# “Meta-evaluation” of fisheries management procedures

Stock Assessment Methods Working Group
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Wellington

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SEAFOOD INDUSTRY COUNCIL

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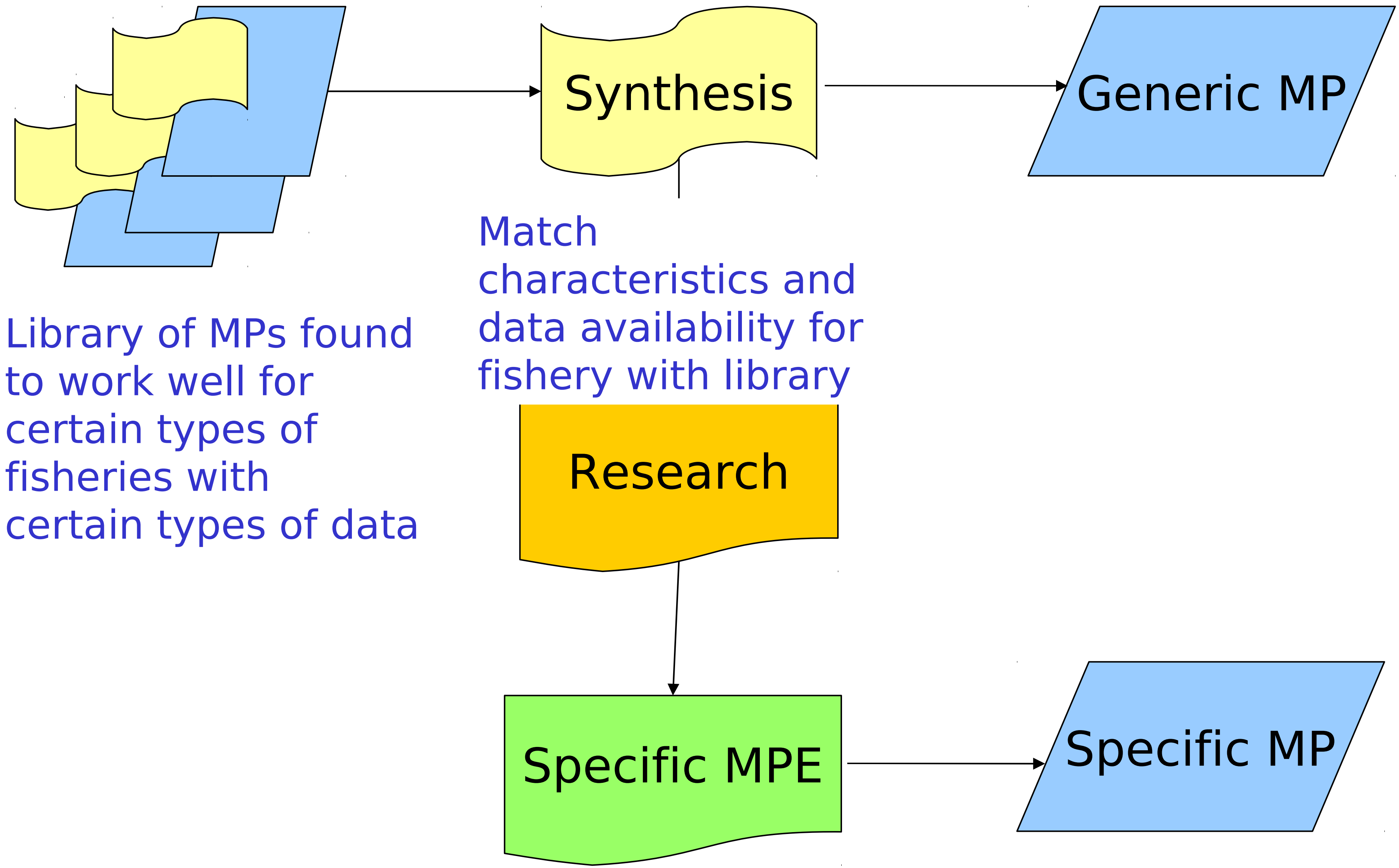
## Generic management procedures

- Develop generic "**off-the-shelf**" management procedures to be applied **in *lieu* of** case specific work
- **Fill the gap** between nothing and full management procedure evaluation
- **Not** attempting to:
    - Find "one-size-fits-all" standards
    - Justify less spending on research and monitoring
    - Say assessments are not needed
- An **interim MP** that can be improved upon some time in the future when data, capacity and funding are available
- Focus on fisheries that have little or no data

# Applying an “off-the-shelf” MP



## Improvement of fishery-management advice through simulation testing of harvest algorithms

J. G. Cooke

Schnute *et al*. (2007) identify the need for a global effort within the stock assessment community to develop software to implement general MSE frameworks. However, an equally important need at present is to identify whether there are "universal laws" which pertain to management strategies. Although they remain to be proved, such rules might include "management strategies based on empirical indicators are more likely than model-based management strategies to respond to major shifts in population abundance albeit at the cost of larger inter-annual variation in catches and stock sizes". A global meta-analytic analysis based on MSEs for a variety of regions could be used to "test" such proposed "laws". The availability of sets of such "laws" could be used for regions for which the resources needed to conduct MSEs are lacking.

### Closing remark

To date, development and testing of harvest algorithms, and in particular the construction of test scenarios, has required a substantial input of labour by the fishery scientists involved. This has been a limiting factor in the application of the approach to fishery management. However, as experience is gained as to which kinds of harvest algorithms work well, and as a "library" of standard test scenarios accumulates, future implementations of the approach to new fisheries may involve little more than fine-tuning of existing algorithms and test scenarios, so that more general use of the approach becomes practicable.

# Refocusing Stock Assessment in Support of Policy Evaluation

André E. Punt

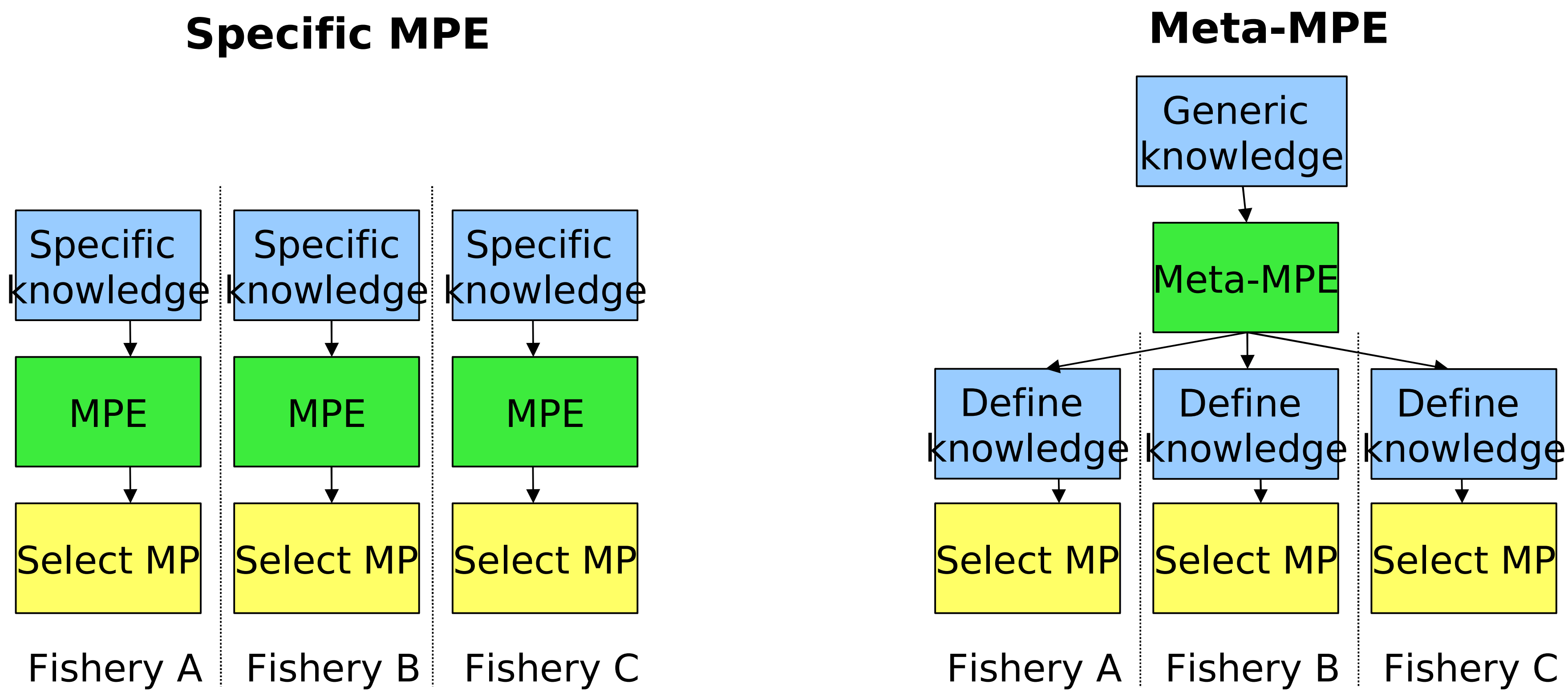
## Knowledge & uncertainty in MPE

- Candidate MPs are evaluated over the range of uncertainty
- Chose MP that performs most robustly **given current knowledge**
- **MP choice** is as much a function of uncertainty as dynamics of the fishery
- With **less uncertainty**, we would have selected a less robust, more optimal MP that **better suits** the actual dynamics of the fishery and which would on average **better achieve management objectives**
- But the best MP in evaluations is the **best choice given current knowledge** and the candidate set of MPs

# Meta-MPE : lumping then splitting

- Meta-MPE: management procedure evaluation using a very **wide range of parameter values** and **operational characteristics** of fisheries
- Just like a specific-MPE except
  - Generalised simulation model capable of dealing with ..
  - Very **wide parameter probability distributions** representing alternative population and fishery dynamics
  - Parameters for alternative **operational characteristics**, e.g.
    - X years of data of type Y with CV of Z
    - X% returned fish die
- Meta-MPE = specific-MPE that we would do if all we '**knew**' about the fishery was "it's a fishery".

# Meta-MPE : lumping then splitting



# Generic simulation model

Simple population dynamics : age structured, single sex

Several types of monitoring and analyses:

Survey: c.v. determined by the management procedure; subject to bias

CPUE: raw (subject to rises in catchability) and “standardised” (not subject to rises in catchability)

Weight, length, age samples: means, weights, Z analyses

Parameterised to allow for “natural” priors:

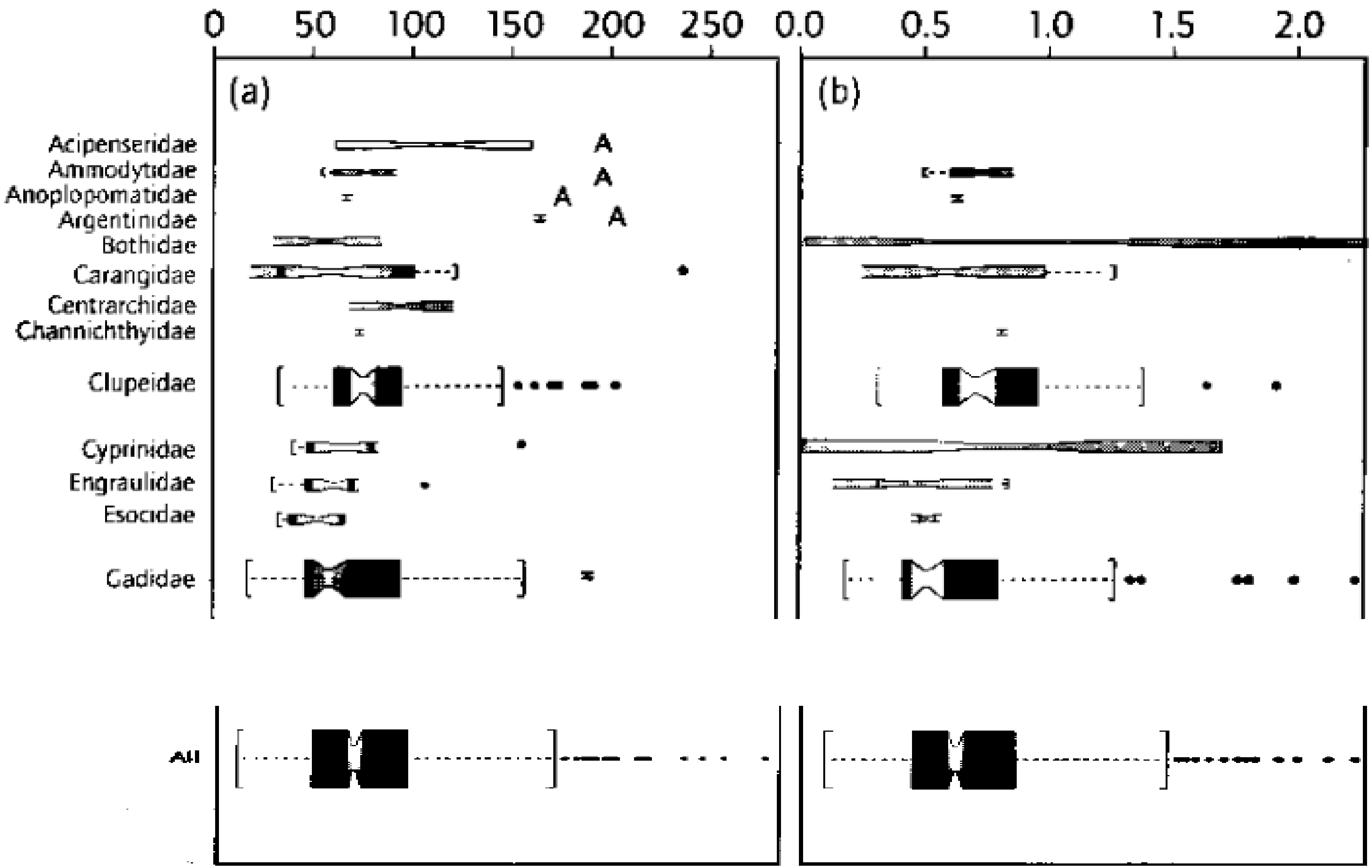
Exploitation history parameterized by:

- when exploitation started: U(0,50)
- when exploitation trend changed U(0,1)
- What exploitation rate was when it changed U(0,1)
- What exploitation rate is now U(0,1)

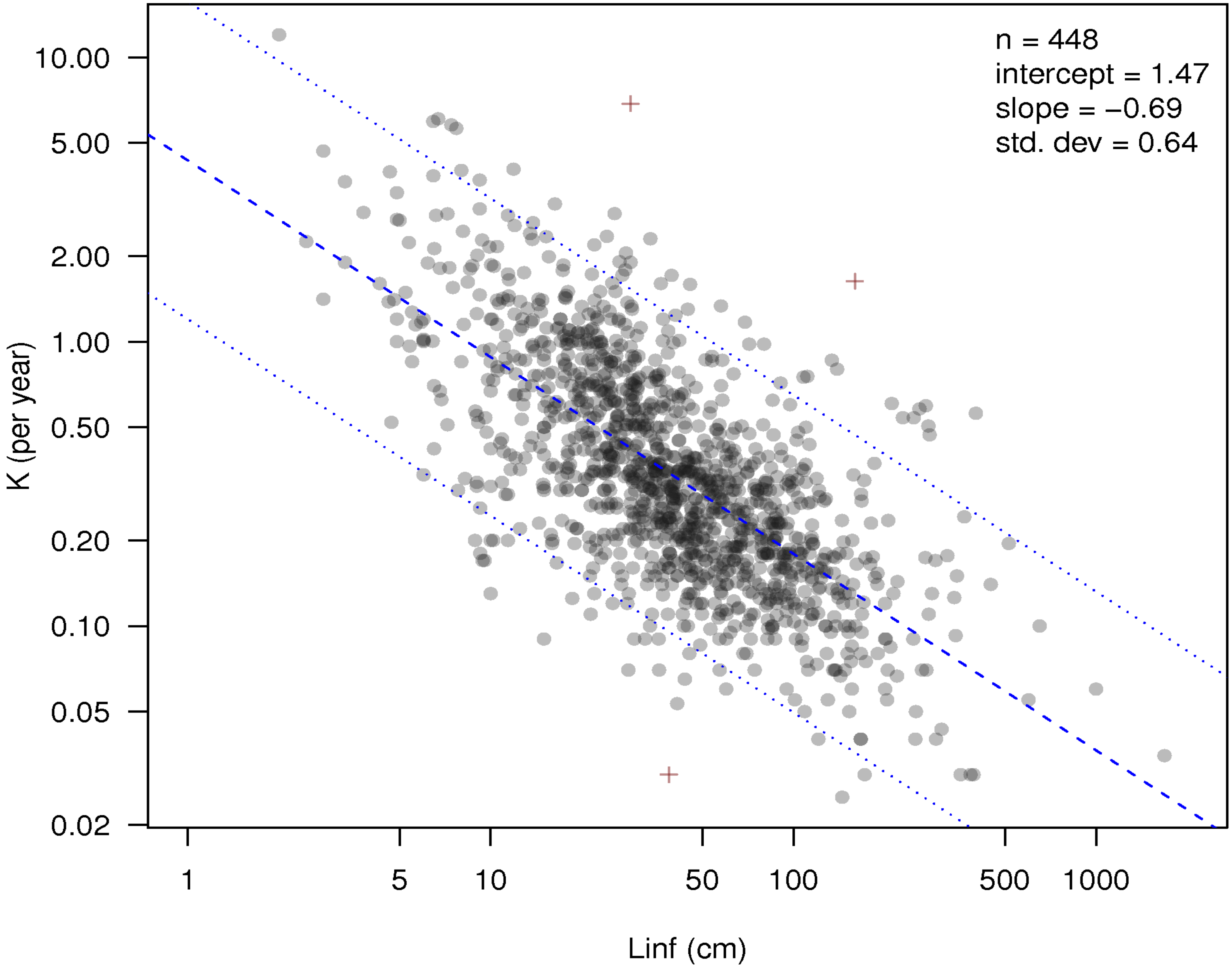
```
struct ZKWeightPerFish{
	//Pauly(1984) p56 eq5.11
	double Winf;
	double Wsel; //The weight at first capture

	double Calculate(const double& weightPerFish){
		double w = pow(weightPerFish,1./3.);
		return (pow(Winf,1./3.)-w)/(w-pow(Wsel,1./3.));
	}
};

struct ZKLengthsMean{
	//Beverton & Holt (1956)
	//Pauly (1984) p55 equ5.9
	double Linf; //Operating Linf
	double Thresh; //The minimum length used for calculating the mean length. Paramete

	double Calculate(const LengthSample& lengths){
		//Calculate the mean length of all fish in the sample greater than LengthCutoff
		double mode = lengths.Mode();
		double thresh = mode*(1+Thresh);
		double mean = lengths.MeanAbove(thresh);
		return (Linf-mean)/(mean-thresh);
	}
};
```

# Generic priors

- Generalizations of the knowledge from data-rich stocks are helpful for data-poor stocks
- Examples of **meta-analysis**, **life history theory** for fish: e.g.
  - Pauly (1980) M-growth-temperature relation
  - Charnov (1993) “life history invariants”
  - Myers et al (1999) stock-recruitment database
  - Harley et al (2001) hyper-stability/depletion of CPUE
- FishBase – database of life history characteristics of many fish species



0
50
100
150
200
250
0.0
0.5
1.0
1.5
2.0
(a)
(b)
Acipenseridae
Ammodytidae
Anoplopomatidae
Argentinidae
Bothidae
Carangidae
Centrarchidae
Channichthyidae
Clupeidae
Cyprinidae
Engraulidae
Esocidae
Gadidae
A
A
A
A
All


n = 448
intercept = 1.47
slope = −0.69
std. dev = 0.64
K (per year)
10.00
5.00
2.00
1.00
0.50
0.20
0.10
0.05
0.02
1
5
10
50
100
500
1000
Linf (cm)

**Abstract**—Priors are existing information or beliefs that are needed in Bayesian analysis. Informative priors are important in obtaining the Bayesian posterior distributions for estimated parameters in stock assessment. In the case of the steepness parameter ($h$), the need for an informative prior is particularly important because it determines the stock-recruitment relationships in the model. However, specifications of the priors for the $h$ parameter are often subjective. We used a simple population model to derive $h$ priors based on life history considerations. The model was based on the evolutionary principle that persistence of any species, given its life history (i.e., natural mortality rate) and its exposure to recruitment variability, requires a minimum recruitment compensation that enables the species to rebound consistently from low critical abundances ($N_c$). Using the model, we

# A prior for steepness in stock-recruitment relationships, based on an evolutionary persistence principle

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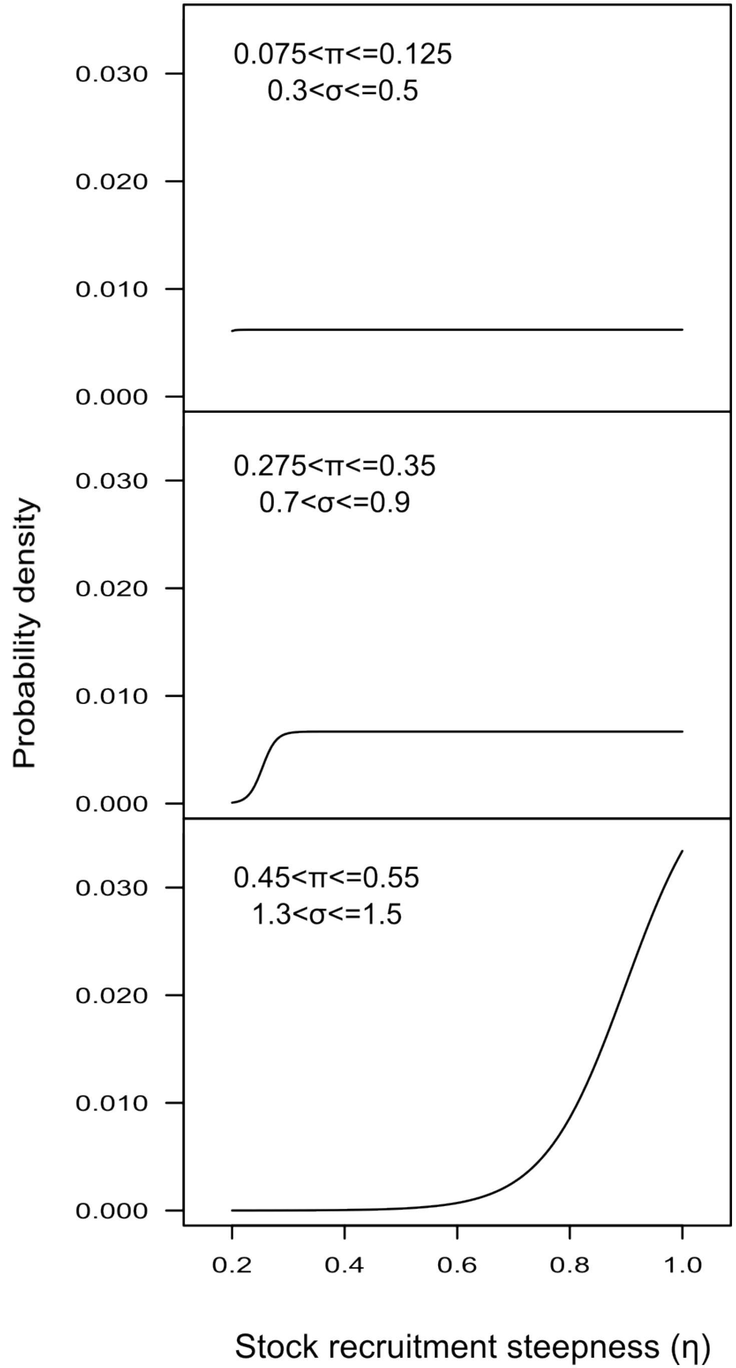


0.075<π<=0.125
0.3<σ<=0.5
0.275<π<=0.35
0.7<σ<=0.9
0.45<π<=0.55
1.3<σ<=1.5
Probability density
0.000
0.010
0.020
0.030
0.2
0.4
0.6
0.8
1.0
Stock recruitment steepness (η)

# Generic knowledge: allows for “imputation”

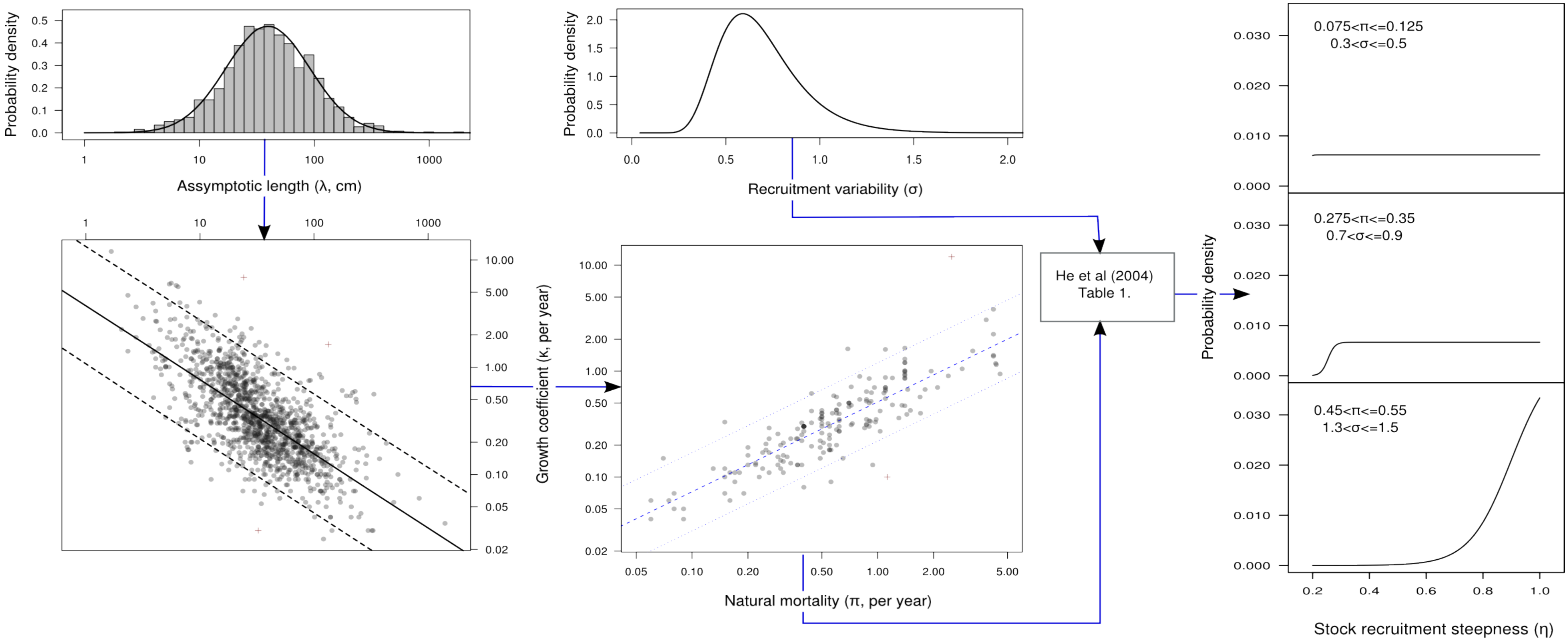
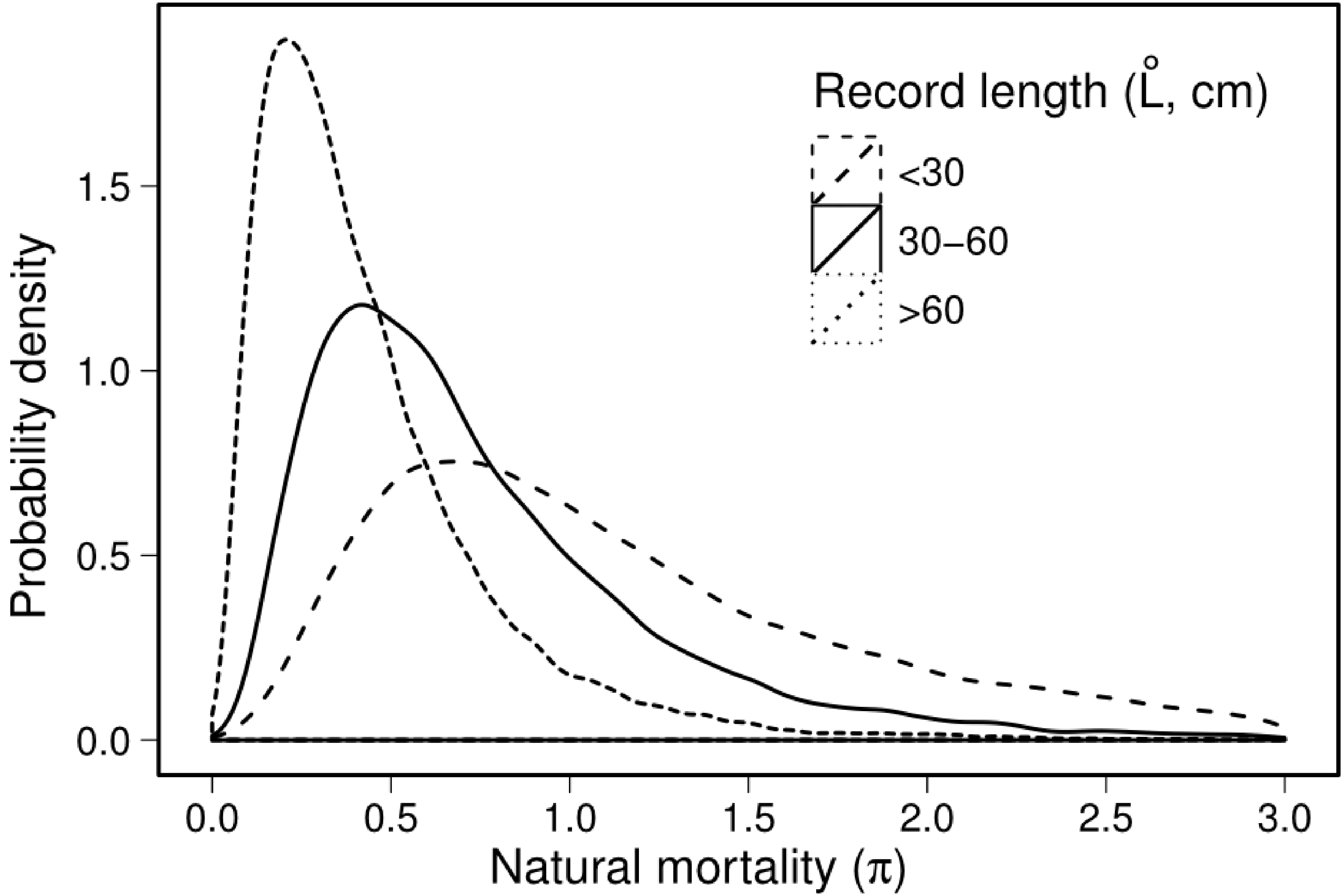


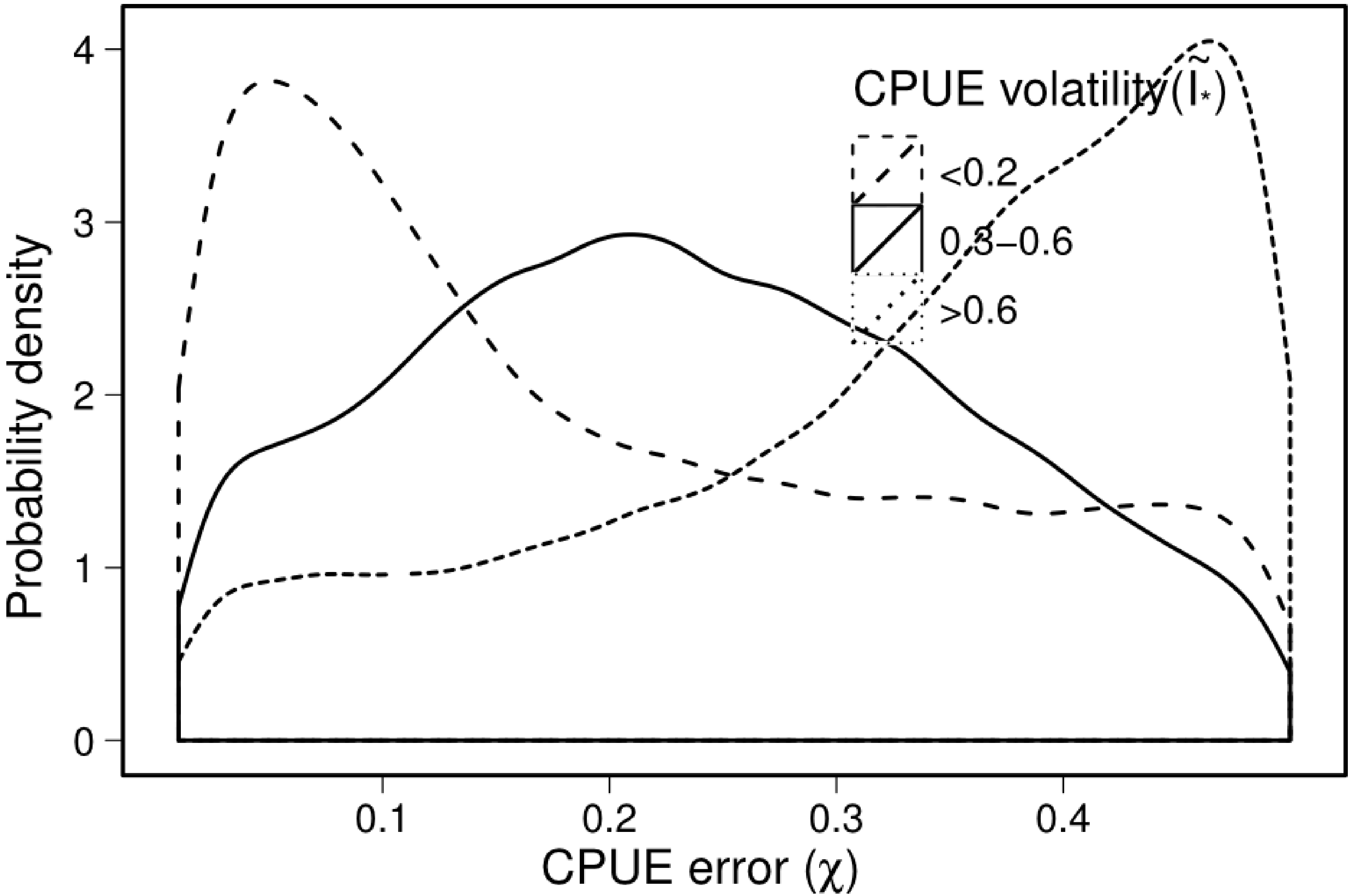
**Table 4: Parameter priors used in the meta-evaluation and partition analysis. Where a single value is given it indicates a fixed values was used for a parameter. Prior distribution types and their parameters are, B: Beta(alpha,beta), U: Uniform(min,max), LU: Log-uniform(min,max), LN: Lognormal(mean,sd), *:Indicates that the 'default' prior defined in Bentley & Stokes (in prep a) was used.**

| | Symbol | Prior |
|---|---|---|
| ***Biological parameters*** | | |
| Asymptotic length | $\lambda$ | See Table 5 |
| Growth rate coefficient | $\kappa$ | Relationship with $\lambda$ see Table 5 |
| Age at which length is zero | $\tau$ | U(-6,0) |
| Coefficient of variation of length at age | $\varrho$ | LU(0.05,0.5)* |
| Instantaneous rate of natural mortality | $\pi$ | Relationship with $\kappa$ see Table 6 |
| Intercept of the length weight relationship | $\alpha$ | U(0.01,0.04) |
| Exponent of the length weight relationship | $\beta$ | U(2.7,3.3) |
| Length at 50% maturity (as a fraction of asymptotic length) | $\gamma$ | U(0.5,0.7) |
| Steepness of maturity ogive | $\delta$ | U(0,1)* |
| Standard deviation of recruitment deviates | $\sigma$ | LN(0.6,0.2)* |
| Autocorrelation of recruitment deviates | $\varsigma$ | LU(0.01,0.7) |

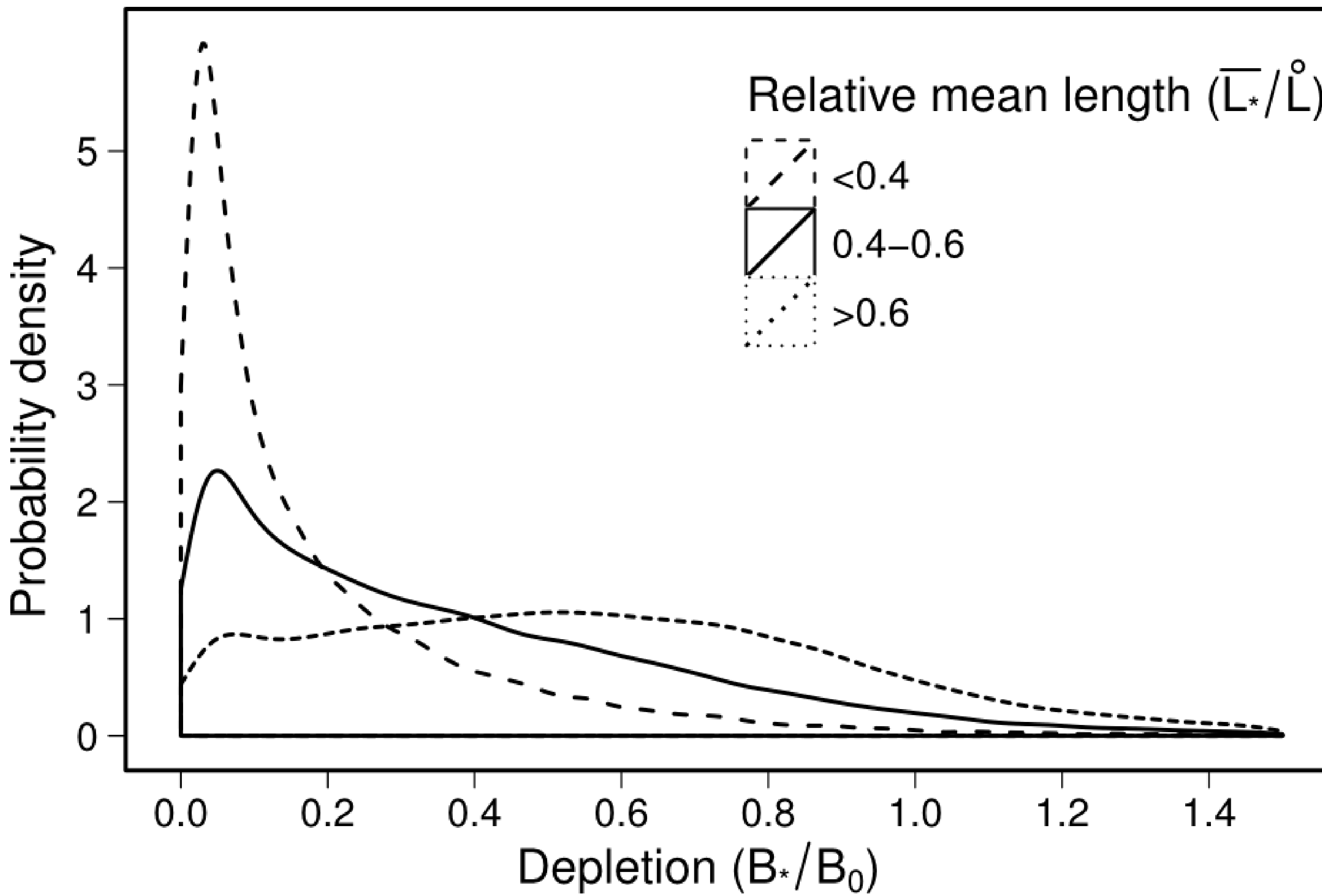
| | |
|---|---|
| **CatchNowMean** | Current catch relative to mean catch |
| **CatchNowMax** | Current catch relative to maximum catch |
| **CpueSlope** | Slope of CPUE over entire series |
| **CpueSlope10** | Slope of CPUE in last 10 years |
| **CpueSlope5** | Slope of CPUE in last 5 years |
| **CpueCoeffVari** | Coefficient of variation in CPUE |
| **CpueVariability** | Average annual variation in CPUE (%) |
| **CpueVolatility** | Inter-annual volatility (sd of log changes) |
| **WeightsQ10** | Current 10$^{th}$ percentile of weight of caught fish |
| **WeightsMedian** | Current median weight of caught fish |
| **WeightsMode** | Current mode of weight of caught fish |
| **WeightsMean** | Current mean of weight of caught fish |
| **WeightsQ90** | Current 90$^{th}$ percentile of weight of caught fish |
| **WeightsMax** | Current max of weight of caught fish |
| **LengthsQ10** | Current 10th percentile of length of caught fish |
| **LengthsMedian** | Current median length of caught fish |
| **LengthsMode** | Current mode of length of caught fish |
| **LengthsMean** | Current mean of length of caught fish |
| **LengthsQ90** | Current 90th percentile of length of caught fish |
| **LengthsMax** | Current max of length of caught fish |
| **AgesQ10** | Current 10th percentile of ages of caught fish |
| **AgesMedian** | Current median ages of caught fish |
| **AgesMode** | Current mode of ages of caught fish |
| **AgesMean** | Current mean of ages of caught fish |
| **AgesQ90** | Current 90th percentile of ages of caught fish |
| **Bnow** | Estimate of current spawning biomass relative to virgin spawning biomass |



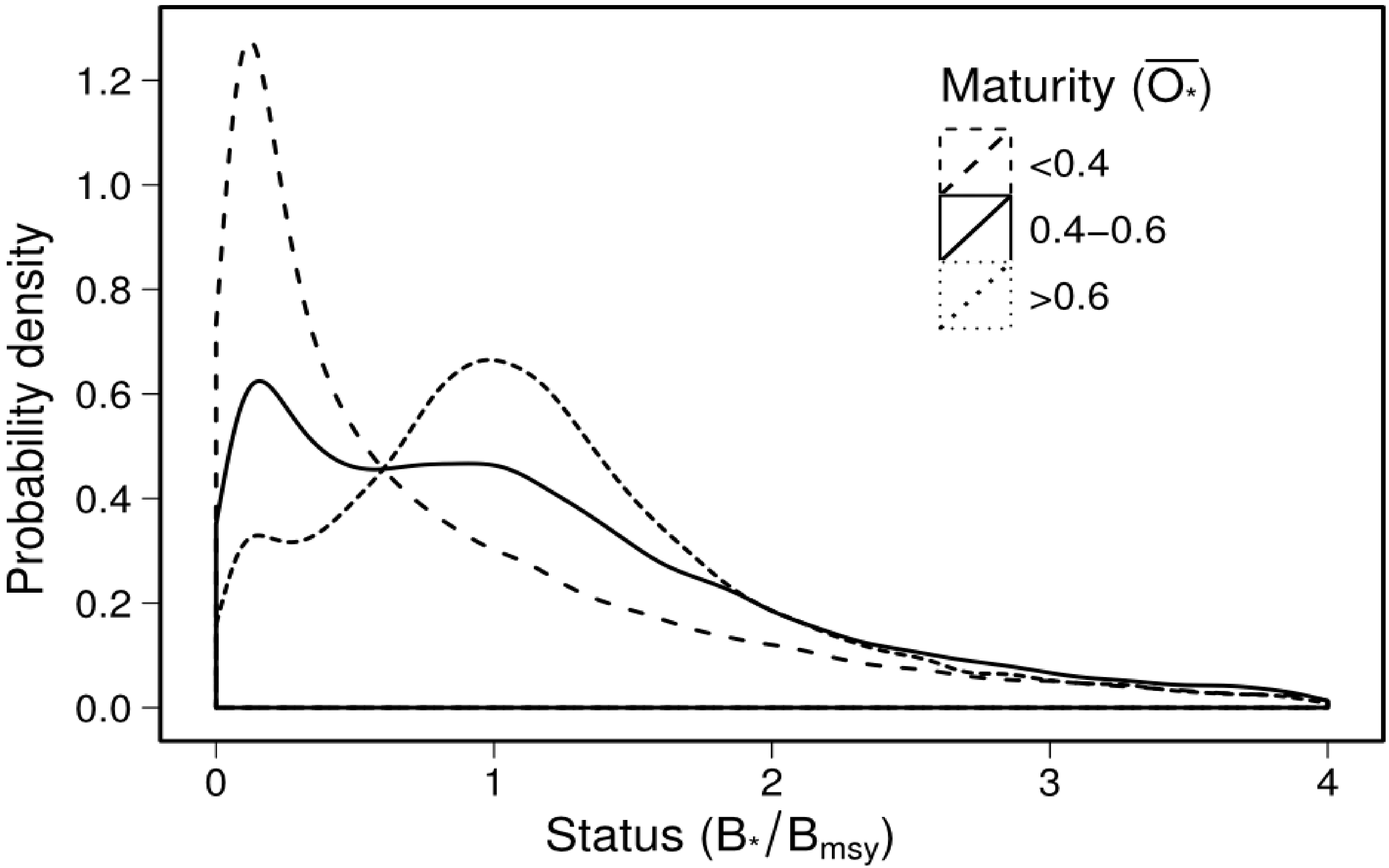
Record length (L̊, cm)
<30
30–60
>60
Probability density
0.0
0.5
1.0
1.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Natural mortality (π)



CPUE volatility ($\tilde{I}_*$)
<0.2
0.3–0.6
>0.6
Probability density
0
1
2
3
4
0.1
0.2
0.3
0.4
CPUE error ($\chi$)



Relative mean length ($\overline{L_*}/\mathring{L}$)
<0.4
0.4–0.6
>0.6
Probability density
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Depletion ($B_*/B_0$)



Maturity ($\overline{O_*}$)
<0.4
0.4–0.6
>0.6
Probability density
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
1
2
3
4
Status ($B_*/B_{msy}$)

# Generic management procedures

- Already several **classes** of management procedure developed for fisheries around the world
- Most MP classes are **already fairly generic** – have **parameters that can be tuned** to suit different fisheries
- To be used in meta-MPE framework need to be implemented (in computer programming code) so that they
  - **work under a wide range of possible scenarios**
  - **work with a variety of data sources**
- For this project implemented a limited number of MP classes: that illustrate a range of data requirements:
  - **PRAC** (Proportion of recent average catch): Fixed TACC
  - **PHER** (Proportion of historical exploitation rate): CPUE or survey only
  - **TRZK** (Target range for Z/K): mean weight, mean length or age frequency only
  - **MAST** (Matrix of abundance and size trends): CPUE or survey and mean length data

## Management procedures classes: e.g. MAST

- Each class has **control parameters** that can be adjusted
- Operated every ***f*** years
- Changes TACC up or down by **a fixed proportion (*c*)**
- Based on **trends in size and abundance** over **fixed time horizon** (***h*** years)
- Separate thresholds for what is considered a significant up or down trend in abundance or size
- Can use alternative sources of data for abundance – survey or CPUE

# Management procedure instances

- A specific MP class with a certain set of control parameters is an **instance**
- **MAST(2,5,3,0.05,50,0.2,0.1)** =
  - operated every **2** years
  - trends calculated over previous **5** years
  - abundance index from survey (**3**)
  - abundance trend significant if greater than +/- 5%
  - mean length based on effective sample size of 50 fish
  - mean length trend significant if greater than +/- 20%
  - change in TACC of +/-10%
- For each MP class tested about 1700 instances (combinations of parameters)


Weight based
Length based
Age based
0
1
4
5
6
7
Estimated mortality ratio (Z/K)
Year
Method
1
2
3

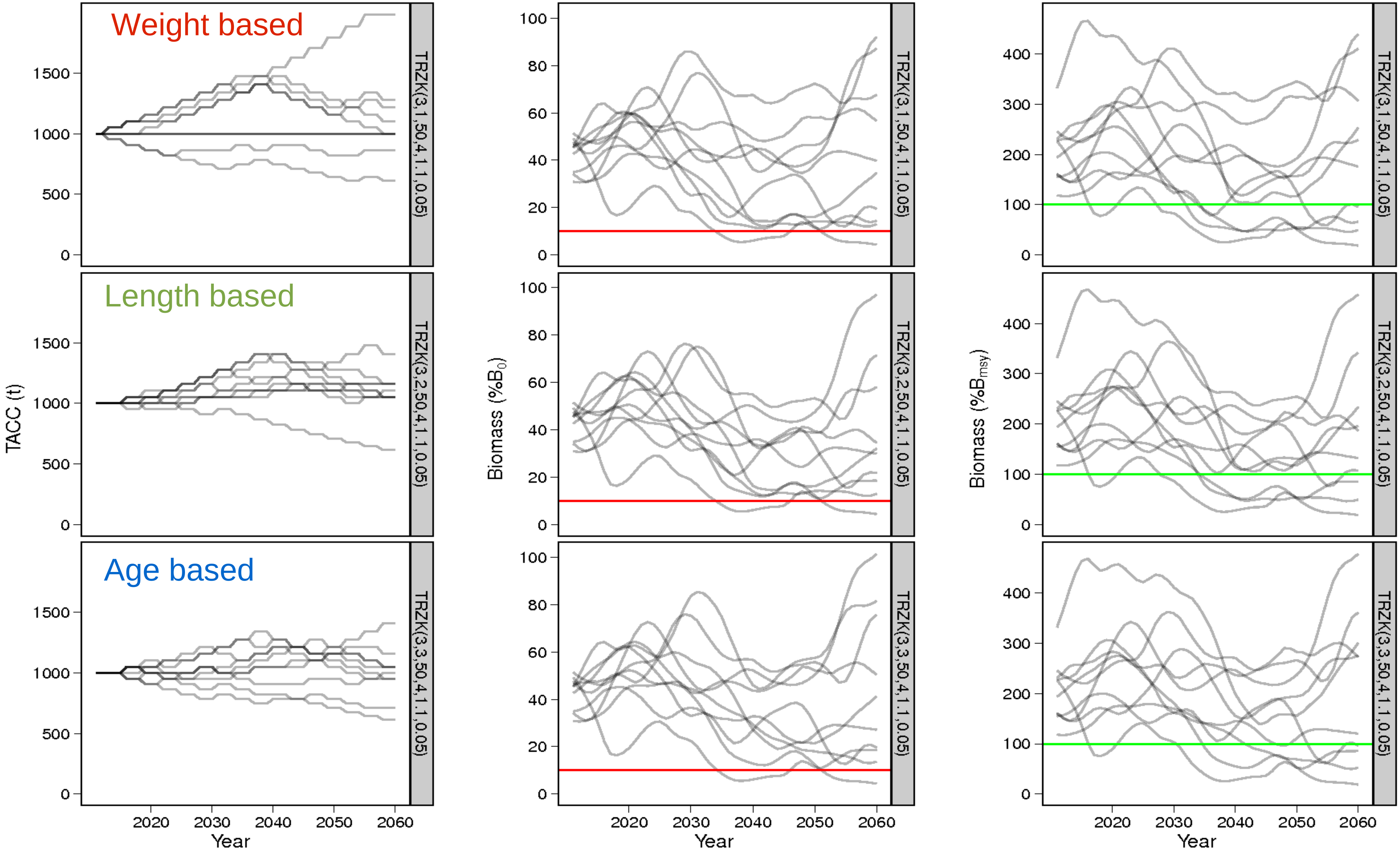
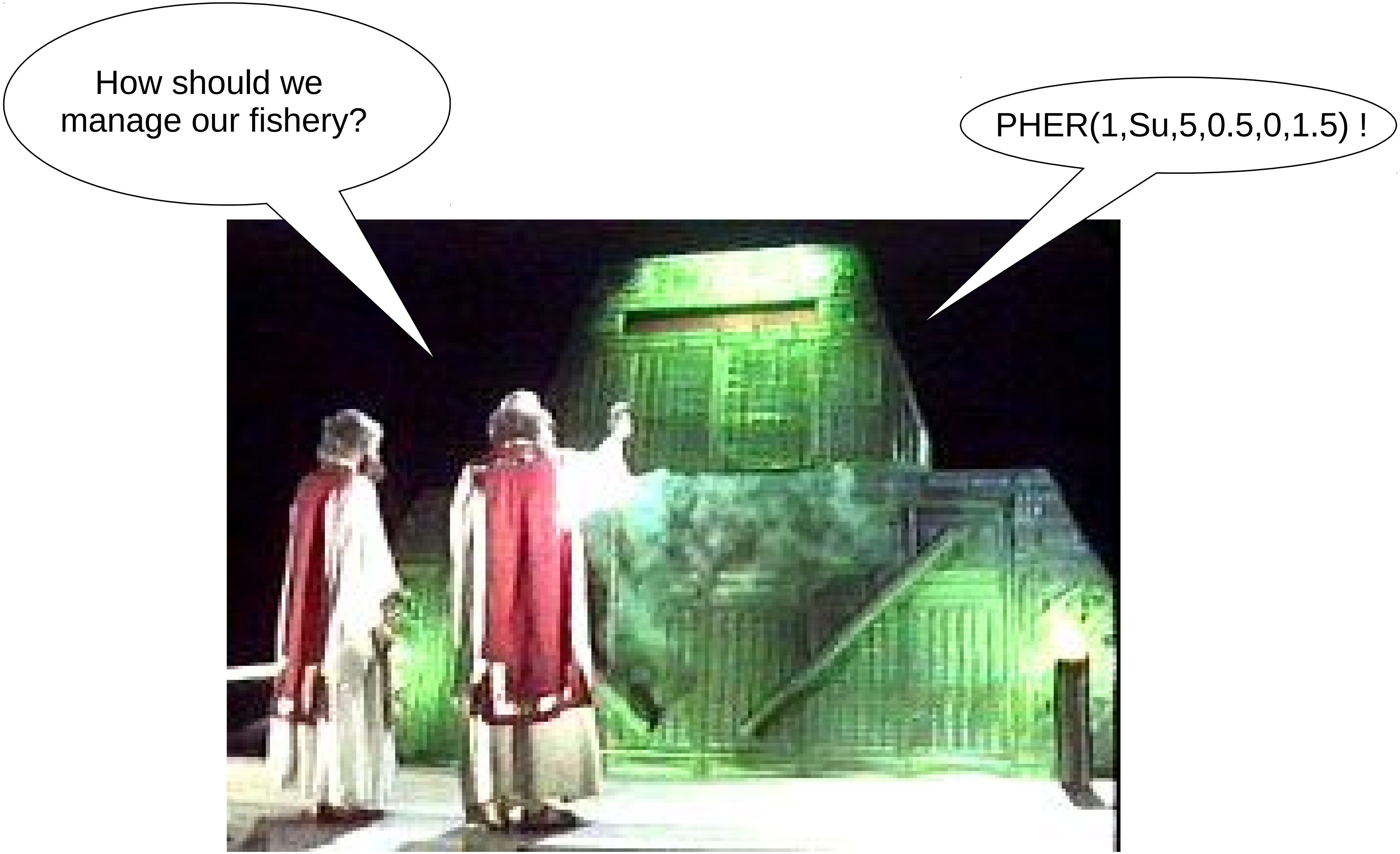
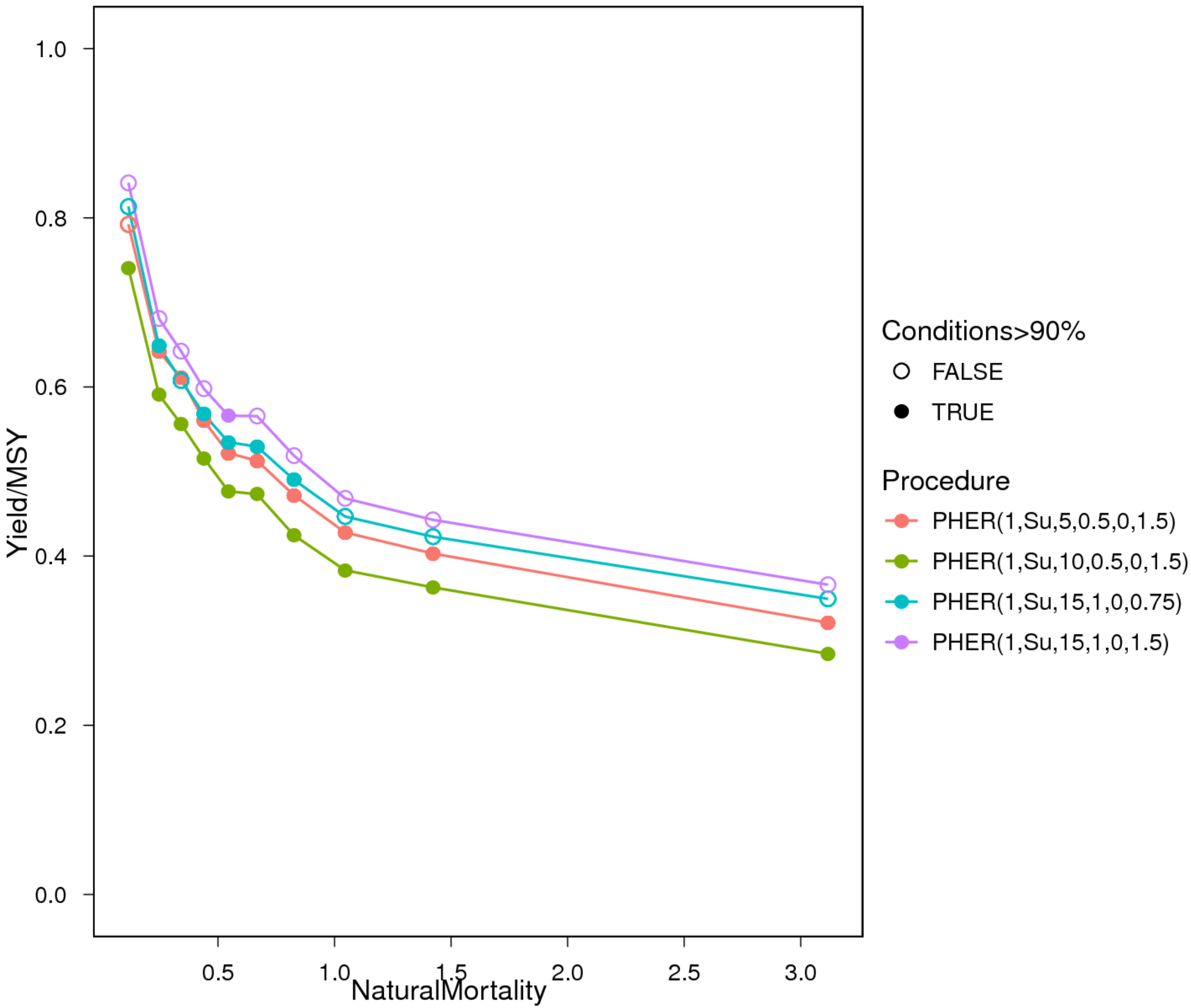

Weight based
Length based
Age based
TACC (t)
Biomass (%$B_0$)
Biomass (%$B_{msy}$)
Year
TRZK(3,1,50,4,1,1,0.05)
TRZK(3,2,50,4,1,1,0.05)
TRZK(3,3,50,4,1,1,0.05)
0
500
1000
1500
20
40
60
80
100
200
300
400
2020
2030
2040
2050
2060

**Table 3: The number of instances, and combinations of control parameter evaluated, for each class of management procedure.**

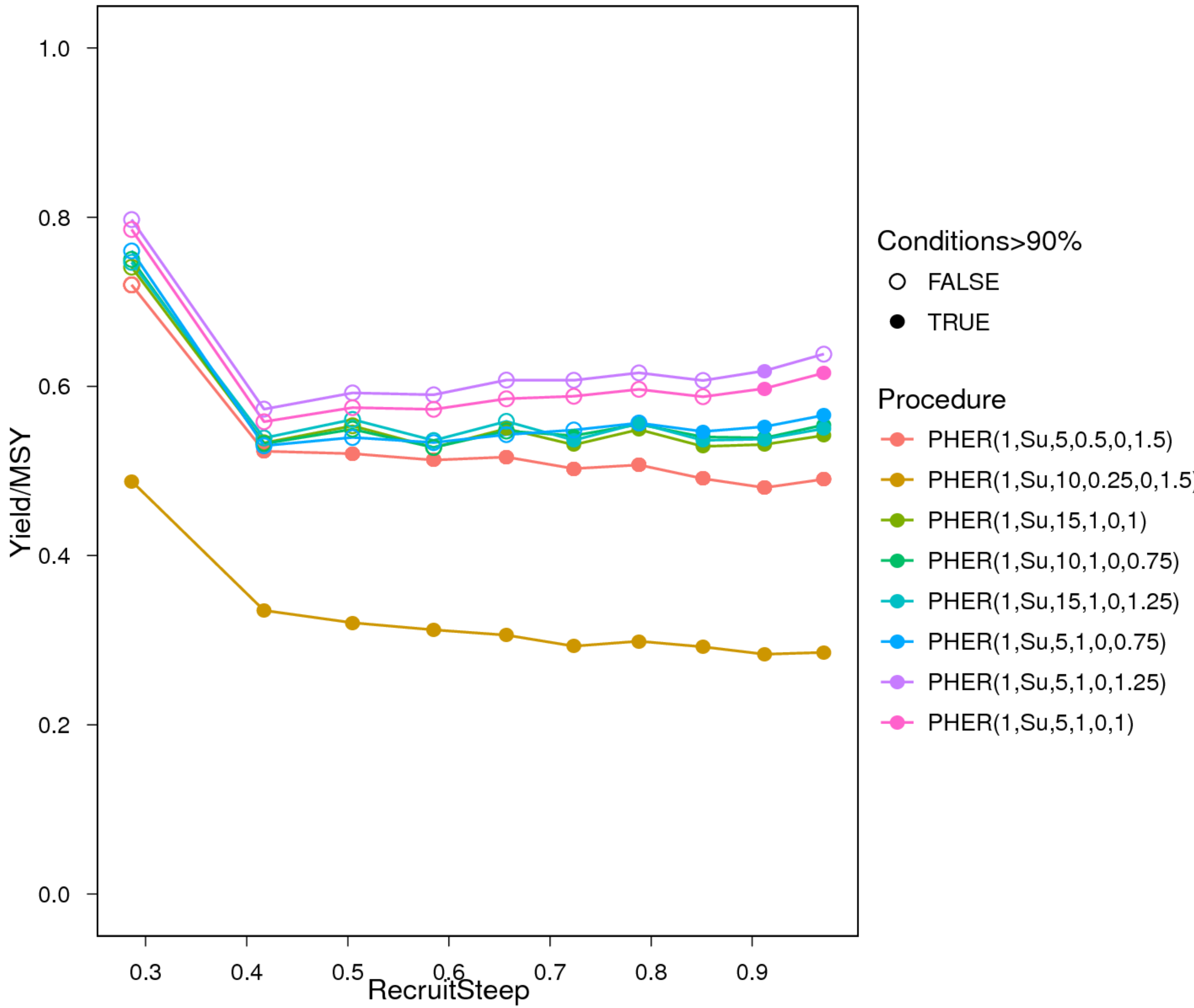
| PRAC | PHER | TRZK | MAST |
|---|---|---|---|
| Instances: 31 | Instances: 1728 | Instances: 1728 | Instances: 1728 |
| Horizon (*h*): 5 | Frequency (*f*): 1,2,3 | Frequency (*f*): 1,2,3 | Frequency (*f*): 1,2,3 |
| Multiplier (*m*): (0.035,0.044,...,0.8,1,1.25,...,22.73,28.42) | Source (*s*): 1 (unstandardized CPUE), 2 (standardized CPUE), 3 (survey) | Source (*s*): 1 (mean weight), 2 (mean length), 3 (age frequency) | Horizon (*h*): 3,5,10 |
| | Horizon (*h*): 5,10,15 | Precision (*p*): 0.1,0.2,0.3 | Abundance method (*m*): 1,2,3 |
| | Ratio multiplier (*r*): 0.25,0.5,1,1.5 | Midpoint (*m*): 1,2,3,4 | Abundance threshold (*a*): 0.05,0.1,0.2,0.4 |
| | Lower multiplier (*l*): 0,0.25,0.5,1 | Range (*r*): 1.1,1.25,1.5,2 | Size precision (*p*): 0.3 |
| | Upper multiplier (*u*): 0.75,1,1.25,1.5 | Change (*c*): 0.05,0.1,0.2,0.4 | Size threshold (*s*): 0.05,0.1,0.2,0.4 |

5215 MPs x 100000 parameter replicates
= 52 million, 50 year evaluations
= ~ 4hrs computing time
= 6.4 Gb file of performance statistics

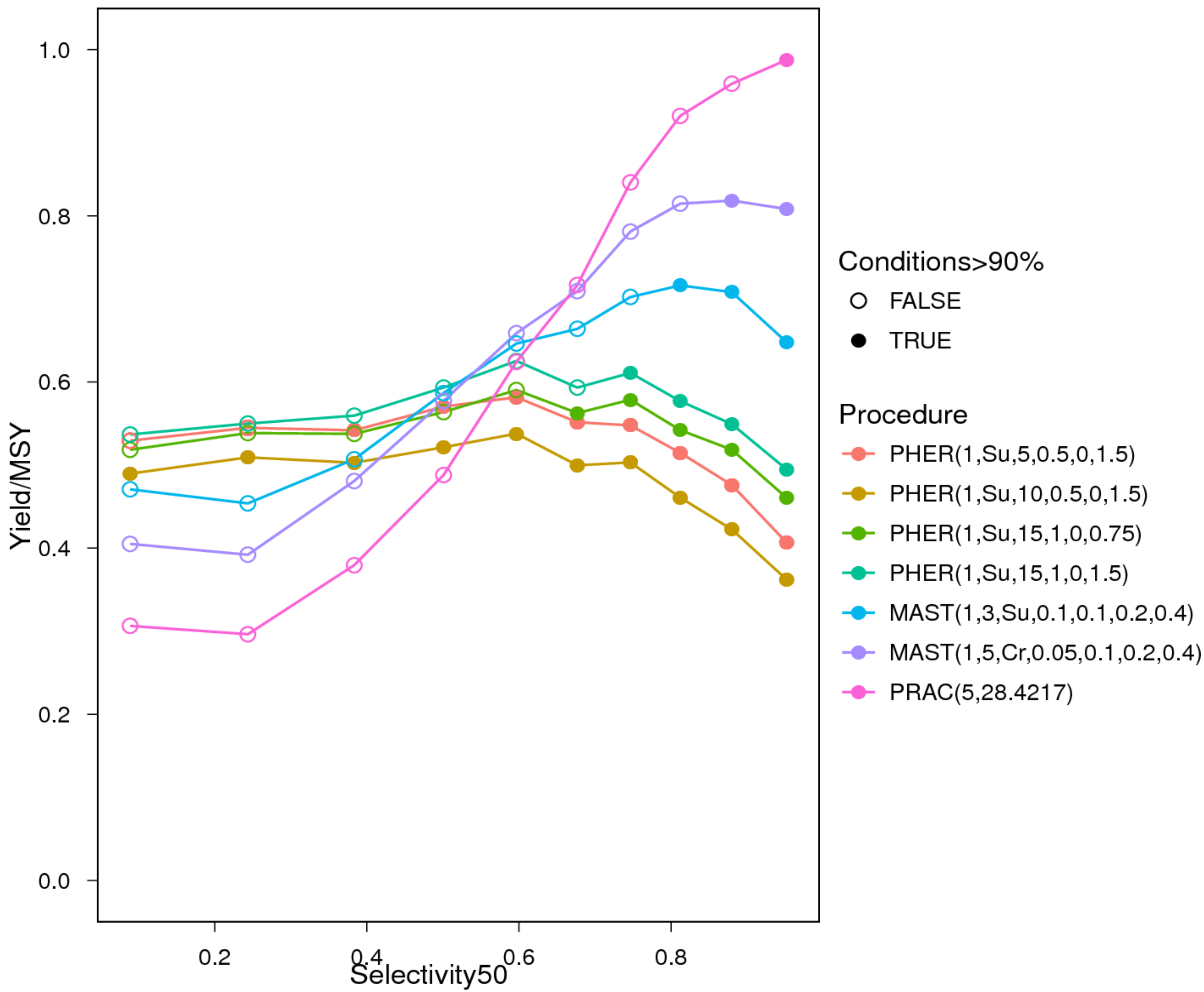

How should we manage our fishery?
PHER(1,Su,5,0.5,0,1.5) !

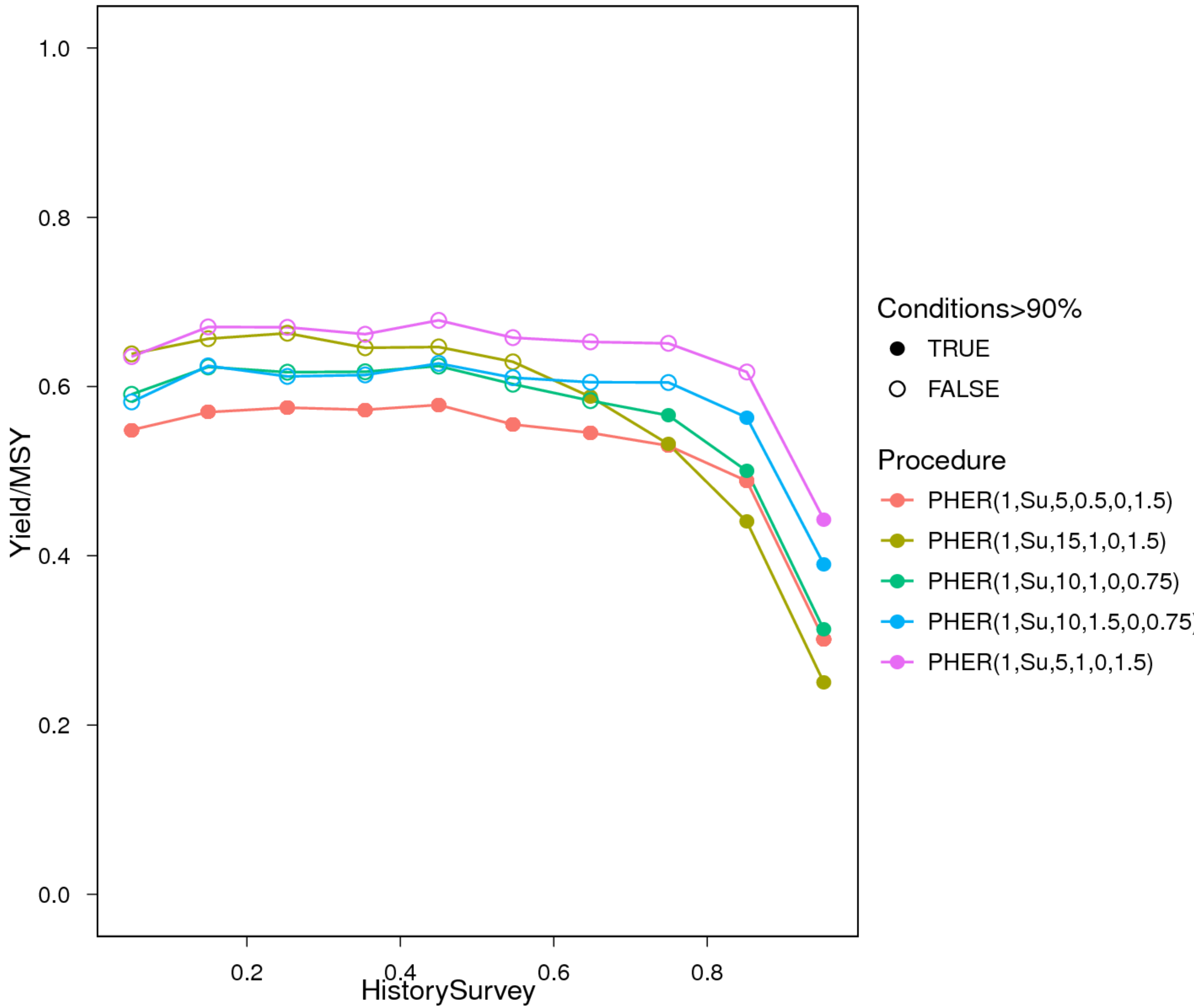


1.0
0.8
0.6
0.4
0.2
0.0
Yield/MSY
0.5
1.0
1.5
2.0
2.5
3.0
NaturalMortality
Conditions>90%
FALSE
TRUE
Procedure
PHER(1,Su,5,0.5,0,1.5)
PHER(1,Su,10,0.5,0,1.5)
PHER(1,Su,15,1,0,0.75)
PHER(1,Su,15,1,0,1.5)



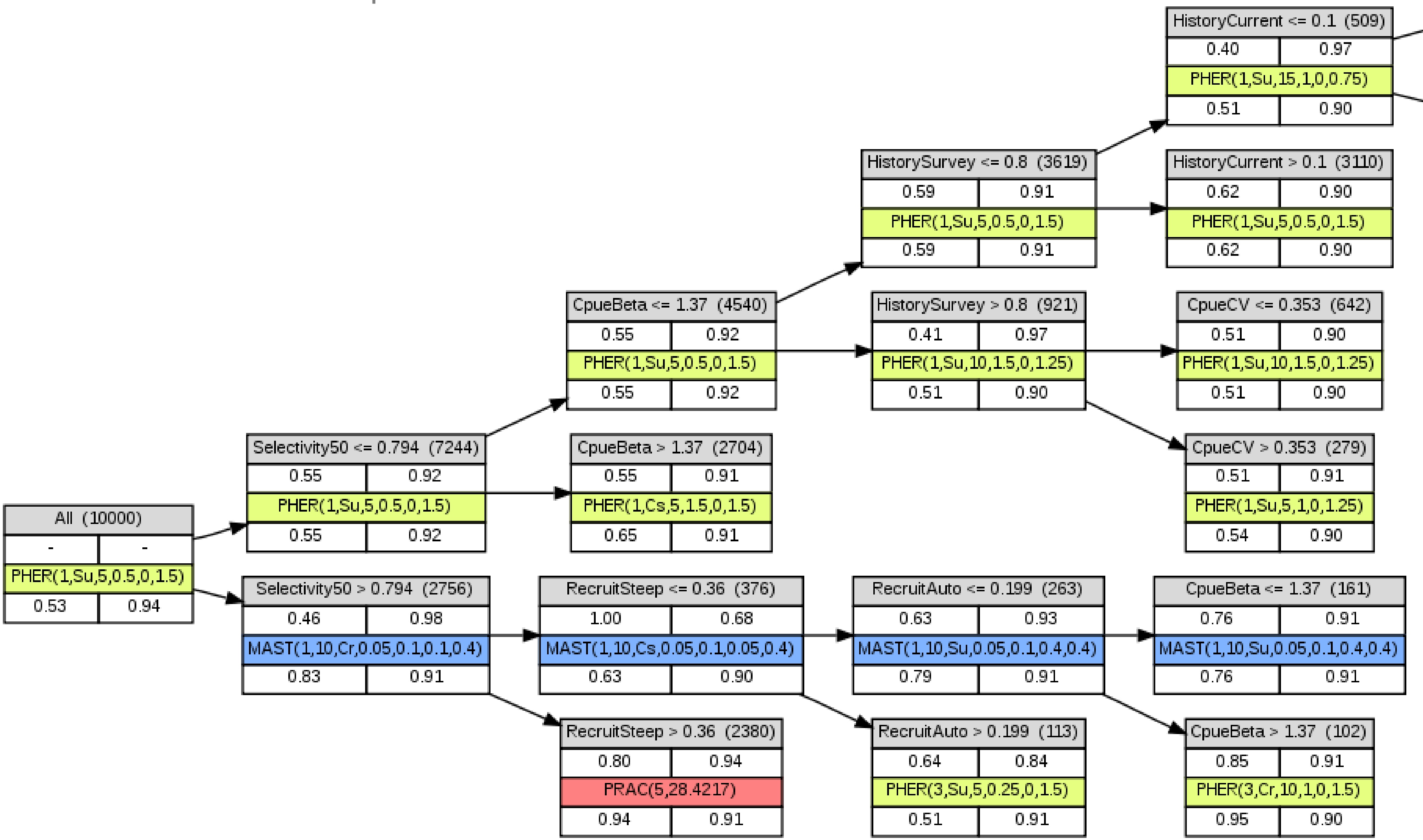
1.0
0.8
0.6
0.4
0.2
0.0
Yield/MSY
0.3
0.4
0.5
0.6
0.7
0.8
0.9
RecruitSteep
Conditions>90%
FALSE
TRUE
Procedure
PHER(1,Su,5,0.5,0,1.5)
PHER(1,Su,10,0.25,0,1.5)
PHER(1,Su,15,1,0,1)
PHER(1,Su,10,1,0,0.75)
PHER(1,Su,15,1,0,1.25)
PHER(1,Su,5,1,0,0.75)
PHER(1,Su,5,1,0,1.25)
PHER(1,Su,5,1,0,1)


Yield/MSY
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
Selectivity50
Conditions>90%
FALSE
TRUE
Procedure
PHER(1,Su,5,0.5,0,1.5)
PHER(1,Su,10,0.5,0,1.5)
PHER(1,Su,15,1,0,0.75)
PHER(1,Su,15,1,0,1.5)
MAST(1,3,Su,0.1,0.1,0.2,0.4)
MAST(1,5,Cr,0.05,0.1,0.2,0.4)
PRAC(5,28.4217)

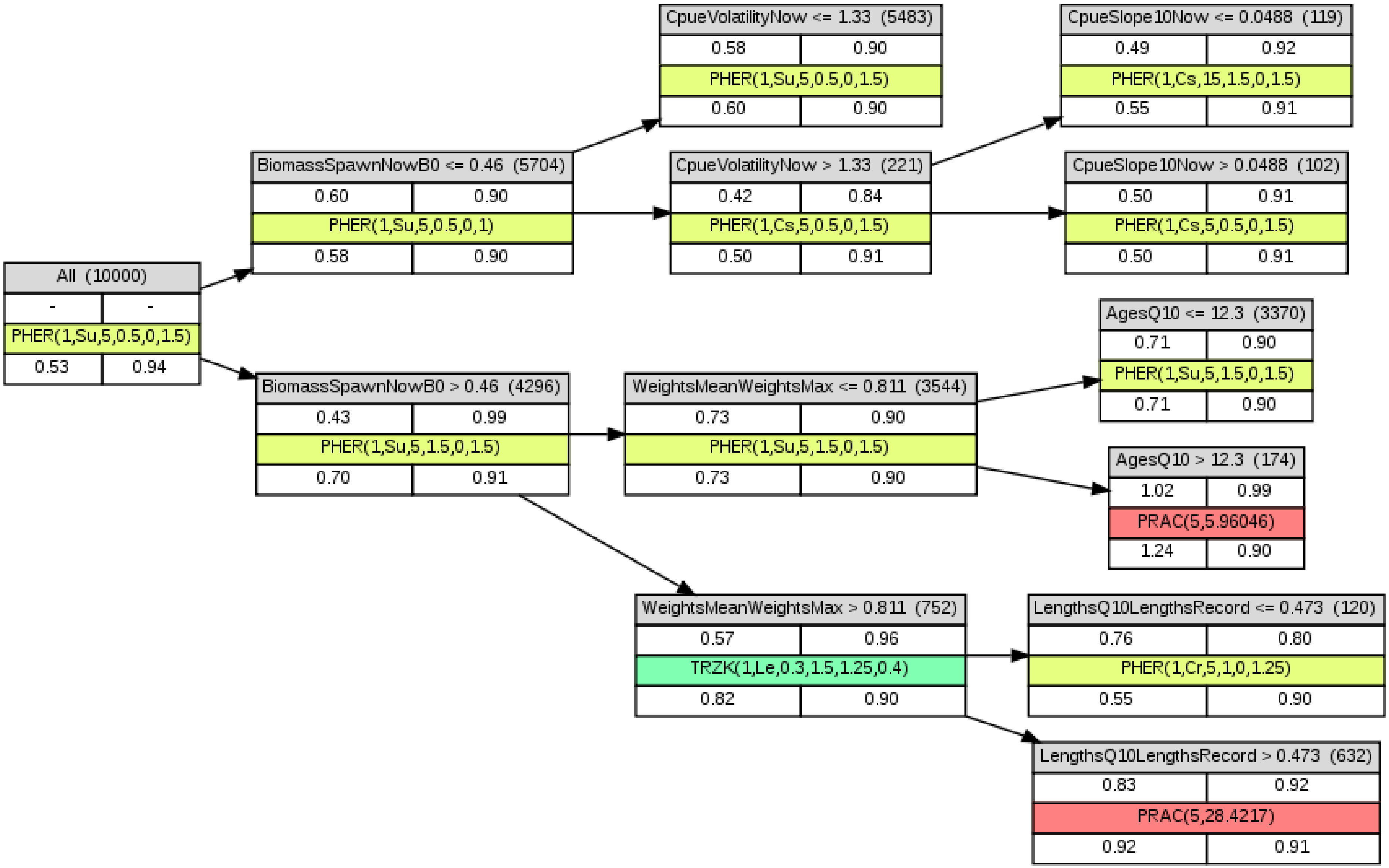


1.0
0.8
0.6
0.4
0.2
0.0
Yield/MSY
0.2
0.4
0.6
0.8
HistorySurvey
Conditions>90%
TRUE
FALSE
Procedure
PHER(1,Su,5,0.5,0,1.5)
PHER(1,Su,15,1,0,1.5)
PHER(1,Su,10,1,0,0.75)
PHER(1,Su,10,1.5,0,0.75)
PHER(1,Su,5,1,0,1.5)

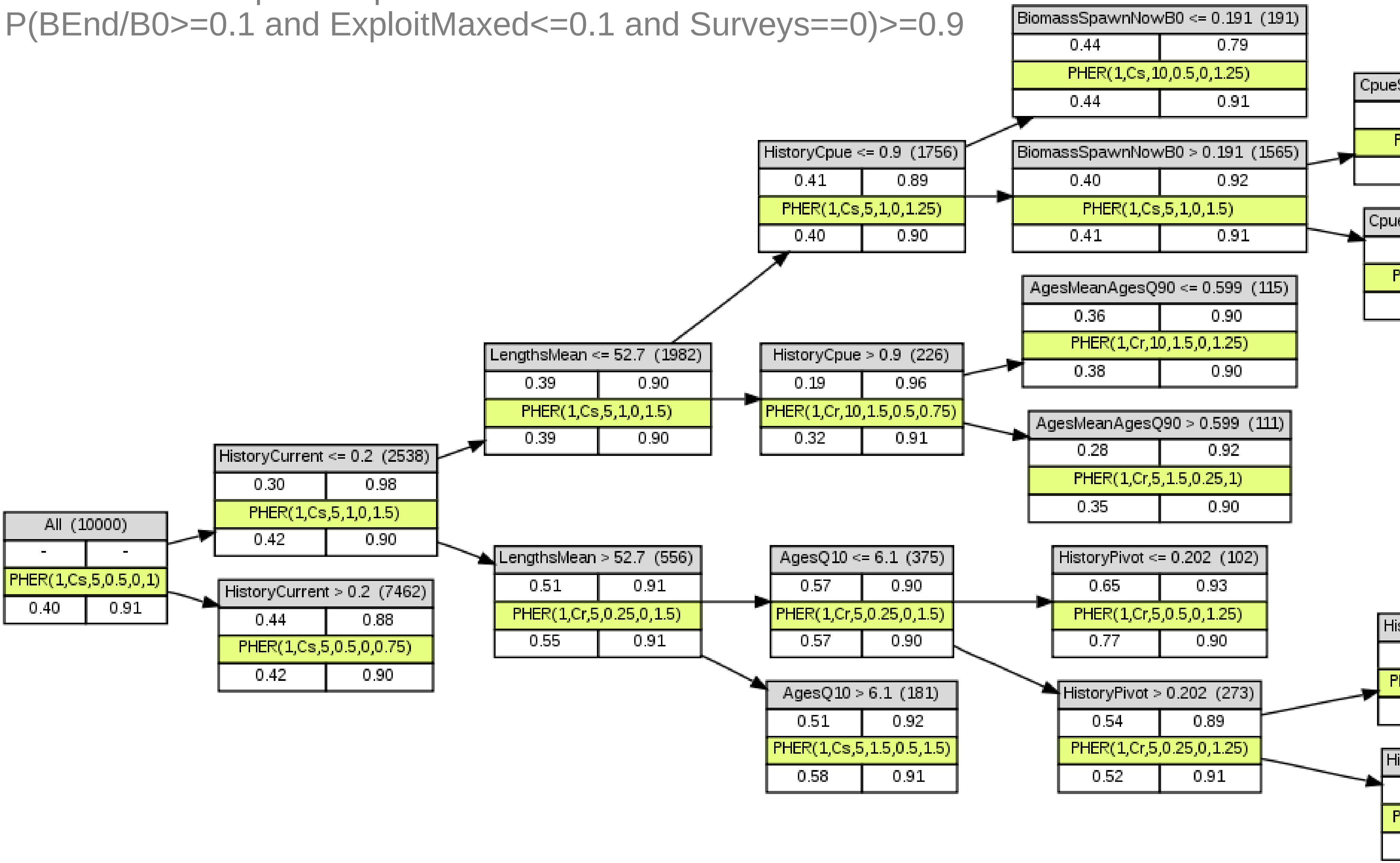
# Selection tree based on parameters



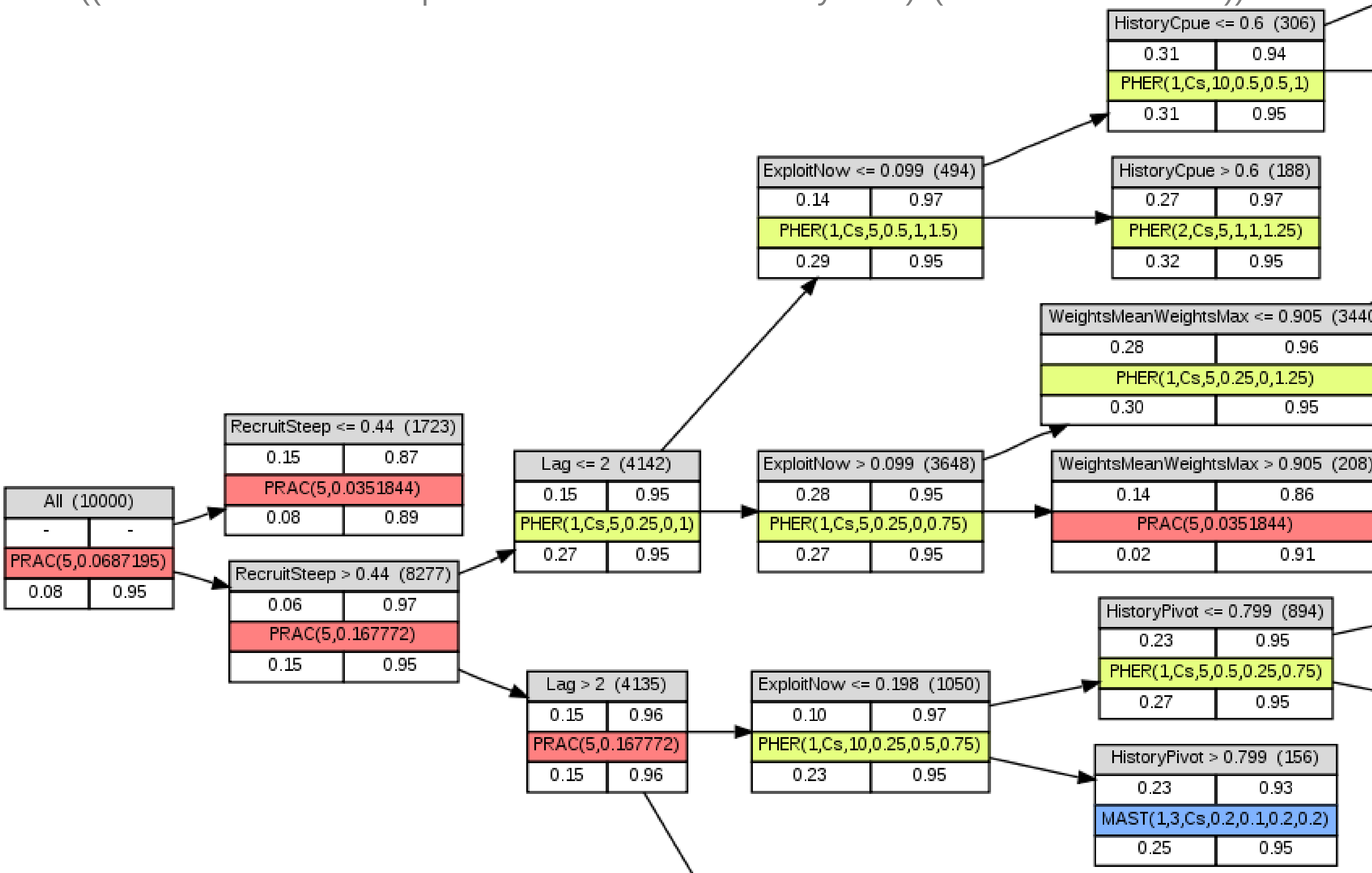
# Selection tree based on variables

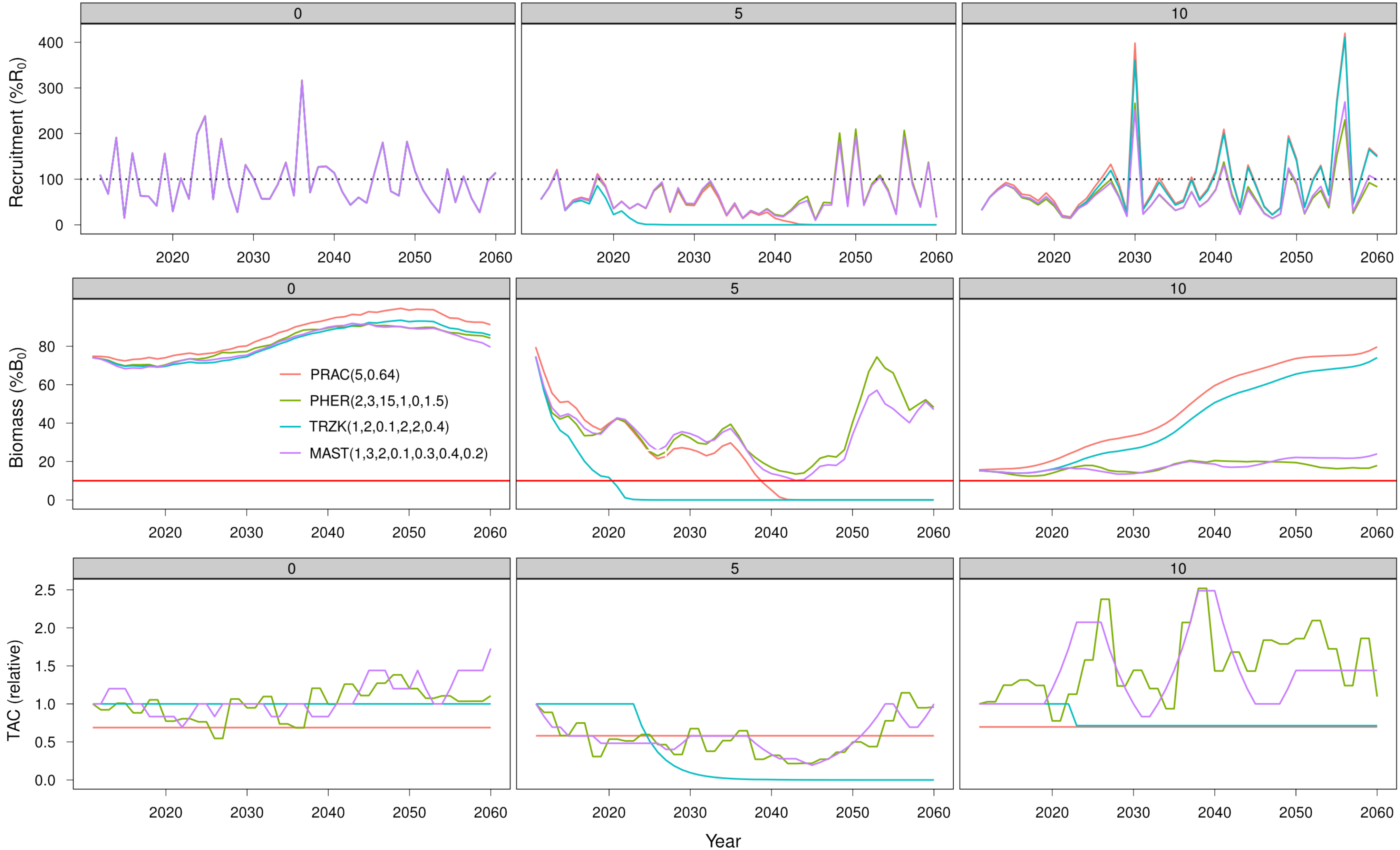


Selection tree depends upon conditions
P(BEnd/B0>=0.1 and ExploitMaxed<=0.1 and Surveys==0)>=0.9



Selection tree depends upon conditions
mean((BEnd/B0>=0.1 and ExploitMaxed<=0.1 and Surveys==0)x(1-HssSoftBreached)) >=0.95





0
5
10
Recruitment (%$R_0$)
Biomass (%$B_0$)
TAC (relative)
Year
PRAC(5,0.64)
PHER(2,3,15,1,0,1.5)
TRZK(1,2,0.1,2,2,0.4)
MAST(1,3,2,0.1,0.3,0.4,0.2)

Selection trees are useful for illustrating concepts:

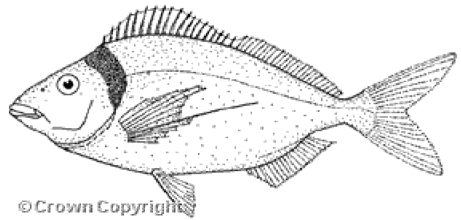
- Successive splitting of evaluation results into small subsets
- Benefits of increasing knowledge
- Diminishing benefits of increasing knowledge

Not all that useful for actually choosing a management procedure for a particular fishery:

- Don’t always know answer to question in a tree

# Using meta-MPE: define a subset

Define a subset of replicates
for the TAR 3 fishery...




```
Subset TAR3;

TAR3.CriterionAdd(Criterion(NaturalMortality,Uniform(0.08,0.15)));/
TAR3.CriterionAdd(Criterion(LengthK,Normal(0.2009,0.02));//Annal
TAR3.CriterionAdd(Criterion(LengthLinf,Normal(44.6,0.4));
```

...specify any knowledge
of biology,...

```
TAR3.CriterionAdd(Criterion(CPUETrend5,Uniform(-0.1,0)));
TAR3.CriterionAdd(Criterion(CPUETrend10,Uniform(-0.05,0.05)));
TAR3.CriterionAdd(Criterion(CpueVolatility,Uniform(0.03,0.05)));
```

...CPUE trends and
variability,...

```
TAR3.CriterionAdd(Criterion(SurveyTrend5,Uniform(-0.1,0)));
TAR3.CriterionAdd(Criterion(SurveyTrend10,Uniform(-0.05,0.05)));
TAR3.CriterionAdd(Criterion(SurveyCV,Uniform(0.15,0.25)));
```

...survey trends and
variability...

```
TAR3.Restrict();
```

...restrict replicates based on these criteria.

# Using meta-MPE: evaluate over subset

Define a utility function for this fishery...

```
double TAR3Utility(const Evaluation& eval){
    return
        (eval.HssSoft<0.1) *
        (eval.Changes<0.5) *
        (eval.Yield*600 - eval.Survey*100000 - eval.Lengths*10 - eval.Ages*100);
}
```

Only accept if meets Fish Harvest Strategy Standard...

...and if frequency of TAC changes less than every 2 years...

...otherwise maximize net profit (combine yield with costs of monitoring)

```
TAR3.Evaluate(TAR3Utility);
```

Evaluate all MPs over subset with respect to this utility function...

```
std::cout<<TAR3.Top50();
```

Output top 50 MPs and go on to provide detailed summaries of performance statistics for stakeholder selection...

# Specific knowledge: quick stock-take from reports

MFish Plenary report

Fisheries Assessment Reports (FARs)

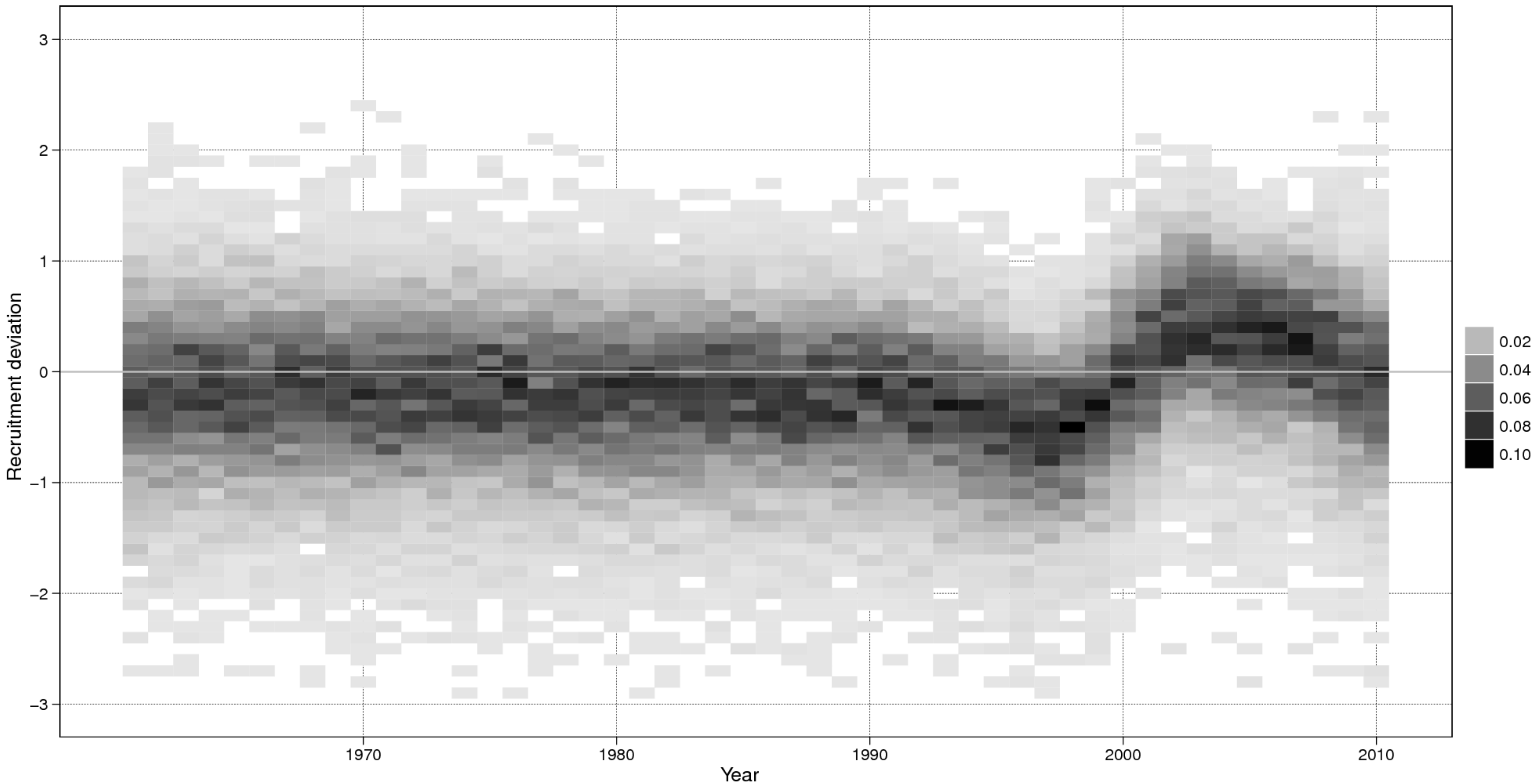
SeaFIC Adaptive Management Programme (AMP) Reports

## Estimated parameters

| Type | Parameter | Symbol | GUR3 | STA7 | BNS1 |
|---|---|---|---|---|---|
| **Biological** | | | | | |
| Mortality | Instantaneous rate of natural mortality | $\pi$ | U(0.2,0.4)[1] | U(0.1,0.3)[2] | A: U(0.04,0.08)[3]<br>B: U(0.2,0.4)[4]<br>C: ~ $\kappa$* |
| Growth | Asymptotic length | $\lambda$ | U(41.2,50.1)[5] | U(78.8,84.0)[6] | A: U(72,93)[7]<br>B: U(80,90)[8]<br>C: U(70,100)[9] |
| | Growth coefficient | $\kappa$ | U(0.390,0.530)[10] | U(0.116,0.133)[11] | A: U(0.07,0.13)[12]<br>B: U(0.24,0.36)[13]<br>C: ~ $\lambda$* |

## Observed variables

| Group | Description | GUR3 | STA7 | BNS1 |
|---|---|---|---|---|
| Catch | Current catch relative to mean catch | U(123%,185%) | U(101%,152%) | U(76%,114%) |
| | Current catch relative to maximum catch | U(75%,112%) | U(56%,83%) | U(48%,72%) |
| CPUE | Slope of over entire series | U(4%,8%) | U(-1%,3%) | U(-8%,-4%) |
| | Slope of over last 10 years | U(12%,20%) | U(-4%,0%) | U(-12%,-6%) |
| | Slope of over last 5 years | U(4%,8%) | U(-2%,2%) | U(-20%,-10%) |
| | Coefficient of variation | U(0.41,0.61) | U(0.14,0.21) | U(0.31,0.46) |
| | Average annual variation (%) | U(0.17,0.25) | U(0.12,0.18) | U(0.12,0.18) |
| | Inter-annual volatility (s.d. of log changes) | U(0.19,0.28) | U(0.16,0.24) | U(0.15,0.23) |
| Survey | 3 year multiplier | U(1.5,3.5) | U(0.9,1.4) | |



3
2
1
0
−1
−2
−3
Recruitment deviation
1970
1980
1990
2000
2010
Year
0.02
0.04
0.06
0.08
0.10

## Global meta-MPE: how useful is it?

Test bed for MP development of a library

When developing a new MP:

- Does it better an incumbent?
- In which areas of parameter space does it do well/badly?
- What uncertainty is it’s performance sensitive to?

# Meta-MPE parts

- Generic priors
  - Current version from superficial meta-analyses
  - Useful for filling in gaps in knowledge (in a consistent, informed way) for specific-MPE
  - Useful also for stock assessments?
- Generic model
  - Population dynamics model simple e.g no dome shaped selectivity, same-sex
- Generic management procedure library
  - Current set of MPs is small
  - Useful for specific-MPE
- Evaluation subset analysis
  - Useful for analysing results of specific-MPE