>
How do we check the rule is robust?

Considered several types of Uncertainty:

• **Process uncertainty** (e.g. recruitment variability, stock-recruit relationship, natural mortality)
• **Observation uncertainty** (e.g. generate “future” survey and CPUE data, with observation error added).
• **Model uncertainty** (do alternative models fit the data adequately?)
• **Estimation uncertainty** – how well do the data determine the parameters (and predictions) of the model (age-structured model implemented in ADMB)
• **Implementation uncertainty** – given a management decision, how well is it enforced or implemented? Different implementation error magnitudes for each of the three sectors based on recent observed catches

4 operating models x 200 replicates of each
Range of alternative weightings tested

**ONLY PRESEASON 1+**

- **HCR4**
  - CPUE(TVH), 0.15
  - CPUE(TIB), 0.05
  - Preseas0+, 0.1
  - Preseas1+, 0.6

- **rHCR1**
  - Preseas1+, 0.6
  - Preseas0+, 0.1

**HIGH PRESEASON 1+**

- **HCR5**
  - CPUE(TVH), 0.15
  - CPUE(TIB), 0.05
  - Preseas0+, 0.1
  - Preseas1+, 0.8

- **rHCR8**
  - Preseas1+, 0.5
  - CPUE(TIB), 0.2

**MORE PRESEASON 0+**

- **rHCR3**
  - CPUE(TVH), 0.05
  - CPUE(TIB), 0.05
  - Preseas1+, 0.6

- **HCR12**
  - Preseas0+, 0.0
  - CPUE(TVH), 0.5
  - CPUE(TIB), 0.5

**BALANCED OPTION**

- HCR4
- rHCR1

**HIGHER CPUE WEIGHTING**

- HCR5
- rHCR8

**NO PRESEASON**

- rHCR3
- HCR12

**X**

- ONLY PRESEASON 1+ (HCR4)
- MORE PRESEASON 0+ (rHCR3)
X LOSERS

2 & 4 (no log) – too variable

11 (hockey rule based on survey values) – too variable

12 (constant catch) – too risky

10 (constant average catch) – too low
Empirical Harvest Control Rule (eHCR)

Regression on log of slopes of all indices (pre1+, pre0+, CPUE_TVH, CPUE_TIB) with weightings as shown in pie graph

\[ TAC_{y+1} = \left[ 0.7 \cdot (1 + s_{y}^{presurv,1}) + 0.1 \cdot \left( 1 + s_{y}^{presurv,0} \right) + (1 + s_{y}^{CPUE,TVH}) + (1 + s_{y}^{CPUE,TIB}) \right] \cdot \overline{C}_{y-4,y} \]

if \( TAC_{y+1} > 1000t \Rightarrow TAC_{y+1} = 1000 \)

where
- \( \overline{C}_{y-4,y} \) is the average achieved catch during the past 5 years, including the current year i.e. from year \( y-4 \) to year \( y \),
- \( s_{y}^{presurv,1} \) is the slope of the logarithms of the preseason survey 1+ abundance index, based on the 5 most recent values;
- \( s_{y}^{presurv,0} \) is the slope of the logarithms of the preseason survey 0+ abundance index, based on the 5 most recent values;
- \( s_{y}^{CPUE,TVH}, s_{y}^{CPUE,TIB} \) is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values;
- \( 0.7, 0.1 \) are tuning parameters
Proxy empirical limit reference point triggers additional action such as surveys, full stock assessment, closure
Key Recommendations

• Empirical harvest control rule uses survey inputs together with other data as part of balanced portfolio that accounts for inter-annual variability as well as medium-term trends
• Extensive stakeholder engagement
• Use a Reference set of alternative operating models to bound uncertainty
• Implementation uncertainty can be important to include
• Robustness testing – with inputs from stakeholders
• Warning system triggers actions but not immediate closure unless decline persists into second year
Risk-cost-catch framework

High risk = need for precautionary management = lower fishery catches

Low risk = less need for precautionary management = higher fishery catches

LESS DATA

KEEP CALM AND COLLECT DATA

MORE DATA
Comparison with Constant Catch

Higher risk with constant catch that is similar to average from selected adaptive rule

Bsp < 0.32K

High risk of closure with constant catch

Median 690t
Harvest Control Rules: towards tiers and risk equivalency

• Tier 1 (Bonus Tier): Additional Midyear survey (1+ and 2+ relative abundance)

• Tier 2 (Current Tier): Monitoring information: Total catch (TIB, TVH, PNG), Preseason survey (0+, 1+ relative abundance), CPUE standardised indices of abundance from TIB and TVH sectors (2+ index)

• Tier 3 (Penalty Tier): No fishery-independent survey - CPUE

• Tier 4 (Lowest Tier): No monitoring information – constant catch
Evaluating risk and calibrating penalty/bonus

MSE tested scenarios: Catch and Risk are medians from 800 simulations (4 operating models)
Risk Equivalency Simulation Results

Higher risk with only CPUE especially if accounting for additional uncertainties – suggests penalty discount factor of ca. -20%

Higher catch for similar risk with extra survey – suggests bonus discount factor of ca. -5%
Bêche de Mer pose some unique challenges

Recruitment sporadic – non-static
MSY – multispecies – different life histories – high value – changing market demands due to price, processing technology and competition with aquaculture

Recruitment

• Appears to be sporadic and unpredictable
• Depleted populations can be very slow to recover
  – 7-20 years
MSE used to test Rotational Zoning Scheme (RZS) on Great Barrier Reef

- In 2004 a Rotational Zoning Scheme (RZS) was introduced in response to concerns about localised and serial depletion of sea cucumber stocks; designed by the members of the Queensland Sea Cucumber Association.
- Each zone is available for harvesting in the fishery once every 3 years for 15 days of fishing.

Worldwide RZS used for abalone, corals, geoduck clams, sea urchins and scallops.
Reference Set – bound uncertainties
(validated by comparing with available survey estimates & observed range of variability)

M. Natural mortality:
   M1: average mortality estimates for each species + average growth
   M2: slow growth scenario

H. Steepness parameter:
   H1: \( h \) is fixed at 0.7
   H2: \( h \) is fixed at a more conservative value of 0.5;

R. Recruitment frequency:
   R1: Recruitment assumed continuous but random
   R2: Recruitment assumed pulsed and uncertain

K. Starting biomass:
   K1: estimated or input values based on survey estimates;
   K2: alternative estimates
Trade-off curve between risk and revenue

- Can distinguish between performance of alternative management strategies even given uncertainties
- Compromise option tested across range of species

3 year rotation cycle time has low risk and high revenue

Plaganyi et al. (2015) PNAS
Key Recommendations

- MSE testing showed RZS applied to sea cucumbers in a multispecies fishery on Australia’s Great Barrier Reef significantly reduces the risk of overall and localized species depletion.
- Works best if also implement limits on catch and minimum size, effort is spread throughout the fishery so that the entire population of patchily-distributed species periodically has a chance to grow and breed unfished.
- Can distinguish between performance of alternative strategies even when including considerable uncertainty in population dynamics.
- Approach accounts for unknown and non-static MSY – focuses instead on evaluating and reducing risk whilst optimising economic gains.

Rotational Zoning Scheme (RZS)
Unique life history strategies also have management implications for forage fish

- Crucial species in food webs
- Small, often schooling pelagic species
- Sardines, anchovies, sand eels, krill, herring...
- Feed on plankton and transfer energy to upper trophic levels
Used MSE to show only Precautionary Management Protects Predators and Fisheries

Compares a constant F strategy, $F = F_{\text{msy}}$, with hockey stick strategy with $B_{\text{min}} = 0.4 \, B_0$ and maximum F equal to 0.5 $F_{\text{msy}}$

**Key**
- Conventional
- Precautionary

---

**Predator declines**
*(compared to no forage fishing)*

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Precautionary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-20</td>
<td>-28</td>
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<td>-100</td>
</tr>
<tr>
<td>-80</td>
<td>-100</td>
<td></td>
</tr>
</tbody>
</table>

**Probability of forage collapse**

- $42\%$
- $6\%$

**Forage yield**
*(% of MSY)*

- $100\%$ MSY
  - $87\%$ of MSY
  - $51\%$ of MSY
• Use highly adaptive approaches that involve some combination of tradeoff analysis and adaptive management, including in-season adjustments and simulation analysis to negotiate tradeoffs with stakeholders (de Moor, Butterworth & De Oliveira 2011),

• South Africa pelagic fishery (sardine and anchovy) – recognition that food requirements of predators such as African penguins need to be accounted for in the management process
Management Strategies for industry and conservation

• Harvest control rules need to account for both target species and dependent predator
• Link penguin population model with outputs of the operating models that underpin the testing of Management procedures for sardine and anchovy (de Moor and Butterworth, 2012)

Bayesian estimation fitting counts of moulting penguins and re-sightings of tagged penguins to estimate Robben Island penguin demographic parameters and link these to prey abundance data
MAIN FINDINGS NOT AS EXPECTED

• Model indicated a lack of impact of changes in anchovy abundance on penguin annual reproductive success

• Primary reason for the post-2003 penguin decline = increase in adult natural mortality

• Attributed to reduced abundance of sardine off the South African west coast

➢ Mainly a consequence of a recent east-ward shift in the sardine distribution

The impact of fishing on penguin numbers through the reduction in total sardine biomass by the fishery is rather small, especially when compared with other factors influencing the dynamics.

Compare distributions of 10-year projections of sardine

Using MSE to evaluate whether life history affects tradeoffs

M = 0.5  
Max age: 6 yrs

M = 1.05  
Max age: 6 yrs

M = 0.4  
Max age: 15 yrs

Other parameters that vary: maturity, fishery selectivity, weight at age
Life history affects tradeoffs

Base case: \( h = 0.6 \), autocorrelated observation error

*Siple, Essington & Plagányi in review*
Delayed detection of changes in biomass
Key Recommendations

• Harvest control rule performance depends on life history characteristics (e.g., maximum age; level of variability in productivity).
• Shorter-lived species at risk when consecutive low-productivity years > spawning age.
• Species with lower-frequency changes in recruitment (e.g., sardine) - benefits from lower biomass limits vs less precautionary rules ok for menhaden or anchovy.
• Performance of control rules for forage fish depends on ability of stock assessments to detect rapid changes in biomass hence survey uncertainty in balancing tradeoffs, especially for species with low-frequency variation in abundance.

Siple, Essington & Plagányi in review
Outline

• (a) highly variable stocks:
  • Torres Strait tropical rock lobster fishery
  • Bêche de mer fisheries
  • Northern Prawn Fishery
  • Forage fisheries

• (b) impacts and approaches for dealing with changing climate

• (c) ecosystem and socio-ecological interactions altering sustainable yield reference levels
Sea cucumber / bêche-de-mer
Testing alternative management strategies: resource impacted by fishing and climate

• **Fishery:** 8 bêche-de-mer species on 27 reef units (in 8 zones) in the Torres Strait, NE Australia, fished by indigenous fishers

• **Medium term:** 2011-2030

• **Attribution.** Climate change identifiable as separate from other impacts (fishery exploitation)

• **Model:** Spatial multi-species age-structured discrete model with stochastic recruitment

Dry sandfish >$200 kg

Plaganyi, Skewes et al. 2013. Climatic Change
MSE as a risk management tool

- Climate **risk assessment** used as an input to dynamic model
- **Reference Set** (rather than single model) used to capture key uncertainties
- Tested the **performance** (especially in the face of **uncertainty**) of alternative **harvest strategies** in meeting fishery objectives, such as ensuring:
  - low **risk** of depletion (overall and local)
  - **high probability** of good catch / average profits
  - low **risk** of changing the multi-species community composition
  - **high probability** of managing through climate variability and change
Results: local depletion per zone and species

Quantify risk (and associated uncertainty) to all 8 species in each of the 8 zones

DEPLETION (Bsp) RELATIVE TO NO FISHING & NO CLIMATE CHANGE

b) With high and medium risk impacts

i) H. scabra

ii) H. whitmaei

iii) A. Mauritiana

iv) H. fuscogilva

v) T. ananus

vi) A. echinites

vii) A. miliaris

viii) B. argus

Increased risk under climate change
## Performance Summary - Harvest Strategies

<table>
<thead>
<tr>
<th>Harvest strategy</th>
<th>Risk of suboptimal management</th>
<th>Risk of depletion below Blim</th>
<th>Risk of local depletion</th>
<th>Average annual profit (US$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Current catch (status quo)</strong></td>
<td>50</td>
<td>13</td>
<td>12</td>
<td>5.31</td>
</tr>
<tr>
<td><strong>B. No monitoring:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Double catches</td>
<td>75</td>
<td>25</td>
<td>23</td>
<td>10.6</td>
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<tr>
<td>Profit maximisation</td>
<td>50</td>
<td>13</td>
<td>12</td>
<td>5.31</td>
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<tr>
<td>Location choice based on area and distance</td>
<td>50</td>
<td>13</td>
<td>16</td>
<td>5.31</td>
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<td>Spatial rotation (3 yr)</td>
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<td>13</td>
<td>5</td>
<td>3.35</td>
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<td>Closed areas/sensitive species (Warrior, Sand)</td>
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<td>13</td>
<td>9</td>
<td>2.72</td>
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<td>Multi-species catch composition</td>
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<td>13</td>
<td>6</td>
<td>3.08</td>
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<td><strong>C. Adaptive feedback/monitoring:</strong></td>
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<tr>
<td>Hockey stick</td>
<td>38</td>
<td>13</td>
<td>9</td>
<td>3.65</td>
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<tr>
<td>Hockey stick with spatial management</td>
<td>13</td>
<td>13</td>
<td>1</td>
<td>5.31</td>
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<tr>
<td>Spatial closure (Single species in Zone) (30%K)</td>
<td>38</td>
<td>13</td>
<td>8</td>
<td>5.11</td>
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<td>Spatial closure (Entire Zone) (30%K trigger)</td>
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<td>13</td>
<td>5</td>
<td>3.19</td>
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<tr>
<td>Spatial closure (Entire Zone) (20%K trigger)</td>
<td>13</td>
<td>13</td>
<td>7</td>
<td>4.09</td>
</tr>
</tbody>
</table>

- Risk of sub-optimal management: the percentage of species for which the median 2030 spawning biomass level was less than Btarg (0.48K)
- Risk of depletion below Blim: percentage of species for which the lower 90% confidence limit of the 2030 RS projections was less than Blim
Key Recommendations

- Under a changing climate need to pre-test climate-smart strategies that account for multiple objectives & complexities e.g. sustainable catches & system resilience

- **Status quo** management would result in half the species falling below target levels, moderate risks of overall and local depletion, and significant changes in species composition

- The three non-monitoring based strategies successful in reducing risks, but decreases in average profit

- Higher profits (for the same risk levels) achieved with strategies that included monitoring and hence adaptive management

- **Spatial** management approaches based on adaptive feedback performed best overall
Outline

• (a) highly variable stocks:
  • Torres Strait tropical rock lobster fishery
  • Bêche de mer fisheries
  • Northern Prawn Fishery
  • Forage fisheries

• (b) impacts and approaches for dealing with changing climate

• (c) ecosystem and socio-ecological interactions altering sustainable yield reference levels
Including social objectives and drivers: Tropical Rock Lobster

**Panulirus ornatus**
Ornate rock lobster

Torres Straits Treaty: “...acknowledg[ing] and protect[ing] the traditional way of life and livelihood of the traditional inhabitants including their traditional fishing and free movement.”

http://www.tsirc.qld.gov.au/%3Cfront%3E/culture-cultural-protocols
Spatial Operating Model: Biological population model*

(*inputs: surveys, catch/effort data, life history data)

- employment
- new entrants
- spatial localised effects

Economic sub-models:
- Profit
- Supply chain

Socio-cultural
Equity
Consistent with custom
New entrants

Biological
Stock status
Localised depletion
Risk to resource

Economic
Profit by subsector
Employment
Value added

EXAMPLE PERFORMANCE INDICATORS
Building up the Bayesian network … drivers motivations of indigenous lobster fisher participation

Van Putten et al. 2012
Bayesian Network (BN) model: quantifying changes in participation to inform evaluation of alternative management strategies

- Considers the variability in participation of indigenous fishers under key economic and socio-cultural drivers.
- Changes in the provision of logistics, infrastructure, and building social capital (e.g., key leaders) and capacity (e.g., improving business knowledge) expected to have significant impact on the occurrence of full-time fishing.
- Study shows that capacity building programs are important drivers for participation.
- In model, allows one to quantify change in fisher participation based on economic and socio-cultural drivers (incl external drivers).
Key Points – triple bottom line considerations

• Complexity of trade-offs between social and economic considerations.

• Trade-offs between economic indicators such as profit and social indicators such as lifestyle preferences.

• Approach makes explicit the ‘triple bottom line’ sustainability objectives involving trade-offs between economic, social and biological performance.
MICE can variably focus on ecological, environmental and human components.

Define an integrated index that captures how the “quality” of an ecosystem is assessed by a user, and hence may result in feedback response in terms of future participation by user groups.
GULLS – evaluating alternative adaptation options

- Climate drivers: e.g. data inputs or biophysical models
- Species sensitivity analyses
- SYSTEM MODEL: e.g. MICE, Atlantis, EwE
- Socio-economic data
- ADAPTATION OPTION
- Supply chain connecting products to consumers
- Adaptive feedback
- Simulation testing
- Stakeholder review
- Adjust

Models of Intermediate Complexity for Ecosystem Assessments

Hobday et al (2016) RFBF
Key Recommendations

• **Heterogeneity** in sectors important – where, how, why people fish - understand the drivers and motivations, socio-cultural and economic importance of fishing

• Can use both **qualitative and quantitative** social information

• **Trade-offs** between social and economic considerations complex

• Ongoing work to incorporate dynamic feedbacks in social-ecological models that take into account hard-to-quantify aspects such as the combination of characteristics or activities that make a place or activity special - **Sense of Place Index (SOPI)**

• Need to account in MSE testing for the sometimes influential role of **non-static social and psychological drivers of changes** in participation in a fishery, in turn influencing fishing effort
Thank you

Oceans and Atmosphere
Dr Éva Pláganyi
Principal Research Scientist
Brisbane, Australia

t  +61 7 3833 5955
e  eva.plaganyi-lloyd@csiro.au
w  www.csiro.au

Acknowledgements
Roy Deng
Ingrid van Putten
Trevor Hutton
Mick Haywood
Nicole Murphy
Tim Skewes
Emma Lawrence
Sean Pascoe
Margaret Siple (UW)

Lenfest Forage Fish Task Force
Belmont forum GULLS team

Stakeholders

Funding
AFMA
CSIRO