Data Use in the Assessment of Main Hawaiian Islands Bottomfish

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Stock Assessment and Management Strategy Evaluation Process

- **Abundance**
  - Resource Survey,
  - Fishery CPUE,
  - Age/Size Data

- **Biology**
  - Age,
  - Growth,
  - Maturity

- **Catch**
  - Logbooks,
  - Observers,
  - Age/Size Data

- **Advanced Model**
  - Habitat,
  - Climate,
  - Ecosystem

- **Socioeconomics**

- **Optimum Yield**

- **Population Model**

- **Stock Status**

- **Mgt. Strategy Evaluation**
Deep 7 bottomfish species are:
(1) Opakapaka (*Pristipomoides filamentosus*);
(2) Kalekale (*Pristipomoides sieboldii*);
(3) Lehi (*Aphareus rutilans*);
(4) Gindai (*Pristipomoides zonatus*);
(5) Onaga (*Etelis coruscans*);
(6) Ehu (*Etelis carbunculus*);
(7) Hapuupuu (*Epinephelus quernus*).
## Hawaii Federal Bottomfish Fishery
Bottomfish Management Unit Species (BMUS)

### Snappers -- Family Lutjanidae

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onaga</td>
<td><em>Etelis coruscans</em></td>
</tr>
<tr>
<td>Ehu</td>
<td><em>Etelis carbunculus</em></td>
</tr>
<tr>
<td>Opakapaka</td>
<td><em>Pristipomoides filamentosus</em></td>
</tr>
<tr>
<td>Kale kale</td>
<td><em>Pristipomoides sieboldii</em></td>
</tr>
<tr>
<td>Lehi</td>
<td><em>Aphareus rutilans</em></td>
</tr>
<tr>
<td>Gindai</td>
<td><em>Pristipomoides zonatus</em></td>
</tr>
<tr>
<td>Taape</td>
<td><em>Lutjanus kasmira</em></td>
</tr>
<tr>
<td>Uku</td>
<td><em>Aprion virescens</em></td>
</tr>
<tr>
<td>Yellowtail kale</td>
<td><em>Pristipomoides auricilla</em></td>
</tr>
</tbody>
</table>
MPAs: Bottomfish Restricted Fishing Areas in State of Hawaii Waters

The 12 Revised BRFAs Include:
12% of Bottomfish Habitat Depth Range (50-200 fm) in the MHI
20% of Potentially Important Habitat Areas (PIHAs)

Legend

- BRFAs as Revised After Public Input (lettered in purple)
- Kaho‘olawe Island Reserve (closed, although not a BRFAs)
- Commercial Fish Catch Reporting Areas

* BRFAs were relettered following changes in response to public input. Please refer to the new BRFA letters after May 2006.
Deep Handline Gear
Reported Hawaii Bottomfish Catch Used in the 2010 Assessment

Bottomfish reported catch (thousand pounds)

Deep7 bottomfish
Primary bottomfish

Fishing Year

0.0 0.2 0.4 0.6 0.8 1.0 1.2
Reported Catch of Deep7 Hawaii Bottomfish

Reported Catch of Deep7 Hawaii Bottomfish by Fishing Year
For All Catch Scenarios, 1949-2010
Estimates of Unreported to Reported Catch Ratios of Deep7 Hawaii Bottomfish by Fishing Year Under Baseline Catch Scenario II, 1949-2010

- **Fishing Year**
  - 1950
  - 1960
  - 1970
  - 1980
  - 1990
  - 2000
  - 2010

- **Unreported to reported catch ratio**
  - 0.0
  - 0.5
  - 1.0
  - 1.5
  - 2.0
  - 2.5
  - 3.0

- **Species**
  - Hapuupuu
  - Kalekale
  - Opakapaka
  - Ehu
  - Onaga
  - Lehi
  - Gindai
Species Composition by Decade

Archipelagic bottomfish catch composition by species group and decade

![Graph showing species composition by decade for Archipelagic bottomfish catch.]
Baseline Catch Scenario (Catch Scenario II) and Alternative Unreported Catch Scenarios I and III

Estimates of Unreported Catch of Deep7 Hawaii Bottomfish by Fishing Year and Catch Scenario, 1949-2010
MHI CPUE Standardization: Data

• Hawaii State (HDAR) logbook data, 1949-2010
  - All Deep7 bottomfish catch reports in Main Hawaiian Islands

• Fishing year for commercial license period used
  - Example: Fishing Year 1949 is 7/1/48 to 6/30/49
  - Corresponds to Hawaii commercial license period
  - Matches seasonal pattern of biology and fishery

• Bottomfish single-day trips used in analysis
  - Deep handline gear (> 90% Deep7 catch)
  - At least 17% Deep7 bottomfish by weight
  - Up to 1500 pounds of bottomfish per day
MHI CPUE Standardization: Model

• What predictors are available to standardize CPUE during 1949-2007?
  – Fishing year (Relative abundance trend)
  – Month (Seasonal effect)
  – Reported fishing area (Spatial effect)

• Treatment of fishing areas for standardization
  – If area accounts for ≥1% of bottomfish catch by weight, then treat area as single unit
  – If area accounts for <1% of bottomfish catch, then use in aggregate area unit for Island region
HDAR fishing areas used as factors in GLM
Number of Bottomfish Fishing Trips by Year

- Number of Fishing Trips: 0, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000

Taken from 2008 assessment update
Number of Bottomfish Fishing Trips with Non-Bottomfish Catch by Year

Taken from 2008 assessment update
Ratio of bottomfish catch to total of all species catch for deep handline gear trips in the MHI
Bottomfish CPUE adjustment coefficients used to account for putative increases in fishing technology in the directed deep handline fishery during 1949-2007 taken from the 2005 stock assessment (Moffitt et al. 2006).

\[ \text{CPUE}_T = q \cdot C_T \cdot B_T \]

Fishing Year

<table>
<thead>
<tr>
<th>Fishing Year</th>
<th>Catchability Coefficient Multipliers (CT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>0.8</td>
</tr>
<tr>
<td>1960</td>
<td>1.0</td>
</tr>
<tr>
<td>1970</td>
<td>1.2</td>
</tr>
<tr>
<td>1980</td>
<td>1.4</td>
</tr>
<tr>
<td>1990</td>
<td>1.6</td>
</tr>
<tr>
<td>2000</td>
<td>1.8</td>
</tr>
<tr>
<td>2010</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Average Increase in Fishing Power of 1.2%/yr
Bottomfish CPUE adjustment coefficients to account for possible increases in Hawaiian bottomfish fishing technology during 1949-2007 (Scenario III) similar to those used in the 2005 stock assessment (Moffitt et al. 2006). The assumption that changes in fishing power were negligible (Scenario I) was the baseline CPUE Scenario used to model the relative abundance of Deep7 bottomfish in the current assessment.
Model selection analysis to choose the structure of the generalized linear model (GLM) to standardize Deep7 bottomfish CPUE among 16 alternative models using Akaike’s information criterion (AIC).

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Structure of CPUE Predictor</th>
<th>R-square</th>
<th>Number of Data Points</th>
<th>Mean Square Error</th>
<th>Number of Parameters</th>
<th>AIC Value</th>
<th>ΔAIC</th>
<th>Model Relative Likelihood</th>
<th>Model Probability</th>
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<tbody>
<tr>
<td>Std1</td>
<td>Y+A+M</td>
<td>0.234</td>
<td>150535</td>
<td>1.161</td>
<td>152</td>
<td>22750.2</td>
<td>284.0</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std2</td>
<td>Y+A+M+A*M</td>
<td>0.248</td>
<td>150535</td>
<td>1.149</td>
<td>1039</td>
<td>22959.9</td>
<td>493.8</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std3</td>
<td>Y+M+M</td>
<td>0.146</td>
<td>150535</td>
<td>1.294</td>
<td>74</td>
<td>23800.1</td>
<td>16433.9</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std4</td>
<td>Y+A+Q</td>
<td>0.233</td>
<td>150535</td>
<td>1.162</td>
<td>144</td>
<td>22876.8</td>
<td>410.6</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std5</td>
<td>Y+M+Q</td>
<td>0.145</td>
<td>150535</td>
<td>1.295</td>
<td>66</td>
<td>39023.7</td>
<td>16557.5</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std6</td>
<td>Y+A+Q+A*M</td>
<td>0.239</td>
<td>150535</td>
<td>1.155</td>
<td>387</td>
<td>22466.1</td>
<td>0.0</td>
<td>1.000</td>
<td>1.000</td>
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<tr>
<td>Std7</td>
<td>Y+M+Q+I*M</td>
<td>0.147</td>
<td>150535</td>
<td>1.291</td>
<td>75</td>
<td>38599.2</td>
<td>16133.1</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std8</td>
<td>Y+A+M+Y*A</td>
<td>-</td>
<td>150535</td>
<td>-</td>
<td>4930</td>
<td>— Did not converge --</td>
<td>-</td>
<td></td>
<td></td>
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<tr>
<td>Std9</td>
<td>Y+M+M+Y*I</td>
<td>0.166</td>
<td>150535</td>
<td>1.264</td>
<td>251</td>
<td>35817.2</td>
<td>13351.0</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std10</td>
<td>Y+A+Q+Y*I</td>
<td>0.237</td>
<td>150535</td>
<td>1.157</td>
<td>317</td>
<td>22599.6</td>
<td>133.5</td>
<td>0.000</td>
<td>0.000</td>
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<td>Std11</td>
<td>Y+A+M+Y*M</td>
<td>0.243</td>
<td>150535</td>
<td>1.152</td>
<td>783</td>
<td>22827.4</td>
<td>361.3</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Std12</td>
<td>Y+M+M+Y*I</td>
<td>0.149</td>
<td>150535</td>
<td>1.289</td>
<td>107</td>
<td>38406.5</td>
<td>15940.3</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Std13</td>
<td>Y+M+M+Y*M</td>
<td>0.156</td>
<td>150535</td>
<td>1.283</td>
<td>705</td>
<td>38864.8</td>
<td>16398.7</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Std14</td>
<td>Y+A+Q+Y*A</td>
<td>-</td>
<td>150535</td>
<td>-</td>
<td>4922</td>
<td>— Did not converge --</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std15</td>
<td>Y+M+Q+Y*I</td>
<td>0.165</td>
<td>150535</td>
<td>1.266</td>
<td>243</td>
<td>35944.0</td>
<td>13477.8</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Std16</td>
<td>Y+M+Q+Y*M</td>
<td>0.150</td>
<td>150535</td>
<td>1.289</td>
<td>239</td>
<td>38682.1</td>
<td>16216.0</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Results: Significant spatial patterns in CPUE

Area Coefficients Relative to Standard Fishing Area 331 in the Main Hawaiian Islands

Area Coefficient Relative to Area 331 = 1

- 0.105-0.3864
- 0.3964-0.526
- 0.536-0.7748
- 0.7848-1.2672
- 1.2772-2.636
Comparison of Time Series of Estimated Year Coefficients From CPUE Standardization Models For Deep7 Bottomfish in the Main Hawaiian Islands With and Without Area by Quarter Interactions
Comparison of Nominal and Standardized CPUE of Deep7 Bottomfish Caught with Handline Gear in the Main Hawaiian Islands by Fishing Year, 1949-2010

Fishing Year


Nominal Deep7 Bottomfish CPUE (lbs/trip)

Standardized Deep7 Bottomfish CPUE (lbs/trip)

Nominal CPUE

Standardized CPUE
Baseline Relative Abundance Index (CPUE Scenario I) and Alternative Fishing Power Scenarios

Standardized CPUE of Deep7 Bottomfish in the Main Hawaiian Islands by fishing year and CPUE Scenario, 1949-2010

<table>
<thead>
<tr>
<th>Fishing Year</th>
<th>Scenario I</th>
<th>Scenario II</th>
<th>Scenario III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>1960</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>1970</td>
<td>250</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>1980</td>
<td>300</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>1990</td>
<td>350</td>
<td>400</td>
<td>450</td>
</tr>
<tr>
<td>2000</td>
<td>400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>450</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Catch and CPUE Scenarios for Baseline Model and Sensitivity Analyses

<table>
<thead>
<tr>
<th>Catch Scenarios</th>
<th>Catch and CPUE Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch Scenario I (S1)</td>
<td>S1 and C1</td>
</tr>
<tr>
<td>Catch Scenario II (S2)</td>
<td>S2 and C1</td>
</tr>
<tr>
<td>Catch Scenario III (S3)</td>
<td>S3 and C1</td>
</tr>
<tr>
<td>Catch Scenario IV (S4)</td>
<td>S4 and C1</td>
</tr>
<tr>
<td>CPUE Scenarios</td>
<td>CPUE Scenario I (C1)</td>
</tr>
<tr>
<td>Catch Scenarios</td>
<td>Catch and CPUE Scenarios</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Catch Scenario I</td>
<td>Catch Scenario I and CPUE Scenario I</td>
</tr>
<tr>
<td>Catch Scenario II</td>
<td>Catch Scenario II and CPUE Scenario I</td>
</tr>
<tr>
<td>Catch Scenario III</td>
<td>Catch Scenario III and CPUE Scenario I</td>
</tr>
<tr>
<td>Catch Scenario IV</td>
<td>Catch Scenario IV and CPUE Scenario I</td>
</tr>
</tbody>
</table>

| CPUE Scenarios | CPUE Scenario I | CPUE Scenario II | CPUE Scenario III |
## Multispecies Fishery-Independent Survey for MHI

<table>
<thead>
<tr>
<th>Gear</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Fish Trap        | --Relatively inexpensive  
                  --Can use smaller vessels  
                  --Wide range of bottom types  
                  --Species composition and size composition data | --Size selectivity  
                  --Species selectivity interactions  
                  --Requires consistent & effective bait  
                  --Limited utility for pelagic habitats  
                  --Movement required |
| Camera devices   | --Relatively expensive  
                  --Can use smaller vessels  
                  --Wide range of bottom types  
                  --Samples benthic zone  
                  --Species composition and some size composition data | --Size limitations based on mesh selectivity  
                  --Domain of influence difficult to specify  
                  --Day vs night visibility, also turbidity differences  
                  --Species ID via video  
                  --Interpretation of species counts on video  
                  --Movement required |
| Bottom Longline  | --Effective for bottomfish  
                  --Relatively inexpensive  
                  --Can use smaller vessels  
                  --Wide range of habitats  
                  --Species composition and size composition data | --Movement required  
                  --Requires consistent & effective bait  
                  --Gear saturation  
                  --Potential depredation of hooked fish  
                  --Loss of bait reduces effective sampling time |
Recently discovered photograph of Moses with the original commandments

“Truth is so large a target that nobody can wholly miss hitting it, but at the same time, nobody can hit all of it with one throw.”
~ Aristotle

Fishery-Independent Surveys: Why Sampling Is So Difficult

Randomize, stratify, replicate
Beware of inappropriate application of probability levels
Use sampling gear with consistent deployment and easy maintenance
Bottomfish Production Model: Input Data

• Catch Data - All BMUS Reported Commercial and Estimated Unreported Catch, Excluding Taape and Kahala, by Fishing Year
  - Main Hawaiian Islands, 1949-2007
  - Mau and Hoomalu Zones, 1988-2007

• CPUE Data - Standardized CPUE for MHI from GLM by Fishing Year
  - Main Hawaiian Islands, 1949-2007
  - Mau and Hoomalu Zones, 1988-2007
Bottomfish production model

\[ B_{T+1} = B_T + R \cdot B_T \left( 1 - \left( \frac{B_T}{K} \right)^M \right) - C_T \]

- \( B_T \) is Deep7 bottomfish biomass in year \( T \)
- \( C_T \) is Deep7 catch biomass in year \( T \)
- \( R \) is the intrinsic growth rate
- \( K \) is the carrying capacity
- \( M \) is the biomass production shape parameter
Bottomfish Production Model

Net Biomass Production

MSY = $H_{MSY} \cdot B_{MSY}$

Relative biomass = $B_T / B_{MSY}$

Relative harvest rate = $H_T / H_{MSY}$

Biomass ($B_t$)

B$_{MSY}$

K

0
Variation in growth curves showing estimates of expected size at age of the primary Deep7 bottomfish opakapaka (*Pristipomoides filamentosus*) in the Hawaiian Archipelago

Hawaiian Archipelago

$L_\infty = 667 - 971$ mm FL

$k = 0.146 - 0.534$ yr$^{-1}$

(Daily, LFA, OTC, Tag-recapture)
Updated estimates of growth curves and expected size at age of opakapaka (*Pristipomoides filamentosus*) from lead-radium and bomb radiocarbon ageing
Choosing a prior for the intrinsic growth rate of the Deep7 complex using the approach described in Musick (1999) ~ Conclude that Deep7 complex has low productivity with R bounded by 0.05 and 0.15 and central tendency of R=0.1

<table>
<thead>
<tr>
<th>Deep 7 Species</th>
<th>Productivity Category</th>
<th>Intrinsic Growth Rate $r$ (y$^{-1}$)</th>
<th>von Bertalanffy $K$ (y$^{-1}$)</th>
<th>Fecundity (y$^{-1}$)</th>
<th>Age at Maturity $T_{MAT}$ (y)</th>
<th>Expected Life Span $T_{MAX}$ (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hapuupuu (Epinephelus quernus)</td>
<td>Low</td>
<td>-</td>
<td>0.16-0.23</td>
<td>-</td>
<td>&gt;7 y</td>
<td>11 y</td>
</tr>
<tr>
<td>Kalekale (Pristipomoides seiboldii)</td>
<td>Medium</td>
<td>-</td>
<td>0.12-0.33</td>
<td>-</td>
<td>-</td>
<td>7 y (Medium)</td>
</tr>
<tr>
<td>Opakapaka (Pristipomoides filamentosus)</td>
<td>Low</td>
<td>-</td>
<td>0.15-0.25</td>
<td>$\geq10^5$</td>
<td>3.5 y</td>
<td>$\sim40$ y (Low)</td>
</tr>
<tr>
<td>Ehu (Etelis carbunculus)</td>
<td>Low</td>
<td>-</td>
<td>0.06-0.19</td>
<td>$\geq10^5$</td>
<td>-</td>
<td>13 y (Low)</td>
</tr>
<tr>
<td>Onaga (Etelis coruscans)</td>
<td>Low</td>
<td>-</td>
<td>0.11-0.27</td>
<td>-</td>
<td>-</td>
<td>13 y (Low)</td>
</tr>
<tr>
<td>Lehi (Aphareus rutilans)</td>
<td>Medium</td>
<td>-</td>
<td>0.16</td>
<td>-</td>
<td>-</td>
<td>8 y (Medium)</td>
</tr>
<tr>
<td>Gindai (Pristipomoides zonatus)</td>
<td>Medium</td>
<td>-</td>
<td>0.23</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Choosing the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the Main Hawaiian Islands in 1949 under the baseline catch Scenario II and CPUE Scenario I.
Choosing the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the Main Hawaiian Islands in 1949 under the baseline catch Scenario II and CPUE Scenario I.

Posterior mean estimate $P^*$ of initial MHI proportion of carrying capacity in 1949 as a function of the prior mean for the initial proportion of carrying capacity in the Main Hawaiian Islands under catch Scenario II.

$P^* = 0.53$ at Lowest RMSE
Results of the catch Scenario II CPUE Scenario I production model fit to the observed standardized Deep7 bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

Observed standardized CPUE Scenario I of Deep7 bottomfish versus predicted CPUE by fishing year, 1949-2010, under Catch Scenario II.
Standardized log-scale residuals of the production model fit to standardized CPUE Scenario I by fishing year, 1949-2010, under Catch Scenario II.

Trend: No, $P=0.08$

Normality: No, $P=0.03$

Constant variance: Yes, $P=0.35$
Estimates of exploitable biomass of Deep7 Hawaii bottomfish under catch Scenario II and CPUE Scenario I by fishing year, 1949-2010.
Estimates of exploitation rate of Deep7 Hawaii bottomfish under catch Scenario II and CPUE Scenario I by fishing year, 1949-2010.
Overfishing status of Deep7 Hawaii bottomfish under the baseline model in 2010

Baseline Catch Scenario II and CPUE Scenario I: Distributions of Estimates of Harvest Rate in 2010 and Overfishing Limit for Deep7 Hawaii Bottomfish
Biomass depletion status of Deep7 Hawaii bottomfish under the baseline model in 2010

Baseline Catch Scenario II and CPUE Scenario I: Distributions of Estimates of Exploitable Biomass in 2010 and Overfished Limit for Deep7 Hawaii Bottomfish
A Total Annual Catch Limit Example:
Choose Probability of Overfishing $P^* = 0.25$

Odds of overfishing $= \frac{P^*}{1 - P^*} = 1:3$

$F_{P^*} = -\log\left(1 - \frac{C_{P^*}}{B}\right)$
Projection results for estimates of total allowable commerical catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for probabilities $P^*$ of overfishing in under baseline catch Scenario II and CPUE Scenario I.
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
<td>0</td>
<td>1.05</td>
<td>0.92</td>
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<tr>
<td>0.05</td>
<td>147</td>
<td>0.02</td>
<td>1.03</td>
<td>0.91</td>
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<tr>
<td>0.10</td>
<td>197</td>
<td>0.09</td>
<td>1.02</td>
<td>0.90</td>
</tr>
<tr>
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<td>0.99</td>
<td>0.87</td>
</tr>
<tr>
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<td>0.87</td>
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<td>0.97</td>
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</tbody>
</table>
Decision table showing consequences of setting TACs for Deep7 bottomfish (1000 pounds) to produce a low probability of overfishing of $P^* = 0.25$ in fishing year 2012 under CPUE Scenarios I, II, and III versus the true state of nature

<table>
<thead>
<tr>
<th>True State of Nature</th>
<th>Catch II CPUE I</th>
<th>Catch II CPUE II</th>
<th>Catch II CPUE III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catch and CPUE Scenario Used to Set TAC</strong></td>
<td><strong>Pr(H_{2012}&gt;H_{MSY})</strong></td>
<td><strong>Pr(H_{2013}&gt;H_{MSY})</strong></td>
<td><strong>B_{2013}/B_{MSY}</strong></td>
</tr>
<tr>
<td><strong>Catch II CPUE I</strong></td>
<td>0.25</td>
<td>0.24</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>TAC = 277</strong></td>
<td><strong>Pr(H_{2012}&gt;H_{MSY})</strong> = 0.25</td>
<td><strong>Pr(H_{2013}&gt;H_{MSY})</strong> = 0.24</td>
<td><strong>B_{2013}/B_{MSY}</strong> = 1.00</td>
</tr>
<tr>
<td><strong>Catch II CPUE II</strong></td>
<td>0.19</td>
<td>0.18</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>TAC = 249</strong></td>
<td><strong>Pr(H_{2012}&gt;H_{MSY})</strong> = 0.19</td>
<td><strong>Pr(H_{2013}&gt;H_{MSY})</strong> = 0.18</td>
<td><strong>B_{2013}/B_{MSY}</strong> = 1.00</td>
</tr>
<tr>
<td><strong>Catch II CPUE III</strong></td>
<td>0.06</td>
<td>0.06</td>
<td>1.01</td>
</tr>
<tr>
<td><strong>TAC = 163</strong></td>
<td><strong>Pr(H_{2012}&gt;H_{MSY})</strong> = 0.06</td>
<td><strong>Pr(H_{2013}&gt;H_{MSY})</strong> = 0.06</td>
<td><strong>B_{2013}/B_{MSY}</strong> = 1.01</td>
</tr>
</tbody>
</table>
Multivariate Benefit Streams for Forecasts: Hawaii Bottomfish

**Status: Probability of Overfishing**
- Probability of Overfishing in 2012
- Deep7 Bottomfish Commercial TAC (000 lbs) in 2012

**Yield: Average Catch & Variability**
- Deep7 Bottomfish Total Commercial and Unreported Catch (000 lbs) in 2012
- Catch Weight
- 95% CI

**Supply: Exploitable Biomass & Variability**
- Deep7 Exploitable Biomass (1000 lbs) in 2013
- Average Biomass
- 95% CI
- BMSY
- BMSST

**Efficiency: Average CPUE & Variability**
- Projected Deep7 Bottomfish CPUE (lbs/trip) in 2013
- Average CPUE
- 95% CI

**Multivariate Benefit Streams for Forecasts: Hawaii Bottomfish**
Insular Bottomfish Resources: Data Summary

• Stock Structure ~ More research needed, ongoing Pacific Islands Fisheries Group tagging

• Relative Abundance ~ Fishery-independent survey needed, gear calibration studies ongoing

• Fishery Catch ~ Sampling unreported recreational catch, preparation of Waialua Boat Club survey

• Life History & Biology ~ Some ongoing studies but many gaps exist and more studies are needed

• Stock Assessment ~ More abundance, biology, and catch sampling would improve the information and databases needed for status determination and ACL projections

"Data, data, data … I can not make bricks without clay."

~ Sherlock Holmes, The Adventure of the Copper Beeches
Thank you ~ Mahalo!