EXTENDING THE CATCH-MSY APPROACH USING AUXILIARY DATA: WESTERN PACIFIC EXPERIENCE

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OUTLINE

• Background of the Western Pacific region
  • Fisheries
  • Data collection
  • Data limited situation

• Annual catch limit requirements
  • ABC control rules

• Shifting to model based approaches

• Biomass-augmented catch MSY approach

• Impact to regional fishery management
BACKGROUND OF THE WP REGION
Background of the WP region

- High species & fishery diversity
- Culturally important
- Low economic value
- Spatially variable
BACKGROUND OF THE WP REGION

- Commercial monthly fish report
- Aquarium Fish Report
- Aku Boat Trip Report
- Deep-sea Handline Trip Report
- Tuna Handline Trip Report
- Net, Trap, Dive Activity Report
- Bait Report
- Commercial Aquarium Marine Dealer Report
- Commercial non-Aquarium Marine Dealer Report
- Personal Aquarium Cash Sales Report
- Personal Sales Report

- Boat-based creel survey
- Shore-based creel survey
- Commercial Dealer reports
- Trans-shipment data
- Net-exemption data
- HMRFSS
Background of the WP region

- 1000+ species in the FEP = 115 ACLs
- 2 stock assessments
  - bottomfish
- Creative thinking
  - Quota to EFH proxies
- Uncertainties unquantifiable
ACL requirements – ABC Control Rules

**Tier 1 Stock**
Reliable estimates of OFL and uncertainty in OFL from statistically based stock assessments

**Tier 2 Stock**
OFL and uncertainty in OFL estimated from statistically based stock assessments, but are not considered reliable

**Tier 3 Stock**
OFL and uncertainty in OFL estimated from DCAC-SRA and through re-sampling and are not considered reliable

**Tier 4 Stock**
OFL and uncertainty in OFL are unknown; MSY is known but there is no current fishery for the stock

**Tier 5 Stock**
OFL and uncertainty in OFL are unknown; MSY is also unknown but there is catch data available for the stock

ABC = Pₚ*(OFL)

OFL = Bᵥ \left[\frac{F_{MSY}}{F_{MSY} + M}\right][1 - \exp(F_{MSY} + M)]

- OFL is estimated as
- Bᵥ is forecasted estimate of B in year y, the year for which the harvest limit is set;
- M is natural mortality coefficient;
- Pₚ is the P* **percentile of the probability distribution of OFL**;

- OFL is not necessarily normally distributed; and
- the shape and particularly the width of the distribution reflect the uncertainty in the estimate of OFL.

If median catch is > BMSY,
ABC = 1.0*median catch

If median catch is > MSST, but below BMSY,
ABC = 0.67* median catch

If median catch is < MSST (overfished),
ABC = 0.33* median catch

ABC = 0.70 F_{MSY} (91% of MSY)
Family | ACL (lbs)
--- | ---
Surgeons | 19,516
Snappers | 18,839
Groupers | 5,600
Mollusks | 16,694
Jacks | 9,460
Emperors | 7,350
Parrots | 8,145

**Annual Catch (lbs)**

- **Parrotfish Catch**: y = 0.7529x + 20.302, R² = 0.5695
- **Geometric Mean**: y = 0.0011x + 16.925, R² = 0.024

**Catch vs. Biomass**

- **Catch**: Graph showing the catch for 2009 and 2011.
- **Biomass**: Graph showing biomass for 2009 and 2011.

**Scaridae Boat Catch**

- Graph showing scaridae boat catches with linear regression equation and R² value.

**Scaridae Shore Catch**

- Graph showing scaridae shore catches with linear regression equation and R² value.
SHIFTING TO MODEL BASED APPROACHES

A simple method for estimating MSY from catch and resilience

Steven Martell¹ & Rainer Froese²

Estimating Surplus Production and Maximum Sustainable Yield from Biomass Data when Catch and Effort Time Series are not Available

S. GARCIA, P. SPARRE and J. CSIRKE

Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations

Alec D. MacCall

Depletion-Based Stock Reduction Analysis: A catch-based method for determining sustainable yields for data-poor fish stocks

E.J. Dick*, Alec D. MacCall
# Biomass-Augmented Catch-MSY

<table>
<thead>
<tr>
<th>Model</th>
<th>Catch history</th>
<th>Biomass</th>
<th>Est. M</th>
<th>R &amp; K</th>
<th>Estimate depletion</th>
<th>Result</th>
<th>Probability distribution</th>
<th>ABC C-R</th>
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<td>MSY</td>
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<td>Y</td>
<td>P*</td>
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<td>Sustain. yield</td>
<td>Y</td>
<td>P*</td>
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SHIFTING TO MODEL BASED APPROACHES

- Hardness
- Slope
- Complexity
- Depth

AREA & UNITS: RANDOM REA SURVEY

- RANDOMIZED HARD-BOTTOM LOCATION WITHIN 0-30 M DEPTHS
- PAIRED 15-M-DIAMETER CYLINDERS
- PHOTOGRAPHS OF BENTHOS TAKEN ALONG TRANSECTS
- STATIONARY-POINT-COUNT SURVEYS OF FISHES
### Shifting to Model Based Approaches

<table>
<thead>
<tr>
<th>Island</th>
<th>(n)</th>
<th>Area 0-30 m hardbottom (Ha)</th>
<th>Emperor</th>
<th>Goatfish</th>
<th>Grouper</th>
<th>Jack</th>
<th>Parrotfish¹</th>
<th>Reef Shark</th>
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<td>171</td>
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<th>Snapper</th>
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<th>Wrasse¹</th>
<th>Surgeonfish</th>
<th>Others</th>
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<td>45,721</td>
<td>98,025</td>
<td>807,079</td>
<td>859,116</td>
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</table>

**SOURCE:** Williams 2010. US Pacific reef fish biomass estimates based on visual survey data. PIFSC Internal Report IR-10-024
Biomass-augmented Catch-MSY

SOURCE: Martell and Froese 2012

Schaefer Model

\[ b_{t+1} = \left( b_t + rb_t \left(1 - \frac{b_t}{k}\right) - c_t \right) e^{x_t} \]

Biomass trajectories (green lines) depend on parameters

Task is to find workable combinations of \( r \) and \( k \) values which are chosen from reasonable priors and can accommodate the catch series while keeping biomass within set boundaries

These combinations give a list of possible MSY values from which we get a mean or median and distribution for MSY

Schaefer Model:

- \( b_t \) = biomass in year \( t \)
- \( b_0 \) = biomass at start
- \( c_t \) = catch in year \( t \)

\[ \text{MSY} = \frac{rk}{4} \]
Biomass-augmented Catch-MSY

1. Read input data:
   - catch series
   - biomass series with CVs
   - resilience
   - various ranges
   - parameters $\sigma$ and $\rho$

2. $\lambda = \text{biomass to } k \text{ ratio: } (\lambda_i = b_i / k)$
   - determine range of values for $\lambda_0$ and $\lambda_n$
   - define a $\lambda_0$ vector spread over $\lambda_0$ range

3. Chose 30000 $r_i$ from r-range
   Chose 30000 $k_i$ from k-range

4. Loop over $i$, ($r_i, k_i$ pairs)

5. Set $r_i, k_i$ pair to FAIL

6. Loop over $j$, ($\lambda$ vector)

7. Calc. $b_i$ from $r_i, k_i, b_0 = \lambda_j \times k_i, \sigma$

10. Reset $r, k$, pair to PASS

8. Any $b_i/k$ out of range?
    Yes
    Any $b_i$ out of range?
    Yes

9. Any $b_i$ out of range?
    Yes

12. 1st time?
    Yes

13. Refine $r$ & $k$ ranges
    Yes
    Refine $r$ & $k$ ranges
    No
    Exit

Calc. MSY vector from passing $r_i, k_i$ pairs

$Y_i = r_i \times k_i / 4$

New $r$-range = \{min($r^*$) $\cdots$ 1.2 x max($r^*$)\}

$x_a = \min[k^* | r^* < 1.1 \times \min(\text{first } r \text{ range})]$

$x_b = \max[k^*_i Y(r^*_i, k^*_i) < \exp(\log(Y^*))]$

New $k$-range = \{0.9 x min($k^*$) $\cdots$ min($x_a, x_b$)\}

Exit
BIOMASS-AUGMENTED CATCH-MSY

1. Read input data:
   - catch series
   - biomass series with CVs
   - resilience
   - various ranges
   - parameters $\sigma$ and $\rho$

2. $\lambda = \text{biomass to } k \text{ ratio: } (\lambda_t = b_t / k)$
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3. chose 30000 $r_i$ from r-range
   - chose 30000 $k_i$ from k-range

4. loop over $i$, $(r_i, k_i)$ pairs

5. set $r_i, k_i$ pair to FAIL

6. loop over $j$, (\lambda vector)

7. calc. $b_t$ from $r_i, k_i, b_0 = \lambda_i \times k_i$, $\sigma$

8. any $b_i/k$ out of range?

9. any $b_i$ out of range?

10. reset $r, k$ pair to PASS

11. calc. MSY vector from passing $r_i, k_i$ pairs

12. 1st time?

13. refine $r$ & $k$ ranges

   - yes
   - loop over $i$, $(r_i, k_i)$ pairs
   - set $r_i, k_i$ pair to FAIL
   - loop over $j$, (\lambda vector)
   - calc. $b_t$ from $r_i, k_i, b_0 = \lambda_i \times k_i$, $\sigma$
   - any $b_i/k$ out of range?
   - any $b_i$ out of range?

   - yes
   - reset $r, k$ pair to PASS
   - exit

   - no
   - $Y_i^* = r_i^* \times k_i^*/4$

   - new-$r$-range = $\{\min(r^*) \ldots 1.2 \times \max(r^*)\}$

   - $x_a = \min[k^* \mid r^* < 1.1 \times \min(\text{first } r \text{ range})]$

   - $x_b = \max[k_i^* \mid Y(r_i^*, k_i^*) < \exp(\log(Y^*))]$

   - new-$k$-range = $\{0.9 \times \min(k^*) \ldots \min(x_a, x_b)\}$

   - yes
   - $r^* = \text{all good } r$-values
   - $k^* = \text{all good } k$-values

   - loop over $i$, $(r_i, k_i)$ pairs
   - set $r_i, k_i$ pair to FAIL
   - loop over $j$, (\lambda vector)
   - calc. $b_t$ from $r_i, k_i, b_0 = \lambda_i \times k_i$, $\sigma$

   - any $b_i/k$ out of range?

   - any $b_i$ out of range?

   - yes
   - reset $r, k$ pair to PASS
   - exit

   - no
   - 13

13. exit
BIOMASS-AUGMENTED CATCH-MSY
Biomass-augmented Catch-MSY

Hawai’i, MSY distributions
BIOMASS-AUGMENTED CATCH-MSY

Hawaii
IMPLICATION TO FISHERY MANAGEMENT

- Based on the probability distribution around the mean MSY estimate
- Quantiles of the one tail distribution
- 5% increment
- P* analysis
### Implication to Fishery Management

<table>
<thead>
<tr>
<th>Tier 1 Stock</th>
<th>Tier 2 Stock</th>
<th>Tier 3 Stock</th>
<th>Tier 4 Stock</th>
<th>Tier 5 Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable estimates of OFL and uncertainty in OFL from statistically based stock assessments</td>
<td>OFL and uncertainty in OFL estimated from statistically based stock assessments, but are not considered reliable</td>
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</tr>
</tbody>
</table>

**ABC = PP*(OFL)**

- OFL is estimated as
- $B_y$ is forecasted estimate of $B$ in year $y$, the year for which the harvest limit is set;
- $M$ is natural mortality coefficient;
- $P_p$ is the $P^*$ percentile of the probability distribution of OFL;

- OFL is not necessarily normally distributed; and
- the shape and particularly the width of the distribution reflect the uncertainty in the estimate of OFL.

**OFL = $B_y \left[ \frac{F_{MSY}}{F_{MSY} + M} \right] [1 - \exp(F_{MSY} + M)]**

If median catch is $> BMSY$, **ABC = 1.0*median catch**

If median catch is $> MSST$, but below $BMSY$, **ABC = 0.67* median catch**

If median catch is $< MSST$ (overfished), **ABC = 0.33* median catch**
**Implication to Fishery Management**

- OFL can be identified (MSY as a proxy)
- Uncertainties can be quantified
- Risk can be determined
- \( P^* \) analysis dimensions
  - Model information
  - Uncertainty characterization
  - Stock status
  - Productivity-susceptibility
- Multi-year specification

\( P^* = 50\% \)
### Implication to fishery management

#### A. Group 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%

<table>
<thead>
<tr>
<th>Group</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
<th>35%</th>
<th>40%</th>
<th>45%</th>
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<td>819.6</td>
<td>843.1</td>
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<td>97.7</td>
<td>100.7</td>
</tr>
<tr>
<td>Other CREMUS</td>
<td>361.2</td>
<td>366.7</td>
<td>372.4</td>
<td>378.2</td>
<td>385.2</td>
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<td>398.1</td>
<td>403.4</td>
<td>409.4</td>
<td>419.5</td>
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<tr>
<td>Spiny lobster</td>
<td>114.8</td>
<td>122.5</td>
<td>127.8</td>
<td>131.7</td>
<td>135.3</td>
<td>139.0</td>
<td>142.4</td>
<td>145.9</td>
<td>149.0</td>
<td>152.3</td>
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<tr>
<td>CRE-crustaceans</td>
<td>23.8</td>
<td>26.30</td>
<td>28.2</td>
<td>29.9</td>
<td>31.5</td>
<td>32.9</td>
<td>34.3</td>
<td>35.5</td>
<td>36.8</td>
<td>38.0</td>
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</tbody>
</table>
Next Steps

- CIE review of the Biomass-augmented Catch-MSY method
- Develop a set of integrated extensions to the Catch-MSY method to better inform current estimates of depletion.
- Web-based interface for SSC and Council members to interact with [SHINY App].
- Training & application
MAHALO NUI

- Dr. Pierre Kleiber – WPFMC SSC member
- Dr. Steve Martell – IPHC
- Dr. Gerard DiNardo – NMFS-SWFSC

- American Samoa – Dept. Marine & Wildlife Resources
- Guam – Division of Aquatic & Wildlife Resources
- Hawaii – Division of Aquatic Resources
- CNMI – Division of Fish & Wildlife

- NOAA-Coral Reef Conservation Program
“Errors using inadequate data are much less than those using no data at all” --- Charles Babbage 1799-1871 – invented the first mechanical computer