Management of datapoor stocks in mixed fisheries

The good, the adequate and the arbitrary

Helena Geromont

Marine Resource Assessment and Management Group (MARAM),

Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa

OUTLINE

- Introduction
- Mixed fishery and bycatch management
- Defining realistic metrics
- Data-poor methods
- MSE: evaluating trade-offs
- Some conclusions

Current state of world fisheries

Stocks with quantitative assessments: 10%

- High-value
- Data-rich
- Expertise-rich

Unassessed stocks: 90%

- Low-value, often inshore, often mixed fisheries
- Limited funding, limited monitoring =>Data-poor
- Often limited numerical expertise and limited infrastructure

Need for simple quantitative management

Rich versus poor

Data-rich assessment methods are not applicable to data-poor fisheries:

- Lack of funds for extensive data collection/data analyses
- Insufficient data to estimate model parameters reliably
- Lack of expertise to apply complex statistical methods annually
- Complex assessments not always that realiable anyway

Require simple approaches:

- Generic rather than stock-specific (no annual species-specific assessments)
- Broad-brush rather than optimal (overall multi-stock rebuilding goals)
- Easily understood by fishery stakeholders (need buy-in to work)
- Rely on few data (start simple and move towards data-moderate methods)
- Robust to high levels of uncertainty (precautionary but economically viable)

Keep it simple stupid!

US: New England groundfish mixed-fishery

Problems with management system:

- Pre-2010: Days-At-Sea (DAS)
- Post-2010: Hard Annual Catch Limits (ACL)

Many groundfish stocks remain overfished

Age-based models give biased estimates of abundance (retrospective patterns)

Catches well below optimum yield (OY)

Single species interpretation of multispecies yield

Rothschild (2013):

Define clear and realistic management goals

Adopt simpler stock assessment approaches

Use simpler metrics to measure performance

Rothschild, BJ, Keiley, EF, and Jiao, Y. 2013. Failure to eliminate overfishing and attain optimum yield in the New England groundfish fishery. ICES Journal of Marine Science. DOI:10.1093/icesjms/fst118

Example: New England groundfish

Risk/yield tradeoffs

Reducing risk (overall, or a specific species?)

- Annual catch limits(ACLs) are set much lower than OFLs for each species
- Choice of precautionary buffer somewhat arbitrary (75% F_{MSY})
- Single-species assessments questionable => unreliable F estimates
- Continued overfishing for some species despite buffers: biological goals not met

Achieving OY (overall, or a specific species?)

- Total landings of all stocks substantially less sum of ACLs
- Once species-specific ACLs are reached, the fishery starts choking
- Loss of revenue: economic goals of fishery not met

$$C_y << \sum_s ACL_y^s << \sum_s OFL_y^s$$

"Weakest link" management

Multi-species fishery management goals not met

ACL: Annual Catch Limit < OFL: Overfishing Limit

Example: SA small pelagics fishery

Directed catch: anchovy, adult sardine

Bycatch: juvenile sardine, horse mackerel

Aim: Limit juvenile sardine and horse mackerel bycatch in small pelagics fishery

=>impacts adult sardine and horse mackerel directed catches

Trade-off: cannot optimise directed sardine and anchovy simultaneously

Joint Management Procedure (JMP):

1) Total Annual Catch for anchovy (TAC^A)and adult sardine (TAC^S), and

2) Total Annual Bycatch (TAB^S) for juvenile sardine

Simple empirical MP based on bi-annual hydroacoustic surveys (data-rich)

Nov: initial TAC^S/TAC^A/TAB^S -> May mid-year update: revise TAC^A/TAB^S

De Moor CL and DS Butterworth. Incorporating technological interactions in a joint MP for SA sardine and anchovy. In Management Science in Fisheries. An introduction to simulation-based methods. Ed: Edwards, TT and Dankel, DJ. 2016. Routledge. 460pp

Example: SA small pelagics: horse mackerel bycatch

Aim: Limit juvenile horse mackerel bycatch in small pelagics fishery

=>impacts adult horse mackerel fishery: threefold Y/R gain

1) Precautionary Upper Catch Limit (PUCL)

Fixed PUCL: Choking of anchovy fishery:

=>avoid areas with high horse mackerel bycatch

=>loss of anchovy catch

2) Flexible $PUCL_3$: three-year allocation

$$allocation_y = PUCL_3 - bycatch_{y-1} - bycatch_{y-2}$$

Add restriction to limit annual take:

$$bycatch_y < 0.5PUCL_3$$

Need restrictions, with flexibility to deal with high R fluctuations

Furman, L. B. 2014 Using Management Strategy Evaluation to address problems arising as a result of competing users of the South African horse mackerel resource. MSc Thesis 132 pp.

Example: SA demersal fishery

Inshore/Offshore trawl management:

- Hake directed TAC and effort limitation (DAS) to curb bycatch targeting
- PUCLs for kingklip and monkfish bycatch

In addition: Limit juvenile kingklip bycatch

Implement time/area restrictions:

- Moratorium on trawling in some months in some areas to reduce catch of species that are known to aggregate in those areas
- "kingklip box": seasonal area closure
- Avoid large spawning aggregations of kingklip

Simple solution that works => compliance by industry

PUCL: Precautionary Upper Catch Limit

Example: SA inshore trawl fishery

ePUCLs (experimental Preliminary Catch Limits):

Voluntary limits for minor bycatch species (eg kob, carpenter, panga)

Pilot project: Industry body manages ePUCLs to avoid dumping

Catch limits based on annual stock assessments (ASPM) for key bycatch species

Data: 1995-2011 survey index (government run observer program)

standardised CPUE (likely biased)

catch time series (total landings not well known)

Not so much data-poor but management-poor (lack of government funding/monitoring/compliance)

Voluntary ePUCLs: Hake trawl industry taking initiative with pressure from MSC: manage bycatch or lose hake certification!

Greenston, JD and Attwood CG. 2013. Assessing the feasibility of a bycatch co-management programme in South Africa's inshore trawl fishery. Report for he Responsible Fisheries Alliance.

Challenges specific to mixed fisheries

- Different productivity levels
  - Low M stocks more vulnerable to overfishing,
  - Need more precaution/constraints for vulnerable stocks
  - Large fluctuations in stock size for shorter-lived species
- Different depletion levels
  - Need rebuilding strategies for depleted stocks
  - but not waste potential yield from healthy stocks
- Different economic value
  - Catch directed according to market value and availability
- Different objectives, different performance indicators

Aim

Balance management trade-offs:

- Maximise future catch (OY) of priority stocks
- Reduce risk of overfishing/ undue depletion
- Avoid underfishing
- Maintain economic stability: avoid choking

Need a balanced management approach:

- Select realistic objectives: set attainable targets and limits for each stock
- Choose simple metrics to measure performance
- Prioritise stocks/species
- Balance overall trade-offs and performance of stock group.
- Need management approach that addresses bioeconomic concerns

Need to formalise an approach to do all that

OY: Optimum Yield

Metrics to measure performance

Example:

MSC certification criteria and performance indicators

MSC performance indicators

Certification scores are based on:

- Principle1 — Sustainability of stock
- Principle 2 — Environmental impact of fishery
- Principle 3 — Effective management of fishery

Focus MSE on Principle 1 performance indicators.

Principle 3 implicit when adopting an MP approach.

MSC stock status scores

SG60: stock biomass “likely” above point where recruitment becomes impaired (PRI)

30%-ile of probability interval above PRI

SG80: stock biomass ”highly likely” above PRI and fluctuating about MSY level

20%-ile of probability interval above PRI

median of probability interval above B_{MSY}

SG100: “certain” that stock above PRI and fluctuating about or above MSY level

5%-ile of probability interval above PRI

median of probability interval above B_{MSY}

Limit Reference Point (LRP): PRI=$0.5B_{MSY}$

Target Reference Point (LRP): B_{MSY}

Apply scoring system to multi-species fishery: SG60 for incidental bycatch, SG80 for important bycatch species and SG100 for high-value target species

MSC rebuilding time frames (PI 1.1.2)

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 generation time

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

Generation time: $t_{gen} = t_0 - 1/k \ln(1 - L_{opt}/L_{inf})$

Shortcut method: $t_{gen} = a_{mat} + 1/M$

Select MP and buffer to achieve biomass recovery in a pre-specified time

Three questions, not so many answers…

Where are we now?

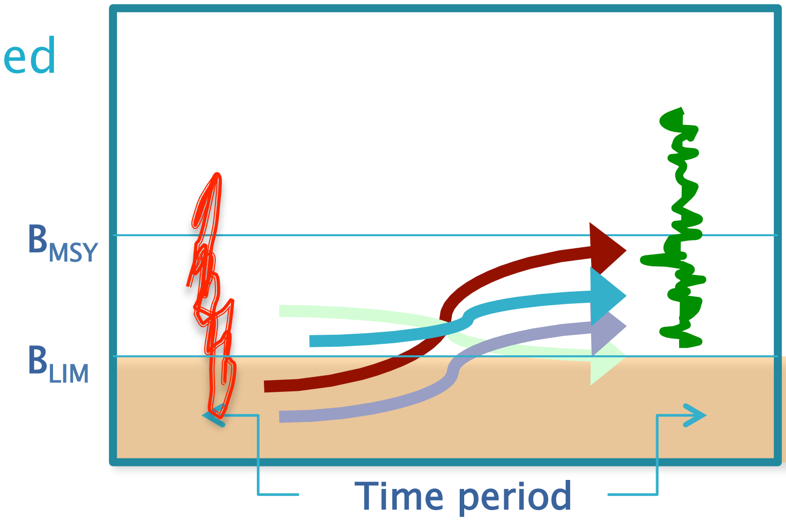
Don't know

Data poor, no assessment, or biased

Where do we go?

Move stock towards target (B_{MSY})

Maintain stock above limit



How do we get there?

An MP that requires few but (reliable) data to give directional advice.

Dynamic system, fluctuations in stock size unavoidable

Poor data

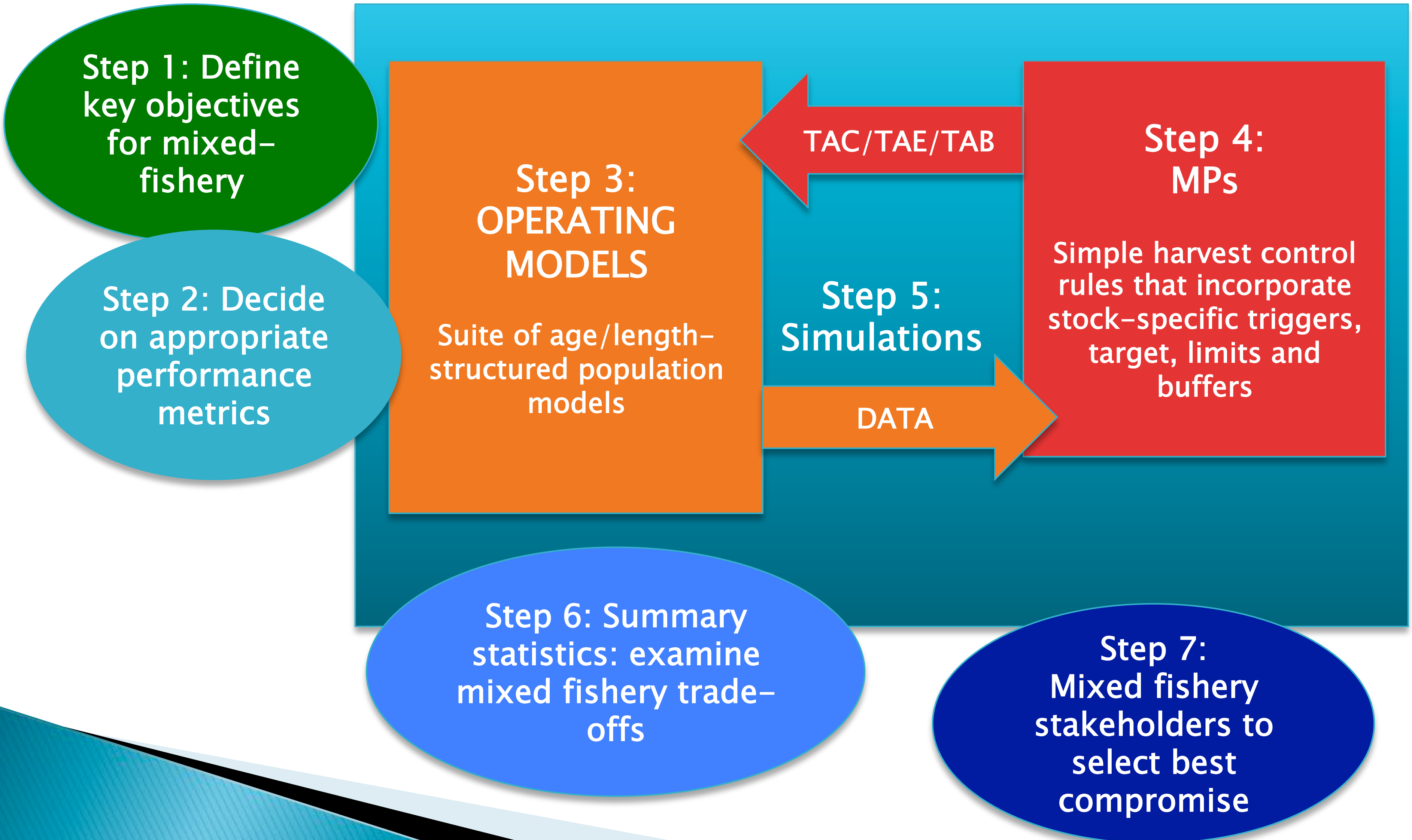
Biased assessments

Unrealistic expectations

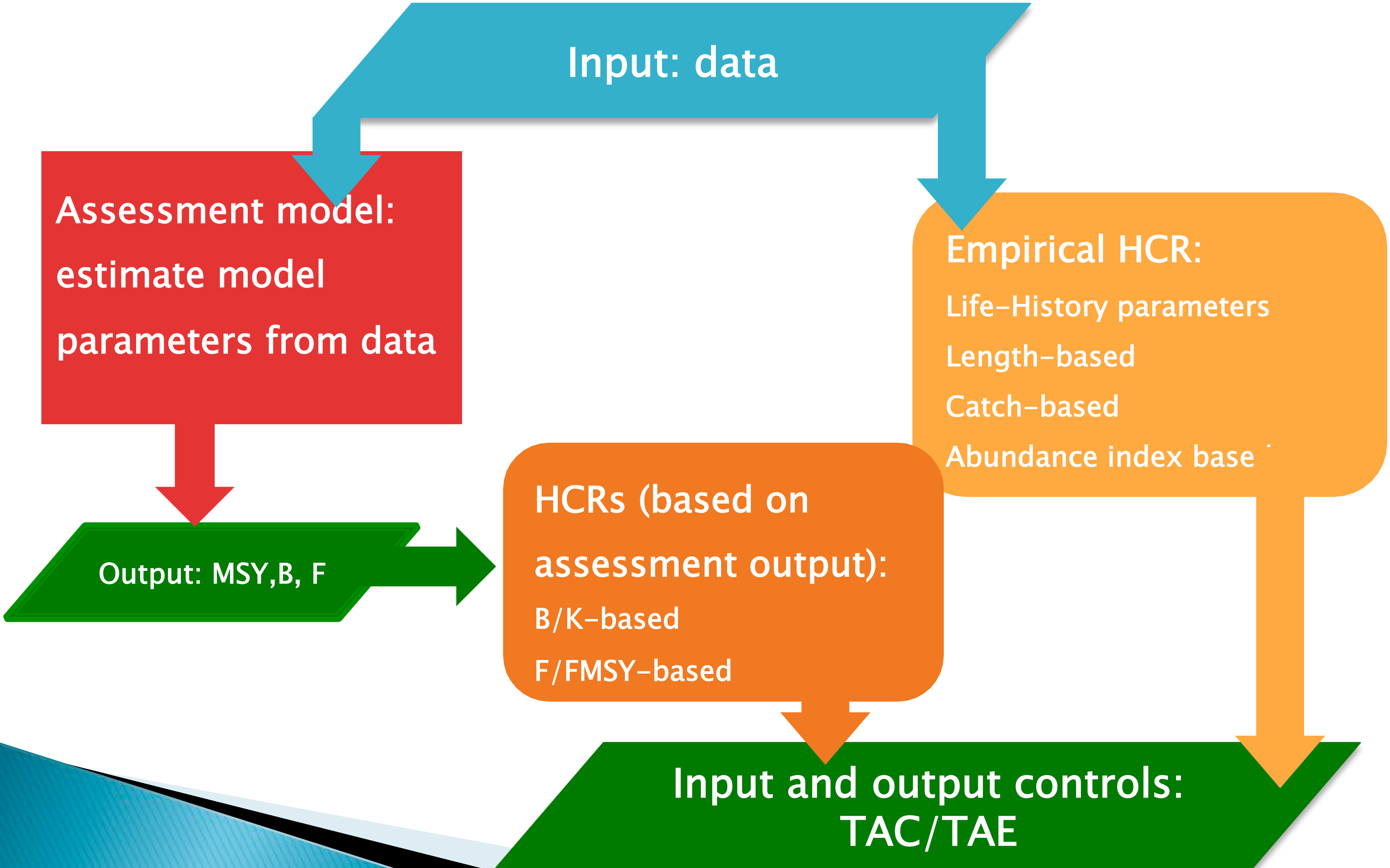
- Account for high levels of uncertainty
- Keep control rules simple
- Lower expectations
- Balance trade-offs between species

Management Strategy Evaluation

MSE: Evaluate performance

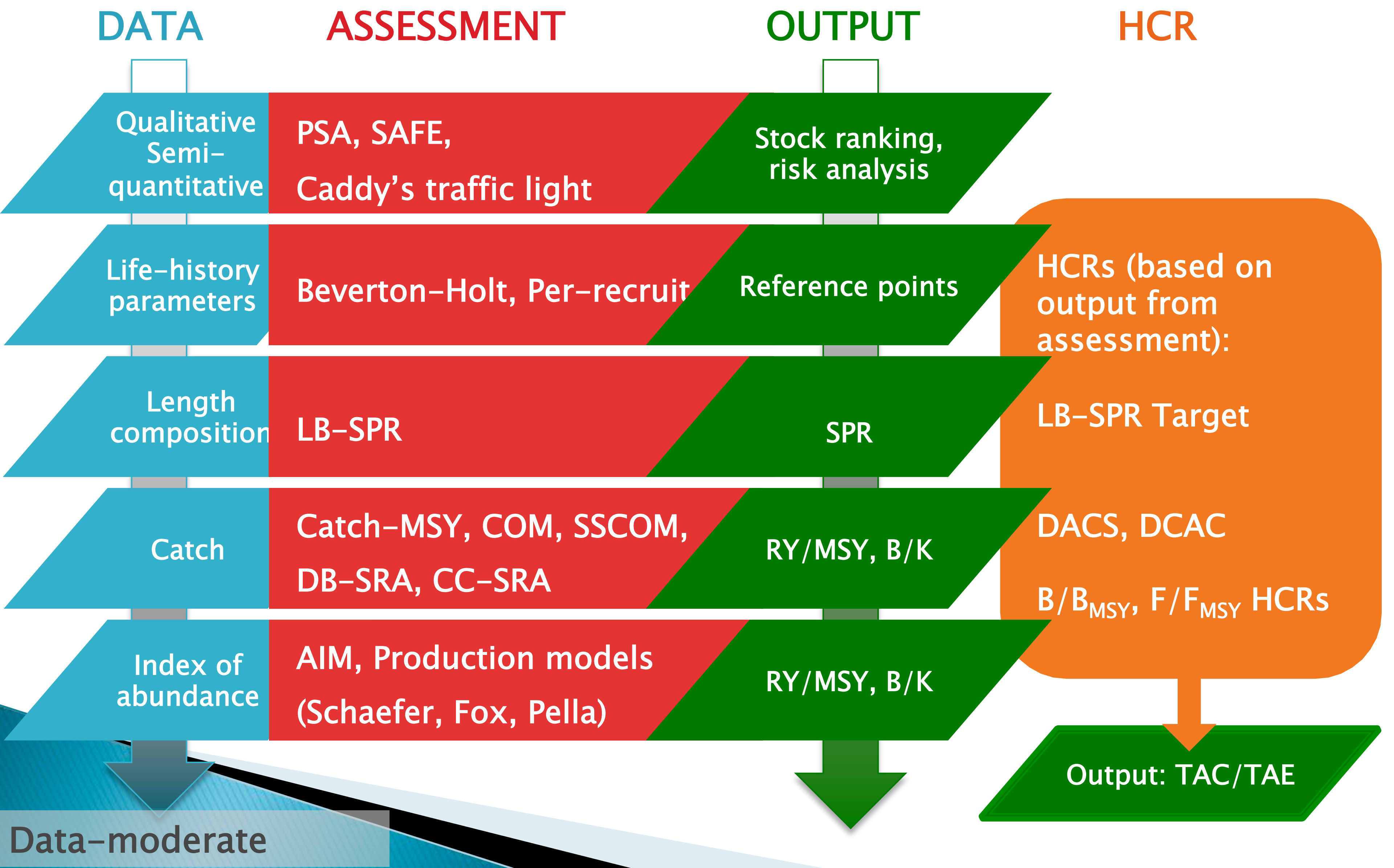


Datapoor methods: Model-based vs Empirical

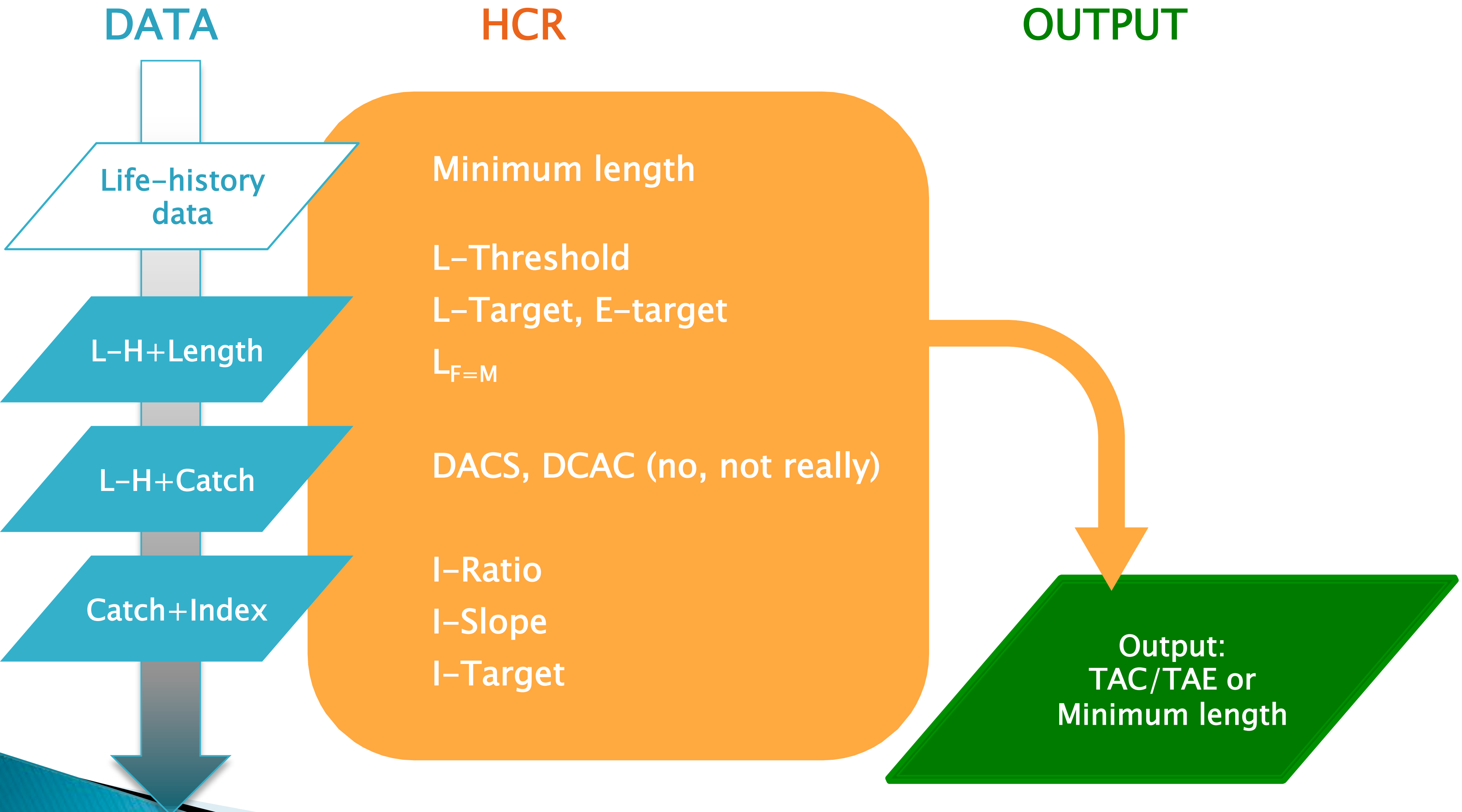


Data-poor

Typical data-poor assessment methods



Typical empirical methods



Example methods: input controls

Life-history parameters (*M, k, b*)

minlen

$$L^{\min} = xL^{\text{opt}} \qquad 0.7 \le x \le 1$$

Etarget

$$E_{y+1} = E_y\left[w + (1-w)\left(\frac{L_y^{\text{recent}}}{L^{\text{opt}}}\right)\right]$$

Lopt is the length at which the biomass of cohort is maximised

$$L^{opt} = b/(M/\kappa + b)$$

$$0 \le w \le 1$$

Length data

Advantages: Simple input control rules can be applied when historic time-series data are lacking. Life-history parameters are widely available. Cost effective management

Disdvantages: No historical trend information to track changes in biomass. Does not take dynamic effects into account

Example methods: catch based

Catch time series (C_y)

DACS

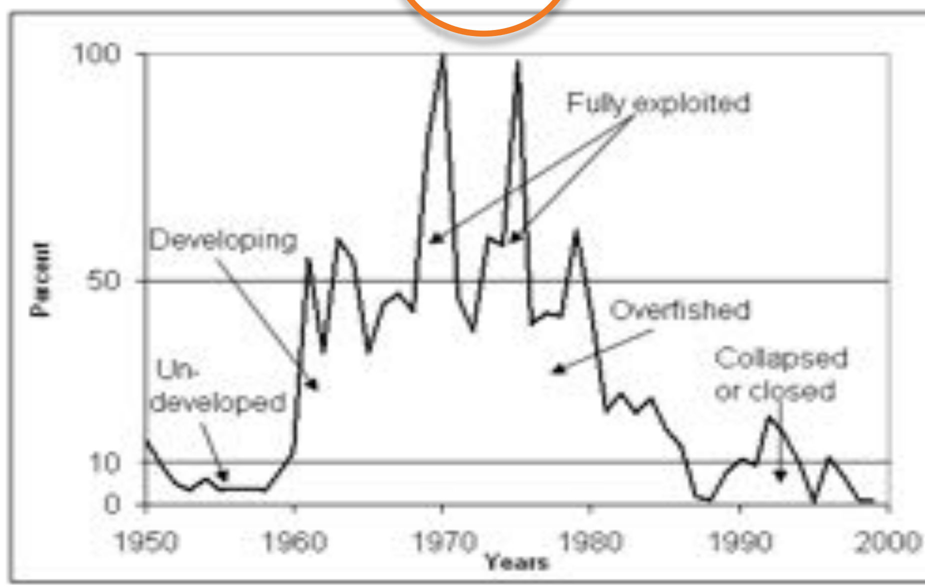
$$TAC_{y+1} = s\ (1/n \sum C_y) = 2B/K\ (1/n \sum C_y)$$

~~DCAC~~

$$TAC_{y+1} = DCAC = \frac{\sum C_y}{n + \Delta / (MSYL \times c \times M)}$$

Advantages: Catch time-series data are available for many fisheries.

Disadvantages: Catches are affected by effort regulations, catchability, etc. An estimate of current depletion is not available for most data-poor fisheries.



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).

Example methods: length based

Mean length index (L_y)

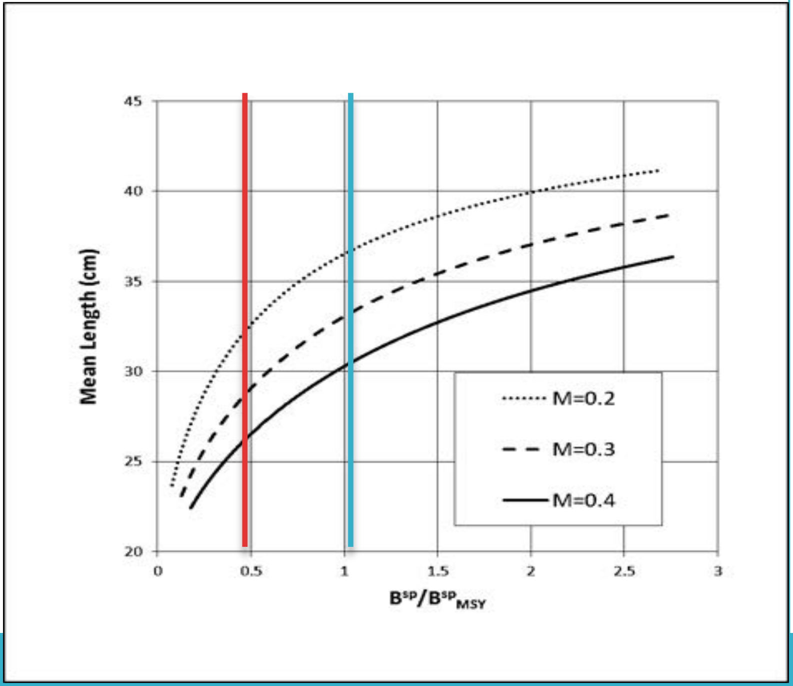
Lstep

$$TAC_{y+1} = TAC_y \pm \text{step if } L_y^{recent} \begin{matrix} > L^{\text{upper threshold}} \\ < L^{\text{lower threshold}} \end{matrix}$$

Ltarget

$$TAC_{y+1} = TAC^{\text{target}} \left[w + (1-w) \left(\frac{L_y^{\text{recent}} - L^0}{L^{\text{target}} - L^0} \right) \right]$$

- Advantages: data easy and cheap to collect. Intuitive HCRs=> Stakeholder participation.
- Disadvantages: Mean length is an indirect index – not directly proportional to abundance! Delay in feed-back (worse for longer-lived stocks with lower M). Recruitment pulses affect catch profile



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}.

Example methods: Index based

CPUE or survey index *(I_y)*

8) Islope

$$TAC_{y+1} = TAC_y(1+\lambda \text{ slope}(I_y))$$

9) Itarget

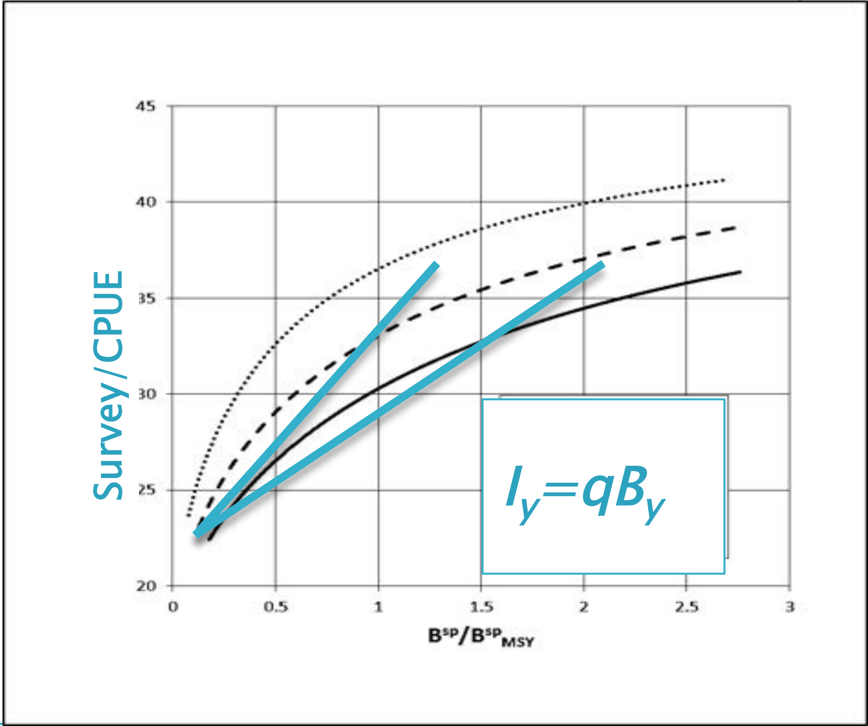
$$TAC_{y+1} = TAC^{\text{target}}\left[w+(1-w)\left(\frac{I_y^{\text{recent}} - I^0}{I^{\text{target}} - I^0}\right)\right]$$

10) ~~Iratio~~

$$TAC_{y+1} = TAC_{y-1}\left(1/2\sum_{y-2}^{y-1} I_y\right) / \left(1/3\sum_{y-5}^{y-3} I_y\right)$$

Advantages: Direct index of abundance. Track trends in B.

Disadvantages: Scientific surveys can be costly. CPUE data much easier/cheaper to collect, but undetected bias (changes in q) could be problematic.



Management Strategy Evaluation (MSE):

Simulation test 7 datapoor MPs
using MSC performance metrics

Construct Operating Model (OM) baskets

Group stock-types with similar characteristics in depletion/ productivity baskets. Bayes-like approach to encompass uncertainty

Productivity/ Depletion	Medium productivity (0.1<M<0.3)	Low productivity (0.04<M<0.1)
At/above target: 0.4<B/K<0.6	OM1: Mackerel-type stock At/above target	OM2: Rockfish-type stock At/above target
Medium depletion: 0.2<B/K<0.4	OM1a: Mackerel-type stock Depleted	OM2a: Rockfish-type stock Depleted
Very depleted: 0.05<B/K<0.2	OM1b: Mackerel-type stock Very depleted	OM2b: Rockfish-type stock Very depleted

Simulation test MPs for each stock group/basket

Selection of MPs and precautionary buffers to simulation tested

Data	MPs	Buffers
Life-history pars (*L-H*)	minlen0,…,minlen5	0%, 10%, 20%, 30%, 40%, 50%
Mean length index (L_y)	Lstep0,…,Lstep5	0%, 10%, 20%, 30%, 40%, 50%
	Etarget0,…,Etarget5	0%, 10%, 20%, 30%, 40%, 50%
	Ltarget0,…,Ltarget5	0%, 10%, 20%, 30%, 40%, 50%
Catch time series (C_y)	DACS0,…,DACS5	0%, 10%, 20%, 30%, 40%, 50%
CPUE or survey index (I_y)	Islope0,…,Islope5	0%, 10%, 20%, 30%, 40%, 50%
	Itarget0,…Itarget5	0%, 10%, 20%, 30%, 40%, 50%

Software:

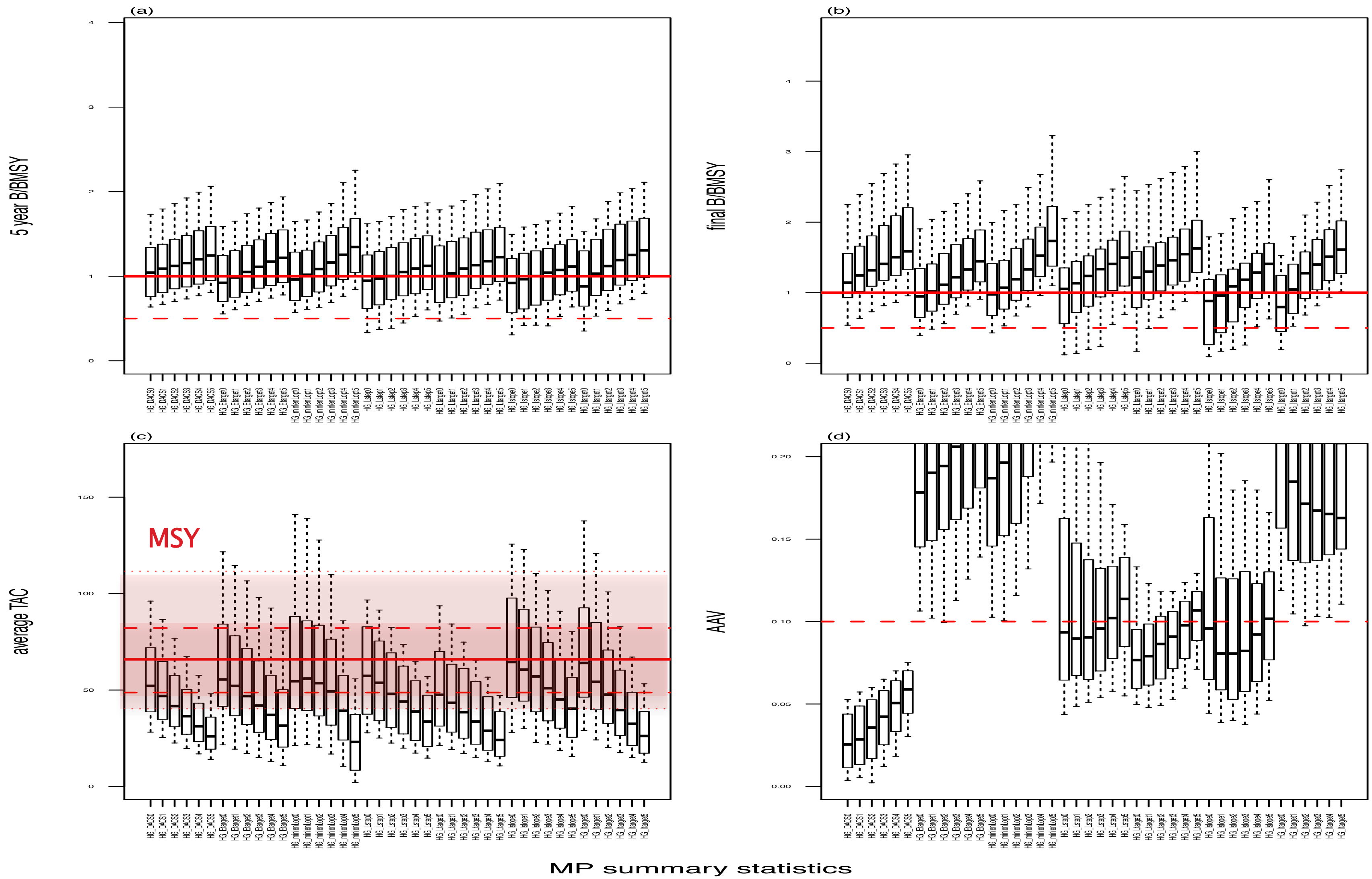
Automate MSE with DLM Toolkit package developed by Tom Carruthers (2015)

Toolkit V3.2.1 now available on Cran repository

Carruthers, T. R., Kell, L. T., Butterworth, D. D. S., Maunder, M. N. Geromont, H. F., Walters, C., McAllister, M. K., Hillary, R. Levontin, P., Kitakado, T., and Davies, C. R. Performance review of simple management procedures. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv212.

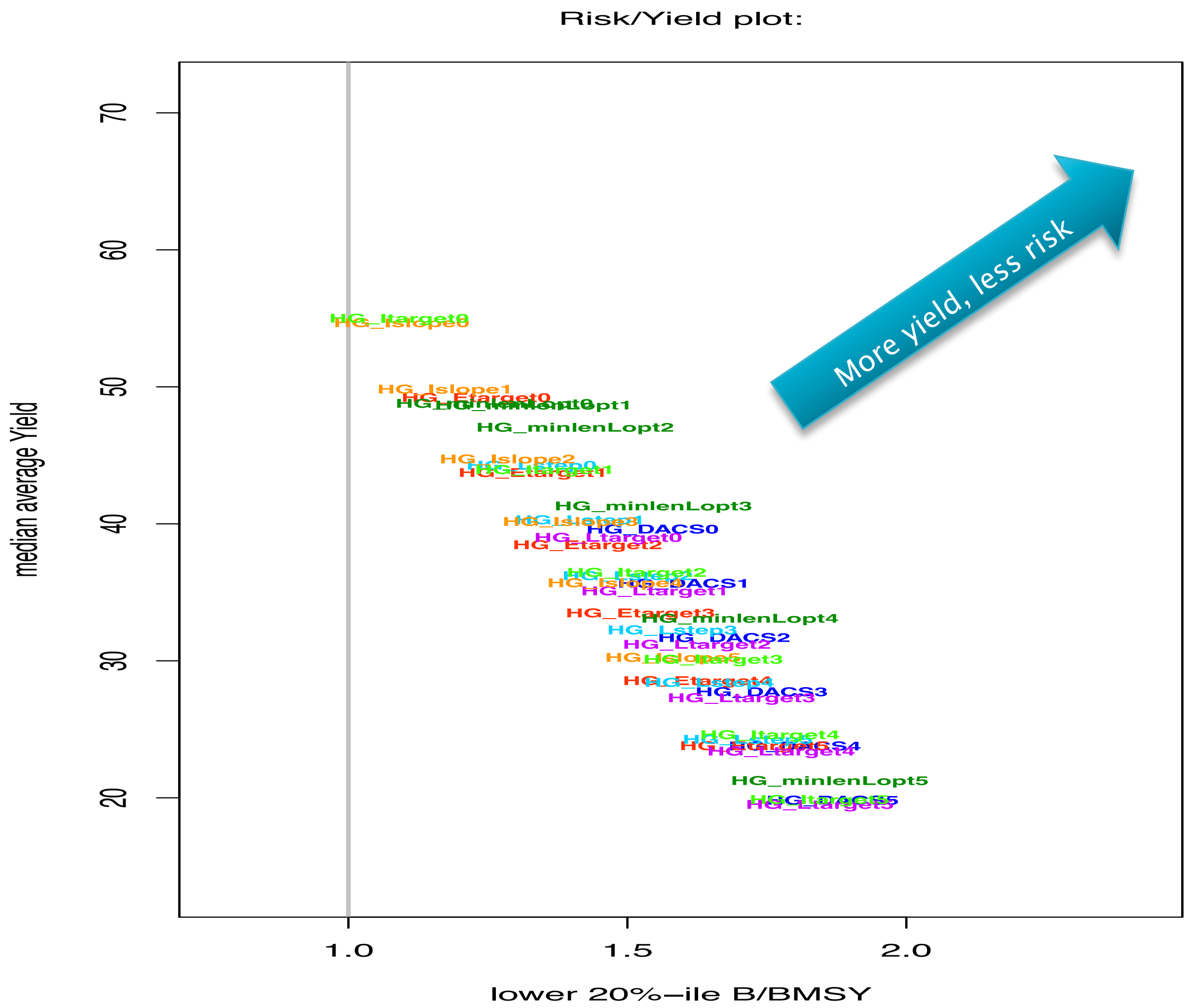
OM1a (moderately depleted/productivity): 10-year projections

Boxplots: whiskers:5%-iles (SG100), boxes:20%-iles (SG80), bars: medians



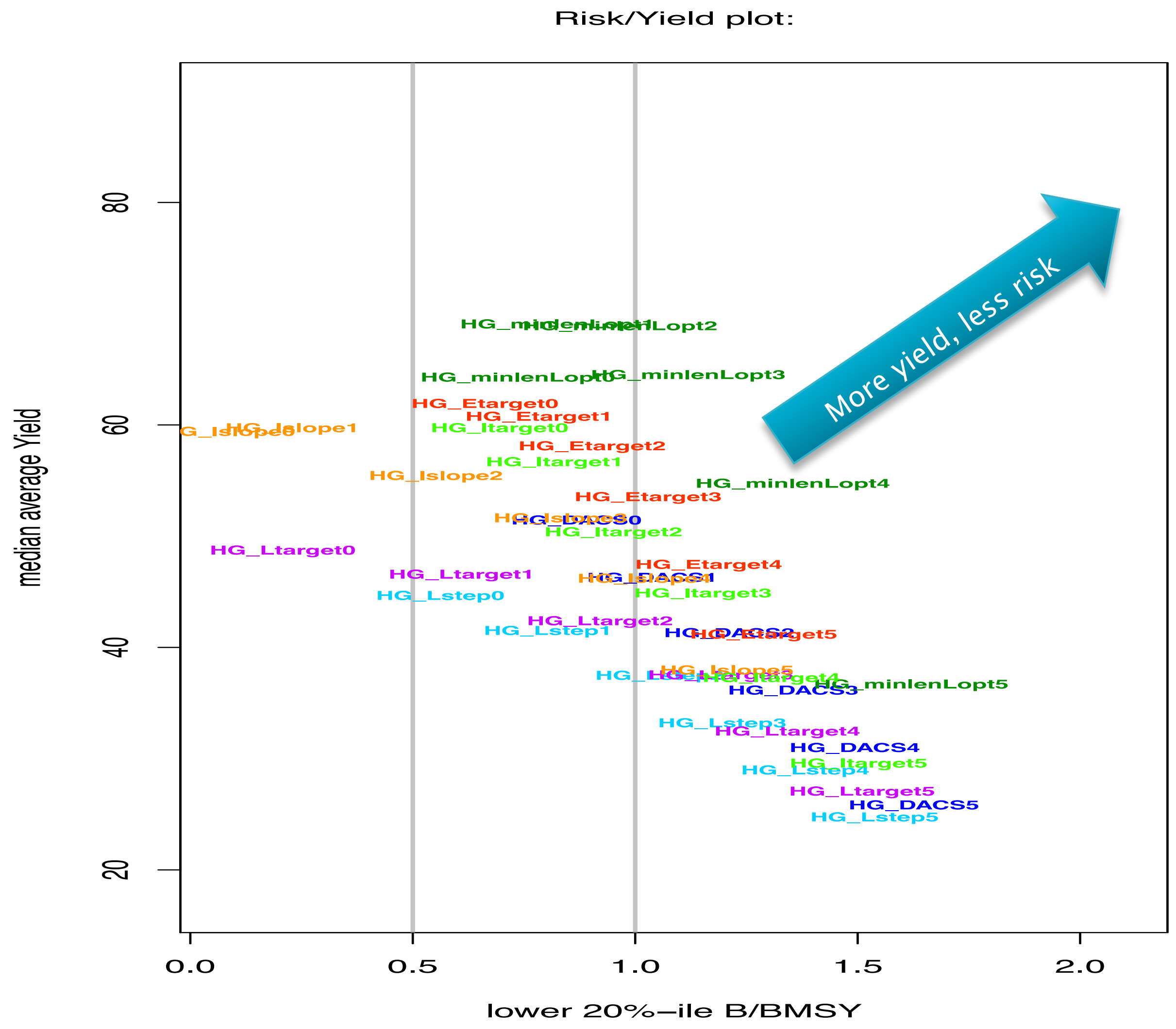
OM1a: moderately depleted/medium productivity

Risk/Yield tradeoffs after 10 years



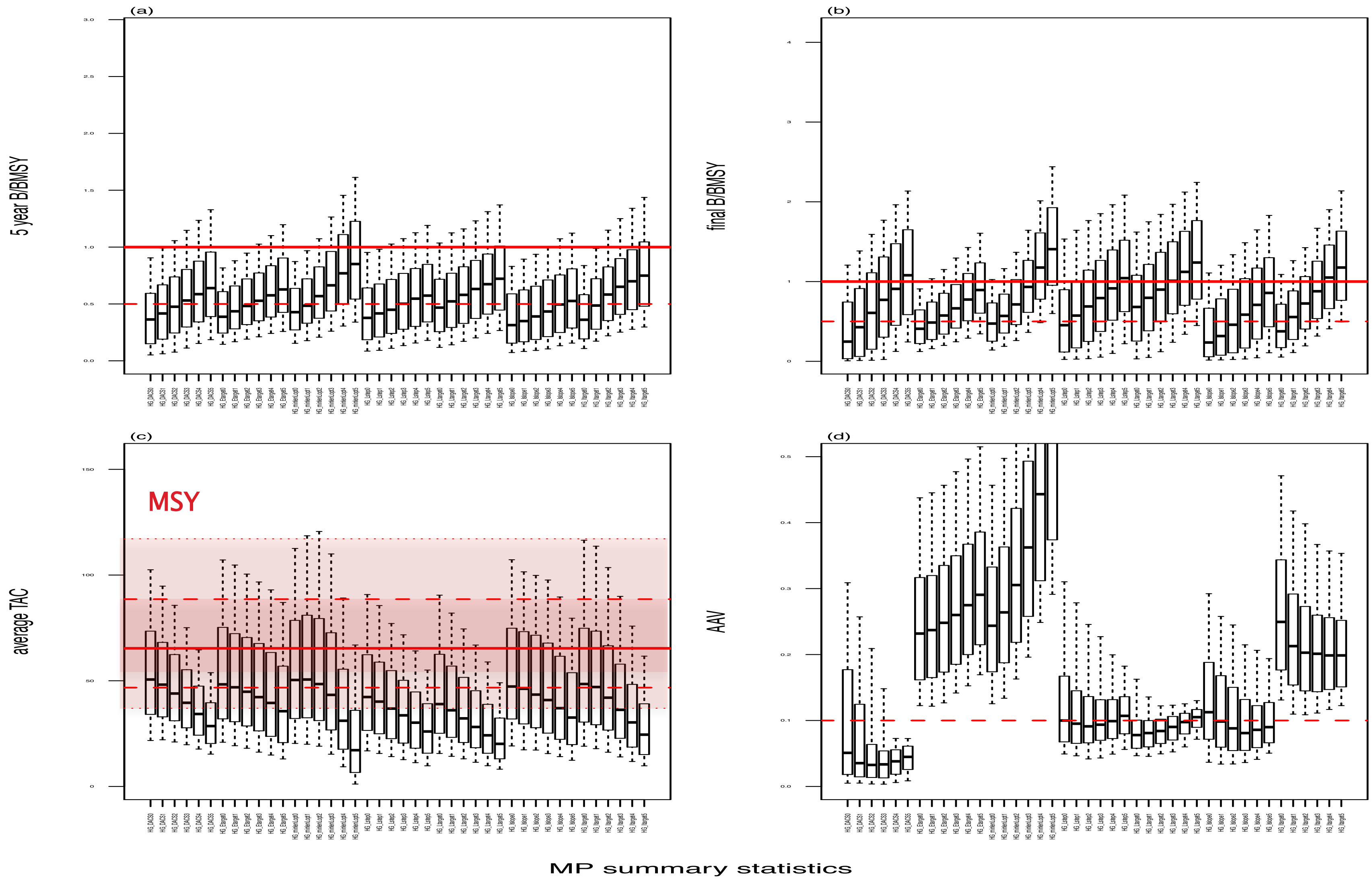
OM1a: moderately depleted/medium productivity

Risk/Yield tradeoffs after 20 years



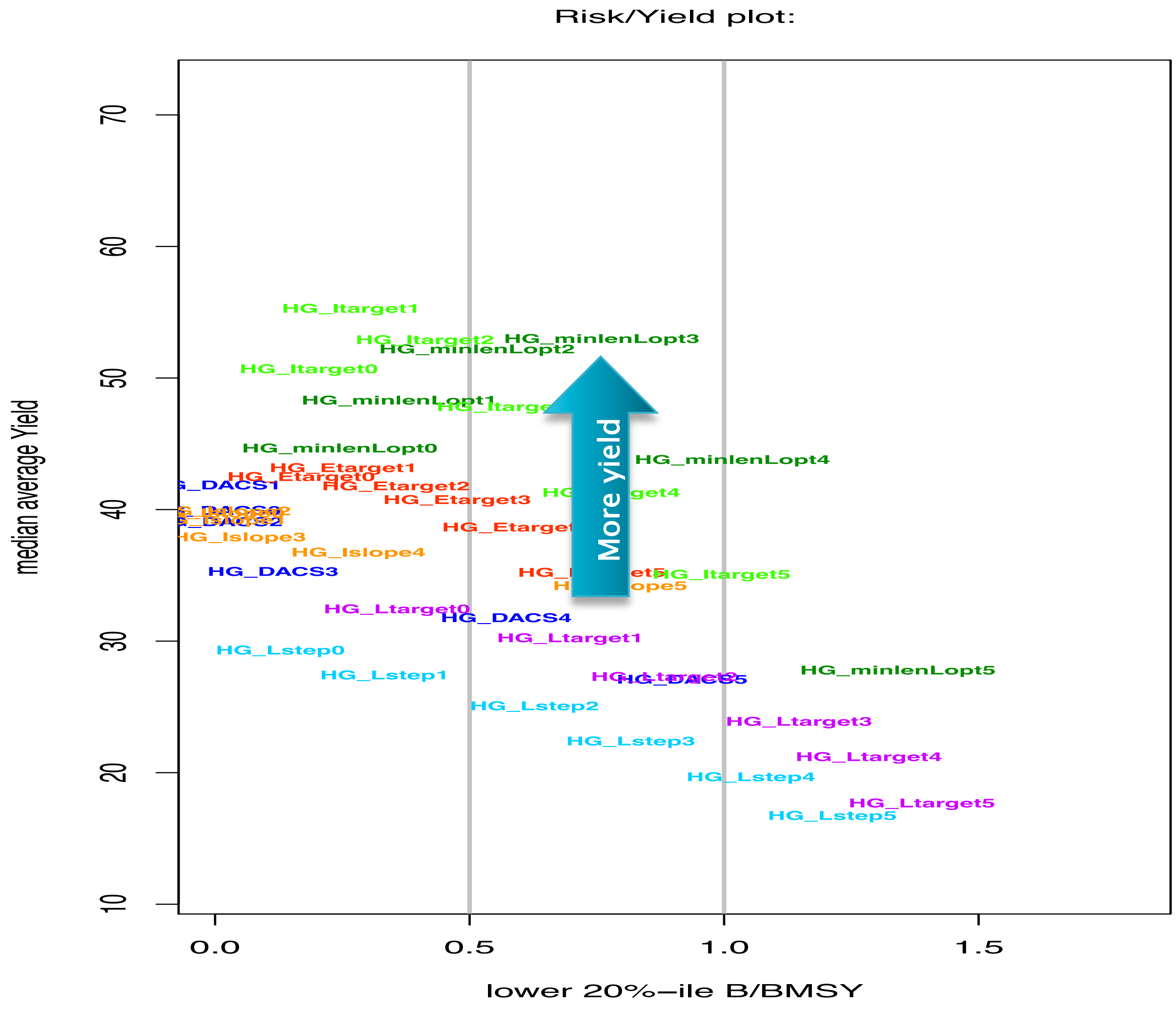
OM1b (severely depleted/medium productivity): 10-year projections

Boxplots: whiskers:5%-iles (SG100), boxes:20%-iles (SG80), bars: medians



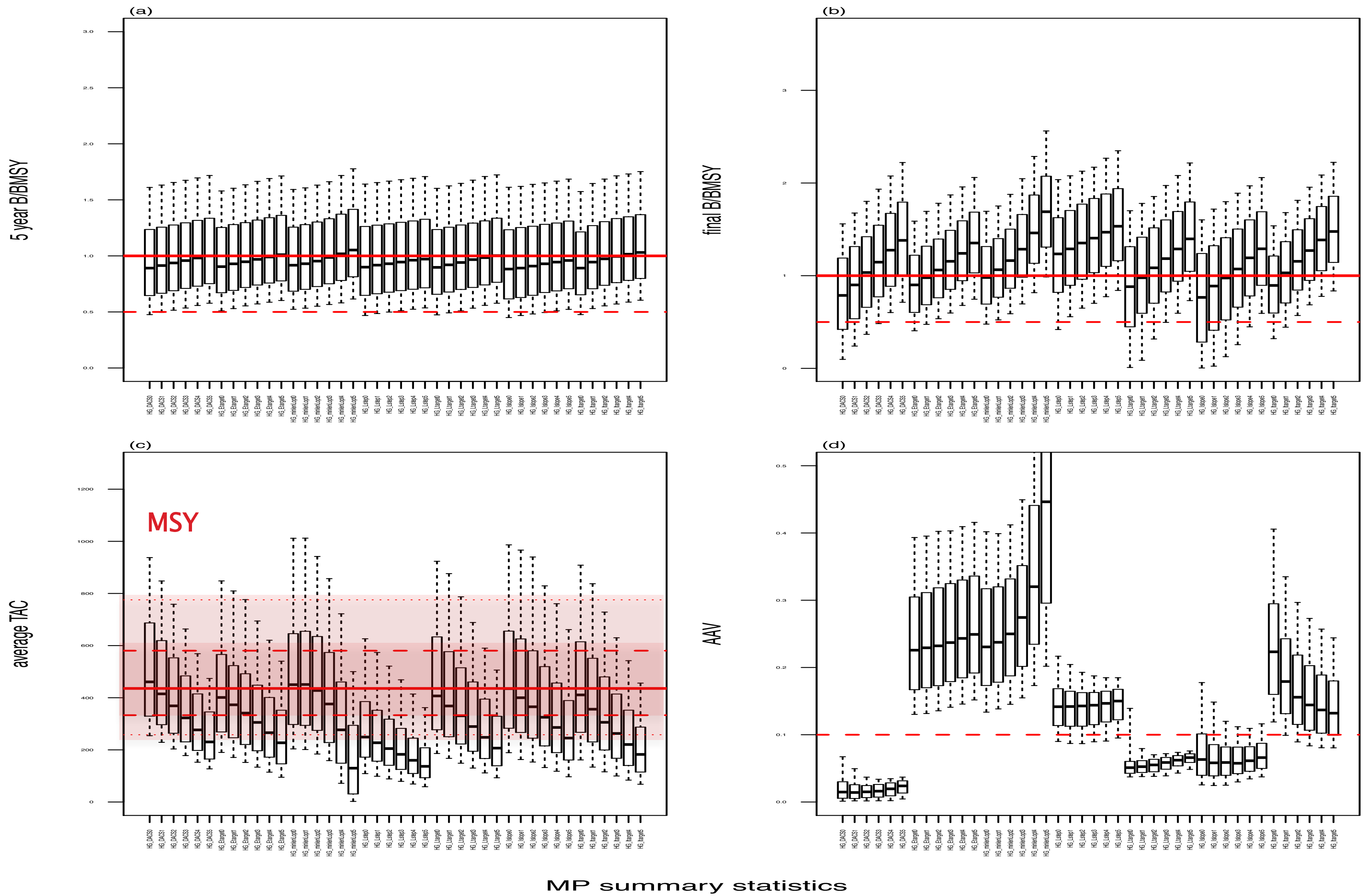
OM1b: severely depleted/medium productivity

Risk/Yield tradeoffs after 20 years



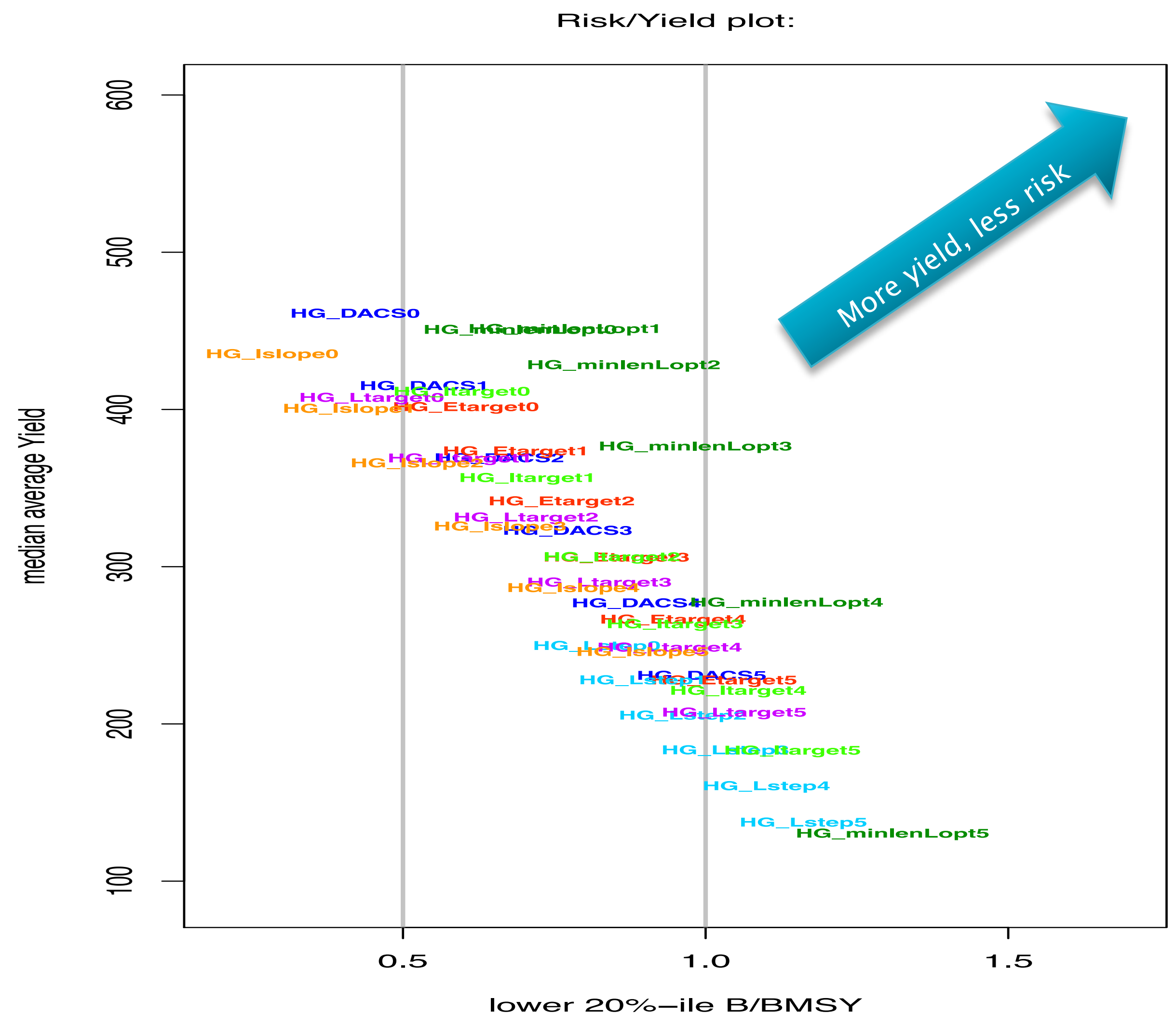
OM2a (moderately depleted/low productivity): 20-year projections

Boxplots: whiskers:5%-iles (SG100), boxes:20%-iles (SG80), bars: medians



OM2a: moderately depleted/low productivity

Risk/Yield tradeoffs after 20 years



OM2b (severely depleted/low productivity): 20-year projections

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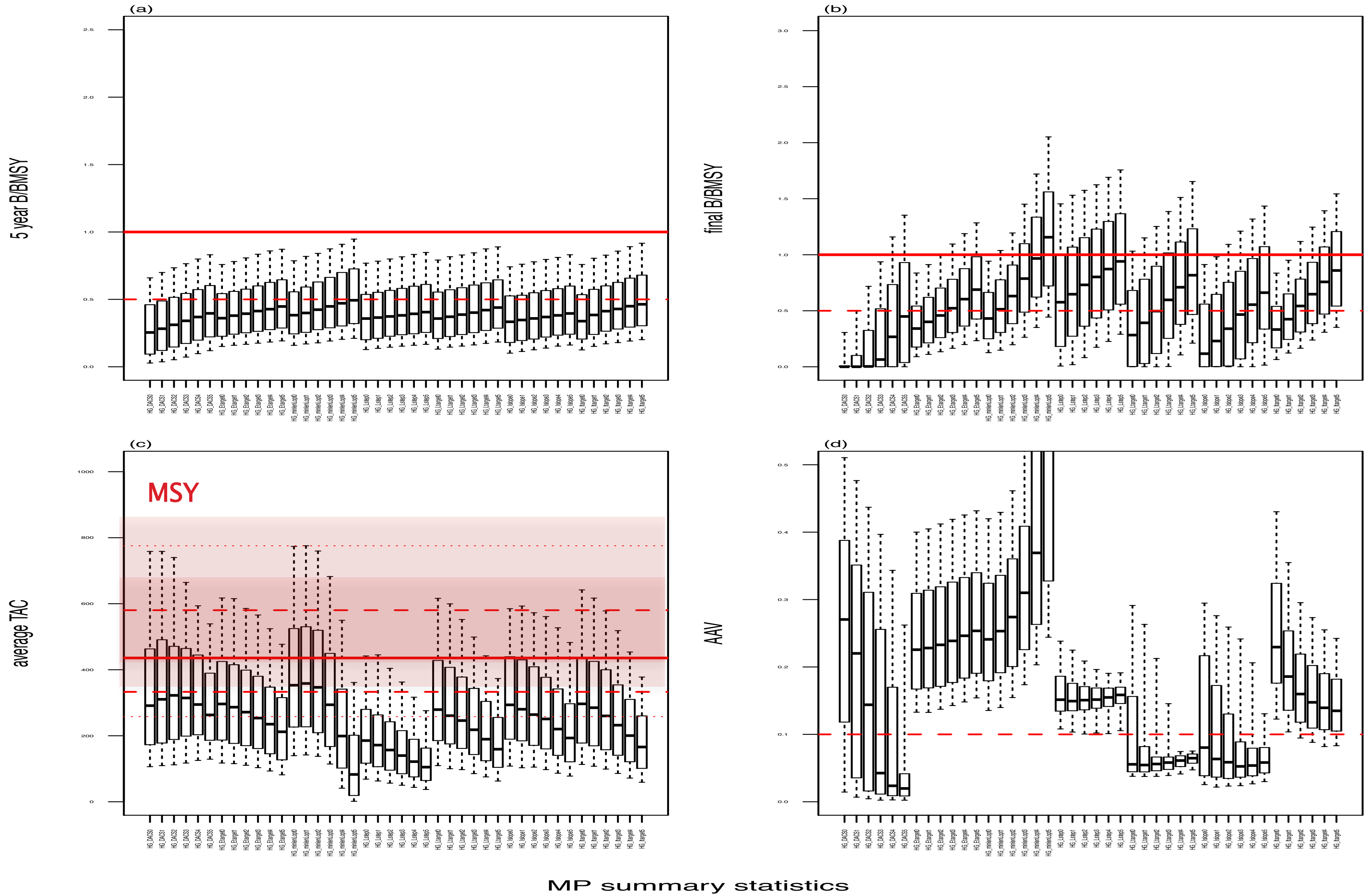
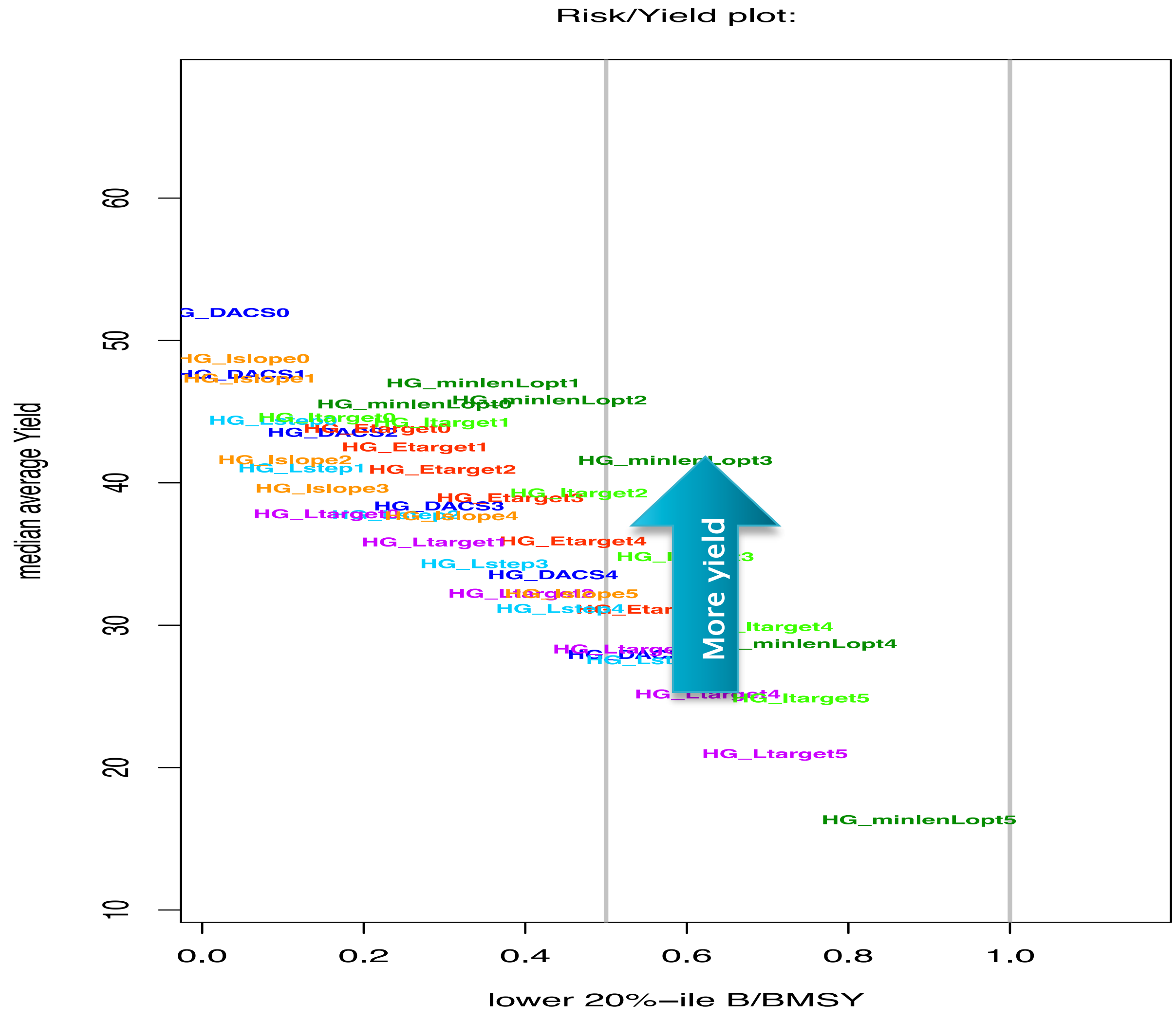


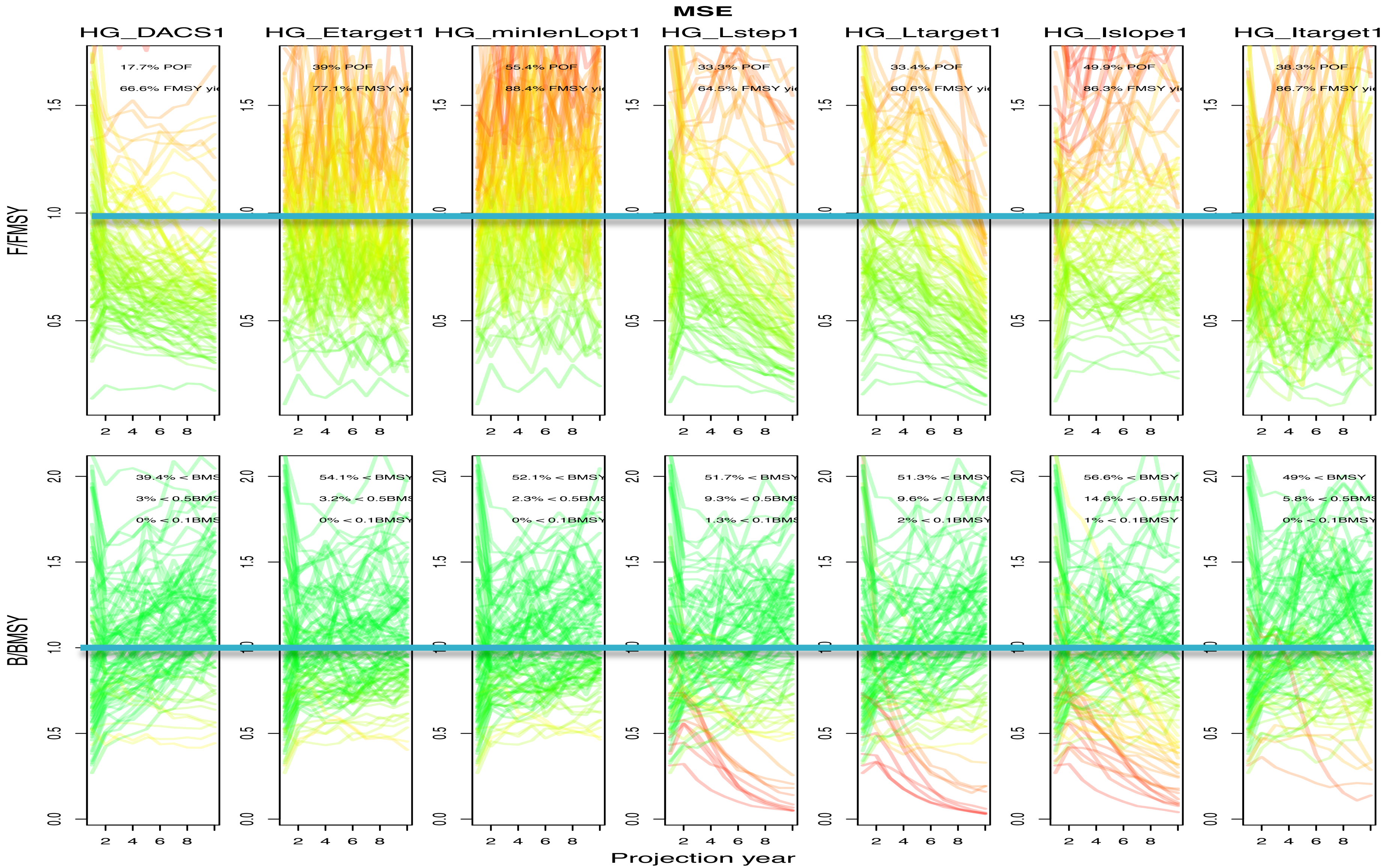
OM2b: severely depleted/low productivity

Risk/Yield tradeoffs after 20 years

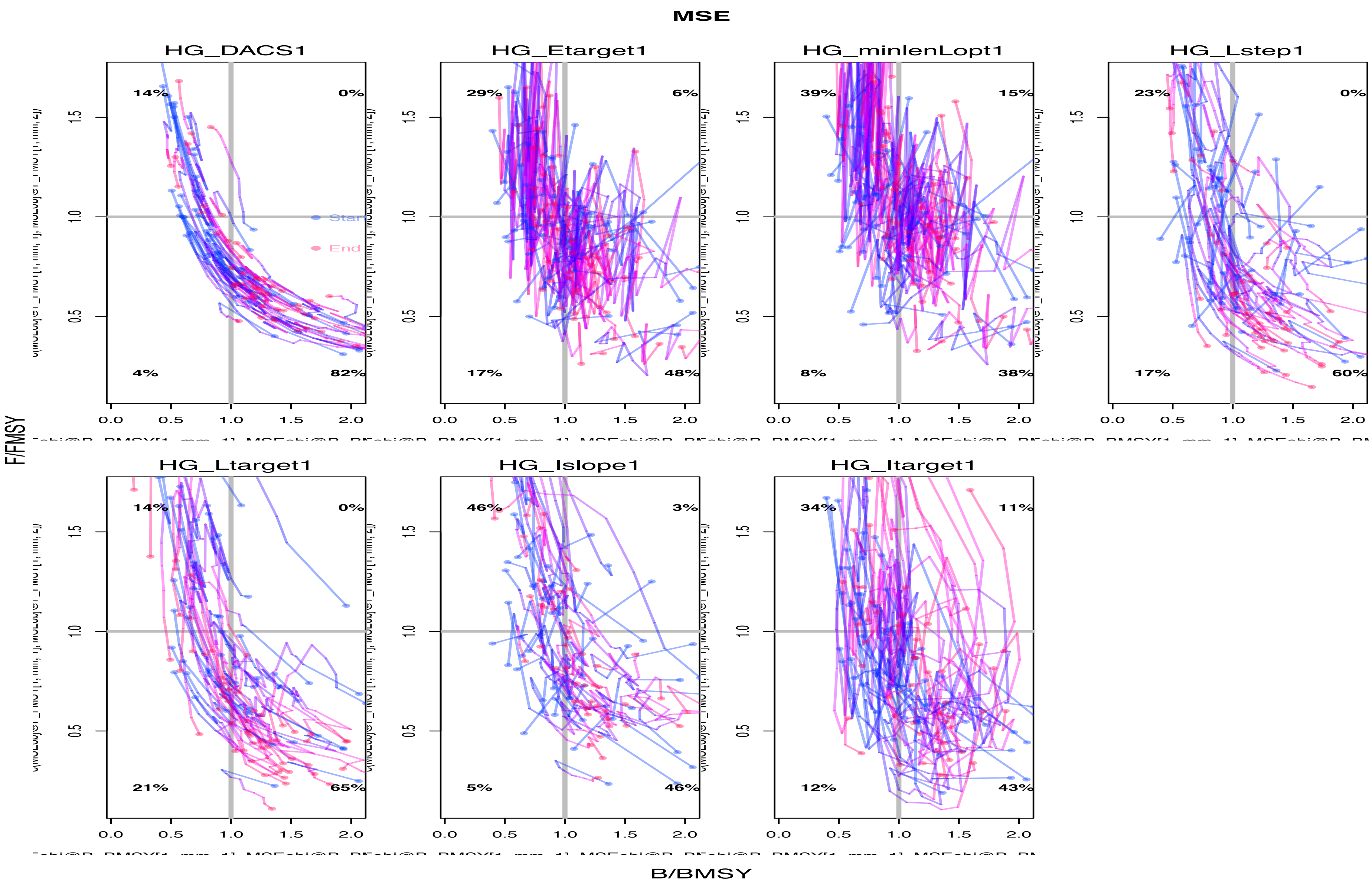


OM1a: Reference case basket

10yr projection plots with MPs using 10% buffers



OM1a: Kobe plots for10-year projections with 10% buffer MPs



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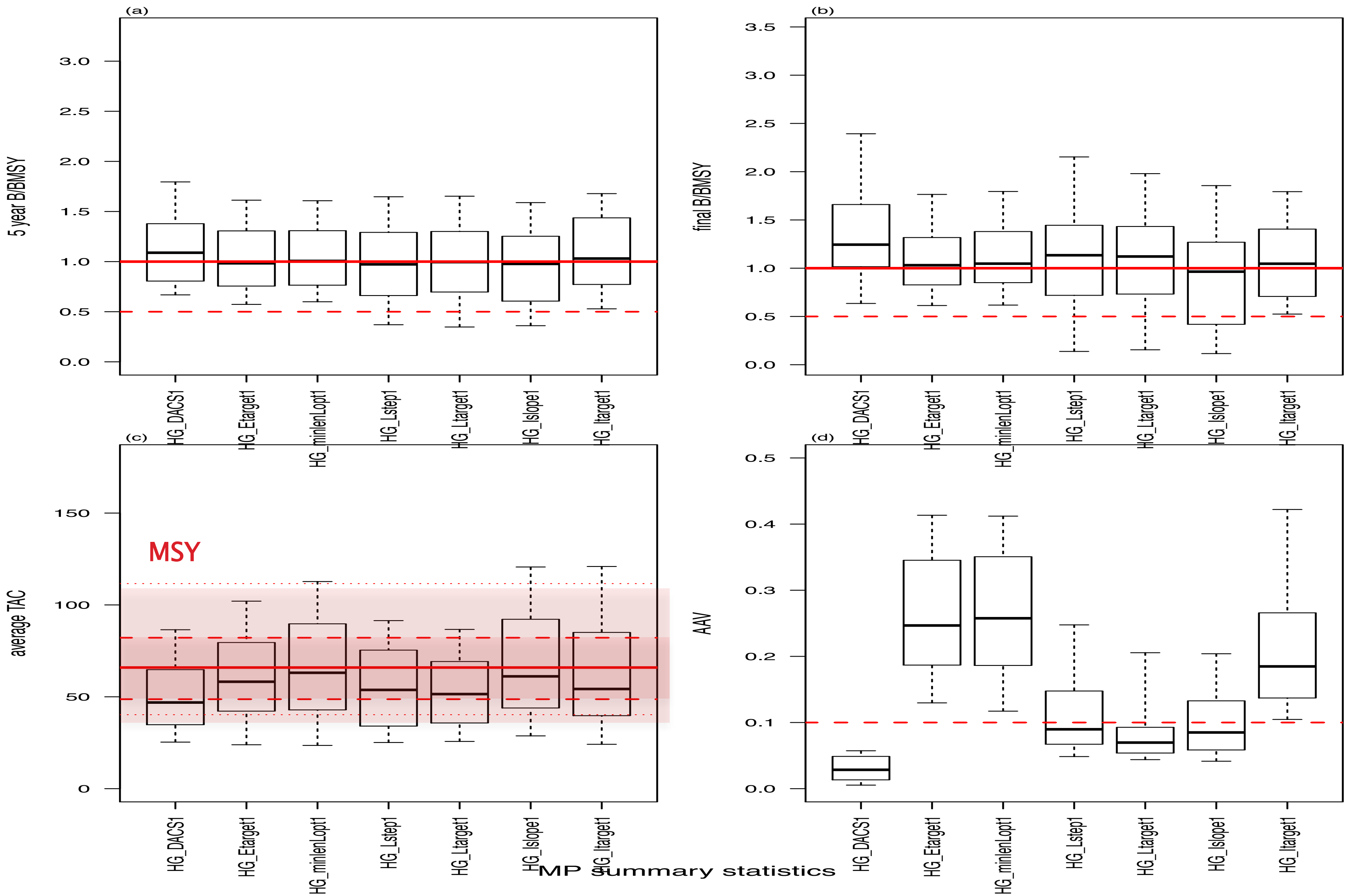


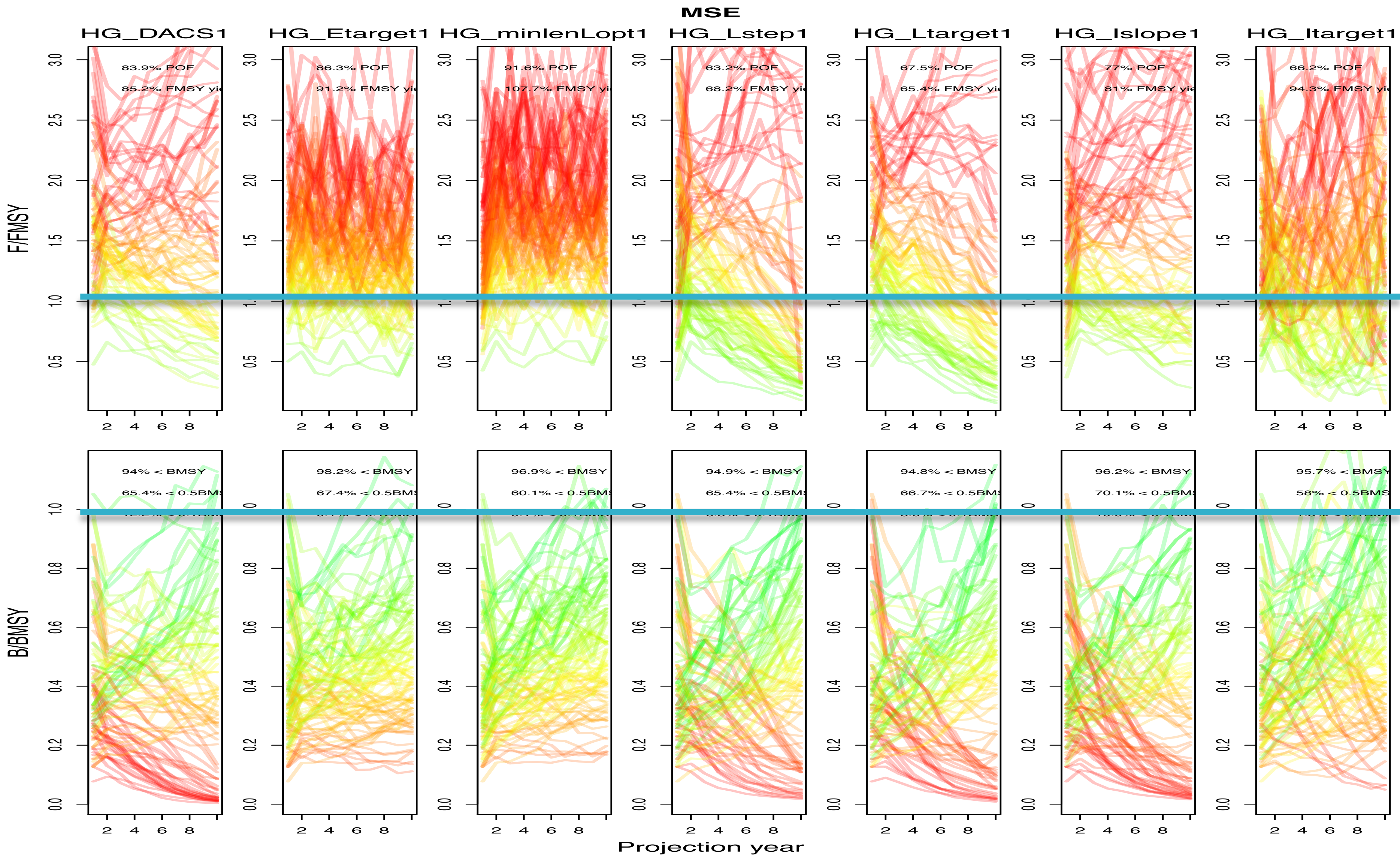
Robustness tests:
misclassification of stock in generic basket

Productivity/ Depletion	Medium productivity (0.1<M<0.3)	Low productivity (0.04<M<0.1)
At/above target: 0.4<B/K<0.6	OM1: Mackerel-type stock At/above target	OM2: Rockfish-type stock At/above target
Medium depletion: 0.2<B/K<0.4	OM1a: Mackerel-type stock Depleted	OM2a: Rockfish-type stock Depleted
Very depleted: 0.05<B/K<0.2	OM1b: Mackerel-type stock Very depleted	OM2b: Rockfish-type stock Very depleted

Not risk prone

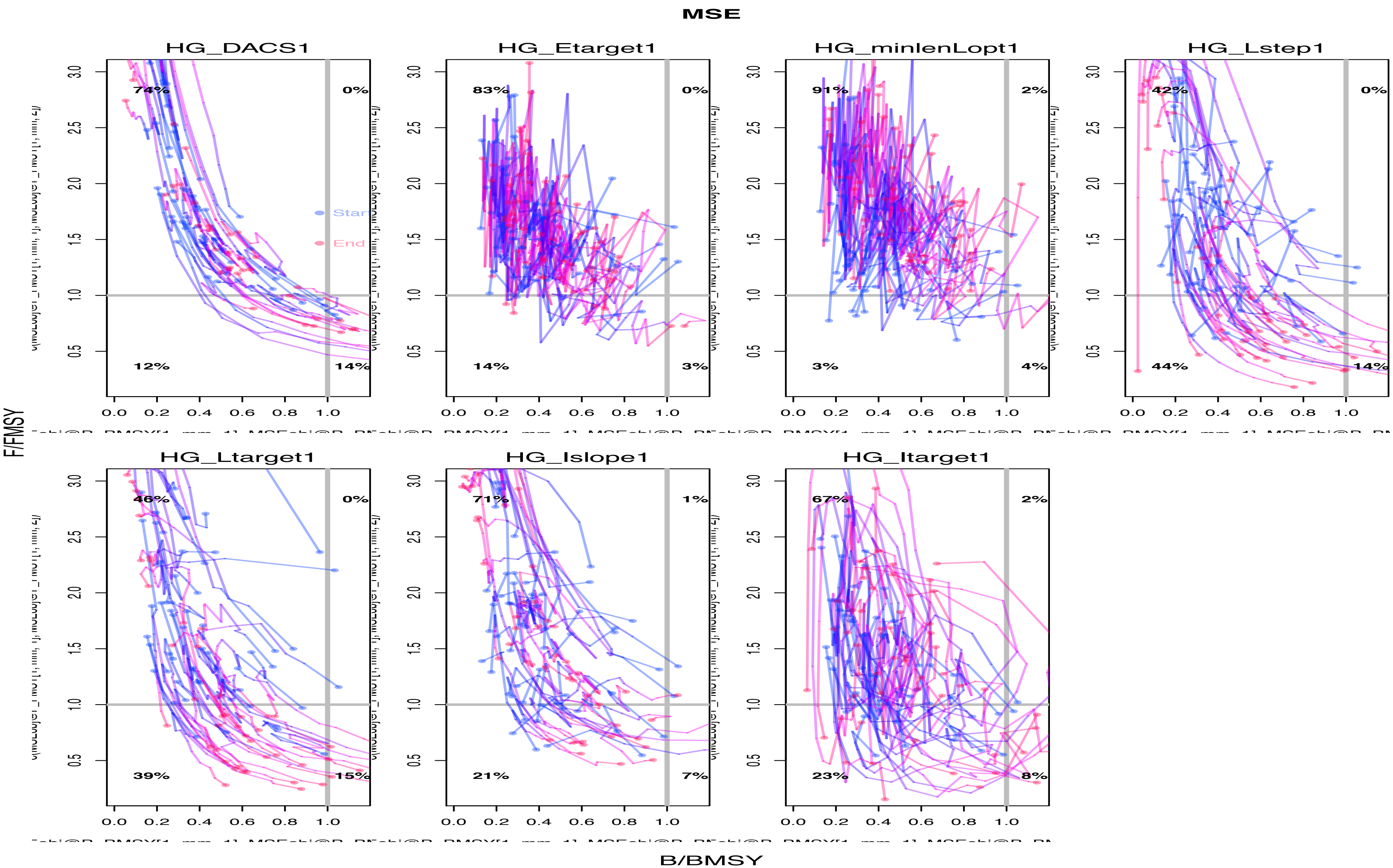
OM1b: True B/K lower than expected

10yr projection plots with MPs using 10% buffers



OM1b:

Kobe plots for10-year projections with 10% buffer MPs



OM1b: 10yr projection boxplots with MPs using 10% buffers

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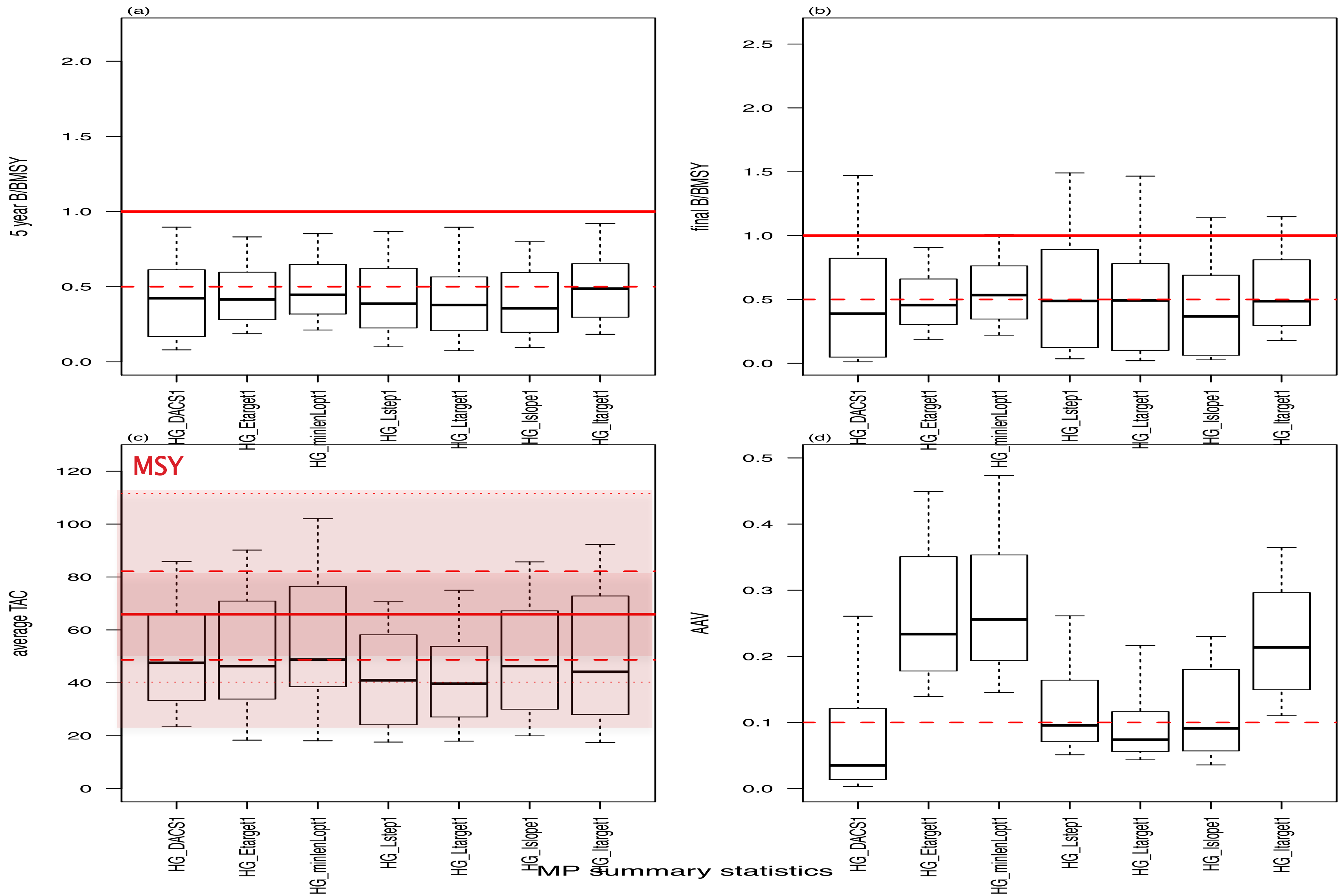
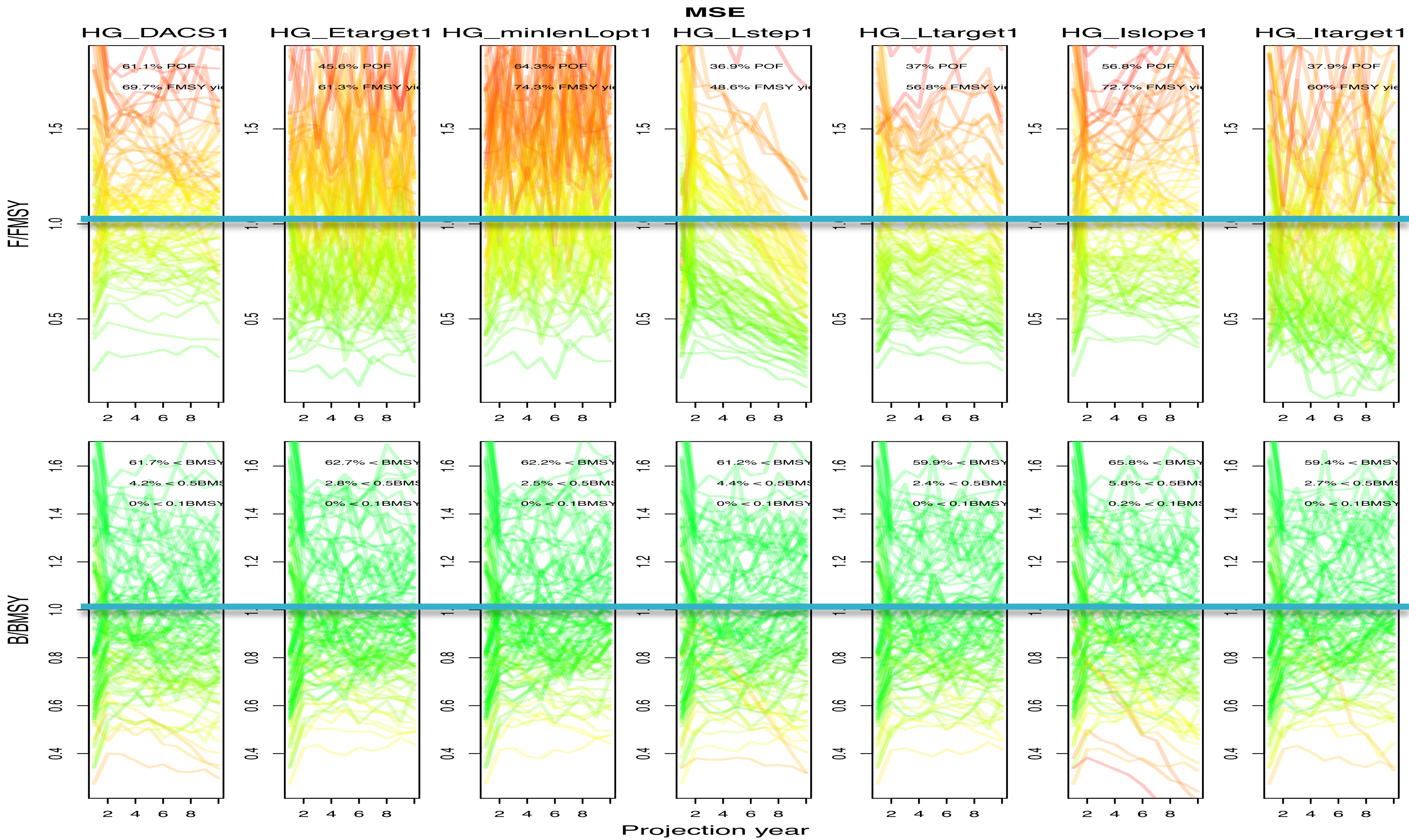


OM2a: True M lower than expected

10yr projection plots with MPs using 10% buffers



OM2a: True M lower than expected

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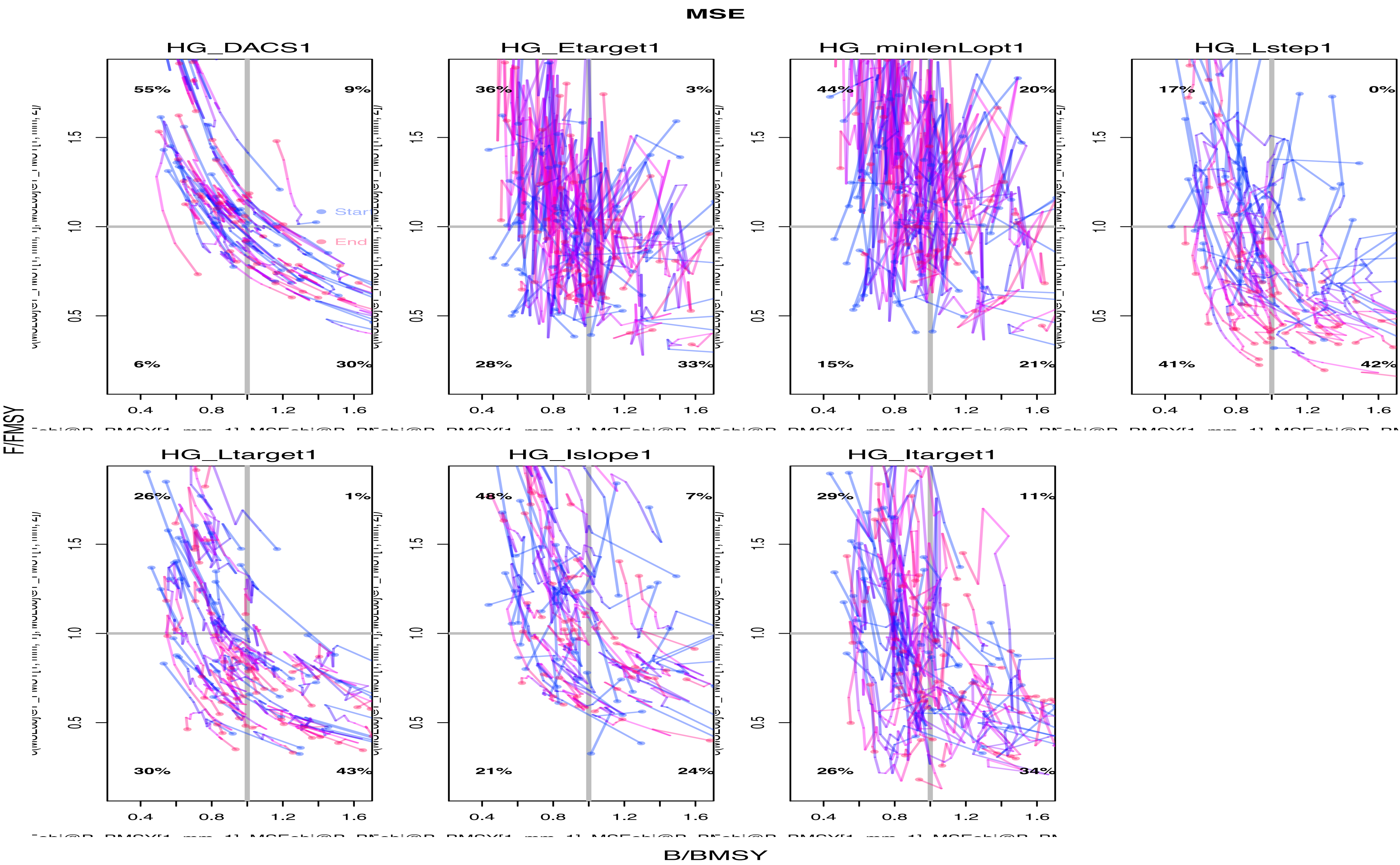

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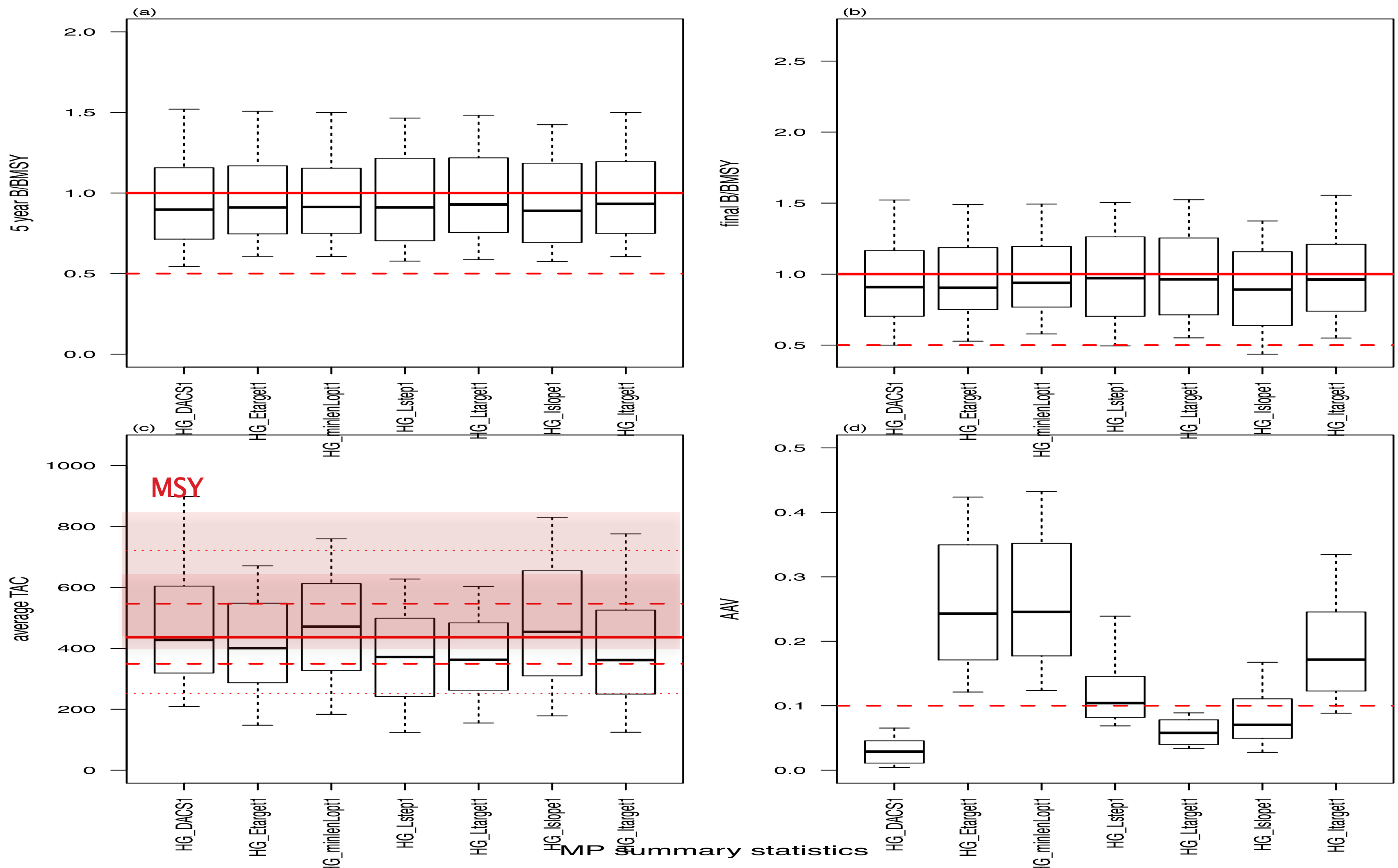
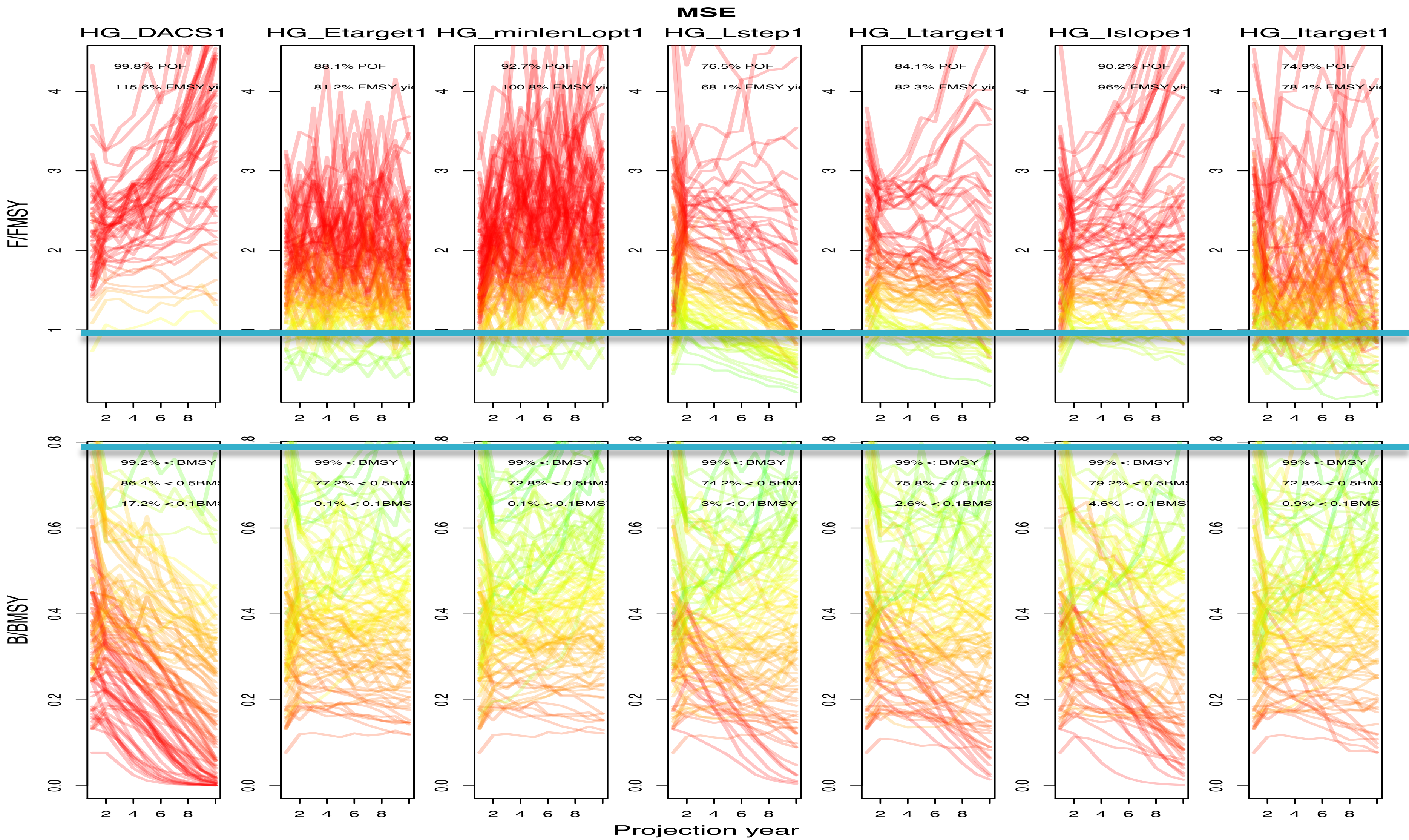


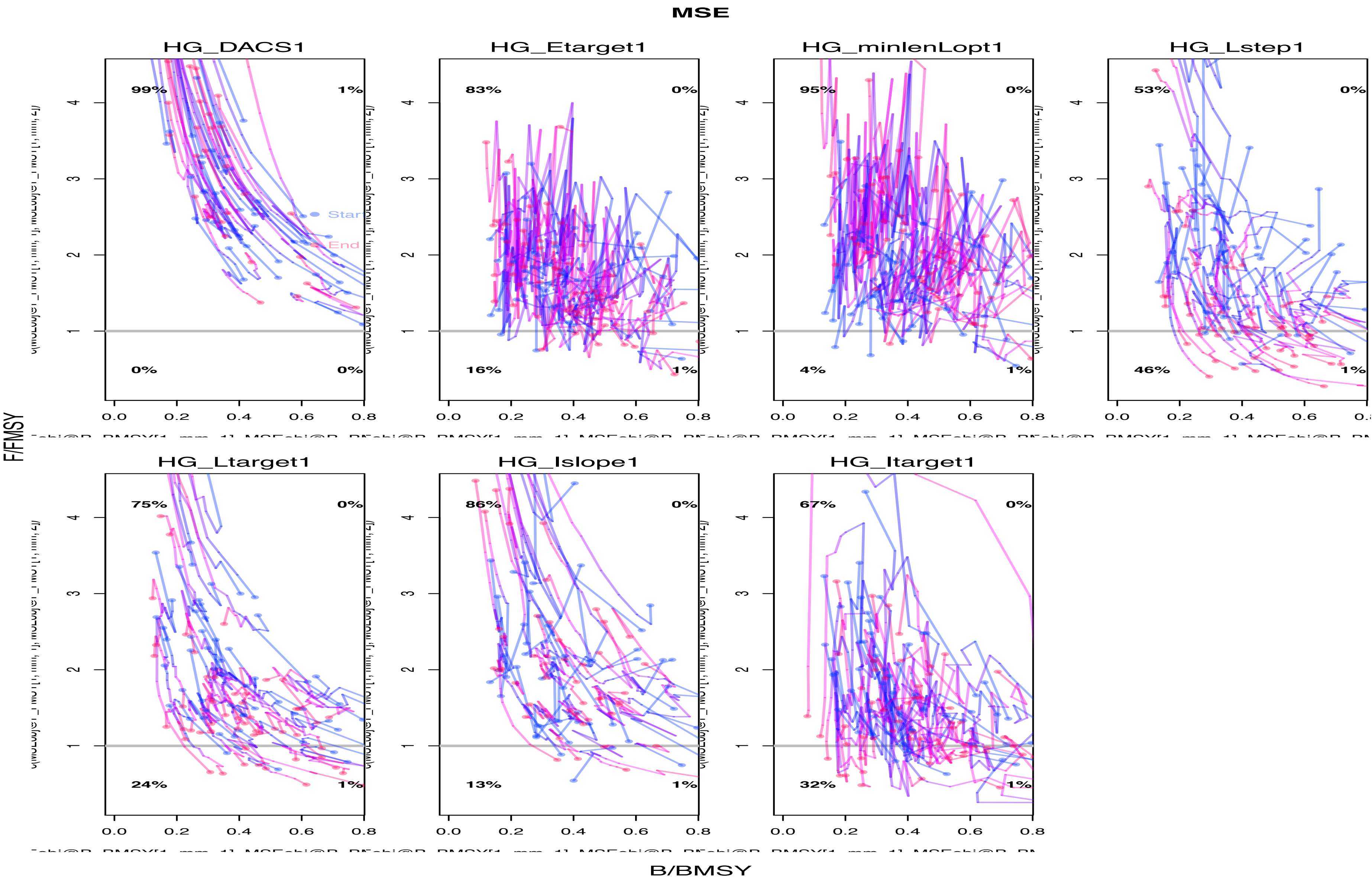
OM2b: True M and B/K lower than expected

10yr projection plots with MPs using 10% buffers



OM2b: True M and B/K lower than expected

Kobe plots for10-year projections with 10% buffer MPs



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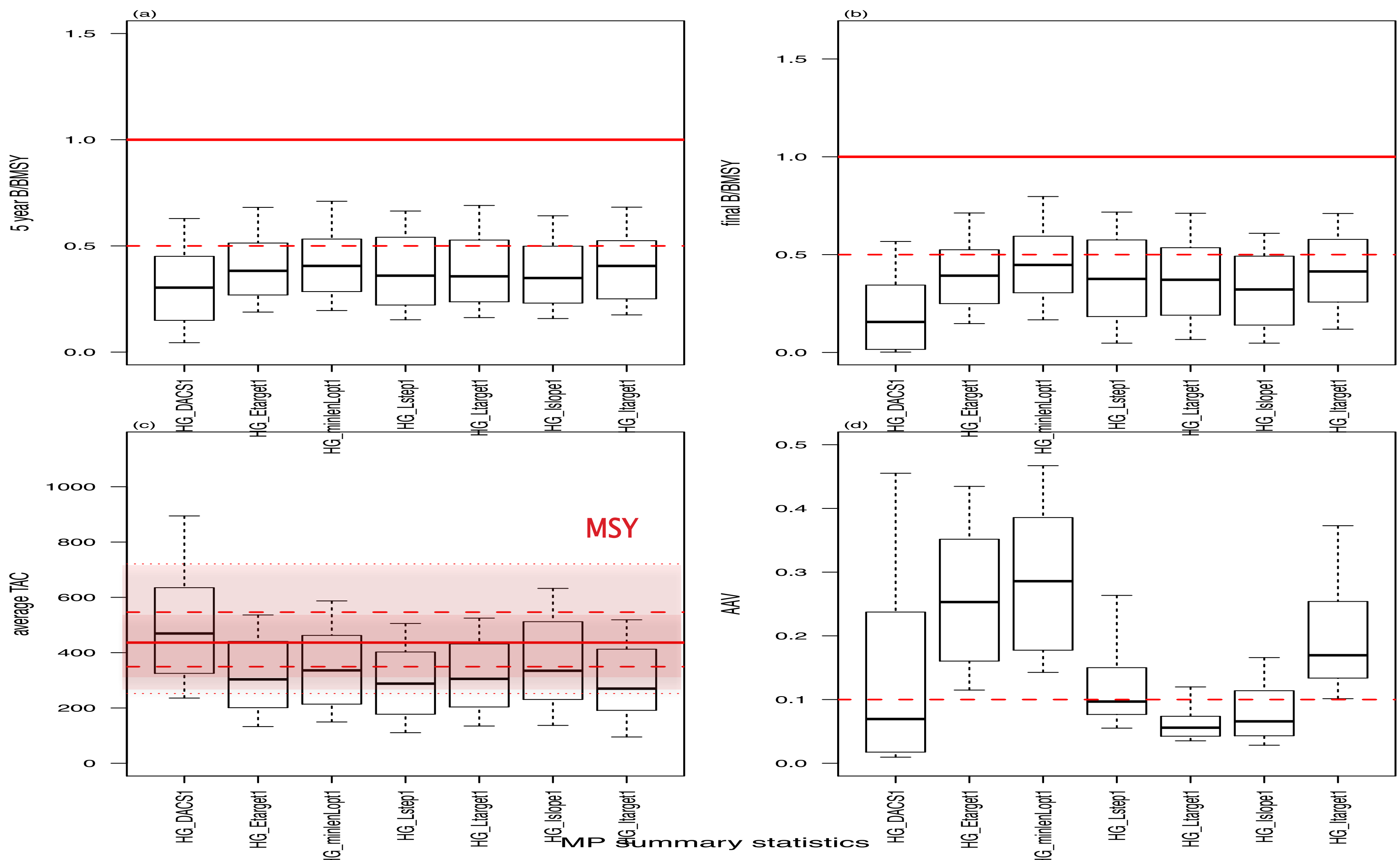

MP buffers required to achieve 60/80/100 pass score

Medium productivity stock (10y)

Moderately depleted

OM1a	Bycatch 1	Bycatch 2	Target
Minlen	0%	10%	10%
Etarget	0%	10%	20%
DACS	0%	0%	0%
Lstep	0%	20%	50%
Ltarget	0%	10%	30%
Islope	10%	20%	50%
Itarget	0%	10%	20%

Severely depleted

OM1b	Bycatch 1	Bycatch 2	Target
Minlen	20%	40%	50%
Etarget	30%	NA	NA
DACS	40%	50%	NA
Lstep	30%	50%	NA
Ltarget	10%	30%	NA
Islope	50%	NA	NA
Itarget	20%	40%	NA

Low productivity stock (20y)

Moderately depleted

OM2a	Bycatch 1	Bycatch 2	Target
Minlen	0%	10%	10%
Etarget	0%	20%	20%
DACS	0%	20%	40%
Lstep	0%	0%	10%
Ltarget	0%	20%	40%
Islope	10%	30%	50%
Itarget	0%	10%	20%

Severely depleted

OM2b	Bycatch 1	Bycatch 2	Target
Minlen	30%	50%	NA
Etarget	50%	NA	NA
DACS	NA	NA	NA
Lstep	30%	NA	NA
Ltarget	50%	NA	NA
Islope	NA	NA	NA
Itarget	40%	NA	NA

Some conclusions

- Prioritise species and organise into stock groups or stock baskets
- Define appropriate performance indicators for target and major and minor bycatch stocks: Different precautionary levels for categories to avoid choking
- Develop and tune MPs for target stocks

  Incorporate flexible multi-annual allocations for bycatch,

  time/area closures where appropriate, and

  exceptional circumstance clauses for low/bumper years
- Keep buffers within reason- too much precaution is wasteful
- Not possible to optimise yield consistently / not possible to avoid risk completely

  => Decide on acceptable trade-offs with stakeholders
- Simulation test (joint) MPs to achieve acceptable performance overall

Thank you

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