IATTC Risk Analysis

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Key messages on the IATTC risk analysis

- Assessments are uncertain and probability statements need to be evaluated
- Develop alternative hypotheses to address issues with assessment
- Hierarchical structure to represent hypotheses
- Combine probability distributions across models
- Model weighting based on a set of metrics to assign model probabilities (e.g. diagnostics) not just fit (e.g. AIC)

Introduction: Why we need a risk analysis

- Assessments are uncertain
- IATTC HCR for tropical tunas (Resolution C-16-02) addresses uncertainty through probability statements
  - "if the probability that F will exceed the limit reference point (FLIMIT) is greater than 10%, as soon as is practical management measures shall be established that have a probability of at least 50% of reducing F to the target level (FMSY) or less, and a probability of less than 10% that F will exceed FLIMIT."
- Evaluations
  - Current status relative to reference points
  - Status under different management scenarios
- Transition from single base-case assessment to set of reference models

Introduction: Main concept

- A rigorous statistical framework is not applicable
  - Multiple model assumptions are possible
  - Stock assessment models are complex and highly parameterized
  - Models are misspecified
  - Process variation is ignored
  - Data are not weighted appropriately
- Data should not be solely used to weight models

Introduction: Main features

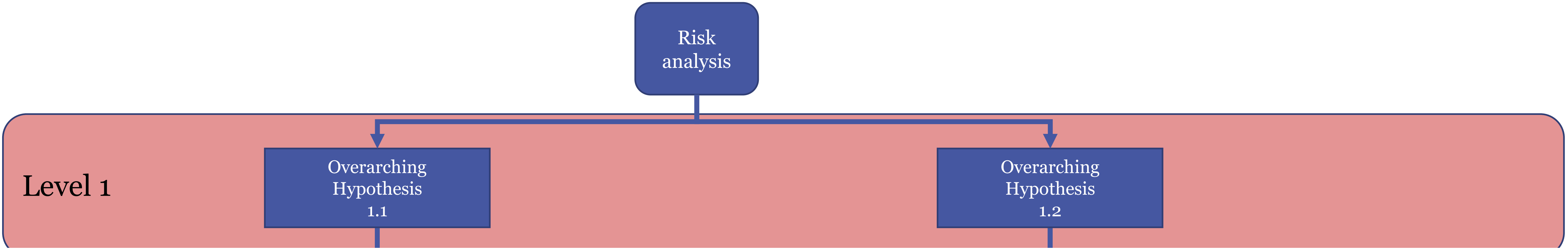
1. Hypotheses developed to address issues
2. Hypotheses represented by stock assessment models
3. Hypotheses are grouped into a hierarchical framework
    - Avoids any hypothesis dominating
    - Facilitates model development and weight assignment
4. Sub-hypotheses represent models with parameters that cannot be reliably estimated
5. Multiple metrics to evaluate plausibility of the hypotheses
6. Model fit only plays a limited role
7. Efficient approach to eliminate unlikely hypotheses

Introduction: 5 main steps

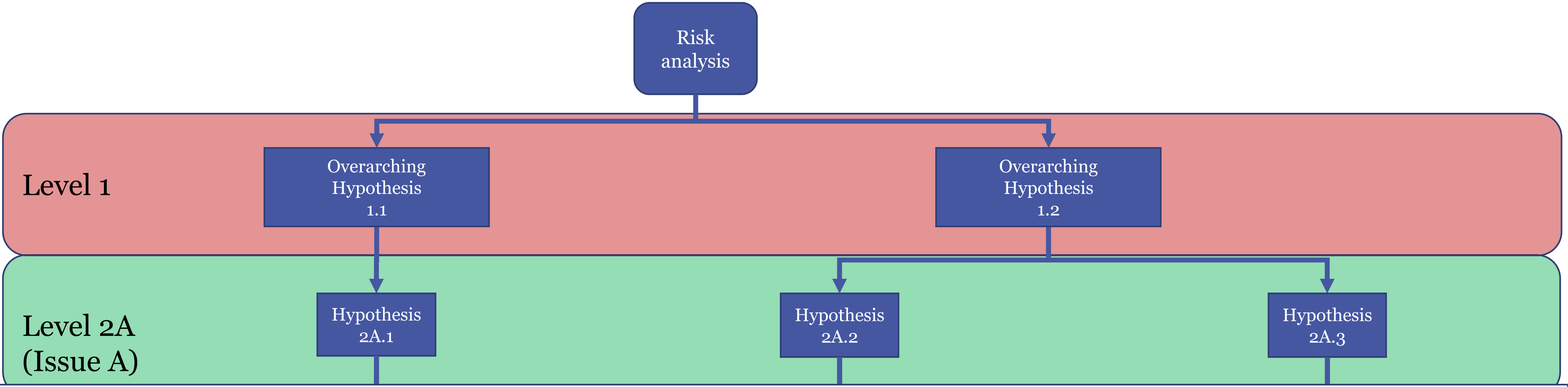
1. Establishing a hierarchy of hypotheses and models
2. Define a weighting system for hypotheses and models
3. Calculate the probability distributions for quantities of interest for a model
4. Combine probability distributions across models
5. Present the results in the form of a risk analysis

1. Hierarchy of hypotheses and models

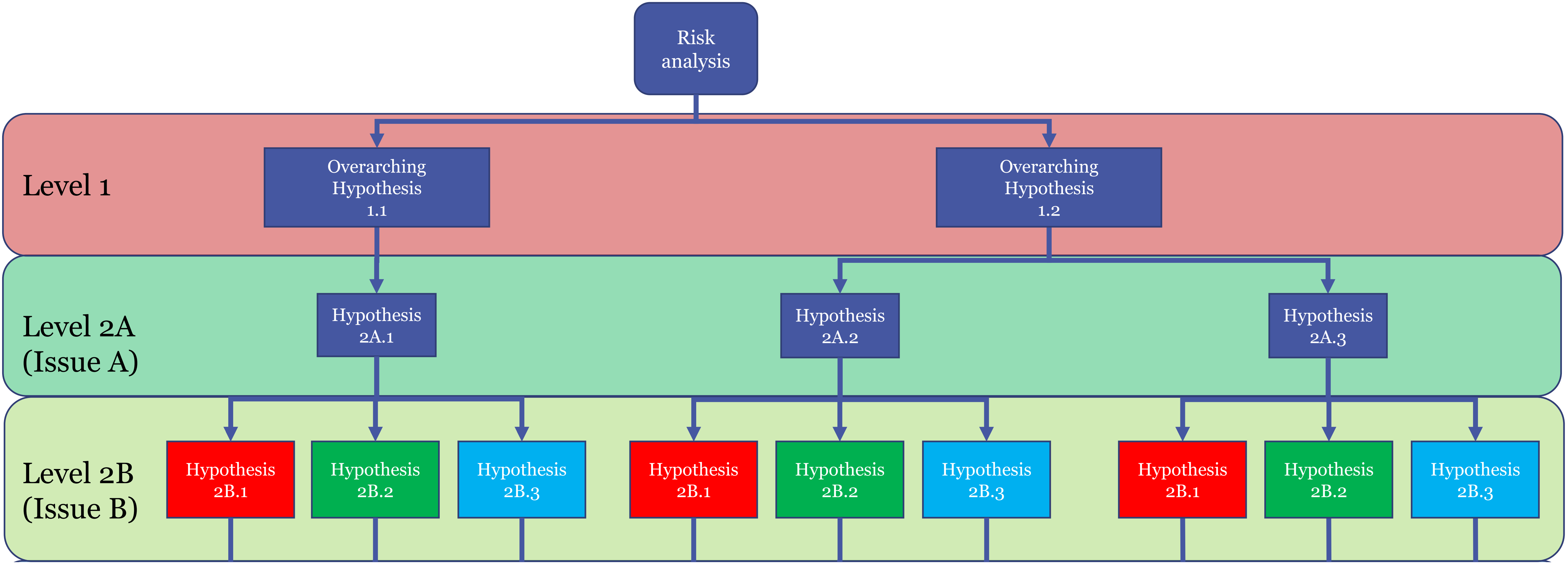
Risk analysis



- Level 1: Overarching hypotheses
  - Broad states of nature (e.g. the number of stocks)
  - Represented by a variety of models and data
  - Not evaluated by fit to data
  - Expert opinion for weights



- Level 2: Hypotheses
  - Represented by a model
  - Divided into sub-levels (A, B, …) where each sub-level addresses an issue in the assessment
  - Sub-levels are typically used in combination to solve all the assessment issues
  - Aid in assigning weights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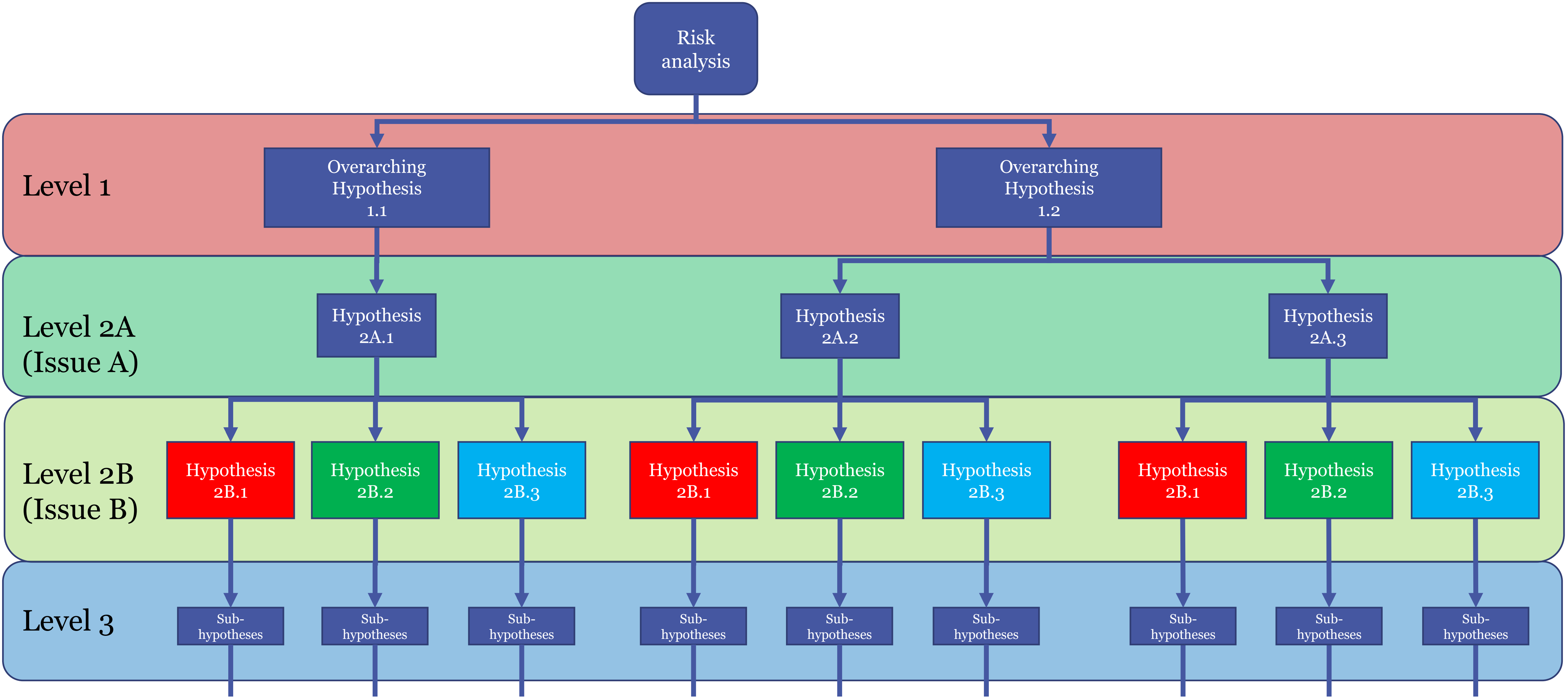
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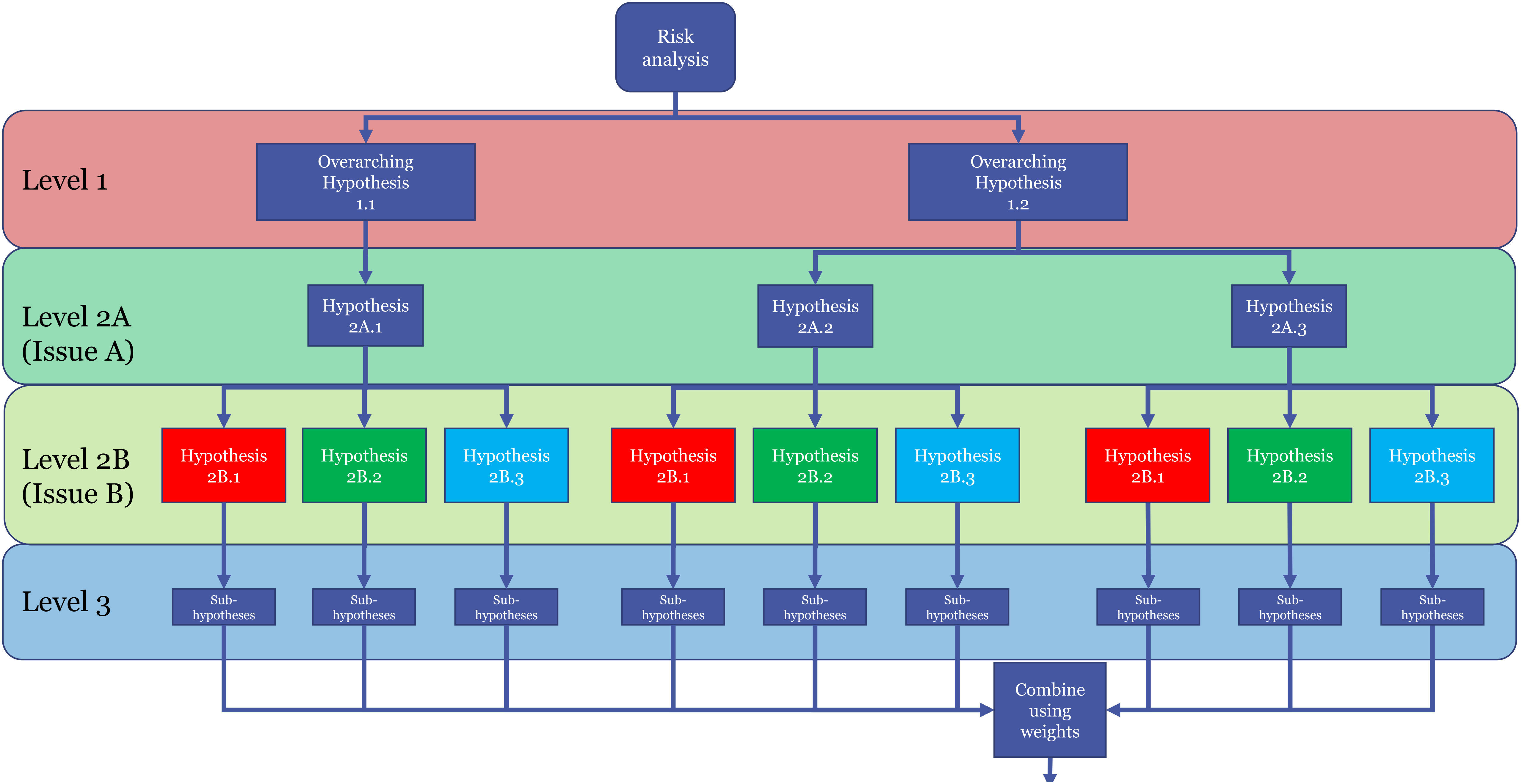
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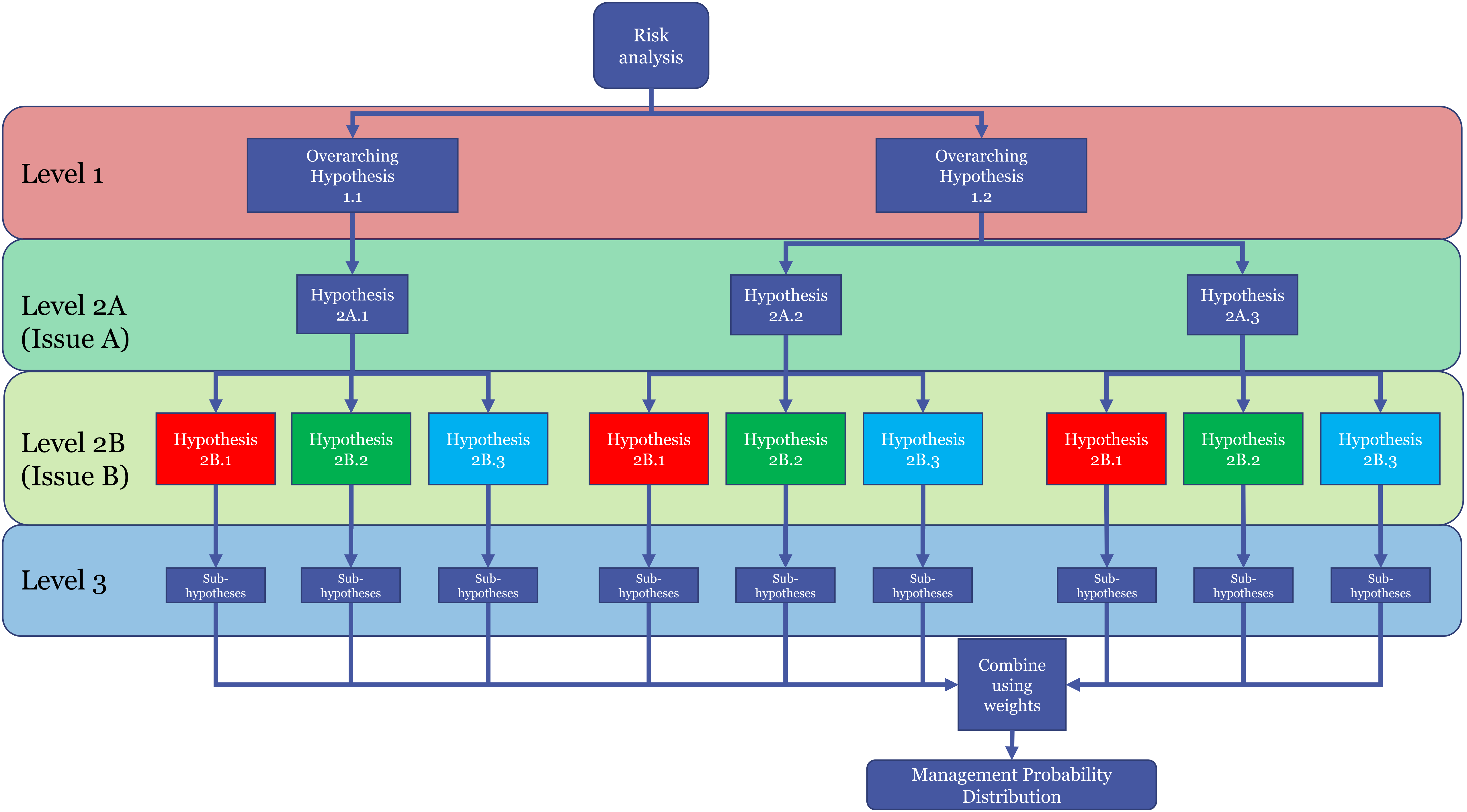
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Combine using weights
Management Probability Distribution

2. Defining a weighting system for hypotheses and models

a) Establish weight categories

b) Select weight metrics

c) Assign weights and rescale to be used in a probabilistic framework

d) Ensure the number of hypotheses is practical

Weighting system: weight categories

- Weighting is subjective
- Use general weight categories
- Assign each category a numeric value

Weight Category	Value
None:	0
Low:	0.25
Medium:	0.5
High:	1.0

Weighting system: Weight metrics

- W(Expert): Assigned “a-priori”, without consideration of model fit
- W(Convergence): Model convergence criteria of the estimation algorithm
- W(Fit): Fit of model to data
- W(Plausible parameters): Plausibility of estimates of parameters representing the hypothesis
- W(Plausible results): Plausibility of model results
- W(Diagnostics): Reliability of the model based on diagnostics

Weighting system: Diagnostics

- W(ASPM, R0, Catch curve)
- W(Retrospective analysis)
- W(Composition residuals)
- W(Index residuals)
- W(Recruitment residuals)

Calculating probability distributions for quantities of interest for a model

- Normal approximations based on the estimate and standard error
- Some standard errors are approximated
- The resulting distribution is rescaled to obtain P(Quantity|Model=m).
- Works well when the data is very informative
- Probability distribution may be asymmetrical
- Posteriors derived from limited MCMC analyses used to evaluate appropriateness of the approximation

Presenting the results in the form of a risk analysis

- Plot distributions by components (e.g. hypotheses at level 2A and 2B)
- Cumulative density functions (CDFs) can be used to determine the probability of exceeding the reference points.
- Decision tables
  - Outcome of specific management action under different states of nature.
  - The states of nature could be the individual models, combinations of models, or a derived quantity (e.g. biomass).
  - The probability of each state of nature is also included
- Risk curves
  - Probability of outcome versus management action

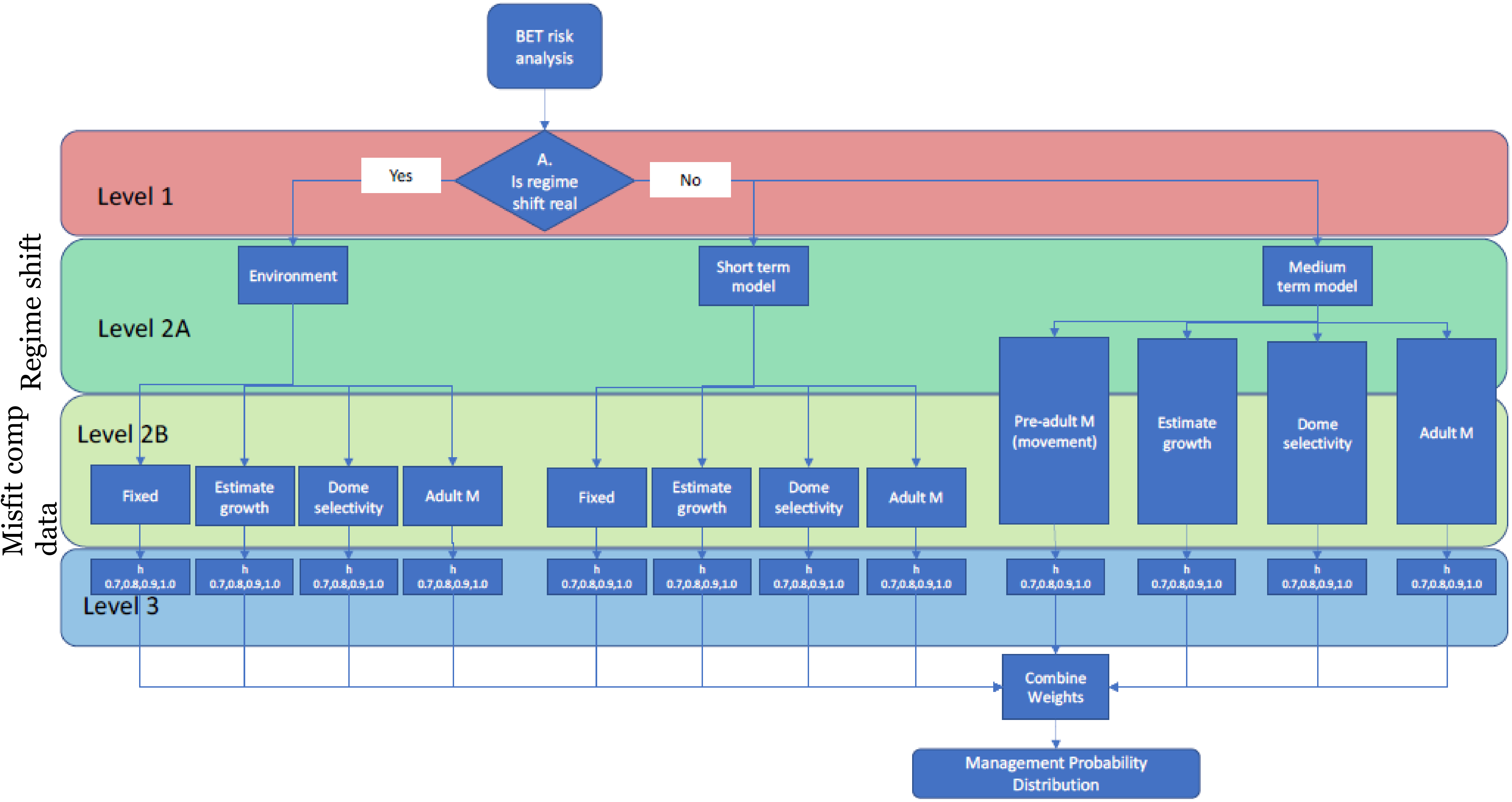
Application: bigeye tuna

- Conducted in Stock Synthesis
- Many fisheries
- CPUE and length composition data
- Overarching hypothesis: is regime shift in recruitment when fishery on juveniles expanded real
- Issues

  A. Regime shift

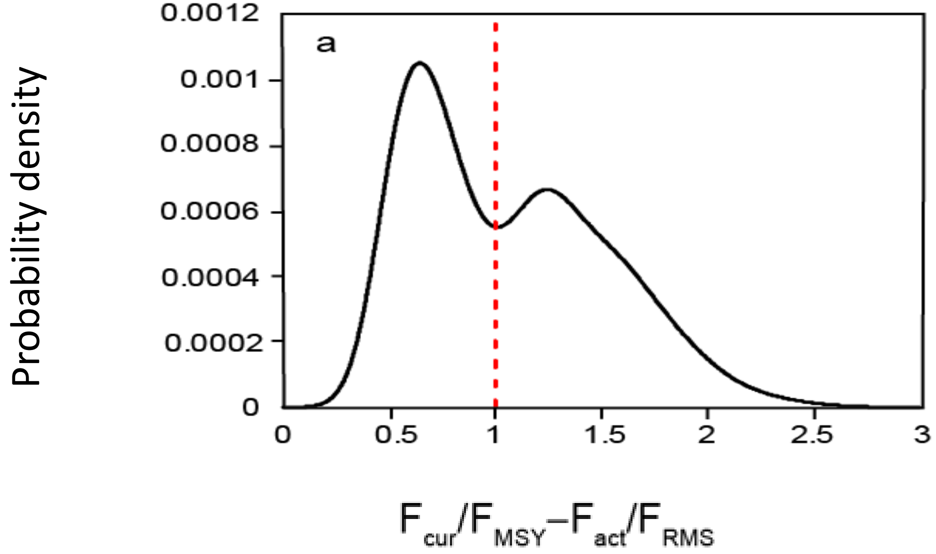
  B. Misfit to large fish in composition data from asymptotic fishery
- Panel of experts that subjectively assign weights

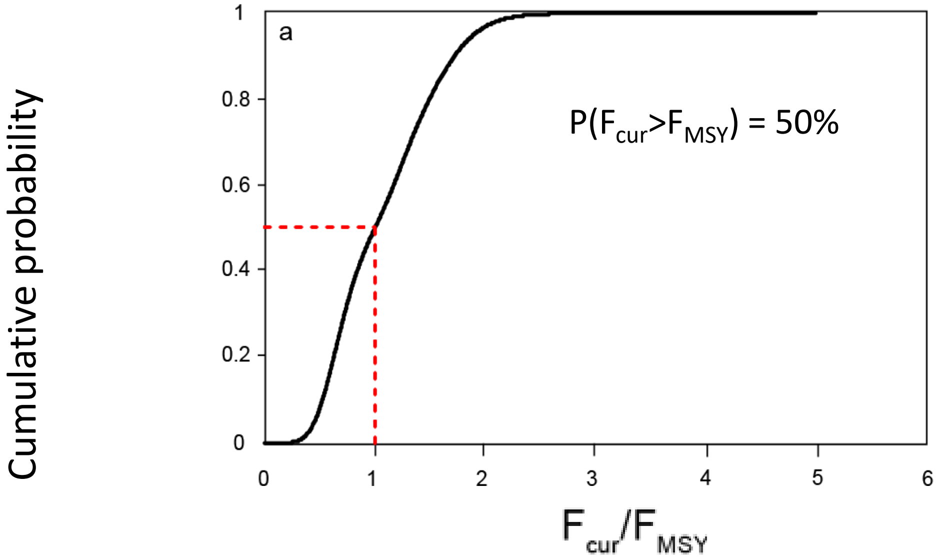
Flow chart for bigeye tuna



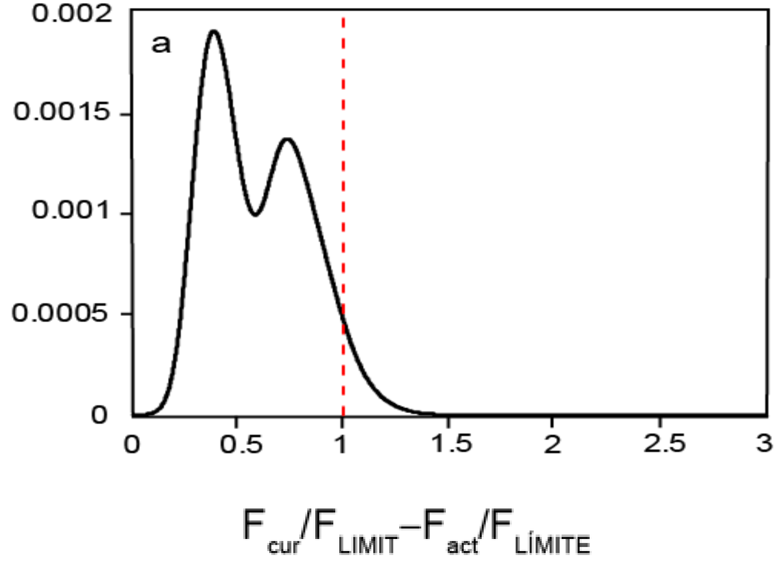
BET: F_{cur} probability distributions relative to RPs

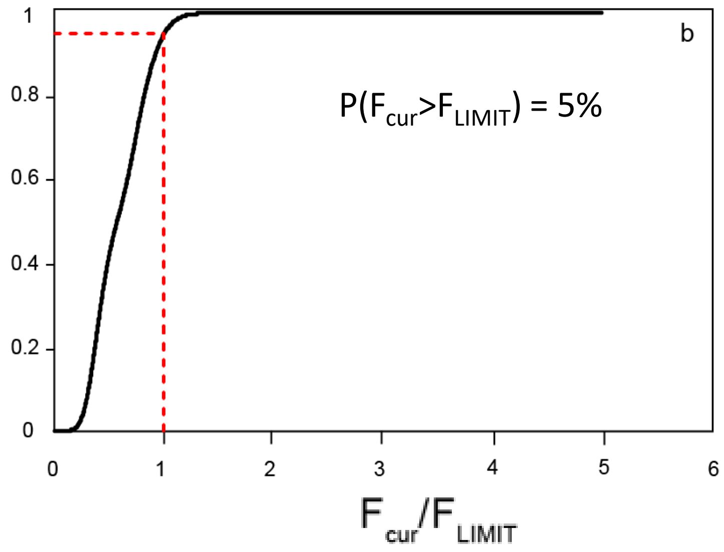
TARGET



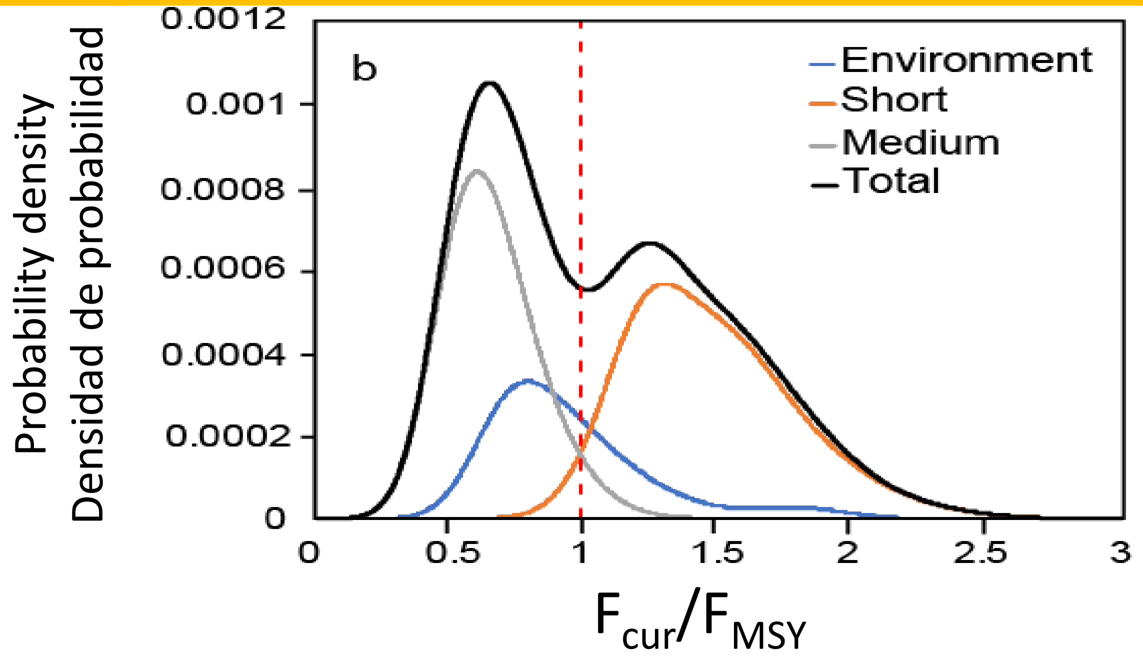


LIMIT



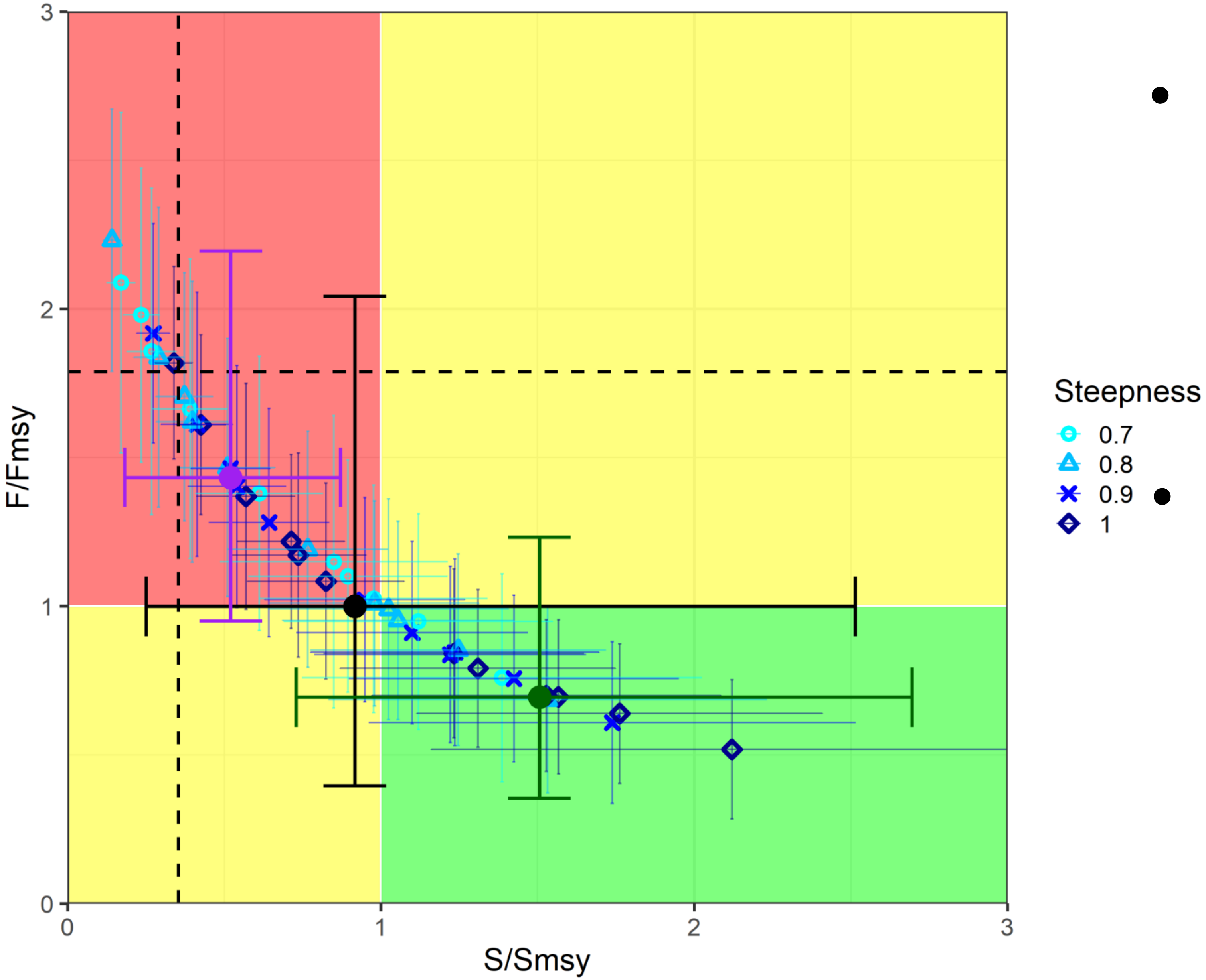


BET: Composition of F_{cur}/F_{MSY} prob. distribution



BET

BET: Current stock status (Kobe plot)



- TARGETS
  - 50% probability that F_{MSY} has been exceeded: $P(F_{cur}>F_{MSY})$ = 50%
  - 53% probability that S_{cur} is below S_{MSY}: $P(S_{cur}<S_{MSY})$ = 53%
- LIMITS
  - There probability that either *S* and *F* limit reference points have been exceeded is not negligible: $P(S_{cur}<S_{LIMIT})$ = 6%; $P(F_{cur}>F_{LIMIT})$ = 5%

Summary: main concepts

- Develop alternative hypotheses to address issues with assessment
- Hierarchical structure to represent hypotheses
- Model weighting based on a set of metrics to assign model probabilities (e.g. diagnostics) not just fit (e.g. AIC)

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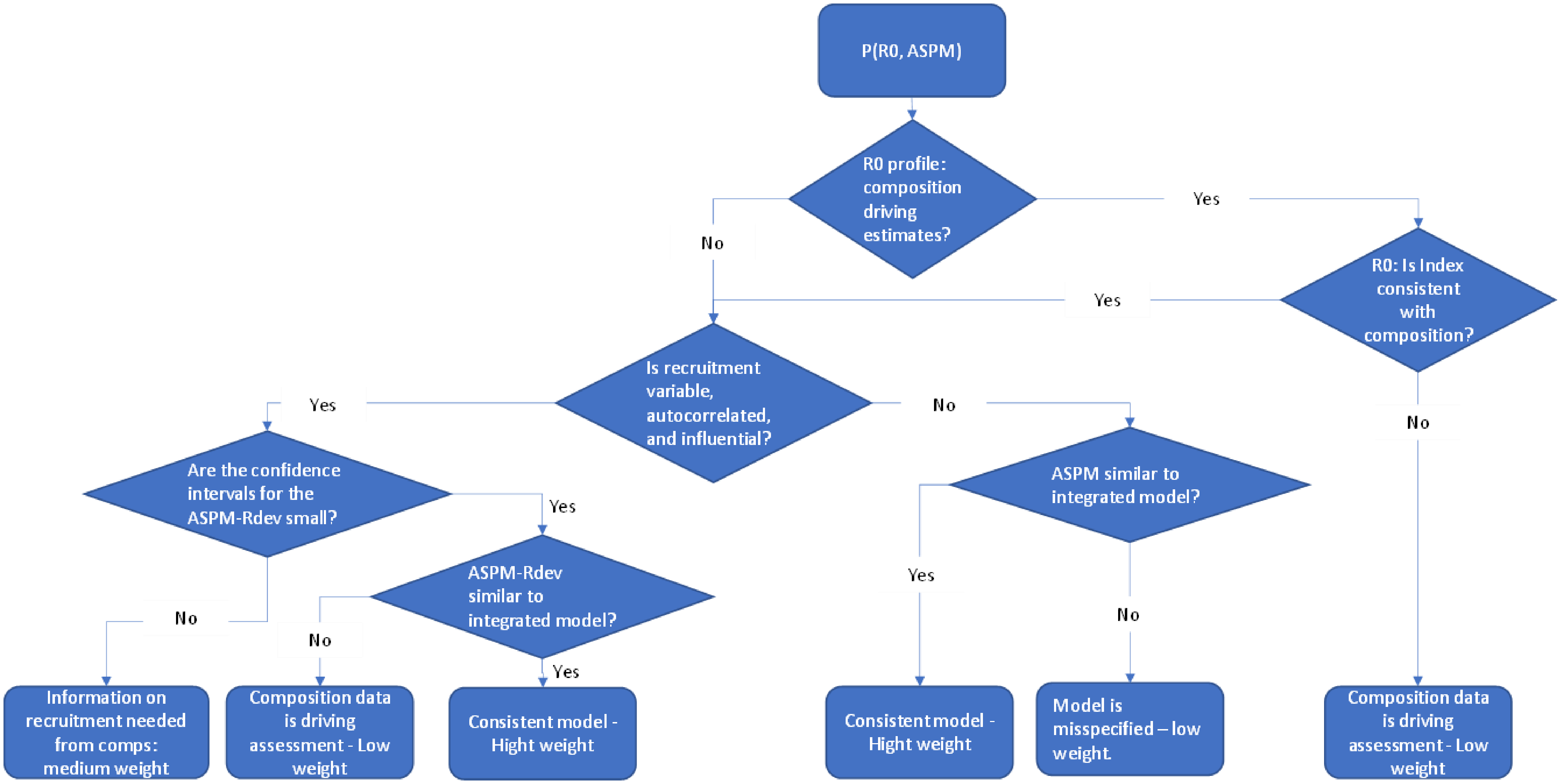
Weighting system: R0 profile and ASPM diagnostic



Weighting system: Assigning and rescaling weights

- When should the weights be rescaled to sum to one
  - Level 1
    - Rescale across all overarching hypotheses
    - Weights will then be multiplied by the weights from the other levels.
  - Level 2
    - Rescale within each sub-level (e.g. A, B, …) within a branch of the hierarchy
    - Exception is model fit with different or down-weighted data.
    - Rescale within groups of models with the same data
  - Level 3
    - Rescale to sum to one within a branch of the hierarchy (i.e. for a given Level 2 hypothesis).

Weighting system: Assigning and rescaling weights

- How to assign the weights for a specific model relative to the other models
  - Level 1
    - W(Expert) relative to all overarching hypotheses.
  - Level 2
    - W(convergence), W(Plausible parameters), W(Plausible results) and W(Diagnostics) relative to all models and hypotheses.
    - W(Fit) relative to models that use the same data independent of branches in the hierarchy
    - W(Expert) relative to models in the same branch of the hierarchy (e.g. assuming a Level 1 overarching hypothesis is true).
  - Level 3
    - Relative to models in the same branch of the hierarchy (i.e. for a given Level 2 hypothesis).

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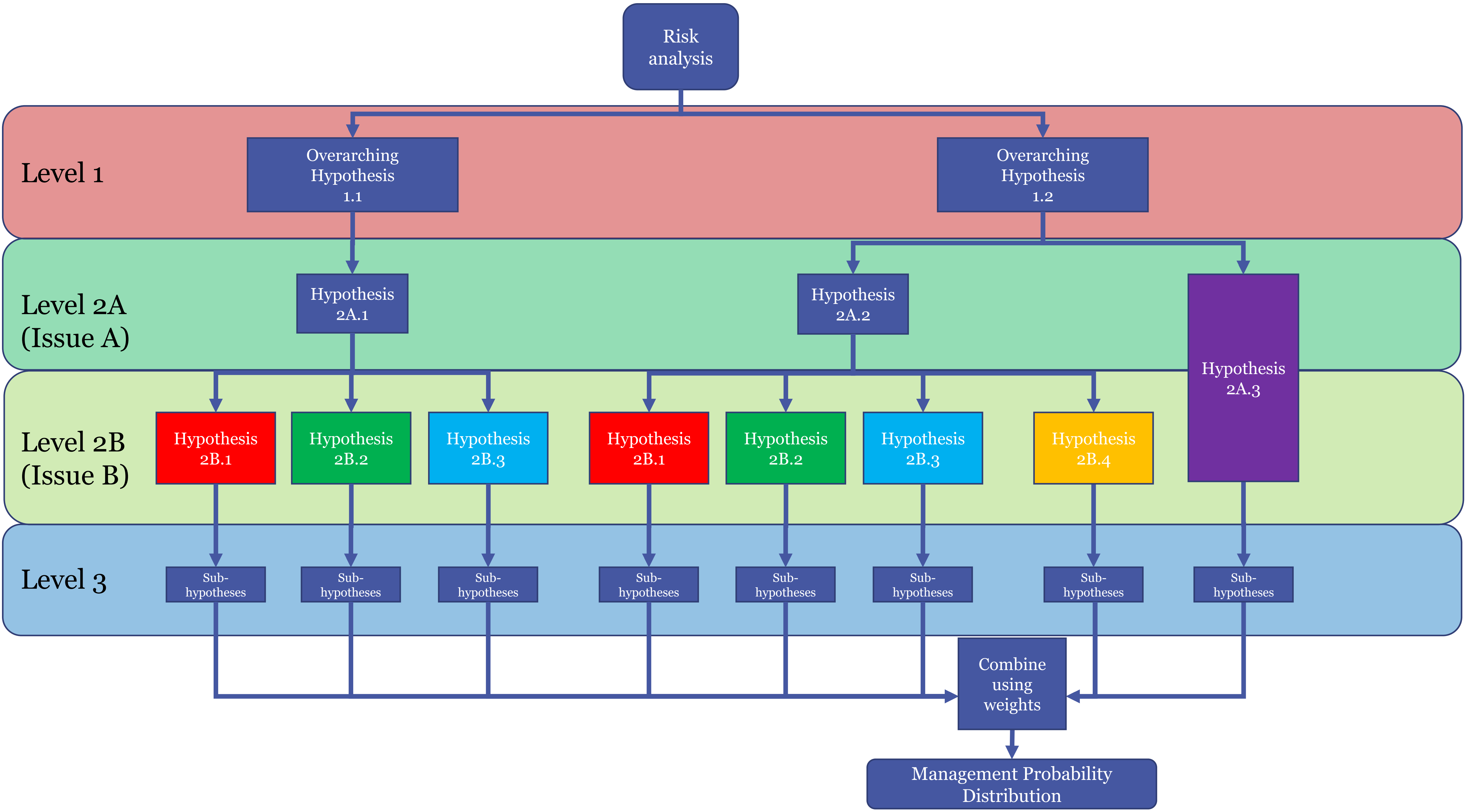
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Management Probability Distribution

Combining probability distributions across models

a) Determine the weight of each model: W(model)

b) Rescale the values from (a): “P(Model = m)”

c) Calculate the probability of the quantity of interest for each model, rescaled so that they sum to one: P(Quantity |Model=m).

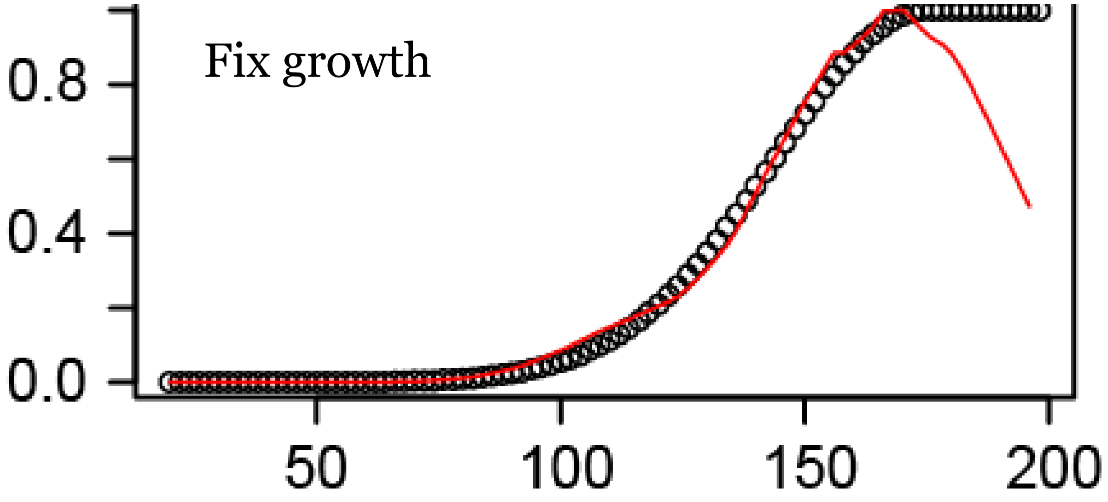
d) Multiply (b) and (c) for each model in the collection and sum across models: P(Quantity).

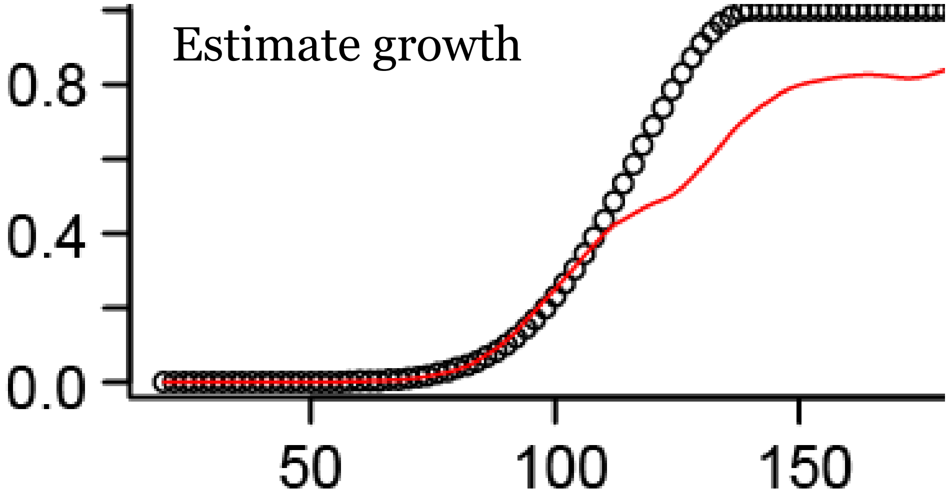
e) Evaluate (d) for all management quantities.

$$P(Quantity) = \sum_{m \in \{Models\}} P(Quantity|Model = m)P(Model = m)$$

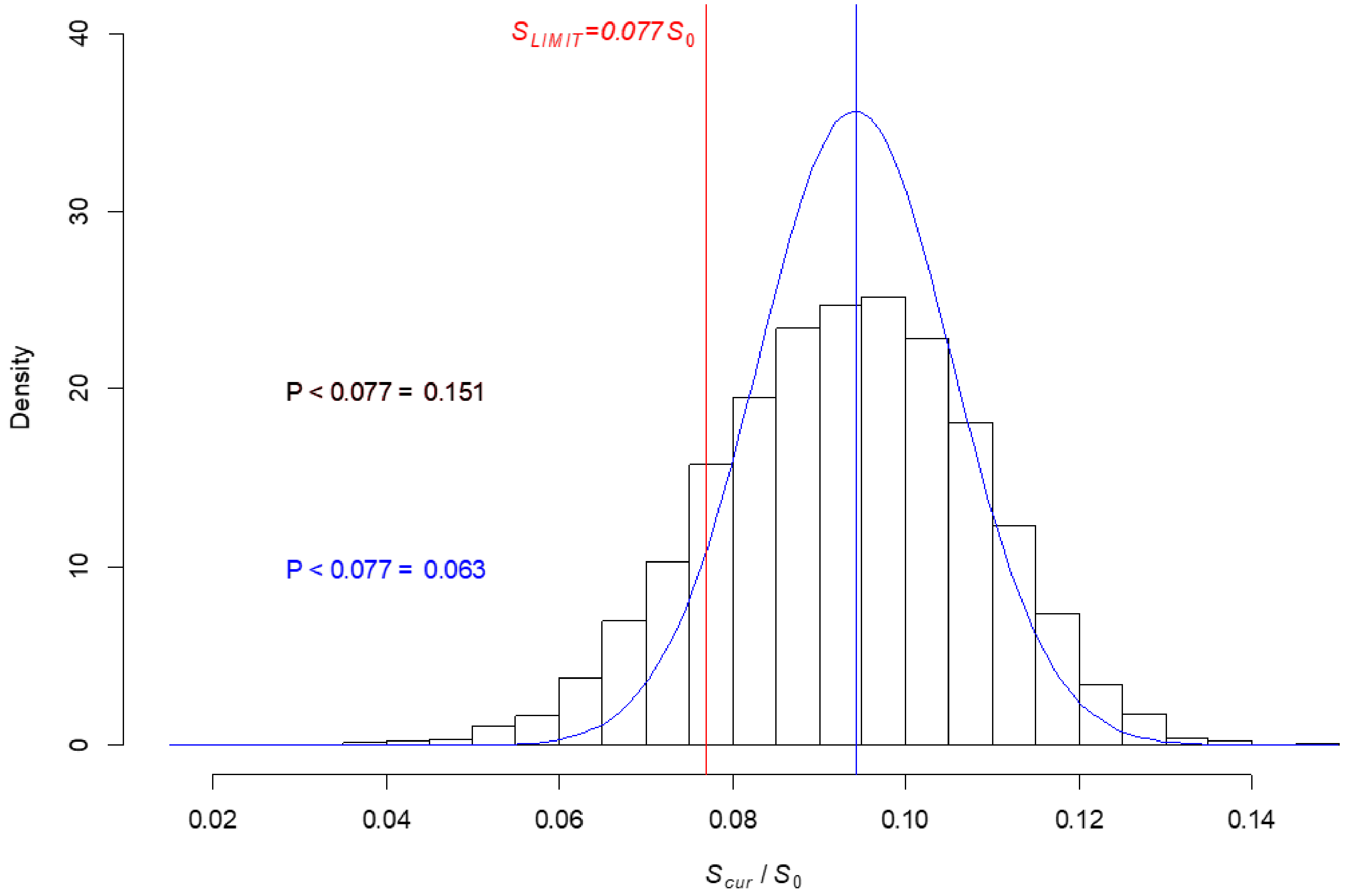
Weighting system: W("Empirical" selectivity)

- Compares "Empirical" selectivity with estimated selectivity
- "Empirical" is the catch at length in numbers divided by the estimated abundance at length in numbers
- Focusses on larger fish which are more influential





Probability distributions: MCMC comparison



Other presentations and documents

1. **Identify alternative hypotheses**
    - YFT: SAC-11-J; BET: SAC-11 INF-F
2. **Implement stock assessment models representing alternative hypotheses**
    - YFT: SAC-11-07; BET: SAC-11-06
3. **Assign relative weights to each hypothesis (model)**
    - YFT: SAC-11 INF-J; BET: SAC-11 INF-F
4. **Compute combined probability distributions for management quantities**
    - SAC-11-08

Documents
https://www.iattc.org/Meetings/Meetings2020/SAC-11/IATTC%20Scientific%20Meeting%20and%20Working%20Groups%202020ENG.htm
Presentations
https://www.youtube.com/playlist?list=PLKeH-azh54PVfbUDbePSLcZvIozGXSHRa

Discussion

- Are we doing ensemble modelling or just model development/selection?
- Need more objective and transparent scoring
- Other diagnostics
  - Posterior predictive checks and Frequentist equivalents
  - One-step-ahead predictions
- We use data for parameter uncertainty but diagnostics for model uncertainty

Introduction: Assessment uncertainty

- Parameter uncertainty
  - Standard practice in stock assessment
  - Confidence intervals on quantities of interest
- Model structure uncertainty
  - Sensitivity analysis
  - Multiple models
  - Combine models
  - Model weights
- Uncertainty about the future (e.g. process variation)
  - E.g. recruitment variation
  - Not implemented yet
  - Can’t evaluate biomass reference points

Presenting results: Decision tables

<table>
<tr><td rowspan="2"></td><td>State of nature</td><td rowspan="2">Total</td></tr>
<tr><td>Probability</td></tr>
<tr><td>Management action</td><td>Outcome</td><td>Outcome</td></tr>
</table>

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Presenting results: Decision tables

<table>
<tr><td rowspan="2"></td><td>Model, group of models, derived quantity</td><td rowspan="2">Total</td></tr>
<tr><td>Probability</td></tr>
<tr><td>Catch, Effort, Closure days</td><td>Catch, Biomass, P(F>F_{LIMIT})</td><td>Outcome</td></tr>
</table>

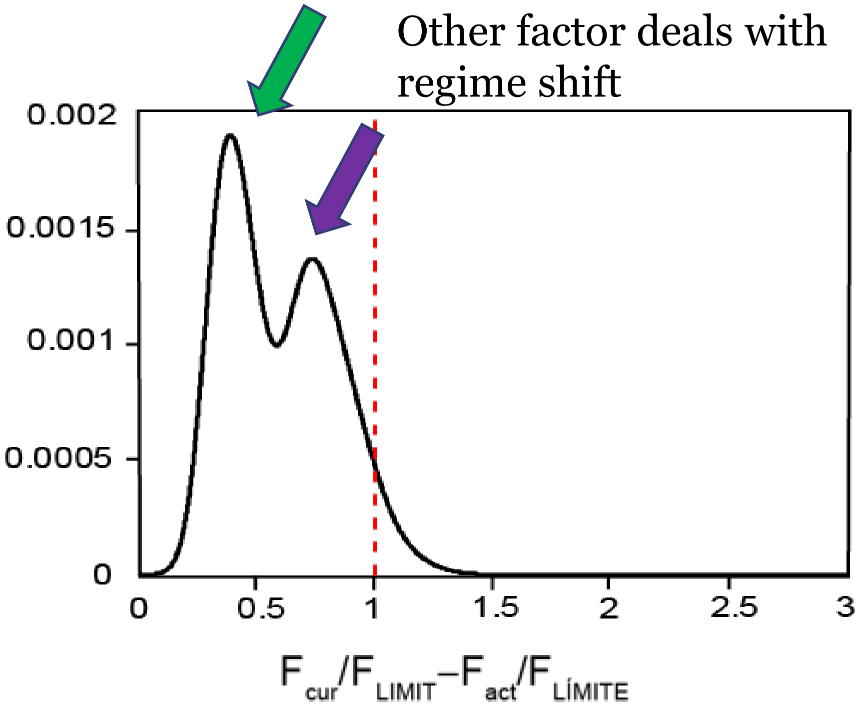
Presenting results: IATTC Risk curves and decision tables

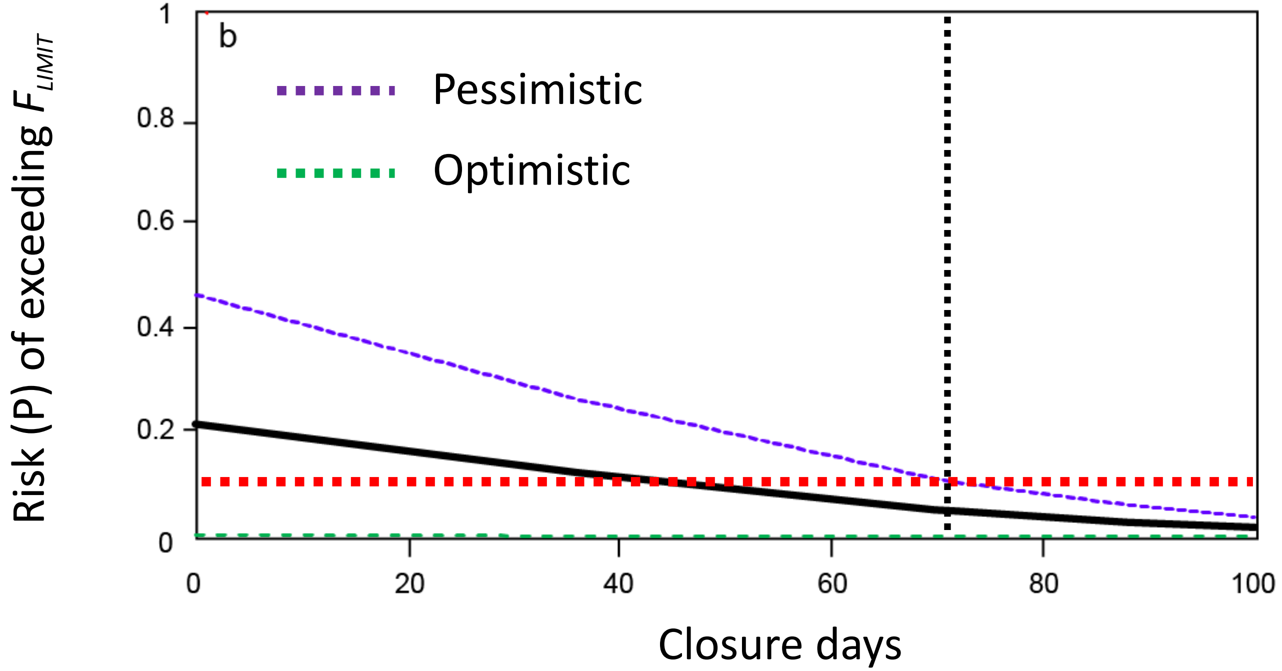
- Outcome of different levels of fishery closures
- Assumes fishing mortality is proportional to the days the fishery is open
  - 365 – days of closure
  - Adjusted for changes in fishing capacity and the Corralito
- $P(F>F_{MSY})$ and $P(F>F_{LIMIT})$
- Need to do projections for spawning biomass so not provided

BET: Risk curves for exceeding F_{LIMIT}

High biomass removes regime shift

Other factor deals with regime shift





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BET: Decision table

Closure days	Env-Fix	Env-Gro	Env-Sel	Env-Mrt	Srt-Fix	Srt-Gro	Srt-Sel	Srt-Mrt	Mov	Gro	Sel	Mrt	Comb
P(model)	0.01	0.13	0.05	0.02	0.04	0.22	0.11	0.07	0.01	0.24	0.09	0.02	
***P*(F>F_{MSY})**											Probability	≤50%	>50%
0	1.00	0.48	0.78	0.98	1.00	1.00	0.99	1.00	0.47	0.09	0.31	0.65	0.62
36	1.00	0.32	0.63	0.93	1.00	0.99	0.97	1.00	0.30	0.03	0.17	0.45	0.56
70	1.00	0.19	0.44	0.84	1.00	0.97	0.92	0.99	0.15	0.01	0.07	0.25	0.50
72	1.00	0.18	0.43	0.83	1.00	0.96	0.91	0.98	0.14	0.01	0.06	0.24	0.49
88	1.00	0.13	0.35	0.75	1.00	0.93	0.87	0.97	0.09	0.00	0.04	0.17	0.46
100	1.00	0.09	0.28	0.67	1.00	0.88	0.81	0.95	0.06	0.00	0.02	0.11	0.43
***P*(F>F_{LIMIT})**											Probability	≤10%	>10%
0	0.97	0.00	0.04	0.17	0.89	0.39	0.37	0.57	0.00	0.00	0.00	0.00	0.21
36	0.79	0.00	0.01	0.06	0.67	0.19	0.18	0.33	0.00	0.00	0.00	0.00	0.12
70	0.33	0.00	0.00	0.01	0.38	0.07	0.06	0.14	0.00	0.00	0.00	0.00	0.05
72	0.30	0.00	0.00	0.01	0.36	0.06	0.06	0.13	0.00	0.00	0.00	0.00	0.05
88	0.11	0.00	0.00	0.00	0.25	0.03	0.03	0.08	0.00	0.00	0.00	0.00	0.03
100	0.04	0.00	0.00	0.00	0.17	0.02	0.02	0.04	0.00	0.00	0.00	0.00	0.02

Weighting system: Reducing the number of models

- All model combinations is impractical
- Some diagnostics are computationally intensive
- Metrics assigned zero eliminate a model
- Eliminating groups of models
  - Define a “base” model
  - The base model is the simpler model
  - If base model is eliminated, then the other models derived from this model are also eliminated
  - Need to consider the reason for the elimination because other models may correct for the reason the base model was eliminated

1. Hierarchy of hypotheses and models

- Level 1: Overarching hypotheses
  - Broad states of nature (e.g. the number of stocks)
  - Represented by a variety of models and data
  - Not evaluated by fit to data
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- Level 2: Hypotheses
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  - Aid in assigning weights

Introduction - Hierarchy of hypotheses and models

- Level 3: Sub-hypotheses
  - Evaluated differently
    - Avoid the influence of data
    - Reduce the number of analyses
    - Convenience
  - Typically encompassed by a single hypothesis
  - Can be represented by restricting a model (e.g. fixing the value of a parameter, such as steepness)
  - Applied to most, if not all, models on Level 2.

2. Defining a weighting system for hypotheses and models

Weighting system: W(Fit)

- Does not use standard AIC rules
- $W(Fit) = Low + (High - Low) \times (1 - [\Delta AIC / \max(\Delta AIC)])$
- Needs same data and same data weighting
- For models with data specific to a parameter (e.g. age at length data for growth), calculate AIC without those data
- Otherwise, models with different data evaluated separately
- Modelled process variability brings additional complications

Outline

- Introduction
- Hierarchy of hypotheses and models
- Weighting system
- Probability distributions for quantities of interest
- Combining probability distributions across models
- Presenting results
- Summary

Summary

- Assessments are uncertain
- IATTC HCR for tropical tunas (Resolution C-16-02) addresses uncertainty through probability statements
- Transition from single base-case assessment to set of reference models
- Hierarchy of hypotheses to define models
- Rigorous statistical framework is not applicable
- Set of metrics to assign model probabilities
- Decision table to present outcome of alternative management actions