



SECOND BIGEYE TUNA MANAGEMENT WORKSHOP (BMW02)

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Honolulu, Hawaii (Hybrid)

AGENDA 5. SHAPE OF THE HARVEST CONTROL RULES

WCPFC-BMW02-2026-WP06

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SPC-OFP¹

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Introduction

For the interim skipjack and South Pacific albacore MPs, the Commission adopted a specific HCR shape (see CMM 2023-05, Annex 1 for example). However, for the bigeye harvest strategy the Commission has tasked itself with adopting a management procedure (MP) that controls both the longline fisheries with catch or effort limits and purse seine fleets through a FAD open period. It would be possible to achieve the same target reference point (TRP) under different combinations of longline catch and/or effort and FAD open period (BMW02-2026-WP03, SPC-OFP 2026), so each MP consists of a continuum of harvest control rules (HCRs) all tuned to achieve the same stock status in the long-term. The shape of the HCRs along the continuum is defined by a design formulation which specifies how the HCRs are generated from the nuclear grid. The HCR formulation and the resulting shapes must be tested and compared so that managers can identify the one that achieves their objectives.

SC21 and BMW01 supported a 'Hillary step' HCR shape, consistent with the adopted skipjack and South Pacific albacore HCRs. This has formed the basis of analyses presented to SC22 (SC22-MI-WP-03 and SC22-MI-WP-04) and to this BMW2 under Agenda Item 3.3 (SPC-OFP 2026). However, these analyses are based on HCR pairs of one specific 'shape', in that the ascending and descending limbs (at stock sizes above and below those spanned by the Hillary step) are consistent.

Based upon SPC's understanding of the process proposed by the Commission, if the estimation method estimates the stock status to be on the Hillary step, then the resulting FAD open period and longline catch are negotiated along the 'arc of possibilities' identified by the nuclear grid (SPC-OFP 2026). This then defines the heights of the Hillary steps of the FAD open period/longline HCR pairs. However, if the estimated stock status is not on the Hillary step, i.e. is sufficiently above or below the agreed TRP that alternative action is required, the total change to fishing will be determined by the HCR formulation, but the portion of this change absorbed by each fishery may still be negotiated. The shape of the HCR pairs defined by the HCR formulation influences the performance of the MP.

To illustrate the importance of the shape of the HCR to the left of the Hillary step, i.e. the part of the HCR that is used if the estimated stock status is sufficiently below the agreed TRP, the probabilities of being to the left of the Hillary step or on the bottom step for selected MPs are shown in Table 2, taken from the evaluations in WP05.

Table 1 Probabilities of being to the left of the Hillary step or on the bottom step for the scenario in which the bigeye MP manages the WCPO longline fisheries, excluding SIDS, for MPs with HCR formulation 1.

MP	Target	Probability of being estimated to the left of the Hillary step	Probability of being estimated on the bottom step
5	Lower TRP	0.085	0.035
8	Upper TRP	0.202	0.019

These probabilities demonstrate that the estimated stock status is not always on the Hillary step and can be either on the curve to the left or on the bottom step.

There is therefore a need to define and test alternative HCR formulations to enable Commission members to understand their implications and decide which formulation best meets the desired trade-offs between fishery-wide and gear-specific performance indicators. Based upon the volume of results already generated and presented under BMW2 Agenda Item 3, these additional analyses are only practical where the range of candidate bigeye MPs (in terms of spatial scenario and TRP) have been refined (BMW02 Agenda Item 4).

Different HCR formulations only change the height of the lower and upper step of the HCRs since the height of the Hillary steps are determined by the combinations of longline catch and FAD open period along the arc of possibilities. This means that if the estimation method estimates the stock status to be on the Hillary step there would be no difference in the performance of different HCR designs. However, if the estimation method estimates the stock status to be to the left of the Hillary step, performance of different HCR designs may differ, particularly in regard to the fishery specific outcomes. It is therefore important to test alternative HCR design formulations using MSE.

As the HCR pairs are to be negotiated, the proposed approach is that the Commission adopt an HCR design formulation rather than a specific HCR pair. During negotiations, the desired longline bigeye catch limit or FAD open period can be identified for a given estimation method output. An HCR formulation describes how HCR pairs are developed at any point along the continuum. The alternative is to adopt specifically designed and tested unique pairs of HCRs, which is impractical within the time available.

To examine the impact, we evaluate the performance of two alternative HCR formulations. For both formulations, the HCR pairs designed would achieve the agreed TRP in the long-term but may have potentially different fishery specific outcomes.

Methods

The spatial scenario (fisheries and area of application) and the TRP components to the bigeye MP have not been decided. Rather than presenting results for all options, a subset has been chosen to demonstrate the effect of the HCR formulation on performance. Two HCR formulations were evaluated across all spatial scenarios and two TRPs (the lower and upper TRP with 50% thresholds).

The HCR is made up of several components: three steps of increasing height, connected by a curve and the right-hand slope (Figure 1). The candidate HCR formulations specify precise positions of these components.

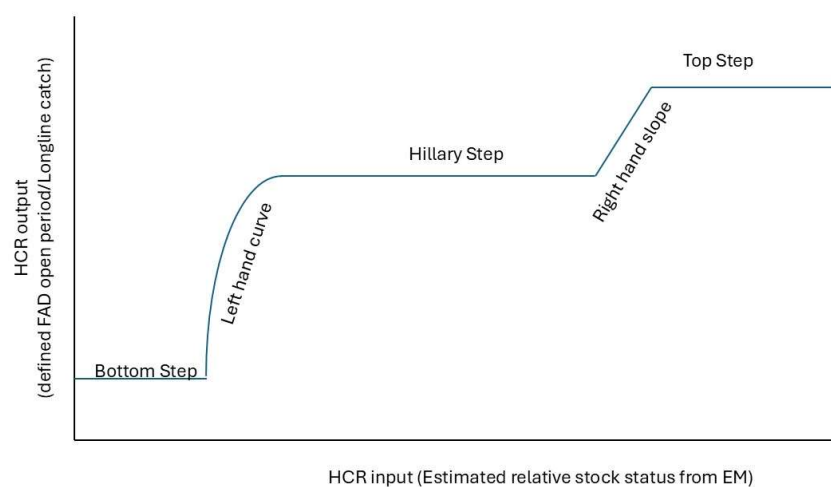


Figure 1. Naming convention for HCR components applied within this document

The two HCR design formulations examined have several common components: the range of HCR inputs each step spans and the heights of the Hillary steps, specified by the nuclear grid projections. These are described in more detail below.

The difference between the two examined formulations is the height of the ‘bottom step’ that sets the minimum HCR outputs at low levels of HCR input (low stock status) and impacts the steepness of the left hand curve.

The positions of the HCR components

Positions of the HCR components, i.e. the range of HCR inputs they span, are determined by the agreed TRP and the LRP.

The estimated stock status ideally remains on the Hillary step of the HCR as it fluctuates over time. Therefore, the position of the Hillary step, i.e. the range of HCR inputs that it spans, is such that the agreed TRP lies within the step range.

The candidate TRPs for bigeye are expressed as multipliers of the average spawning biomass depletion ($SB/SB_{F=0}$) in 2012-2015, e.g. if the most recent $SB/SB_{F=0}$ relative to the average

$SB/SB_{F=0}$ in 2012-2015 equals 0.94 then the stock is at the requested lower TRP (6% below 2012-2015 levels).

The input to the HCRs, however, is taken from the output of the estimation method (EM) and is a relative index of abundance: the estimated spawning biomass (SB) relative to the average estimated SB in 2012-2015. Using this relative value as the EM output was found to better estimate the true stock status and was supported by SC22.

The HCR input is therefore not directly comparable to the TRP value in terms of depletion. However, it is feasible to translate the HCR input (EM output value) into the equivalent expected bigeye stock depletion relative to the average level in 2012-2015. This is described in Appendix 1.

In the two tested HCR design formulations, the Hillary step ranges from the agreed TRP -0.05 (left hand end) to agreed TRP $+0.10$ (right hand end), converted to the EM equivalent value (see Appendix 1). Within the updated OM grid of 1152 models (Agenda Item 3.1, WCPFC-BMW02-2026-WP02), if using the lower TRP, the Hillary step ranges between the HCR input values of 0.76 and 1.21.

The bottom step ranges between zero and the EM equivalent value of the LRP: 0.68. The top step ranges between the EM equivalent value of the agreed TRP $+0.30$ and 1, e.g. if using the lower TRP the top step would start at 1.80.

These HCR input ranges are summarised in Table 2 and shown diagrammatically in Figure 2. The HCR input positions of the HCR components are unaffected by their heights and are the same for both the FAD open and longline catch HCRs. Specification of these values is a key step in the development of the HCR design formulation.

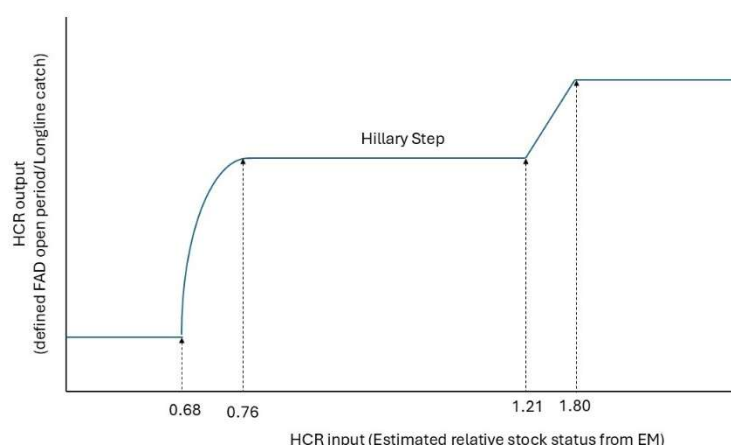


Figure 2. Diagrammatical representation of the location of the change points in the evaluated HCR shapes relative to the HCR input (EM output - not to scale)

Table 2. Input ranges of the HCR components. These ranges are unaffected by the choice of HCR design formulation. The HCR input column is specified in terms of SB/SBF=0. These are then converted to EM equivalent positions (see Appendix 1).

Component	HCR input position (as SB/SBF=0, then converted to EM equivalent values using equation 1)
Hillary Step	Between TRP−0.05 and TRP+0.10; the TRP is not in the step's centre ¹
Bottom Step	Between 0 and the LRP (0.2)
Top Step	Between TRP+0.30 and 1
Left-hand curve ²	Between LRP (0.2) and TRP−0.05
Right hand slope	Between TRP+0.10 and TRP+0.30

¹ The EM equivalent values of the TRPs are intentionally not in the middle of the Hillary step, with the right-hand side of the Hillary step being longer to allow for a higher estimated index of abundance before fishing pressure increases.

² Curve equation: $y = a - (a-b) * \exp(-c * x)$, where a is the maximum attainable y, b is y at x=0 and c is the curve parameter, fixed at 10.

The heights of the HCR components

As agreed at BMW01, the HCR outputs are the EEZ FAD open period in months (noting that a 3/5 EEZ/HS FAD closure period ratio is assumed), and bigeye catch of the longline fisheries that are specified as being managed through the MP.

The heights of the Hillary steps, i.e. the longline bigeye catch limit and the FAD open period, are designed to achieve the agreed TRP in the long-term. The intention is that if the EM estimates the relative index of stock abundance to be around the EM equivalent TRP, the selected combination of the FAD open period and the corresponding longline catch limit (or vice-versa) maintain the stock around the agreed TRP in the long-term (Figure 3).

The height of the top steps for all candidate HCR design formulations is 110% of the Hillary step height, i.e. it is relative to the height of the Hillary step, noting that the FAD open period cannot be more than 12 months.

The heights of the Hillary and top steps are therefore unaffected by choice of candidate HCR design formulation.

The key difference between the candidate HCR design formulations is the height of the bottom steps (Table 3). The height of the bottom step affects the HCR outputs if the HCR input is to the left of the Hillary step, i.e. the estimated stock status is sufficiently lower than the agreed TRP.

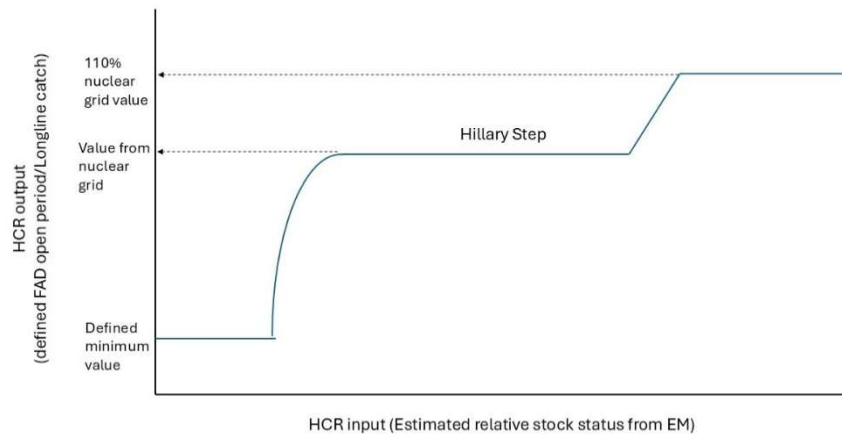


Figure 3. Diagrammatical representation of the HCR output values (PS FAD open period/longline catch) defined by the different steps in the HCR (not to scale).

HCR formulation 1

For this formulation, the bottom step is 40% of the Hillary step height for both the FAD open and longline catch HCRs, i.e. for HCRs with higher Hillary step heights the bottom step will also be higher. As the top step is 110% of the Hillary step height (Figure 3) the relative shapes of HCRs designed using this formulation are the same for any Hillary step height. This means that if the HCR input is to the left of the Hillary step, both the resulting longline catch limit and FAD open period will be lower than the Hillary step by the same proportion.

HCR formulation 2

For this formulation, the bottom step of the FAD open period is fixed at 8 months and the longline catch limit at 0.75 times the associated average longline catch in 2019-2021 (for longline fisheries managed through the bigeye MP). For any HCR pair therefore, the height of the bottom step is the same and does not change with Hillary step height. Note that the average catch of longline fisheries managed through the bigeye MP depends on the bigeye MP spatial scenario.

These two designs are tested using a single MP - the WCPO excluding SIDS bigeye MP spatial scenario, along with the agreed TRP at the lower TRP ($0.94 \times SB_{F=0,2012-2015}$).

Table 3. Outputs (EEZ FAD open period or longline bigeye catch) of the three steps for each candidate HCR design formulation.

Component	HCR formulation 1	HCR formulation 2
Hillary Step	Designed to achieve TRP in the long-term.	Designed to achieve TRP in the long-term.
Bottom Step	40% of Hillary step height	Fixed at 8 months open and 0.75 the average longline catch in 2019-2021, depending on the bigeye MP spatial scenario.
Top Step	110% of Hillary step height	110% of Hillary step height

Examples

HCR pairs from the different candidate HCR formulations are shown for two different HCR input values to demonstrate the potential impact. HCR pairs are shown, with different Hillary step heights based on the ‘FAD favoured’, ‘longline favoured’ and ‘intermediate’ examples (see Agenda Item 3.2). The resulting HCR outputs for different HCR inputs are shown on the plots and in the tables. The ‘longline favoured’ and ‘intermediate’ examples are shown in Appendix 2.

These examples demonstrate how the choice of HCR design formulation can affect the resulting longline catch limit and FAD open period when the HCR input is not on the Hillary step.

Example 1: ‘FAD favoured’

In this example, the Hillary step of the FAD open HCR is at 12 months (‘FAD favoured’). Two HCR input values are evaluated, one on the Hillary step and one on the curve to the left of the step (Table 4, Figure 4).

Table 4. Example HCR output values for the FAD favoured HCR pairs evaluated at two different input values.

HCR design	HCR input	Longline catch limit (000mt)	EEZ FAD open period (months)
HCR 1	0.7	29.90	6.83
HCR 1	1.0	52.50	12.00
HCR 2	0.7	38.41	9.13
HCR 2	1.0	52.50	12.00

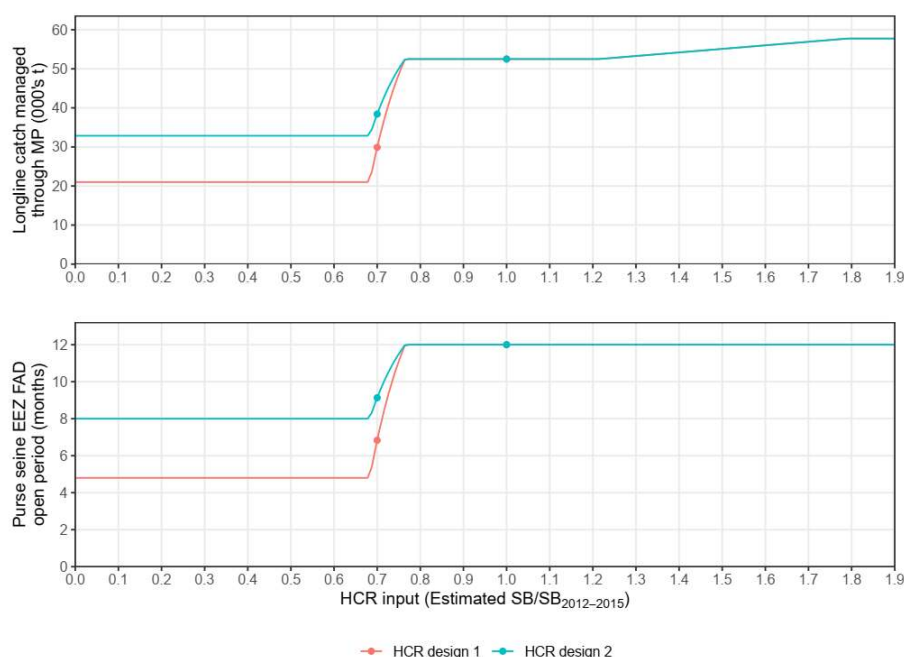


Figure 4. FAD favoured HCR pairs with different HCR designs. The points represent the HCRs being evaluated at different inputs as an illustration.

Results

As described above, MPs based around two HCR formulations were evaluated. The two formulations differ through the heights of the bottom steps. The full results can be found in the Appendices of WP05.

Example probabilities of being above the LRP for the two HCR formulations and two targets are shown in Table 5. This demonstrates that selection of the HCR formulation can impact the probability of being above the LRP, even though the differences shown here are relatively small.

Table 5. Probability of being above the Limit Reference Point in the long-term for the scenario in which the bigeye MP manages the WCPO longline fisheries, excluding SIDS.

Target	HCR formulation 1	HCR formulation 2
Lower TRP	0.88	0.86
Upper TRP	0.95	0.93

Example expected catches in the long-term for MPs with these two HCR formulations can be seen in Figure 5. Relative performance of these two HCR formulations is similar on average, with small differences seen in the whiskers. However, Table 1 shows that there is a not insignificant probability of being to the left of the Hillary of the step. It is therefore important to consider how any possible reductions in overall fishing pressure will be distributed between fishery segments.

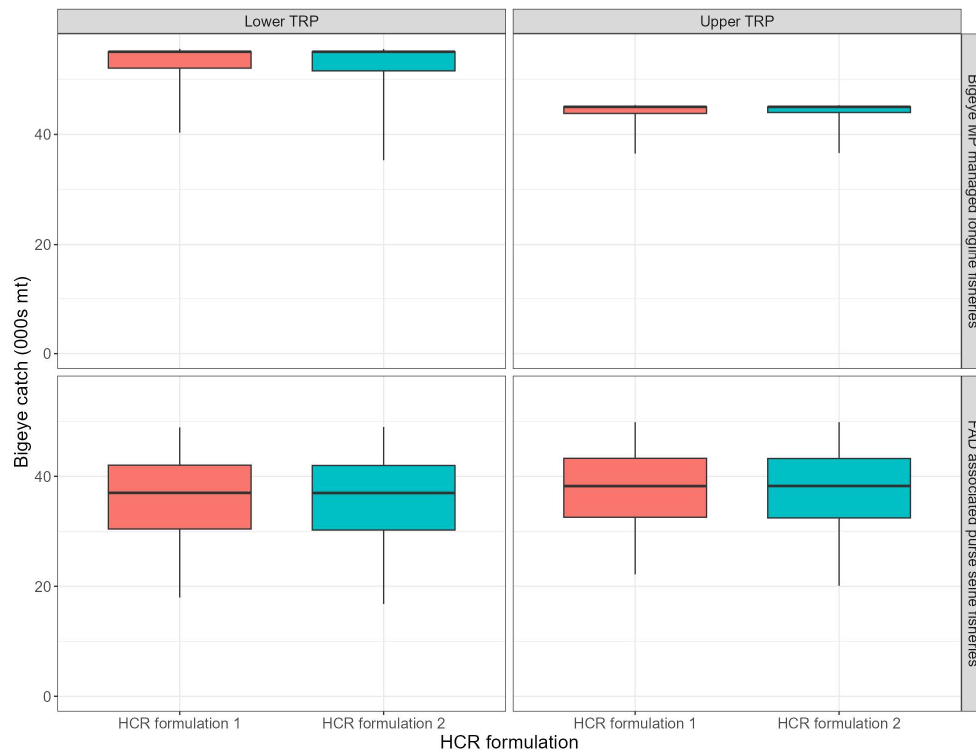


Figure 5. Expected long-term annual bigeye catch (000s mt) of the longline fisheries managed through the bigeye MP (top row) and FAD associated purse seine fishery (bottom row) for the scenario in which the bigeye MP manages the WCPO longline fisheries excluding the SIDS. Each box is an MP designed to achieve a specific TRP objective (upper or lower TRP). The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the solid horizontal line is the median value.

Discussion

The approach described has identified ‘formulations’ that define HCR shapes, specifically in this case for the descending limb of the HCR and associated lower step height. This is needed to facilitate the Commission’s wishes to negotiate across the ‘arc of possibilities’ so that for a specific combination of FAD open period and longline catch pairs, the HCR design can be generated and tested.

Given resources and time, under the assumption that BMW02 can narrow down the range of spatial structures/controlled fleets and TRP option scenarios that need to be evaluated, there is the potential to evaluate alternative HCR shapes for consideration by WCPFC23.

We therefore invite BMW2 to:

- Consider the approach used to define the design of candidate HCR shapes presented here
- Provide guidance on the shape of a limited number (e.g. 2) of alternative HCR shapes to be evaluated for that reduced set of combinations – specifically defining the HCR’s descending (and if desired ascending) limb(s).

- That shape should be specified as a ‘formulation that allows all HCRs to be pre-specified, given the Commission’s planned negotiations across the arc of possibilities’.

References

Scott, F., Scott, R., Wickens, M., Yao, N., Dabea, A., Hamer, P., Pilling, G. M. 2026. *Bigeye Tuna Management Procedure Design and Implementation Considerations*. WCPFC-SC22-2026-MI-WP03.

Scott, F., Scott, R., Wickens, M., Yao, N., Dabea, A., Hamer, P., Pilling, G. M. 2026. *Bigeye Tuna Management Procedure Evaluations*. WCPFC-SC22-2026-MI-WP04.

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SPC-OFP. 2026. *Operating Model Framework and Robustness Testing for Bigeye Tuna in the WCPO: Updates to the Operating Model Following SC22*. WCPFC-BMW02-2026-WP02.

Wickens, M., Scott, F. and Scott, R. 2026. *Update to the Estimation Method for Bigeye Tuna in the WCPO*. WCPFC-SC22-2026-MI-WP-02.

Appendix 1. Approach to translating the EM output into TRP metrics

By projecting the OM grid at a range of future fishing levels it is possible to fit a relationship between the ‘true’ relative spawning biomass depletion, as taken from the OM grid, and the estimated relative index of abundance as estimated by the EM (HCR input), similar to the approach in (Wickens 2026) (Figure 6). This relationship captures the observed level of bias from the EM testing results.

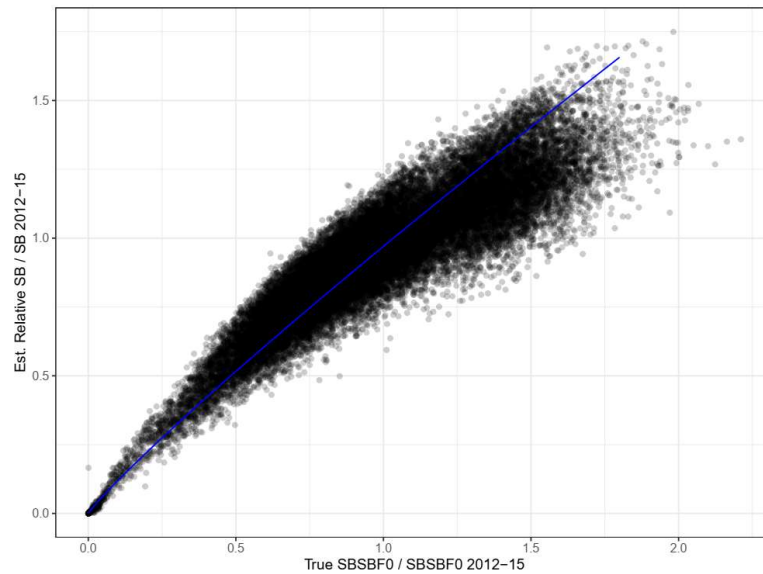


Figure 6. Spawning biomass relative to the average spawning biomass in 2012-2015 as estimated by the estimation method against the ‘true’ spawning biomass depletion relative to the average spawning biomass depletion in 2012-2015 taken from the operating model grid. The blue line shows the fitted relationship between them.

The fitted relationship can be summarized as:

$$\log(Est.SB/SB_{2012-15}) = -0.03041 + 0.91091 \log\left(True \frac{SB/SB_{F=0}}{SB/SB_{F=0} \text{ 2012-15}} \right) \quad (1)$$

It has an R-squared value of 0.91 and is shown to work well at low levels of relative spawning biomass depletion.

This relationship can be used to determine the ‘EM equivalent’ TRP value, so that the position of the Hillary step can be designed around it. For example, the lower TRP (0.94 * average spawning biomass depletion 2012-2015) is equivalent to an EM estimated relative index of 0.92, whereas the upper TRP (1.06 * average spawning biomass depletion in 2012-2015) is equivalent to an EM estimated relative index of about 1.02.

Appendix 2. Examples of different HCR formulations

This appendix includes two further comparisons of the different HCR formulations, evaluated on and off the Hillary step.

Example 2: ‘Intermediate’

In this example, the Hillary step of the FAD open HCR is at 10.5 months (‘intermediate’). The same two HCR input values are shown as above, one on the Hillary step and one on the curve to the left of the step (Table 6, Figure 7).

Table 6. Example HCR output values for the ‘intermediate’ HCR pairs evaluated at two different input values.

HCR design	HCR input	Longline catch limit (000mt)	EEZ FAD open period (months)
HCR 1	0.7	31.04	5.93
HCR 1	1.0	55.00	10.50
HCR 2	0.7	38.93	8.69
HCR 2	1.0	55.00	10.50

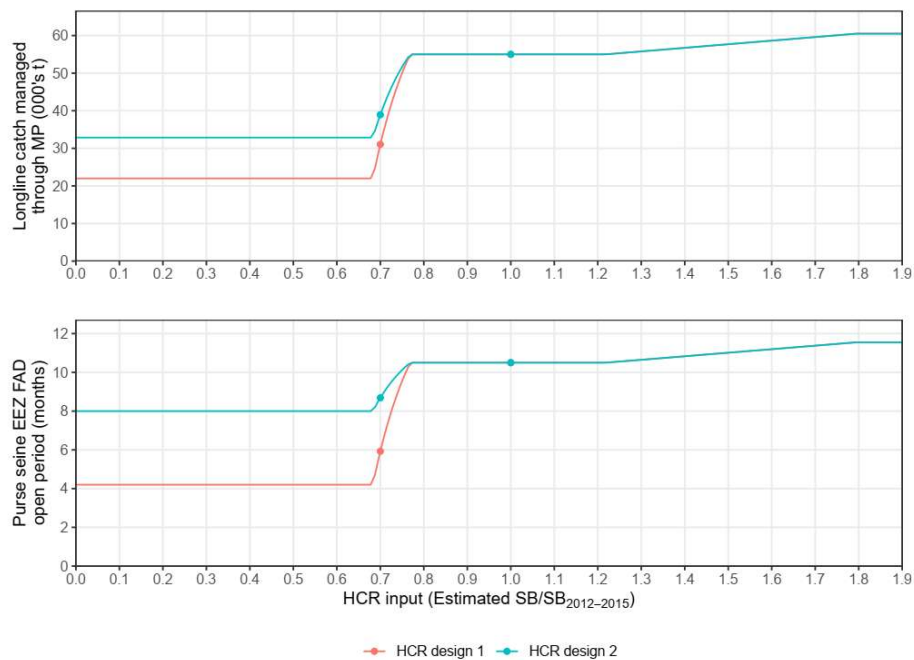


Figure 7. Intermediate HCR pairs with different HCR designs. The points represent the HCRs being evaluated at different inputs as an illustration.

Example 3: 'Longline favoured'

In this example, the Hillary step of the FAD open HCR is at 9 months ('longline favoured'). The same two HCR input values are shown as above, one on the Hillary step and one on the curve to the left of the step (Table 7, Figure 8).

Table 7. Example HCR output values for the 'longline favoured' HCR pairs evaluated at two different input values.

HCR design	HCR input	Longline catch limit (000mt)	EEZ FAD open period (months)
HCR 1	0.7	31.69	4.96
HCR 1	1.0	57.50	9.00
HCR 2	0.7	39.07	8.25
HCR 2	1.0	57.50	9.00

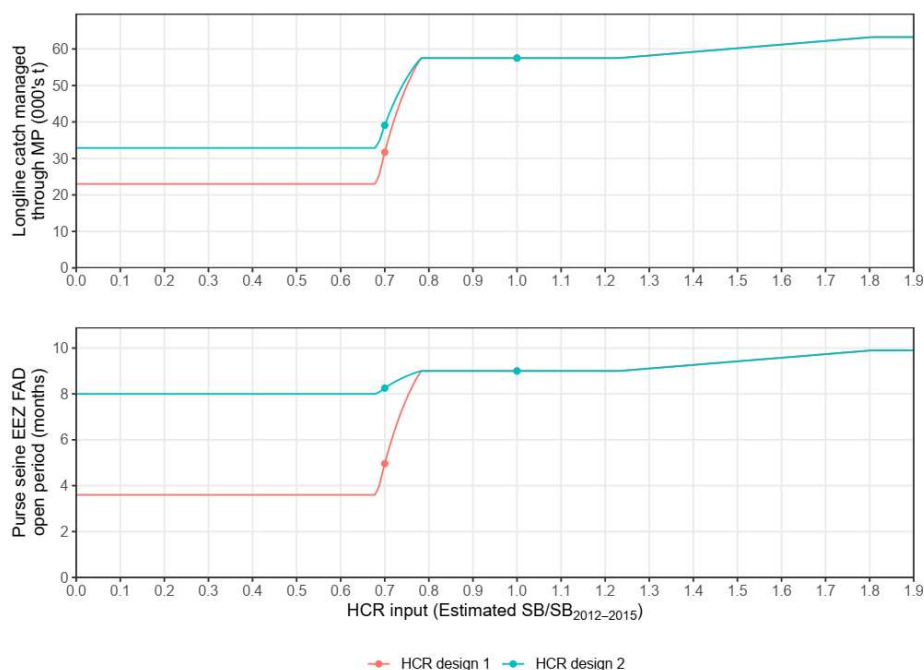


Figure 8. Longline favoured HCR pairs with different HCR designs. The points represent the HCRs being evaluated at different inputs as an illustration.