PFMC Control Rule

Exploitation rate vs relative spawning biomass

40% threshold

25% Overfished threshold

Below 25% overfished threshold exploitation rate is set by species rebuilding plan
Sardine Fishery Simulation Results: Average biomass vs average catch for 13 proposed management policies, 240 exploitation rates (0.0025-0.6) and 9260 policies with a wide range of cutoffs (0-1000 TMT), constant fractions (0.05-1.0) and maxcats (50-1000 TMT).

Catch: Biomass Plot

- Maximum Catch (MC)
- Option L
- MSY
- Option A
- Fisher’s Status Quo
- Option J
- Sci. Preferred

Average Catch (TMT)

Average Midyear Biomass (TMT)

maxcat = 100 TMT
Exploitation Rate with Groundfish and CPS Control Rules

- **Groundfish Control Rule**
- **CPS Control Rule**
Sardine Exploitation Simulation Run

Sardine 1000 year simulations with exploitation rates from 0.0025 to 0.6
(no cutoff or maxcat)

MSY = 179,900 MT
E = 0.1175
Biomass of 1,408,000 MT
E vs Biomass Loss

A sardine in the catch is worth N sardines in the sea.

222 MT at E = 0.115
29 MT at E = 0.10
15 MT at E = 0.0825
10 MT at E = 0.065
Catch increase vs Biomass decline

A bird in the hand is worth two in the bush.
A sardine in the catch is worth N in the sea.

222 MT at 180 TMT

The set-aside for forage by higher trophic level species was determined by calculation of the decline in average biomass resulting from a MT increase in average catch. This was based on the general rule that a fish needs 10 gms of food to add 1 gm in weight.

This occurs when the average catch reaches about 147 TMT in the exploitation simulations under constant exploitation rates (i.e. the red circles in the previous figure).
## COMPARISON OF MANAGEMENT OPTIONS

<table>
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<tr>
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<th>150</th>
<th>500</th>
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<tbody>
<tr>
<td><strong>CUTOFF</strong></td>
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<tr>
<td><strong>FRACTION</strong></td>
<td>0.1</td>
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<td>SST</td>
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<td><strong>MAXCAT</strong></td>
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<td><strong>AVE. CATCH</strong></td>
<td>177</td>
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<td>145</td>
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<td><strong>AVE. BIOMASS</strong></td>
<td>1,427</td>
<td>1,622</td>
<td>1,712</td>
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Units TMT
## Sardine Management Options

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<tr>
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<th>Max. Catch</th>
<th>Stochastic MSY</th>
<th>Fishermen’s Preferred</th>
<th>Science team Preferred</th>
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<tr>
<td>Maxcat</td>
<td>1000</td>
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<td>Fraction</td>
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<td>0.12</td>
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<td>0.05-0.15</td>
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<td>Cutoff</td>
<td>1000</td>
<td>0</td>
<td>50</td>
<td>150</td>
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<tr>
<td>Ave. catch</td>
<td>208</td>
<td>180</td>
<td>151</td>
<td>145</td>
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<tr>
<td>Median catch</td>
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<td>128</td>
<td>104</td>
<td>182</td>
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<tr>
<td>SD Catch</td>
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<td>180</td>
<td>137</td>
<td>67</td>
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<tr>
<td>Ave. Biomass</td>
<td>981</td>
<td>1,408 *</td>
<td>725</td>
<td>1,951 *</td>
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<tr>
<td>Ave. Depletion</td>
<td>32%</td>
<td>46%</td>
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<td>% No catch</td>
<td>47%</td>
<td>0%</td>
<td>5%</td>
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<td>% Years Bio.</td>
<td>94%</td>
<td>84%</td>
<td>39%</td>
<td>96%</td>
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<td>&gt; 0.4 MMT</td>
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<td>(Ave. Biomass unfished 3,050)</td>
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</tbody>
</table>
Sardine forage by age from 1 MMTs (age 1+)
March (1) cohort with warm and cold simulations
O.76 MMT forage with warm SST and 1 MMT age 1+ biomass

(25% eggs and first 2 weeks: 22% other YOY: 53% age 1+)
Lifetime biomass levels of the first March cohorts in the 10th years of simulations with warm and cold SST, January biomass = 1 MMT

Accumulative total biomass over life of cohort
- Warm SST = 17.5 MMT
- Cold SST = 3.5 MMT

Annual biomass increase
- + 39%
- - 5%

Egg Biomass
- 39,327 MT Cold SST
- 32,640 MT Warm SST

Oil Content
- 20%
- 13%