1st WORKSHOP ON CONNECTING THE IOTC SCIENCE AND MANAGEMENT PROCESSES (SMWS01)

Data poor approaches

INDIAN OCEAN TUNA COMMISSION
Secretariat

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Catch-only methods:
a brief review and new developments

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Why catch-only methods

- Majority of stocks (> 80% of global catch) have no formal stock assessment.
- Classical assessment requires various data.
- Most fisheries have catch data.
- Most fisheries have catch data only.
- Catch data are easier to collect than other types of data.
- Until now it has been impossible to use catch data alone for sound fisheries management.

Existing catch-only methods

- Depletion-corrected average catch (DCAC)
- Depletion-Based Stock Reduction Analysis (DB-SRA)
- Stock Synthesis using only a time series of catches (SS-CO)
- Stochastic stock reduction analysis
- Catch-MSY
- Catch-based method for classifying stock status
- Feasible stock trajectories

Additional methods

- XDB-SRA—Depletion-Based Stock Reduction Analysis extended using survey index data.
- SS-CL—Simple implementation of the Stock Synthesis platform that uses catch and a time series of length composition data.
- SS-CI—Simple implementation of the Stock Synthesis platform that uses catch and a time series of survey indices.

Some references

- Bentley, N. and Langley, A.D. 2012. Feasible stock trajectories: a flexible and efficient sequential estimator for use in fisheries management procedures. Canadian Journal of Fisheries and Aquatic Sciences 69: 161-177.
- Dick, E.J., and MacCall, A.D. 2011. Depletion-Based Stock Reduction Analysis: A catch-based method for determining sustainable yields for data-poor fish stocks. Fisheries Research 110: 331-341.
- MacCall, A.D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. ICES Journal of Marine Science 66: 2267–2271.
- Martell, S., and Froese Rainer. 2013. A simple method for estimating MSY from catch andresilience. Fish and Fisheries.
- Walters, C.J., Martell, S.J.D., Korman, J., 2006. A stochastic approach to stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences 63: 212–223.
- Wetzel, C.R. and Punt, A.E. 2011. Model performance for the determination of appropriate harvest levels in the case of data-poor stocks. Fisheries Research 110: 342–355.
- NMFS. 2011 (May). Calculating acceptable biological catch for stocks that have reliable catch data only (only reliable catch stocks – ORCS).
- NMFS. 2011 (June). Assessment Methods for Data-Poor Stocks Report of the Review Panel Meeting.
- Numerous papers on classifying global stock status

NMFS assessments

1. What are the data requirements of the method?
2. What are the conditions under which the method is applicable?
3. What are the assumptions of the method?
4. Is the method correct from a technical perspective?
5. How robust are model results to departures from model assumptions and atypical data inputs?
6. Does the model provide estimates of uncertainty? How comprehensive are those estimates?
7. What level of review is appropriate for assessments conducted using the method?

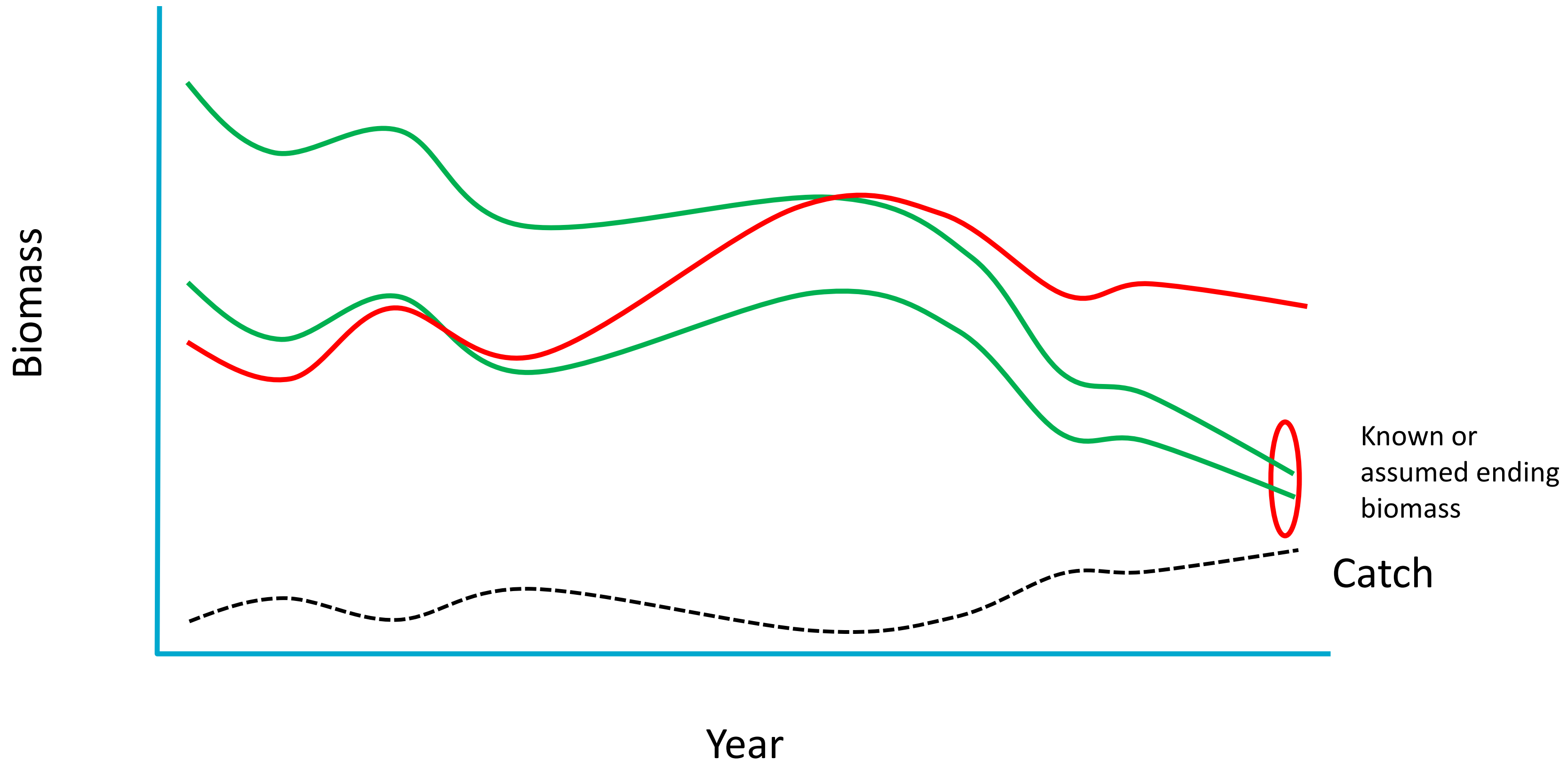
Data requirement for existing methods

- Time series of catch over a reasonably extended period (>10 years).
- Priors:
  - natural mortality M
  - F_{MSY}/M
  - B_{MSY}/B_0
  - steepness h
  - depletion level D (= B_{cur}/K),
  - age-at-maturity T_{mat}
  - growth rate r
  - carrying capacity K.

General procedure for stochastic stock reduction analysis

1. Specify priors (including depletion level) and a population model.
2. Randomly drawn initial biomass in year 1 from assumed distribution and range.
3. Draw a parameter set from the prior distributions (r, K, M, F_{msy}/M, B_{msy}/B_0, etc).
4. Apply all these values into a population model and subtract the know annual catch.
5. If the biomass trajectory ends within specified range of the depletion level, keep the iteration and all the parameters. Otherwise, discard the iteration.
6. Repeat these steps many times.
7. Use the retained iterations for parameter inference.

Stochastic stock reduction



General comments for existing methods

- Priors, particularly the assumed depletion level, can have substantial effect on the results.
- Requires more than catch data. Prior information may be difficult to get.
- Additional quantities (e.g., ending biomass, depletion level etc.) are assumed, not estimated from the method itself.
- Low efficiency of stochastic method (difficult in “thread the needle”).

New development

- Estimate B_{cur}, no other priors
- Optimised catch-only method

Estimate B_{cur}

- Estimate biomass based on fishery catch or survey data.
- Assume no other priors (r, K, M, F_{msy}/M, etc.).
- Instead of assuming a depletion level, try to estimate biomass in one recent year.

Limitations

- Results depend on how good is the estimated one year biomass.
- Estimating one year biomass may be impossible in many fisheries.

OCOM—optimized catch-only method

Default method

- Use a simple biomass dynamics model with parameters ***K*** and ***r***.
- Define a large range of ***K*** and a series of assumed depletion levels ***d***, including all possible values.
- Use optimization algorithm to search for ***r*** that corresponds to each assumed ***K*** and ***d***.
- Derive basic parameters: ***K***, ***r***, **MSY**: Determine the linear section of the log(***r***)~log(***K***) plot for each ***d*** level, narrow down possible ***d*** range from **MSY**~***d*** plot.
- Rerun the model using these parameters to obtain biomass trajectories, ending biomass B_{cur}, and depletion ***D***.
- Project to future biomass to explore alternative harvest policies.

Improvement with auxiliary life history data

- Life history parameters: growth parameters ($\boldsymbol{L}_{inf}$, $\boldsymbol{\kappa}$), maximum age, age at maturity, natural mortality.
- Estimate ***M*** from other life history parameters.
- Estimate ***r*** range from ***M***.
- Feed this ***r*** range into OCOM model.

- Life history parameters are available for most fish species.

Step 1: model and priors

- Simple biomass dynamics model

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{B_0}\right) - C_t$$

- Set up wide parameter ranges:

Theoretically: $0 < K < \infty$; $0 < r < \infty$; $0 < D < 1$

In practice: $C_{max} < K < 100*C_{Max}$; $0 < r < 3$; $0 < D < 0.8$

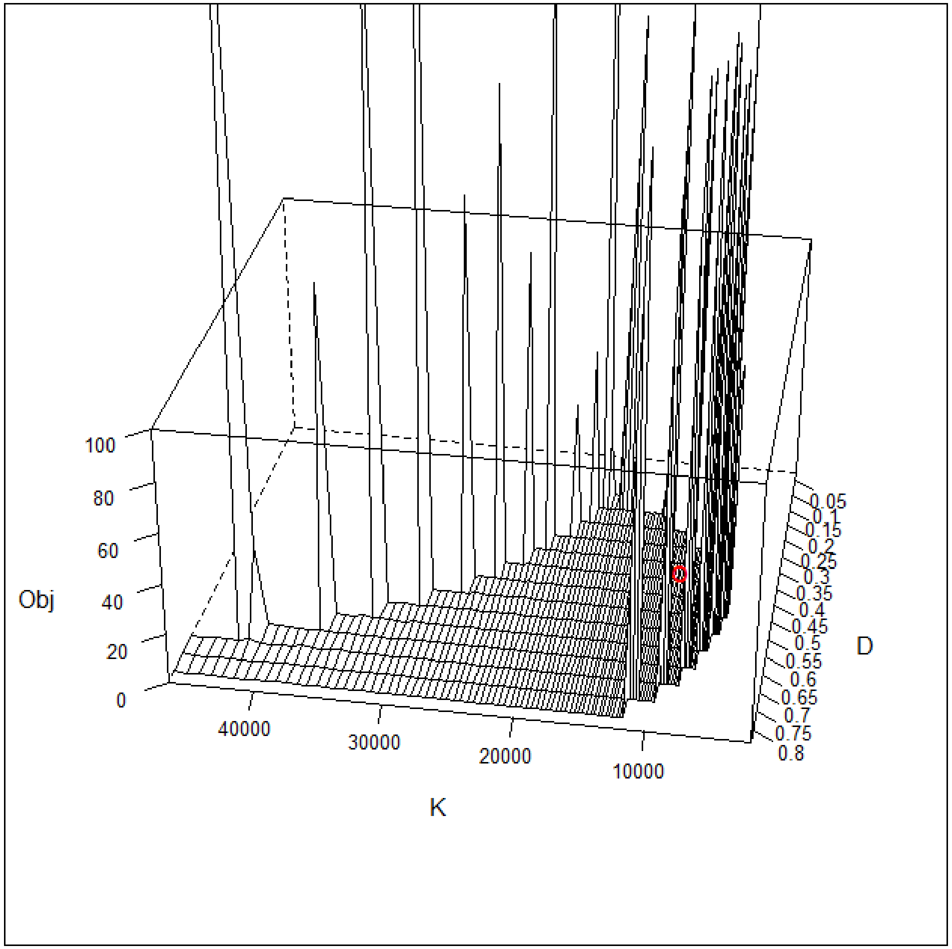
Step 2: search for feasible solutions

- Set up series of equally spaced *K*s (100 to 1000) from min to max.
- Set up series of equally spaced *ds* (10 to 100) from min to max.
- Search through all *K*s and *d*s for feasible *r* values using optimization function by minimizing $|B_{cur} - d*K|$.

Step 3: excluding unlikely values

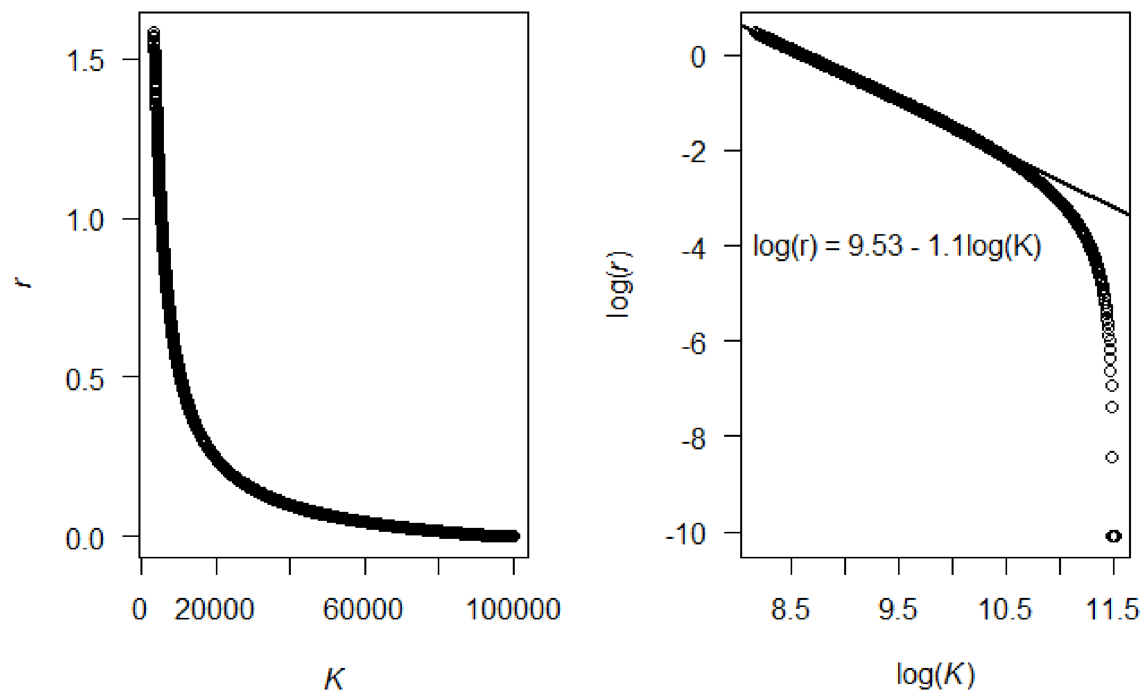
- Method 1: keep [*K*, *r*, *d*] pairs with objective < alpha**K*

- True value
  - K = 10,000
  - D = 0.38

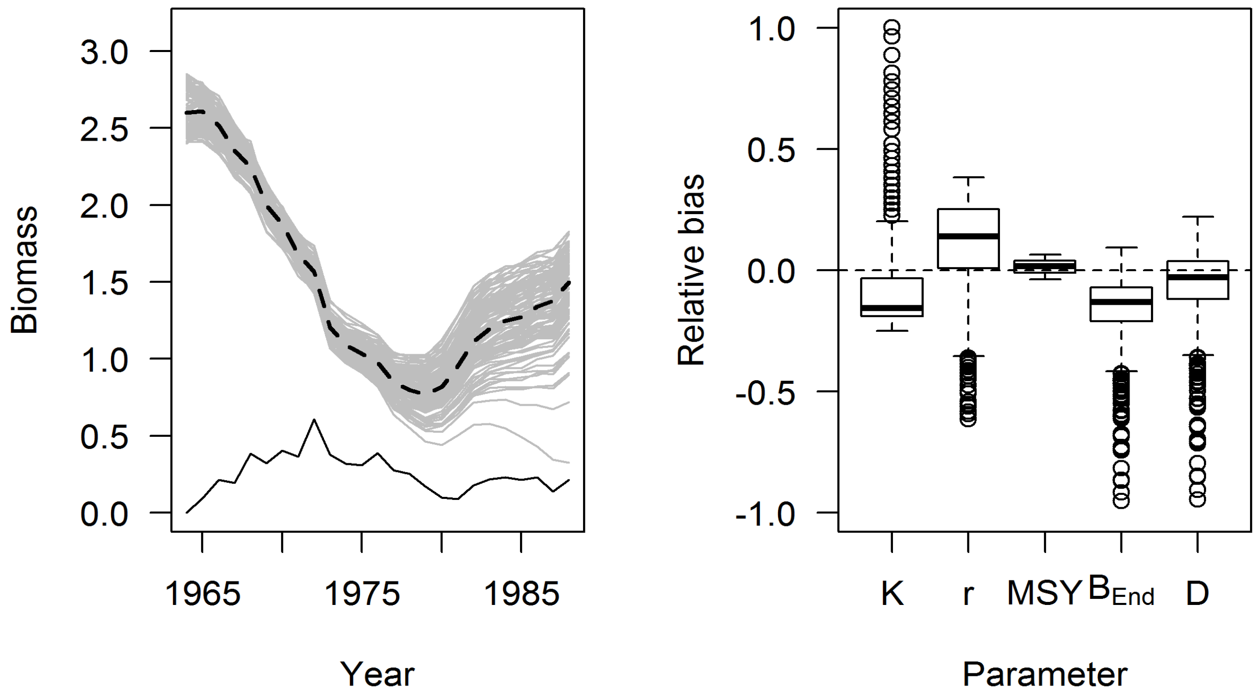


Step 3: excluding unlikely values

- Method 2: biologically feasible [*K*, *r*, *d*] pairs



Testing and comparing OCOM with data-rich methods

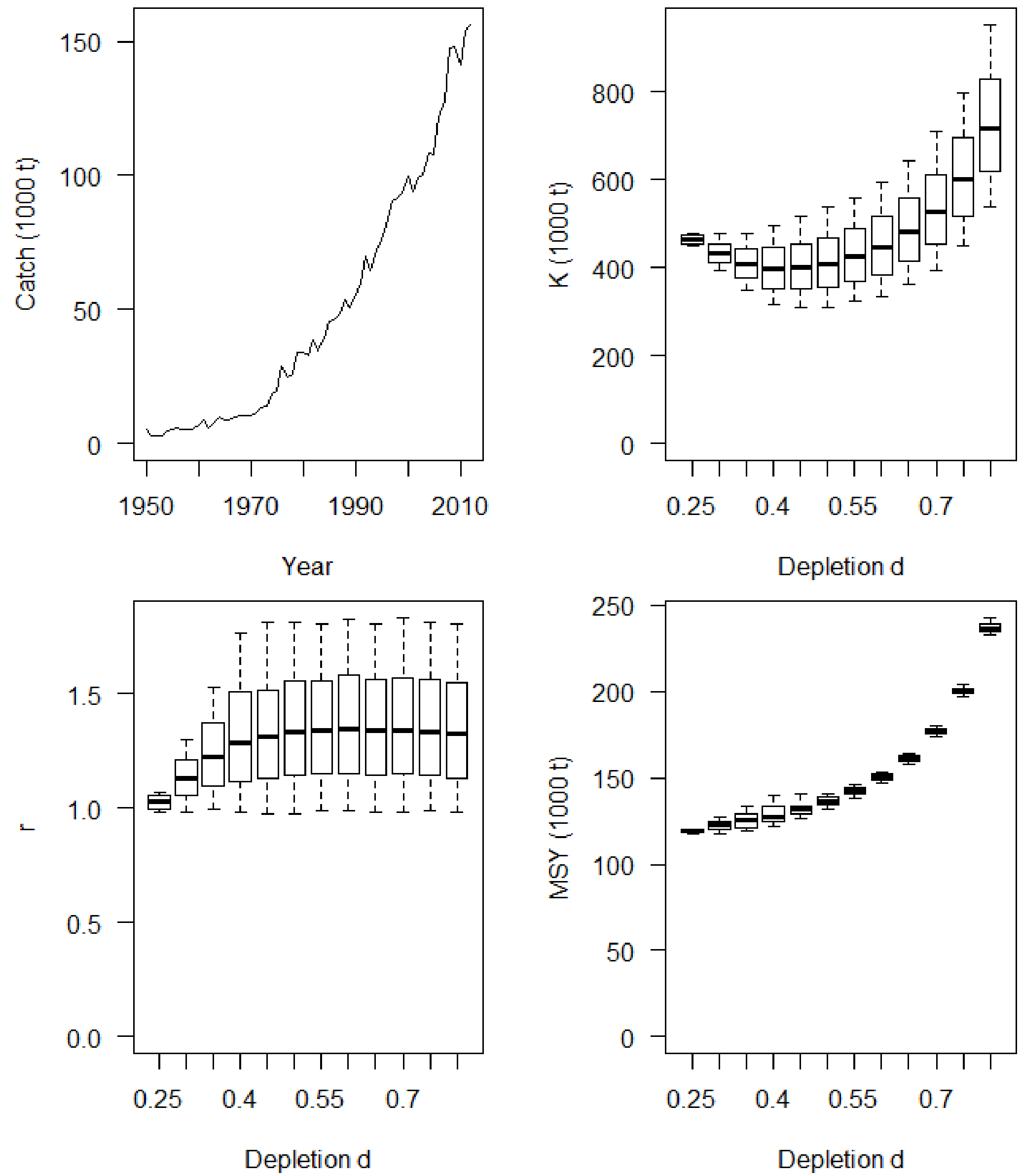


Robustness

- The default method is robust when the stock has a modest population growth rate ***r*** and depletion level ***D***.
- When ***r*** or ***d*** is very low or very high, the default method should include information regarding the productivity and depletion.
- Catch patterns and the initial depletion have little impact.
- Errors in catch data cause similar bias in the estimated ***K***, ***MSY***, B_{End}, but have little impact on ***r*** and ***D***.

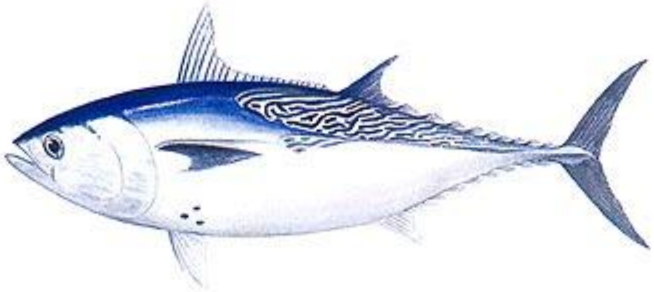
Kawakawa

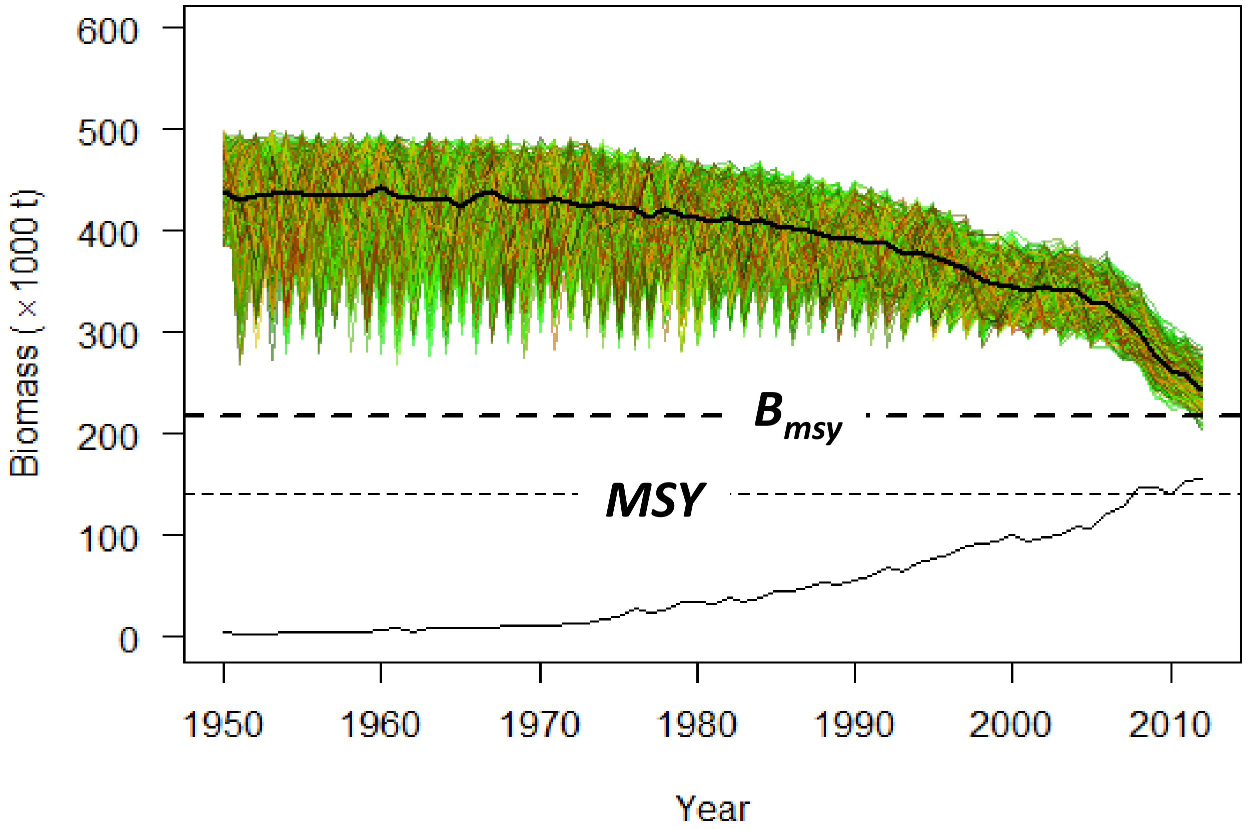
- Use life history parameters
  - L_{inf}, κ, T_{mat}, T_{max},
  - M.
  - $r = 2 F_{msy} = 2*0.87*M$



CSIRO

Kawakawa





600
500
400
300
200
100
0
Biomass (× 1000 t)
B_{msy}
MSY
1950
1960
1970
1980
1990
2000
2010
Year

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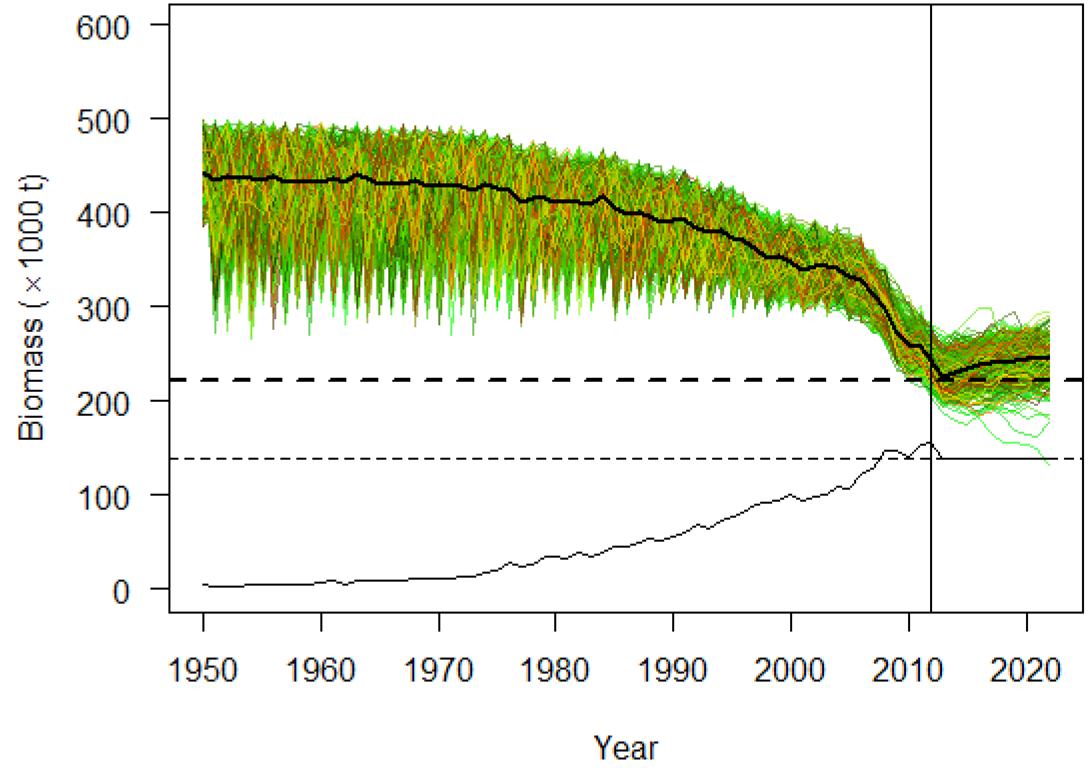
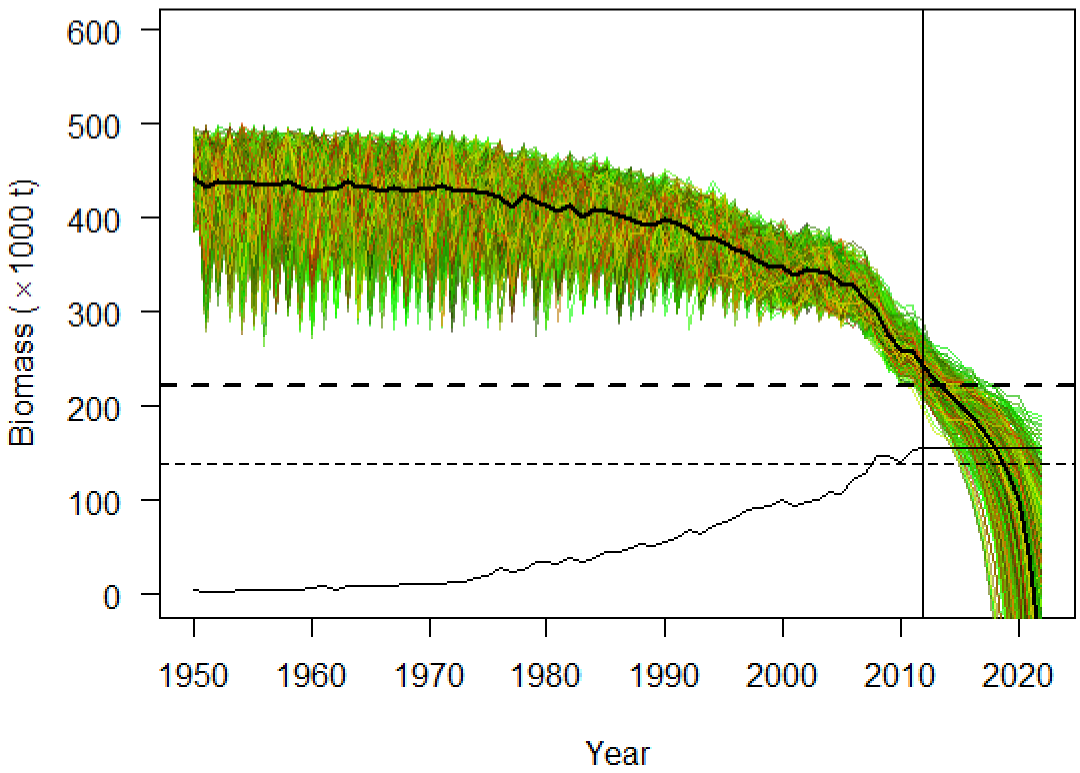
- C_{future} = MSY



Kawakawa

- $C_{\mathbf{future}} = C_{2012}$



Application

- The method allows quantitative assessment for stocks with catch-only data.
- This method is very low-cost and quick.

Thank you

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Depletion-corrected average catch

$$Y_{sust} = \frac{\sum C}{n + \dfrac{1 - B_{LYR} / B_0}{0.4cM}}$$

$$\frac{1 - B_{LYR} / B_0}{0.4cM} \quad \Leftrightarrow \quad F_{msy} = M = \frac{MSY}{B_{msy}}$$

$\Delta = 1 - B_{LYR}/B_0$