Performance Comparison

MP1-MP5. Median values over 20-year projection (2020-2040).*

Best scores
MP1
MP3   MP2

SUMMARY OF RESULTS
Management procedure 1 (MP1) performs best, scoring well for all 6 performance metrics over the 20-year projection period. MP3 also scores highly but with less stability in catches from year to year. MP2 performs well for yield-related metrics at the sacrifice of population health.

READING THIS CHART

This chart **compares the performance of 5 management procedures (MP) against 6 performance metrics**.

Each value is a median for X operating models over 20 years in the projection period 2020-2040.

⬡ The **filled hexagons on top** represent an **average score of all** performance metrics for each management procedure. It provides a quick comparison of overall MP performances. **Larger areas indicate better overall performance**.
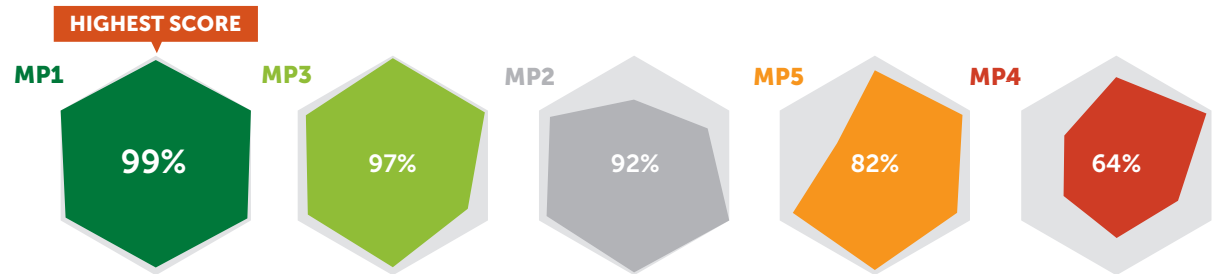
⬡ **The lines in the bottom spider plot** connect **individual scores** for the performance metrics in each management procedure. Scores closer to the exterior edge indicate better performance.
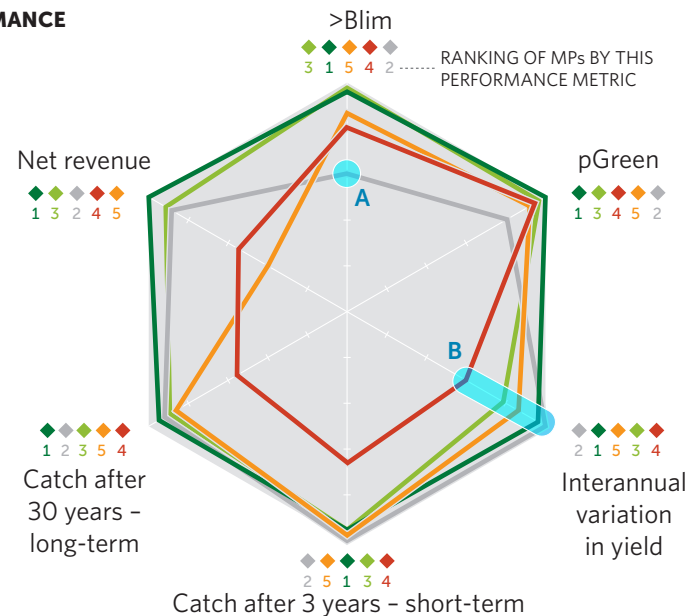
Glossary

Blim Biomass limit reference point

pGreen Probability that the population is not overfished and not subject to overfishing (i.e., in the green quadrant of the Kobe plot)

MANAGEMENT PROCEDURE **Overall scores** (average of 6 performance metrics)

HIGHEST SCORE

MP1	MP3	MP2	MP5	MP4
99%	97%	92%	82%	64%

PERFORMANCE METRICS

>Blim

◆◆◆◆◆
3 1 5 4 2 ---- RANKING OF MPs BY THIS PERFORMANCE METRIC

Net revenue
◆◆◆◆◆
1 3 2 4 5

pGreen
◆◆◆◆◆
1 3 4 5 2

A

B

Catch after 30 years – long-term
◆◆◆◆◆
1 2 3 5 4

Interannual variation in yield
◆◆◆◆◆
2 1 5 3 4

Catch after 3 years – short-term
◆◆◆◆◆
2 5 1 3 4

Notes

A *Maximizing catch in the short-term has a tradeoff of increasing the likelihood of the population declining below the limit reference point.*

B *MP2 has the lowest interannual variation in catch, making it the most stable MP, while MP4 has the most variation and least stability.*

*The plot can also be used to show the results at the end of the projection period.

Performance Comparison

MP1-MP5. Median values over 20-year projection (2020-2040).*

Best scores
MP1
MP3   MP2

SUMMARY OF RESULTS
Management procedure 1 (MP1) performs best, scoring well for all 4 performance metrics over the 20-year projection period. MP3 also scores highly, with the highest probability of being in the Kobe green quadrant but with slightly less stability in catches from year to year, lower catch, and a lower net revenue. MP2 performs well for yield-related metrics at the sacrifice of population health.

READING THIS CHART

This chart **compares the performance of 5 management procedures (MP) against 4 performance metrics**. Only those with relevant differences are shown in the chart.

Each value is a median for X operating models over 20 years in the projection period 2020-2040.
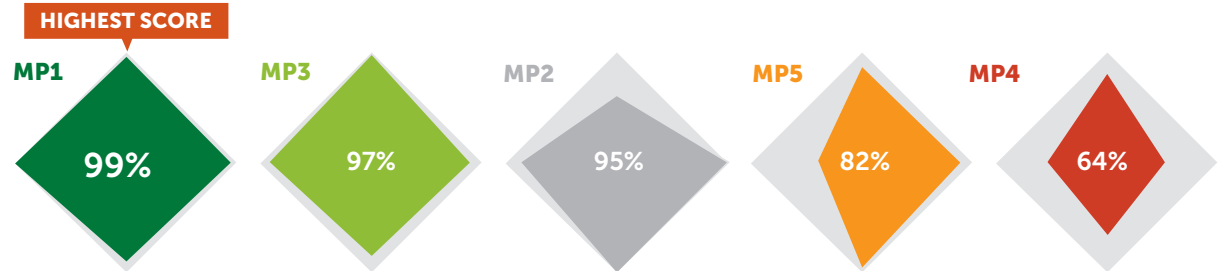
◆ The **filled diamonds on top** represent the **average score for all** performance metrics for each management procedure. It provides a quick comparison of overall MP performances. **Larger areas indicate better overall performance.**

◇ **The lines in the bottom spider plot** represent **individual scores** for performance metrics in each management procedure. Scores closer to the exterior edge indicate better performance.
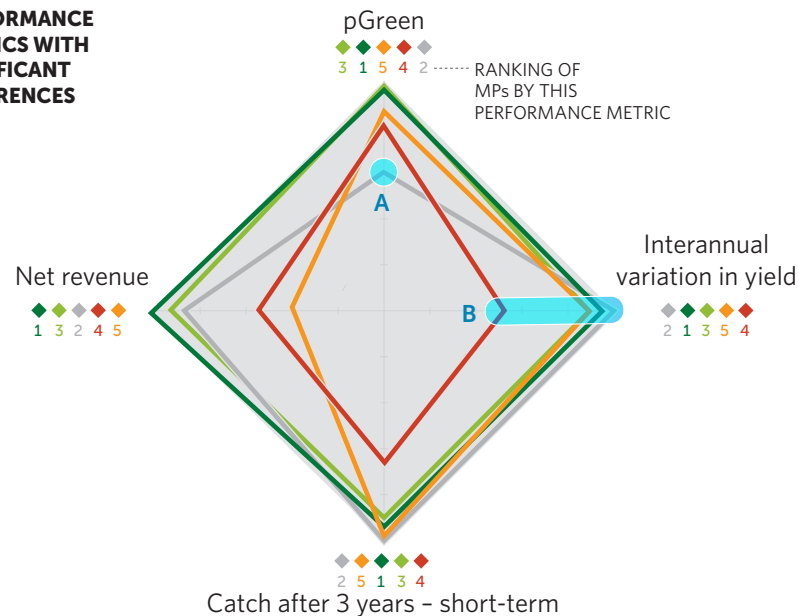
Glossary

Blim Biomass limit reference point

pGreen Probability that the population is not overfished and not subject to overfishing (i.e., in the green quadrant of the Kobe plot)

MANAGEMENT PROCEDURE Overall scores (average of 4 performance metrics)

HIGHEST SCORE

MP1	MP3	MP2	MP5	MP4
99%	97%	95%	82%	64%

PERFORMANCE METRICS WITH SIGNIFICANT DIFFERENCES

pGreen
3 1 5 4 2 ······· RANKING OF MPs BY THIS PERFORMANCE METRIC

Net revenue
1 3 2 4 5

A

B

Interannual variation in yield
2 1 3 5 4

Catch after 3 years – short-term
2 5 1 3 4

PERFORMANCE METRICS WITH NO SIGNIFICANT DIFFERENCES

• >Blim

• Catch after 30 years – long-term

Notes

A *Maximizing catch in the short-term has a tradeoff of decreasing the likelihood that the population is in the green quadrant of the Kobe plot.*

B *MP2 has the lowest interannual variation in catch, making it the most stable MP, while MP4 has the most variation and least stability.*

*The plot can also be used to show the results at the end of the projection period.

Performance Comparison

MP1-MP5. Median values over 20-year projection (2020-2040).*

Best scores

MP1

MP3   MP2

SUMMARY OF RESULTS

Management procedure 1 (MP1) performs best, scoring well for all performance metrics over the 20-year projection period except short-term catch, a necessary tradeoff to ensure long-term population health and fishery prosperity. MP3 also scores highly but with slightly lower population health and a lower net revenue. MP4 scores highest in terms of short term catch at the expense of the 5 other performance metrics for which there are significant differences across MPs.

READING THIS CHART

This chart **compares the performance of 5 management procedures (MP) against 10 performance metrics**.

Each value is a median for X operating models over 20 years in the projection period 2020-2040.

● The **large dots** represent the **average score for all** performance metrics in each management procedure. It provides a quick measure of overall MP performance.

• **Small dots** represent **individual scores** for performance metrics in each management procedure.

➡ Scores on the right side of the scale indicate better performance

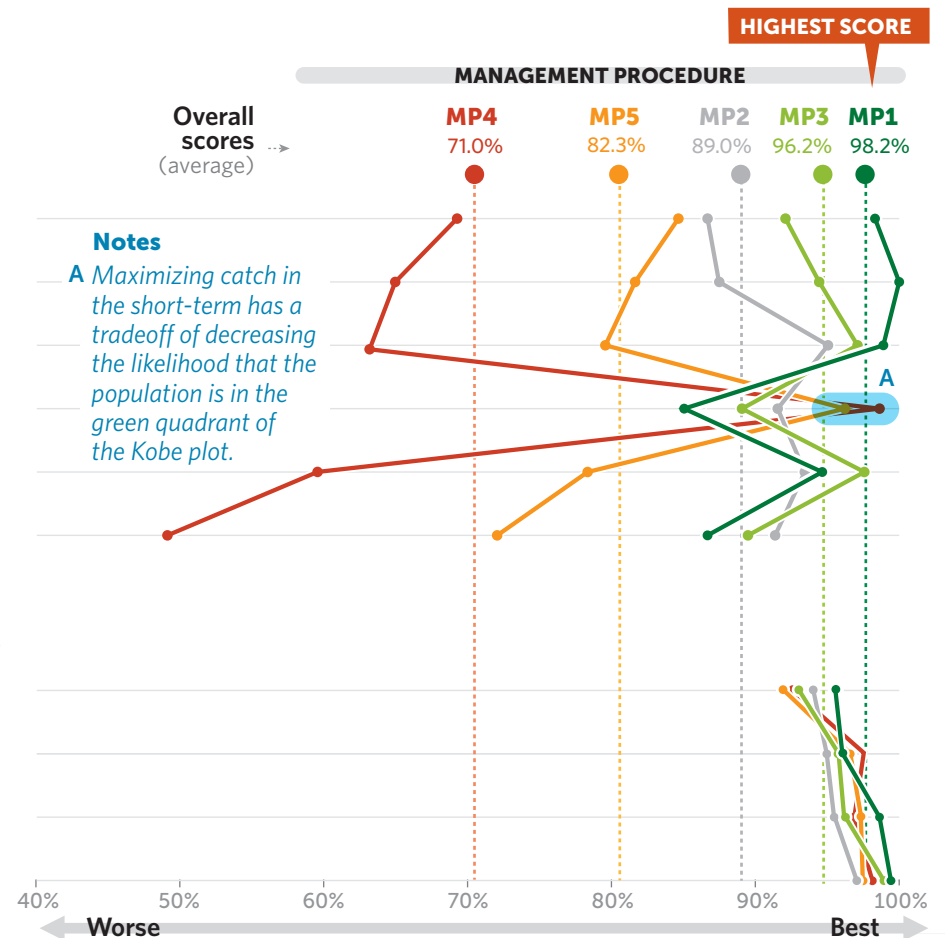## Glossary

Blim Biomass limit reference point

pGreen Probability that the population is not overfished and not subject to overfishing (i.e., in the green quadrant of the Kobe plot)

HIGHEST SCORE

MANAGEMENT PROCEDURE

PERFORMANCE METRICS WITH SIGNIFICANT DIFFERENCES ACROSS MPs

Overall scores (average)

MP4	MP5	MP2	MP3	MP1
71.0%	82.3%	89.0%	96.2%	98.2%

Net revenue

pGreen

>Blim

Notes

A *Maximizing catch in the short-term has a tradeoff of decreasing the likelihood that the population is in the green quadrant of the Kobe plot.*

Catch after 3 years – short-term

A

Catch after 30 years – long-term

Interannual variation in yield

NO SIGNIFICANT DIFFERENCES

Minimize bycatch

Equitable fishing opportunities

CPUE

Food security

40%   50%   60%   70%   80%   90%   100%

⬅ **Worse**   **Best** ➡

*The plot can also be used to show the results at the end of the projection period.

Performance Comparison

MP1-MP5. Median values over 20-year projection (2020-2040).

Best scores
MP1
MP3   MP2

SUMMARY OF RESULTS
Management procedure 1 (MP1) performs best, scoring well for all performance metrics over the 20-year projection period except short-term catch, a necessary tradeoff to ensure long-term population health. MP3 also scores highly, particularly for long-term catch and avoiding the limit reference point, but with much lower short-term catch, less stability in catches from year to year and a lower chance of being in the Kobe green quadrant. MP4 performs well for short-term yield at the sacrifice of population health.

READING THIS CHART

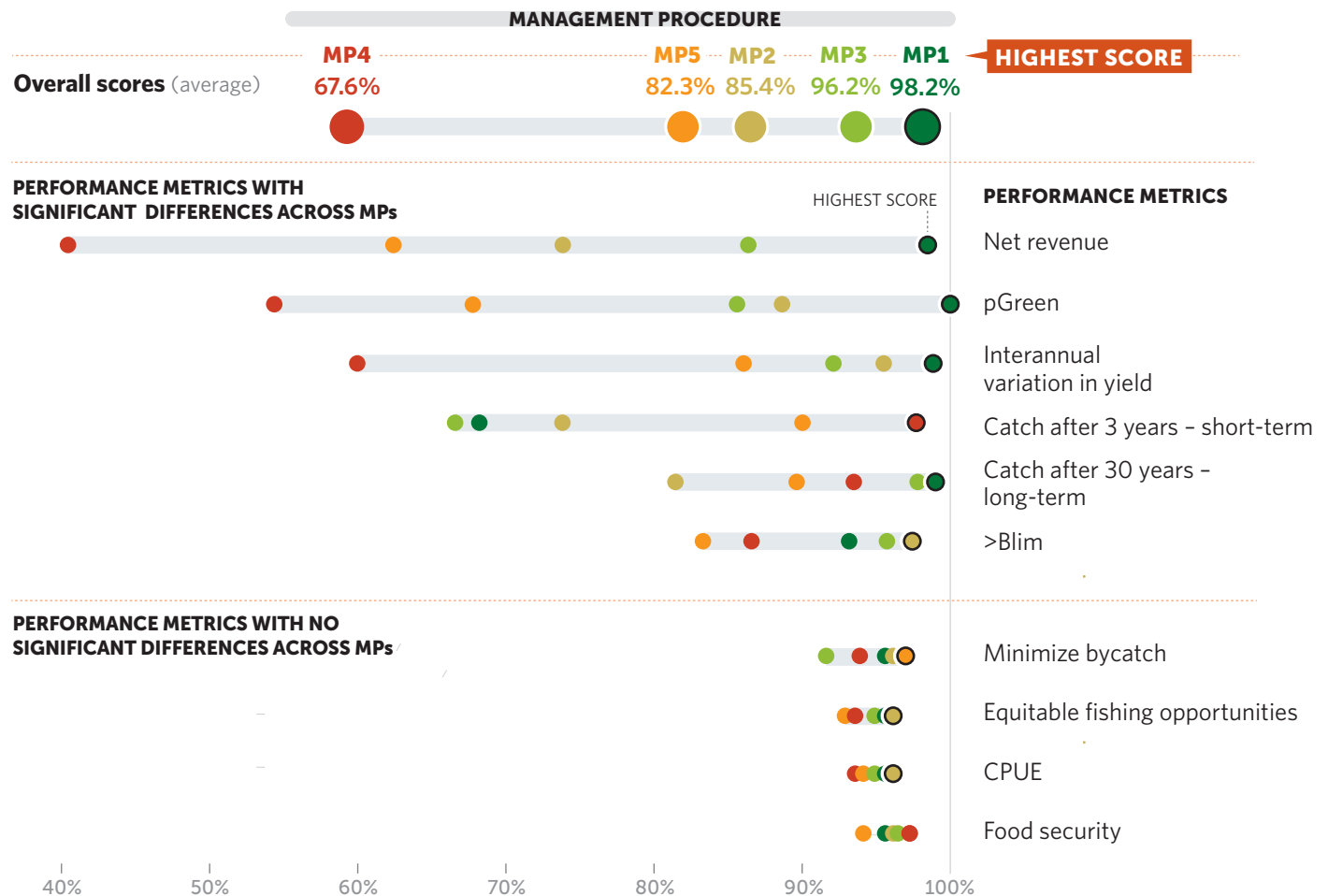This chart **compares the performance of 5 management procedures (MP) against 10 performance metrics**.

Each value is a median for X operating models over 20 years in the projection period 2020-2040.

● The **large dots** represent the **average score for all** performance metrics in each management procedure. It provides a quick measure of overall MP performance.

● **Small dots** represent **individual scores** for performance metrics in each management procedure.

➡ Scores on the right side of the scale indicate better performance.

⬌ Performance metrics with the largest differences across MPs are shown first as they may be key to assessing and choosing a MP.

Glossary

Blim Biomass limit reference point

pGreen Probability that the population is not overfished and not subject to overfishing (i.e., in the green quadrant of the Kobe plot)

MANAGEMENT PROCEDURE

| MP4 | MP5 | MP2 | MP3 | MP1 | HIGHEST SCORE |

Overall scores (average)
67.6%   82.3%   85.4%   96.2%   98.2%

PERFORMANCE METRICS WITH SIGNIFICANT DIFFERENCES ACROSS MPs

HIGHEST SCORE

PERFORMANCE METRICS

Net revenue

pGreen

Interannual variation in yield

Catch after 3 years – short-term

Catch after 30 years – long-term

>Blim

PERFORMANCE METRICS WITH NO SIGNIFICANT DIFFERENCES ACROSS MPs

Minimize bycatch

Equitable fishing opportunities

CPUE

Food security

40%   50%   60%   70%   80%   90%   100%

Projection of trade-off between catch and biomass

MP1-MP6 over 2020-2040 period.

Best scores
MP3
MP2 MP4

SUMMARY OF RESULTS
Management procedure 3 (MP3) performs best, with the highest probability of being in the green quadrant of the Kobe plot (i.e., not overfished, no overfishing) over the 20-year projection period. MP2 also performs well but with a higher probability of being in the orange (i.e., overfished, no overfishing). MP5 performs poorly, likely to remain in the red quadrant of the Kobe plot (i.e., overfished, no overfishing) for nearly the entire projection period.

READING THIS CHART

This chart **compares** and **ranks projected median values for X operating models over time for six management procedures**, and shows the level of **uncertainty**. Segments within each bar are another way of looking at the error bars in the Kobe plot. They show the percentage of runs that fall in each of the Kobe quadrants in each projection year. The probability of being in the green quadrant should be ≥**60%**, a common management objective.

UNCERTAINTY
MEDIAN OF OTHER MPs
THIS MP
LAST PROJECTION YEAR
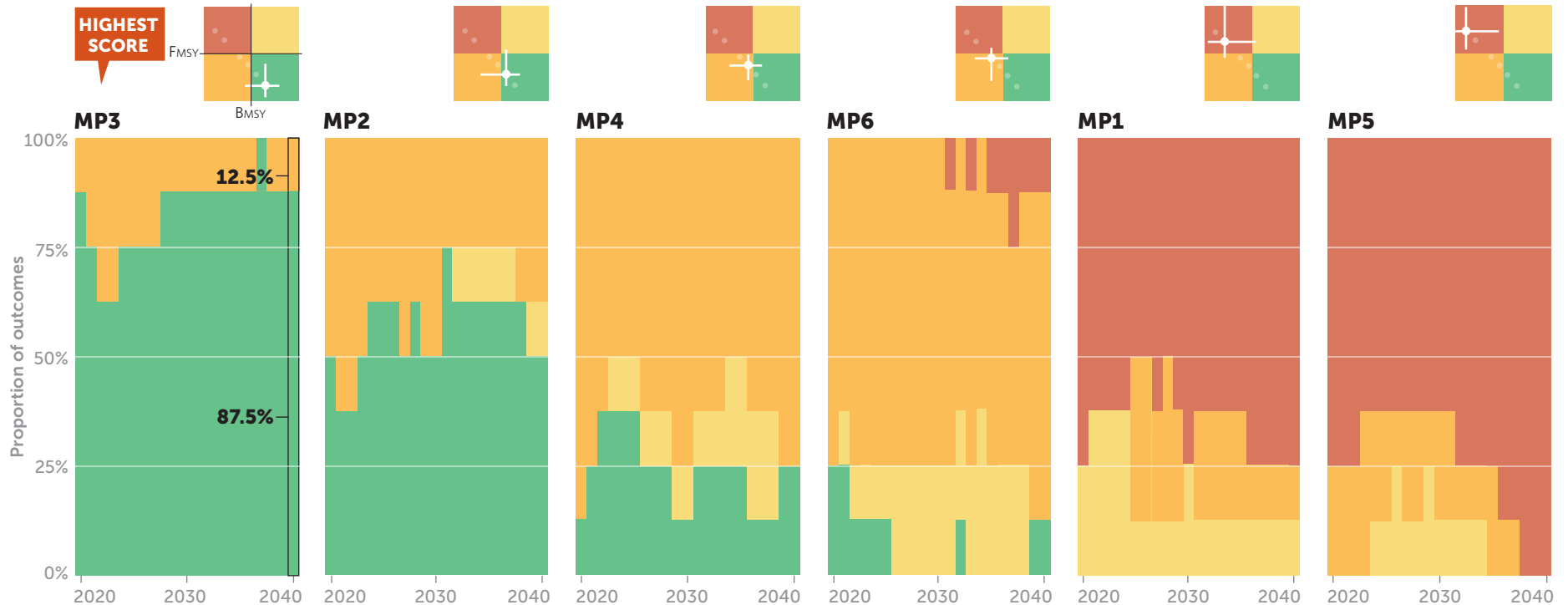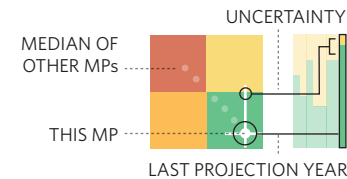
Stock size projection

Historical (1950-2016) and projections for MP1-MP5, plus Zero-Catch (2017-2040). Index (1950=100%).
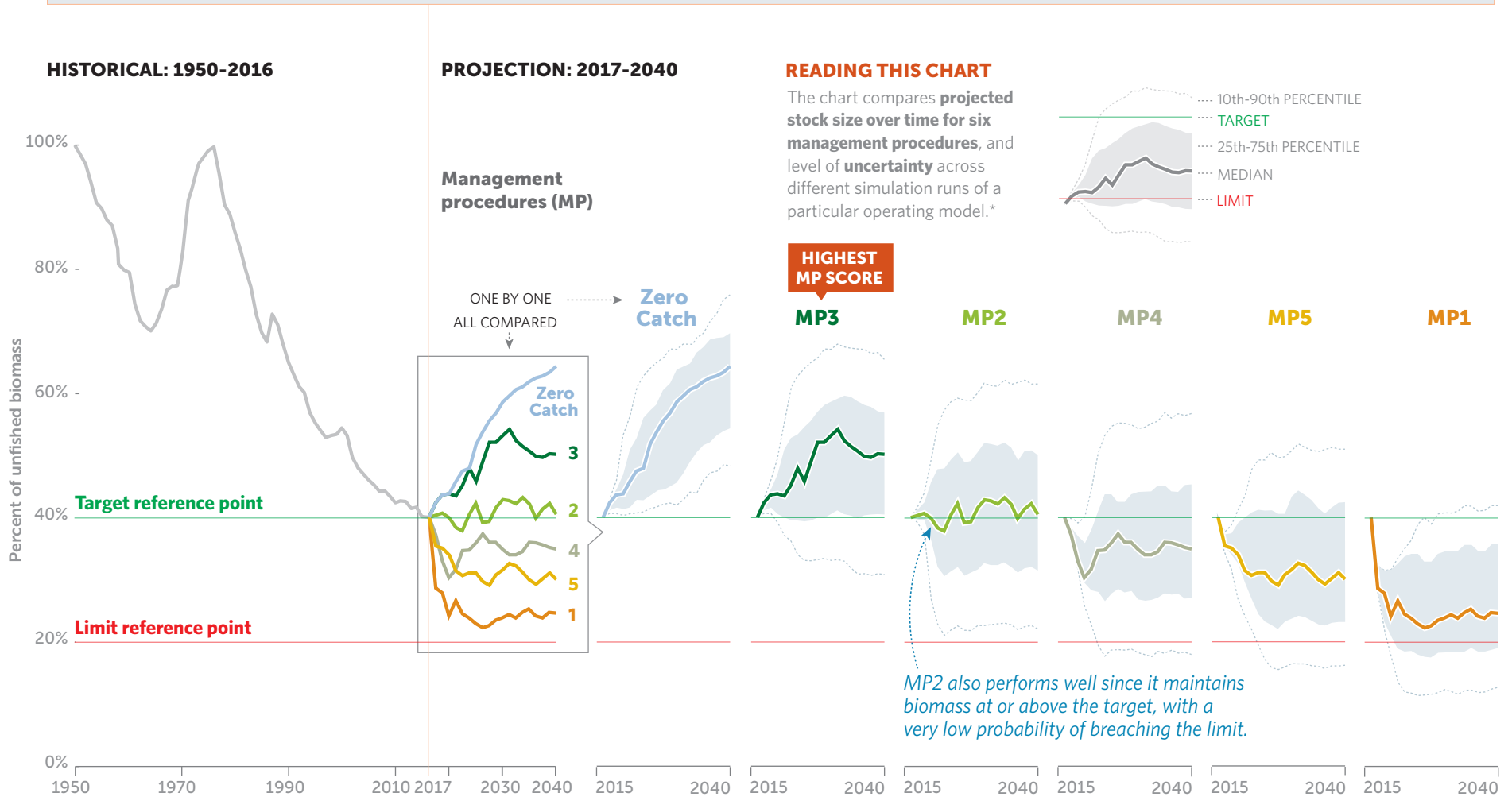

Best scores
MP2
MP3 MP4

SUMMARY OF RESULTS

Management Procedure 2 (MP2) performs best, maintaining biomass around the target reference point and well above the limit reference point over the 20-year projection period. MP3 also performs well, with projected biomass remaining well above both the target and limit reference points over the 20-year projection period, but it is ranked lower than MP2 since it is unnecessarily higher than the target. MP1, MP4, and MP5 are not suitable options as biomass is projected to be consistently below the target reference point.

HISTORICAL: 1950-2016

PROJECTION: 2017-2040

READING THIS CHART

The chart compares **projected stock size over time for six management procedures**, and level of **uncertainty** across different simulation runs of a particular operating model.*

- 10th-90th PERCENTILE
- TARGET
- 25th-75th PERCENTILE
- MEDIAN
- LIMIT

Management procedures (MP)

ONE BY ONE ········▶
ALL COMPARED

HIGHEST MP SCORE

Zero Catch   MP3   MP2   MP4   MP5   MP1

Percent of unfished biomass

100%

80%

60%

Zero Catch

3

40% — **Target reference point**

2

4

5

20% — **Limit reference point**

1

0%

1950   1970   1990   2010 2017   2030   2040

2015   2040   2015   2040   2015   2040   2015   2040   2015   2040   2015   2040

MP2 also performs well since it maintains biomass at or above the target, with a very low probability of breaching the limit.

*This chart type can also be used to show results averaged across all operating models.

Trade-off: catch/biomass

Six management procedures (MP1-MP6). Median in final year of 2020-2040 projection.

Best scores
MP2
MP3

SUMMARY OF RESULTS
Management procedure 2 (MP2) and MP3 perform best, maintaining the stock around B_{MSY} while fishing around the target reference point. While MP4 and MP6 also project a sustainable stock, fishing effort is lower than necessary. The failure of MP5 stems from severe overfishing, resulting in an overfished stock.

READING THIS CHART

The chart **compares trade-offs** in six management procedures (MPs) for X operating models by measuring two co-dependent performance metrics: **fishing mortality** (vertical axis) and **biomass** (horizontal axis).
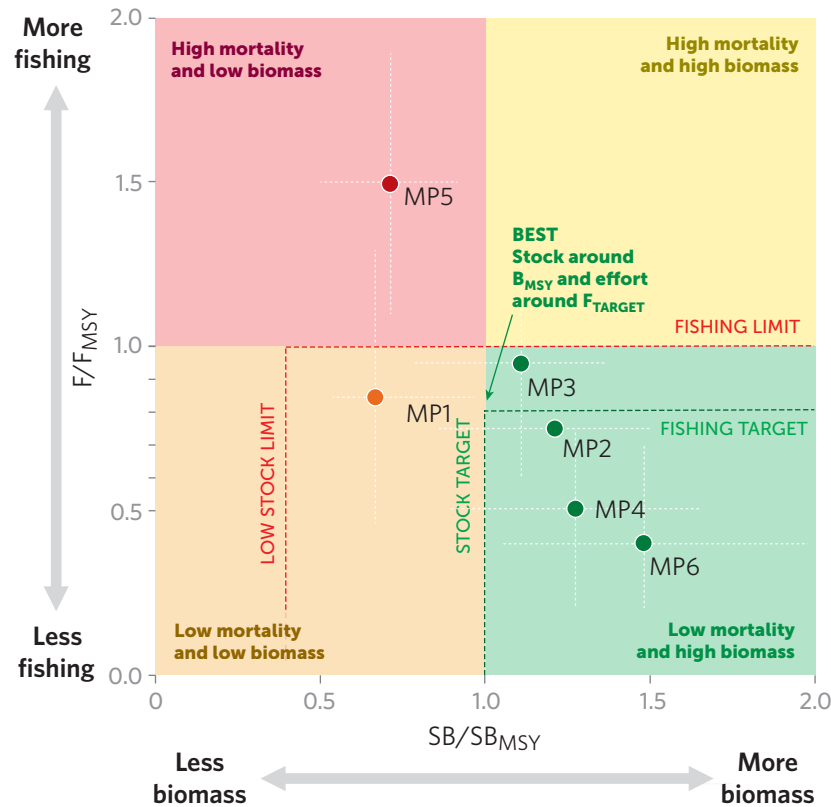
Index (1 = target)

The **dots** represent the median value for the final year of the projected period 2020-2040. **Dotted lines** around dots are error bars representing 90th percentiles.

Performance metrics measured

F/F_{MSY} Fishing mortality relative to fishing at maximum sustainable yield.

SB/SB_{MSY} Spawning biomass relative to the spawning biomass that enables a fish stock to deliver the maximum sustainable yield

More fishing

Less fishing

High mortality and low biomass

High mortality and high biomass

BEST
Stock around B_{MSY} and effort around F_{TARGET}

FISHING LIMIT

LOW STOCK LIMIT

STOCK TARGET

FISHING TARGET

MP5

MP1

MP3

MP2

MP4

MP6

Low mortality and low biomass

Low mortality and high biomass

F/F_{MSY}

SB/SB_{MSY}

Less biomass

More biomass

RESULTS RANKING

HIGHEST SCORE

- MP3 — Stock around B_{MSY} and effort
- MP2 — around F_{TARGET}
- MP4 — Sustainable stock
- MP6 — but low fishing
- MP1 — Effort around F_{MSY} but low stock
- MP5 — Overfishing, jeopardizing stock sustainability

Trade-off: catch/biomass

Six management procedures (MP1-MP6). Median in final year of 2020-2040 projection.

Best scores

MP3

MP2   MP4

SUMMARY OF RESULTS
Management Procedure 3 (MP3) performs best, scoring well for both performance metrics over the 20-year projection period. While MP2 scores highly, biomass is above the target reference point, and fishing mortality could be higher. MP1 and MP5 do not perform well for either performance metric as a result of overfishing.
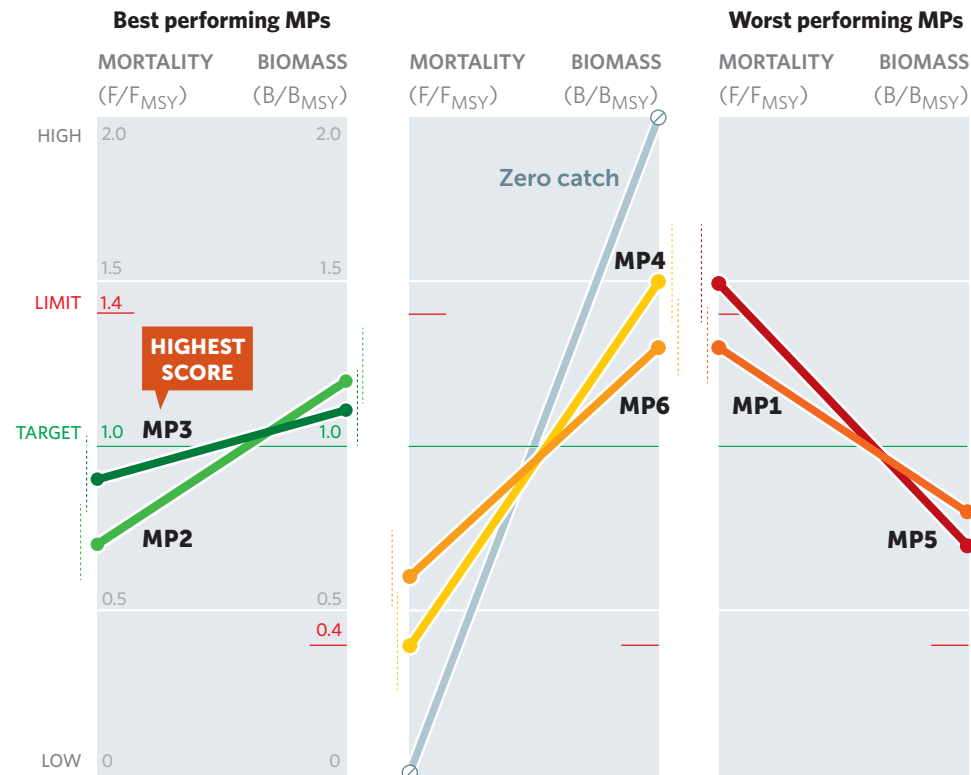
READING THIS CHART

The chart compares trade-offs in **six management procedures (MPs)** for X operating models by measuring two co-dependent performance metrics: **fishing mortality** (left axis) and **biomass** (right axis). MPs are grouped in similar pairs, from best to worst performance. A Zero Catch option is shown for comparison.

• The **dots** represent the median value for the final year of the projected period 2017-2040. **Dotted lines** next to the dots are error bars representing 90th percentiles.

Performance metrics measured

F/F_{MSY} Fishing mortality relative to fishing at maximum sustainable yield

B/B_{MSY} Biomass relative to the biomass that enables a fish stock to deliver the maximum sustainable yield

Best performing MPs

MORTALITY (F/F_{MSY})	BIOMASS (B/B_{MSY})
HIGH 2.0	2.0
1.5	1.5
LIMIT 1.4	
HIGHEST SCORE	
TARGET 1.0 MP3	1.0
	MP2
0.5	0.5
	0.4
LOW 0	0

Both indicators are near their targets. Lines like this (nealy horizontal and closer to the target) are preferred.

MORTALITY (F/F_{MSY}) **BIOMASS** (B/B_{MSY})

Zero catch

MP4

MP6

The MPs show inefficient or insufficient fishing since abundant biomass can sustain higher mortality rates.

Worst performing MPs

MORTALITY (F/F_{MSY}) **BIOMASS** (B/B_{MSY})

MP1

MP5

Overfishing makes these MPs unsustainable.

RESULTS RANKING

	F/F_{MSY}	B/B_{MSY}
● **MP3**	**0.9**	**1.1**
● MP2	0.7	1.2
● MP4	0.4	1.5
● MP6	0.6	1.3
● MP1	1.3	0.8
● MP5	1.5	0.7

Trade-off and performance: catch/biomass

Three management procedures (MP1–MP3). Median values over 20-year projection period (2020–2040).

Best scores

C_{av}	MP1
AAV	MP2
B_{final}	MP3
B_{lowest}	MP3

SUMMARY OF RESULTS

Management procedure 3 (MP3) scores best for biomass-related metrics over the 20-year projection period. MP1 and MP2 score higher for yield-related metrics, at the sacrifice of population health.
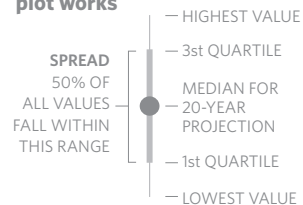
READING THIS CHART

Key

Management procedure

● MP1   ● MP2   ● MP3

⊘ Zero future catches
(largest possible recovery within projection period)

The chart **compares** performance of different candidate management procedures (MP) across X operating models, showing **trade-offs between actionable metrics of catch** (2 performance metrics on the left) **and resulting biomass** or fish abundance (2 performance metrics on the right).
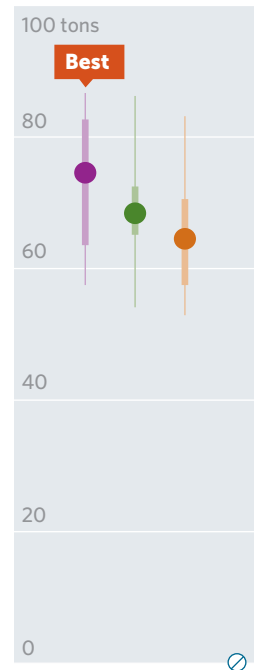
How a box plot works

- HIGHEST VALUE
- 3st QUARTILE

SPREAD
50% OF ALL VALUES FALL WITHIN THIS RANGE

- MEDIAN FOR 20-YEAR PROJECTION
- 1st QUARTILE
- LOWEST VALUE

CATCH

C_{av}

Average annual catch over the projection period.

⬆ **Higher is better**
(if resource is stable)

100 tons

Best

80

60

40

20

0   ⊘

AAV

Average percent change in catch from year to year.

⬇ **Lower is better**
(fishery is stable)

100%

80%

60%

Best

40%

20%

0%   ⊘
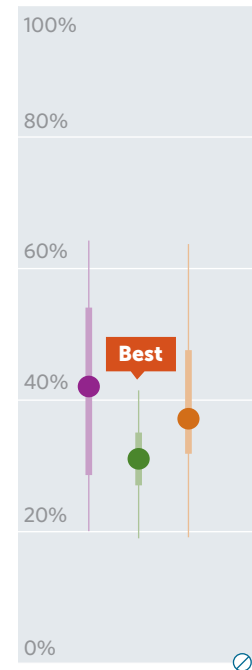
ABUNDANCE

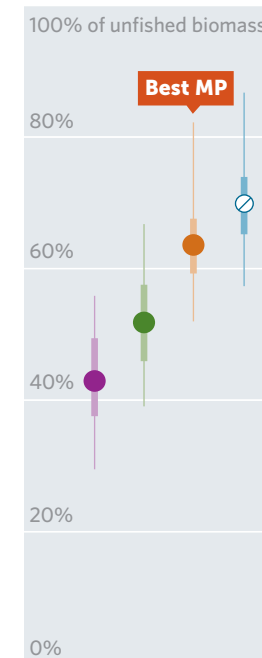### B_{final}

Biomass relative to unfished biomass at the end of the projection period.

⬆ **Higher is better**
(resource status healthy)

100% of unfished biomass

Best MP

80%

60%

40%

20%

0%

B_{lowest}

Lowest value of projected biomass during the projection period.

⬆ **Higher is better**
(low risk, safer resource)
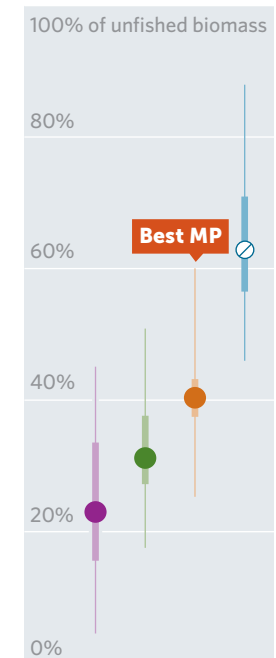
100% of unfished biomass

80%

Best MP

60%

40%

20%

0%

Trade-off and performance: catch/biomass

Three management procedures (MP1-MP3). Median values over 20-year projection period (2020-2040).

Best scores

MP3

SUMMARY OF RESULTS

Performance varies across the individual operating models (OMs), but overall, management procedure 3 (MP3) performs best, scoring well for all 4 performance metrics across the 12 operating models over the 20-year projection period. For almost all OMs, MP3 does not allow biomass to decline as much as the other MPs, and it also leads to the greatest stability in catches.
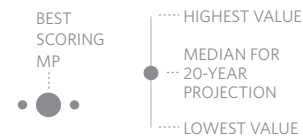
READING THIS CHART

Key

Management procedure
- ● MP1   ● MP2   ● MP3

⊘ Zero future catches (largest possible recovery within projection period)

The chart **compares** performance of different candidate management procedures (MP) showing **trade-offs between actionable metrics of catch** (2 performance metrics on top) **and resulting biomass** or fish abundance (2 performance metrics on the bottom). 12 different operating models are compared.

BEST SCORING MP

········ HIGHEST VALUE

········ MEDIAN FOR 20-YEAR PROJECTION

········ LOWEST VALUE

Performance metric ▼

Operating model

1 2 3 4 5 6 7 8 9 10 11 12

C_{av}
Average annual catch over the projection period.

AAV
Average percent change in catch from year to year.

B_{final}
Biomass relative to unfished biomass at the end of the projection period.

B_{lowest}
Lowest value of projected biomass during the projection period.

CATCH

100K tons

BETTER ↑

0

100 %

BETTER ↓

Best

ABUNDANCE

100%

BETTER ↑

0%

Best

100%

BETTER ↑

0%

Best

Performance comparison

MP1-MP5 for different operating models. Median values over 20-year projection (2020-2040).*

Best scores

MP3

MP2 MP5

SUMMARY OF RESULTS
Management procedure 3 (MP3) performs best, scoring well for all 6 performance metrics across the 12 operating models over the 20-year projection period. MP2 also scores highly. MP1 and MP4 perform well for the short-term catch metric at the sacrifice of population health.

READING THIS CHART

This chart **compares performance** of

6 performance metrics in

5 management procedures (MP) for a set of

12 operating models (columns)

Each value is a median over a 20-year projection period.

The hexagon edges in each chart connect **individual scores** for the performance metrics in that management procedure. Points closer to the exterior edge indicate better performance.

The **percentages** represent an **average score of all** performance metrics in each management procedure. It provides a quick comparison of overall MP performances. **Filled hexagons with larger areas indicate better overall performance**.

OVERALL MP SCORE

X%

HIGHEST SCORE FOR THIS PERFORMANCE METRIC IS IN THIS OPERATING MODEL
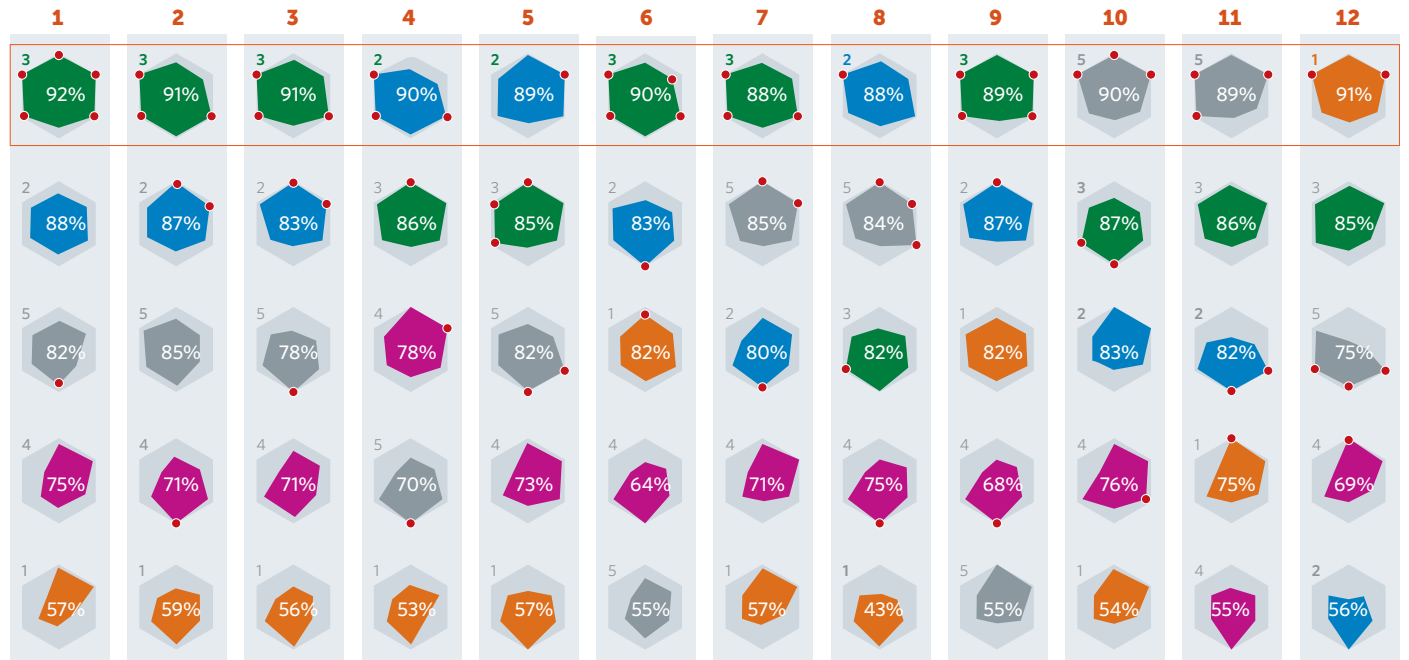
Management procedure

- MP1
- MP2
- MP3
- MP4
- MP5

Performance metrics measured
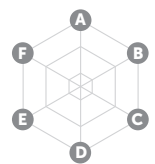
A **>Blim** means the stock biomass is above the limit reference point (indicator of **abundance**).
B **pGreen** gives the probability that the stock is not overfished or subject to overfishing (indicator of **fishery status**).
C **Interannual variation in yield** gives the percent change in catch from year to year (indicator of **stability**).
D **Catch after 3 years - short term** gives the short-term catch (indicator of **yield**).
E **Catch after 30 years - long term** gives the long-term catch (indicator of **yield**).
F **Net revenue** gives the annual fishery profits (indicator of **abundance**).

Operating model

1	2	3	4	5	6	7	8	9	10	11	12
3 92%	3 91%	3 91%	2 90%	2 89%	3 90%	3 88%	2 88%	3 89%	5 90%	5 89%	1 91%
2 88%	2 87%	2 83%	3 86%	3 85%	2 83%	5 85%	5 84%	2 87%	3 87%	3 86%	3 85%
5 82%	5 85%	5 78%	4 78%	5 82%	1 82%	2 80%	3 82%	1 82%	2 83%	2 82%	5 75%
4 75%	4 71%	4 71%	5 70%	4 73%	4 64%	4 71%	4 75%	4 68%	4 76%	1 75%	4 69%
1 57%	1 59%	1 56%	1 53%	1 57%	5 55%	1 57%	1 43%	5 55%	1 54%	4 55%	2 56%

Best scoring MP in each model

This chart shows a median across time, but it can also be used to show the results at the end of the projection period.

Stock size projection

Historical (1980-2020) and projections for MP1-MP6 (2021-2040). 10 operating models.

Best scores
MP1
MP2

SUMMARY OF RESULTS

Management procedure 1 (MP1) performs best, with projected biomass fluctuating at or above the target reference point over the 20-year projection period in nearly every operating model (OM). MP2 also scores highly, particularly under OM 6, but projects biomass to be consistently below the target reference point in 4 OMs. MP6 is likely to fail, with biomass consistently below both the target and reference points.

HISTORICAL
1980-2020

PROJECTIONS
2021-2040

Management procedure
- MP1
- MP2
- MP3
- MP4
- MP5
- MP6
- Zero catch

READING THIS CHART

The chart compares **projected stock size over 20 years for six management procedures and a zero catch option** in 100 simulations by **10 operating models**.

TARGET
10th-90th PERCENTILE
MEDIAN FOR EACH MP
LIMIT

Operating model

1   2   3   4   5   6   7   8   9   10

Highest MP

Lowest

Percent of unfished biomass

100%
80%
60%
40% — TARGET
20% — LIMIT
0%

1980   2000   2020

'20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40   '20 '30 '40

Zero catch

MP