Are data-poor fisheries certifiable?

Generic Management Procedures and precautionary management

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Fisheries management: data-poor

Key questions:

Where are we now?  
No reliable estimate

Where do we go?  
Somewhere close to $B_{\text{MSY}}$

How do we get there?  
Simple generic HCR that relies on few data to give directional advice (at minimum).

Keep it simple stupid!
The challenge

What we know we don’t know: stock status unknown
  Little knowledge of current depletion
    (where are we now?)
  Little knowledge of $B_{MSY}$ (where do we go?)

What we think we know: limited data
  Some knowledge of life-history parameters
  A catch time-series (likely incomplete and biased/noisy)
  Length data (possibly a mean length index)
  Short index of abundance (if “data-moderate”)
Need to account for high levels of uncertainty

- model uncertainty (model parameters values unknown)
- process error (stochastic effects)
- observation error (noisy data plus bias)
- implementation error (inadequate monitoring)

SIMULATION TEST!
Precautionary management approach

Need simple and cheap management solutions that work in practice

They must be robust to high levels of uncertainty

Have feedback to respond to changes in abundance

Achieve biomass targets within realistic time periods

Avoid unnecessary fluctuations in catch advice

Identify appropriate reference points and precautionary buffers to offset increasing uncertainty levels associated with few data

Incorporate incentives to collect key data to move from data-poor to data-moderate
MSE: Evaluate performance

Step 1: Objectives

Step 2: Performance statistics

Step 3: OPERATING MODELS
A suite of population models that represent the “true” underlying resource dynamics (encompassing alternative assumptions about data and model parameters)

TAC/TAE

Step 5: MSE Simulations

Step 4: MPs
Generic HCR to automate/generate annual catch advice (TAE or TAC) (or simple assessment+HCR)

DATA

Step 6: Summary statistics

Step 7: Decision tree ranking MPs
Group stocks with similar characteristics in depletion/productivity/fleet baskets. Simple example:

<table>
<thead>
<tr>
<th>Productivity/Depletion</th>
<th>Low (M&lt;0.2)</th>
<th>Medium (0.2&lt;M&lt;0.4)</th>
<th>High (M&gt;0.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B/K&lt;0.2 (below &lt; PRI)</td>
<td>M:U[0.05,0.2] B/K:U[0.05,0.2]</td>
<td>M:U[0.2,0.4] B/K:U[0.05,0.2]</td>
<td>M:U[0.4,1] B/K:U[0.05,0.2]</td>
</tr>
<tr>
<td>0.2&lt;B&lt;K&lt;0.4 Below BMSY</td>
<td>M:U[0.05,0.2] B/K:U[0.2,0.4]</td>
<td>M:U[0.2,0.4] B/K:U[0.2,0.4]</td>
<td>M:U[0.4,1] B/K:U[0.2,0.4]</td>
</tr>
<tr>
<td>B/K&gt;0.4 Near (above BMSY)</td>
<td>M:U[0.05,0.2] B/K:U[0.4,0.7]</td>
<td>M:U[0.2,0.4] B/K:U[0.4,0.7]</td>
<td>M:U[0.4,1] B/K:U[0.4,0.7]</td>
</tr>
</tbody>
</table>

Parameterise a set of age-structured operating models for each group/basket
Bayes-like approach: sample from prior distributions for key model parameters
Classification of stocks

Productivity (M or M/k):

- Low, medium or high productivity?
- Species with similar life-history data

Depletion:

- Very depleted (<0.5B_{MSY}), depleted (<B_{MSY}), or at target?
- Difficult: data-poor => no assessment
- Use qualitative and semi-quantitative methods
- Use gray literature
- Use FAO evaluations of the status of world fisheries
Parameterisation of OMs
(Example: depleted stock of medium productivity)

DLMtool “Stock” object

- Depletion: B/K: U[0.2,0.4]
- Natural mortality rate: M: U[0.1,0.3]
- Steepness of S–R: h: U[0.25,0.70]
- Growth parameters: k: U[0.18,0.28] L_inf: U[38 42] t_0: U[−2.2,−1.8]

DLMtool “Observation” object:

- L–H pars: Log–normal CV=0.1
- Catch–at–length: CV: U[0.05,0.15]
- Index of abundance: CV: U[0.1,0.4]
- Catch time series: CV: U[0.1,0.3]

DLMtool “Fleet” object:

- Fishing selectivity (vulnerability of oldest age): U[0.4,0.8]
Management Procedure

Assessment

- Assessments
  - Data-poor
    1. Qualitative and semi-quantitative
    2. Per-recruit
    3. Length composition
    4. Catch time-series
    5. Abundance index
  - Data-moderate

Input: data

- Output: SPR
- Output: Reference points
- Output: Decision trees, rankings
- Output: SPR
- Output: MSY, B/K

Management

- HCRs (based on data)
  1. SPR-based
  2. B/K-based
  3. Length-based
  4. Catch-based
  5. Abundance index based

Output: Catch limits, TAC/TAE

Assessment Management Data

Data-poor: 1, 2, 3, 4, 5
Data-moderate: 1, 2, 3
Data-poor assessment methods

**DATA**
- Qualitative
- Life-history parameters
- Length composition
- Catch
- Index of abundance

**ASSESSMENT**
- FK, PSA, traffic light, F-ratio, L-indicators
- Per-recruit
- LB–SPR
- Catch–MSY, COM, SSCOM, DB–SRA, CC–SRA
- AIM, RY, Production model (Schaefer)

**OUTPUT**
- Stock ranking, Decision trees, Bayesian priors
- Reference points
- Current SPR
- RY, MSY, $B_y$
- $B/B_{MSY}, F/F_{MSY}$
- $B_y$, and possibly MSY and/or RY

**MANAGEMENT**
- Harvest Control Rules:
  - SPR,
  - $B/B_{MSY}, F/F_{MSY}$

- Output: TAC/TAE
Data-poor assessments (available on DLM Toolkit)

a) Yield-per-recruit: $F_{MSY}$ proxy

b) Spawning Potential Ratio (LB–SPR): Proxy for stock status

Coupled with a target HCR

c) Depletion-Based Stock Reduction Analysis (DB–SRA): estimate MSY

Coupled with a MSY HCR
Data–poor MPs

DATA

- Reference points
- Length
- Catch
- Index of abundance

MANAGEMENT

- HCRs (based directly on data):
  - L–Threshold, L–Target, $L_{F=M}$
  - DACS, DCAC
  - I–Ratio, I–Slope, I–Target

OUTPUT

Output: TAC/TAE
Data–poor HCRs (available on DLM Toolkit)

**Data-poor HCRs**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) MSY rule:</td>
<td>$\text{TAC}_{y+1} = \text{DCAC} = \frac{\sum C_y}{n + \left(MSYL \times c \times M\right)}$</td>
</tr>
<tr>
<td>b) Threshold rule:</td>
<td>$\text{TAC}_{y+1} = \text{TAC}<em>y \pm \text{step} \text{ if } I</em>{\text{recent}} &gt; I^{\text{upper threshold}} &lt; I^{\text{lower threshold}}$</td>
</tr>
<tr>
<td>Status quo with reference points</td>
<td>$\text{TAC}_{y+1} = \text{TAC}_y (1 + \text{slope}(I_y))$</td>
</tr>
<tr>
<td>c) Slope rule</td>
<td></td>
</tr>
<tr>
<td>Directional (no target or limit)</td>
<td></td>
</tr>
<tr>
<td>d) Target rule</td>
<td>$\text{TAC}<em>{y+1} = \text{TAC}^{\text{target}} \left[w + (1 - w) \left(\frac{I</em>{\text{recent}}}{I^{\text{target}}} \times \frac{I^0}{I^0}\right)\right]$</td>
</tr>
<tr>
<td>Target and limit reference points</td>
<td></td>
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</tbody>
</table>

Where $I = \text{mean length index, or LB-SPR index, or CPUE/survey index}$ and $\text{TAC}^{\text{target}} = \text{proxy for MSY (DCAC or DACS)}$
Equilibrium mean length in catch as a function of spawning biomass for age-independent natural mortality rates, $M$, of 0.2, 0.3 and 0.4 $yr^{-1}$.

**Advantage:** Easy and cheap to collect.

**Disadvantage:** Mean length is an indirect index – not directly proportional to abundance! Delay in feedback at higher biomass levels (worse for longer-lived stocks (lower $M$)).

Same problem for catch-at-length data.
Advantage: Direct index of abundance.

Disadvantage: Scientific surveys can be costly. CPUE data much easier/cheaper to collect, but bias (changes in q) could be problematic.
Data: Total annual catch

Advantage: Time-series data are usually available for most fisheries.

Disadvantage: Catch data alone are not informative about stock size. Total removals are not well known for data-poor fisheries due to insufficient monitoring.

Catch time-series shown as a percentage of the maximum catch to illustrate the transition phases of a typical fishery (Froese and Kesner-Reyes, 2002).

\[ C_y \neq qB_y \]

E not constant
### MSC stock status scores

<table>
<thead>
<tr>
<th>Stock Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SG60:</strong></td>
<td>stock likely above point where recruitment becomes impaired (PRI) stock above PRI ($0.2B_0$ or $0.5 , B_{MSY}$) no decline in one biomass proxy</td>
</tr>
<tr>
<td><strong>SG80:</strong></td>
<td>stock highly likely above PRI and fluctuating about MSY level stock above PRI no decline in two biomass proxies one proxy to indicate high productivity level</td>
</tr>
<tr>
<td><strong>SG100:</strong></td>
<td>certain that stock above PRI and fluctuating about or above MSY level stock above PRI no decline in three biomass proxies two proxies to indicate high productivity level where “likely”=70%-ile, “highly likely”=80%-ile; “certain”=95%-ile</td>
</tr>
</tbody>
</table>

*Default reference points: $B_{MSY}=0.4B_0$, PRI=$0.2B_0$*

Current stock status not known, but score into probability to achieve target
Reference points:

SG60: stock likely in yellow zone
SG80: stock highly likely in orange zone
SG100: Stock in green zone with some certainty

Overfishing and overfished

Fishing mortality rate

\( F_{\text{LIMIT}} \)

\( F_{\text{TARGET}} \)

Overfished

SG60

SG80

SG100

Spawning biomass

\( B_{\text{LIMIT}} \)

\( B_{\text{TARGET}} \)

\( B_0 \)
Precautionary buffers

Less data and increased levels of uncertainty require more precautionary management and larger buffers

Buffers serve as an incentive to collect data and move stocks from

i) data–poor to data–moderate and

ii) very depleted to moderately depleted.

Example:

• Data–poor and MSC score SG60: $B/B_{MSY} > 0.5 \Rightarrow \text{Buff}=25\%$
• Data–moderate and MSC score SG80: $B/B_{MSY} \pm 1 \Rightarrow \text{Buff}=10\%$
• Data–rich and MSC score SG100: $B/B_{MSY} \pm 1 \Rightarrow \text{Buff}=0\%$

Need to simulation test alternative buffer sizes
SG60: Rebuilding time twice the generation time, but not longer than 20 years. Monitor to check that rebuilding strategies are effective.

SG80: Some evidence (high likelihood) of recovery within time period.

SG100: Short rebuilding time period of between 5 years and one generation time for stock. Strong evidence (high likelihood) of recovery within time period.

Generation time: \( t_{\text{gen}} = t_{\text{opt}} = t_0 - \frac{1}{k} \ln\left(1 - \frac{L_{\text{opt}}}{L_{\text{inf}}}\right) \)

Shortcut method: \( t_{\text{gen}} = a_{\text{mat}} + \frac{1}{M} \)

Tune HCRs to achieve target in pre-selected time-period \( ?\% \) of the time.
SG60: MP is expected to achieve objectives
The MP is likely to work
Monitoring is in place to provide feedback

SG80: MP is responsive to stock status (feedback)
Elements of MP work together to achieve objectives
MP may not be fully tested, but evidence shows that objectives are met

SG100: MP is responsive to stock status and is designed to achieve objectives
The MP has undergone comprehensive robustness testing
Evidence shows that objectives are met
MP can maintain stock at target levels
MP is reviewed and improved periodically

Aim to produce a guide to appropriate MPs according to stock and fishery types, depletion levels and associated buffer to achieve MSC scores.
Summing up...

Need consolidated approach to management, which includes data-collection.

Automate management advice: implement a simple HCR that can be updated every 4/5 years (inline with MSC certification schedule).

Adopt an MP approach which includes fishery stakeholders to inform on management objectives and trade-offs into MSC scoring module.

Match control rules to stock characteristics and available data.

Index-based HRCs perform best: collect data to construct a reliable direct index of abundance (survey or CPUE).

Need HCRs with feedback control to self-correct.

HCRs must be shown to be adequately risk-averse.
Timeline

1. **Categorisation of stock groups and specification of OMs:**
   Identification of generic baskets of stock types. Setting up of generic OMs using DLM Toolkit and example input data files. Specification of robustness tests, reference points, performance statistics and appropriate projection periods (generation times).

2. **Specifications of candidate methods:**
   Identify candidate MPs corresponding to each OM basket. Specification of reference points (targets and limits) and precautionary buffers for each MP.

3. **MSE:**
   Simulation testing and tuning of MPs for each OM basket. Evaluation of appropriate control parameters and precautionary buffers for each MP.

4. **Decision tree:**
   Inspection of final summary statistics. Comparison performance for each basket to rank methods and construction of a decision tree to aid with method selection.

5. **MSC scoring module:**
   Coding of DLM Toolkit module to translate performance statistics to MSC scoring.
Deliverables

Technical specifications of stock categorisation and OMs:

Technical specifications of candidate HCRs:
HCRs corresponding to each basket. Specification of control parameters, reference points (targets and limits) and precautionary buffers for each HCR.

Technical document summarising MSE results:
Summary of comparative performance of HCRs across alternative baskets. Identification of key uncertainties and trade-offs.

Decision tree:
Drafting of a decision tree to prioritise methods and data according to generic basket (stock/fishery type and depletion range), with assumptions/advantages/disadvantages of each method. Identification of key data and uncertainties to prioritise future research.

MSC scoring module:
A DLM Toolkit module to translate performance statistics to MSC scoring. Operational module for fishery stakeholders to tune candidate MPs.
<table>
<thead>
<tr>
<th><strong>Collaboration: global data–poor initiatives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UBC (DLM Toolkit):</strong></td>
</tr>
<tr>
<td>R package to perform MSE which includes many data–poor HCRs. LB–SPR will soon be incorporated. Contact: Tom Carruthers, Adrian Hordyk</td>
</tr>
<tr>
<td><strong>CSIRO (SESSF Harvest Strategy Policy):</strong></td>
</tr>
<tr>
<td>Tier system to group stocks according to data and methods (Tier 4 for data–poor stocks). HCRs fully tested using MSE. Contact: Tony Smith</td>
</tr>
<tr>
<td><strong>NOAA (Fishery Management Plan):</strong></td>
</tr>
<tr>
<td>NPFMC uses a Tier system to groups stocks according to reliability of estimates of B and MSY reference points. PFMC groups stocks into 3 categories: data–rich, data–moderate and data–poor according to type of assessment methods used. Contact person: Andre Punt</td>
</tr>
<tr>
<td><strong>ICES (WKLIFE):</strong></td>
</tr>
<tr>
<td>European data–poor methods Working Group based on life–history traits. Stocks categorised according to data and methods. Contact: Jose De Oliveira</td>
</tr>
<tr>
<td><strong>SNAP:</strong></td>
</tr>
<tr>
<td>Data–poor initiative. In–house MSE code unknown. Similarities in approach. Contact: Jono Wilson, Natalie Dowling</td>
</tr>
<tr>
<td><strong>JRC (a4a):</strong></td>
</tr>
<tr>
<td>European stock assessment initiative. FLR code fully tested and documented. Moving towards testing of data–poor methods. Contact: Ernesto Jardim</td>
</tr>
<tr>
<td><strong>FAO:</strong></td>
</tr>
<tr>
<td>On–going data poor MSE projects; FAO data–base. Contact: Yimin Ye, Marcello</td>
</tr>
</tbody>
</table>
Carruthers et al. (In review). Performance review of simple management procedures. ICES Journal of Marine Science

MSE to compare a range of MPs for setting catch-limits in fisheries. Performance evaluated with respect to

- life-history type,
- level of stock depletion,
- data quality and
- auto-correlation in recruitment strength.

Evaluate robustness of MPs to biases in data.

⇒ Performance sensitive to biases in catch data.
⇒ Best performance: MPs based on absolute biomass or stock depletion estimates

Need a scientific survey
Comparative performance: DLM Toolbox MPs

Yield–risk trade–offs for herring and bluefin tuna using DLM Toolkit (from Carruthers et al. submitted)
Harvest Strategy Policy (HSP):

Four tiers to classify stocks from data-rich to data-poor:

Tiers 1 and 2: Stocks with robust quantitative assessments

Tier 3. Stocks with no quantitative assessment but with estimates M and fishing mortality $\rightarrow$ F-type HCR (5% discount factor)

Tier 4. Stocks with no quantitative assessment but with reliable CPUE data $\rightarrow$ target-type HCR (15% discount factor)
The North Pacific Fishery Management Council (NPFMC) adopts six tiers to classify stocks from data-rich to data-poor:

Tier 1, 2 and 3: Stocks with quantitative assessments and reliable estimates of B and MSY reference points (RFs), or proxies.

Tier 4. Stocks with reliable estimates of B but lacking MSY RFs.

Tier 5. Stocks with reliable estimates of B and M (no RFs).

\[-HCR: F=M \text{ (25\% discount factor)}\]

Tier 6. Catch-only stocks: Stocks with no quantitative assessment.

\[-HCR: C_{ave} \text{ (25\% discount factor)}\]

Data-poor
The Pacific Fishery Management Council (PFMC) adopts three categories to classify stocks from data-rich to data-poor:

Category 1: Data-rich $\rightarrow$ age/length disaggregated assessment

Category 2: Data-moderate $\rightarrow$ age-aggregated assessment (uncertainty buffer of 0.25)

Category 3: Data-poor $\rightarrow$ $C_{ave}$, DCAC, DB–SRA (uncertainty buffer of 0.5)
ICES (Europe)

Six categories to classify stocks from data-rich to data-poor:

1. Data-rich stocks with accepted quantitative assessments.
2. Stocks with quantitative assessments (used qualitatively).
3. Stocks with reliable index: -> index-based HCR
4. Stocks with reliable catch data -> DCAC
5. Data-poor stocks with landings data only -> PSA
6. Stocks negligible landings -> PSA
Develop a assessment and management framework for data–poor fisheries:


2. Evaluate the costs/benefits of additional data:

   Quantify the costs of data collection and analysis. Evaluate benefits of extra data to reduce uncertainty/risk. Design adaptive management guidelines for fishers. Assist fishers to maximise economic benefits from monitoring, data collection and improved management.

Implement assessment and management framework for depleted data–poor fisheries:

Thank you