TROPICAL ROCK LOBSTER WORKING GROUP (TRLWG) Thursday Island	MEETING 18 3 October 2025
PRELIMINARIES	**Agenda Item 1** **For NOTING**

RECOMMENDATIONS

1. That the WG **NOTE**:
    a. an acknowledgement of Traditional Owners;
    b. the Chair's welcome address;
    c. apologies received from members unable to attend.
2. That the WG consider and **ADOPT** the draft agenda, which was circulated to members on 4 September 2025.
3. That WG members and observers:
    a. **DECLARE** all real or potential conflicts of interest in the Torres Strait Rock Lobster Fishery at the commencement of the meeting (**Attachment 1a**);
    b. **DISCUSS** whether the member may or may not be present during discussion of or decisions made on the matter which is the subject of the conflict;
    c. **ABIDE** by decisions of the RAG regarding the management of conflicts of interest; and
    d. **NOTE** that the record of the meeting must record the fact of any disclosure, and the determination of the RAG as to whether the member may or may not be present during discussion of, or decisions made, on the matter which is the subject of the conflict.

BACKGROUND

1. As at 25 September 2025, no apologies had been received.

Declarations of interest

2. Consistent with the *Protected Zone Joint Authority (PZJA) Fisheries Management Paper No. 1* (FMP1), which guides the operation and administration of PZJA advisory committees, members are asked to declare any real or potential conflicts of interest.
3. WG members are asked to confirm the standing list of declared interests (**Attachment 1a**) is accurate and provide an update to be tabled if it is not.
4. FMP1 recognises that members are appointed to provide input based on their knowledge and expertise and as a consequence, may face potential or direct conflicts of interest. Where a member has a material personal interest in a matter being considered, including a direct or indirect financial or economic interest; the interest could conflict with the proper performance of the member's duties. Of greater concern is the specific conflict created

where a member is in a position to derive direct benefit from a recommendation if it is implemented.

5. When a member recognises that a real or potential conflict of interest exists, the conflict must be disclosed as soon as possible. Where this relates to an issue on the agenda of a meeting this can normally wait until that meeting, but where the conflict relates to decisions already made, members must be informed immediately. Conflicts of interest should be dealt with at the start of each meeting. If members become aware of a potential conflict of interest during the meeting, they must immediately disclose the conflict of interest.
6. Where it is determined that a direct conflict of interest exists, the committee may allow the member to continue to participate in the discussions relating to the matter but not in any decision-making process. They may also determine that, having made their contribution to the discussions, the member should retire from the meeting for the remainder of discussions on that issue. Declarations of interest, and subsequent decisions by the committee, must be recorded accurately in the meeting minutes.

TRLWG Declarations of interests from most recent meetings

Name	Position	Declaration of interest
Members		
Dr David Brewer	Interim Chair	To be declared.
Dr Laura Blamey	Scientific Member	Contributes to other Torres Strait research projects that receive research funding, including Torres Strait climate change and fisheries project. No other interests in the fishery.
Mr Les Pitt	Traditional Inhabitant Member – Kemer Kemer Meriam	Traditional Inhabitant Member Kemer Kemer Meriam, TIB licence holder and runs an independent freezer facility on Erub Island. Board member of Zenadth Kes Fisheries.
Mr Monti Naawi	Traditional Inhabitant Member - Kulkalgal	To be declared.
Mr Aaron Tom	Traditional Inhabitant Member – Guda maluylgal	To be declared.
Mr Kame Mathew Paipai	Traditional Inhabitant Member - Maluyilgal	To be declared.
Mr Thomas Fujii	Traditional Inhabitant Member - Kaiwalalgal	Traditional Inhabitant Member Kaiwalalgal. Queensland East Coast TRL and TIB license holder. Zenadth Kes Fisheries member.
Mr Jake Kingdon	Industry Member	To be declared.
Mr Trent Butcher	Industry Member	To be declared.
Mr Mark Dean	Industry Member	TVH boat operator
Mr Keith Brightman	TSRA Member	TSRA Fisheries Project Manager, TSRA holds multiple TVH TRL fishing license on behalf of Torres Strait Communities but does not benefit from them. No personal pecuniary interest.
Ms Jenny Keys	QDAF Member	Queensland Fishery manager of tropical rock lobster fishery, aquarium and coral fisheries. Nil interests.
Mr Ryan Murphy	AFMA Member	Employed by AFMA. Senior Manager for Torres Strait Fisheries. Nil interests.
Ms Georgia Bourke	Executive Officer	Employed by AFMA. Senior Management Officer for Tropical Rock Lobster Fishery. Nil interests.
Observers		
Mr Joseph Posu	PNG National Fisheries Authority	To be declared.

Mr Bonny Koke	PNG National Fisheries Authority	To be declared.
Mr Dimas Toby	TSRA Fisheries Portfolio member	To be declared.
Dr Eva Plaganyi	CSIRO Invited Participant	To be declared.
Mr Quinten Hirakawa	TSRA	TSRA employee, TIB license holder with a TRL endorsement.
Mr John Glaister	TRLWG Chair	To be declared.
Mr Timothy Ward	TRLRAG Chair	To be declared.

TROPICAL ROCK LOBSTER WORKING GROUP (TRLWG) Thursday Island	MEETING 18 3 October 2025
UPDATES FROM MEMBERS	Agenda Item 2 For NOTING

RECOMMENDATIONS

1. That the WG **NOTE** updates provided by:
   a) Traditional inhabitant and industry members;
   b) Scientific members;
   c) Government agencies;
   d) Papua New Guinea National Fisheries Authority (PNG NFA) representative; and
   e) Native Title body representative (if in attendance).

BACKGROUND

1. Verbal reports are sought from Traditional inhabitant, industry and scientific members under this item, with particular emphasis on market and export impacts to the current 2024-25 fishing season.
2. It is important that the WG develops a common understanding of any strategic issues, including economic, fishing and research trends relevant to the management the TRL Fishery. This includes within adjacent jurisdictions. This ensures that, where relevant, the WG is able to have regard for these strategic issues and trends.
3. WG members are asked to provide any updates on trends and opportunities in markets, processing and value adding. Industry is asked to contribute advice on economic and market trends where possible. Scientific members are asked to contribute advice on any broader strategic research projects or issues that may be of interest to the Torres Strait in future.
4. Government agency members are asked to provide updates relevant to the TRL Fishery.
5. AFMA has a standing invite for officials from the PNG National Fisheries Authority (NFA) and a Native Title Body representative to attend all PZJA advisory committee meetings. If in attendance, updates are welcome from these participants.

TROPICAL ROCK LOBSTER WORKING GROUP (TRLWG) Thursday Island	MEETING 18 3 October 2025
REVISING THE EMPIRICAL HARVEST CONTROL RULE (eHCR)	**Agenda Item 3** **For RECOMMENDATION**

RECOMMENDATIONS

1. That the WG **NOTE** that:
   a. CSIRO undertook Management Strategy Evaluation (MSE) testing to explore options for an alternative empirical Harvest Control Rule (eHCR) under the Tropical Rock Lobster (TRL) Harvest Strategy (**Attachment 3a**) in response to anomalous circumstances since 2020, undermining the application of the eHCR implemented in the current harvest strategy (the current eHCR).
   b. a range of alternative eHCRs identified by CSIRO were discussed at the Tropical Rock Lobster Resource Assessment Group on 9 October 2024 (TRLRAG 37), 10-11 December 2024 (TRLRAG 38) and at the TRL Working Group on 12 December 2024 (TRLWG 17). A summary of stakeholder views is provided at **Attachment 3b**.
   c. The RAG and WG were unable to deliver consensus advice and the PZJA Standing Committee felt it important to balance both sets of views between stakeholder groups in the short term, recommending that the PZJA agree to a global TAC of 688 tonnes for the 2024-25 fishing season.
      (i) This TAC reflected a midpoint between the TAC outputs derived from the two harvest control rules in question ("Seahorse" – 581 tonnes and "Dolphin" – 796 tonnes
   d. In response to this outcome, CSIRO undertook additional Management Strategy Evaluation (MSE) testing on a variant of the Seahorse and Dolphin rules that yielded the PZJA-agreed TAC for the 2024-25 fishing season.
      (i) This harvest control rule is known as "Osprey".
      (ii) Further details on the different harvest controls rules will be presented by Dr Eva Plaganyi from CSIRO. A non-technical summary is provided at **Attachment 3c**, and a technical report with full methodology is at **Attachment 3d**.
   e. AFMA has evaluated each rule against different considerations (**Attachment 3e**) and recommends adopting the Osprey rule as the revised harvest control rule.
2. That the WG **NOTE** an overview of TRLRAG 40 (2 October 2025) discussions presented by the TRLRAG Chair, Dr Tim Ward.
3. That the WG **RECOMMEND** the Osprey rule as the revised eHCR to be applied under the TRL Harvest Strategy.

KEY ISSUES

Why the rule is changing

4. A revised eHCR under the TRL Harvest Strategy is being developed because the current eHCR, which uses total average catch as an input, is no longer considered appropriate. The average catch multiplier used in the current eHCR has proven an unreliable indicator of abundance as actual catches have been constrained due to non-stock-related reasons, namely market issues.

5. *Ad hoc* adjustments to the current eHCR have been applied in recent seasons, however it is best practice to review current methods and seek improvements that continue to best achieve the objectives of the Harvest Strategy and the TRL Fishery. This is especially true in the rapidly changing conditions (both economic and environmental) that the TRL Fishery continues to face.

6. Each of the three HCRs under consideration has been scientifically tested and shown to achieve sustainability objectives for the TRL Harvest Strategy. That is, each poses the same (very low) risk to the sustainability of the stock and aims to maintain the stock around the target reference point (i.e., 65% of unfished biomass).

7. The key trade-off between the three HCR options is the variability in TACs year to year, based on how closely the inputs track the TRL abundance from the pre-season survey and incoming recruitment class of lobsters (1+). **Attachment 3c** illustrates a 20-year projection of catch distribution and spawning biomass for each of the eHCR options.

What are the different options?

8. The Seahorse rule:
    a. Is an MSE tested and fine-tuned version of the ad-hoc adjustments that have been made to the default eHCR in recent years that uses the previous season's TAC value instead of the actual catch multiplier.
    b. Has low variability in RBC outputs - lower 20-year average RBCs but higher RBCs during poor years and lower RBCs during good years.
    c. Will track changes up or down much more slowly and with a slow turnaround
    d. Greater certainty in RBC outputs year to year, expect to generate an RBC in the range of 485t – 644t, 80 per cent of the time.

9. The Dolphin rule:
    e. Greater variability in RBC outputs – higher 20-year average RBCs, but subject to lower RBCs during poor years, and high RBCs during good years, relative to the Seahorse rule.
    f. Is more immediately responsive to changes in stock levels and adjusts up and down more quickly, and goes to higher and lower levels on average than the Seahorse Rule.
    g. Places more weighting on most recent pre-season 1+ lobster index, therefore adjusts the RBC more rapidly and responsively
    h. Factors in pre-season survey precision and adjusts weighting if less precise survey
    i. Would expect to generate an RBC in the range of 427t – 919t 80 per cent of the time.

10. The Osprey rule:
    j. Is an MSE tested and fine-tuned rule that produces a compromise mid-point RBC between other two rules.
    k. Moderate variability in RBC outputs – higher 20-year average RBCs than the Seahorse rule, but lower than that of the Dolphin rule.
    l. Places more weighting on most recent pre-season 1+ lobster index that is designed to bring down the RBC more in poor years, but with small bonuses in good years, though the response is not as rapid or drastic compared to the Dolphin.
    m. Factors in pre-season survey precision and adjusts weighting if less precise survey
    n. Would expect to generate an RBC in the rage of 440t – 791t, 80 per cent of the time.
11. **Table 1** shows a summary of the RBC projection statistics for each of the eHCR options.
12. The Osprey rule seeks to maximise value in the fishery in good years (more than the Seahorse) and better maintains opportunity during poor years (more than the Dolphin). Overall, on average, the Osprey exhibits larger increases and decreases in the TAC than the Seahorse rule. The moderate variability in TACs year to year can provide new fishery entrants with more certainty while allowing long-term fishers greater opportunity to maximise value in good fishing years, including better sustaining that opportunity in poor fishing years.
13. Higher catches from the whole fishery generally better supports market costs and infrastructure (regardless of who is marketing the product) by spreading the fixed costs over a greater volume of product and number of transactions. This supports the fishery's overall economic value and, by extension, beach prices to fishers.
14. The Osprey rule may also reduce the risk of early fishery closure if TIB catches are artificially constrained by a lower TAC in good years, compared with that of the Seahorse rule. The current season (2024-25) proved to be a very good year, as indicated by the 1+ survey results, the 2024 stock assessment results indicating a spawning biomass of 84% of the 1973 reference (B_0) levels and as reflected in the increased total catch in both sectors (double the previous seasons' TIB catch). The TIB sector would have taken more than 80% of its TAC this season under a Seahorse RBC of 260 tonnes. With more favourable market conditions, the TIB sector may have faced an early season closure under a Seahorse rule RBC.
15. **Table 2** illustrates a comparison of this season's catch (2024-25) against the mid-point and alternate TACs under the Seahorse and Dolphin rules. Potential value is based on an assumed average beach price of $40/kg and differences are compared to value under the mid-point TAC.
16. AFMA Management has evaluated each rule against considerations (**Attachment 3e**) based on PZJA agreed fishery objectives and objectives under the *Torres Strait Fisheries Act 1984* (**Attachment 3f**). AFMA considers the Osprey rule to be a practical, efficient and appropriate eHCR.
17. The purpose of the TRL Harvest Strategy and a harvest control rule is to establish a set of transparent and pre-agreed rules to determine the amount of TRL that can be taken sustainably within a season, in accordance with the objectives for the fishery. That is, independent of the pre-season survey results each year and independent of how the market is behaving at any given time.

18. It was developed to take into account key fishery specific attributes including:
    a. potential for large, unpredictable inter-annual variations in availability and abundance of TRL;
    b. that TRL is a shared resource important for the traditional way of life and livelihood of traditional inhabitants, commercial and recreational sectors; and
    c. advice from the RAG industry members to maintain stock abundance at recent levels (2005-2015) (TRLRAG17 on 31 March 2016).
19. The TRL Harvest Strategy contains other safety nets to ensure ongoing sustainability of the stock, including minimum and maximum RBC limits, explicit action to be taken should the stock breach the limit reference point, and more conservative target (65% versus 48% unfished biomass) and limit (32% versus 20%) reference points than the Commonwealth Fisheries Harvest Strategy Policy and Guidelines.

BACKGROUND

The empirical Harvest Control Rule (eHCR)

20. The eHCR is an integral component of the TRL Harvest Strategy that is used to determine an RBC each fishing season.
21. The current eHCR formula uses a multiplier based on the average annual catch over the last five years (using available catch from TIB, TVH and PNG sectors), and a statistic that measures the relative performance of the fishery based on the following data inputs:
    - the pre-season survey index of abundance of juvenile recruiting 1+ lobsters (70 per cent weighting);
    - the pre-season survey index of abundance of newly recruited 0+ lobsters (10 per cent weighting);
    - the standardised CPUE index from the TVH sector (10 per cent weighting); and
    - the standardised CPUE index from the TIB sector (10 per cent weighting).
22. The Commonwealth Fisheries Harvest Strategy Policy and Guidelines, upon which the TRL Harvest Strategy is based as best practice, specifies that harvest strategies are to be reviewed every five years but may be reviewed earlier if necessary.
23. Section 2.13 of the TRL Harvest Strategy provides guidance on when a review may be required earlier than 5 years, including relating to changing external drivers.
24. As external drivers, ongoing market and economic pressures recently encountered in the fishery are beyond what was considered when the eHCR was developed and warrant a revision of the eHCR.

***Table 1.** Summary of eHCR candidates showing category name as well as variant for different types of rules. Variants in **bold** were the two previous preferred rules and the Osprey variant in bold developed as a midpoint solution. The table shows the median projected RBC (Recommended Biological Catch) (tons) based on MSE (Management Strategy Evaluation) testing over a 20-year projection period and using 4 OMs (800 simulations), with values shown corresponding to the post-RAG revised MSE. The third and fourth columns show the range of RBCs that are projected 50% (half) and 80% (often) of the time respectively. The minimum and maximum RBC is capped at 300t and 1000t respectively.*

	Median RBC (20 yr projection period)	50% of time RBC in range	80% of time RBC in range	minimum	maximum
Seahorse rule	564t[1]	519-608t	485-644t	300t	818t
Dolphin rule (619)	593t	477-720t	398-852t[2]	300t	1000t
Dolphin rule (640)	607t	487-738t	406-876t	300t	1000t
Dolphin rule (670)	638t	512-776t	427-919t[3]	300t	1000t
Osprey rule (619)[4]	600t	507-696t	440-791t	300t	1000t
Osprey rule (640)	620t	523-719t	454-817t	300t	1000t
Osprey rule (670)	647t[5]	545-751t	474-854t	300t	1000t
Rules not in final selection set					
Turtle rule (619)	*613t*	*563-660t*	*527-704t*	*300t*	*873t*
Turtle rule (640)	*634t*	*582-682t*	*544-727t*[6]	*300t*	*930t*

***Table 2.** Comparison of this seasons' catch (2024-25) and potential value against the mid-point and alternate TACs under the Seahorse and Dolphin rules. Potential value is based on an assumed average beach price of $40/kg and differences are compared to value under the mid-point TAC. Sectoral TACs are rounded for illustrative purposes.*

eHCR	**Global TAC**	**TIB**				**TVH**			
		TAC	**2024-25 Catch** (as at 24 Sept)	**% Catch vs TAC**	**Potential value ($40/kg live)**	**TAC**	**2024-25 Catch**	**% Catch vs TAC**	**Potential value ($40/kg live)**
Seahorse	582 tonnes	260 tonnes	210.48t	81%	$10.4 mil (-$4.2 mil)	133 tonnes	132.2t (as at 22 June 2025)	>100%	$5.32 mil (-$0.96 mil)
Dolphin	797 tonnes	356 tonnes	210.48t	59%	$14.24 mil (+$2.2 mil)	182 tonnes	155.72t (as at 24 Sept)	85.5%	$7.28 mil (+$1 mil)
Mid-point (Osprey)	688 tonnes	307 tonnes	210.48t	68.5%	$12.28 mil	157 tonnes	155.72t (as at 24 Sept)	99.21%	$6.28 mil

[1] Lowest median catch
[2] Most conservative in a bad year
[3] Least conservative in a good year i.e. highest catch that year
[4] Midpoint rule that yields PZJA-recommended TAC for 2024-25 season
[5] Highest median catch
[6] Least conservative in a bad year

Attachment 3a

Australian Government
Australian Fisheries Management Authority

Torres Strait Tropical Rock Lobster Fishery Harvest Strategy

November 2019

Box 7051, Canberra Business Centre, ACT 2610 / Ph (02) 6225 5555 / Fax (02) 6225 5500 / AFMA Direct 1300 723 621 afma.gov.au

This harvest strategy is based on outcomes from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans and Atmosphere Division project, *Torres Strait Tropical Rock Lobster (TRL) fishery surveys, stock assessment, harvest control rules and RBC*. The project was funded by the Australian Fisheries Management Authority (AFMA).

AFMA Project No. 2016/0822.

Project Authors: Éva Plagányi (Principal Investigator), Darren Dennis, Roy Deng, Robert Campbell, Trevor Hutton, Mark Tonks

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CONTENTS

GLOSSARY

Types of reference points:

Reference Point	Description
Metarule	A rule that describes how the RBCs obtained from an assessment should be adjusted in calculating a recommended TAC
Target	The desired state of the stock or fishery (for example, MEY or B_{TARG})[1]
Limit	The level of an indicator (such as biomass or fishing mortality) beyond which the risk to the stock is regarded as unacceptably high[1]
MEY	The sustainable catch or effort level for a commercial fishery that allows net economic returns to be maximised. In this context, maximised equates to the largest positive difference between total revenue and total cost of fishing[1]
MSY	The maximum average annual catch that can be removed from a stock over an indefinite period under prevailing environmental conditions[1]

Notation:

Notation	Description
B	Spawning biomass - the total weight of all adult (reproductively mature) fish in a population[1]
B_0	The unfished spawning biomass (determined from an appropriate reference point)
F	Fishing mortality rate
B_{LIM}	Biomass limit reference point - the point beyond which the risk to the stock is regarded as unacceptably high[1]
B_{TARG}	Biomass target reference point - the desired biomass of the stock[1]

Other acronyms:

Acronym	Description
CPUE	Catch per unit effort
eHCR	Empirical Harvest Control Rule
HCR	Harvest Control Rule - pre-determined rules that control fishing activity according to the biological and economic conditions of the fishery (as defined by monitoring or assessment). Also called ‘decision rules’. HCR are a key element of a harvest strategy[1]
HSP	*Commonwealth Fisheries Harvest Strategy Policy: Framework for applying an evidence-based approach to setting harvest levels in Commonwealth fisheries* (June 2018)
HS	Torres Strait Tropical Rock Lobster Fishery Harvest Strategy
PZJA	Protected Zone Joint Authority

[1] Definition sourced from the *Commonwealth Fisheries Harvest Strategy Policy: Framework for applying an evidence-based approach to setting harvest levels in Commonwealth fisheries* (June 2018)

MSE	Management Strategy Evaluation - a procedure whereby alternative management strategies are tested and compared using simulations of stock and fishery dynamics[1]
RBC	Recommended Biological Catch
TRLRAG	Protected Zone Joint Authority Tropical Rock Lobster Resource Assessment Group
TRLWG	Protected Zone Joint Authority Tropical Rock Lobster Working Group
TAC	Total Allowable Catch- the annual catch limit set for a stock, species or species group. Used to control fishing mortality within a fishery[1]
Tiered approach	A framework that uses different control rules to cater for different levels of uncertainty about a stock
TIB	Traditional inhabitant boat
TVH	Transferrable vessel holder
TRL	Tropical Rock Lobster
TSPZ	Torres Strait Protected Zone

OVERVIEW

The Torres Strait Tropical Rock Lobster Fishery (the Fishery) Harvest Strategy (HS) sets out the management actions needed to achieve the agreed Fishery objectives. The HS describes the performance indicators used for monitoring the condition of the stock, the fishery-independent survey and stock assessment procedures and the rules applied to determine the recommended biological catch (RBC) and the total allowable catch (TAC) each fishing season.

The HS uses a single tier approach with an empirical harvest control rule (eHCR) that is used to determine a RBC. The eHCR uses the pre-season survey index of abundance of juvenile (1+) and newly recruited (0+) Tropical Rock Lobster (TRL) and the catch per unit effort (CPUE) indices for the traditional inhabitant boat (TIB) and transferrable vessel holder (TVH) fishing sectors. The eHCR has been extensively tested using Management Strategy Evaluation (MSE) (Plagányi *et al.* 2018). The RBC is the best available scientific advice on what the total fishing mortality (landings from all sectors and discards) should be for the stock. The RBC is used to negotiate Australia-Papua New Guinea catch sharing and recommend TACs (an enforced limit on total catches).

The HS meets the requirements of the *Commonwealth Fisheries Harvest Strategy Policy: Framework for applying an evidence-based approach to setting harvest levels in Commonwealth fisheries* (June 2018) *(*HSP) by applying a precautionary approach to the reference points and measures to be implemented in accordance with the reference points. This is reflected in the use of proxy reference points that are more precautionary than those specified in the HSP. The eHCR is designed to decrease exploitation rate as the stock size decreases below the target reference point. The HS uses a biomass target reference point equal to recent levels (2005-2015) that take account of the fact that the resource is shared and important for the traditional way of life and livelihood of traditional inhabitants and is biologically and economically acceptable. The HS proxies are B_{LIM} is 32% of B_0, B_{TARG} is 65% of B_0.

Further work for the HS will include the development of a tiered approach. The tiered approach applies different types of control rules to cater for different amounts of data available and to account for changes to uncertainty on stock status. A tiered approach adopts increased levels of precaution that correspond to increasing levels of uncertainty about the stock status, in order to maintain the same level of risk across the different tiers.

The status of the stock and how it is tracking against the HS, is reported to the Tropical Rock Lobster Resource Assessment Group (RAG), Tropical Rock Lobster Working Group (TRLWG) and the Protected Zone Joint Authority (PZJA). The stock assessment is conducted periodically to evaluate stock status relative to reference levels and, in doing so, performance of the eHCR. The stock assessment includes considerations of the catch rates in current and previous fishing seasons, how the catches compare to the RBCs, stock status indicators in relation to the reference points and an RBC for the upcoming fishing season.

1 BACKGROUND

This Torres Strait Tropical Rock Lobster Fishery (the Fishery) Harvest Strategy (HS) has been developed in accordance with the *Commonwealth Fisheries Harvest Strategy Policy: Framework for applying an evidence-based approach to setting harvest levels in Commonwealth fisheries* (June 2018) (HSP) and consistent with objectives of the *Torres Strait Fisheries Act 1984* (the Act).

The Fishery HS takes into account key fishery specific attributes including:

a) there is potential for large, unpredictable inter-annual variations in availability and abundance of Tropical Rock Lobster (TRL);

b) TRL is a shared resource important for the traditional way of life and livelihood of traditional inhabitants, commercial and recreational sectors (Tropical Rock Lobster Resource Assessment Group (TRLRAG) 20, 4-5 April 2017); and

c) advice from the TRLRAG industry members to maintain stock abundance at recent levels (2005-2015) (TRLRAG 17, 31 March 2016).

1.1 COMMONWEALTH FISHERIES HARVEST STRATEGY POLICY

The objective of the HSP is the ecologically sustainable and profitable use of Australia's Commonwealth commercial fisheries resources (where ecological sustainability takes priority) - through implementation of harvest strategies.

To pursue this objective the Australian Government will implement harvest strategies that:

a) ensure exploitation of fisheries resources and related activities are conducted in a manner consistent with the principles of ecologically sustainable development, including the exercise of the precautionary principle

b) maximise net economic returns to the Australian community from management of Australian fisheries - always in the context of maintaining commercial fish stocks at sustainable levels

c) maintain key commercial fish stocks, on average, at the required target biomass to produce maximum economic yield from the fishery

d) maintain all commercial fish stocks, including byproduct, above a biomass limit where the risk to the stock is regarded as unacceptable (B_{LIM}), at least 90 per cent of the time

e) ensure fishing is conducted in a manner that does not lead to overfishing - where overfishing of a stock is identified, action will be taken immediately to cease overfishing

f) minimise discarding of commercial species as much as possible

g) are consistent with the *Environment Protection and Biodiversity Conservation Act 1999* and the *Guidelines for the Ecologically Sustainable Management of Fisheries*.

For fisheries that are managed jointly by an international organisation or arrangement, the HSP does not prescribe management arrangements. This includes management arrangements for commercial and traditional fishing in the Torres Strait Protected Zone (TSPZ), which are governed by provisions of the Torres Strait Treaty and the *Torres Strait Fisheries Act 1984*. However, it does articulate the government's preferred approach.

The HSP provides for the use of proxy settings for reference points to cater for different levels of information available and unique fishery circumstances. This balance between prescription and flexibility encourages the development of innovative and cost effective strategies to meet key policy objectives. Proxies, including those that exceed the minimum standards, must be demonstrated to be compliant with the HSP objective.

With a harvest strategy in place, fishery managers and stakeholders are able to operate with pre-defined rules, management decisions are more transparent, and there are likely fewer unanticipated outcomes necessitating hasty management responses. However, due to the inherently natural variability of TRL abundance there may be a need for significant changes in recommended catch on an annual basis.

1.2 DEVELOPMENT OF THE TRL HARVEST STRATEGY

The HS has been developed in consultation with the TRLRAG (meeting no. 17 on 31 March 2016; meeting no. 18 on 2-3 August 2016; meeting no. 19 on 13 December 2016; meeting no. 20 on 4-5 April 2017; meeting no. 22 on 27-28 March 2018; meeting no. 24 on 18-19 October 2018; and meeting no. 25 on 11-12 December 2018; out of session 16 September-9 October 2019) and TRLWG (meeting no. 6 on 25-26 July 2017; meeting no. 9 on 19-20 February 2019; out of session 16 September-9 October 2019). This HS replaces the interim HS developed for the Fishery in 2008.

2 TRL FISHERY HARVEST STRATEGY

2.1 SCOPE

This HS applies to the whole Fishery and it takes into account catch sharing arrangements between Australia and Papua New Guinea (PNG).

The HS outlines the control rules used to develop advice on the recommended biological catch (RBC) and to recommend total allowable catches (TACs) (an enforced limit on total catches). The HS sets the criteria that pre-agreed management decisions will be based on in order to achieve the HS objectives.

Over time the HS may be amended to use a tiered approach to cater for different amounts of data available and different types of assessments (for example mid-season surveys and annual assessments). Underpinning a tiered HS is increased levels of precaution with increasing levels of uncertainty about the stock status. Each tier has its own harvest control rule (HCR) and associated rules that are used to determine a RBC.

2.2 OBJECTIVES

The operational objectives of the HS are to:

a) Maintain the stock at (on average), or return to, a target biomass point B_{TARG} equal to recent levels (2005-2015) that take account of the fact that the resource is shared and important for the traditional way of life and livelihood of traditional inhabitants and is biologically and economically acceptable.

   - The agreed B_{TARG} is more precautionary than the default proxy B_{MEY} (biomass at maximum economic yield) level as outlined in the HSP.

b) Maintain the stock above the limit biomass level (B_{LIM}), or an appropriate proxy, at least 90 per cent of the time.

   - The agreed B_{LIM} is more precautionary than the default proxy HSP B_{LIM}.

c) Implement rebuilding strategies, if the spawning stock biomass is assessed to fall below B_{LIM} in two successive years.

2.3 RECOMMENDING TACs FROM RBCs

The RBC is the recommended total catch of TRL (both retained and discarded) that can be taken by all sectors within the TSPZ and waters declared as areas outside but near to the TSPZ, including Australian and PNG fishers. The HSP states that when setting the TAC for the next fishing season the HS should take into account all sources of fishing mortality.

The HS does not include catches taken by non-commercial fishing sectors, for example traditional, recreational or research catches. The TRLRAG recommended at meeting no. 18 on 2-3 August 2016 that non-commercial catches not be estimated in the stock assessment model or when setting the TAC at this time, noting the likely low level of overall catch and the lack of accurate data. However, if unaccounted fishing mortality were to increase significantly this may impact on the performance of the stock assessment. The HS may be updated in the future to account for changing circumstances in the Fishery, the review provisions are described in **Section 2.13**.

2.4 MONITORING

Biological data for the Fishery are monitored by a range of methods listed below. Currently there is no ongoing monitoring strategy in place to collect economic information.

Fishery independent surveys

A key component of the monitoring program is the fishery-independent survey which provides a time-series of relative abundance indices for TRL. Fishery-independent surveys have been conducted in the Fishery since 1989. Historically (1989-2014 and 2018), mid-season (July) surveys focused on providing an index of abundance of the spawning (age 2+) and juvenile (age 1+) lobsters. Mid-season surveys have been replaced with pre-season (November) surveys (2005-2008; 2014 to current) which focus on providing an index of recruiting (age 1+) lobsters as close as possible to the start of the fishing season to support the transition to quota management and setting of a TAC. Pre-season surveys also provide indices of recently-settled (age 0+) lobsters, which may become useful under quota management as they allow forecasting of stock one year in advance and are used in the eHCR.

Catch and effort information

Fishers in the transferrable vessel holder (TVH) sector are required to record catch and effort information in the Torres Strait Tropical Rock Lobster Daily Fishing Log (TRL04). The following data are recorded for each TVH fishing operation: the port and date of departure and return, fishing area, fishing method, hours fished and the weight (whole or tails) of TRL retained. Fishers in both the TVH and traditional inhabitant boat (TIB) sectors are required to record catch information in the Torres Strait Fisheries Catch Disposal Record (TDB02). The provision of effort information under the TDB02 is voluntary. Some processors previously (2014-2016) reported aggregate TIB catch information directly to AFMA predominantly through the Torres Strait Seafood Buyers and Processors Docket Book (TDB01).

2.5 INTEGRATED STOCK ASSESSMENT MODEL

The stock assessment model (termed the ‘Integrated Model’) (Plagányi *et al.* 2009) was developed in 2009 and is an Age-Structured Production Model, or Statistical Catch-at-Age Analysis (SCAA) (e.g. Fournier and Archibald 1982). It is a widely used approach for providing RBC advice and the associated uncertainties.

The model integrates all available information into a single framework to assess resource status and provide a RBC. The model addresses all of the concerns highlighted in a review of the previous stock assessment approach (Bentley 2006, Ye *et al*. 2006, 2007). The model is fitted to the mid-season and pre-season survey data and TIB and TVH catch per unit effort (CPUE) data. The growth relationships used in the model were revised from the previous stock assessment model (Ye *et al*. 2006) to ensure that the modelled individual mass at age more closely resembled field measurements. The model has been used as an Operating Model in a Management Strategy Evaluation (MSE) framework to support the management of the Fishery (Plagányi *et al.* 2012, 2013, 2018).

The stock assessment model is non-spatial and assumes (conservatively) that the Torres Strait Tropical Rock Lobster Fishery stock is independent of the Queensland East Coast Tropical Rock Lobster Fishery stock. A spatial version of the model has been developed as part of an earlier MSE project, and can be used to investigate plausible linkages between these stocks (Plagányi *et al*. 2012, 2013).

The model includes three age-classes only (0+, 1+ and 2+ age lobsters) as it is assumed that lobsters migrate out of the Torres Strait in October each year. Torres Strait TRL emigrate in spring (September-November) and breed during the subsequent summer (November-February) (MacFarlane and Moore 1986; Moore and Macfarlane 1984). A Beverton-Holt stock-recruitment relationship is used (Beverton and Holt 1957), allowing for annual fluctuation about the average value predicted by the recruitment curve. The model is fitted to the available abundance indices by maximising the likelihood function. Quasi-Newton minimisation is used to minimise the total negative log-likelihood function (using the package AD Model Builder™) (Fournier *et al*. 2012).

2.6 EMPIRICAL HARVEST CONTROL RULE

The empirical harvest control rule (eHCR) recommended by the TRLRAG uses the pre-season survey 1+ and 0+ indices, both standardised CPUE indices (TVH and TIB), applies the natural logarithms of the slopes of the five most recent years' data and the average catch over the past five years, with an upper catch limit of 1,000 t. The relative weightings of the eHCR indices are 70 per cent pre-season survey 1+ index, 10 per cent pre-season survey 0+ index, 10 per cent TIB sector standardised CPUE and 10 per cent TVH sector standardised CPUE.

The basic formula is:

$$
\begin{aligned}
RBC_{y+1} = {} & wt\_s1 \cdot \left(1 + s_y^{presurv,1}\right) \cdot \overline{C}_{y-4,y} + wt\_s2 \cdot \left(1 + s_y^{presurv,0}\right) \cdot \overline{C}_{y-4,y} \\
& + wt\_c1 \cdot \left(1 + s_y^{CPUE,TVH}\right) \cdot \overline{C}_{y-4,y} + wt\_c2 \cdot \left(1 + s_y^{CPUE,TIB}\right) \cdot \overline{C}_{y-4,y}
\end{aligned}
$$

Or if RBC_{y+1} > 1000t, TAC_{y+1} = 1000.

Where:

$\overline{C}_{y-4,y}$ is the average achieved catch during the past 5 years, including the current year i.e. from year *y*-4 to year *y*,

$s_y^{presurv,1}$ is the slope of the logarithms of the preseason survey 1+ abundance index, based on the 5 most recent values;

$s_y^{presurv,0}$ is the slope of the logarithms of the preseason survey 0+ abundance index, based on the 5 most recent values;

$s_y^{CPUE,TVH}, s_y^{CPUE,TIB}$ is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values;

wt_s1, wt_s2, wt_c1, wt_c2 are tuning parameters that assign relative weight to the preseason 1+ (wt_s1) and 0+ (wt_s2) survey trends compared with the CPUE TVH (wt_c1) and TIB (wt_c2) trends.

2.7 REFERENCE POINTS

The HS reference points are:

a) The unfished biomass B_0 is the model-estimate of spawning stock biomass in 1973 (start of the Fishery). $B_0 = B_{1973}$.

b) The target biomass B_{TARG} is the spawning biomass level equal to recent levels (2005-2015) that take account of the fact that the resource is shared and important for the traditional way of life and livelihood of traditional inhabitants and is biologically and economically acceptable. B_{TARG} is the proxy for B_{MEY}, $B_{TARG} = 0.65\ B_0$.

   - The agreed B_{TARG} is more precautionary than the default proxy B_{MEY} (biomass at maximum economic yield) level as outlined in the HSP. The TRLRAG noted a B_{TARG} higher that the HSP default was considered important for the Fishery because: 1) the stock is a shared resource that is particularly important for traditional fishing; 2) the stock has high variability; and, 3) all industry members recommended the HS maintain the stock around the relatively high current levels (TRLRAG meeting no. 17, 31 March 2016 and meeting no. 18, 2-3 August 2016).

c) The limit biomass B_{LIM} is the spawning biomass level below which the risk to the stock is unacceptably high and the stock is defined as 'overfished'. B_{LIM} is agreed to be half of B_{TARG}, $B_{LIM} = 0.32\ B_0$.

   - The agreed B_{LIM} is more precautionary than the default proxy HSP B_{LIM}.

d) If the limit reference point (B_{LIM}) is triggered in two successive years then the Fishery is closed.

e) The target fishing mortality rate F_{TARG} is the estimated level of fishing mortality rate that maintains the spawning biomass around B_{TARG}. $F_{TARG} = 0.15$.

- F_{TARG} = 0.15 is the target fishing mortality rate that corresponds to an optimal level in terms of economic, biological and social considerations (TRLRAG meeting no. 18, 2-3 August 2016).

Rational for reference points

The HSP recognises that each stock/species/fishery will require an approach tailored to the fishery circumstances, including species characteristics. The HSP identifies that the selection of reference points within harvest strategies need to be realistic with respect to the scale or nature of the fishery and the resources available to manage it. Reference points should be set at levels appropriate to the biology of the species and the proper functioning of the broader marine ecosystem. Further, stocks that fall below B_{LIM} will be subject to the recovery measures stipulated in the HSP. A number of adaptive management approaches may be used to deal with this, such as pre-season surveys to provide estimates of abundance to which the eHCR is applied.

The Fishery is characterised by a highly variable stock where majority of the catch (since 2001 due to the introduction of a minimum size limit) is from a single cohort. The stock assessment model and MSE testing have identified the target biomass should be set between 65 and 80 per cent of the unfished biomass to account for the importance of the stock for the traditional way of life and livelihood of traditional inhabitants and to achieve biological and economic objectives. The HS's higher average target biomass level, compared to the default HSP target of 0.48 per cent of unfished biomass, reduces the risk of recruitment being compromised.

The unfished biomass (B_0) is calculated within the stock assessment model, the value of unfished biomass and target biomass have therefore varied over time in response to annual data updates and model parameter settings and estimates. Estimates of unfished biomass and target biomass are particularly sensitive to changes to parameter *h*, which determines the steepness of the stock-recruit relationship, and the input parameter that controls the level of stock-recruit variability.

Independent of variability to the unfished biomass value, the target fishing mortality rate F_{TARG} = 0.15 is applied to maintain the spawning biomass around the biomass target reference point (B_{TARG}), which is the average level over the past two decades. This is assumed to be a proxy for B_{MEY} because stakeholders agreed that this target level corresponded to an optimal level in terms of economic, biological and social considerations (TRLRAG meeting no. 18, 2-3 August 2016).

The biomass limit reference point (B_{LIM}) is 32 per cent of unfished biomass. The higher limit reference point, compared to the HSP proxy of 20 per cent of unfished biomass, is supported by recommendations of similar limit reference points for other highly variable species such as forage fish (Pikitch *et al.* 2012). Due to the changing values of unfished biomass and target biomass the value of the limit reference point, taken as half the target reference point, has previously varied between 32 and 40 per cent of unfished biomass.

Recent MSE testing identified that a limit reference point of 40 per cent unfished biomass is too conservative, it would result in the limit reference point being breached more frequently and add unnecessary precaution to the HS. The TRLRAG agreed to set the limit reference point at 32 per cent of unfished biomass with the condition that if the stock falls below the limit reference point in two successive years it triggers a Fishery closure. The eHCR is more precautionary than the HSP criterion to 'maintain all commercial fish stocks, including byproduct, above a biomass limit where the risk to the stock is regarded as unacceptable (B_{LIM}), at least 90 per cent of the time'. The HSP provides for the designation of a limit reference point above the proxy (B_{20}) where this has been estimated or is deemed appropriate.

2.8 eHCR AND STOCK ASSESSMENT CYCLE

The eHCR and stock assessment cycle is as follows:

- The eHCR is run in November each year to provide a RBC by 1 December for the following fishing season.
- A stock assessment is run on a three year cycle by March, unless the stock assessment is triggered by a decision rule **(Section 2.10)**. The stock assessment determines the Fishery stock status and evaluates the performance of the eHCR and identifies if any revisions to the eHCR are required.
- If the eHCR needs to be revised, the stock assessment is conducted annually to estimate the RBC until the revised eHCR is agreed.

2.9 DATA SUMMARY

The annual data summary reviews the nominal and standardised CPUE from the TIB and TVH sectors, as well as total catch from all sectors, the size-frequency information provided from a sub-sample of commercially caught TRL and the fishery-independent survey indices of 0+ and 1+ age lobsters. The data summary is used as an indicator to identify if catches correspond to the RBC, and to monitor CPUE.

2.10 DECISION RULES

The decision rules for the HS are:

Maximum catch limit

- The eHCR includes a maximum catch limit of 1000 t. Once the HS is implemented the cap will be reviewed after three years using MSE testing with the updated stock assessment model.

Pre-season survey trigger

- If in any year the pre-season survey 1+ index is 1.25 or lower (average standardised number of 1+ age lobsters per survey transect) it triggers a stock assessment.

Biomass limit reference point triggered

- If the pre-season survey trigger is triggered in the first year, a stock assessment update must be conducted in March.
    - o If after the first year the stock is assessed below the biomass limit reference point, it is optional to conduct a mid-season survey, the pre-season survey must continue annually.
- If the pre-season survey trigger is triggered two years in a row, a stock assessment must be conducted in December (of the second year).

Fishery closure rules

- If the stock assessment determines the stock to be below the biomass limit reference point in two successive years, the Fishery will be closed to commercial fishing.
    - o MSE testing of the eHCR has shown that it is extremely unlikely (<1%) for the Fishery to be closed based on its current performance (Plagányi *et al.* 2018).

Re-opening the Fishery

- Following closure of the Fishery, fishery-independent mid-season and pre-season surveys are mandatory. The Fishery can only be re-opened when a stock assessment determines the Fishery to be above the biomass limit reference point **(Attachment A, Figure 5)**.

Based on the decision rules, there are four alternative possible scenarios **(Section 2.11)** that may occur under the application of the eHCR. Graphic representations of the four scenarios are provided in **Attachment A**.

2.11 DECISION RULE SCENARIOS

Scenario 1 – Pre-season survey trigger not triggered and the eHCR does not require revision

- The pre-season survey trigger is not triggered.
- The eHCR RBCs appear to remain within ranges tested by MSE.
- The updated stock assessment does not indicate any need for revision of the eHCR.
- Application of the eHCR continues unchanged.
- A graphic representation of Scenario 1 is provided in **Attachment A, Figure 1**.

Scenario 2 – Pre-season survey trigger not triggered, eHCR and stock assessment require revision

- The pre-season survey trigger is not triggered.

- The eHCR RBCs appear to remain within ranges tested by MSE.
- The updated stock assessment indicates the eHCR recommended RBCs are outside the revised ranges tested by MSE, indicating that the eHCR should be revised.
- Annual RBCs need to be set using annual stock assessments until a revised eHCR has been agreed, after which the revised eHCR is applied.

A graphic representation of Scenario 2 is provided in **Attachment A, Figure 2**.

Scenario 3– Pre-season survey trigger is triggered, eHCR is reviewed by stock assessment and the biomass limit reference point is not breached

- The pre-season survey trigger is triggered in one year.
- A stock assessment update (March) is required to confirm if the biomass limit reference point has been breached. This assessment update determines that the biomass limit reference point has not been breached.
- If the biomass limit reference point is breached once, discussions will be held on preventative measures to reduce the risk of closure.
- The eHCR RBC is applied and consideration is given to revising the eHCR to prevent future incorrect indications that the biomass limit reference point may have been breached.
- The stock assessment continues on a three year cycle, unless triggered to occur by a decision rule.
- A graphic representation of Scenario 3 is provided in **Attachment A, Figure 3**.

Scenario 4 – Pre-season survey trigger is triggered, stock assessment confirms the biomass limit reference point is breached

- The pre-season survey trigger is triggered in one year.
- A stock assessment update (March) is required to confirm if the biomass limit reference point has been breached. This assessment update determines that the biomass limit reference point has been breached.
- The pre-season survey trigger is triggered for a second successive year.
- A second stock assessment update (December) is required to confirm whether the biomass limit reference point has been breached a second time. This assessment update determines that the biomass limit reference point has been breached a second time.
- The commercial fishery is closed until an assessment update confirms that the stock has recovered to above the biomass limit reference point.
    - o If the Fishery is closed to commercial fishing, discussions are held on future management arrangements.

  - Fishery-independent mid-season and pre-season surveys are mandatory and conducted on an annual basis. The Fishery will only re-open when the Fishery is assessed to be above the biomass limit reference point by the stock assessment.
  - The eHCR must be revised before being re-implemented to reduce the risk of the Fishery breaching the biomass limit reference point and for the eHCR to incorporate rebuilding requirements.

- A graphic representation of Scenario 4 is provided in **Attachment A, Figure 4**.

2.12 GOVERNANCE

The status of the Fishery and how it is tracking against the HS is reported to the TRLRAG, TRLWG and the PZJA as part of the yearly RBC and TAC setting process.

2.13 REVIEW

Harvest strategies are to be reviewed every five years. However, it may be necessary to amend harvest strategies earlier if:

- a marked change in stocks targeted occurs, leading to a change in which stocks are categorised as key commercial
- new information substantially changes understanding of the fishery, leading to revised estimates of indicators relative to reference points
- external drivers have unexpectedly increased the risk to a fishery and fish stocks, including environmental or climate drivers that have substantially altered the productivity characteristics (growth or recruitment) of the stock
- performance indicators show that harvest strategies are not working effectively, and that the intent of the HSP is not being met.

Early review may be triggered when either:

- harvest strategies are implemented without formal testing or evaluation using methods such as MSE
- MSE testing did not take adequate account of the changes in risk factors subsequently observed, or
- subsequent estimates of the performance indicators used in the HCR are biased or uncertain to the extent that application of the control rule using these indicators fails to appropriately adjust fishing pressure.

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Torres Strait Tropical Rock Lobster Fishery – alternative annual Harvest Control Rule application scenarios

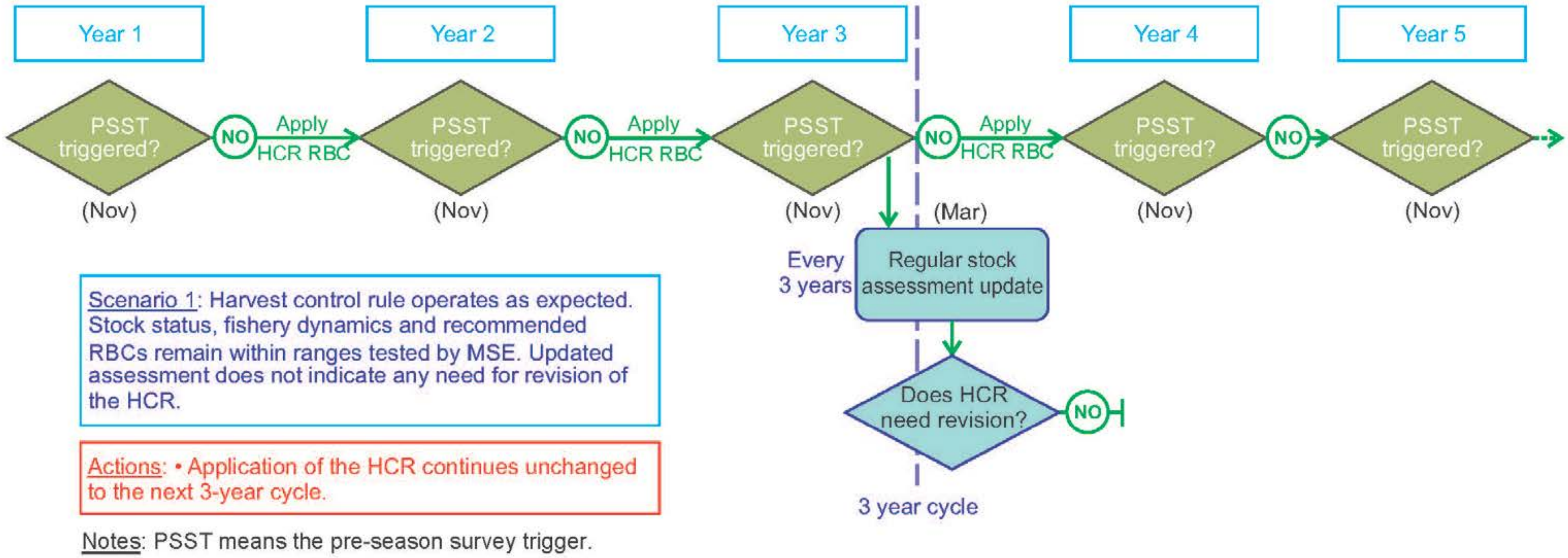


Figure 1. Torres Strait Tropical Rock Lobster Fishery decision rule scenario 1.

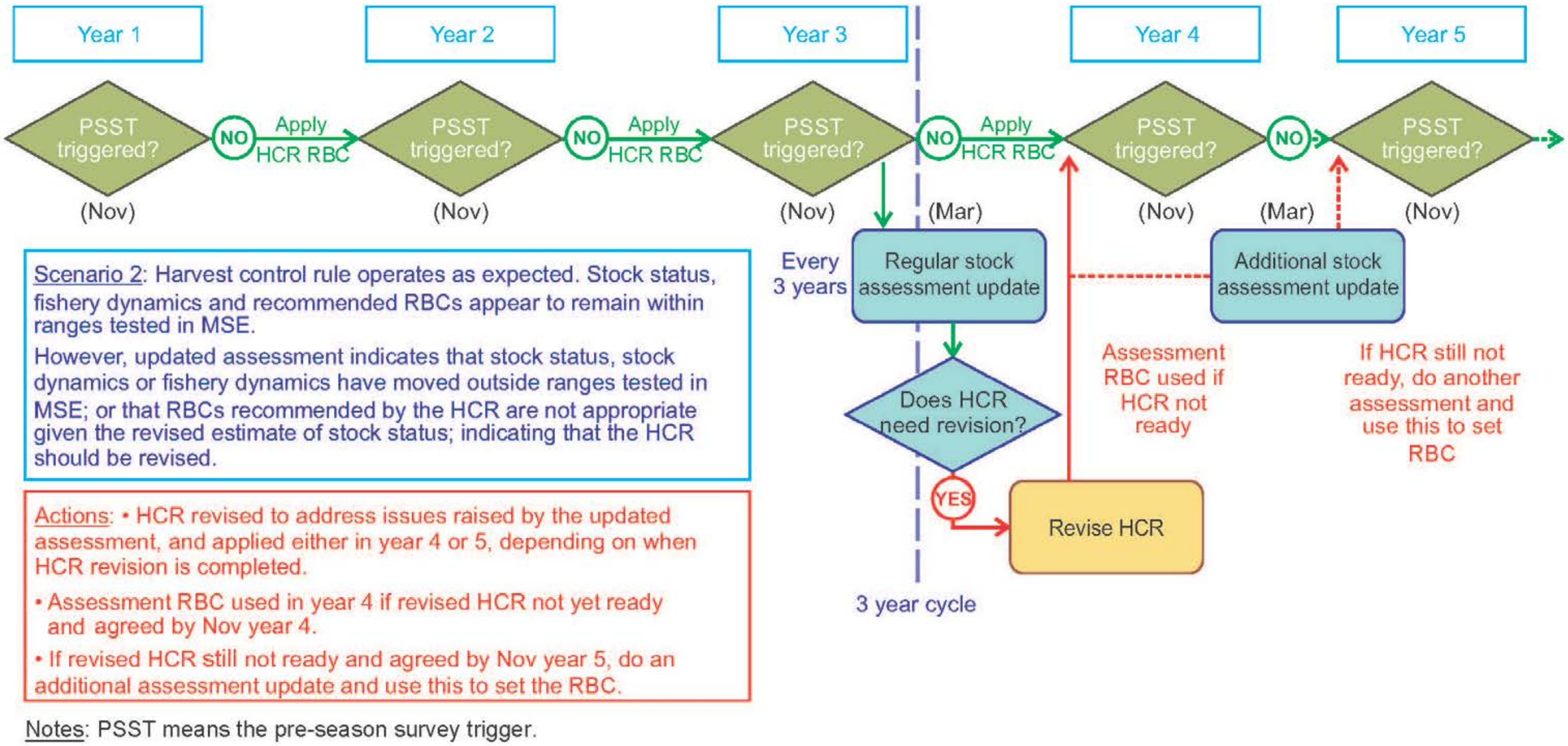
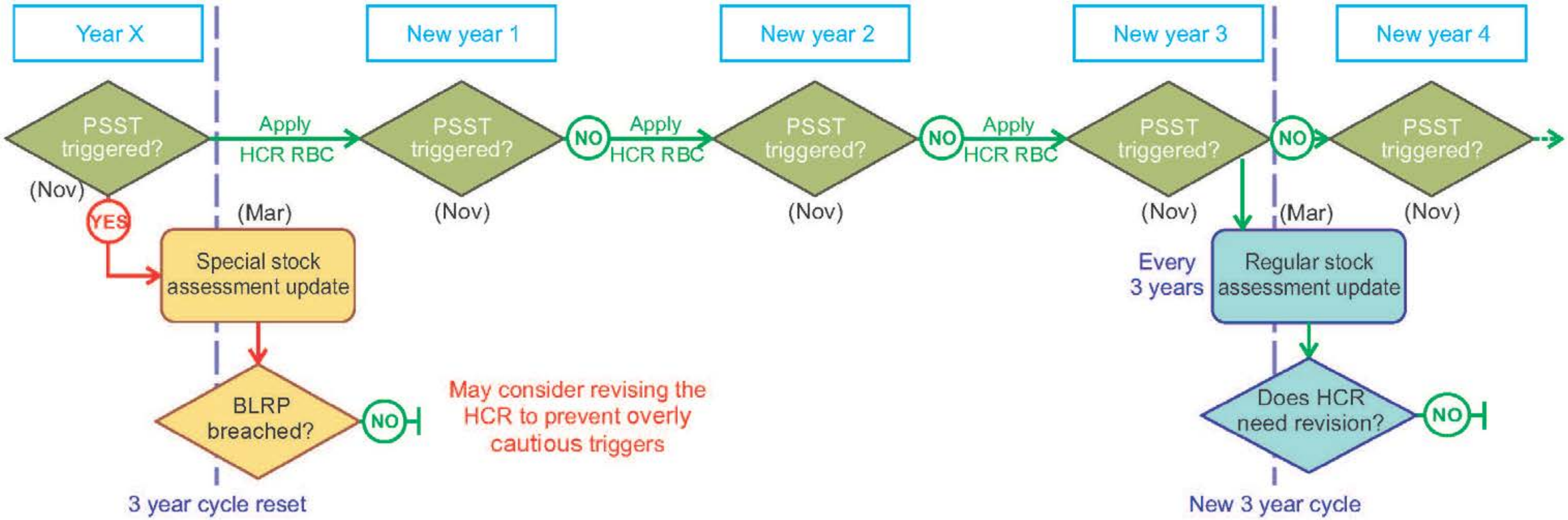


Figure 2. Torres Strait Tropical Rock Lobster Fishery decision rule scenario 2.



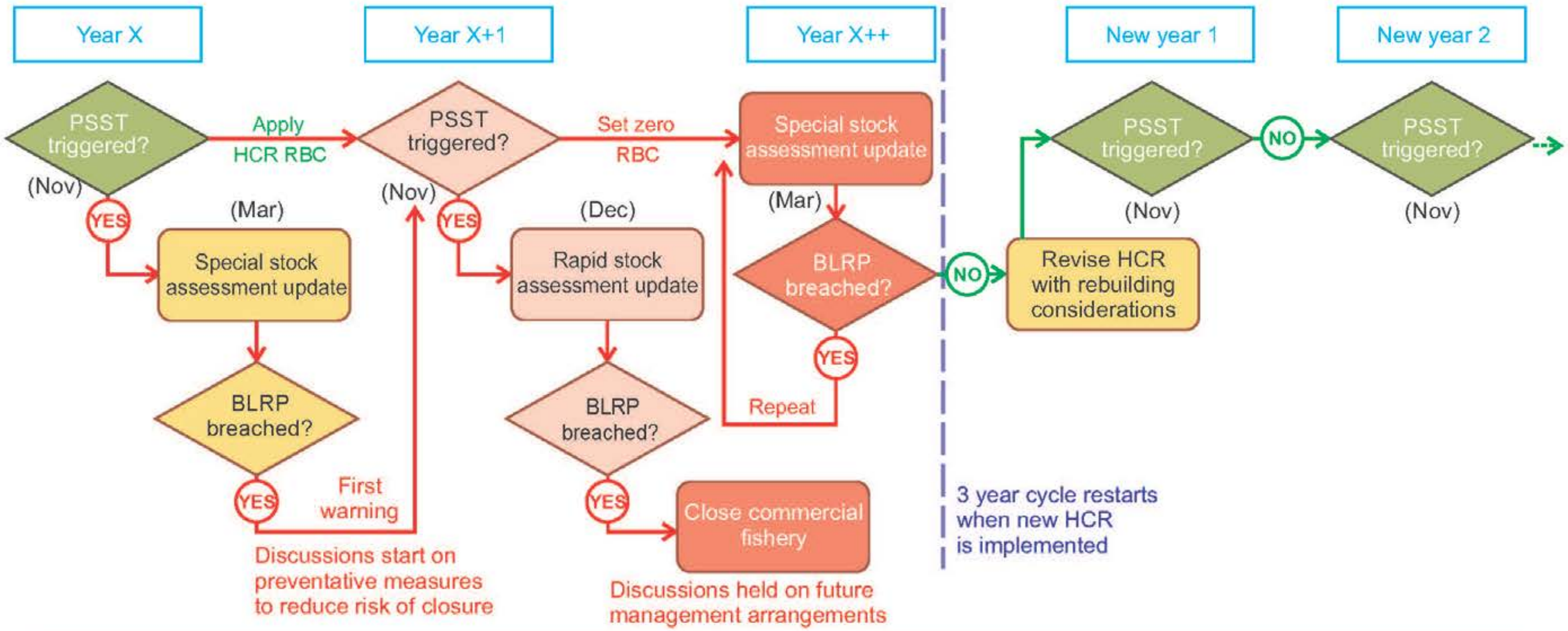
Scenario 3: Application of the HCR in a particular year results in the PSST being triggered, requiring a special assessment update to confirm whether the BLRP has been breached. However, this assessment update determines that the BLRP has not been breached.

Actions: •Application of the HCR continues unchanged, although consideration may be given to revising the HCR to prevent overly cautious triggering of the PSST (refer to Scenario 2).

• The three-year cycle is reset, postponing the next regular assessment update to retain the 3 year spacing between assessments, provided the PSST is not triggered again in that period.

Notes: PSST means the pre-season survey trigger. BLRP means biomass limit reference point.

Figure 3. Torres Strait Tropical Rock Lobster Fishery decision rule scenario 3.



Scenario 4: Application of the HCR in a particular year results in the PSST being triggered, requiring a special assessment update to confirm whether the BLRP has been breached. Special assessment update confirms that the BLRP has indeed been breached.

Application of the HCR the following year results in the PSST being triggered for the second successive year, requiring a second rapid assessment update to confirm whether the BLRP has been breached a second time. Assessment update confirms that the BLRP has been breached again.

The commercial fishery is closed until an assessment update confirms that the stock has recovered to above the BLRP.

Actions: • When it has been confirmed that the BLRP has been breached the first time, discussions will be held on preventative measures to reduce the risk of closure.

• If it is confirmed that the BLRP has been breached for a second year and that the commercial fishery must be closed, discussions will be held on future management arrangements to reduce the risk of future closures.

• If the fishery is closed, annual assessments will be done until an assessment update confirms that the stock has recovered to above the BLRP.

• Before being re-implemented, the HCR will be revised to reduce the risk of breaching the BLRP in future and to incorporate rebuilding requirements.

Notes: PSST means the pre-season survey trigger. BLRP means biomass limit reference point.

Figure 4. Torres Strait Tropical Rock Lobster Fishery decision rule scenario 4.

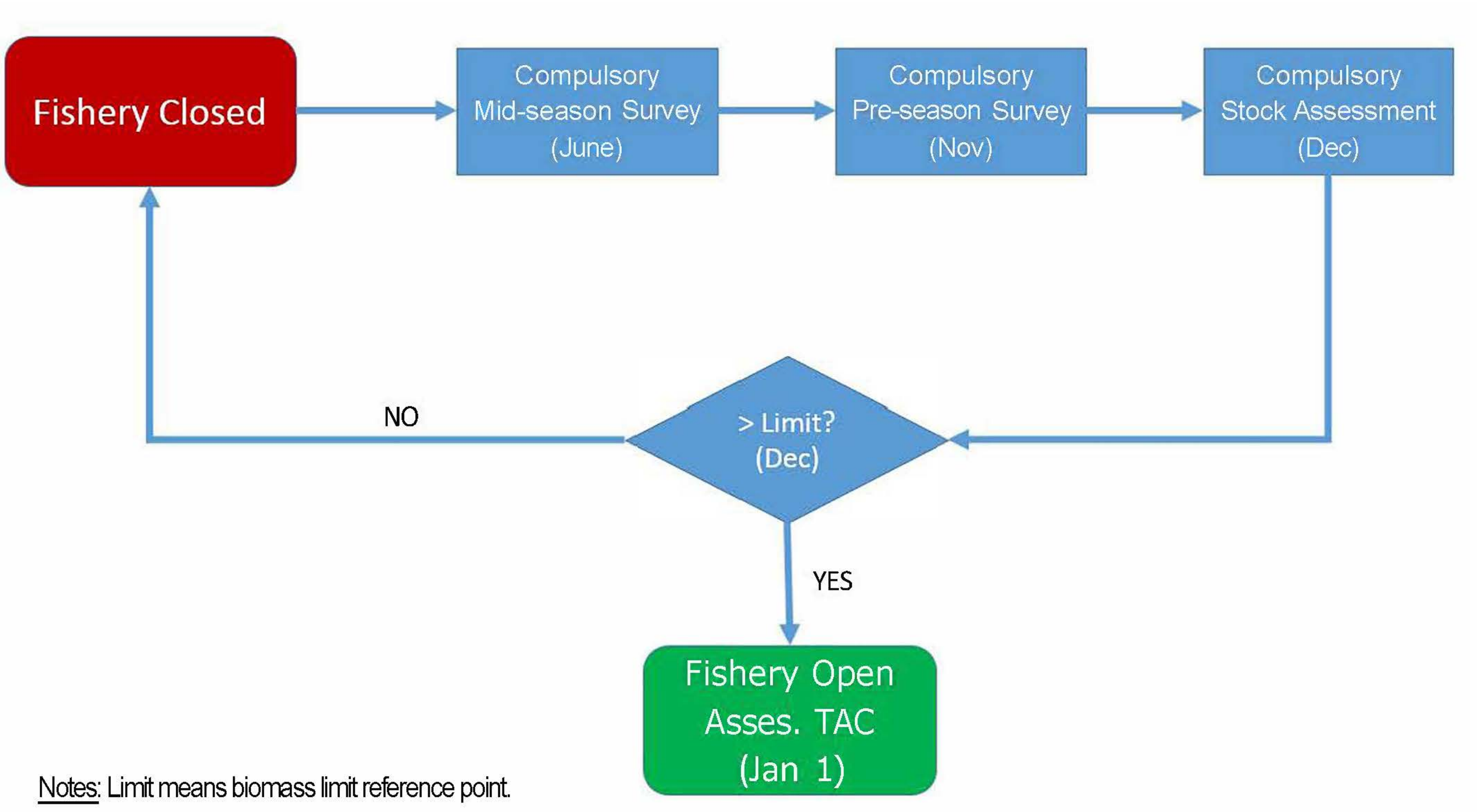


Figure 5. Torres Strait Tropical Rock Lobster Fishery closure and re-opening rule.

Overview of previous TRLRAG and TRLWG views

1. TRLRAG 37 was unable to reach consensus on an agreed way forward for amending or applying an eHCR for the 2024-25 fishing season and beyond.
    a. TVH industry members expressed a preference for the 'dolphin rule' but were willing to accept either.
    b. Government members expressed no preference but noted that both alternatives, 'dolphin rule' or the 'Turtle Rule' were acceptable as both adequately meet the objectives of the TRL Harvest Strategy.
    c. Both scientific members supported either rule, noting that the CSIRO scientific member advised that taking into account feedback from RAG members and using the best scientific advice, the 'dolphin rule' would best meet the objectives but was confident that either rule was suitably precautionary and performed well.
    d. Advice from traditional inhabitant industry members (including views of traditional inhabitant casual observers) with the support of TSRA, out of session, indicated that those members were not in support of either the turtle or dolphin rule, and do not wish to amend the current eHCR but rather continue to apply the ad-hoc (average TAC) method that has been applied in the past three fishing seasons.
2. At TRLRAG38, Traditional Inhabitant members of the WG and the TSRA member supported the Seahorse Rule on the basis that:
    a. the lower RBC is a 'safe option' and provides a benefit to the TIB sector whether the stock is abundant or not,
    b. maintains existing arrangements,
    c. provides stability and more certainty to industry in the longer term; and
    d. is considered to be in pursuit of the primary objective of the Torres Strait Fisheries Act 1984 of protecting the traditional way of life and livelihoods of traditional inhabitants.
3. All TVH industry members at TRLWG 17 (and out of session correspondence following TRLRAG 38) expressed support of the Dolphin Rule and did not support the Seahorse Rule for the following reasons:
    a. It does not appear to be as responsive to short-term changes abundance. While the Seahorse Rule will produce a higher RBC than the Dolphin Rule during poor years, it will produce lower RBCs during good years.
    b. On this basis, it does not meet three of the seven PZJA agreed-management objectives for the TRL fishery, those being:
        (i) to provide for the optimal utilisation, co-operative management with Queensland and PNG and for catch sharing to occur with PNG,
        (ii) to promote economic development in the Torres Strait area with an emphasis on providing the framework for commercial opportunities for Traditional Inhabitants and to ensure that the opportunities available to all stakeholders are socially and culturally appropriate for the Torres Strait and the wider Queensland and Australian community; or to

(iii) optimise the value of the fishery.

c. It produces one of the lowest TACs in recent history, despite the pre-season survey indicating the highest Age 1+ lobster counts and stock abundance from the preliminary stock assessment.

d. It reduces the overall value of the fishery by selecting an eHCR that maintains the RBC at a lower range, which is damaging for all sectors of the industry and has flow-on effects for producers, buyers and customers. Lower catch volumes increase costs and reduce prices for fishers. This diminishes the fishery's economic value, with negative consequences for all involved.

e. Industry should be catching more lobster when it is sustainable to do so - the Dolphin Rule allows this.

4. The economics member of the WG, while acknowledging the trade-off between certainty offered by the Seahorse Rule and flexibility to adjust to positive conditions offered by the Dolphin Rule, expressed support for the Dolphin Rule on the basis that it offers greater overall economic gains compared to the Seahorse Rule, and is better aligned to the objectives outlined in the Act and the Torres Strait Treaty.

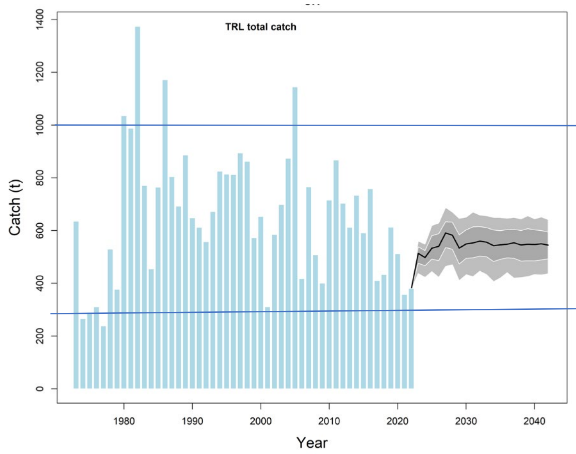
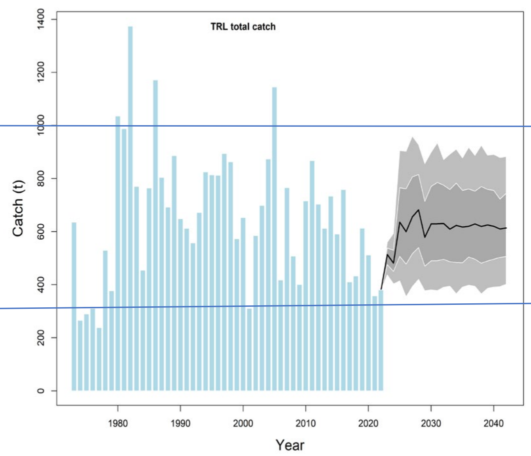
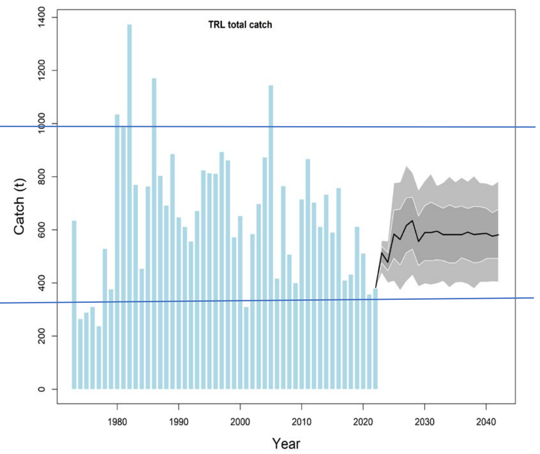
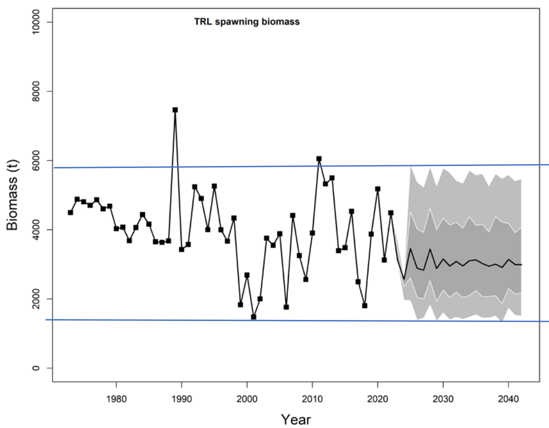
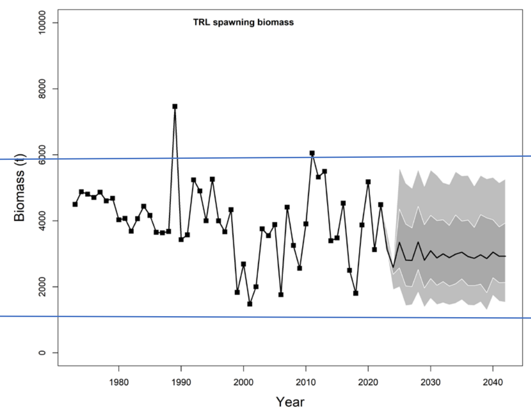
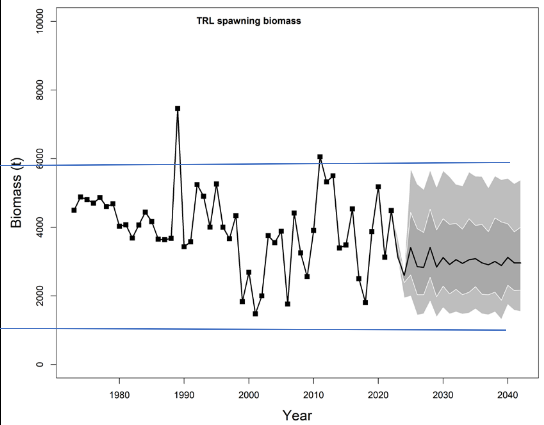
5. The National Fisheries Authority representative also expressed a preference for the Seahorse Rule, noting that it provides more certainty of what future catches may be and did not go to as low levels as the Dolphin Rule.

6. A Traditional inhabitant observer to TRLWG17, noted that the PZJA should be aiming to close the gap on indigenous disadvantage, and that economic opportunities should be a priority. He viewed the dolphin rule as an opportunity for economic gain for traditional inhabitants in the region and questioned why ‘we’ would cut ourselves short.

7. Another traditional inhabitant industry observer to TRLWG17, also preferred the dolphin rule. After having the industry suffer for the past 4 years, he believed now there is an opportunity to capitalise.

Summary of TRL/kaiar empirical Harvest Control Rule (eHCR) candidates

Name	**Seahorse rule** 	**Dolphin rule** 	**Osprey rule** 
Description of rule for setting the annual Recommended Biological Catch (RBC)	Clings to something familiar and provides a RBC that doesn't move very much	Smart, highly adaptable rule that allows rapid response with either big leaps or dives in the RBC	Smart, targeted and adaptable rule but the flight path is smoother than a dolphin's movements (less leaps and dives in RBC)
Uses survey & CPUE trends and weightings as previous?	Yes	Yes	Yes
Gives more weight to most recent TRL 1+ survey index?	No	Yes (influences more than for Osprey)	Yes (but less influence than Dolphin rule)
Accounts for quality/precision of most recent 1+ survey	No	Yes, weights last term by survey standard deviation	Yes, weights last term by survey standard deviation
What's new about this rule?	Replaces average catch multiplier with average of most recent 5 TACs (Total Allowable Catch – all sectors) which dampens variability in the annual RBC	Uses a tuned value that is adjusted annually based on the strength and quality of the most recent 1+ survey (most similar to using annual stock assessments to set the TAC)	Compromise option tuned to output RBCs intermediate between Seahorse and Dolphin rules, with smaller annual adjustments based on the strength and quality of the most recent 1+ survey
Advantages and disadvantages [Note: All 3 rules have been MSE-tested to ensure they are adequately precautionary, consistent with fishery and cultural objectives, and have improved resilience to climate change and market shocks. Unsafe rules removed prior and not shown]	Sets safe TACs that are not as high as they could be in good years, but also not as low as they could be set in poor years, so smaller inter-annual variability (i.e. more consistent RBC from year to year) but doesn't closely track TRL abundance.	Sets safe TACs that most closely track TRL abundance as are high in good years, whereas in poor abundance years, this rule sets lower TACs than the other rules. This results in the largest inter-annual variability. As TRL relies on incoming recruit class strength, this rule also gives more weight to the most recent data, as well as the survey precision. A disadvantage is that the equation is slightly harder to understand.	Sets safe TACs that track TRL abundance but doesn't set TACs quite as high or low in good/bad years as Dolphin rule. As TRL relies on incoming recruit class strength, this rule also gives more weight to the most recent data, as well as the survey precision. A disadvantage is that the equation is slightly harder to understand.

<table>
<tr><td></td><td>Seahorse rule </td><td>Dolphin rule </td><td>Osprey rule </td></tr>
<tr><td>Distributions* of future projected total TRL catch (t) compared with past catches</td><td></td><td></td><td></td></tr>
<tr><td>Distributions* of future projected TRL spawning biomass (t) for TRL compared with historical values.</td><td></td><td></td><td></td></tr>
</table>

* Distributions of future values (solid line is the median; 50% intervals shown by dark shaded grey area, 80% intervals shown using light shaded grey area). Historical TRL catch shown using blue bars and model-estimated historical spawning biomass with black line with square symbols.

For further information

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Australia’s National Science Agency

Revision of the Torres Strait Tropical Rock Lobster / kaiar (TRL) empirical Harvest Control Rule (eHCR)

AFMA Project No. 2021/0816: Torres Strait Tropical Rock Lobster survey, stock assessment and harvest strategy

September 2025

Citation

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AFMA Project No. 2021/0816: Torres Strait Tropical Rock Lobster survey, stock assessment and harvest strategy

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Acknowledgement of Country

CSIRO acknowledges the Traditional Owners of the lands, seas and waters, of the area that we live and work on across Australia and pays its respects to Elders past and present. CSIRO recognises that Aboriginal and Torres Strait Islander peoples have made, and will continue to make, extraordinary contributions to Australian life including in cultural, economic, and scientific domains.

Contents

List of Figures and Tables

Acronyms and Abbreviations

AAV	Average Annual Variability
AIC	Akaike Information Criterion
AFMA	Australian Fisheries Management Authority
BLIM	Biomass limit reference point
BTARG	Biomass target reference point
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
eHCR	empirical Harvest Control Rule
HCR	Harvest Control Rule
HS	Harvest Strategy
LRP	Limit Reference Point
MSE	Management Strategy Evaluation
OM	Operating Model
PNG	Papua New Guinea
PZJA	Protected Zone Joint Authority
RAG	Resource Assessment Group
RBC	Recommended Biological Catch
SST	Sea Surface Temperature
TAC	Total Allowable Catch
TIB	Traditional Inhabitant Boat
TRL	Tropical Rock Lobster
TVH	Transferable Vessel Holder

Acknowledgements

CSIRO acknowledges the Traditional Owners of the land, sea and waters, of the area that we live and work on across Australia. In particular, we would like to acknowledge the Traditional Owners of Torres Strait, namely the Guda Maluilgal, Kemer Kemer Meriam, Kulkalgal, Kaurareg and Maluligal peoples. We acknowledge their continuing connection to their culture and we pay our respects to their Elders past and present. Thank you to all TRLRAG and TRLWG members and observers for constructive comments and feedback on development of a revised eHCR. We thank the CSIRO TRL team (Leo Dutra, Nicole Murphy, Kinam Salee, Steven Edgar, Denham Parker, Mark Tonks, Steph Brodie) for contributing to collection and analysis of survey and other data used as inputs to the eHCR. We gratefully acknowledge funding support for project R2021/0816 from AFMA and CSIRO.

1 Summary

The Harvest Strategy for the Torres Strait tropical rock lobster *Panulirus ornatus* (TRL) or kaiar fishery uses an empirical (data-based) Harvest Control Rule (eHCR) to rapidly provide a Recommended Biological Catch (RBC) based on survey abundance indices, Catch-Per-Unit-Effort (CPUE) indices from Traditional Inhabitant Boat (TIB) and Transferable Vessel Holder (TVH) sectors as well as the recent catches (through an average catch multiplier). The eHCR recommended catch is generally considered robust across a number of alternative scenarios because it is based on medium-term (5 year) trends in all indices, plus the contributions of the trends in the CPUE indices (10% for each of the two CPUE indices) are small relative to the weight accorded to the fishery-independent survey (80%). The eHCR is also designed to dampen variability in the TAC by focussing on 5-year trends in data as opposed to data from just the most recent year.

However, since the 2021-22 fishing season, total TRL catch has been below the TAC due to several external factors affecting the fishery. As these factors were outside the range of impacts for which the eHCR was tested (documented in TRLRAG32 and TRLRAG33 Meeting Records), the RAG recommended to substitute these anomalous catches with the fishery global TAC in the average catch multiplier in the eHCR. TRLRAG32 further recommended, as per ongoing work, that the eHCR be formally revised in future to account for these external impacts.

The 2023 default updated implementation of the eHCR used these substituted catches (i.e. the TAC) for the 2019-20, 2020-21 and 2021-22 seasons, together with the 2022-23 TAC of 521t and hence the average catch multiplier was 585t. Substituting this into the eHCR formula together with the survey and CPUE information resulted in an RBC of 530t for the 2023-24 season.

In 2024, the eHCR was revised and a number of alternative candidates were tested using management strategy evaluation (MSE) and considered as a basis for setting the TAC. The TRLRAG and TRLWG focussed on comparisons between three types of rules in particular, named the Turtle, Seahorse and Dolphin rules to help capture key features of each. As no consensus was reached at the December 2024 meetings, the decision as to which rule to apply to set the 2024/25 TAC was passed to the Protected Zone Joint Authority (PZJA). They advised using the midpoint of the RBC outputs from the Seahorse and Dolphin rules, which resulted in setting a TAC (all sectors) of 688t for the 2024-25 season. The PZJA also encouraged formal selection of a preferred rule for longer term implementation.

To assist the process going forward, CSIRO developed and added to the list of candidates a new rule, termed the Osprey rule, which responds in-between the Seahorse and Dolphin rules and gives an equivalent TAC for the current season and is thus an MSE-tested version of the PZJA compromise solution.

This report summarises the technical details of the Operating Models (OMs) used in the MSE testing as well as specification of alternative eHCR candidates shown with their associated performance statistics. The technical report is complemented by stand-alone non-technical summaries of key comparisons to assess the performance of the final set of eHCRs preferred in past TRLRAG and TRLWG meetings, as well as to add for consideration the PZJA-compromise Osprey Rule. This report therefore provides the scientific basis to support choice by TRLRAG and TRLWG of a revised eHCR for implementation for the medium- to long-term to inform the annual TRL TAC setting process.

2 Introduction

The Torres Strait tropical rock lobster *Panulirus ornatus* (TRL) fishery is shared between Australia and Papua New Guinea (PNG) and managed as a single stock by the Protected Zone Joint Authority (PJZA). The assessment and management includes information from three sectors: Australian Traditional Inhabitant Boat (TIB) and Transferable Vessel Holder (TVH) and the PNG sector which has a one-third share in the fishery (Plagányi et al., 2019). The stock comprises mainly three age classes: recently settled (6 months old, termed 0yr), recruiting (average 1.5 years old, termed 1yr) and fished (average 2.5 years old, termed 2yr). The TRL fishery Harvest Strategy was implemented in 2019 and uses an empirical (data-based) Harvest Control Rule (eHCR) to rapidly provide a Recommended Biological Catch (RBC) based on the recent catches (termed an average catch multiplier), survey abundance indices and Catch-Per-Unit-Effort (CPUE) indices from TIB and TVH sectors.

The TRL Harvest Strategy is based on the Commonwealth Fisheries Harvest Strategy Policy and Guidelines, with best practice recommending that harvest strategies are to be reviewed every five years but may be reviewed earlier if necessary. In addition, Section 2.13 of the TRL Harvest Strategy provides guidance on when a review may be required earlier than 5 years, including relating to changing external drivers.

The 2022-23, 2021-22, 2020-2021, and 2019-2020 total catch were only around 53%, 62%, 55% and 84% respectively of the TAC (lower than the average proportion achieved historically) due to several external factors affecting the fishery. As these factors were outside the range of impacts for which the eHCR was tested (documented in TRLRAG32 and TRLRAG33 Meeting Records), the RAG recommended to substitute these anomalous catches with the fishery global TAC in the average catch multiplier in the eHCR. TRLRAG32 further agreed, as per ongoing work, that the eHCR be formally revised to account for numerous external drivers including ongoing market and economic pressures that have impacted the fishery's performance.

The 2023 implementation of the eHCR used these substituted catches (i.e. the TAC) for the 2019-20, 2020-21 and 2021-22 seasons, together with the 2022-23 TAC of 521t and hence the average catch multiplier for 2023 was 585t. Substituting into the eHCR formula together with the survey and CPUE information resulted in an RBC value of 530t for the 2023-24 season.

In 2024, the eHCR was revised and a number of alternative candidates were tested using management strategy evaluation (MSE) and considered as a basis for setting the 2024-25 TAC. The TRLRAG and TRLWG focussed on comparisons between three types of rules in particular, named the Turtle, Seahorse and Dolphin rules to help capture key features of each (see below). As no consensus for a rule going forward was reached at the December 2024 meetings, the decision as to which rule to apply to set the 2024/25 TAC was passed to the PZJA. They advised using the midpoint of the RBC outputs from the Seahorse and Dolphin rules, which resulted in setting a TAC (all sectors) of 688t for the 2024-25 season. The PZJA also encouraged selecting a preferred rule for longer term implementation. To assist the process going forward, CSIRO developed and added to the list of candidates a new rule, termed the Osprey rule (see Methods), which responds in-between the Seahorse and Dolphin rules and gives the equivalent TAC for the current season and is thus an MSE-tested version of the PZJA compromise solution.

The eHCR has been developed in close consultation with Traditional Owners and stakeholders at a number of meetings, including resource assessment groups (RAGs), fishery working groups and dedicated communication workshops. Effective communication was considered a high priority (see non-technical summary in Appendix A2). For the same reason, eHCR candidates in the revised testing were given easy-identified names as described in Appendix A2 and below.

This document summarises MSE testing to inform options around revising the eHCR to ensure it addresses pre-specified objectives as well as the unforeseen external factors.

The MSE testing in this report extends on the earlier MSE analyses that informed choice and implementation of the current eHCR (Plagányi et al., 2018a) and is described more fully in (Plagányi et al., In review). As previously, the methods used to evaluate the candidate rules are consistent with the best practice guidelines outlined by Punt et al. (2016).

2.1 Empirical Versus Model-Based eHCR

Empirical or model-free approaches have many advantages in that they are simple to develop, easily understood by stakeholders and are computationally easier to implement (Rademeyer et al. 2007) plus are less expensive and require fewer resources to implement and review. They allow rapid testing of many simulations because they avoid iterative minimization routines that are required for fitting models to data (McAllister et al. 1999). They can perform well if associated errors in abundance indicators are small (McAllister et al. 1999). It is well recognised that HCRs and models used as estimators in HCRs do not need to achieve a high degree of realism, but instead the objective should be to achieve good management performance (Cooke 1999).

For the TRL fishery, a fully empirical HCR has the added advantage of not relying on more complex models which fishers and stakeholders may be sceptical about, may find hard to understand and may reduce the sense of ownership of an HCR because it no longer depends just on information and data (including their own CPUE data) that they are familiar with in a fishery. In addition, an eHCR provides greater transparency as it can be shared on a simple spreadsheet.

A disadvantage of an empirical approach is that although it can move a resource in the desired direction, it doesn't inform on the level at which resource abundance will eventually equilibrate (Rademeyer et al., 2007). For TRL, this is addressed by running a stock assessment model every three years (except when additional stock concerns are triggered) to inform on stock status. Periodic eHCR reviews can also be used to recalibrate an eHCR.

Another option is to develop a hybrid empirical and model-based rule. This was considered for TRL because it provides one solution to setting the multiplier or tuning parameter in the eHCR. The idea is that the slope change (i.e., the trend change) indicators could be used to adjust the RBC after multiplying by the assessment-RBC (noting the assessment-RBC termed RBC_{mod} is not equivalent to the eHCR-TAC or RBC_{HCR}), where the RBC_{mod} is the most recent stock assessment-based RBC and RBC_{HCR} is the RBC generated from the eHCR. However, as the stock assessment is only conducted every third year, and there may not be enough time to agree on a stock assessment before the RBC_{HCR} needs to be set, this means there will be up to a 4-year lag between when the RBC_{mod} multiplier term is first available and used in an eHCR calculation. In the years between stock assessments, the eHCR slope indicators can be considered simple 'proxies' for the stock assessment, but there remain several issues. Although this could work well for a longer-lived stock, it's problematic for a shorter-lived highly variable stock such as TRL. This is because there is little or no autocorrelation between recruitment in successive years. Hence, in the stock assessment year, the RBC_{mod} may be set very high or low depending on stock status at the time and has little or no relevance to the stock abundance level in the following years, so there is little justification to use it as a multiplier. A highly variable HCR could likely still work but would need careful calibration as there may be a need to drop the RBC substantially from a high RBC_{mod} in some years or vice versa. Testing a rule of this type would also be computationally time-consuming as requires refitting the stock assessment model every three years in the MSE testing. An additional challenge is the need to increasingly consider replacing the stock assessment model with the climate-linked stock assessment model, and hence during this transition period, there is uncertainty around which is the most appropriate stock assessment model RBC to use in an HCR. There is also the added problem when using the stock assessments in harvest strategies of a process other fisheries have termed 'model shopping', where stakeholders may select models or model runs that result in preferable TAC outcomes.

Given that the TRL stock is managed in a highly precautionary manner and that the survey 1+ recruitment estimates suggest that the population fluctuates about some average value rather than trending longer-term up or down, use of a constant multiplier or tuning parameter was considered a plausible and reliable approach. Choice of plausible ranges for a multiplier for use and refinement in MSE testing were informed by considering long-term catch averages (i.e., demonstrated productivity of the stock) as well as the stock-assessment TACs that were output for each of years 2013-2019. The average of the RBC_{mod} for the 2013-2019 period was 644t with range 320-871t. A range of values was therefore tested to check whether the eHCR manages on average to maintain the stock fluctuating about the target level (which is successfully demonstrated). In the event that the stock starts exhibiting a downward trend or decline, the eHCR is designed to reduce catches and hence try and reverse a decline. Moreover, should the decline be steep, there are a number of safety measures already built into the harvest strategy, such as a lower limit in the form of a Preseason Survey Trigger (PSST) that would trigger a review and, if necessary, an additional stock assessment or survey (see Section 3.5.4 and Appendix A1).

2.2 Management Objectives

The management objectives identified for the TRL fishery are as follows:

- maintain the stock at (on average), or return to, a target biomass point B_{TARG} equal to recent levels (2005-2015) that take account of the fact that the resource is shared and important for the traditional way of life and livelihood of traditional inhabitants and is at a level which is biologically and economically acceptable.

- maintain stocks above the limit biomass level (B_{LIM}), or an appropriate proxy (selected as half the B_{TARG} level), at least 90 per cent of the time.
- Implement rebuilding strategies, if the spawning stock biomass is assessed to fall below B_{LIM} in two successive years.

Candidate HCRs are evaluated as to their ability to maintain the resource as fluctuating about the target level and to ensure that they do not pose unacceptable risk to the spawning biomass. Quantifying the risk to the resource under alternative HCRs assists in the final selection of an HCR which meets the objectives of low risk of depleting the spawning biomass as well as ensuring that potential economic gains are not lost due to an overly conservative approach. Projected future catch rates for the TVH and TIB sectors are used as a proxy for economic performance, and an additional consideration relates to the inter-annual variability in catch. Stakeholders also expressed a preference for an upper limit to be set on the total annual catch to reduce biological risk.

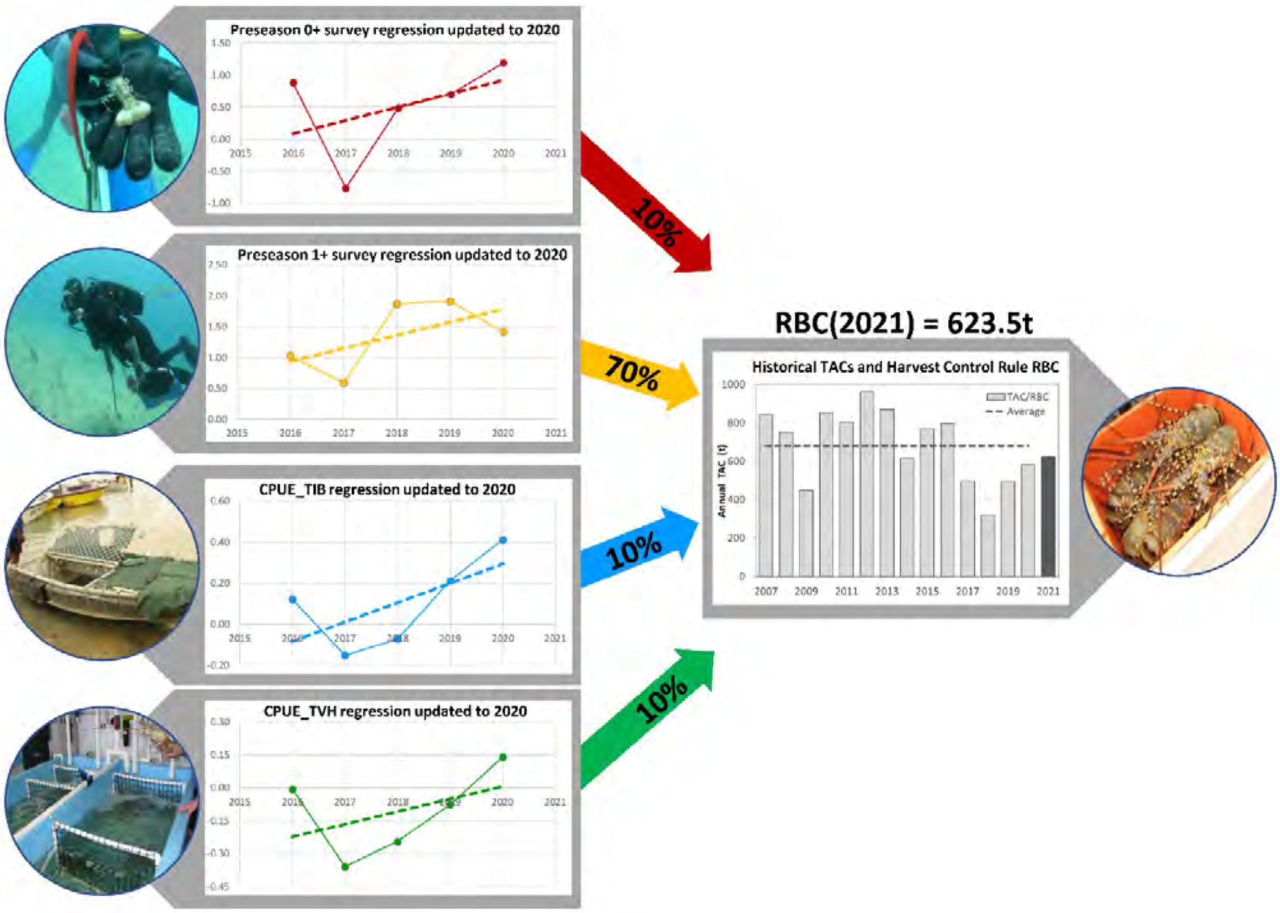
3 Methods

3.1 eHCR Background

The eHCR formula outputs an RBC in December for the upcoming year of fishing (December-October). This calculation is the multiple of the average catch over the last five years (termed the average catch multiplier) and a statistic which measures the relative performance of the fishery based on the following five data inputs (Figure 3-1): (1) Fishery-independent recruiting lobster (1+) standardised relative numbers; (2) Fishery-independent recently-settled lobster (0+) standardised relative numbers; (3) standardised CPUE for TIB sector; (4) standardised CPUE for TVH sector; and (5) total catch (TIB,TVH,PNG) for that year (using data available up until end of October) which is included in the average catch along with the previous 4 years' catch. Different weightings are applied to the four abundance indices included in the relative performance statistic used in the eHCR. These are based on extensive testing to compare performance of alternative weightings while also considering the information content and reliability of each series, as well as a preference expressed by the stakeholders to use a portfolio approach in determining the RBC (Plagányi et al., 2018a).

The fishery-independent Preseason 1+ index is the primary index and is most reliable and direct in terms of indexing the biomass of lobsters that will be available to be caught in the next fishing season. Hence, this index is assigned the highest weighting of 70% based on earlier MSE testing and stakeholder consultation. The fishery-independent Preseason 0+ index provides an early indication of the following year's recruitment, whereas the CPUE indices aim to index the relative abundance of the large 2+ lobsters, the survivors of which will migrate out of the Torres Strait to spawning grounds to the East. Each of these three secondary indices (Survey 0+ and CPUE (TIB and TVH)) are assigned a weighting of 10% (30% total) in the eHCR formula.

Figure 3-1: Schematic summary of the empirical harvest control rule (eHCR) used to calculate the TRL (Tropical Rock Lobster) RBC (Recommended Biological Catch) (example shown for 2021 RBC) based on the CPUE (Catch Per Unit Effort) data from two fishery sectors, the scientific survey indices of two age classes, and the total average catch over the past five years (source Plagányi et al. 2021).



Simulation testing (Plagányi et al. 2016) showed that the best approach is to use the slope of the trends in the secondary indices over the last five years' data (after first taking the natural logarithm of the data) for each of the abundance indices. This allows the RBC to be based on medium-term trends in abundance, rather than on just the current abundance.

Hence the original (2019-2024) eHCR rule is as follows (see also Figure 3-1):

$$RBC_{y+1} = \left[0.7 \cdot \left(1 + s_y^{presurv,1}\right) + 0.1 \cdot \left(\left(1 + s_y^{presurv,0}\right) + \left(1 + s_y^{CPUE,TVH}\right) + \left(1 + s_y^{CPUE,TIB}\right)\right)\right] \cdot \bar{C}_{y-4,y}$$

(Eq1)

Where

$\bar{C}_{y-4,y}$ is the average achieved catch during the past 5 years, including the current year i.e. from year y-4 to year y

$s_y^{presurv,1}$ is the slope of the (logarithms of the) fishery-independent survey 1yr abundance index, based on the 5 most recent values

$s_y^{presurv,0}$ is the slope of the (logarithms of the) fishery-independent survey 0yr abundance index, based on the 5 most recent values

$s_y^{CPUE,TVH}$, $s_y^{CPUE,TIB}$ is the slope of the (logarithms of the) TVH and TIB CPUE abundance index, based on the 5 most recent values.

3.2 Why a need to revise the eHCR?

- The eHCR adopted in 2019 uses total catch in the formula but several external factors (e.g. covid, markets) mean catches have been well below the TAC so 'ad hoc' adjustments have been made in the last few years in which case the TAC has been substituted for total catch in the formula.
- Best practice is to revise an HCR every 5 years if possible.

- Provides an opportunity to retest the eHCR to improve robustness to climate change and other concerns such as discards and differences between total catches and TACs.
- Process is like having a car that's running but could do with a service – with the option to either give it a minor service (turtle rule) or an improved service adding some further fine tuning to run even better (dolphin rule).

3.3 What's staying the same in the eHCR?

- It's a data-based rather than model-based rule i.e. it only uses data as inputs to inform the RBC (Recommended Biological Catch).
- No changes to relative weighting (i.e. relative contribution) of different data sources: Preseason survey 1+ index is the most important (70% weighting) whereas other data (Preseason 0+ survey index, CPUE(TIB), CPUE (TVH)) have 10% weighting each.

3.4 eHCR Revision and technical specification

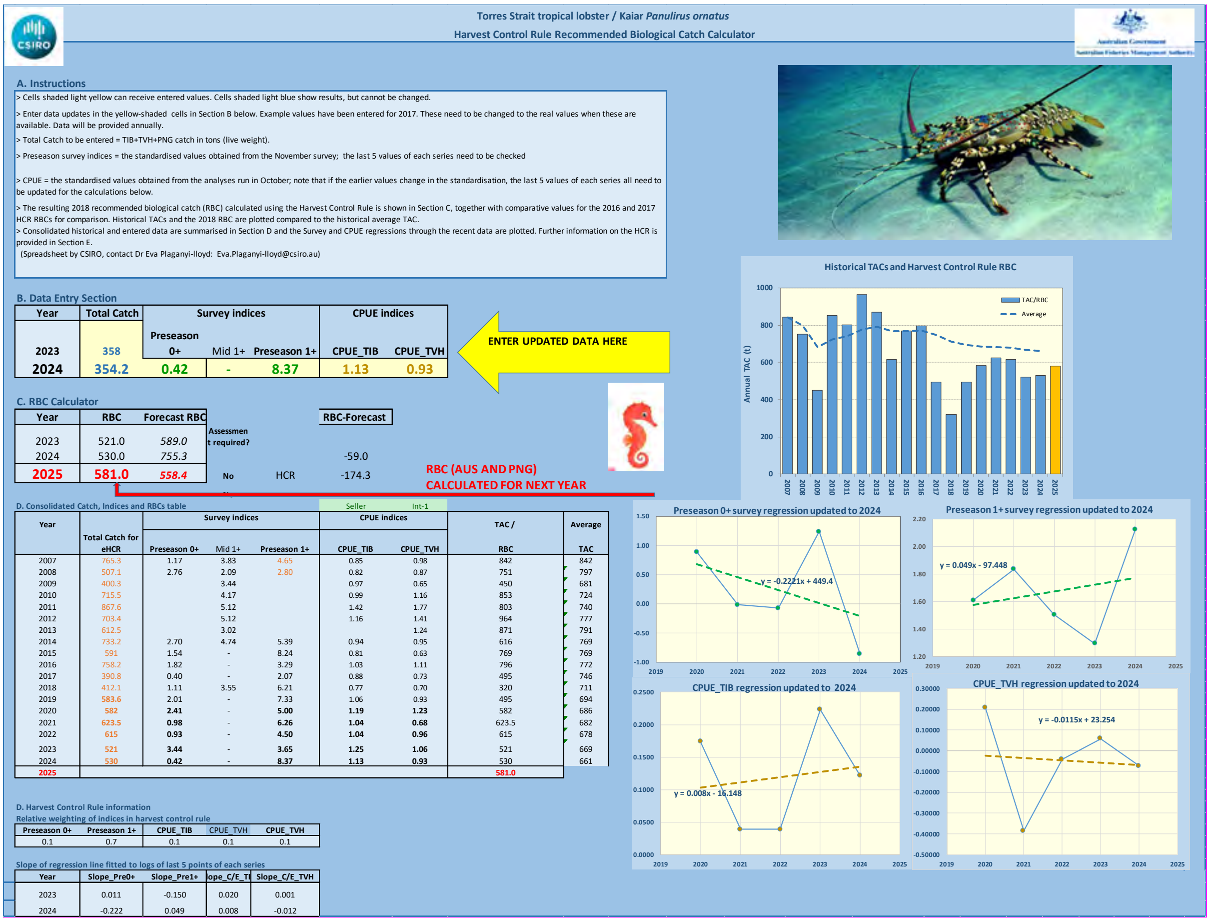
The December 2024 eHCR used the latest available catch, CPUE and Preseason survey data as summarised in Figure 3-2.

The eHCR has been revised as per methods described in Plagányi et al. (in review) and TRLRAG presentations. The methods are currently being externally peer-reviewed and copies of some of this material is provided in Supplementary Appendices A1-A5.

For each HCR, there are many performance statistics output for consideration by stakeholders. For all statistics, values shown are the median of the 800 replicates, together with the 75th and 25th percentiles (i.e., the rectangles encompass 50% of all outcomes for box and whisker plots) as well as the range of values excluding outliers.

The eHCR uses a trend based on 5 most recent data points (i.e. annual adjustments to the RBC rely on whether recent trends are mostly up or down (especially Preseason 1+ index) – for example, Figure 3-3 below shows the slopes used in December 2024.

Figure 3-2: Summary of eHCR inputs in December 2024 showing the slopes of fitted regression lines to the log-transformed Preseason 0+ and 1+ indices, as well as the standardised CPUE data for the TIB (Seller model version) and TVH (Int-1 Model version) sectors. Example shown corresponds to the Seahorse eHCR candidate



Torres Strait tropical lobster / Kaiar *Panulirus ornatus*

Harvest Control Rule Recommended Biological Catch Calculator

A. Instructions

> Cells shaded light yellow can receive entered values. Cells shaded light blue show results, but cannot be changed.
> Enter data updates in the yellow-shaded cells in Section B below. Example values have been entered for 2017. These need to be changed to the real values when these are available. Data will be provided annually.
> Total Catch to be entered = TIB+TVH+PNG catch in tons (live weight).
> Preseason survey indices = the standardised values obtained from the November survey; the last 5 values of each series need to be checked
> CPUE = the standardised values obtained from the analyses run in October; note that if the earlier values change in the standardisation, the last 5 values of each series all need to be updated for the calculations below.
> The resulting 2018 recommended biological catch (RBC) calculated using the Harvest Control Rule is shown in Section C, together with comparative values for the 2016 and 2017 HCR RBCs for comparison. Historical TACs and the 2018 RBC are plotted compared to the historical average TAC.
> Consolidated historical and entered data are summarised in Section D and the Survey and CPUE regressions through the recent data are plotted. Further information on the HCR is provided in Section E.
(Spreadsheet by CSIRO, contact Dr Eva Plaganyi-lloyd: Eva.Plaganyi-lloyd@csiro.au)

B. Data Entry Section

Year	Total Catch	Survey indices			CPUE indices	
		Preseason 0+	Mid 1+	Preseason 1+	CPUE_TIB	CPUE_TVH
2023	358					
2024	354.2	0.42	-	8.37	1.13	0.93

ENTER UPDATED DATA HERE

C. RBC Calculator

Year	RBC	Forecast RBC	Assessment required?		RBC-Forecast
2023	521.0	589.0			
2024	530.0	755.3			-59.0
2025	581.0	558.4	No	HCR	-174.3

RBC (AUS AND PNG) CALCULATED FOR NEXT YEAR

D. Consolidated Catch, Indices and RBCs table

Year	Total Catch for eHCR	Survey indices			CPUE indices		TAC / RBC	Average TAC
		Preseason 0+	Mid 1+	Preseason 1+	CPUE_TIB (Seller)	CPUE_TVH (Int-1)		
2007	765.3	1.17	3.83	4.65	0.85	0.98	842	842
2008	507.1	2.76	2.09	2.80	0.82	0.87	751	797
2009	400.3		3.44		0.97	0.65	450	681
2010	715.5		4.17		0.99	1.16	853	724
2011	867.6		5.12		1.42	1.77	803	740
2012	703.4		5.12		1.16	1.41	964	777
2013	612.5		3.02			1.24	871	791
2014	733.2	2.70	4.74	5.39	0.94	0.95	616	769
2015	591	1.54	-	8.24	0.81	0.63	769	769
2016	758.2	1.82	-	3.29	1.03	1.11	796	772
2017	390.8	0.40	-	2.07	0.88	0.73	495	746
2018	412.1	1.11	3.55	6.21	0.77	0.70	320	711
2019	583.6	2.01	-	7.33	1.06	0.93	495	694
2020	582	2.41	-	5.00	1.19	1.23	582	686
2021	623.5	0.98	-	6.26	1.04	0.68	623.5	682
2022	615	0.93	-	4.50	1.04	0.96	615	678
2023	521	3.44	-	3.65	1.25	1.06	521	669
2024	530	0.42	-	8.37	1.13	0.93	530	661
2025							581.0	

D. Harvest Control Rule information

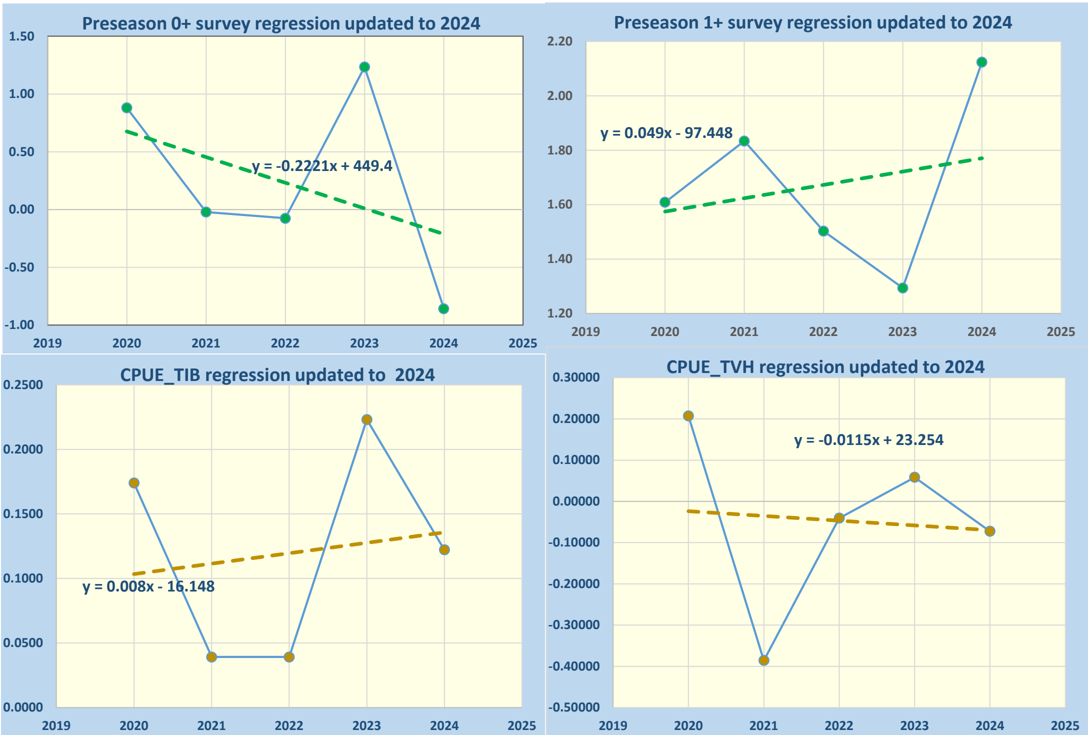
Relative weighting of indices in harvest control rule

Preseason 0+	Preseason 1+	CPUE_TIB	CPUE_TVH	CPUE_TVH
0.1	0.7	0.1	0.1	0.1

Slope of regression line fitted to logs of last 5 points of each series

Year	Slope_Pre0+	Slope_Pre1+	lope_C/E_TI	Slope_C/E_TVH
2023	0.011	-0.150	0.020	0.001
2024	-0.222	0.049	0.008	-0.012

Figure 3-3: Example of the trends fitted to the last five data points prior to and including 2024 for each index: Preseason 0+, Preseason 1+, CPUE_TIB and CPUE-TVH.



3.4.1 THE REVISED CANDIDATES

As part of revising the Harvest Strategy (HS) and selecting a preferred revised eHCR, CSIRO developed a number of alternative kinds of rules that incorporated feedback received from the TRLRAG. The versions considered were those tuned to meet the HS objectives (e.g., keep the TRL/kaiar population fluctuating about the (precautionary) target reference level with very low risk of fishing causing the population to decrease to the limit reference level). The rules were tested by CSIRO using a set of 4 alternative operating models with different parameter settings, different levels and types of uncertainties and climate change impacts, and assuming considerable natural variability.

The following six HCRs were tested (and see Table 3-1):

(1) Constant Catch (**Small fish rule**) – a range of alternative fixed catch values (C) were tested for reference comparison purposes and also to inform on a setting for an Exceptional Circumstances clause in case survey data are not available in a future year, i.e.

$$RBC_{y+1}^{\text{Constant}} = C \qquad \text{(Eq2)}$$

(2) Moving average of TACs (**SeaHorse rule**):

$$RBC_{y+1}^{SeaHorse} = \left[0.7\cdot\left(1+s_y^{presurv,1}\right)+0.1\cdot\left[\left(1+s_y^{presurv,0}\right)+\left(1+s_y^{CPUE,TVH}\right)+\left(1+s_y^{CPUE,TIB}\right)\right]\right]\cdot\bar{A}_{y-4,y}$$

where moving average $\bar{A}$ is as follows: $\bar{A}=\sum_{i=y-4}^{i=y} TAC_i \Big/ 5$ (Eq3)

(3) Constant catch multiplier (**Turtle rule**):

$$RBC_{y+1}^{turtle} = \left[0.7\cdot\left(1+s_y^{presurv,1}\right)+0.1\cdot\left[\left(1+s_y^{presurv,0}\right)+\left(1+s_y^{CPUE,TVH}\right)+\left(1+s_y^{CPUE,TIB}\right)\right]\right]\cdot C^{tune}$$

where alternative settings for tuning parameter C^{tune} are tested. (Eq4)

(4) Highly adaptable (**Dolphin rule**) also includes a tuning parameter C^{tune} as well as survey-square root (*SS*) term:

$$RBC_{y+1}^{dolphin} = \left[0.7\cdot\left(1+s_y^{presurv,1}\right)+0.1\cdot\left[\left(1+s_y^{presurv,0}\right)+\left(1+s_y^{CPUE,TVH}\right)+\left(1+s_y^{CPUE,TIB}\right)\right]\right]\cdot SS_y * C^{tune}$$

and:

$$SS_y = \sqrt{\left(\frac{s_y^{presurv,1}}{\bar{S}^{presurv,1}}\right)\Big/\exp\left(CV_y^{presurv,1}\right)}$$

(Eq5)

such that the RBC is scaled up or down based on (i) the most recent Pre-season survey 1+ index in year *y* ($S_y^{presurv,1}$), relative to the long-term (2005-2023) median reference level $\bar{S}^{presurv,1}$; and (ii) inversely proportional to the exponential of $CV_y^{presurv,1}$, the coefficient of variation of the most recent 1+ survey in year *y* (survey standard error divided by survey observed index value). The dolphin rule therefore gives greater weight to the most recent survey index but weights this information based on the associated precision of that index. Using the square root of this term dampens its influence on the RBC so that it does not overly dominate relative to the longer-term trend information.

(5) Highly variable (**Jellyfish rule**): this rule had the same form as (4) above, except that the slope of the (logarithms of the) Pre-season survey and CPUE abundance indices were

computed using the past three years data, rather than five years as in the default application. A range of examples were tested but did not make the final set of preferred eHCRs so illustrative examples only shown here.

(6) Asymmetric (**Crab rule**): this rule was similar to (4) above but included a power factor τ applied to the Pre-season survey 1+ slope term to give greater weight to the Pre-season 1+ index as well as to respond more strongly to negative (or conversely more positive) trends in the survey index. This rule wasn't preferred so a single example only is shown using power factor 2.

$$RBC_{y+1}^{crab}=\left[0.7\cdot\left(1+s_y^{presurv,1}\right)^{\tau}+0.1\cdot\left[\left(1+s_y^{presurv,0}\right)+\left(1+s_y^{CPUE,TVH}\right)+\left(1+s_y^{CPUE,TIB}\right)\right]\right]\cdot C^{tune}$$

(Eq6)

(7) Adaptable and targeted compromise rule (**Osprey rule**), introduced later in the process in an attempt to support achieving consensus. This rule replaces the survey-square-root (*SS*) term in Equation (Eq5) with a cubed-root term (*SSC*) to dampen slightly the variability in the outputs:

$$RBC_{y+1}^{osprey}=\left[0.7\cdot\left(1+s_y^{presurv,1}\right)+0.1\cdot\left[\left(1+s_y^{presurv,0}\right)+\left(1+s_y^{CPUE,TVH}\right)+\left(1+s_y^{CPUE,TIB}\right)\right]\right]\cdot SSC_y * C^{tune}$$

and:

$$SSC_y=\left(\left(\frac{s_y^{presurv,1}}{\overline{S}^{presurv,1}}\right)\Big/\exp\left(CV_y^{presurv,1}\right)\right)^{1/3}$$

(Eq7)

The term 'shark rules' was used for high risk (of depletion below target reference levels) variants of rules, and in what follows we focus on rules that were preferred by the TRLRAG & TRLWG based on initial discussions of performance statistics as summarised in Section 3.4.5. All rules tested included the existing maximum annual catch limit (1000t) as well as a (new) lower MSE-tested precautionary catch limit of 300t, which corresponded to the lowest historical TAC of 300t and early fishery closure in 2018 (Plagányi et al. 2024). A summary of historical data inputs as well as calculated values of the Dolphin Rule survey-square-root (*SS*) term Osprey Rule cubed-root term (*SSC*) are provided in Table S3- 2.

3.4.2 Reference Set of Operating Models

The stock assessment and climate-linked stock assessment models of Plagányi et al. (2023, Plagányi et al. 2025) were used as the base to modify and expand on developing a set of four operating models (OMs) (Table 3-2). The OMs were assumed to represent reality in terms of the underlying lobster population dynamics, but also captured a broad range of climate change impacts as well as external drivers of fishing effort. The age-structured stock assessment model is a form of Statistical Catch-at-Age Analysis (SCAA) (e.g. (Fournier and Archibald 1982)) that fits to all available fishery-independent (surveys from 1989) and fishery-dependent data. The model was implemented using AD Model Builder which uses quasi-Newton automatic differentiation for statistical inference (Fournier et al. 2012).

The OMs differed in terms of representation of a number of sources of uncertainty (Table 3-2), including parameter uncertainty (such as choice of the stock-recruitment steepness parameter *h*), structural uncertainty (impacts of climate change on lobster recruitment, survival and growth), observation errors (applied when fitting to survey and CPUE data) and implementation uncertainty (level of discarding; difference between TAC and actual total catch summed over three sectors with different error levels assumed; market factors causing catches to be substantially less than TACs in some years).

OM1 was most similar to the stock assessment model but also explicitly represented discards and traditional takes by relevant sectors. OM2 was a more precautionary model variant with lower *h*, in combination with larger implementation errors. OM3 was a climate-linked model with lobster natural mortality *M* and growth influenced by changes in Sea Surface Temperature (SST) (see Figure 3-4) plus the future level of discarding was assumed related to SST. OM4 simulated occasional extreme events in the form of recruitment declines, to represent climate-linked impacts such as strong El Niño's reducing recruitment (Plagányi et al. 2019) as well as intermittent market shocks reducing catches in some years. Further detail on the OMs is provided in A.3 Supplementary Appendix S.3.

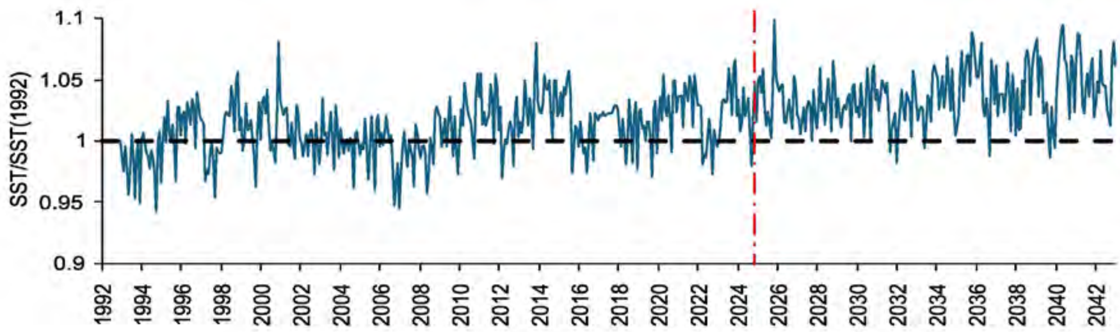
Each of the four OMs was fitted over the historical period 1973 – 2022, and the model then used to do 20-year forward projections. All model results were integrated across these four alternative OMs, with 200 replicates of each OM, yielding a total of 800 simulated projections (termed simulations). The OMs were all assumed to be plausible alternative representations of the system and to reflect key uncertainties, hence they are accorded the same weight rather than AIC-weighting for example, in line with recommendations by Punt et al. (2016).

3.4.3 Future Projections

"Future data" in the form of survey indices of abundance (Pre-season 0yr, 1yr) and sector-specific CPUE series (TIB and TVH) are required by the eHCR to compute a RBC for each of the years in the projection period for each candidate rule tested. These abundance indices (CPUE and surveys) were generated from the OM, assuming the same error structures as in the past (see A.3 Supplementary Information S.3). Future recruitment estimates for each OM were generated using a Beverton-Holt stock-recruitment relationship with plausible annual fluctuations simulated by generating random future deviations with the same variance as observed historically. In addition, OM4 included additional environmentally-driven variation.

The future CPUE series were generated from model estimates for exploitable biomass and catchability coefficients. Future survey data were generated from model estimates of Pre-season survey biomass. Log-normal error variance includes the survey sampling variance with the standard deviation set equal to the average historical values of 0.18 and 0.35 respectively for the 1yr and 0yr indices. For the RBC for year *y*+1, such data are available for year *y*.

Figure 3-4: Projected sea surface temperature (SST) for Torres Strait used in evaluating resilience of the eHCR to climate change. Decadal scale projections are as described in Pethybridge et al. (2020) and derived from the Ocean Forecasting Australia Model version 3 (OFAM-v3) downscaling simulations using the IPCC RCP8.5 high emissions scenario. Plot shows monthly values divided by the start year (1992) equivalent month to highlight the increasing trend, albeit with variability, that is used in model testing.



3.4.4 Simulating RBCs and actual catches

The total RBC was divided in fixed proportions p_f amongst the various sectors *f*, with the following values used for the sector allocations: TIB: 44%, TVH: 23%, PNG: 33%. Model implementation uncertainty was also included and is defined as the difference between the model RBC and the actual catch that is taken in a year. Sources of implementation uncertainty can include unreported catches, discarded catches or lower than expected catches due to capacity constraints, socio-cultural drivers (Van Putten et al. 2013), market factors or pandemics (Plagányi et al. 2021).

Following Plagányi et al. (2018), we modelled the relationship between the RBC for year *y* (RBC_y) and the actual catch in year *y* (C_y), given proportional allocations p_f per sector, as:

$$C_y = \sum_{f=1}^{3} p_f RBC_y \times e^{\varepsilon_y^f} , \quad \varepsilon_y^f \text{ from } N(0; \sigma_f^{\,2}) \tag{8}$$

where catch is the total catch from the three sectors and values for σ_f for each sector and OM were selected based on past observations over the period 2006-2022 (Table 3-2).

3.4.5 Performance Statistics

Projections were conducted over 20 years and 200 replicates of each of the four OMs, i.e. a total of 800 simulations. The same set of random numbers (starting numbers to be able to generate the same replicates again) were used in testing all HCR candidates. In each case the median and 75th and 25th percentiles of all key outputs were computed, and the range of values also shown for the full projection period given that there is a lot of inter-annual variability in stock biomass. Examples of individual trajectories (termed worm plots) are also presented. These are randomly drawn individual replicates of catch, spawning biomass and CPUE trajectories, which are examples of plausible future outcomes, noting that the median projections shown are not representative of any individual plausible outcome and instead are similar to an average taken over the 800 replicates. The following performance statistics, were computed for each candidate eHCR:

- $B_{2042}^{sp} / B_{1973}^{sp}$ the expected median spawning biomass at the end of the projection period (2042), and for all years *y*, relative to the starting (1973) level (used as a proxy for carrying capacity *K*).
- $B_{2042}^{sp} / B_{unfished}^{sp}$ the expected median spawning biomass at the end of the projection period, and for all years *y*, relative to the comparable no-fishing level (i.e. biomass at the end of the 20-year projection period when assuming zero future fishing).
- Risk of depletion: number of times in 20-year forward projection period that biomass decreased below a reference point, expressed as proportion of all individual runs with projected biomass below (a) the Limit Reference Point (LRP) where B_{LIM} = 0.32K and (b) below precautionary level 0.48K.

- Average catch: $\overline{C} = \frac{1}{20}\sum C_y$ over projection period 2023 to 2042
- Average Annual Variability (AAV) of Catch $\frac{1}{20}\sum \frac{|C_y - C_{y-1}|}{C_{y-1}}$
- Projected future CPUE for comparison with historical observations for the TVH (1994-2022) and TIB (2004-2022) sectors
- Projected average fishing mortality

The TRLRAG and TRLWG focussed on comparisons between three types of rules, named the Turtle, Seahorse and Dolphin rules to help capture key features of each. As no consensus was reached at the December 2024 meetings, the decision as to which rule to apply to set the 2024/25 TAC was passed to the PZJA. The PZJA advised using the midpoint of the RBC outputs from the Seahorse and Dolphin rules, which resulted in setting a TAC (all sectors) of 688t for the current season, but they also encouraged selecting a preferred rule for longer term implementation.

To assist the process going forward, CSIRO developed and added to the list of candidates a new rule, termed the Osprey rule, which responds in-between the Seahorse and Dolphin rules and gives the equivalent TAC for the current season as the PZJA compromise solution. The Osprey rule is thus intermediate in its behaviour between the Seahorse rule and the Dolphin Rule. This is because it adjusts the RBC (Recommended Biological Catch) upwards or downwards depending on the strength of the incoming recruitment class as well as other stock indicators, and the ups and downs in the RBC are less than that in the Dolphin rule but more than in the Seahorse rule, as shown below (see also Figure 3-5).

3.5 Visual descriptions of eHCR candidates

1. TURTLE RULE 

(so-named because it results in more stable catches from year to year)

- Only change is to replace average catch multiplier in current eHCR with a new multiplier (set at 619) that has been tuned to meet fishery objectives.
- Basically, this rule is calculated as: RBC = Combined Average Slope of four Indicators * catch tuning parameter C^{tune}

- Depending on whether indicator slopes are going up or down, the rule will adjust the RBC but dampen inter-annual variability.

2. SEAHORSE RULE 

(so-named because it clings to something familiar and doesn't move very much)

- Similar to current eHCR
- Only change is to replace average catch multiplier in current eHCR with a new multiplier that is calculated as the average of the 5 most recent TACs (instead of the 5 most recent catches)
- Basically, this rule is calculated as: RBC = Combined Average Slope of four Indicators * 5yr-average recent TAC

3. DOLPHIN RULE 

(so-named because it's a survey-smart highly adaptable rule)

- Similar to current eHCR and turtle rule but includes an extra multiplier term based on the most recent Preseason 1+ index that has been designed so it brings the RBC down more in years when the Preseason 1+ index is low and allows a small bonus in good years when the Preseason 1+ index is high. This is not symmetrical as e.g. can decrease the RBC in bad years by up to about 40% versus in good years bonus is up to about 12% at most. This design feature was to address feedback from Traditional Owners to be more precautionary in poor years.
- Rule also accounts for survey precision (e.g. large variability in average survey index could be due to survey method or spatial stock variability): more precise survey index has greater weight versus the rule downweighting a less precise survey estimate.
- Basically, this rule is calculated as: RBC = Combined Average Slope of four Indicators * catch tuning parameter C^{tune} * Sqrt(SurvI), where SurvI = Preseason 1+ index relative to median, divided by observed survey measure of precision (technically, the survey coefficient of variation).
- Depending on whether indicator slopes are going up or down, and how good or bad current year's Preseason 1+ index is, PLUS how precise the index is, the rule will adjust the RBC more strongly up or down (i.e. more variable).

4. OSPREY RULE 

(so-named because it's a smart, targeted and adaptable rule but the flight path is smoother than a dolphin's movements)

- Also includes an extra multiplier term based on the most recent Preseason 1+ index that has been designed so it brings the RBC down more in years when the Preseason 1+ index is low and allows a small bonus in good years. However, this rule allows smaller increases in the RBC in good years compared to the Dolphin rule and it also doesn't decrease the RBC in poor years as much as the Dolphin rule does, but it does result on average in bigger increases and decreases in the RBC than the Seahorse rule or the Turtle rule (least variable).
- Rule also accounts for survey precision (e.g. large variability in average survey index could be due to survey method or spatial stock variability): more precise survey index has greater weight versus downweighting of a less precise survey estimate.
- Basically, this rule that matches a compromise solution is calculated as: RBC = Combined Average Slope of four Indicators * tuning parameter C^{tune} (619) * cube-root of (SurvI).
- Depending on whether indicator slopes are going up or down, AND how good or bad current year's Preseason 1+ index is, PLUS how precise it is, rule will adjust RBC **moderately** up or down (i.e., intermediate variability).

Table 3-1: Summary of eHCR categories and detailed candidate names, together with description of category name used for communication with stakeholders, corresponding to icons shown on figures.

Reference name	Description	Variants presented here	No. of yrs for survey & CPUE trend	Power term for survey index	Tuning constant or equation	Include recent survey modifier term
Current approach	eHCR implemented since 2019	Ad hoc approach applied in some years	5	no	Average of past 5 years catch	no
Small (forage) fish	Smooth low cruising as yields low, precautionary TAC	C300; C400; C500; C600; C700	0	no	Fixed constant (shown after 'C' in name)	no
Sea Horse	Stays close to familiar (most similar to current eHCR)	SH	5	no	Average of past 5 TACs	no
Turtle	Steady cruising at a safe level (TAC not very variable)	M566; M619; MRBC (uses previous year's RBC)	5 (see also jellyfish variant)	no	Tuned value	no
Dolphin	Highly adaptable as adjusts to changing conditions with big dives or leaps	SS566; SS619; SS640; SS670	5 (see also jellyfish variant)	no	Tuned value	yes (S = uses survey term & SS = uses square root form)
Osprey	Adaptable as adjusts to changing conditions but with smaller dives and increases than Dolphin rule, while more variable than Seahorse rule	OS619; OS640; OS670	5	no	Tuned value	yes (uses cube-root of survey term)
Jellyfish	Highly variable and can boom and bust rapidly	various from list above but identified by '_3')	3	no	Tuned value	no
Crab	Progresses in an uneven manner	A2_619; A2_640	5	yes	Tuned value	no

Table 3-2. Comparison of Reference Set of Operating Models (OMs) used in MSE testing. σ_{TIB}, σ_{TVH} and σ_{PNG} are respectively the settings used to simulate different implementation error magnitudes for the TIB, TVH and PNG sectors. σ_R is the assumed future variance of variability about the stock-recruitment curve for each OM as shown. See Supplementary for equations.

	OM1	*OM2*	*OM3*	*OM4*
H (steepness)	0.7	0.6	0.7	0.7
σ_R	0.4	0.4	0.32	0.32
Discards as % of total catch (from 2017)	10% with random factor	5%	5% with SST-linked effect	5%
Subsistence percentage of TIB catch	10%	Not explicit	5%	Not explicit
Sigma Future Implementation error (TIB; (TVH; PNG)	0.1; 0.08; 0.15	0.15; 0.12; 0.2	0.1; 0.08; 0.15	0.05; 0.04; 0.06
Future CV (coefficient of variation) for Preseason 0+ and 1+ survey	0.35; 0.186	0.35; 0.186	0.35; 0.186	0.35; 0.186
Sigma CPUE (TIB; TVH)	0.3; 0.3	0.3; 0.3	0.3; 0.3	0.3; 0.3
Future climate change effect	-	-	SST influences survival, growth & discards	-
Future recruitment failure probability	-	-	-	15% probability of 25% decrease in recruitment; with random autocorrelation proportion to also influence following year's recruitment
Future market shocks	-	-	-	20% probability of external impact on catch with decline to 63% of simulated total catch, which is capped at TAC

3.5.1 What if the Preseason survey and other information suggests the stock may be in trouble?

The HS includes a number of other safety checks:

- If the Preseason 1+ survey index is lower than a trigger limit of 1.25 (e.g. as in 2001 and 2005 in past (midyear survey)) this triggers additional precautionary action (See Fig. S1.2).
- Stock assessment is run every 3 years to check to stock status.
- If the stock is assessed as declining to below the limit reference level for 2 years in a row, the fishery is closed the following season.

3.5.2 Exceptional circumstances:

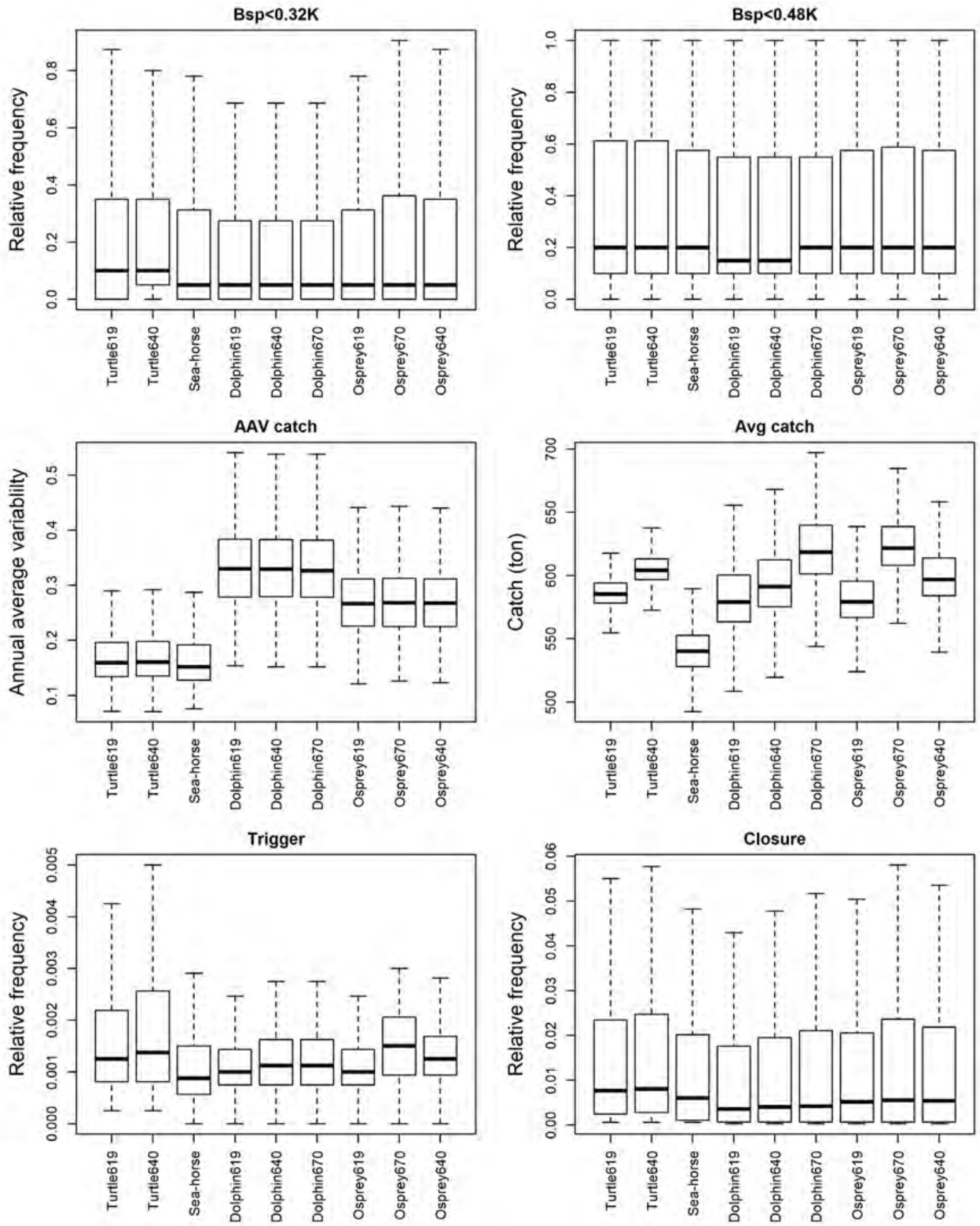
Exceptional circumstances mean that something happens which wasn't anticipated (or MSE-tested for) and possibly has a big impact on the stock or fishery. In such cases, the usual approach to managing the fishery isn't implemented without first considering and discussing the anomalous event and deciding if additional action is needed e.g. another survey, a stock assessment, modified rule or maybe previous testing adequately covered this possibility and no immediate action necessary.

If there are no updated data from the most recent fishing season to inform setting an RBC, the backup option is to set a low fixed TAC. This needs to be a low number such as 300t (200t currently used to open the fishery each year) as there is a need to ensure that an automatically set TAC is precautionary enough even in the worst years. The rules tested in the revising of the eHCR are all adaptive and could bring the TAC down as low as 300t in very bad periods and hence if there are no updated data to inform on stock status, the precautionary approach dictates that one needs to set a precautionary low TAC that accounts for the greater uncertainty of not using updated indicators of stock status. This is why setting a fixed constant TAC for a highly naturally variable stock like kaiar/TRL doesn't work well and if fixed, needs to be very low to be adequately precautionary. In other words, opting to just select a fixed TAC of e.g. 500t going forward would not be precautionary and could put the stock at risk in really bad years. All harvest control rules tested have been designed to reduce a TAC as necessary to protect the stock in really bad years.

3.5.3 What happens if total catches are below or above the TAC?

- If total catches exceed (are greater than) the TAC, overfishing is considered to be occurring.
- If total catches are below the TAC, there is no immediate impact on the revised eHCRs (as they don't use catch data).
- If total catches are low relative to the TAC, empirical indicators may show a positive trend over time which could slightly increase the TAC, but the fishery relies on a new recruitment pulse every year, so TACs will mainly depend on how much incoming recruitment there is.

Figure 3-5: Comparison of some key performance statistics for eHCRs. Plots show the probability of depletion below each of two reference levels, B_{LIM} = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, the total annual catch (t) and relative number of fishery closures triggered in the simulations. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the spread of the outputs (1.5 interquartile range, outliers not shown).



3.5.4 Pre-season Trigger Point

The TRL eHCR specifies that a stock assessment will be conducted every three years to rigorously assess stock status and productivity, and check that the eHCR is working as it is supposed to. As a stock assessment is only scheduled for every third year, action may not be taken quickly enough if the spawning biomass drops to very low levels, and hence an additional precaution has been built into the Harvest Strategy. Based on analysis of the historical pre-season and mid-year survey indices, a pre-season 1yr survey trigger point of 1.25 (average number of lobsters per survey transect and lower than any historically observed values) has been set, such that if this lower limit (LRP) is triggered in any year, then the required action is that a stock assessment be conducted in the following year. This is similar to what is done in some other fisheries, such as decision rules for some of the New Zealand sub-stocks whereby a stock assessment is mandated if CPUE decreases below a specified base level (Bentley et al. 2005).

If the stock assessment suggests that the spawning stock biomass is above the LRP, then the process continues as previously. However, if spawning biomass is assessed as below the LRP, then a stock assessment is again triggered in the following year. If the second stock assessment suggests the stock is above the LRP, then the process again continues as previously, but if the spawning biomass is below LRP (i.e., two consecutive years with spawning biomass below LRP), then the fishery is closed and appropriate action (e.g., implementing surveys, analysing size structure and environmental information) is put in place. In general, the eHCR is therefore applied every year unless the LRP is triggered in two consecutive years, or exceptional circumstances (de Moor et al. 2022) are invoked, such as when conditions observed are outside the bounds of the variability range during MSE testing.

4 Results

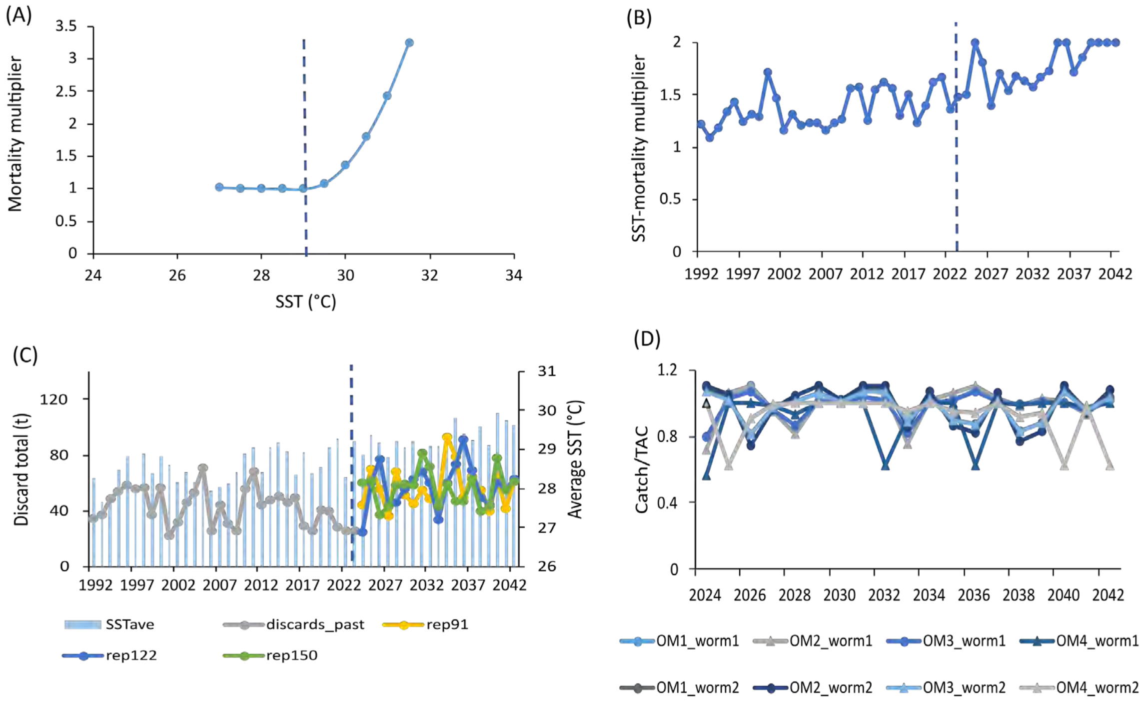
4.1 Operating Models

The four OMs did not vary greatly over the historical period (Figure S3- 1) because they are all fitted to extensive past survey and CPUE indices and hence need to closely replicate past patterns of variability. The climate-linked OM3 estimated a larger starting biomass. However during the early years of the fishery (1973 to 1988), there were no data to inform on stock levels or variability, hence there is low confidence in pre-survey (i.e. pre 1989) estimates of stock status as the model simplistically assumes deterministic recruitment over this period. However, use of a higher *K* (suggesting the stock is currently more depleted than in the other OMs) was considered useful to bound some of the uncertainty in MSE testing.

The climate-linked OM3 was the most parsimonious model (Table S3- 1) and yielded fairly precise estimates of the SST-mortality multiplier (Figure 4-1A), which was applied to all years (Figure 4-1B). Although there is considerable variability in past and projected SST (Figure 3-4), on average there is an increasing trend in average annual SST (Figure 4-1C) which in the model translates into a variable but increasing trend in the mortality multiplier (Figure 4-1B). This multiplier is capped at 2 given the uncertainty in projecting 20 years ahead (Figure 4-1B).

The temperature-dependent mortality multiplier was applied when simulating past and future (with additional random variability) discards using OM3, to simulate plausible future variability in the proportion of catch that is discarded (Figure 4-1). Projected discarded catches added further to the implementation errors that were simulated in all the OMs, as well as total catch exceeding the TAC in some years (Figure 4-1D). Differences in implementation error magnitudes varied depending on the settings used (Table 3-2) and OM4 simulations of occasional low catch years were included to simulate market or supply chain shocks to the system (Figure 4-1D).

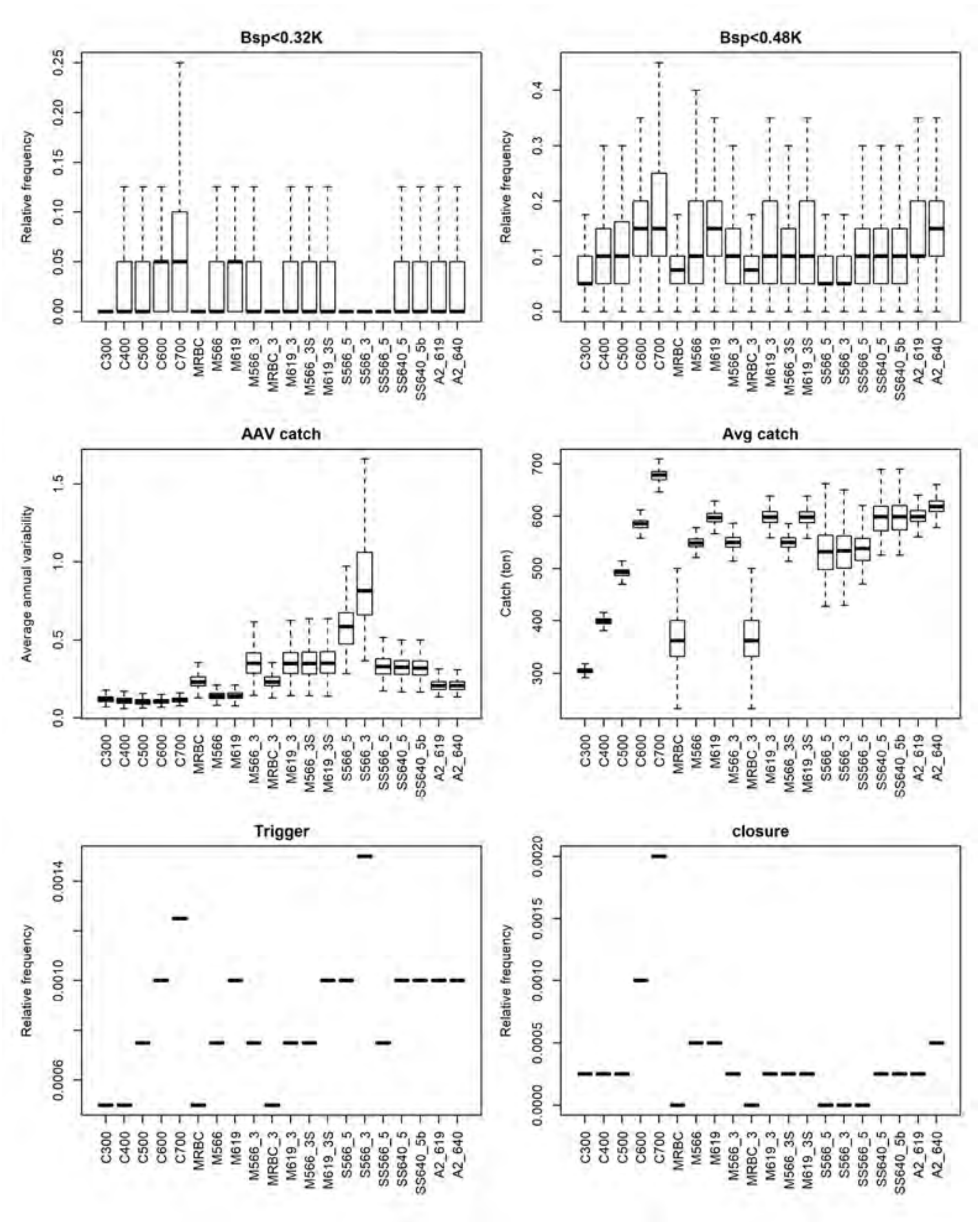
Figure 4-1: Example Operating Model (OM) outputs. (A) Model-estimated form of climate mortality multiplier term as a function of average Sea Surface Temperature (SST) (°C). (B) Past and projected (separated by a vertical line) annual values of the mortality multiplier (capped at 2) applied in OM3 and calculated using the average SST shown as bars in (C) (second y-axis). (C) shows random replicates (worm plots) from OM3, which simulates discards as a temperature-dependent proportion of total catch (past), but with additional random variation applied in projections. (D) shows projected implementation error magnitudes (catch/TAC) from two random worm plots from each of the 4 OMs.



4.2 Performance statistics

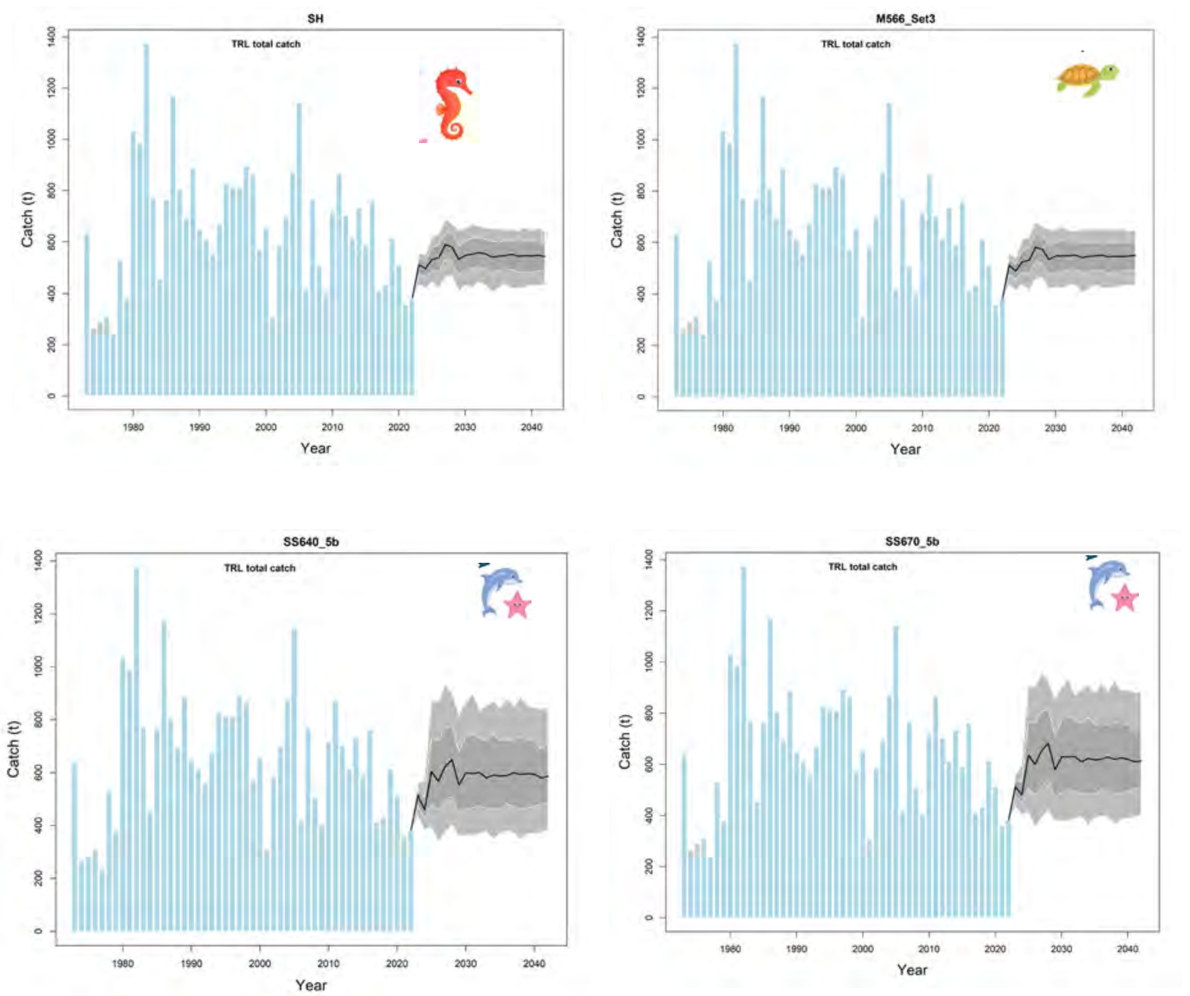
For each eHCR category and variant, a large number of performance statistics were output for consideration by the TRLRAG & TRLWG. The constant catch options highlighted the trade-offs between variability and risk to the stock, with a much higher risk, relative to the more adaptive options, of falling below the limit biomass reference level and of fishery closures if the TAC were to be maintained at a fixed high level (Figure 4-2). Preliminary testing also confirmed a sometimes unacceptably higher average annual variability (AAV) in catch when using a three- instead of five-year trend in the indices of abundance, with no clear positive trade-offs to support Jellyfish variants of the eHCR candidates (Figure 4-2). The Crab rule variants did not reduce risk acceptably (Figure 4-2) and were not preferred by the TRLRAG & TRLWG so are not considered further here. After initial filtering by the TRLRAG & TRLWG of preferred rules, the Turtle and Dolphin rules were considered to show the most promise in terms of yielding high average catch for low risk across a range of alternative variants.

Figure 4-2: Comparison of some key performance statistics during initial screening of eHCRs. Plots show the probability of depletion below each of two reference levels, BLIM = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, the total annual catch (t) and relative number of fishery closures triggered in the simulations. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.



However, after reviewing the performance of a range of eHCRs, some of the TRLRAG & TRLWG expressed concern about fundamentally changing the existing eHCR, and hence a new variant, termed the Seahorse rule was added to the revised set of eHCR candidates. The Seahorse rule performed similar to the Turtle rule in terms of level and variability of future catches, whereas the Dolphin rules were seen to yield much higher catches in some years (more similar to the past catch history) but at the expense of setting much lower catches in years with reduced stock abundance (Figure 4-3).

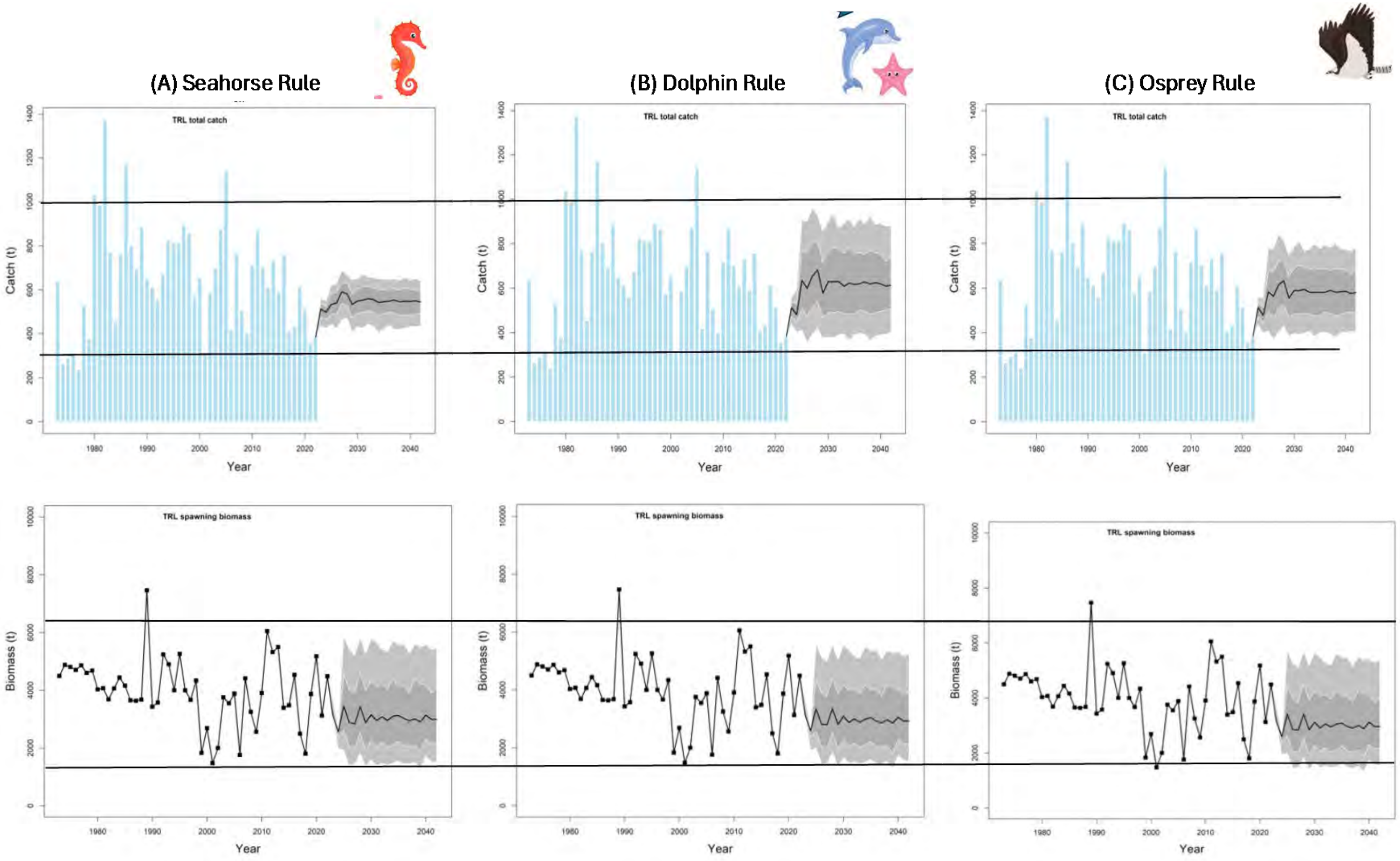
Figure 4-3: Distributions (solid line: median, 50% intervals: dark shaded area, 80% intervals: light shaded area) of future projected total catch (t) for TRL compared with historical values (blue bars) and when using the candidates: Seahorse (AH), Turtle (M566 variant), Dolphin (SS640_5b variant) and Dolphin (SS670_5b variant). All rules shown use a 5-year slope and include a lower bound (b) of 300t. Future simulated catches include implementation errors, and equal weighting of 4 OMs (800 simulations).



The performance of all candidates were also evaluated in terms of projected spawning biomass. For example, the Seahorse and the catch-optimised Dolphin rule (variant SS670) differ substantially in terms of expected future catches, but less so in terms of the distribution of potential future spawning biomass outcomes (Figure 4-4). Projected medians and associated ranges remained close to target levels for spawning biomass relative to the starting (1973) level, as well as relative to the comparable no-fishing level, and projected fishing mortality (after applying implementation errors) fluctuated around the target level (Figure S4- 1).

Focusing on median values can give a false idea of the extent of inter-annual variability that may be observed in future catch and CPUE because the median does not represent an actual trajectory but is similar to an average of all 800 model simulations. Hence examples of individual worm plots (Figure S4- 4) were also presented as these show what any given projection of catch or biomass could look like.

Figure 4-4: Top: Distributions (solid line: median, 50% intervals: dark shaded area, 80% intervals: light shaded area) of future projected total catch (t) for TRL compared with historical values (blue bars) when using the final Seahorse (SH), Dolphin (SS670) and Osprey (Osprey619) eHCRs. Bottom: Distributions of future projected spawning biomass (t) for TRL compared with historical values (square symbols). Plot shows OM1 historical trajectory only.



4.3 Narrowing down preferences for a longer-term eHCR

During the December 2024 TRLRAG and TRLWG meetings, the Seahorse rule and the Dolphin rule (variant SS670) were considered for immediate implementation (before seeing the current year's survey and CPUE results) as well as to replace the existing eHCR on a longer-term basis. However, strong preferences and concerns were expressed around each of these from the TRLRAG & TRLWG, which pertained largely to concerns that one or the other of these rules was too risky or too precautionary, that TACs should continue to be set at more conservative values due to market access uncertainty, that some sectors preferred optimal economic utilization strategies but that this was not necessarily optimal from a cultural perspective and that there was insufficient time to build trust that a changed rule would perform adequately.

Given lack of consensus on an eHCR for immediate application for the 2024-25 fishing season and beyond, the impasse was referred to the PZJA Standing Committee (SC) that met on 7 February 2025. The SC recommended (with the decision subsequently endorsed by the PZJA) that the global TAC for the 2024-25 season should be set at 688 t, reflecting the midpoint between the TAC outputs derived from applying the Seahorse and Dolphin rules to the current season's data. The TRL fishing season opens on 1 December each year (albeit with a hookah ban in place until 1 February) with a fixed low TAC of 200t that is then revised annually in February/March, following PZJA and other Bilateral discussions. The PZJA requested that a long-term eHCR solution be considered more broadly by the TRLRAG & TRLWG, noting that they felt it is important to balance both sets of views for the short term while seeking agreement on long-term arrangements.

4.4 The way forward to adopt a revised eHCR

To support the compromise solution recommended by the PZJA, an additional MSE-tested eHCR rule was developed. This was termed the Osprey rule because - like its namesake - it has a 'flight path' that is highly targeted and adaptable. The Osprey rule applies the cube-root rather than square-root to the survey multiplier term (see Equation 7). This dampens the influence of this term while retaining features including the more adaptive nature of the rule, according more weight to the most recent survey index and accounting for survey variance.

The Osprey rule achieves management objectives through trade-offs in performance statistics that are intermediate between the Dolphin and Seahorse rules (Figure 4-4). Several variants were tested and the Osprey Rule variant OS619 corresponded most closely to the PZJA-recommended compromise between the Dolphin and the Turtle rule as yields a RBC for the 2024-25 season of 690 t. To support building trust in adoption of an eHCR, additional communication materials were prepared (Figure 4-4; Table S2- 1), and peer review of methods sought (Plagányi et al. currently under review). The TRLRAG and TRLWG will therefore need to consider choice of a long-term eHCR for the fishery.

In essence, all of the rules tested adjust the annual RBC upwards or downwards based on recent trends in both the survey and CPUE data, and hence provide rapid adaptive feedback for management. However, the Turtle rule makes adjustments relative to a fixed reference point, the Seahorse rule uses a multiplier that is incrementally changed over time (as is based on a 5-year average of the most recent RBCs), whereas the Dolphin and Osprey rules use a more rapidly adaptive approach that is informed by the most recent survey 1+ index given the fishery relies predominantly on a single cohort each year.

The overall magnitude of RBCs is set by the Catch_tune parameter which is then multiplied by the survey multiplier term and CPUE term. As the survey multiplier increases (i.e. in good survey strength years with good confidence in the survey), the Osprey rule responds by increasing the catch multiplier, but not as much as the Dolphin rule does (Figure 4-5A). Conversely, the Osprey rule decreases the catch multiplier in a similar adaptive manner for years with a poor survey result, but again not to the same extent that the Dolphin rule would reduce the RBC (Figure 4-5A). A consequence is thus that the likely future RBCs based on the Osprey rule will be less variable than is the case for the Dolphin rule (Figure 4-5B).

The performance of ‘compromise rule’ Osprey Rule (variant OS619) and a number of other eHCRs in the reduced final set of candidates are compared in Figure 4-6.

Figure 4-5: (A) Comparison of the Dolphin, Osprey and Turtle rules amplitude of response to changes in the most recent TRL survey 1+ index and quality, illustrated when multiplying this factor and a constant annual multiplier of 619t, noting that the RBC then applies a further increase or decrease to this adaptive tuning term depending on 5-year trends in indicators. (B) Simulated probability distribution (80% of all outcomes) for future Recommended Biological Catches (RBC) (t) when using the Dolphin rule compared with the less variable Osprey rule.

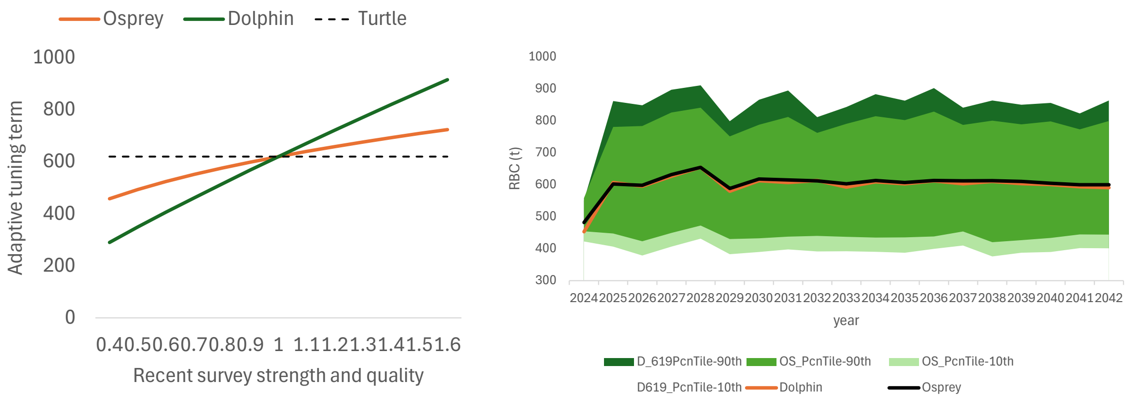
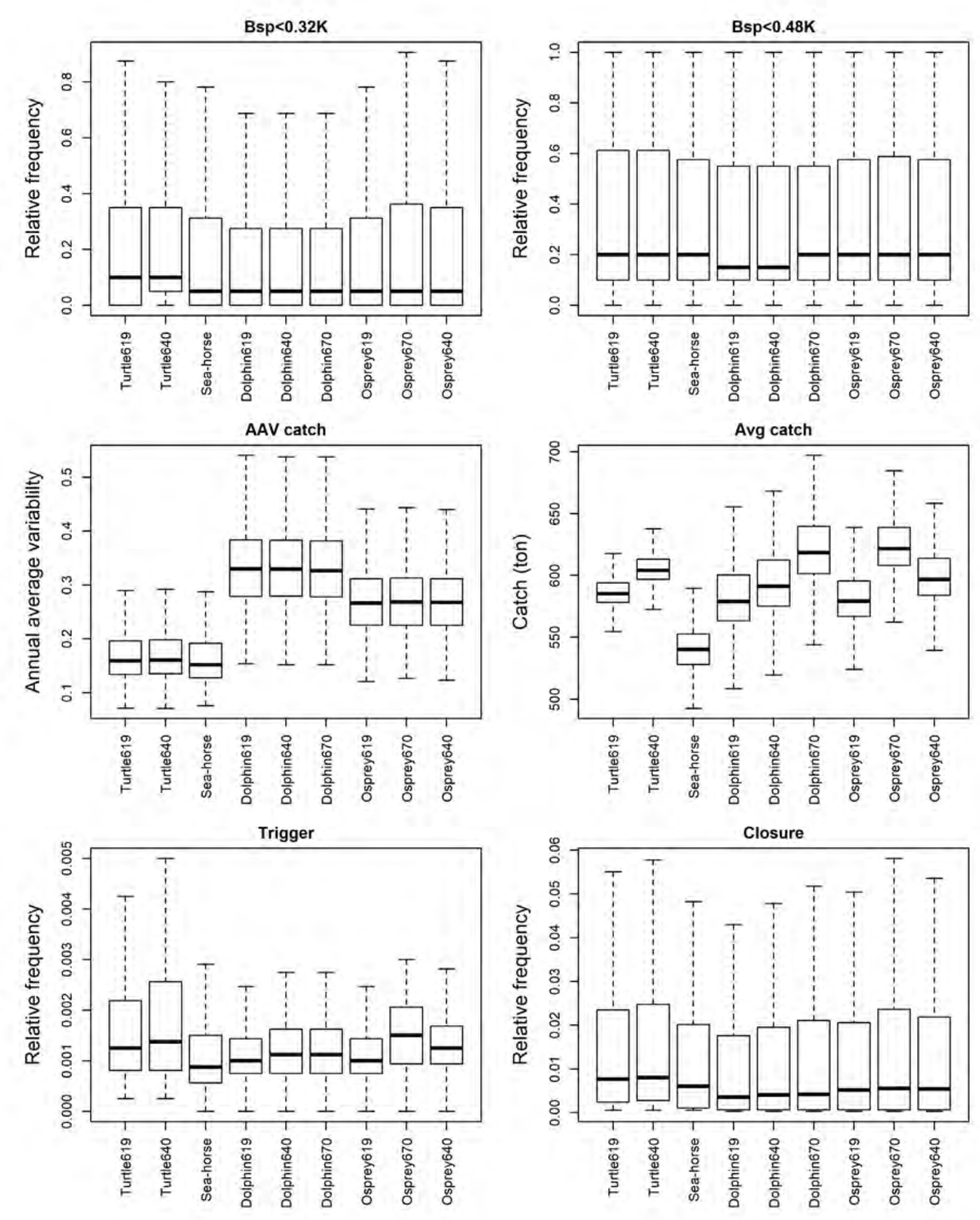


Figure 4-6: Comparison of some key performance statistics for final set of eHCR candidates, including Turtle, Sea-horse, Dolphin and Osprey variants (with associated number referring to the Catch-tune parameter). Plots show the probability of depletion below each of two reference levels, B_{LIM} = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, the total annual catch (t) and relative number of fishery closures triggered in the simulations. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the spread of the outputs (1.5 interquartile range, outliers not shown).



5 Discussion

The TRL fishery transitioned in 2019 from using a traditional annual stock assessment approach to a formal harvest strategy framework and use of an eHCR. The harvest control rule is empirical, as it uses the data directly e.g., recent upward or downward trends in abundance indices are used directly as feedback and hence the RBC changes in the same direction.

Empirical Harvest Control Rules are now implemented in a number of fisheries globally, including for a number of lobster fisheries: Australia's southern rock lobster fishery (Punt et al. 2012), South African rock lobster (Johnston and Butterworth 2005), New Zealand rock lobster (Bentley et al. 2005, Miller and Breen 2010) and the Tristan da Cunha lobster fishery (Johnston and Butterworth 2013). Examples of other fisheries include South African hake (Rademeyer et al. 2008), anchovy and sardine (de Moor et al. 2011) and groundfish fisheries in British Columbia (Cox and Kronlund 2008). The eHCR for Australia's southern lobster is based on the catch-rate for the most recent year and hence reacts quickly to changes in catch-rates (Punt et al. 2012).

The TRL stakeholders expressed a preference to use a portfolio approach drawing on information from several data sources, including survey and CPUE data, albeit with more weight accorded to the most direct and accurate index, the 1yr survey index, compared with the pre-recruit 0yr index and the CPUE indices. The CPUE indices reflect the abundance of the large 2yr lobsters, the survivors of which mostly migrate out of the Torres Strait to breed such that only a very small proportion remain available to be fished in future (Dennis et al. 1992), but their spawning biomass index is an important consideration in terms of ensuring the future sustainability of the stock. There are examples of other Harvest Control Rules that use a combination of CPUE and fishery-independent survey information (e.g. Rademeyer et al. 2008) as well as pre-recruit (puerulus) indices (Bentley et al. 2005). The TRL eHCR is relatively data-rich compared with that applied to other lobster fisheries as the rule uses information from multiple data sources. Harvest Control Rules may also include additional metrics such as size compositions and somatic growth rate (Johnston and Butterworth 2005, Plagányi et al. 2007), and these may be considered in future work.

Empirical HCRs are considered a defensible approach given that they have been shown to perform almost as well as model-based approaches (Rademeyer et al. 2007, Punt et al. 2012, Geromont and Butterworth 2015, Punt et al. 2016). Both model-based and empirical HCR's typically include free parameters that can be adjusted to tune their performance to achieve desired optimal trade-offs between performance statistics. Empirical harvest strategies have demonstrated the ability to achieve objectives such as reversing a decline in a population (Geromont and Butterworth 2015).

However, they can suffer from a lack of information about the exact level of the resource, and hence additional analyses are required to determine what the status of the resource is relative to specified reference levels (Rademeyer et al. 2007). Some approaches use a 'target'-based rule whereby TAC adjustments are based on the magnitude of the difference between the recent CPUE and a target value (Johnston and Butterworth 2013). Compared with model-based HCRs, Rademeyer et al. (2007) and Butterworth (2008) suggest that empirical approaches can be easier to test and are often more easily understandable by stakeholders.

The TRL eHCR has been extensively tested by simulation to provide appropriate trade-offs, taking into account a range of uncertainties and using methods that are now well established internationally (Dankel and Edwards 2016, Punt et al. 2016). The greatest advantages to adopting a eHCR approach are that (1) it can be applied quickly and easily to set a RBC in time for the start of the new fishing season; (2) it provides a transparent and easily understandable tool for stakeholders (e.g., the effect on the RBC of negative or positive decreases/increases in stock abundance indices can be readily seen, and a spreadsheet example is provided to stakeholders for this purpose); (3) it provides a sound basis for setting RBCs without compromising resource status; (4) it properly addresses concerns about scientific uncertainty through simulation testing to ensure that feedback secures reasonably robust performance across a range of plausible alternative resource dynamics; and (5) when tested using the MSE process, it empowers stakeholders by allowing them to transparently assess trade-offs between key performance measures and select the most favourable option taking into account a range of biological, economic, social and cultural considerations (Butterworth and Punt 1999, Plagányi et al. 2007, Rademeyer et al. 2007).

The TRL eHCR specifies that a stock assessment will be conducted every three years to rigorously assess stock status and productivity, and check that the eHCR is working as it is supposed to. As a stock assessment is only scheduled for every third year, action may not be taken quickly enough if the spawning biomass drops to very low levels, and hence an additional precaution has been built into the Harvest Strategy. Based on analysis of the historical pre-season and mid-year survey indices, a pre-season 1yr survey trigger point of 1.25 (average number of lobsters per survey transect and lower than any historically observed values) has been set, such that if this lower limit is triggered in any year, then the required action is that a stock assessment be conducted in the following year. This is similar to what is done in some other fisheries, such as decision rules for some of the New Zealand sub-stocks whereby a stock assessment is mandated if CPUE decreases below a specified base level (Bentley et al. 2005). If the stock assessment suggests that the spawning stock biomass is above the LRP, then the process continues as previously. However, if spawning biomass is assessed as below the LRP, then a stock assessment is again triggered in the following year. If the second stock assessment suggests the stock is above the LRP, then the process again continues as previously, but if the spawning biomass is below LRP (i.e., two consecutive years with spawning biomass below LRP), then the fishery is closed and appropriate action (e.g., implementing surveys, analysing size structure and environmental information) is put in place. In general, the eHCR is therefore applied every year unless the LRP is triggered in two consecutive years.

The eHCR adopted in 2019 used total catch in the formula but a number of external factors (e.g. covid, markets) mean catches have been well below the TAC so 'ad hoc' adjustments have been made in the last few years (substitute TAC for total catch). Best practices dictate that HCRs should ideally be revised every 5 years if possible. Revision of the TRL eHCR also provided an opportunity to retest the eHCR to improve robustness to climate change (given scientific advances since the original rule was developed) and other concerns such as discards and differences between total catches and TACs. The TRLRAG and TRLWG narrowed their focus to three types of rules, namely the Turtle, Seahorse and Dolphin rules. However, as no consensus was reached at the December 2024 meetings, and to assist the process going forward, a new rule, termed the Osprey rule was developed and added to the list of candidates. The Osprey rule yields the equivalent TAC for the current season as the PZJA compromise solution and is intermediate in its behaviour between the Seahorse rule and the Dolphin rule. This is because it adjusts the RBC upwards or downwards depending on the strength of the incoming recruitment class as well as other stock indicators, and the inter-annual changes in the RBC are less than that in the Dolphin rule but more than in the Seahorse rule. At the forthcoming TRLRAG and TRLWG meetings, participants will be provided with further opportunities to understand the different eHCR candidates and select an option for longer-term implementation to ensure the ongoing sustainable management of the TRL fishery.

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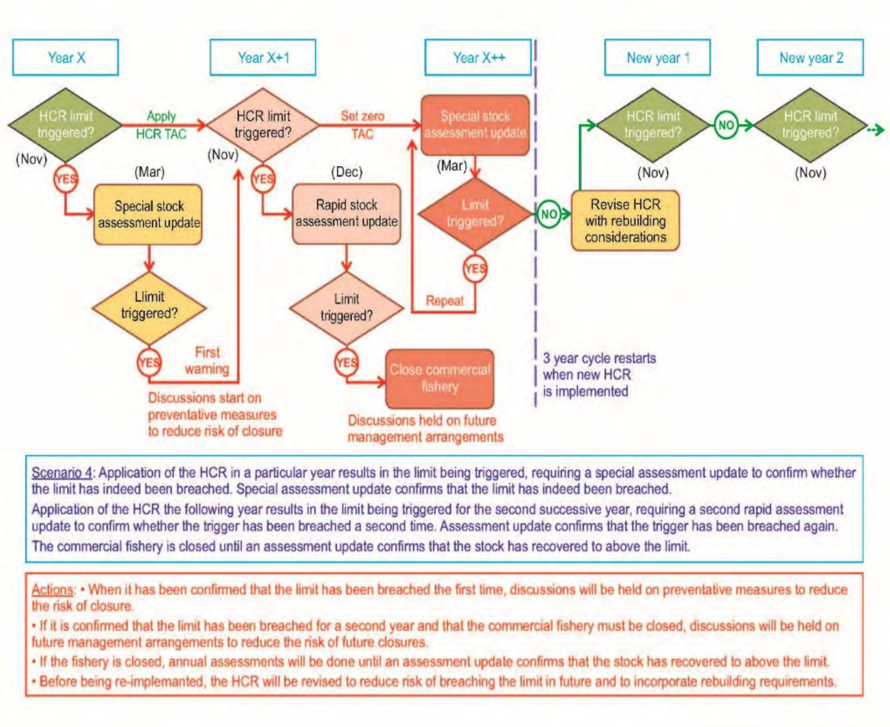
7 Appendices

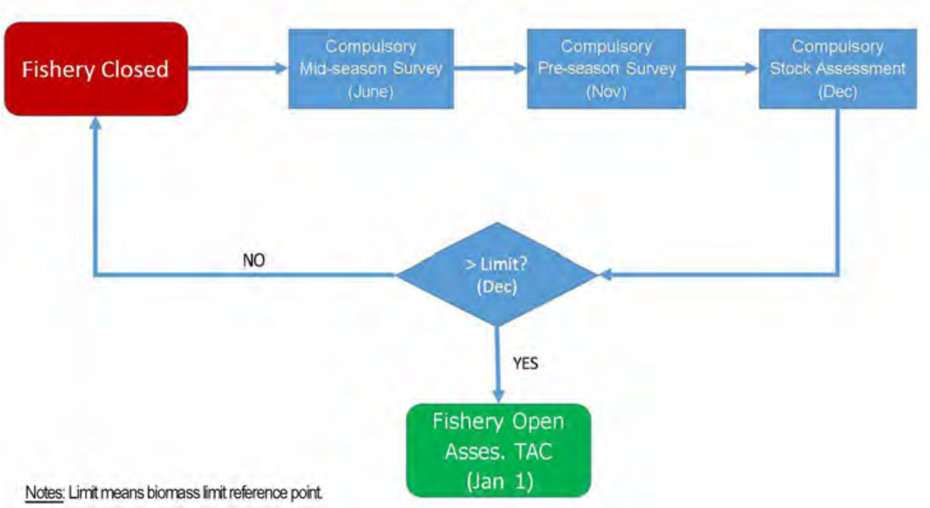
A.1 Supplementary Appendix S.1: Additional technical specifications for eHCRS

The TRL eHCR specifies that a stock assessment will be conducted every three years to rigorously assess stock status and productivity, and check that the eHCR is working as it is supposed to. As a stock assessment is only scheduled for every third year, action may not be taken quickly enough if the spawning biomass drops to very low levels, and hence an additional precaution has been built into the Harvest Strategy. Based on analysis of the historical pre-season and mid-year survey indices, a pre-season 1yr survey trigger point of 1.25 (average number of lobsters per survey transect and lower than any historically observed values) has been set, such that if this lower limit is triggered in any year, then the required action is that a stock assessment be conducted in the following year.

If the stock assessment suggests that the spawning stock biomass is above the LRP, then the process continues as previously (Figure S1- 1). However, if spawning biomass is assessed as below the LRP, then a stock assessment is again triggered in the following year. If the second stock assessment suggests the stock is above the LRP, then the process again continues as previously, but if the spawning biomass is below LRP (i.e. two consecutive years with spawning biomass below LRP), then the fishery is closed and appropriate action (e.g. implementing surveys, analysing size structure and environmental information) is put in place (Figure S1- 1). In general, the eHCR is therefore applied every year unless the LRP is triggered in two consecutive years.

Figure S1- 1: Summary of full TRL harvest strategy process showing process used to inform deviations from straightforwardly applying the eHCR to set a TAC, as well as timing of surveys and stock assessment.





A.2 Supplementary Appendix S.2: Communication approaches

We used a range of approaches to support the communication of technical components of HS and MSE development, including non-technical summaries and resharing graphical recording images to capture key points from discussion sessions in a visually appealing and easily understandable format (Figure S2- 1) (Plagányi et al. 2018).

To explain the role of the TRLRAG & TRLWG, we asked the group to think of themselves as on a selection committee, with the task of selecting the best candidate for the job of setting TACs for the TRL fishery. The candidates had easy-to-recall marine animal names (Figure S2- 2) that captured some key features of how they would perform in the role: for example, jellies represented candidates that were prone to highly variable inter-annual decision-making, turtles were expected to perform in a more steady manner, 'cruising' at precautionary levels, whereas dolphins described candidates that could rapidly respond in a smart manner with leaps or dives to changing conditions. When introducing a new 'compromise' eHCR candidate, this was termed the Osprey rule (after a locally-occurring bird) to reflect that the rule also responds in a smart adaptive way with upward and downward changes in 'flight path', but these are less pronounced than for the Dolphin rule (Figure S2- 3).

Modified versions of an eHCR spreadsheet were also provided to the TRLRAG & TRLWG (Figure S2- 4).

We also showed more conventional performance statistics (see main text) and in response to a request to assist TRLRAG & TRLWG in understanding likely outputs from the different eHCRs, we drew on the past history of the fishery to develop an example of a bad, average and good year (Figure S2- 5) and in each case we computed the example RBC (Recommended Biological Catch) across a range of eHCR candidates. To do so, we reran the stock assessment (2024 Reference Case model) and fitted to the illustrative survey and CPUE series corresponding to each of the bad, average and good years to calculate the stock assessment-based RBC (Figure S2- 5). This provided additional useful context as the eHCR is designed to dampen variability in the TAC to varying extents.

Figure S2- 1Visual stories of the Kaiar Fishery CSIRO research information session held with the TRL community on Thursday Island in November 2016 explaining the fisheries science (Graphic by Dr Sue Pillans, www.drsuepillans.com). See also example published in Plaganyi et al. (2018).

Figure S2- 2: Schematic illustration of key features and category names for different eHCRs tested. Image purchased from Shutterstock.

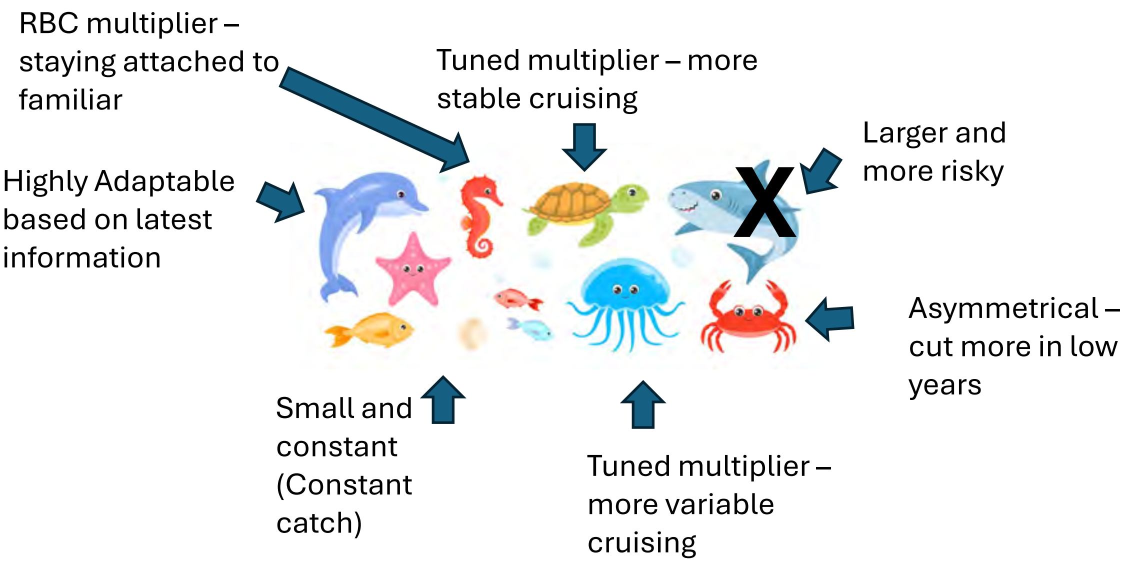


Figure S2- 3: Schematic illustration of additional compromise eHCR candidate termed the Osprey rule, to reflect the smart, adaptive nature of the flight path of these locally-occurring birds. Image purchased from Shutterstock.

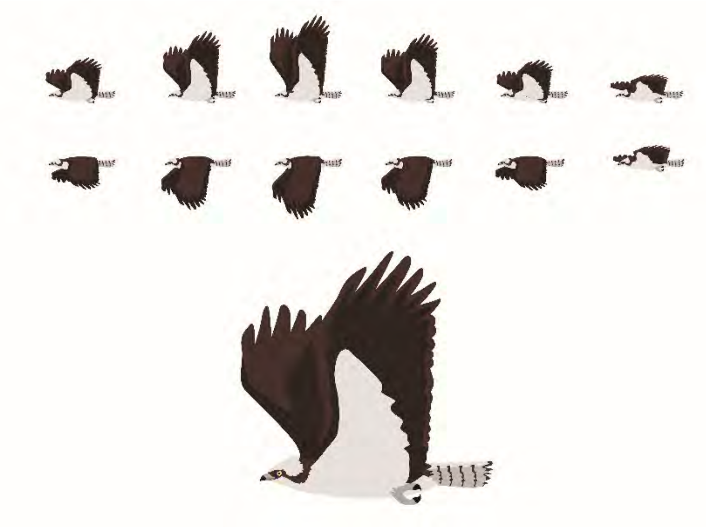
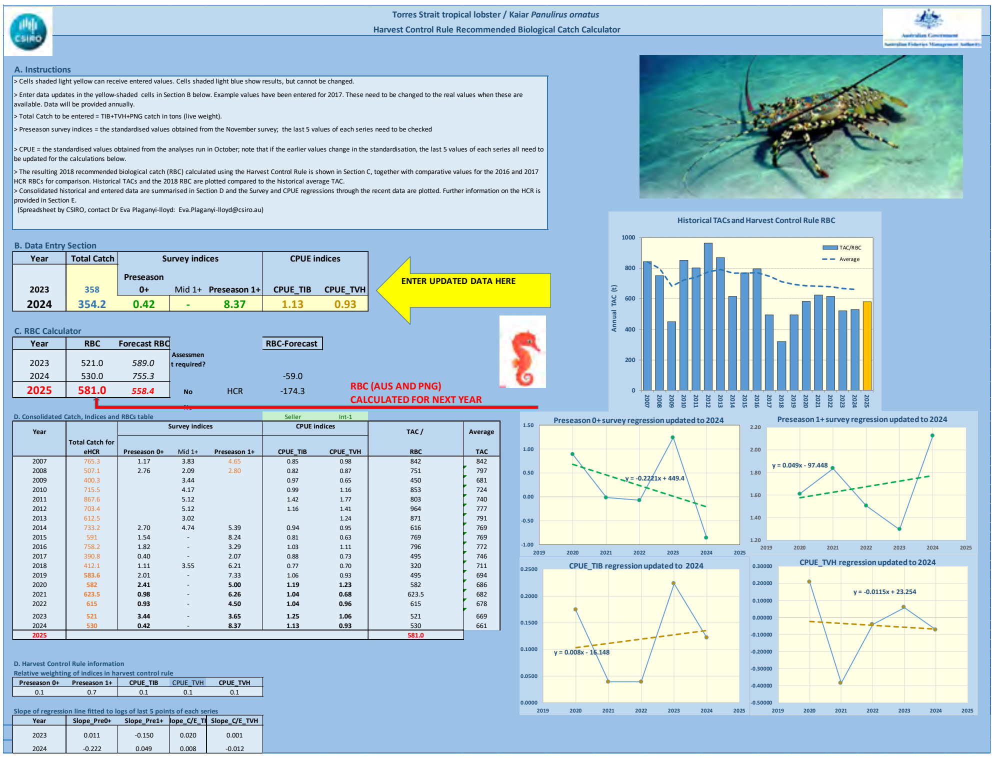


Figure S2- 4: Example of spreadsheet visualisation (prepared using Excel) shared with stakeholders to facilitate understanding and enhance transparency of eHCR approach.



Torres Strait tropical lobster / Kaiar *Panulirus ornatus*
Harvest Control Rule Recommended Biological Catch Calculator

A. Instructions

> Cells shaded light yellow can receive entered values. Cells shaded light blue show results, but cannot be changed.
> Enter data updates in the yellow-shaded cells in Section B below. Example values have been entered for 2017. These need to be changed to the real values when these are available. Data will be provided annually.
> Total Catch to be entered = TIB+TVH+PNG catch in tons (live weight).
> Preseason survey indices = the standardised values obtained from the November survey; the last 5 values of each series need to be checked
> CPUE = the standardised values obtained from the analyses run in October; note that if the earlier values change in the standardisation, the last 5 values of each series all need to be updated for the calculations below.
> The resulting 2018 recommended biological catch (RBC) calculated using the Harvest Control Rule is shown in Section C, together with comparative values for the 2016 and 2017 HCR RBCs for comparison. Historical TACs and the 2018 RBC are plotted compared to the historical average TAC.
> Consolidated historical and entered data are summarised in Section D and the Survey and CPUE regressions through the recent data are plotted. Further information on the HCR is provided in Section E.
(Spreadsheet by CSIRO, contact Dr Eva Plaganyi-lloyd: Eva.Plaganyi-lloyd@csiro.au)

B. Data Entry Section

Year	Total Catch	Survey indices			CPUE indices	
		Preseason 0+	Mid 1+	Preseason 1+	CPUE_TIB	CPUE_TVH
2023	358					
2024	354.2	0.42	-	8.37	1.13	0.93

ENTER UPDATED DATA HERE

C. RBC Calculator

Year	RBC	Forecast RBC	Assessment required?		RBC-Forecast
2023	521.0	589.0			
2024	530.0	755.3			-59.0
2025	581.0	558.4	No	HCR	-174.3

RBC (AUS AND PNG) CALCULATED FOR NEXT YEAR

D. Consolidated Catch, Indices and RBCs table

Year	Total Catch for eHCR	Survey indices: Preseason 0+	Mid 1+	Preseason 1+	CPUE indices: CPUE_TIB	CPUE_TVH	TAC / RBC	Average TAC
2007	765.3	1.17	3.83	4.65	0.85	0.98	842	842
2008	507.1	2.76	2.09	2.80	0.82	0.87	751	797
2009	400.3		3.44		0.97	0.65	450	681
2010	715.5		4.17		0.99	1.16	853	724
2011	867.6		5.12		1.42	1.77	803	740
2012	703.4		5.12		1.16	1.41	964	777
2013	612.5		3.02			1.24	871	791
2014	733.2	2.70	4.74	5.39	0.94	0.95	616	769
2015	591	1.54	-	8.24	0.81	0.63	769	769
2016	758.2	1.82	-	3.29	1.03	1.11	796	772
2017	390.8	0.40	-	2.07	0.88	0.73	495	746
2018	412.1	1.11	3.55	6.21	0.77	0.70	320	711
2019	583.6	2.01	-	7.33	1.06	0.93	495	694
2020	582	2.41	-	5.00	1.19	1.23	582	686
2021	623.5	0.98	-	6.26	1.04	0.68	623.5	682
2022	615	0.93	-	4.50	1.04	0.96	615	678
2023	521	3.44	-	3.65	1.25	1.06	521	669
2024	530	0.42	-	8.37	1.13	0.93	530	661
2025							581.0	

D. Harvest Control Rule information
Relative weighting of indices in harvest control rule

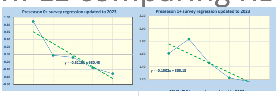
Preseason 0+	Preseason 1+	CPUE_TIB	CPUE_TVH	CPUE_TVH
0.1	0.7	0.1	0.1	0.1

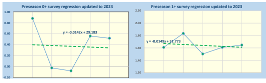
Slope of regression line fitted to logs of last 5 points of each series

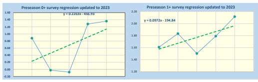
Year	Slope_Pre0+	Slope_Pre1+	lope_C/E_TI	Slope_C/E_TVH
2023	0.011	-0.150	0.020	0.001
2024	-0.222	0.049	0.008	-0.012

Figure S2- 5: Comparison of RBCs (tons) for TRL in a hypothetical bad, average and good year, computed using the stock assessment as well as each of the eHCR candidates as shown.

EXAMPLE comparing RBCs under different scenarios







Method	**BAD yr**	**AVE yr**	**GOOD yr**
Stock assess	***390***	***645***	***921***
Ad hoc	**477**	**554**	**616**
Turtle 566	**489**	**559**	**617**
Turtle 619	**534**	**611**	**675**
Dolphin 619	**353**	**599**	**756**
Dolphin 640	**365**	**620**	**782**
Dolphin 670	**382**	**649**	**818**

Table S2- 1: Non-technical summary of three final TRL/kaiar empirical Harvest Control Rule (eHCR) candidates

Name	**Seahorse rule** 	**Dolphin rule** 	**Osprey rule** 
Description of rule for setting the annual Recommended Biological Catch (RBC)	Clings to something familiar and provides a RBC that doesn't move very much	Smart, highly adaptable rule that allows rapid response with either big leaps or dives in the RBC	Smart, targeted and adaptable rule but the flight path is smoother than a dolphin's movements (less leaps and dives in RBC)
Uses survey & CPUE trends and weightings as previous?	Yes	Yes	Yes
Gives more weight to most recent TRL 1+ survey index?	No	Yes (influences more than for Osprey)	Yes (but less influence than Dolphin rule)
Accounts for quality/precision of most recent 1+ survey	No	Yes, weights last term by survey standard deviation	Yes, weights last term by survey standard deviation
What's new about this rule?	Replaces average catch multiplier with average of most recent 5 TACs (Total Allowable Catch – all sectors) which dampens variability in the annual RBC	Uses a tuned value that is adjusted annually based on the strength and quality of the most recent 1+ survey (most similar to using annual stock assessments to set the TAC)	Compromise option tuned to output RBCs intermediate between Seahorse and Dolphin rules, with smaller annual adjustments based on the strength and quality of the most recent 1+ survey
Advantages and disadvantages [Note: All 3 rules have been MSE-tested to ensure they are adequately precautionary, consistent with fishery and cultural objectives, and have improved resilience to climate change and market shocks. Unsafe rules removed prior and not shown]	Sets safe TACs that are not as high as they could be in good years, but also not as low as they could be set in poor years, so smaller inter-annual variability (i.e. more consistent RBC from year to year) but doesn't closely track TRL abundance.	Sets safe TACs that most closely track TRL abundance as are high in good years, whereas in poor abundance years, this rule sets lower TACs than the other rules. This results in the largest inter-annual variability. As TRL relies on incoming recruit class strength, this rule also gives more weight to the most recent data, as well as the survey precision. A disadvantage is that the equation is slightly harder to understand.	Sets safe TACs that track TRL abundance but doesn't set TACs quite as high or low in good/bad years as Dolphin rule. As TRL relies on incoming recruit class strength, this rule also gives more weight to the most recent data, as well as the survey precision. A disadvantage is that the equation is slightly harder to understand.

A.3 Supplementary Appendix S.3: Additional technical specifications for operating models

A.3.1 Background to Operating Models (OMs)

The Operating Models (OMs) are variants of the stock assessment model that is described in a number of reports and papers, including (Plagányi et al. 2023, Plagányi et al. 2024, Plagányi et al. 2025) and the climate-linked version of the stock assessment model has previously been described in Plagányi et al. (2019).

The Torres Strait (TS) tropical rock lobster (TRL) integrated age-structured stock assessment was developed in 2009 to take account of both fisheries-independent and fisheries-dependent (CPUE) data (Plagányi et al. 2015), in a manner consistent with the principles of integrated stock assessment (Maunder and Punt 2013). The primary data are fishery-independent surveys conducted since 1989, however there was a transition in 2014 (pre-tested over 2006-2009) from use of Mid-year surveys to Pre-season surveys, as it was considered more reliable to conduct a survey of one-year old recruits as close to the start of the fishing season as possible (November) to inform on the likely biomass of the fishable cohort the next year. The stock assessment model uses likelihood contributions from both series, as well as two CPUE data series, as well as other available data (catch-at-age) in computing the total log-likelihood (Table S3- 1).

To account for process error within the stock assessment model and OMs, a series of (year-dependent) additional variance (AV) parameters is also estimated (Table S3- 1). These are applied when fitting to the Preseason 0+ survey index as it is less reliable than the 1+ index, mainly due to the cryptic nature of recently-settled lobsters making them more difficult to survey, plus major environmental anomalies likely influence the distribution and timing of settlement, and hence the representativeness of the 0+ index.

The basic resource dynamics in the stock assessment and OMs are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \qquad \text{(S3.1)}$$

$$N_{y+1,a+1} = \left(N_{y,a}\, e^{-3M/4} - C_{y,a}\right) e^{-M/4} \qquad \text{for } a=1 \qquad \text{(S3.2)}$$

$$N_{y+1,a+1} = \left(N_{y,a}\, e^{-M/2} - C_{y,a}\right) e^{-M/2} \qquad \text{for } a=2 \qquad \text{(S3.3)}$$

where

$N_{y,a}$ is the number of lobsters of age *a* at the start of year *y* (which refers to a calendar year),

R_y is the recruitment (number of 1-year-old lobsters) at the start of year *y*,

M denotes the annual natural mortality rate of lobsters, with reference case (non-year-dependent) value reliably estimated as shown in Table S3- 1, and

$C_{y,a}$ is the predicted number of lobsters of age *a* caught in year *y*

They reflect Pope's form of the catch equation (Pope 1972) (the catches are assumed to be taken as a pulse at midyear for the 2yr class and at the start of the third quarter for the 1yr class) in order to simplify computations.

A Beverton-Holt stock-recruitment relationship is used to estimate the number of recruits R_y at the start of year *y*, allowing for annual fluctuation in the deterministic relationship:

$$R_y = \frac{\alpha B_{y-1}^{sp}}{\beta + B_{y-1}^{sp}} e^{\left(\gamma_y - (\sigma_R)^2/2\right)} \qquad \text{(S3.4)}$$

where B_y^{sp} is the spawning biomass at the start of year *y*, parameters *α, β* are based on the pre-exploitation equilibrium spawning biomass K^{sp}, and the "steepness", *h*, of the stock-recruitment relationship, γ_y reflects fluctuations around the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation σ_R (set at 0.5). The residuals are treated as estimable parameters in the model fitting process (Table S3- 1 and see Plagányi et al. (2025) for further details of likelihood equations).

A hyperstable relationship was assumed between the CPUE relative abundance index for each sector *f* and the exploitable biomass B_y^{ex} as follows:

$$\left(\frac{\hat{C}}{E}\right)_y^f = q_f \left(B_y^{ex}\right)^{hyps^f} \qquad \text{(S3.5)}$$

where $hyps^f$, is the hyperstability parameter per sector *f*, set at 0.5 for the TIB fleet and 0.75 for the TVH fleet.

A.3.2 Data inputs

A summary of key recent data inputs that are relevant to the eHCR is given in Table S3- 2, although we note that in the OM versions used in MSE testing, data were only available up until end of 2022, but we show here the latest data updates up until end of 2024 as these data were input to the eHCR applications used in computing the TAC for the 2024-25 fishing season as discussed in the main text. Details of other data series used in fitting the OMs is provided in the references above. For the

Dolphin and Osprey rules, there is an additional survey-based term (termed *SS* and *SSC* respectively, see Equations 5 and 7 in main text) that gives more weight to both the most recent Preseason survey year's age 1+ index, as well as its associated precision. The term uses the ratio of the current year's age 1+ survey index relative to a fixed reference level computed as the median survey index over the period 2005 to 2023. This same reference level is used in MSE testing, in which future survey estimates are generated randomly.

The differences in the standard error associated with the Preseason age 1+ survey index (Table S3- 2) are partly due to differences in the number of transects per survey, plus environmental variability, as detailed in (Dennis et al. 2015, Plagányi et al. 2024). Hence the Dolphin and Osprey Rules incorporate the CV of the most recent survey in calculations of the Recommended Biological Catch (RBC), with the past values of *SS* and *SSC* provided in Table S3- 2 to support understanding of the approach as well as future implementations of the rule. For example, as evident from Table S3- 2, past SS values have ranged between 0.61 and 1.22, compared with a narrower range for SSC between 0.72 and 1.14. In past years, these are therefore examples of the downweighting or upweighting that these terms would have applied to the RBC based on other inputs to the eHCR. For example, based on the positive Preseason survey index for 2024, and using values as shown in Table S3- 2 in combination with the Equations presented in the main text, the eHCR RBC(2025) corresponding to selected candidate rules is:

- Seahorse Rule: 581t
- Turtle Rule (variant 619): 626 t
- Dolphin Rule (variant 670): 797 t
- Osprey Rule (variant 619): 697t

Note that the Osprey Rule (variant 619) yields a RBC similar to the actual TAC of 688 t which was computed as the average of the Seahorse and Dolphin (variant 670) rules.

A.3.3 Generating Future TRL recruitment estimates

Future recruitment estimates for each OM were generated using the stock-recruitment relationship shown in Equation S3.4 and with plausible annual fluctuations simulated by generating random future deviations with two alternative variances σ_R similar to historical values (Table 3-2 in main text). In addition, OM4 included additional environmentally-driven variation as described in Table 3-2 in main text.

A.3.4 Generating Future Survey and CPUE abundance indices

For MSE testing, "future data" in the form of survey indices of abundance (Pre-season 0yr, 1yr) and sector-specific CPUE series (TIB and TVH) are generated from the OM, assuming the same error structures as in the past.

Survey "data" $I_{y,a}^{fut\_pre}$ for future year *y* and age class *a* are generated from model estimates of pre-season (November) survey biomass for each age class *a* as follows:

$$I_{y,a}^{fut\_pre} = \hat{q}_{pre,a} N_{y,a}^{pre} e^{\varepsilon_{y,a}^{pre}}$$
$$\varepsilon_{y,a}^{pre} = \eta_{y,a}^{pre} \sigma_{a}^{pre} \qquad \text{(S3.6)}$$

where $\eta_{y,a}^{pre} \sim N(0;1)$ and $\sigma_{a}^{pre} = \bar{\sigma}_{a}^{pre}$

Log-normal error variance includes the survey sampling variance with the standard deviation set equal to the average historical values $\bar{\sigma}_{a}^{pre}$ of 0.18 and 0.35 respectively for the 1yr and 0yr indices. For the RBC for year *y*+1, such data are available for year *y*.

The future CPUE "data" series $I_{y,f}^{fut\_CPUE}$ for sector *f* and each year *y* are generated from model estimates for exploitable biomass and catchability coefficients as follows:

$$I_{y,f}^{fut\_CPUE} = \hat{q}_{CPUE,f} B_{y}^{ex} e^{\varepsilon_{y,f}^{CPUE}}$$
$$\varepsilon_{y,f}^{CPUE} = \eta_{y,f}^{CPUE} \sigma_{f}^{CPUE} \qquad \text{(S3.7)}$$

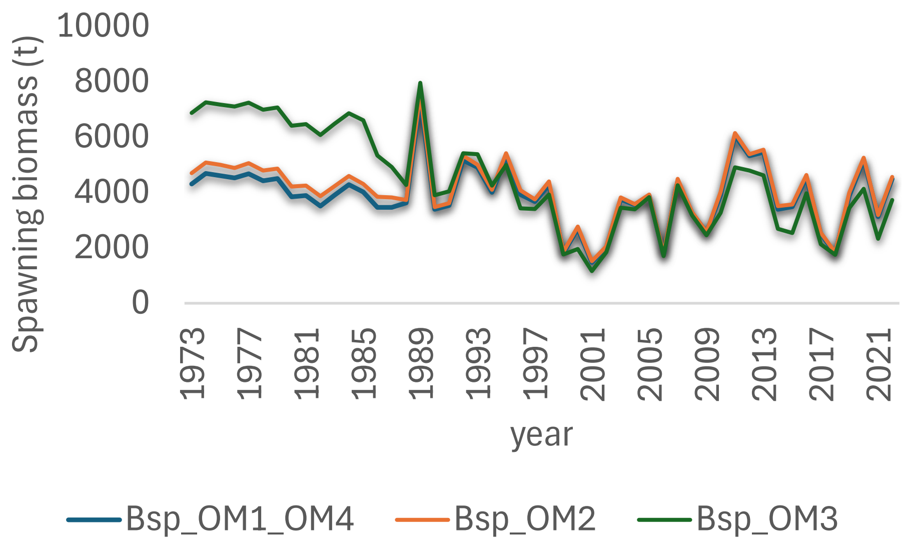
where $\eta_{y,f}^{CPUE} \sim N(0;1)$ and $\sigma_{f}^{CPUE} = \hat{\sigma}_{f}^{CPUE} + \sigma_{ad}$

For the CPUE data, additional sources of variation σ_{ad} were accounted for by adding additional variance converted to a standard deviation σ_{ad} and hence increasing the model-estimated standard deviations $\hat{\sigma}_{f}^{CPUE}$ to 0.3.

A.3.5 Specification of different OMs

Below we focus on modifications to the reference case stock assessment model. OM1 is most similar to the reference case model and Figure S3- 1 shows a comparison between the four OMs used in the MSE testing.

Figure S3- 1: Comparison of the model-estimated TRL spawning biomass (Bsp, t) for years as shown when using each of the four alternative Operating Models (OM), noting that historical model fits for OM1 and OM4 are identical as these model versions differ in settings used for future projections.



A.3.6 Forecasting catch and discard levels

For all OMs, the relationship between the RBC for year *y* (RBC_y) and the actual catch in year *y* (C_y), given proportional allocations p_f per sector, is modelled using the formula:

$$C_y = \sum_{f=1}^{3} p_f RBC_y \times e^{\varepsilon_y^f}, \quad \varepsilon_y^f \ \ from\ N(0;\sigma_f{}^2) \qquad \text{(S3.8)}$$

where catch is the total from the three sectors and a value for σ_f for each sector was selected based on comparison with past observations over the period 2006-2015. Different future (projection) implementation error magnitudes are set for each sector (σ_{TIB}, σ_{TVH} and σ_{PNG}) and different values used for the 4 OMs (see Table 3-2 in main text).

In addition, we used a fairly simplistic method to simulate the risk of periodic market and trade issues negatively impacting the supply chain. To simulate these external factors causing substantial reductions in total catch (similar to that observed in recent years – see Table S3- 2), for OM4, there was a 20% probability (for all future years in all replicates) that total annual catch (from Equation S3.8 above) would be reduced by a third (based on 2022 observations), plus we constrained total catch (from all sources) to never exceed the TAC under this negative-market-factors scenario.

For OMs 1 and 3, in addition to C_y (from Equation S3.8), we explicitly accounted for future discards $C_y^{discard}$ and subsistence catches $C_y^{subsist}$ such that future forecast values of the proportion of the resource harvested each year (F_y) is given by:

$$F_y = \left(C_y + C_y^{discard} + C_y^{subsist}\right) / B_y^{ex} \qquad \text{(S3.9)}$$

Discards are modelled as proportional to the total catch C_y, as well as (for OM3) the *SST_multiplier* using the formula:

$$C_y^{discard} = p_{discard} C_y \times e^{\varepsilon_y^{discard}} \times SST\_M_y \ , \ \varepsilon_y^{discard} \ from \ N(0;\sigma_{discard}{}^2) \qquad \text{(S3.10)}$$

where $p_{discard}$ is the average proportion of discards relative to total catch and $\sigma_{discard} = 0.1$ (see Table 3-2 in main text).

The subsistence catch is either not represented explicitly (OMs 2 ,4) or is assumed a fixed proportion $\rho_{subsist}$ (see Table 2) of the annual TIB catch (OMs 1, 3):

$$C_y^{subsist} = p_{subsist} C_y^{TIB} \ , \ \varepsilon_y^{discard} \ from \ N(0;\sigma_{discard}{}^2) \qquad \text{(S3.11)}$$

A.3.7 Climate-linked model version

The climate-linked OM3 uses as an input data from the Model Intercomparison Project Phase 5 (CMIP5) climate models. The global OGCM is integrated over the historical period (1979-2014) then projected from 2006 to 2101 under a high emission scenario (RCP8.5). Climate data were provided by Richard Matear and Xuebin Zhang (CSIRO) starting in 1992 and climate change (rcp8p5) and control projections up to 2050 (Fulton et al. 2018). The data consists of monthly surface data of temperature (SST; °C), salinity (SSS), phosphate (SPO4; mmol m^{-3}), phytoplankton (SPHYL; mmol N m^{-3}) and primary productivity (PP; mmol C m^{-2} day^{-1}). The downscaled sea surface temperature estimates do not exactly match available (limited) observations from monitoring stations in Torres Strait but were considered useful as a first approximation, and ongoing work is further examining this issue.

The climate-linked OM3 assumes an optimal temperature for *P. ornatus* of 29°C and assumes a non-symmetric pejus type relationship between lobster survival (assumed to be the net outcome of a number of physiological responses to changes in temperature) and SST. As described in Plaganyi et al. (2019), this is parameterised as two separate quadratic functions that intersect at the optimum SST, such that the slope of the response to decreasing versus increasing SST can be different i.e. the impacts of temperatures greater than the optimum are more severe than those of temperatures less than the optimum. Hence the functional forms assumed for the mortality multiplier functions (*SST_multiplier*) are:

$$SST\_multiplier_t = 1 + \tau_1 \left(SST_t - T_O\right)^2 \quad SST_t \le T_0$$
$$SST\_multiplier_t = 1 + \tau_2 \left(SST_t - T_O\right)^2 \quad SST_t > T_0 \qquad \text{(S3.12)}$$

Where T_0 is the optimum SST and SST_t is the monthly average Sea Surface Temperature (°C) at time *t*, with the annual composite SST multiplier (SST_M_y) for year *y* computed as the average of the multipliers for the 12 months of each year. The two slope parameters τ_1, τ_2 can be estimated by fitting to historical data (Table S3- 1). In the model, for all years since 1992 (start of the SST input series), the fixed annual natural mortality *M* is therefore adjusted using the average annual SST-dependent multiplier:

$$M_y^{SST} = M \times SST\_M_y \qquad \text{(S3.13)}$$

Conversely, the average survival proportion S_y for each year *y* is computed simply as:

$$S_y = e^{-M_y} \qquad \text{(S3.14)}$$

The OM3 model-estimated SST-mortality relationship is shown in Figure 4-1 (main text).

Table S3- 1: Summary of model parameter estimates for (A) Operating Models (OM) 1 and 4; (B) OM2 and (C) climate-linked OM3, shown with Hessian-based 90% confidence intervals (CI). Table shows estimates of the starting (1973) spawning biomass Bsp, the annual natural mortality rate (M), the stock-recruitment steepness parameter (h), selectivity (Sel) parameters for three time periods and the values of the CPUE-abundance hyperstability (hyps) parameters for the TVH and TIB sectors. As OMs 1,2 and 4 are not climate-linked model versions, there are no estimates of the two parameters describing the relationship between Sea Surface Temperature (SST) and M. The negative log-likelihood contributions are shown from fitting to catch-at-age (CAA) data from the surveys and historical data, as well as fitting to the mid-year survey (Survey), benchmark surveys and Preseason surveys. The recruitment residual (RecRes) also contributes to the penalised log-likelihood function. For details of the model and plots of the fits to the data series, see (Plagányi et al. 2023, Plagányi et al. 2025)

	(A) OM1 & OM4			(B) OM2			(C) OM3		
Parameter	**Value**	**90% CI**		**Value**	**90% CI**		**Value**	**90% CI**	
$B(1973)^{sp}$ (tons)	4402	3164	5640	4562	3082	6041	6870	4314	9425
M (mortality rate)	0.69	0.57	0.82	0.69	0.57	0.82	fixed 0.69		
h (steepness parameter)	fixed 0.7			**0.60**			fixed 0.7		
Sel (age 1+) 1973-1988	0.42	0.23	0.60	0.41	0.23	0.59	0.48	0.24	0.71
Sel (age 1+) 1989-2001	0.17	0.15	0.19	0.17	0.15	0.19	0.16	0.14	0.17
Sel (age 1+) post2002	0.02	0.00	0.02	0.02	0.00	0.02	0.01	0.01	0.02
Recruitment residuals (1985-2022)		38 parameters			38 parameters			38 parameters	
Additional Variance (AV) parameters: 2005	0.19	-0.52	0.89	0.19	-0.52	0.89	0.23	-0.45	0.91
AV 2006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2008	0.04	-0.28	0.35	0.04	-0.28	0.35	0.16	-0.40	0.72
AV 2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2016	0.45	0.03	0.86	0.45	0.03	0.86	0.25	-0.50	0.99
AV 2017	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
AV 2018	0.45	0.44	0.46	0.45	0.44	0.46	0.23	-0.53	0.98
AV 2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV 2021	0.45	0.43	0.47	0.45	0.43	0.47	0.32	-0.74	1.37
SST-M par1	-			-			**0.01**	**-0.06**	**0.07**
SST-M par2	-			-			**0.36**	**0.23**	**0.49**
Model estimates and depletion statistics									
$B(2022)^{sp}$ (tons)	4308	2940	5676	4696	3201	6191	3732	2588	4876
Current Depletion (Nov) *$B(2022)^{sp}$ / B(1973)sp*	1.04	0.77	1.31	0.97	0.71	1.23	0.54	0.34	0.75
No. parameters estimated	55			55			57		
'-lnL:overall	**-224.17**			-223.95			**-235.65**		
AIC	**-338.33**			**-337.90**			**-357.31**		
Likelihood contributions		**Sigma**	**q**		**Sigma**	**q**		**Sigma**	**q**
-lnL:CAA (Catch-at-age)	-78.38	0.04		-78.24	0.04		-82.88	0.04	
'-lnL:CAAsurv	-20.32	from data		-20.33	from data		-19.43	from data	
-lnL:CAA historic	-22.03	0.13		-22.04	0.13		-21.58	0.14	
-lnL:Survey Index 1+	-16.34	from data	3.964E-07	-16.59	from data	3.898E-07	-18.63	from data	3.226E-07
-lnL:Survey Index 2+	-15.69	from data	4.156E-07	-15.56	from data	4.060E-07	-18.10	from data	4.049E-07
-lnL:Survey benchmark	-3.13	from data		-3.14	from data		-2.89	from data	
'-lnL:PRESEASON	-15.52	from data	8.632E-07	-15.68	from data	8.510E-07	-14.47	from data	7.746E-07
-lnL:PRESEASON 0+	-6.38	from data	2.249E-07	-6.35	from data	2.217E-07	-6.56	from data	1.483E-07
-lnL:CPUE (TVH)	-31.19	0.21	0.0019	-30.88	0.2127	0.0019	-35.72	0.18	0.0020
-lnL:CPUE (TIB)	-23.42	0.17	0.0161	-23.47	0.1647	0.0160	-23.48	0.16	0.0162
'-lnL:RecRes	8.22	0.50		8.33	0.50		8.06	0.50	

Table S3- 2: Summary of available data inputs to compute the eHCR. As this is based primarily on the Preseason age 1+ survey index (PreseasIndex_age1, where PreseasIndex_age0 is the corresponding index for age 0+), data are shown only for years since 2005 when the Preseason survey commenced (for all years from 1989-2013 and in 2018 a Midyear survey was conducted – not shown – see Plagányi et al. 2024, 2025) as the median value of the 1+ index over 2005-2023 is used in the eHCR calculations. The survey standard error and corresponding Coefficient of Variation (CV) for the 1+ index is also shown, as is used to compute the survey-square-root (SS) and cubed-root (SSC) terms. The Standardised CPUE Indices (StdIndex) for the two CPUE sectors, TIB and TVH, are also shown, with the model version being the 'Seller' and 'Int1' versions as described in Plagányi et al. (2025). The Total Torres Strait (TS) tropical rock lobster (TRL) catch (t) is the sum of the total recorded catches from the TIB, TVH and Papua New Guinea sectors. The Total Allowable Catches (TAC) from 2020 are those based on the eHCR, with prior values being stock assessment estimates prior to the fishery formally moving to output controls.

	PreseasIndex_ age0	PreseasIndex_ age1	PreseasIndex_ age1/median*	SE_age1	CV_age1	SS_y	SSC_y	TIB_CPUE_ StdIndex	TVH_CPUE _StdIndex	Total TS TRL catch (t)	TAC (t)
2005	3.57	3.091	0.641	0.547	0.177	0.733	0.813	1.05	1.48	1145	
2006	1.436	5.874	1.218	0.949	0.162	1.018	1.012	0.74	0.69	418	471
2007	1.165	4.645	0.963	0.652	0.140	0.915	0.942	0.86	0.98	765	842
2008	2.763	2.8	0.581	0.496	0.177	0.697	0.786	0.82	0.87	507	751
2009-2013	mid-year surveys only										
2014	2.697	5.391	1.118	0.697	0.129	0.991	0.994	0.94	0.95	733	616
2015	1.539	8.241	1.709	1.179	0.143	1.217	1.140	0.80	0.63	591	769
2016	1.815	3.289	0.682	0.643	0.196	0.749	0.825	1.03	1.11	758	796
2017	0.397	2.072	0.430	0.311	0.150	0.608	0.718	0.89	0.73	391	495
2018	1.111	6.209	1.288	1.97	0.317	0.968	0.979	0.77	0.70	418	320
2019	2.014	7.327	1.520	1.573	0.215	1.107	1.070	1.06	0.93	584	495
2020	2.412	4.998	1.037	0.901	0.180	0.930	0.953	1.19	1.23	486	582
2021	0.979	6.259	1.298	1.056	0.169	1.047	1.031	1.05	0.68	341	623
2022	0.927	4.495	0.932	1.199	0.267	0.845	0.894	1.03	0.96	379	615
2023	3.436	3.647	0.756	0.949	0.260	0.764	0.835	1.24	1.06	358	521
2024	0.424	8.366	1.735	1.891	0.226	1.176	1.114	1.14	0.93	354	530

*median = 4.82 (2005-2023)

A.4 Supplementary Appendix S.4: Additional MSE results

A large number of plots and tables (with the numeric values corresponding to the plots as shown here) were available for review by the TRLRAG & TRLWG, with different presentation styles used to account for individual preferences. For each eHCR candidate, performance statistics were also available for individual Operating Models (OMs) as per Figure S4- 1, Figure S4- 2, Figure S4- 3, Figure S4- 4 below, as well as averaged across the full Reference Set of OMs (Figure S4- 5,Figure S4- 6).

Figure S4- 1: Example of the variability in key performance statistics when using the Seahorse (SH) rule and shown separately for each of the 4 Operating Models (OMs). For each OM, from top left to bottom right, plots show (A) future projected catch, (B) depletion proportion relative to carrying capacity K, (C) projected fishing mortality and (D) risk statistics, namely the probability of depletion below each of two reference levels, BLIM = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, and probability of fishery closure and finally probability of triggering potential closure. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

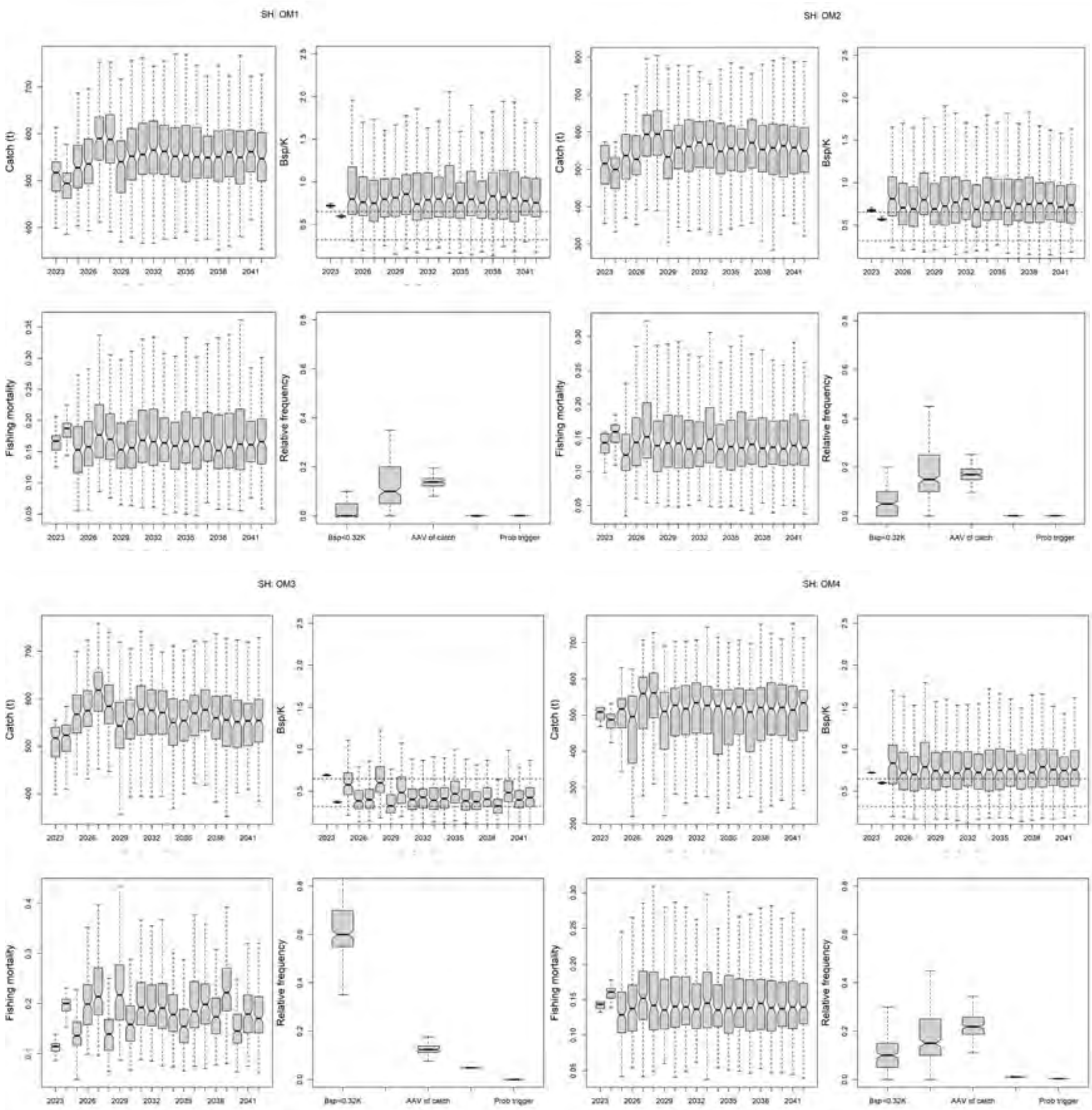


Figure S4- 2: Example of the variability in key performance statistics when using the Osprey (SS670_5b) rule and shown separately for each of the 4 Operating Models (OMs). For each OM, from top left to bottom right, plots show (A) future projected catch, (B) depletion proportion relative to carrying capacity K, (C) projected fishing mortality and (D) risk statistics, namely the probability of depletion below each of two reference levels, BLIM = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, and probability of fishery closure and finally probability of triggering potential closure. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

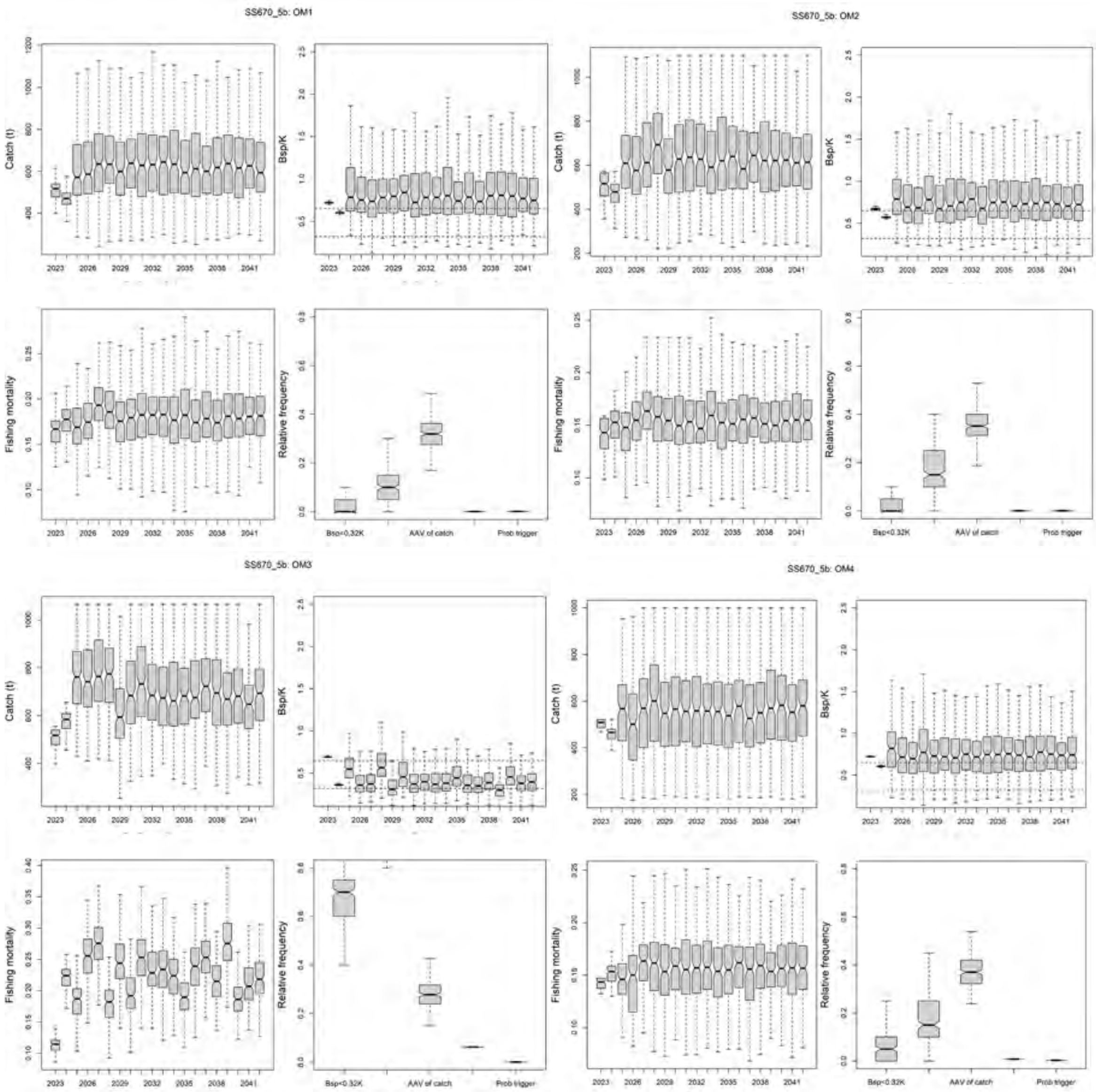


Figure S4- 3: Illustrative example using the Osprey rule (SS670_5b) and 2 contrasting OMs 1 and climate-linked OM3 to highlight differences in the future (A) projected catch (t), Recommended Biological Catch (RBC) (t), (C) Discards (t) and Traditional or subsistence take (t). Notably the simulated discards in OM3 are more variable because they depend on projected Sea Surface Temperature (SST) as well. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

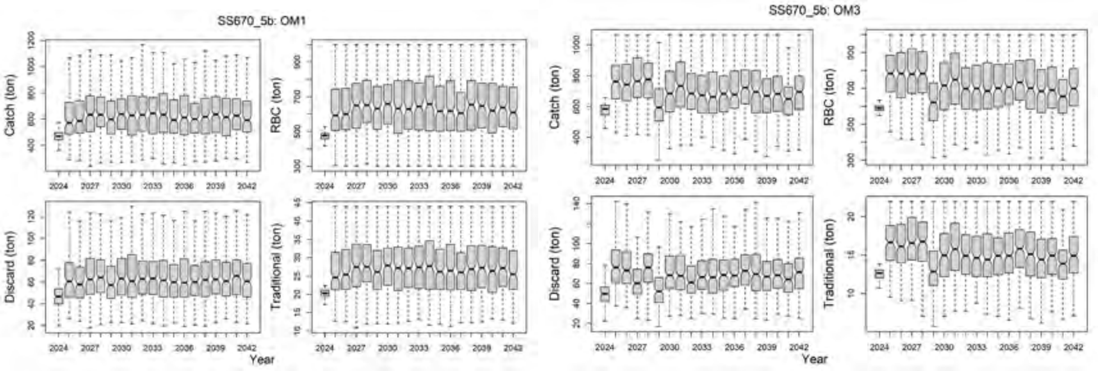


Figure S4- 4: Worm plots showing two randomly selected individual trajectories compared with the median values of total catch and spawning biomass corresponding to OM1 and use of the Seahorse rule, Dolphin rule and Osprey rule.

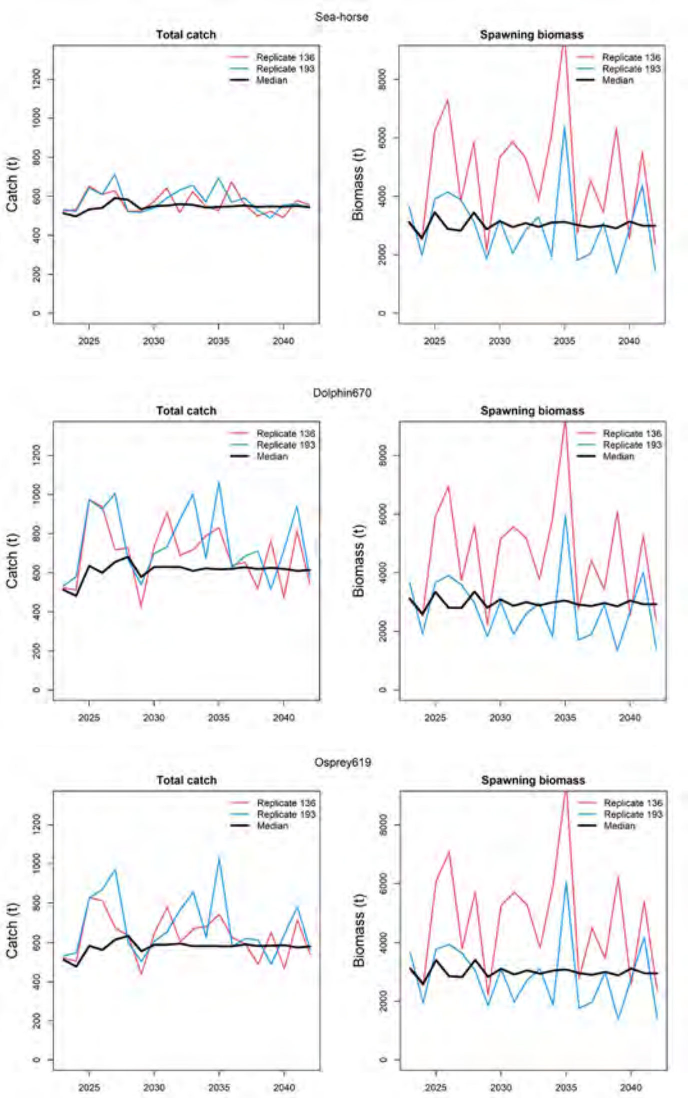


Figure S4- 5: Comparison of risk statistics for final set of eHCRs considered, namely (top row) Seahorse (SH) rule, (2nd row) variants of the Turtle Rule with multipliers (from left to right) 619 and 640; variants of the Dolphin rule with multipliers 619, 640, 670; and variants of the Osprey Rule with multipliers 619, 640, 670. Each subplot shows the probability of depletion below each of two reference levels, BLIM = 0.32K and precautionary level 0.48K limit reference point, together the Average Annual Variability (AAV) of catch, and probability of fishery closure and finally probability of triggering potential closure. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values, with outliers shown as open circles.

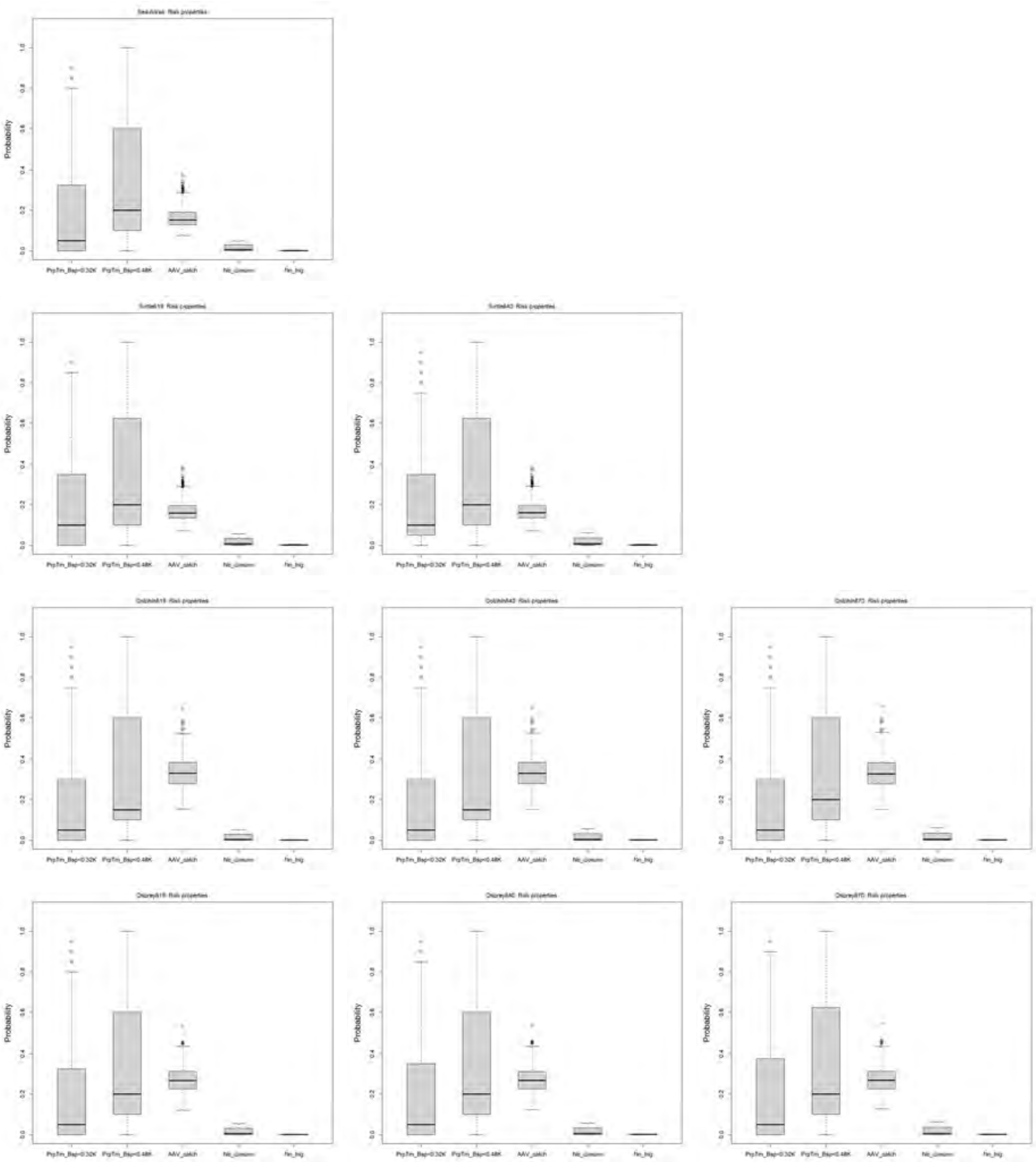
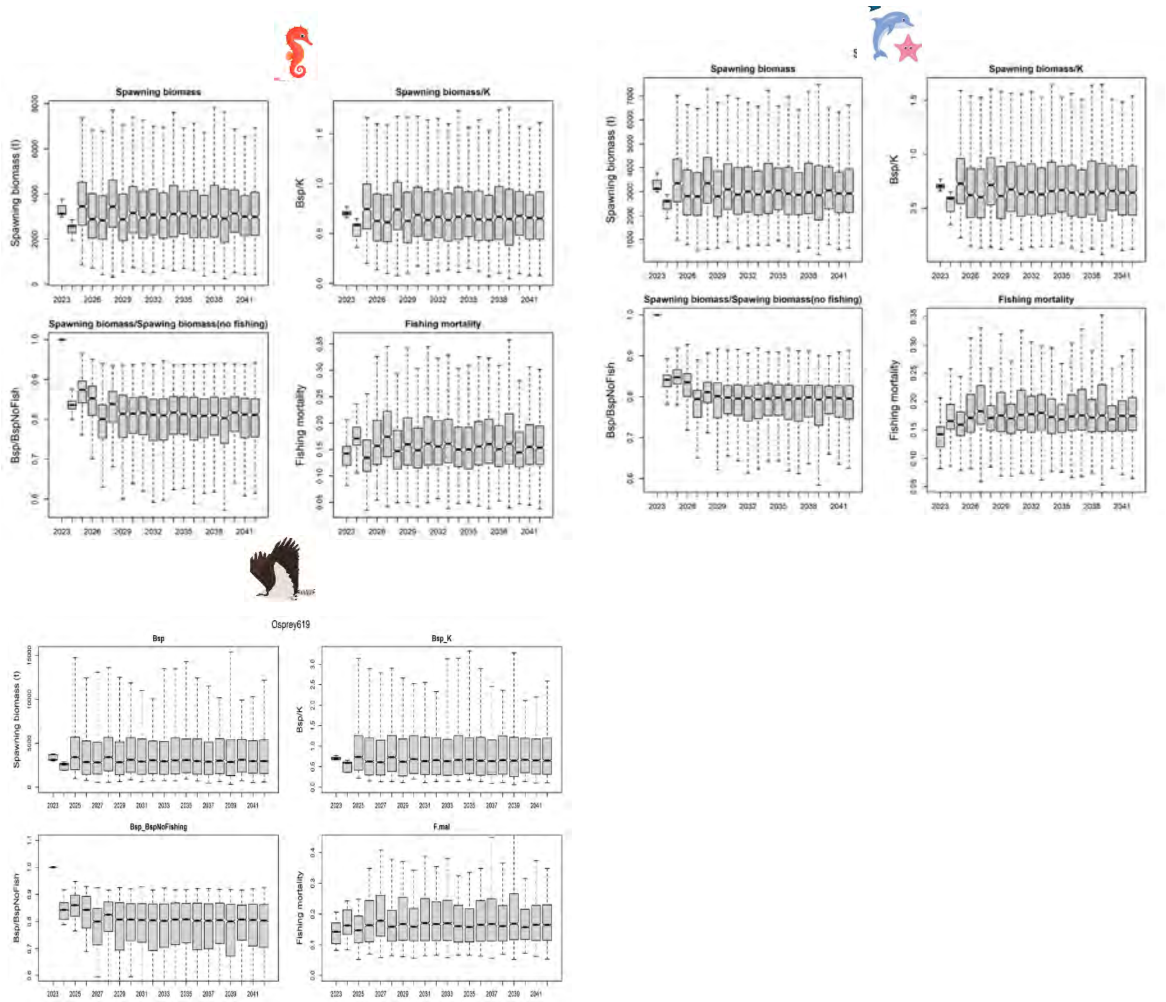


Figure S4- 6: Summary of future projected spawning biomass, depletion proportion relative to carrying capacity K, depletion relative to comparable no-fishing level and fishing mortality for TRL when using the final Seahorse (SH), Dolphin (SS670) and Osprey (Osprey619) eHCRs. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.



A.5 Supplementary Appendix S.5: Fuller set of performance statistics and outputs for final set of eHCR candidates

A full set of performance statistics for the Seahorse, Turtle, Dolphin and Osprey rules (including model variants) are provided in this appendix.

A.5.1 Seahorse Rule

Figure S5- 1: Biomass trajectories with full range variation in the project period for using Seahorse rule. The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

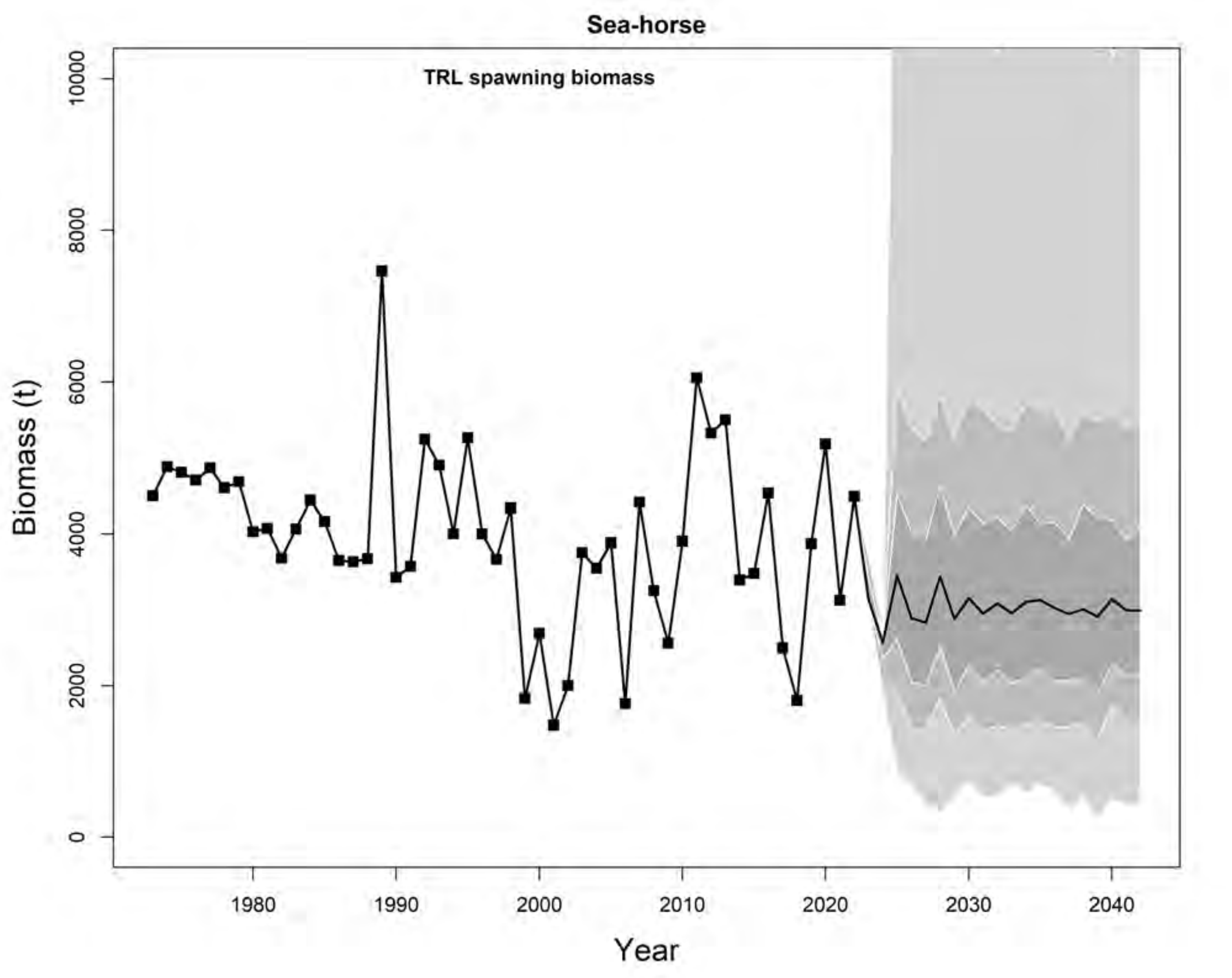


Figure S5- 2: Catch history bar plot and trajectories in the project period for using Seahorse rule. The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

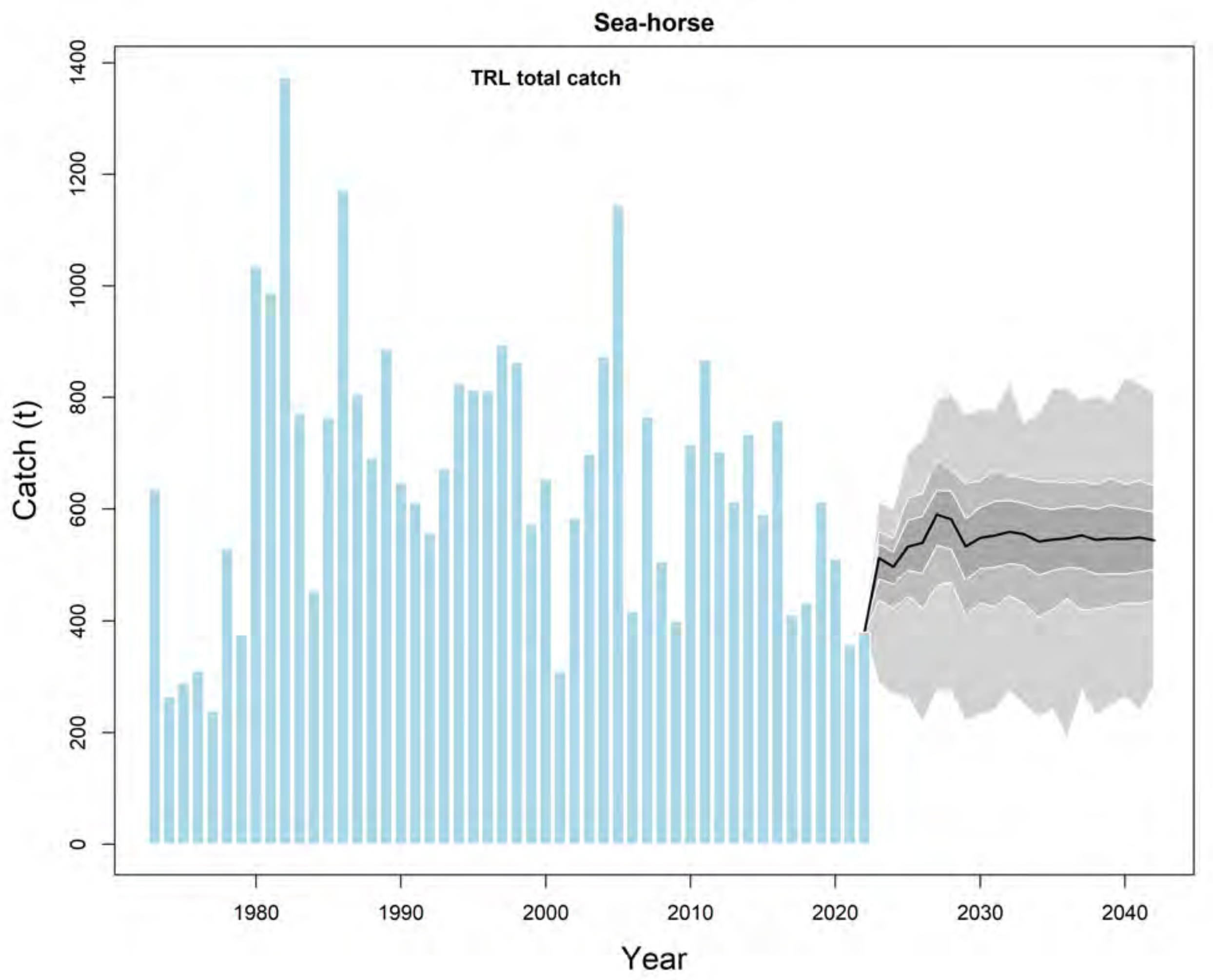


Figure S5- 3: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Seahorse rule.

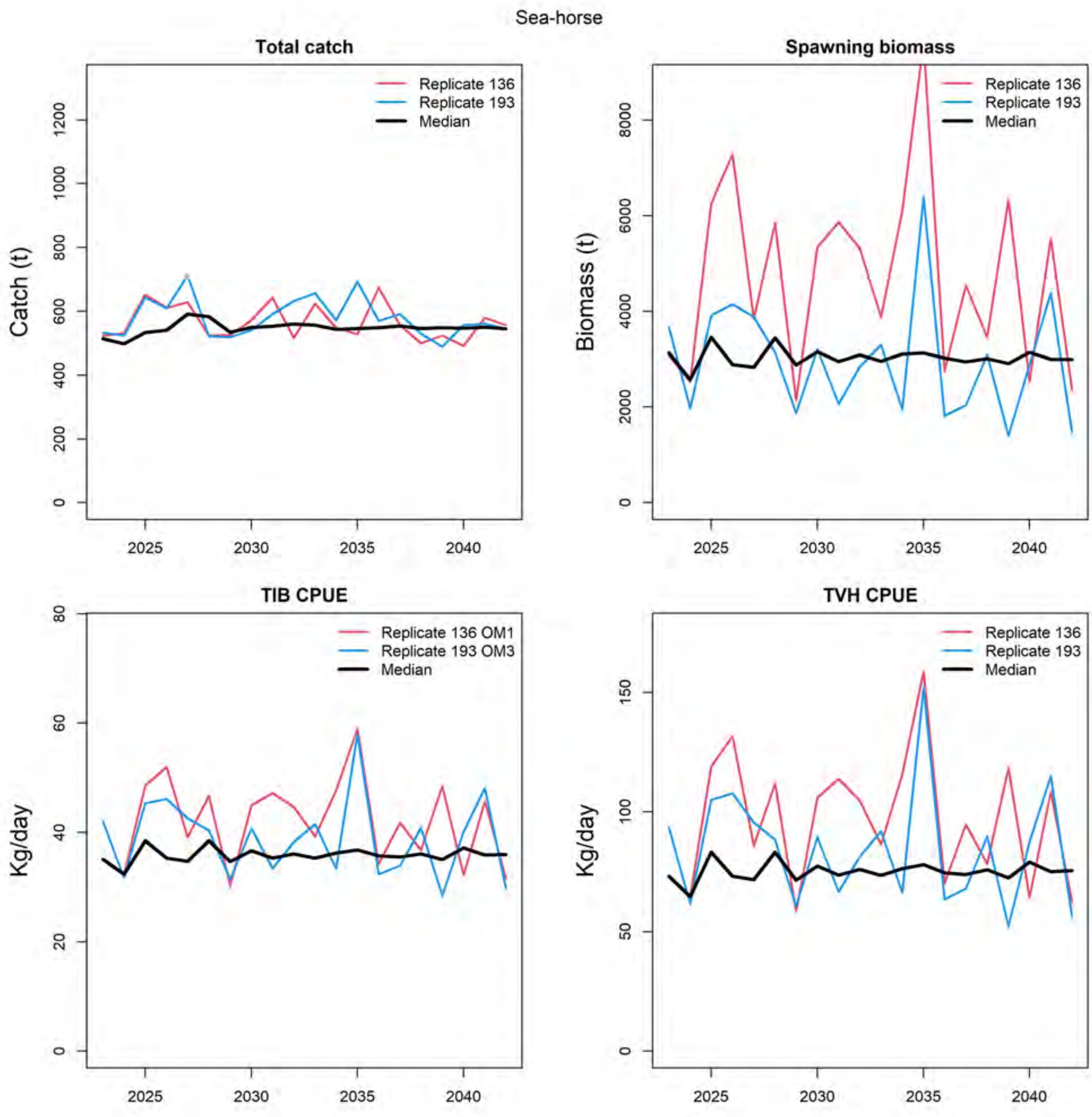


Figure S5- 4: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Seahorse rule. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

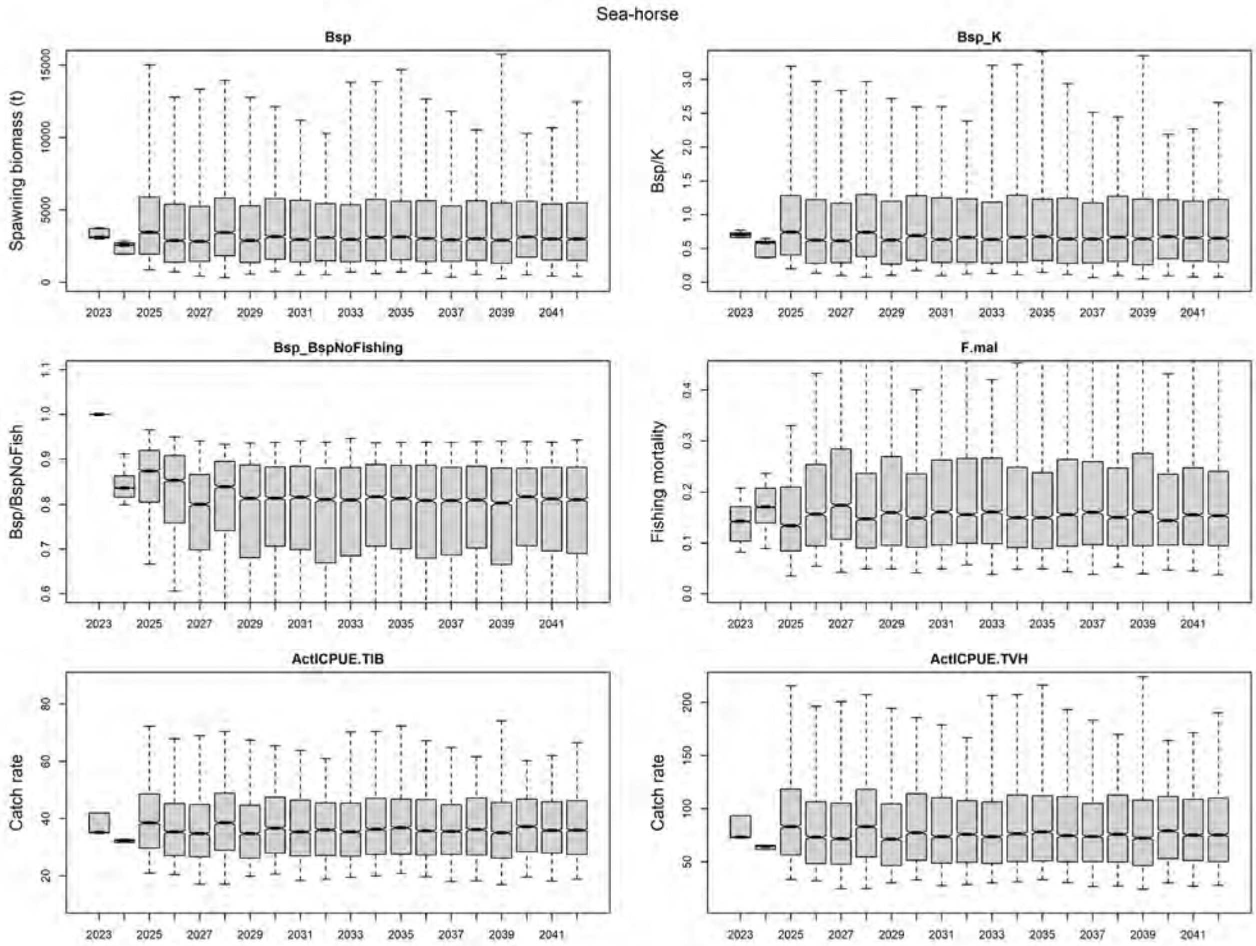


Figure S5- 5: Bar plots of catch related variables from all simulations for using Seahorse rule. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

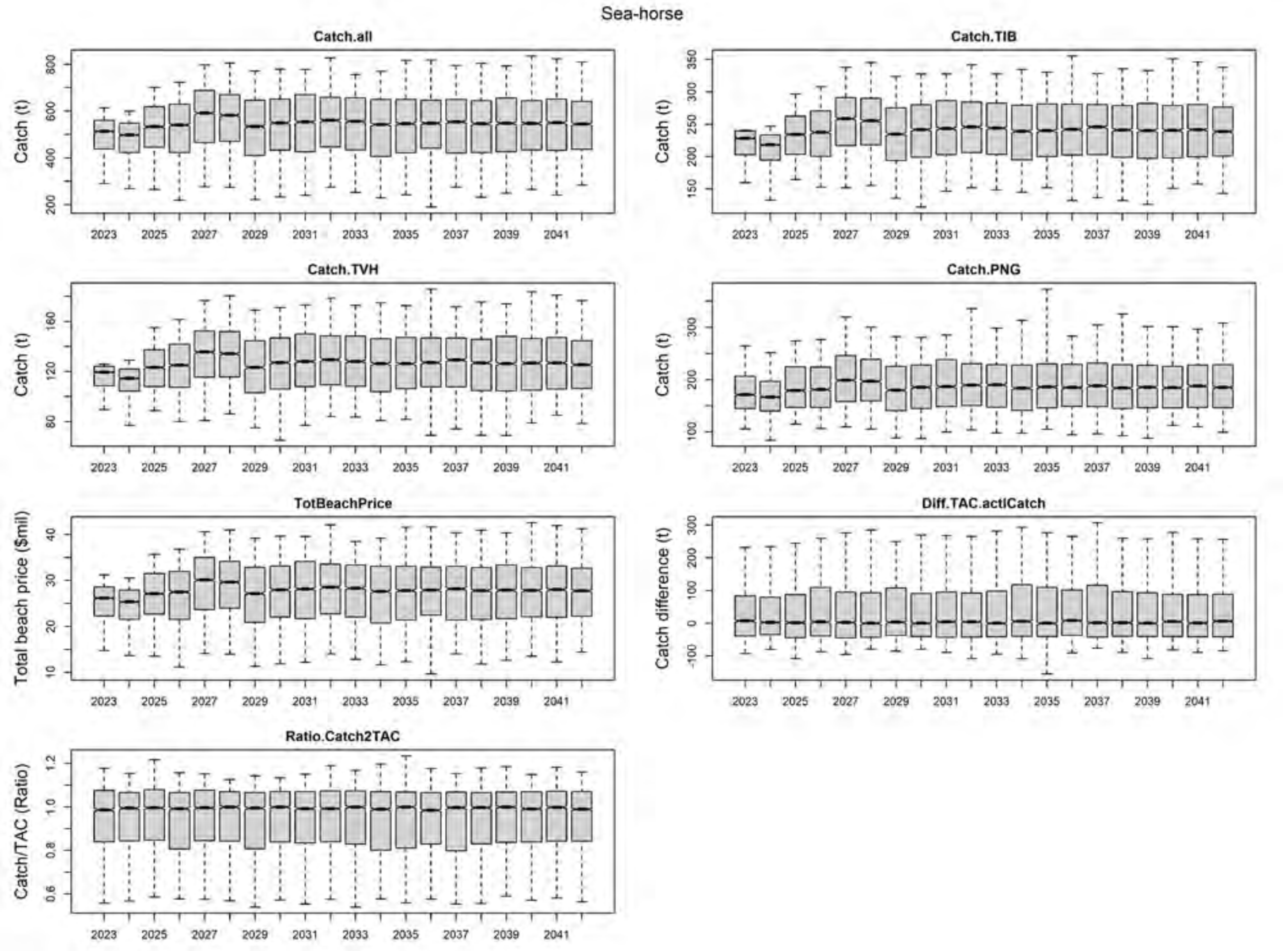
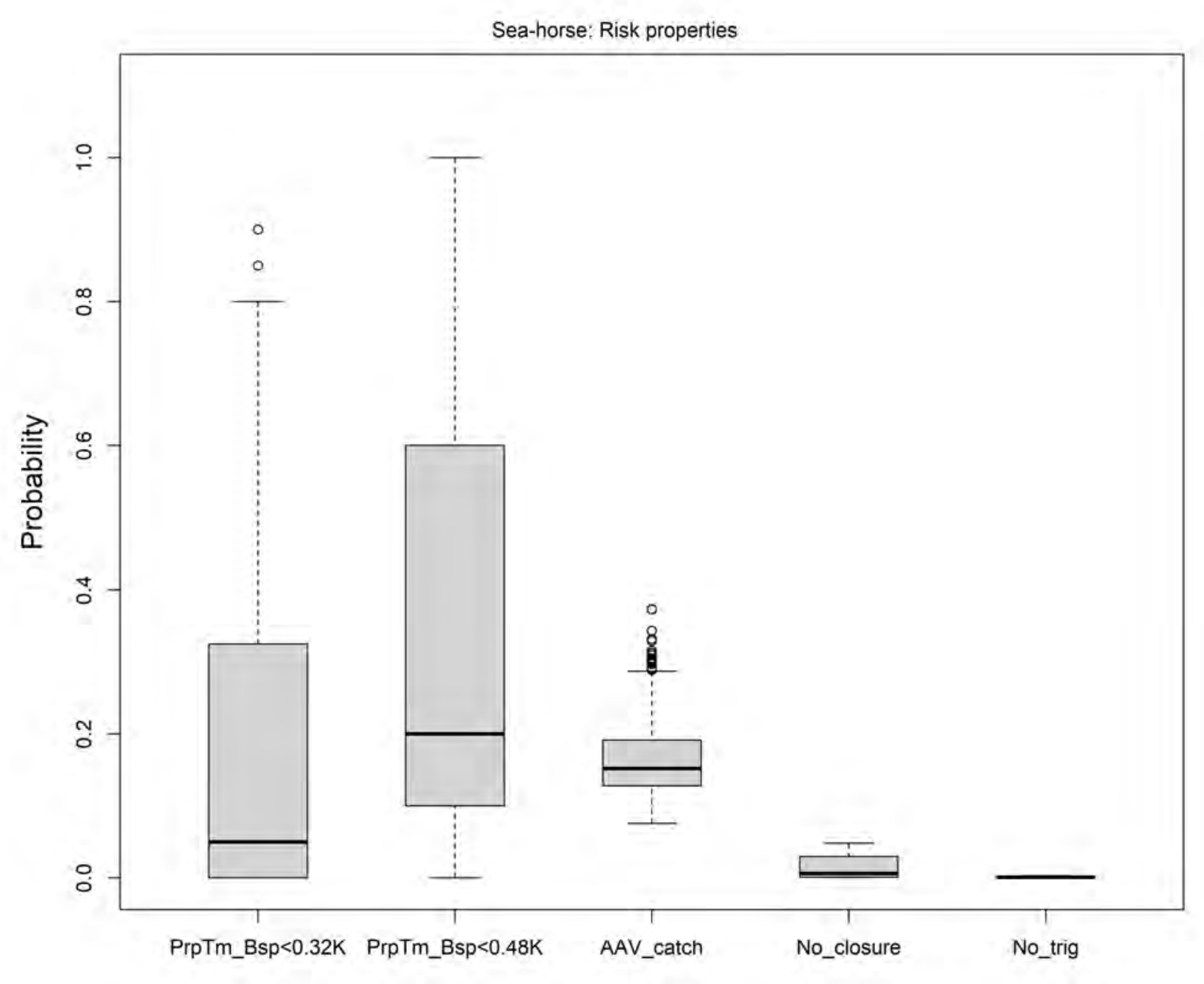


Figure S5- 6: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Seahorse rule. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



A.5.2 Dolphin Rule

Dolphin619

Figure S5- 7: Biomass trajectories with full range variation in the project period for using Dolphin rule (Dolphin619). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

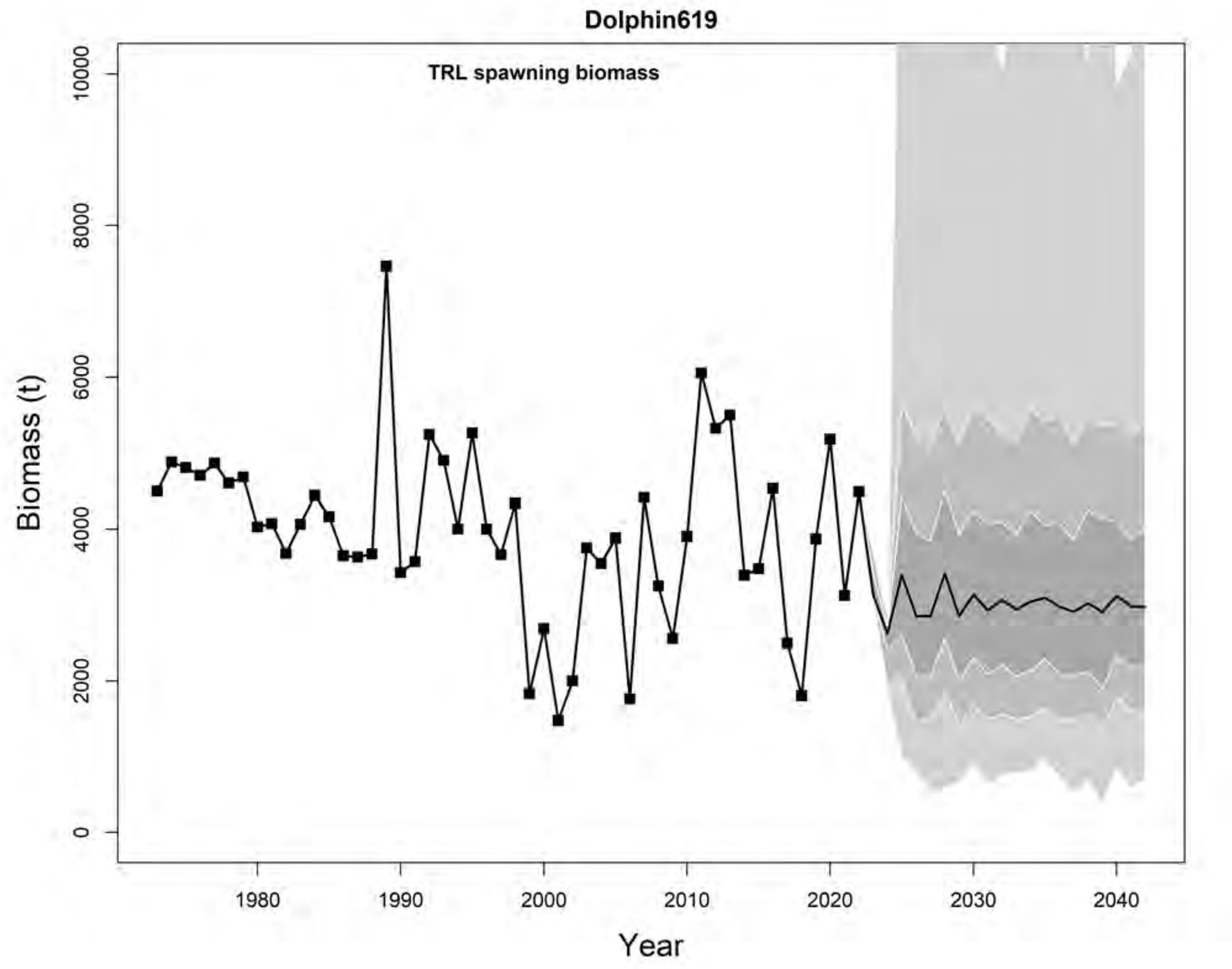


Figure S5- 8: Catch history bar plot and trajectories in the project period for using Dolphin rule (Dolphin619). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

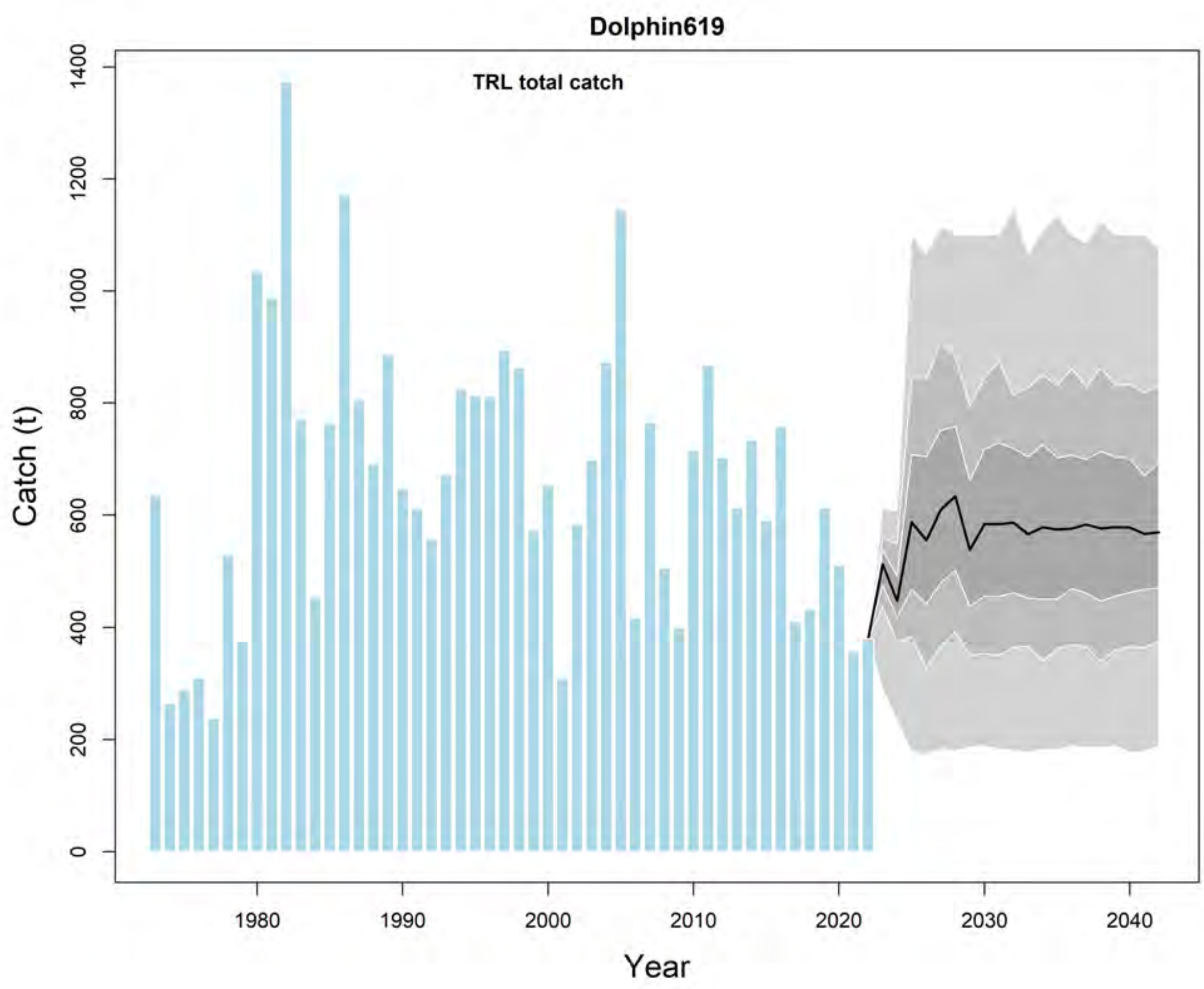


Figure S5- 9: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Dolphin rule (Dolphin619).

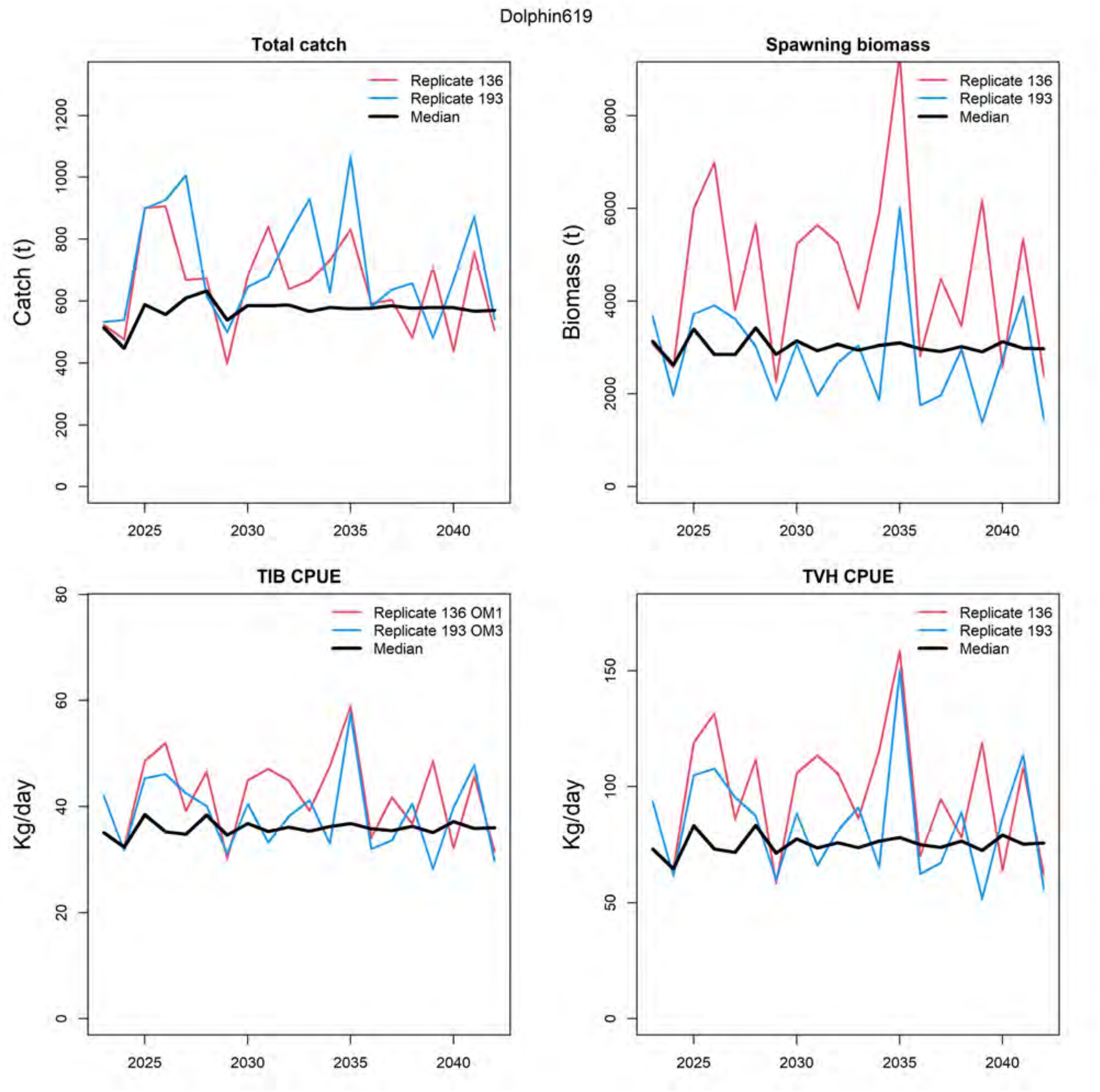


Figure S5- 10: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Dolphin rule (Dolphin619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

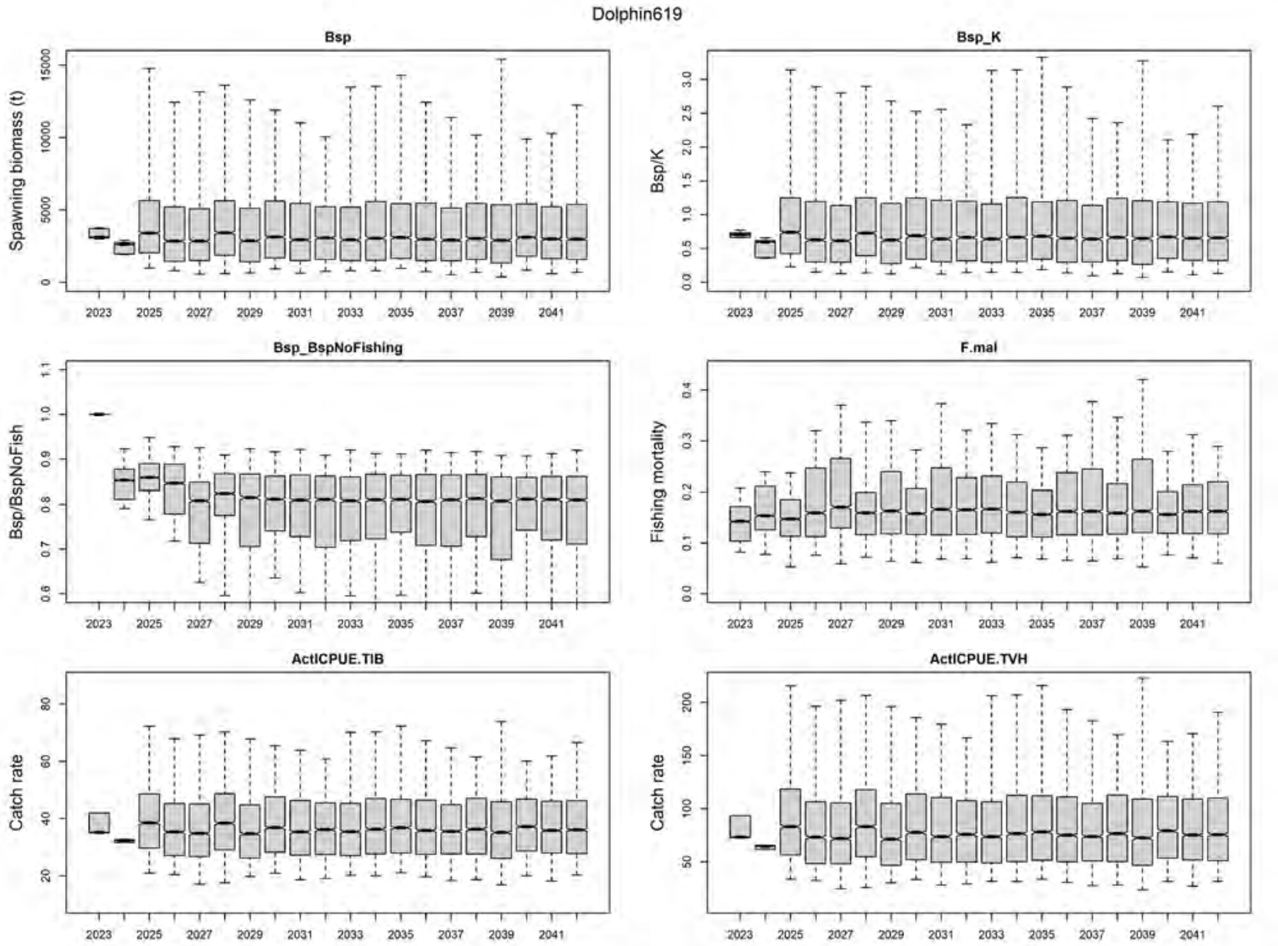


Figure S5- 11: Bar plots of catch related variables from all simulations for using Dolphin rule (Dolphin619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

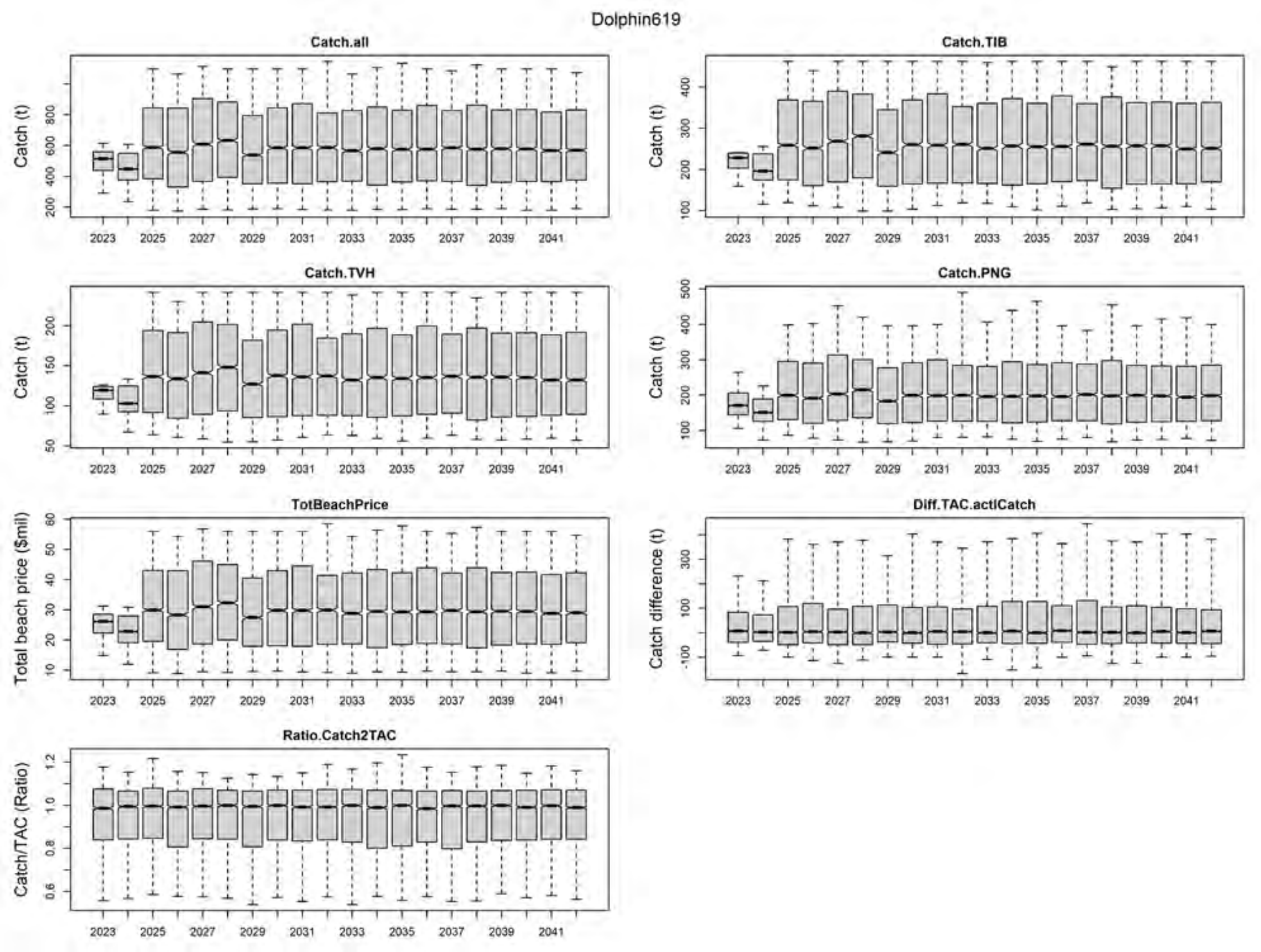
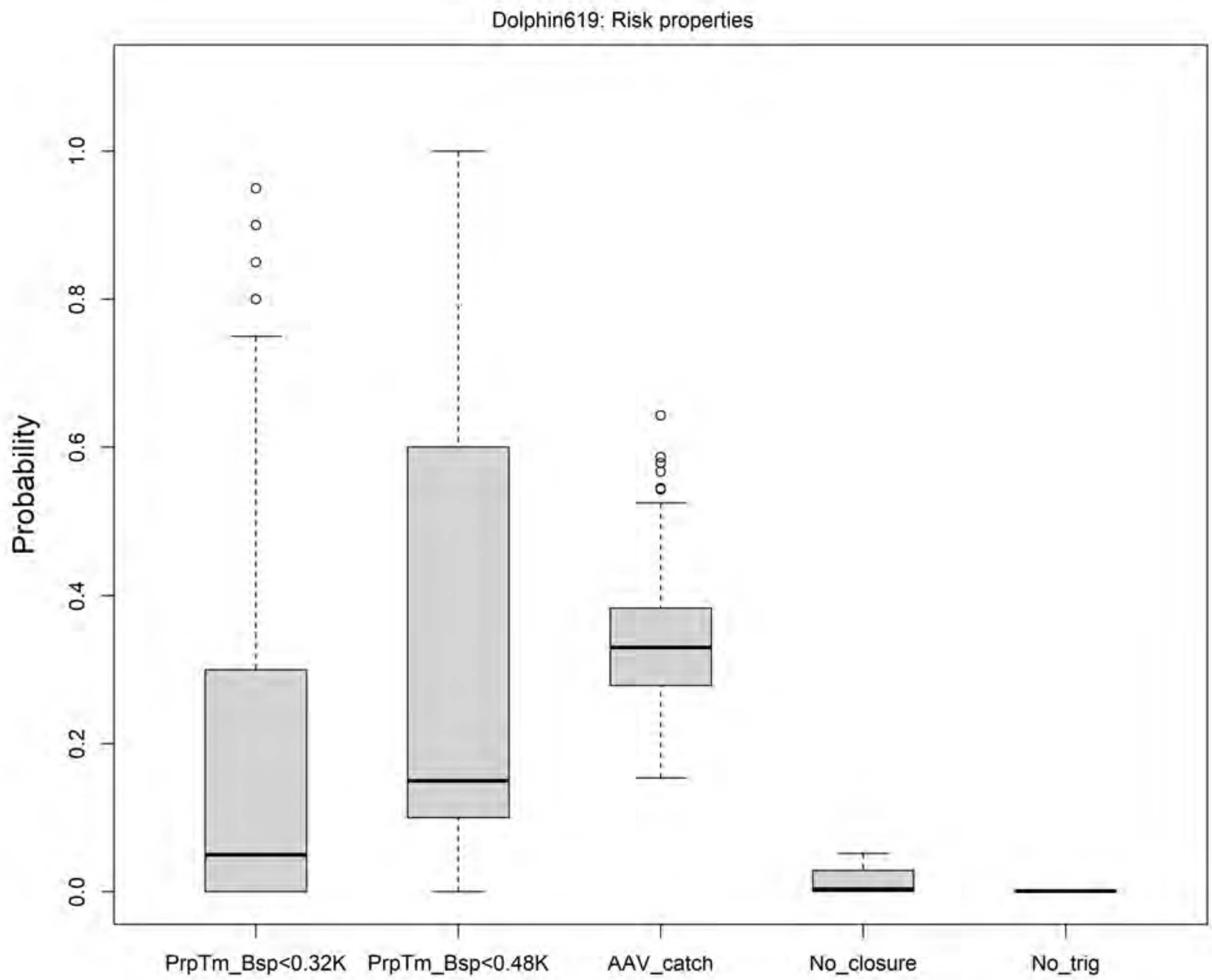


Figure S5- 12: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Dolphin rule (Dolphin619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



Dolphin640

Figure S5- 13: Biomass trajectories with full range variation in the project period for using Dolphin rule (Dolphin640). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

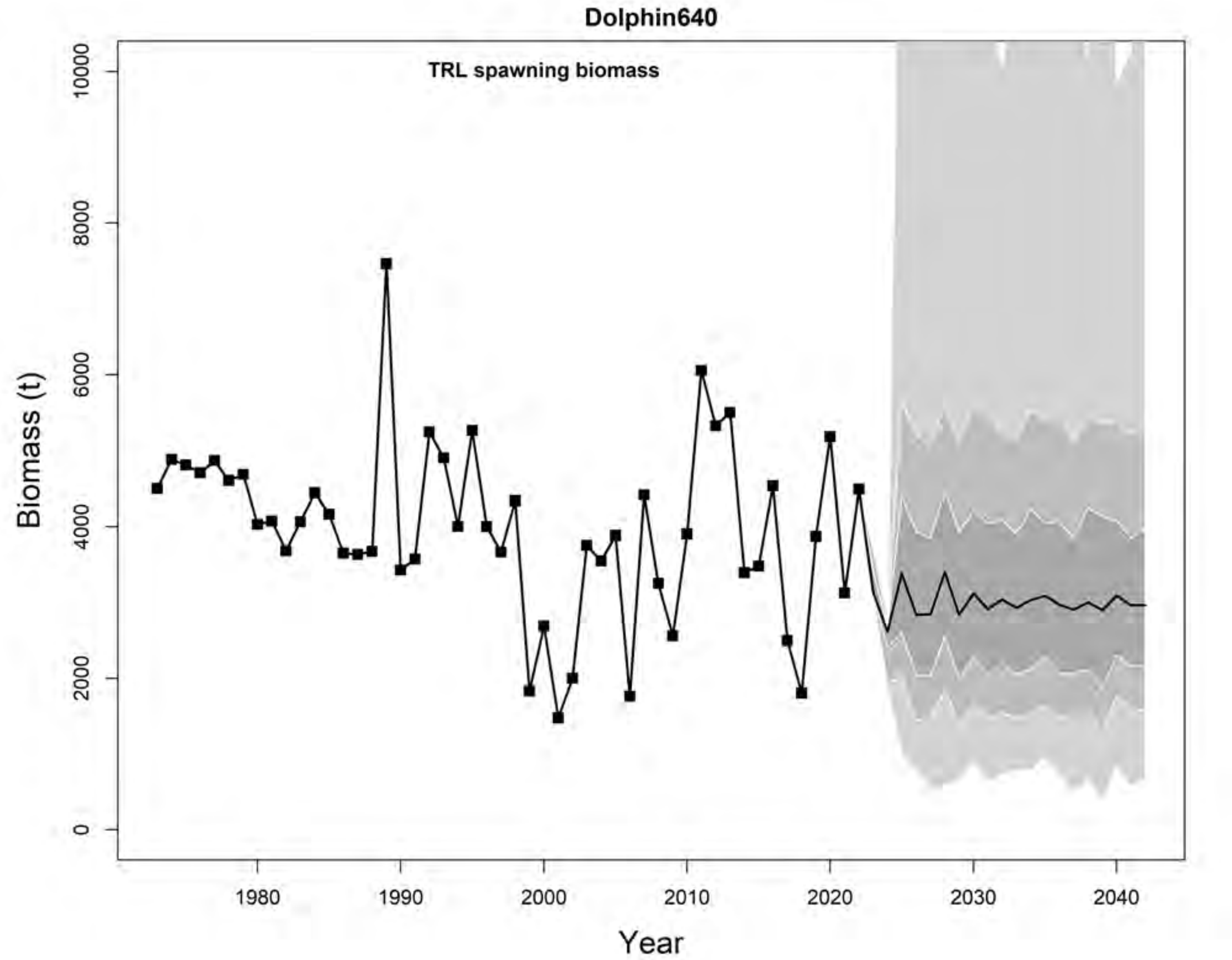


Figure S5- 14: Catch history bar plot and trajectories in the project period for using Dolphin rule (Dolphin640). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

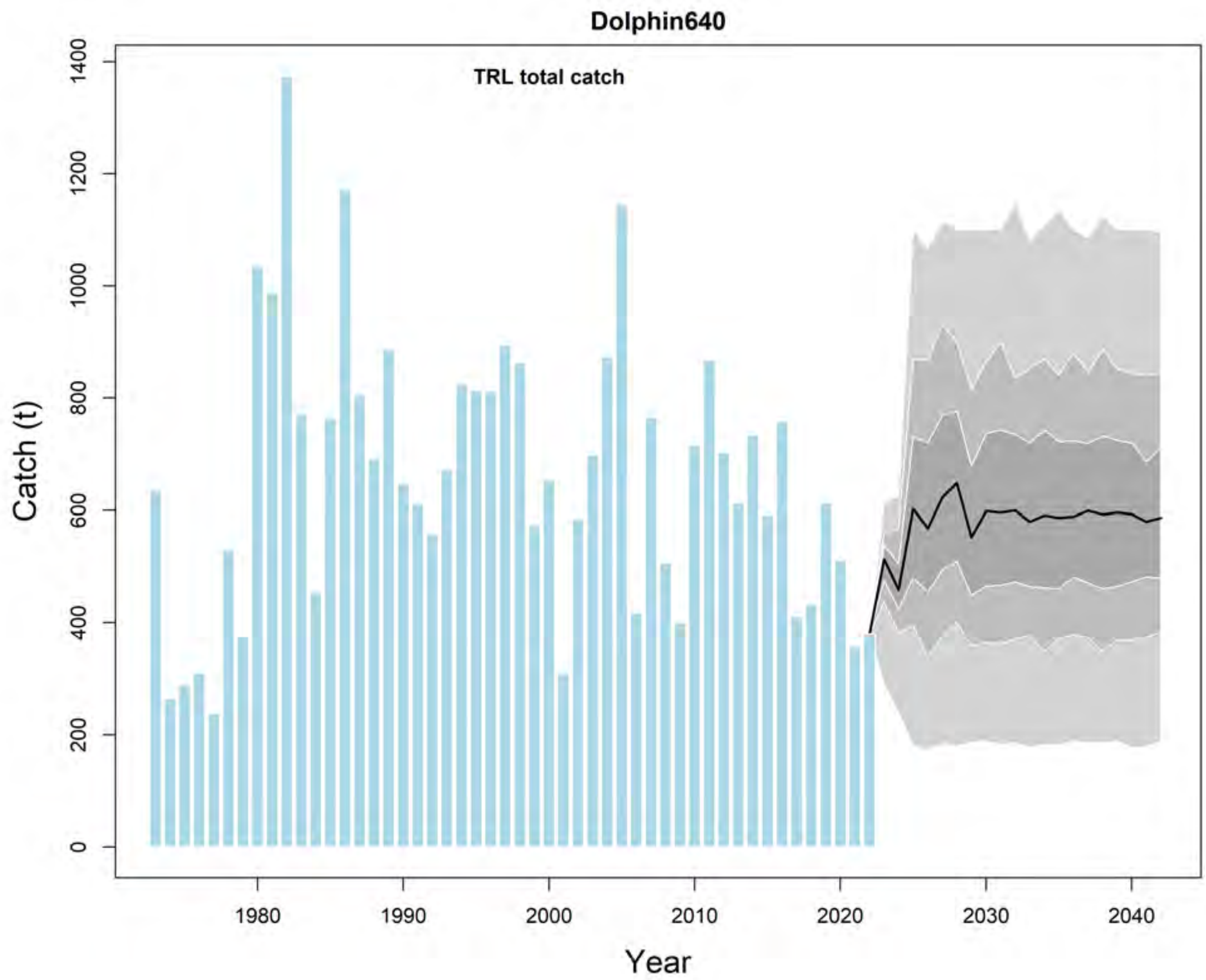


Figure S5- 15: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Dolphin rule (Dolphin640).

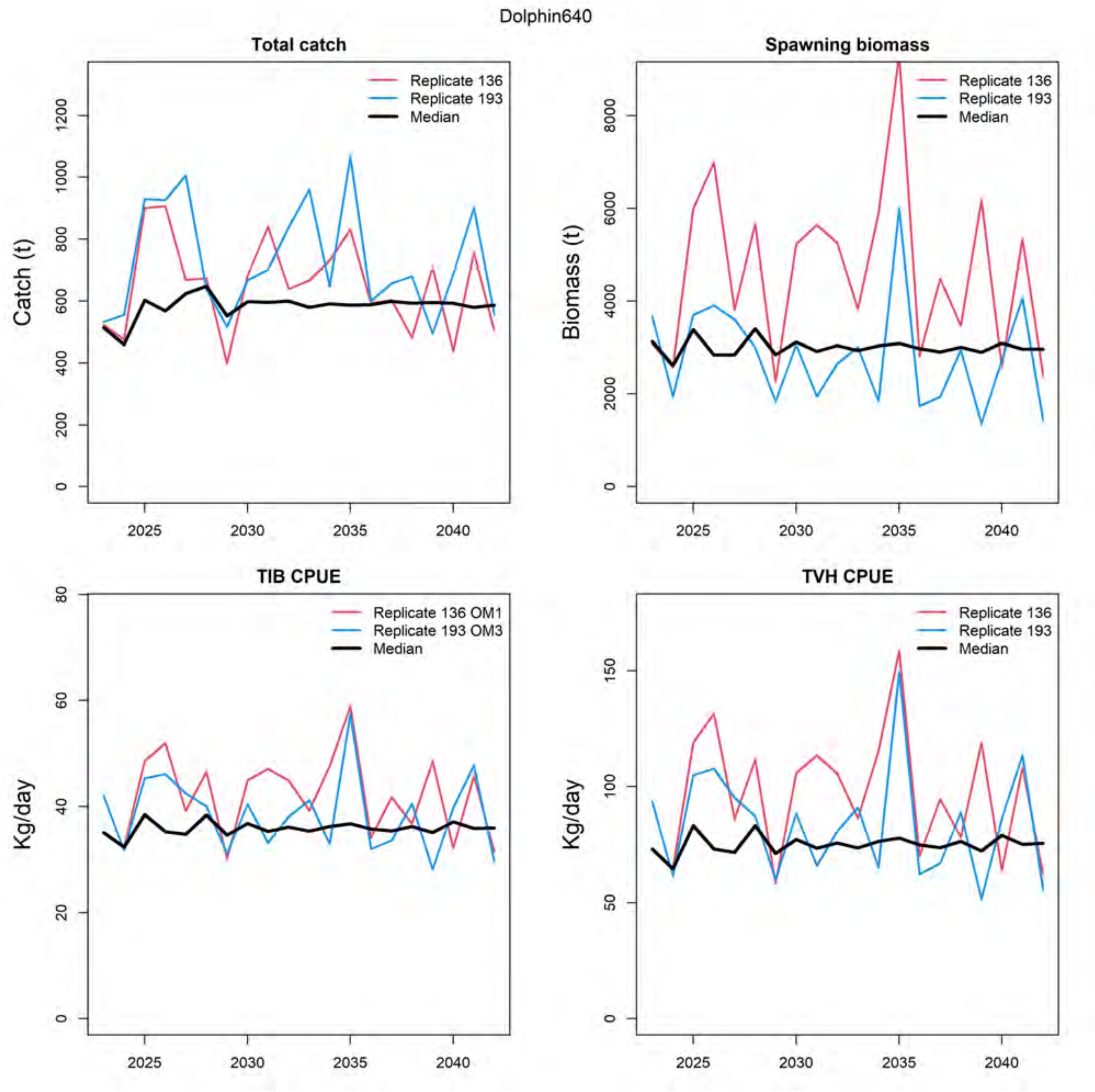


Figure S5- 16: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Dolphin rule (Dolphin640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

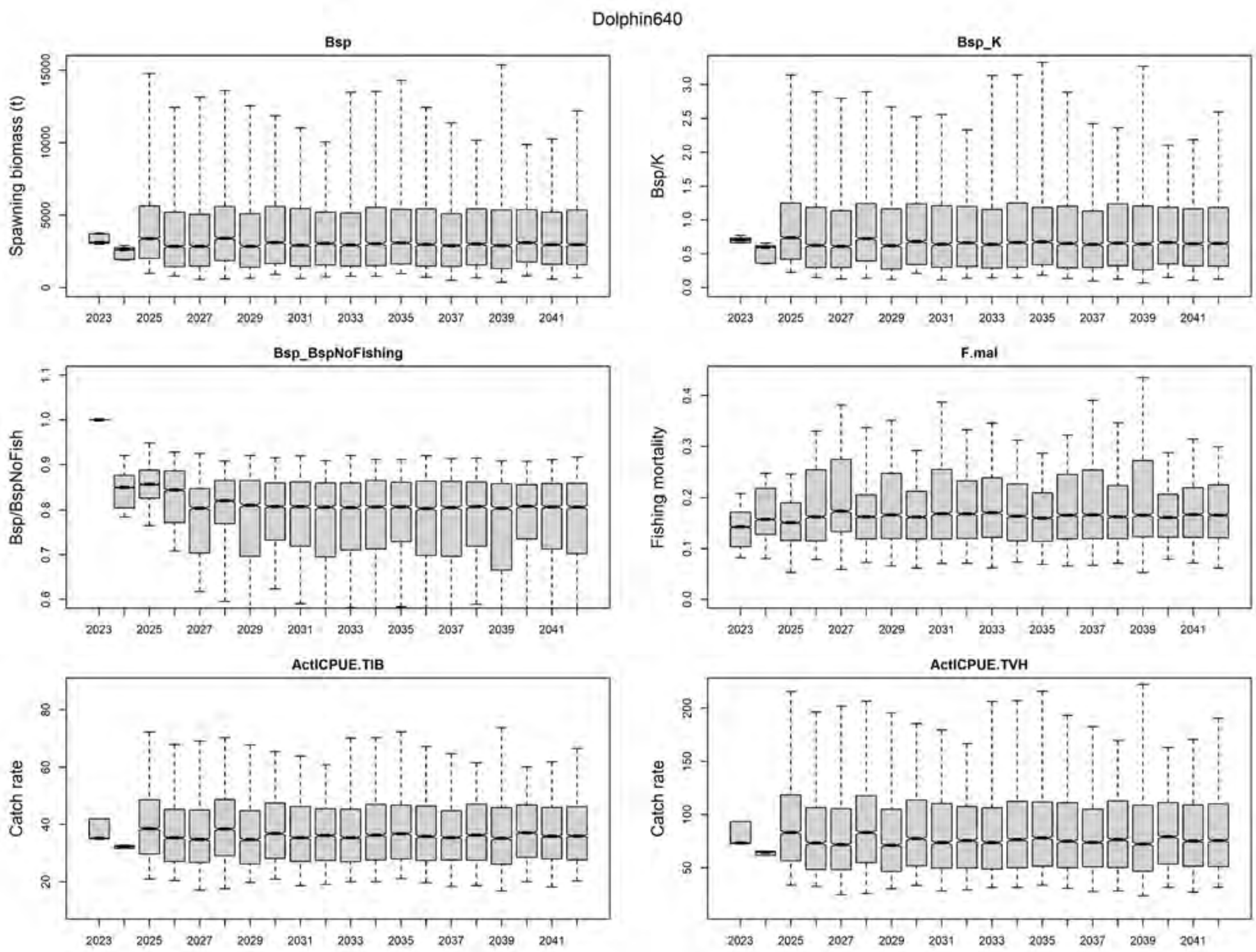


Figure S5- 17: Bar plots of catch related variables from all simulations for using Dolphin rule (Dolphin640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

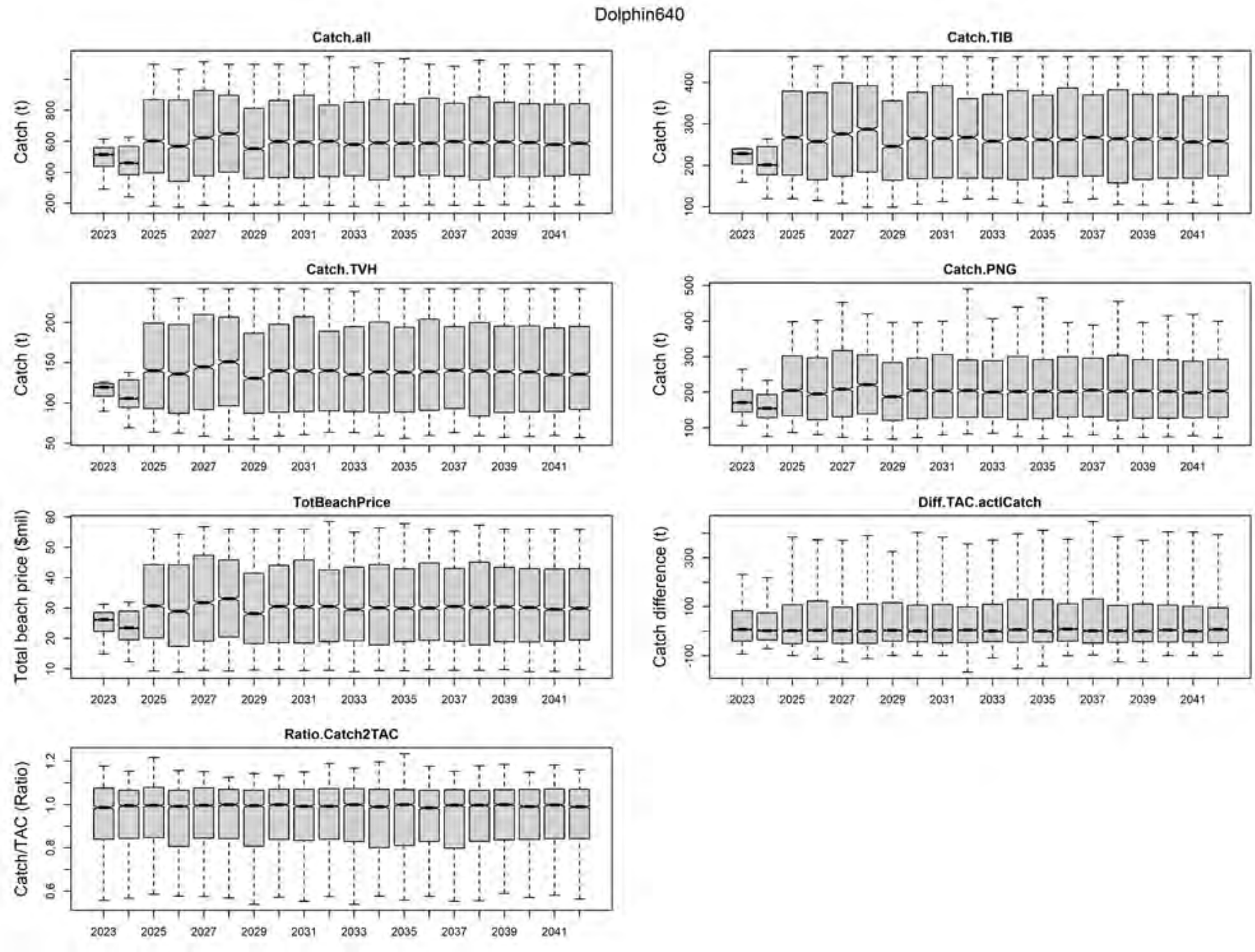
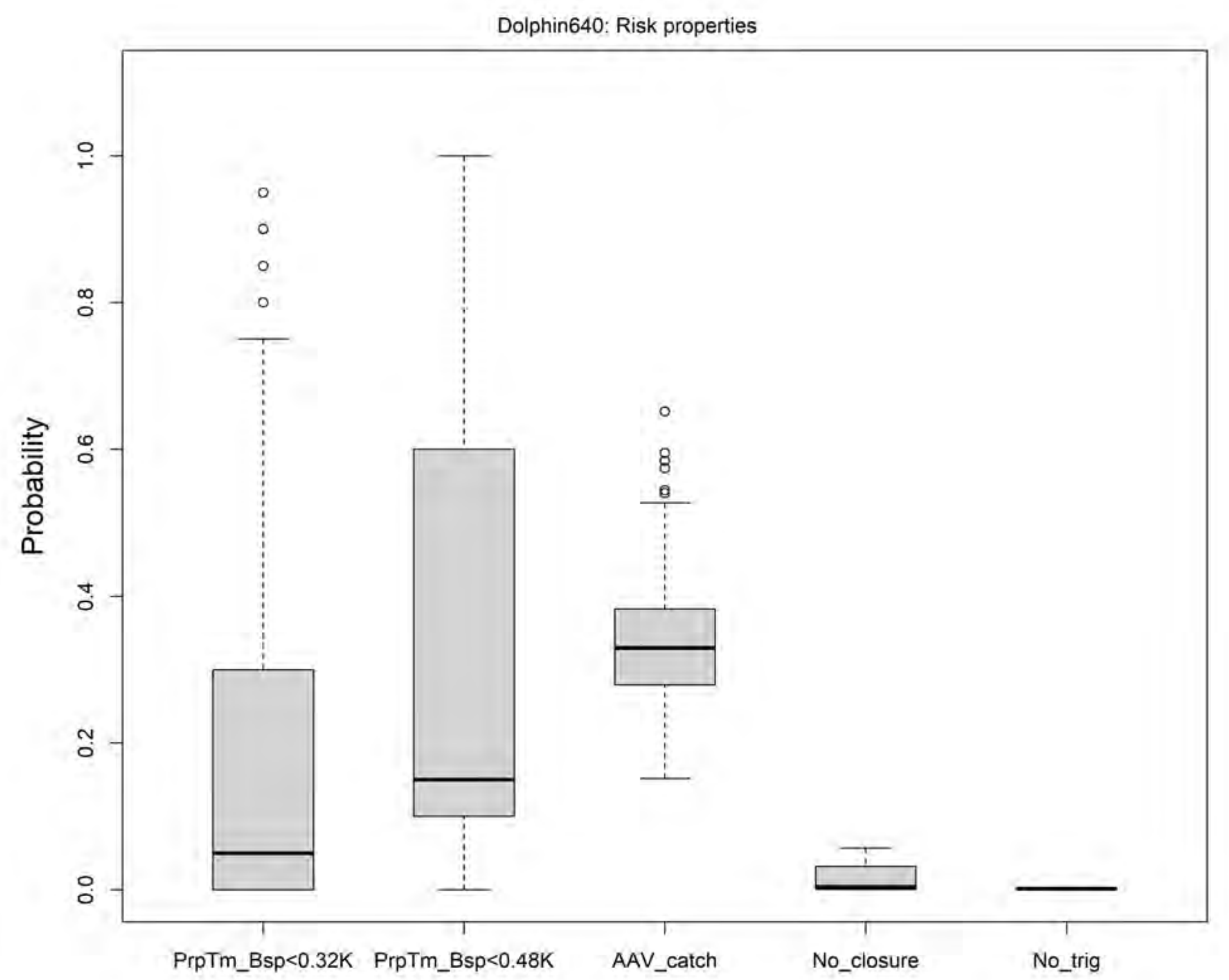


Figure S5- 18: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Dolphin rule (Dolphin640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



Dolphin670

Figure S5- 19: Biomass trajectories with full range variation in the project period for using Dolphin rule (Dolphin670). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

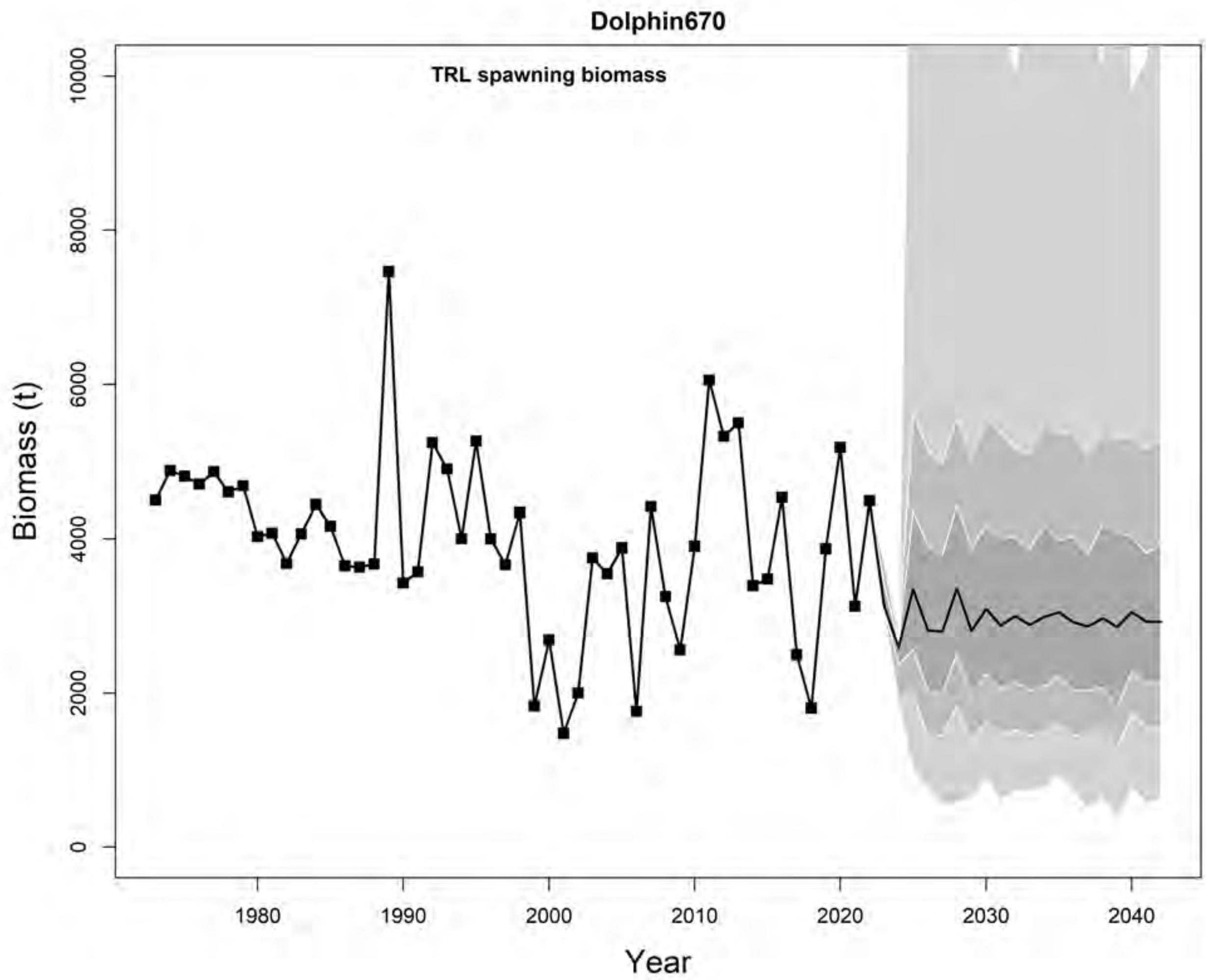


Figure S5- 20: Catch history bar plot and trajectories in the project period for using Dolphin rule (Dolphin670). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

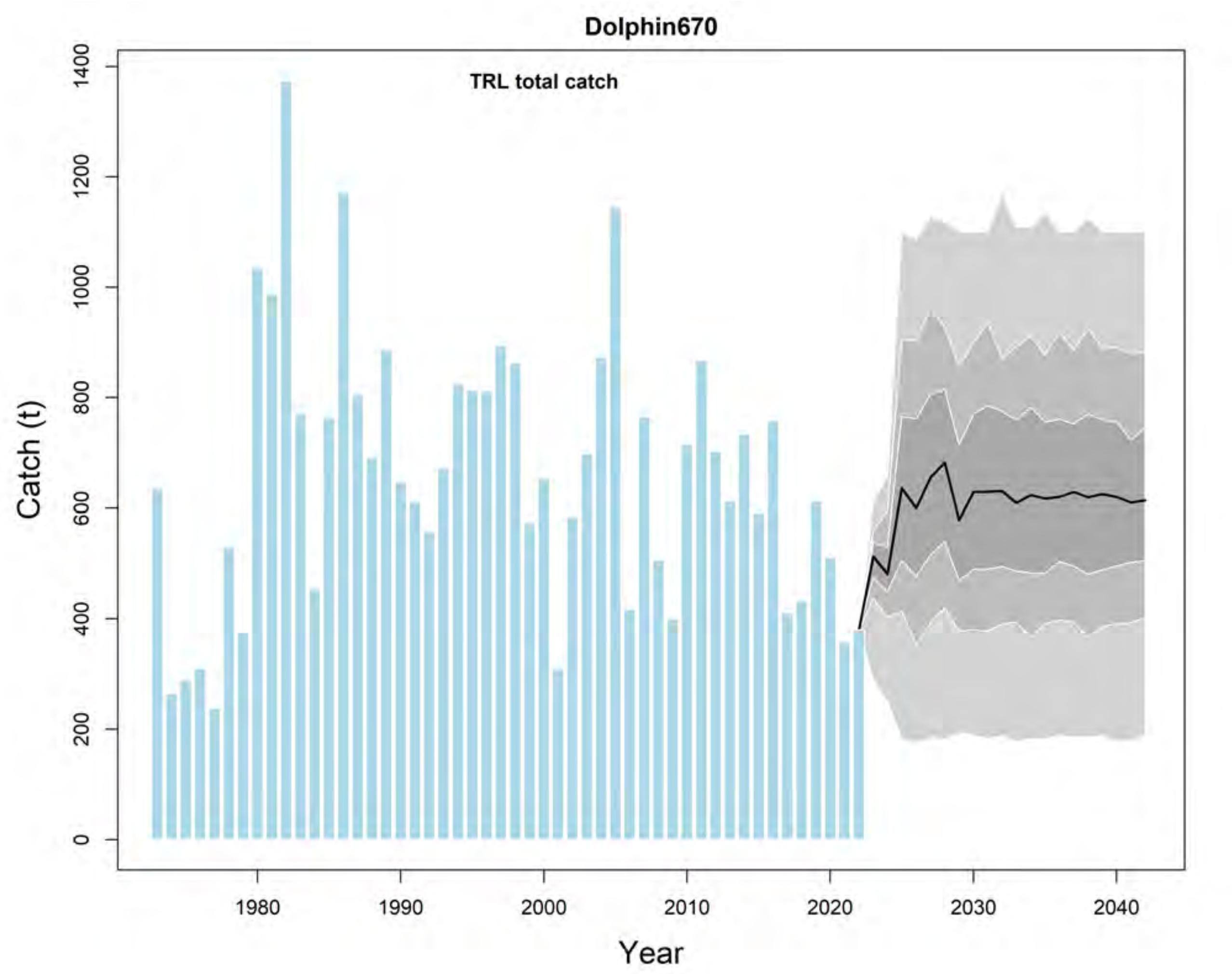


Figure S5- 21: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Dolphin rule (Dolphin670).

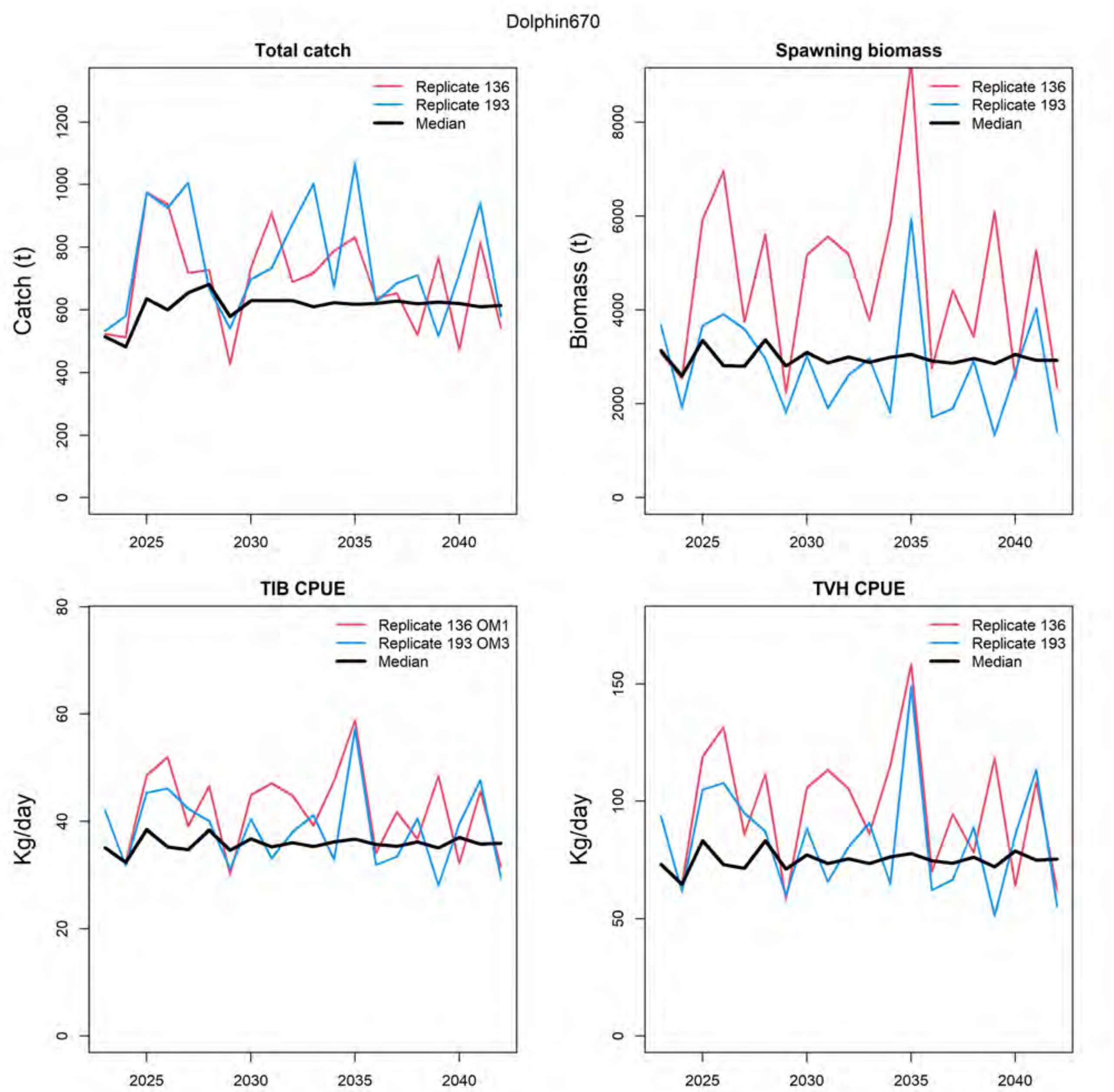


Figure S5- 22: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Dolphin rule (Dolphin670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

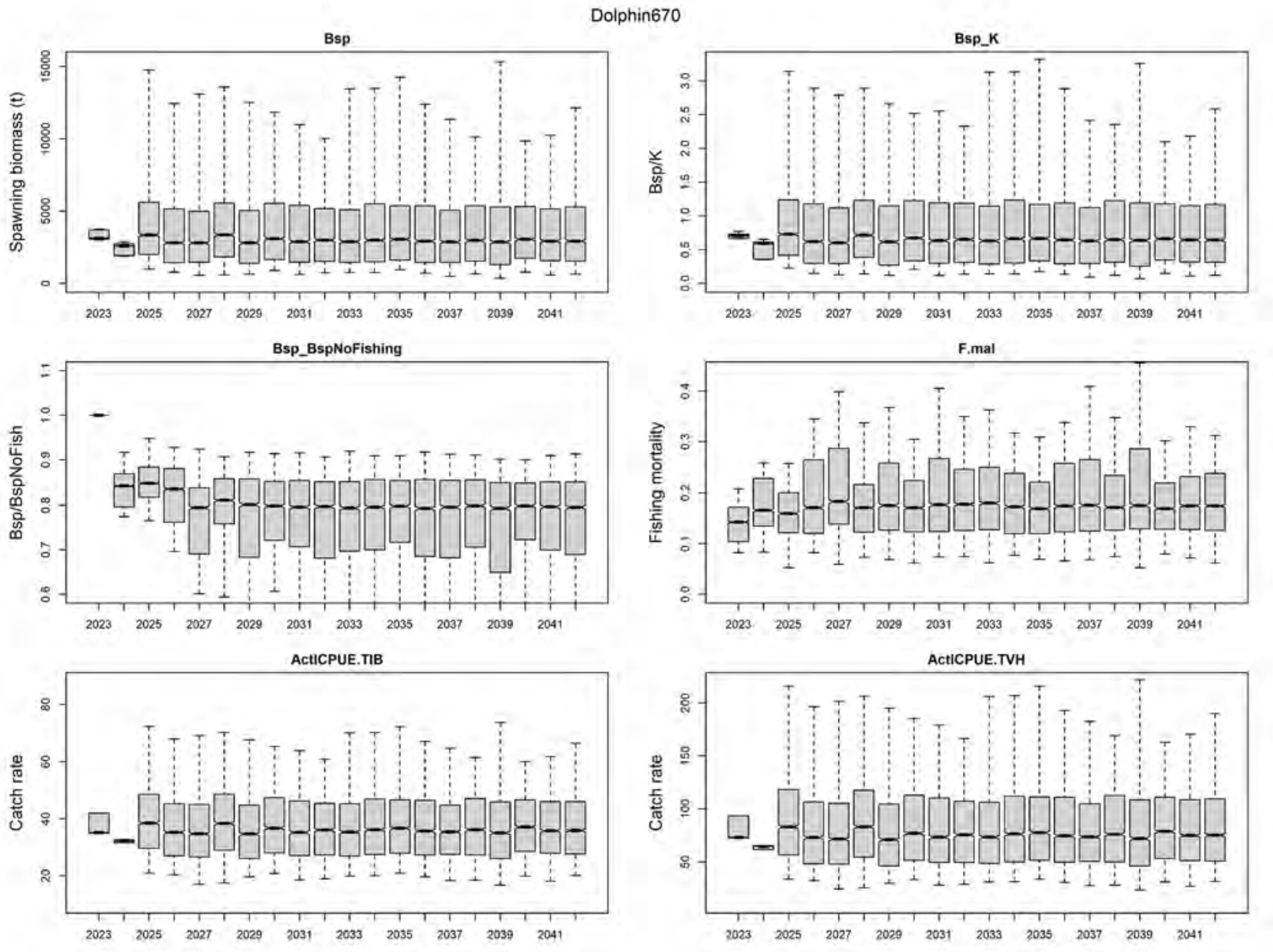


Figure S5- 23: Bar plots of catch related variables from all simulations for using Dolphin rule (Dolphin670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

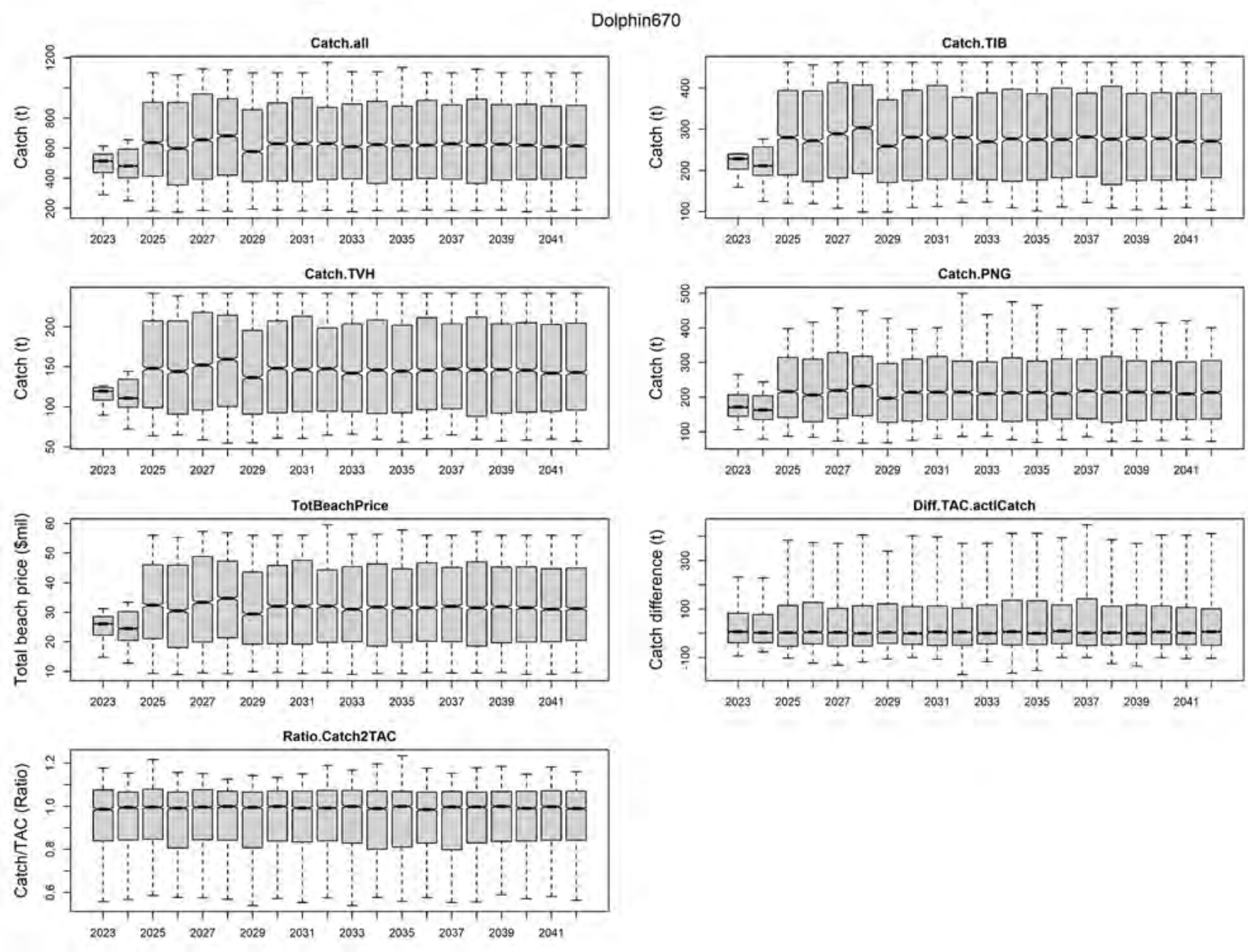
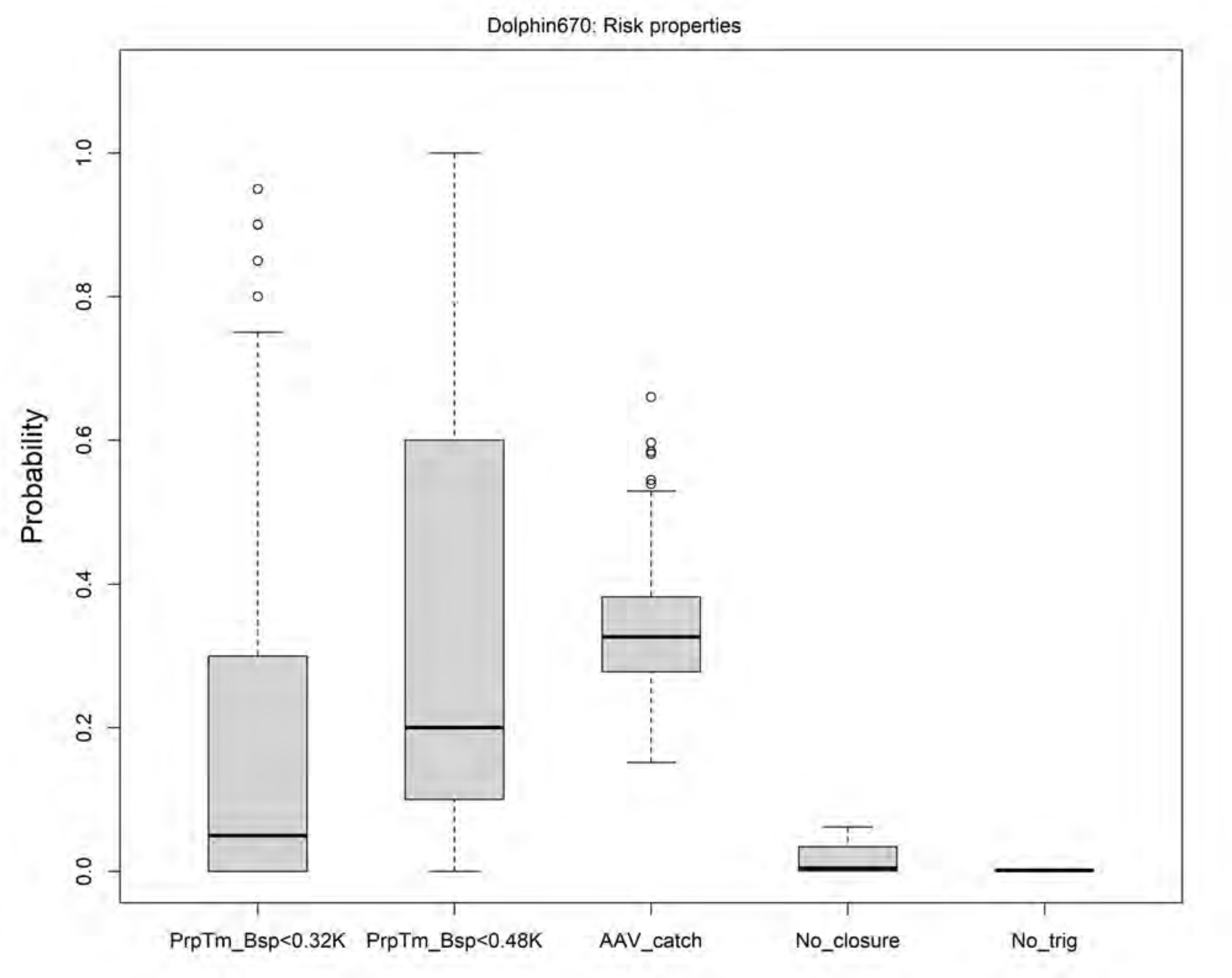


Figure S5- 24: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Dolphin rule (Dolphin670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



A.5.3 Osprey Rule

Osprey619

Figure S5- 25: Biomass trajectories with full range variation in the project period for using Osprey rule (Osprey619). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

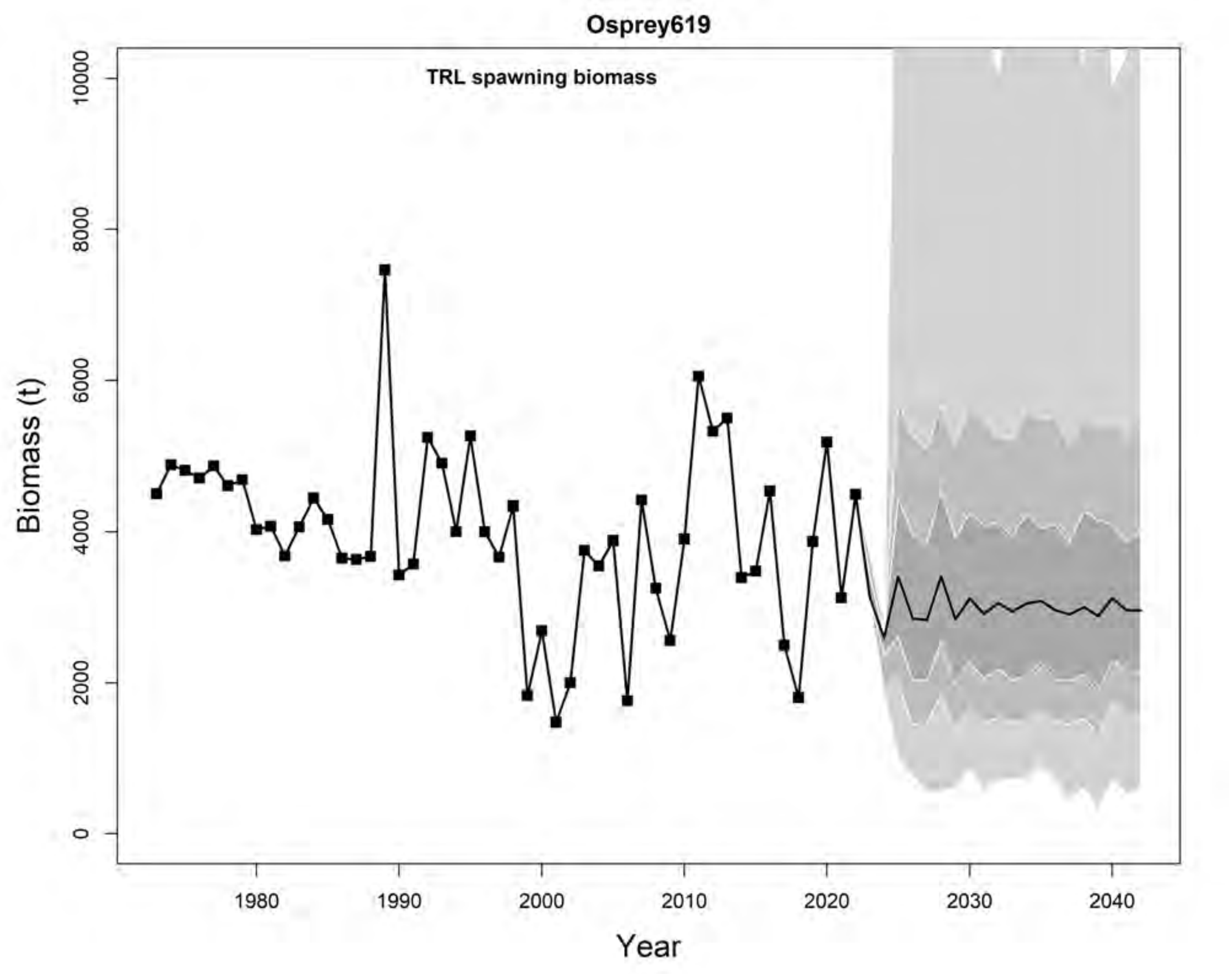


Figure S5- 26: Catch history bar plot and trajectories in the project period for using Osprey rule (Osprey619). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

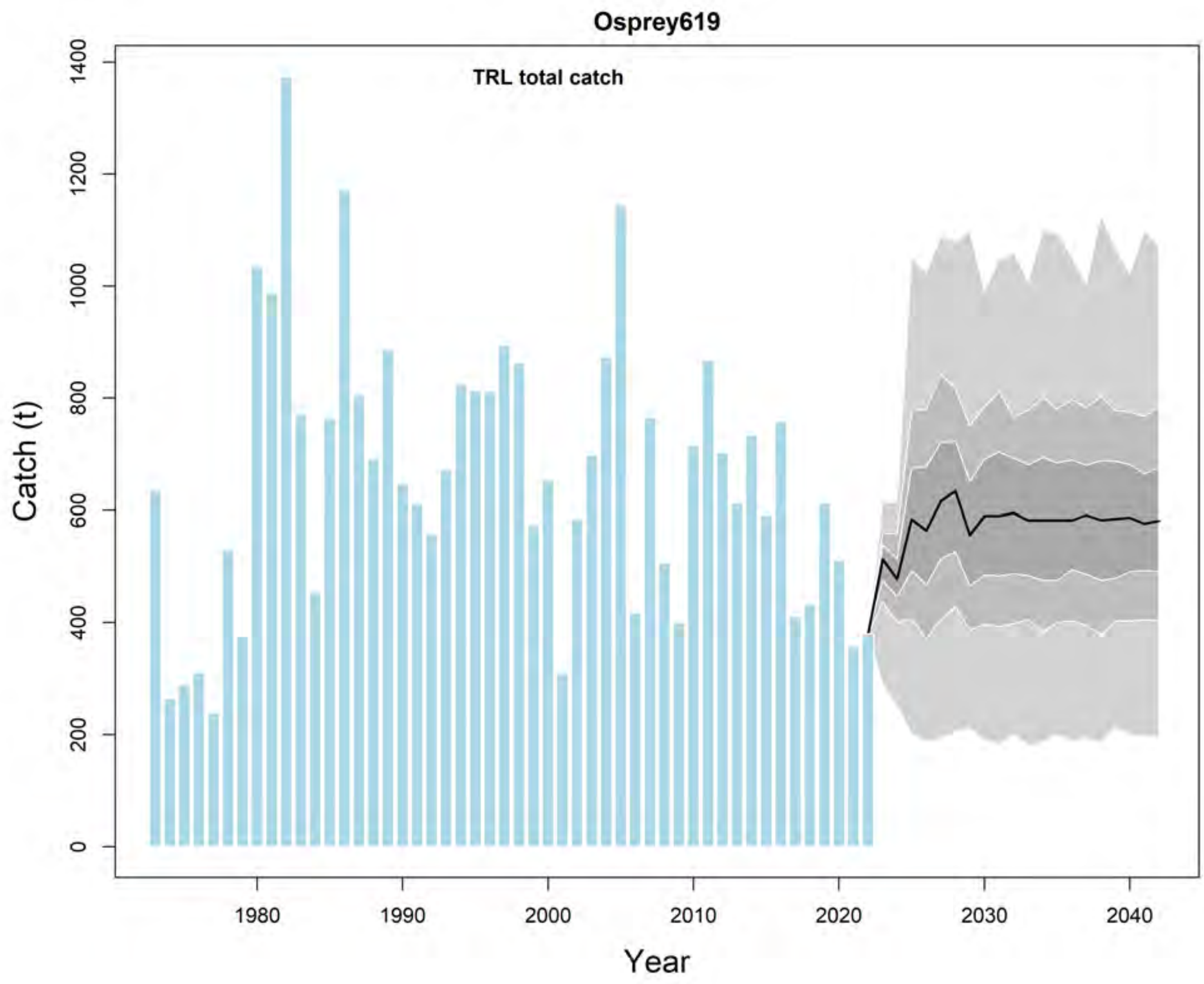


Figure S5- 27: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Osprey rule (Osprey619).

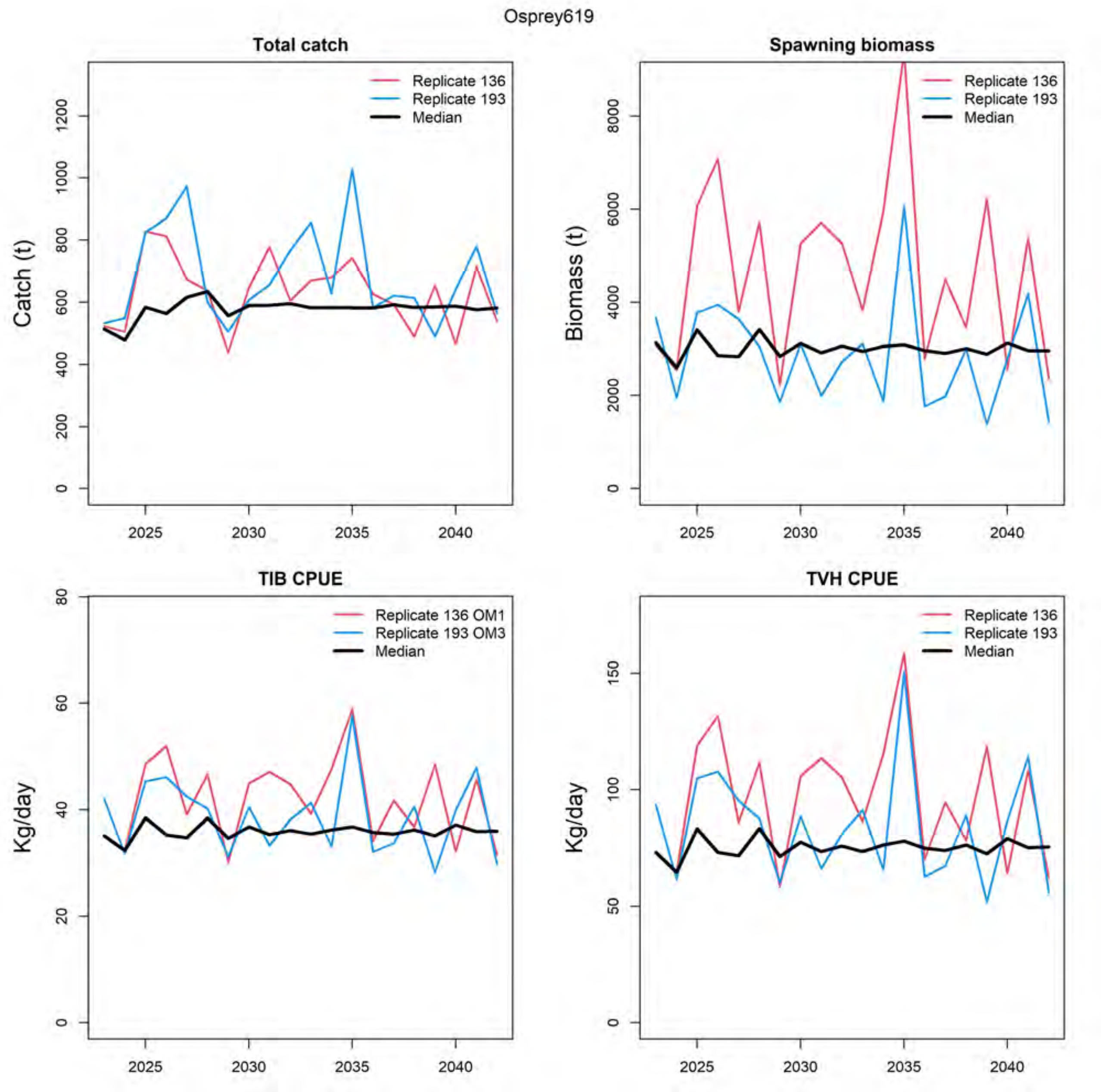


Figure S5- 28: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Osprey rule (Osprey619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

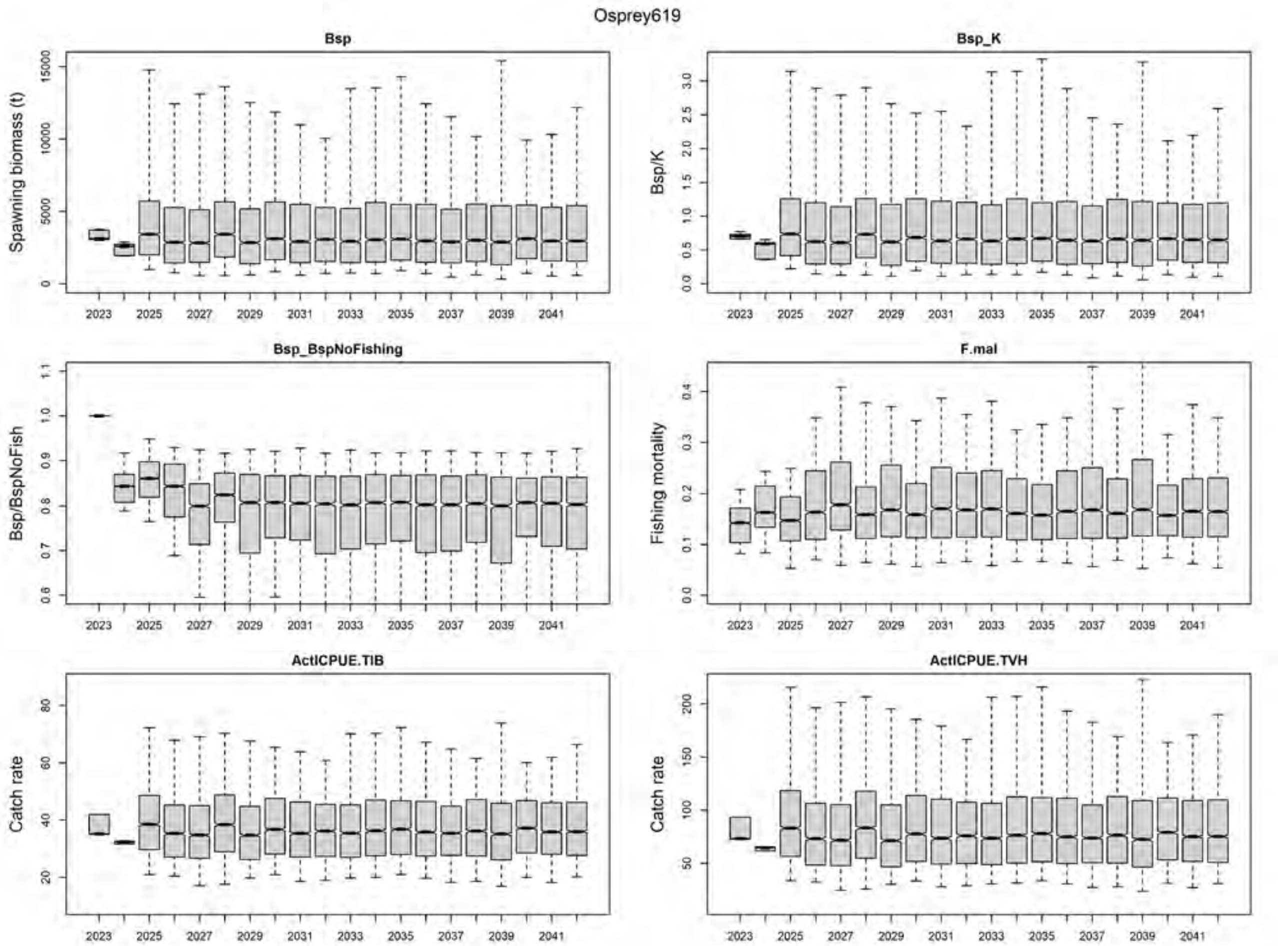


Figure S5- 29: Bar plots of catch related variables from all simulations for using Osprey rule (Osprey619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

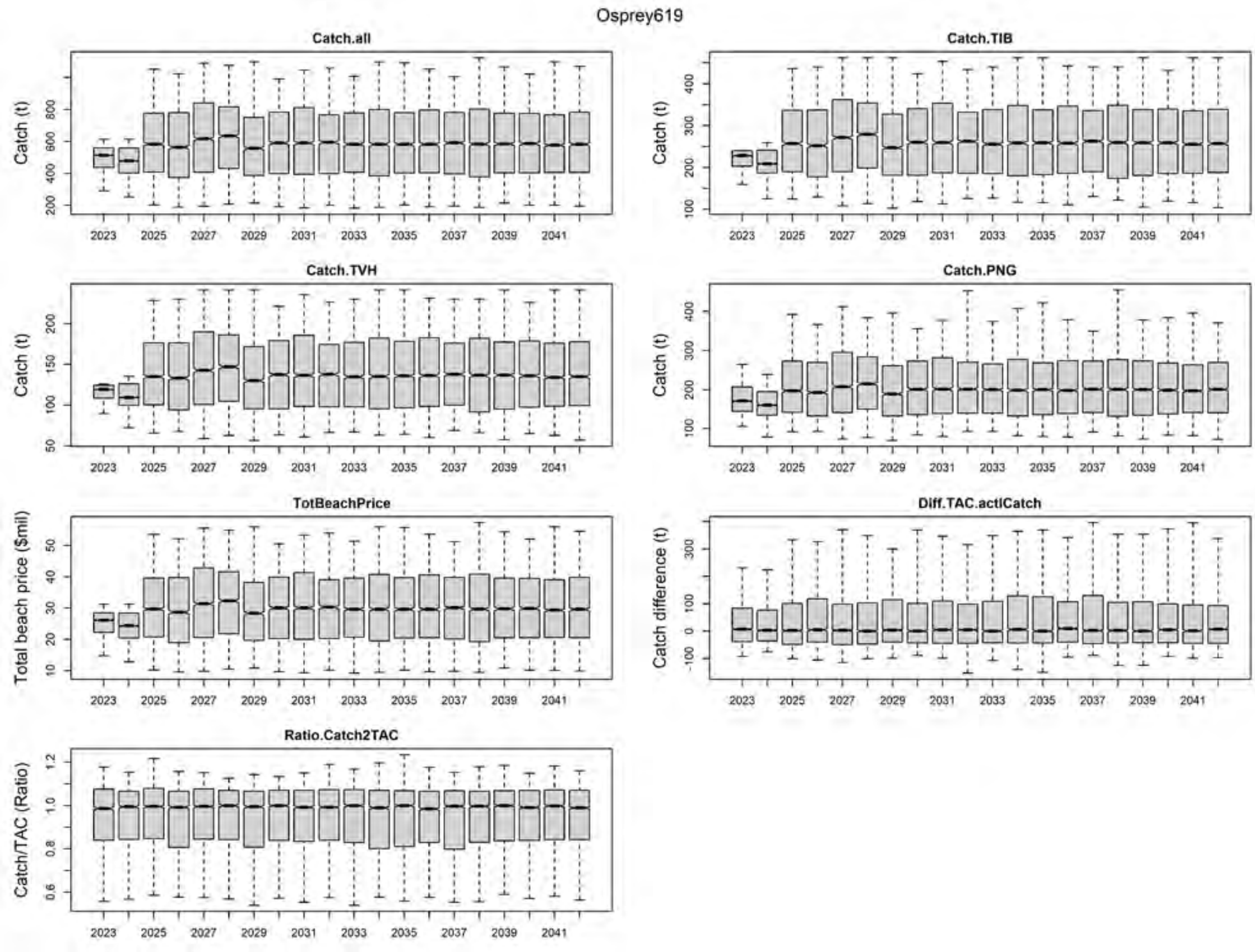
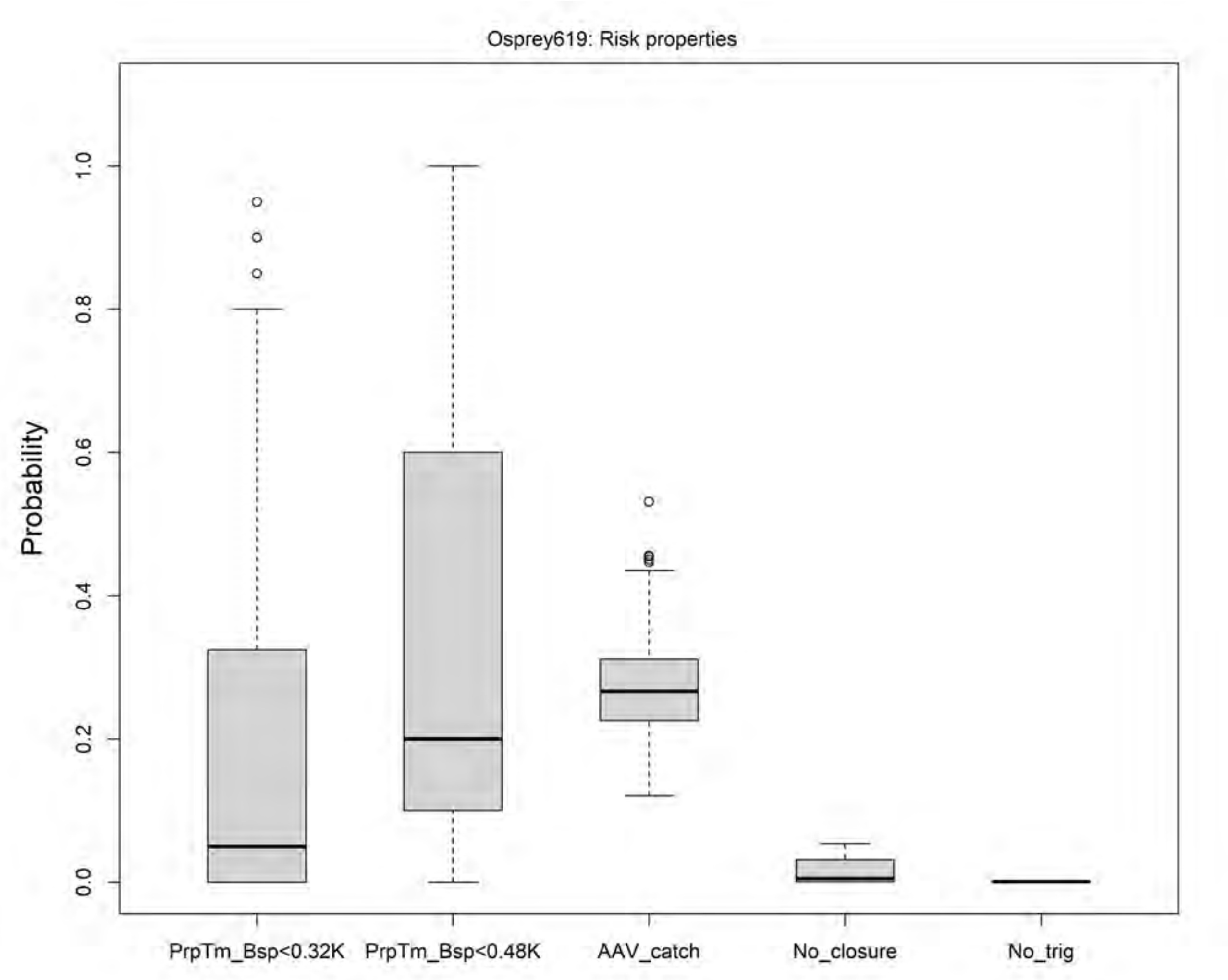


Figure S5- 30: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Osprey rule (Osprey619). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



Osprey640

Figure S5- 31: Biomass trajectories with full range variation in the project period for using Osprey rule (Osprey640). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

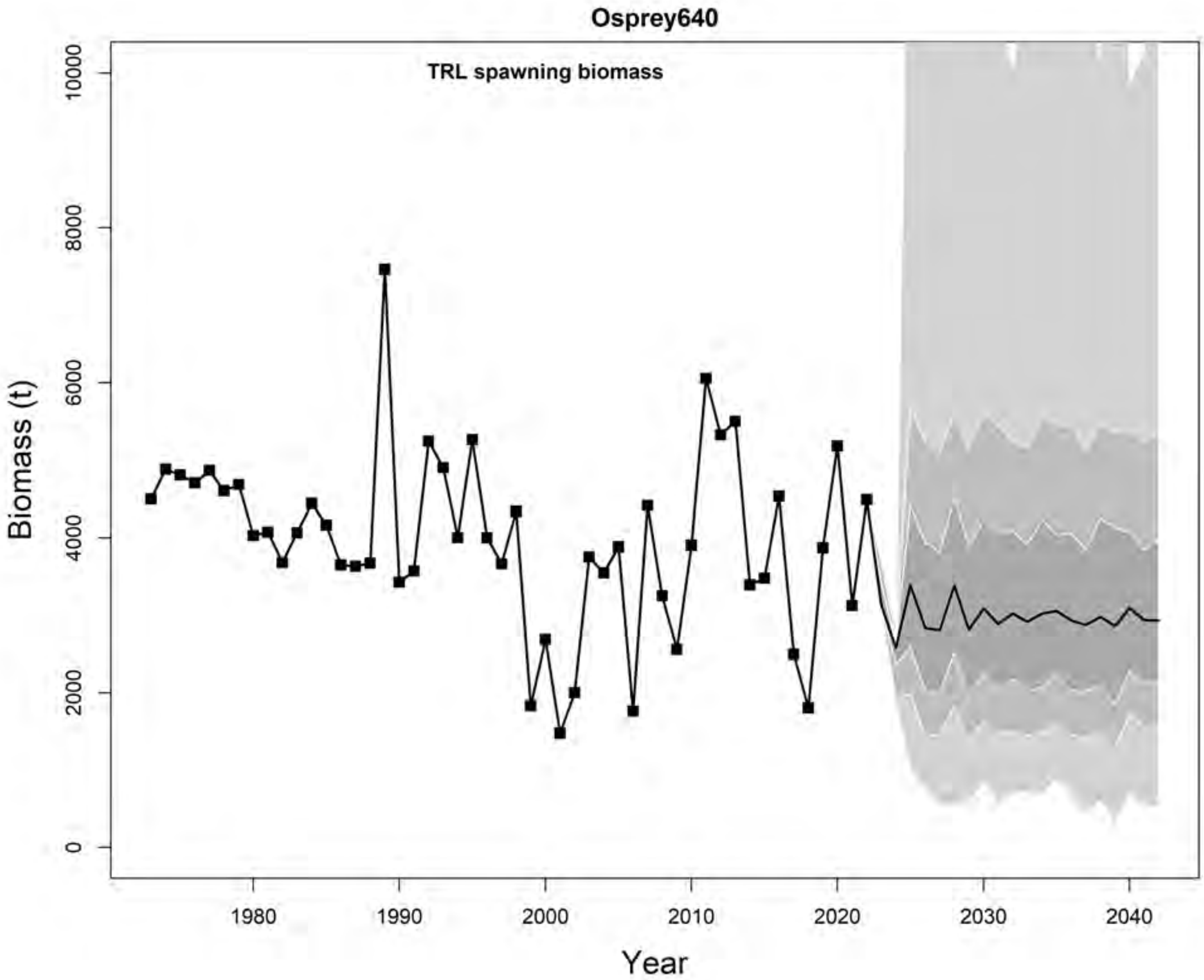


Figure S5- 32: Catch history bar plot and trajectories in the project period for using Osprey rule (Osprey640). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

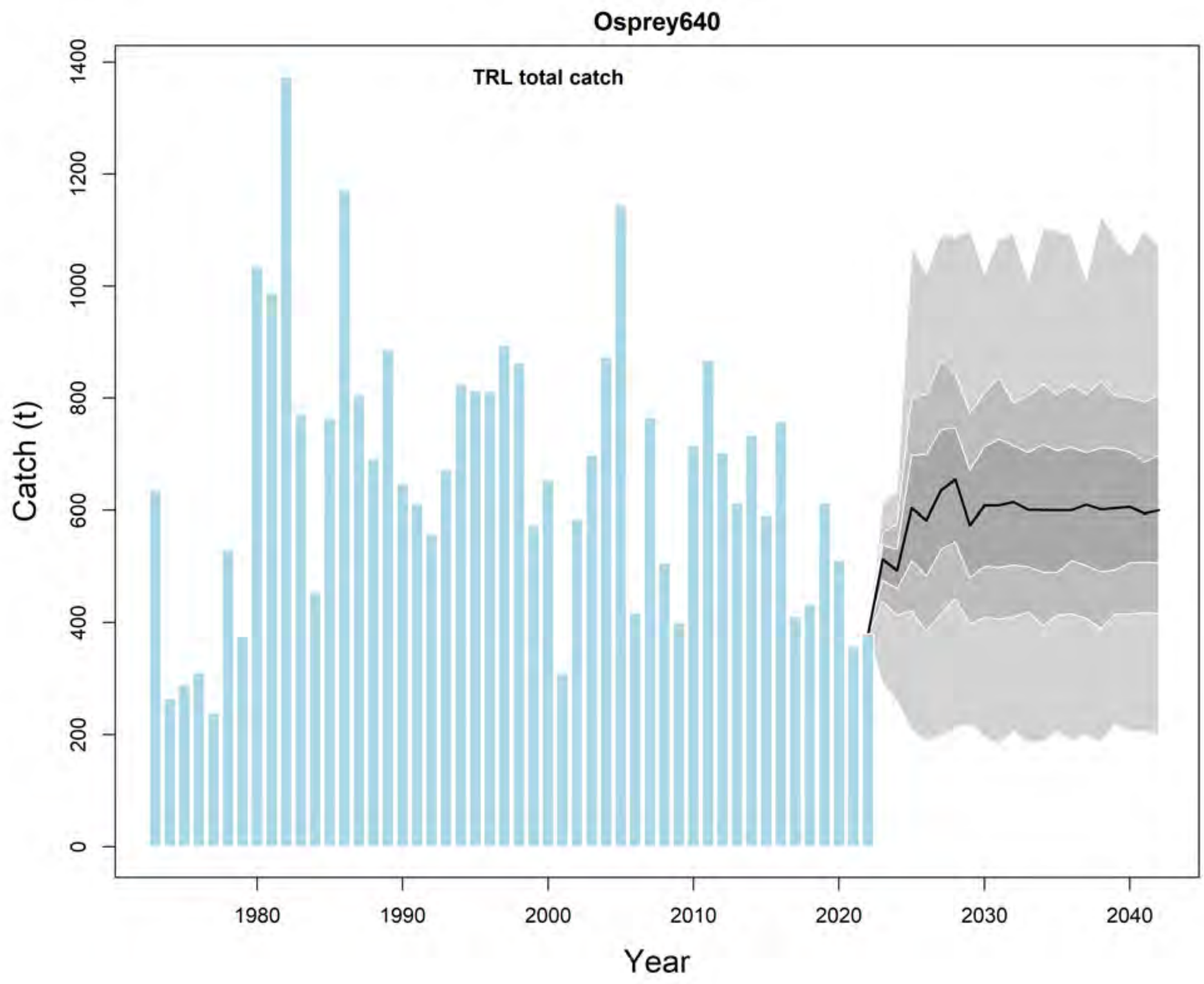


Figure S5- 33: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Osprey rule (Osprey640).

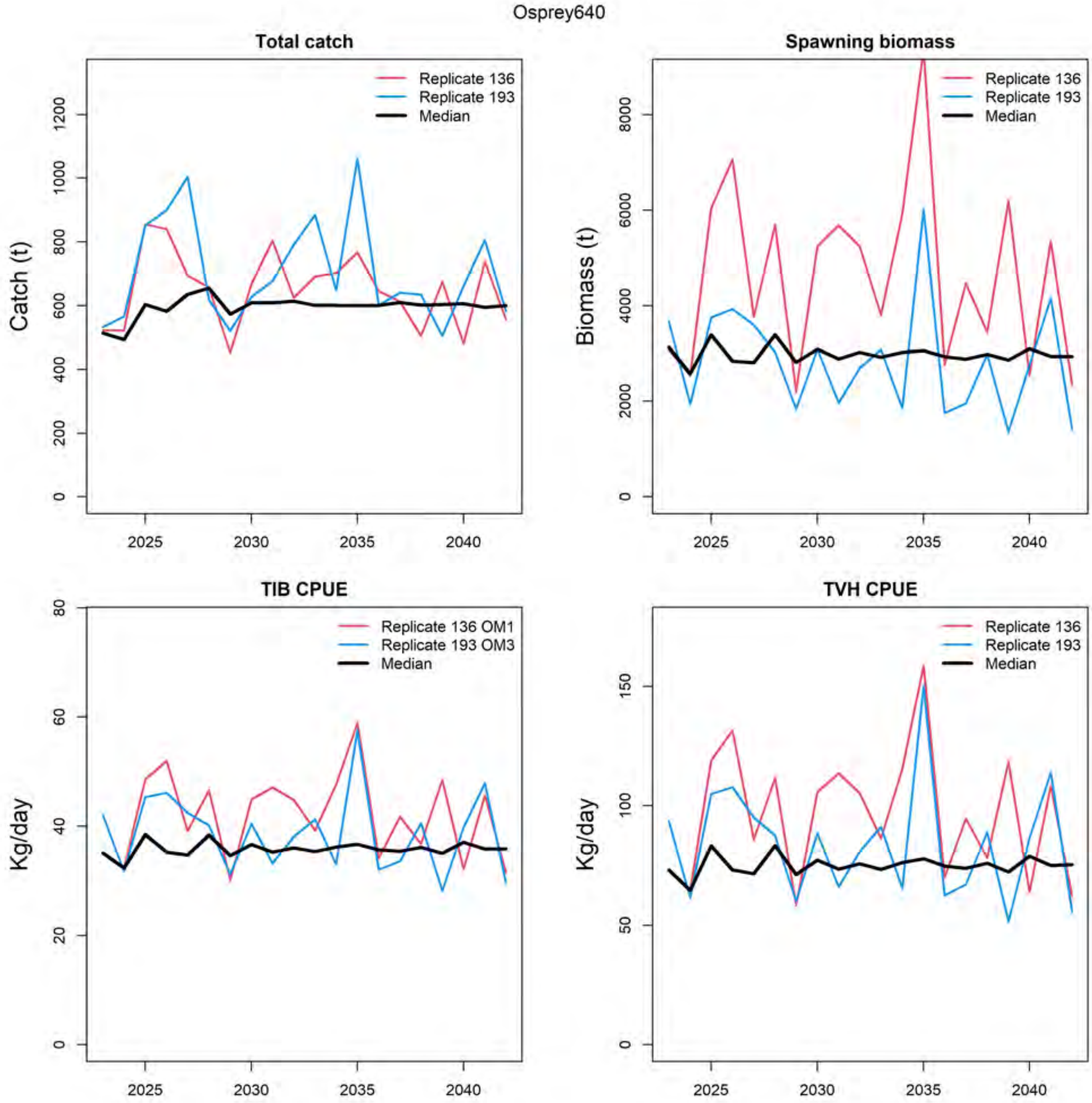


Figure S5- 34: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Osprey rule (Osprey640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

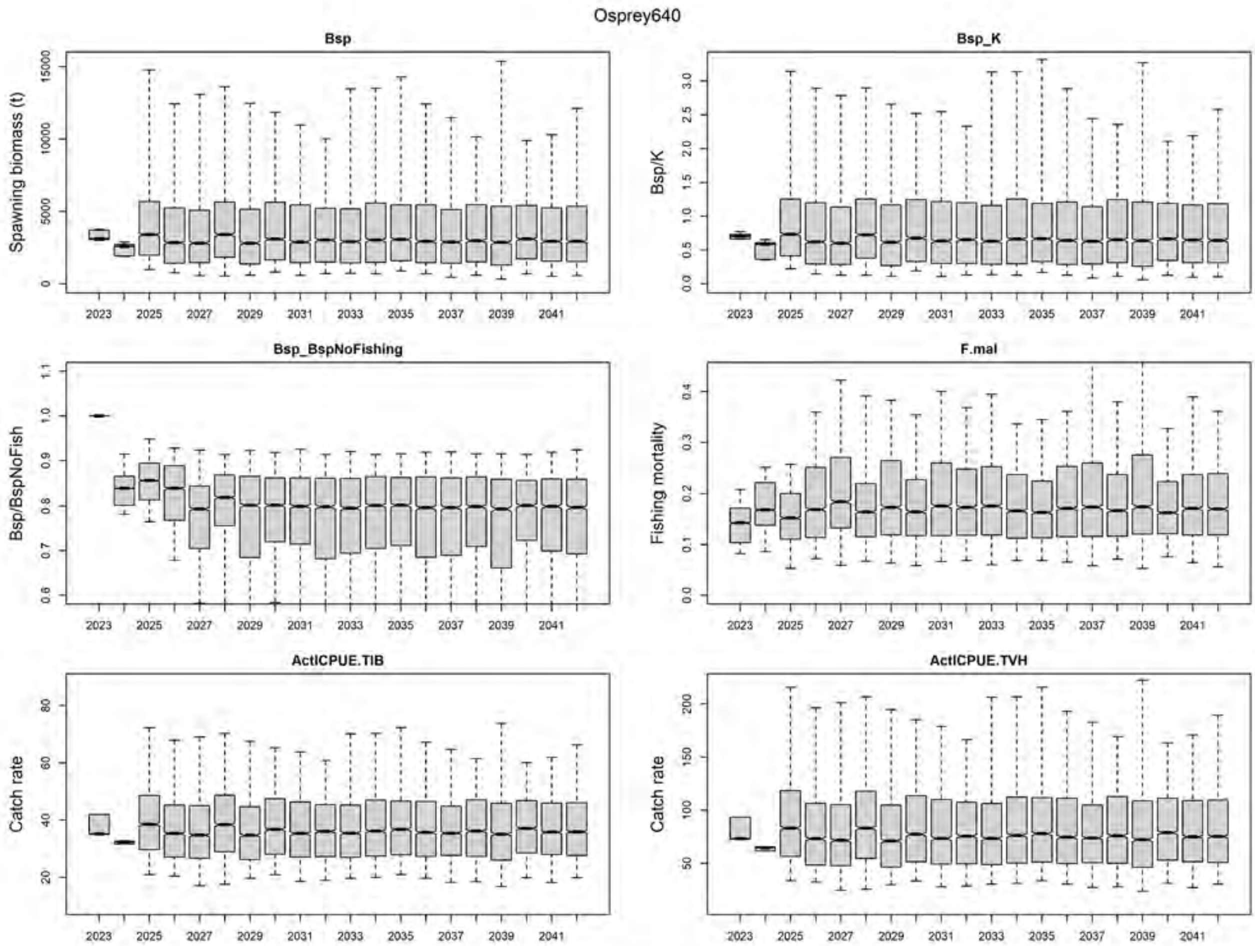


Figure S5- 35: Bar plots of catch related variables from all simulations for using Osprey rule (Osprey640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

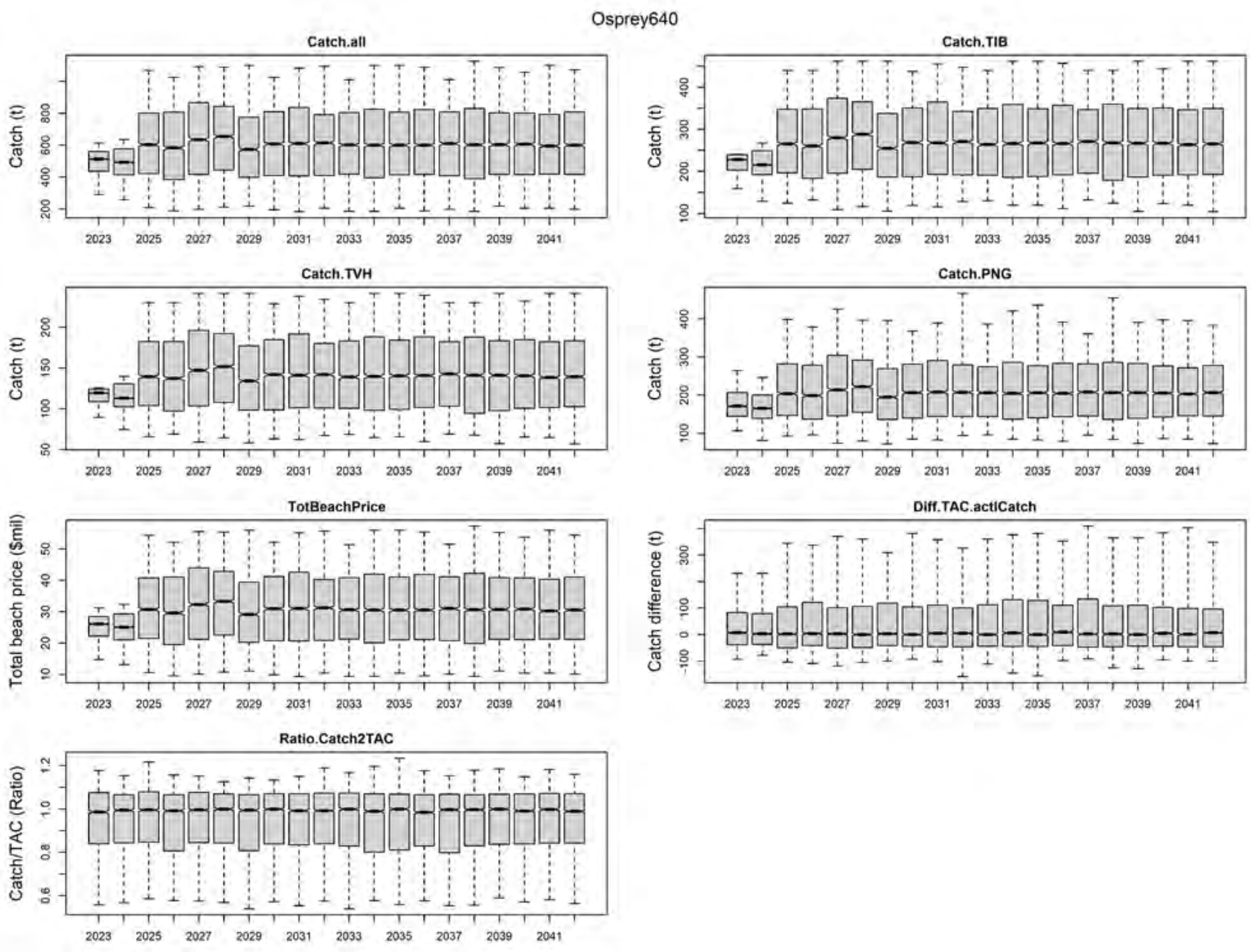
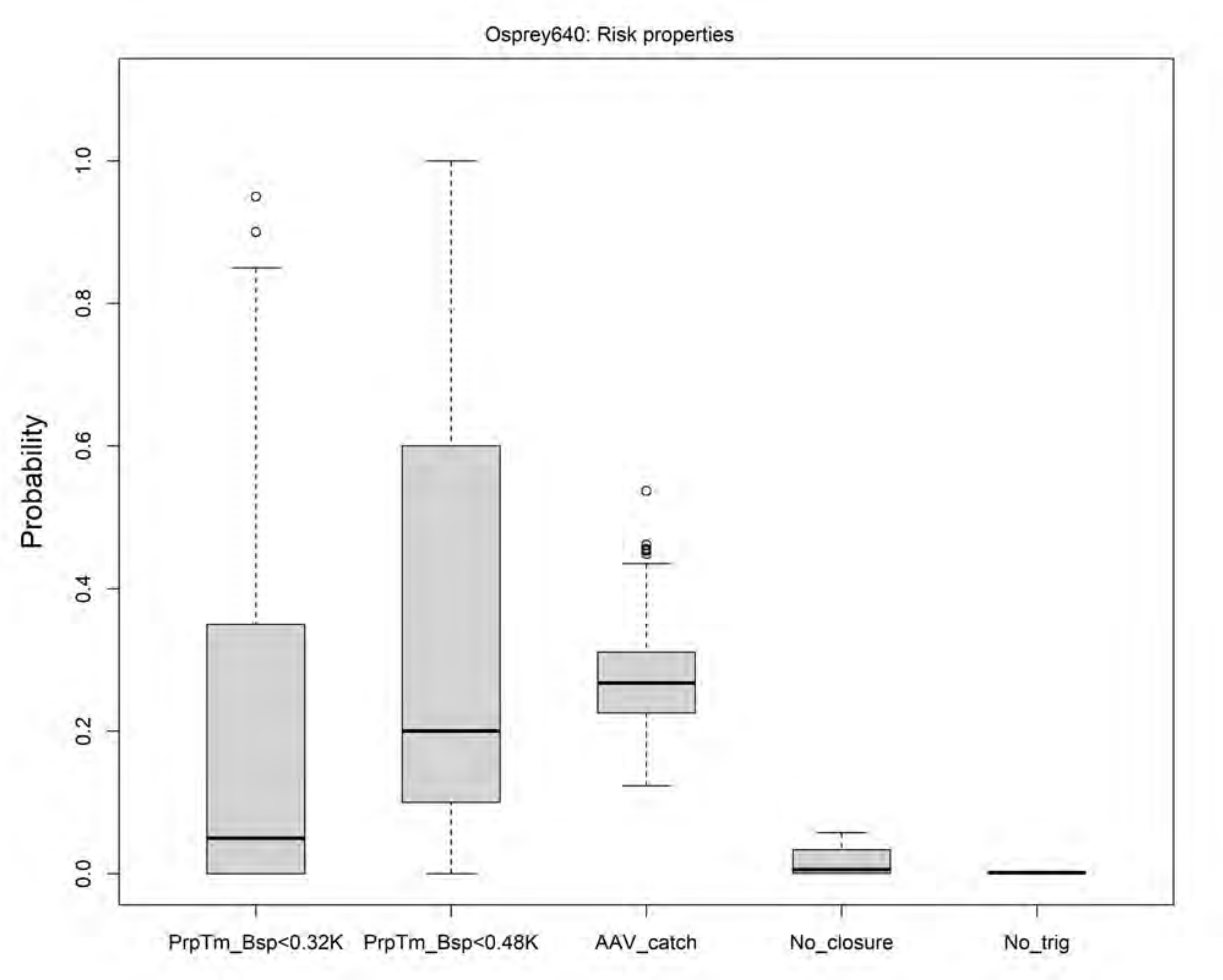


Figure S5- 36: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Osprey rule (Osprey640). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



Osprey670

Figure S5- 37: Biomass trajectories with full range variation in the project period for using Osprey rule (Osprey670). The black line in middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the biomass projected from the simulations.

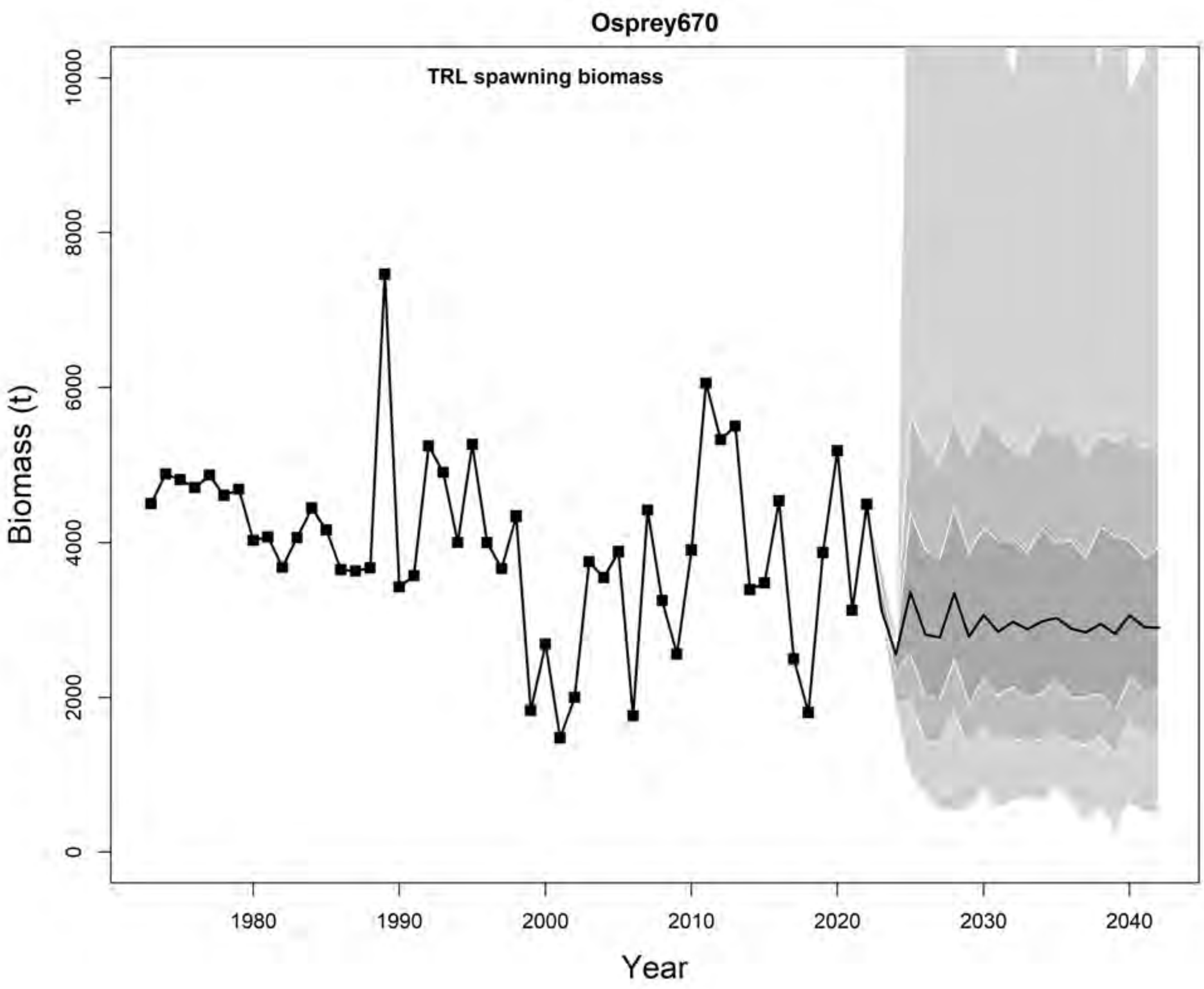


Figure S5- 38: Catch history bar plot and trajectories in the project period for using Osprey rule (Osprey670). The black line in the middle of the shaded areas represents median value and the shaded polygons represent 50% (dark), 75%(grey) and 100% (light grey) of the range of the catch projected from the simulations.

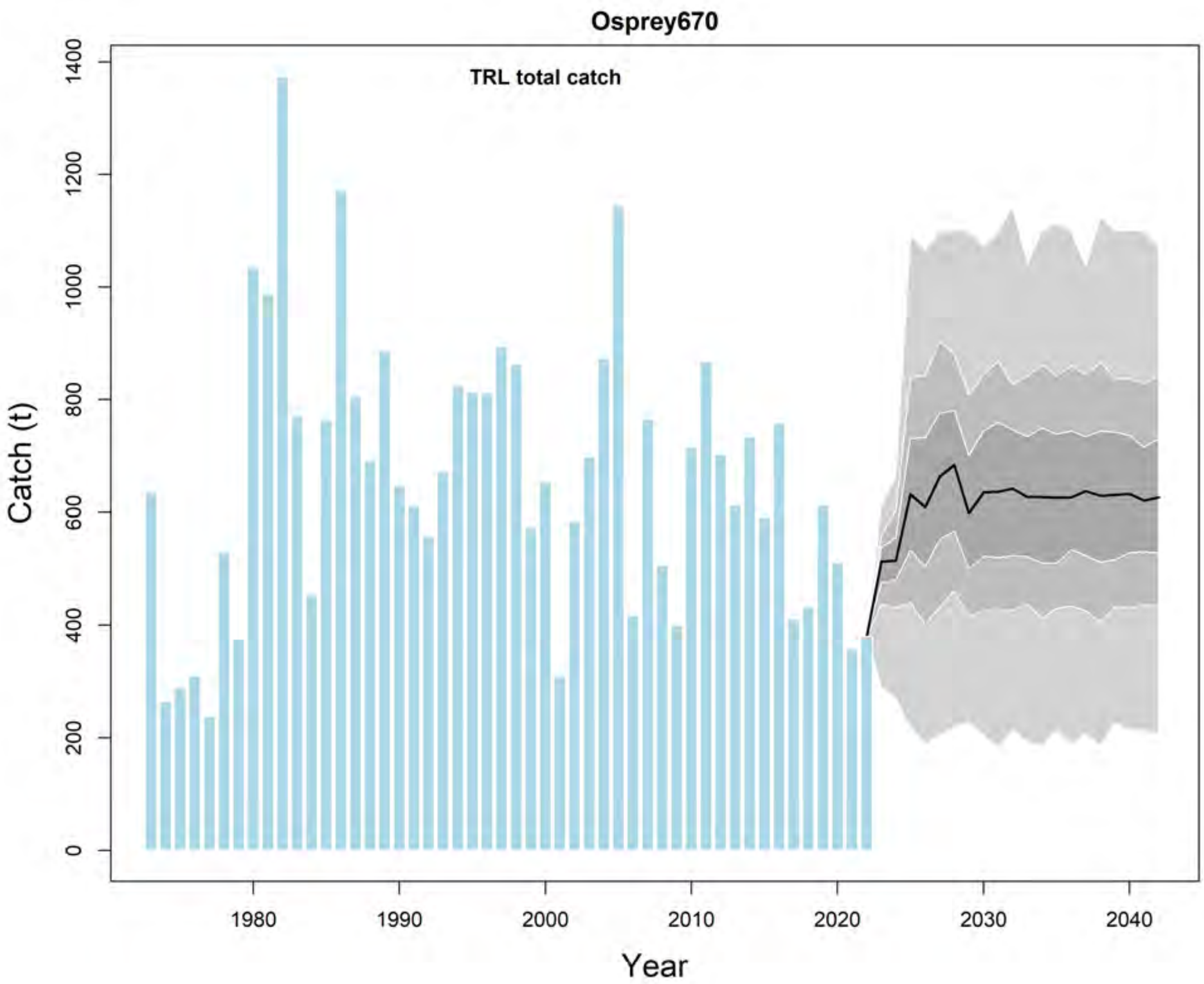


Figure S5- 39: Trajectories of Catch, biomass and CPUEs from two randomly selected replicates out of the simulations comparing with median values for using Osprey rule (Osprey670).

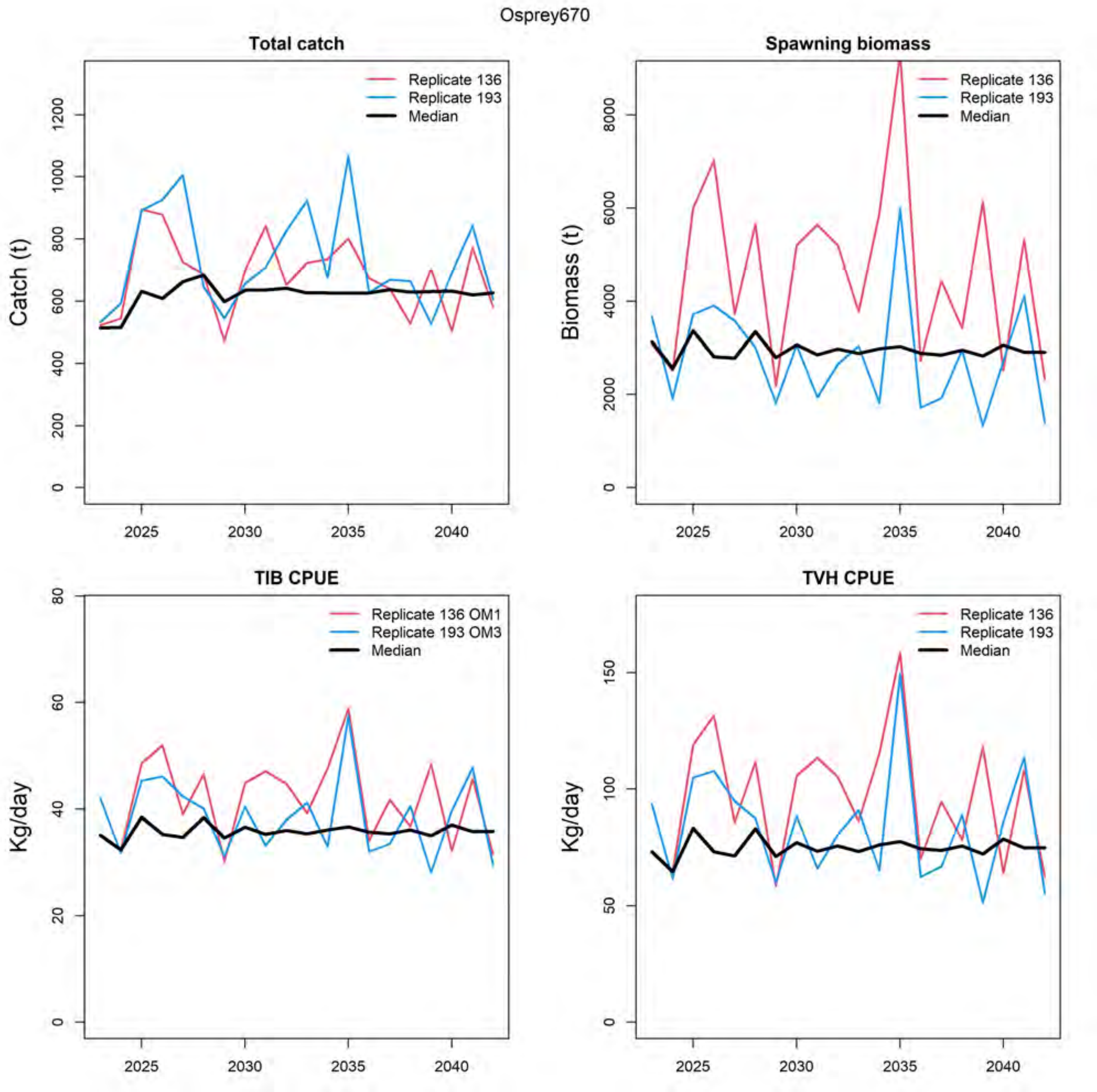


Figure S5- 40: Bar plots of Biomass, K, B/B0 and CPUEs from all simulations for using Osprey rule (Osprey670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

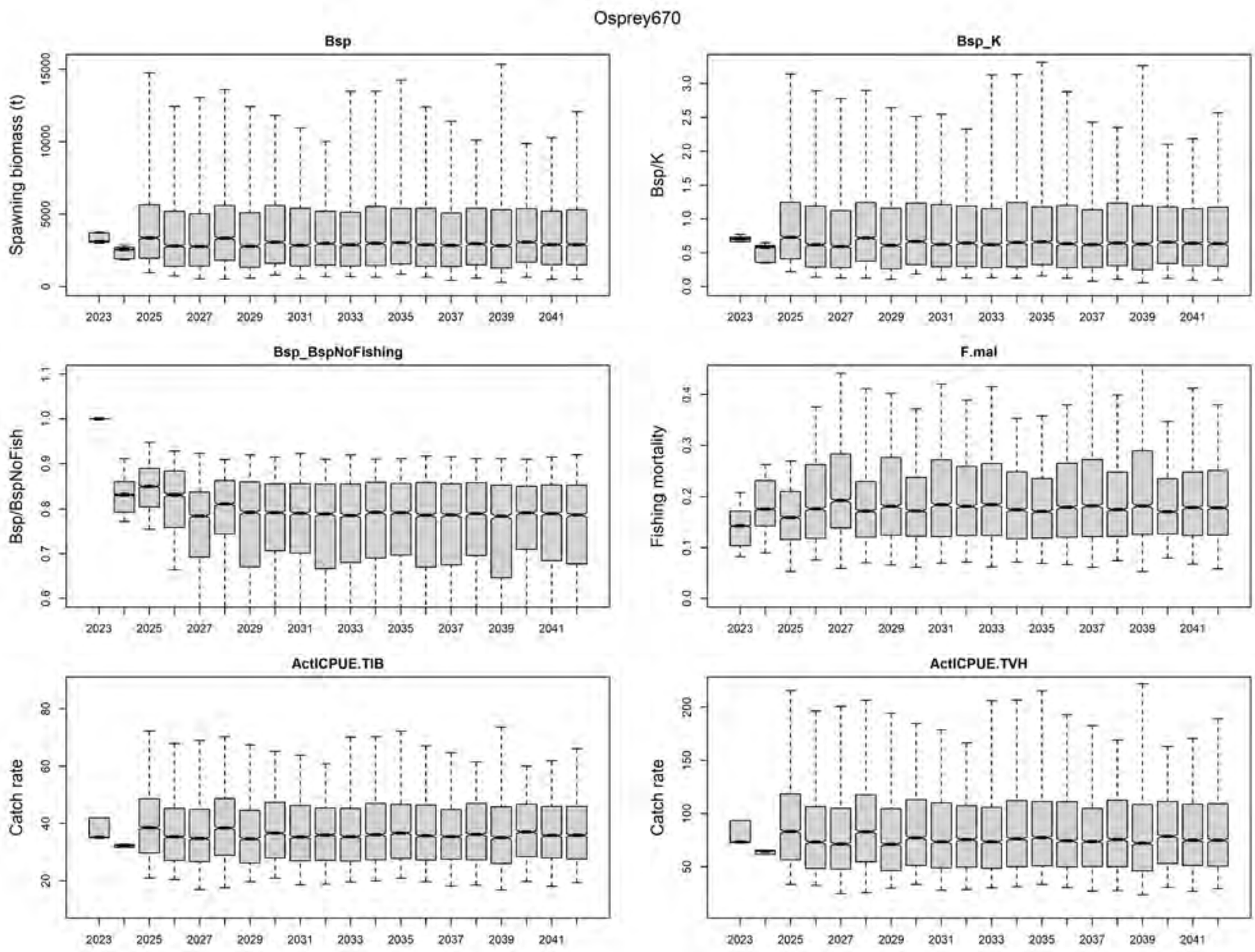


Figure S5- 41: Bar plots of catch related variables from all simulations for using Osprey rule (Osprey670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.

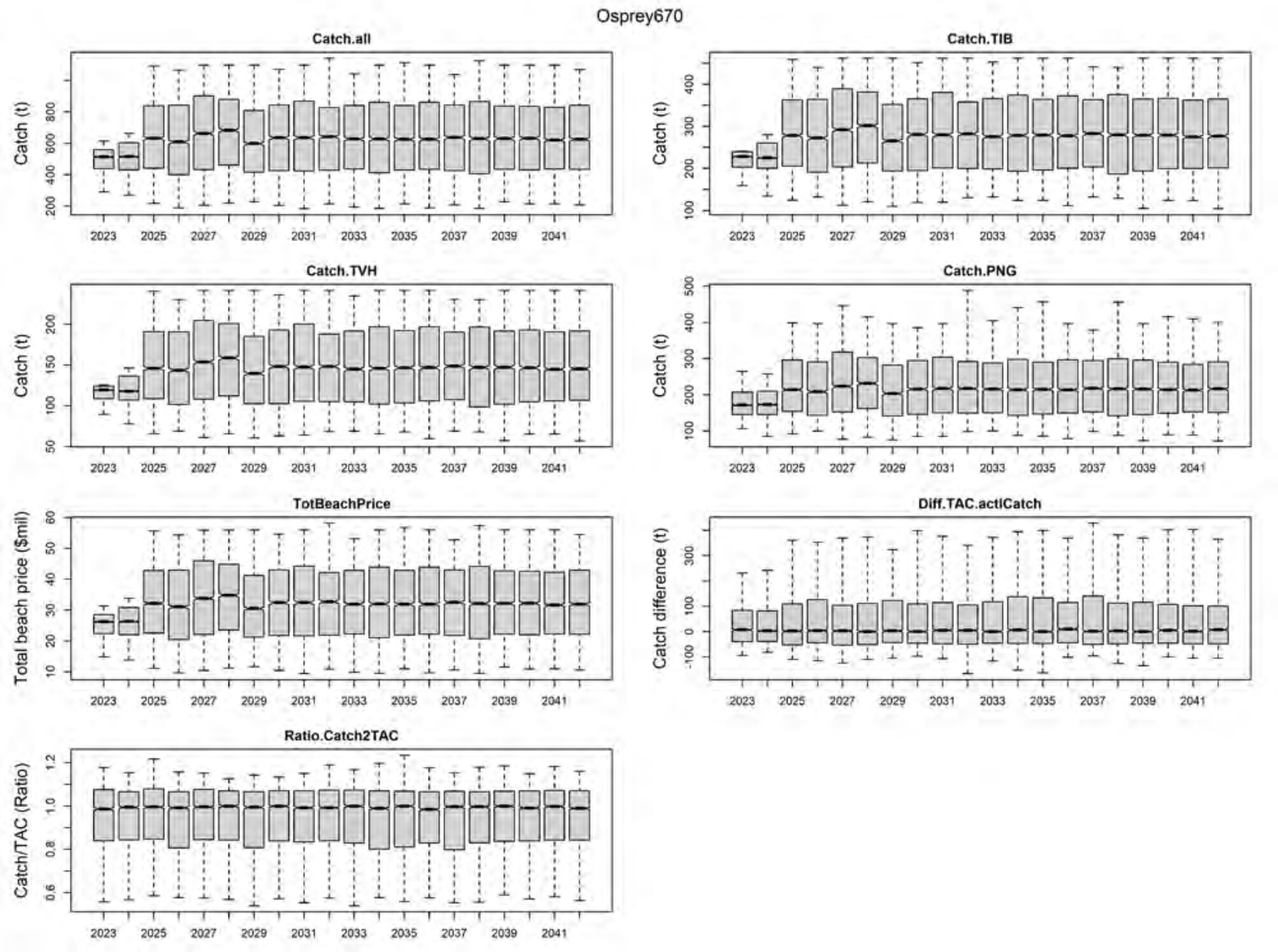
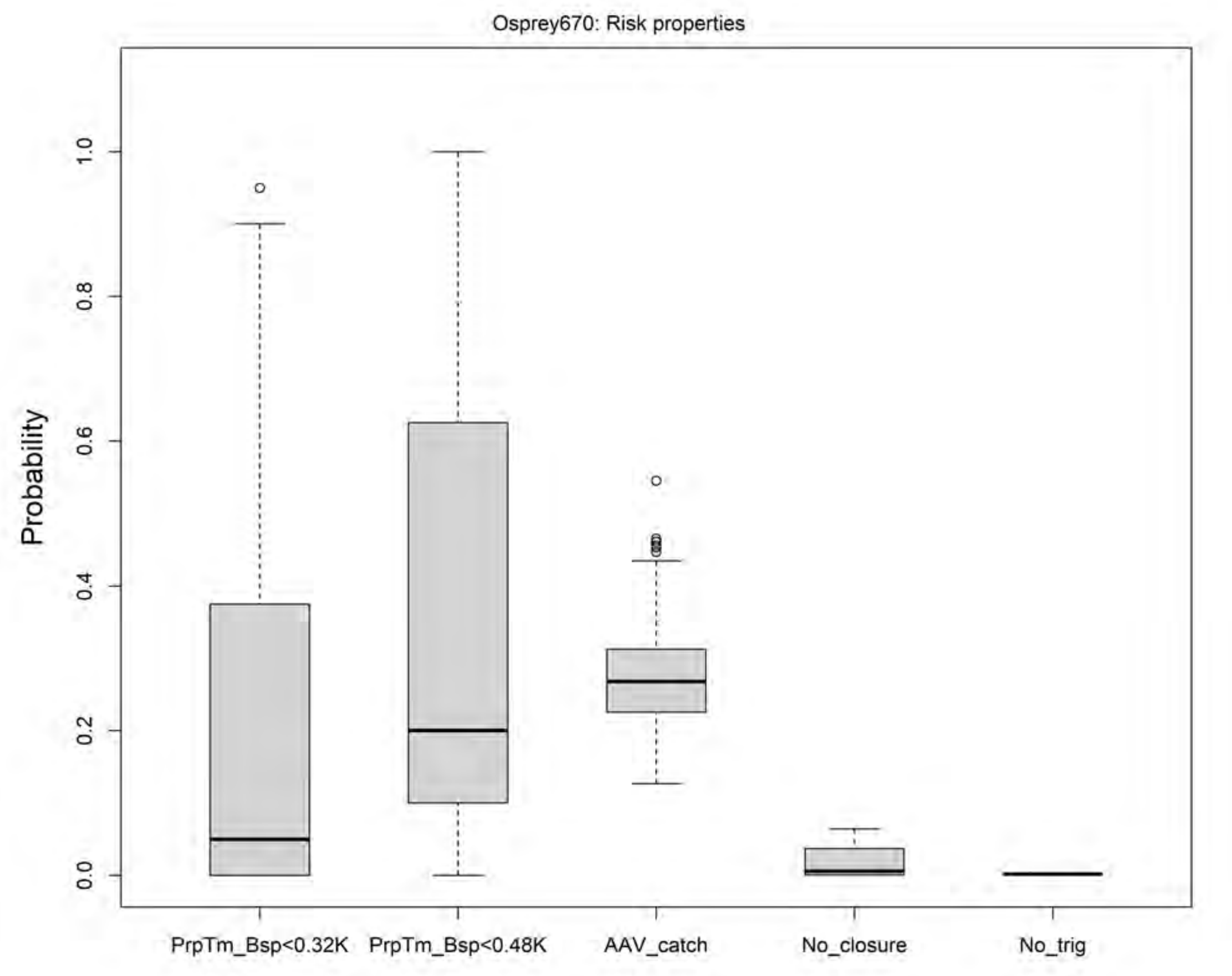
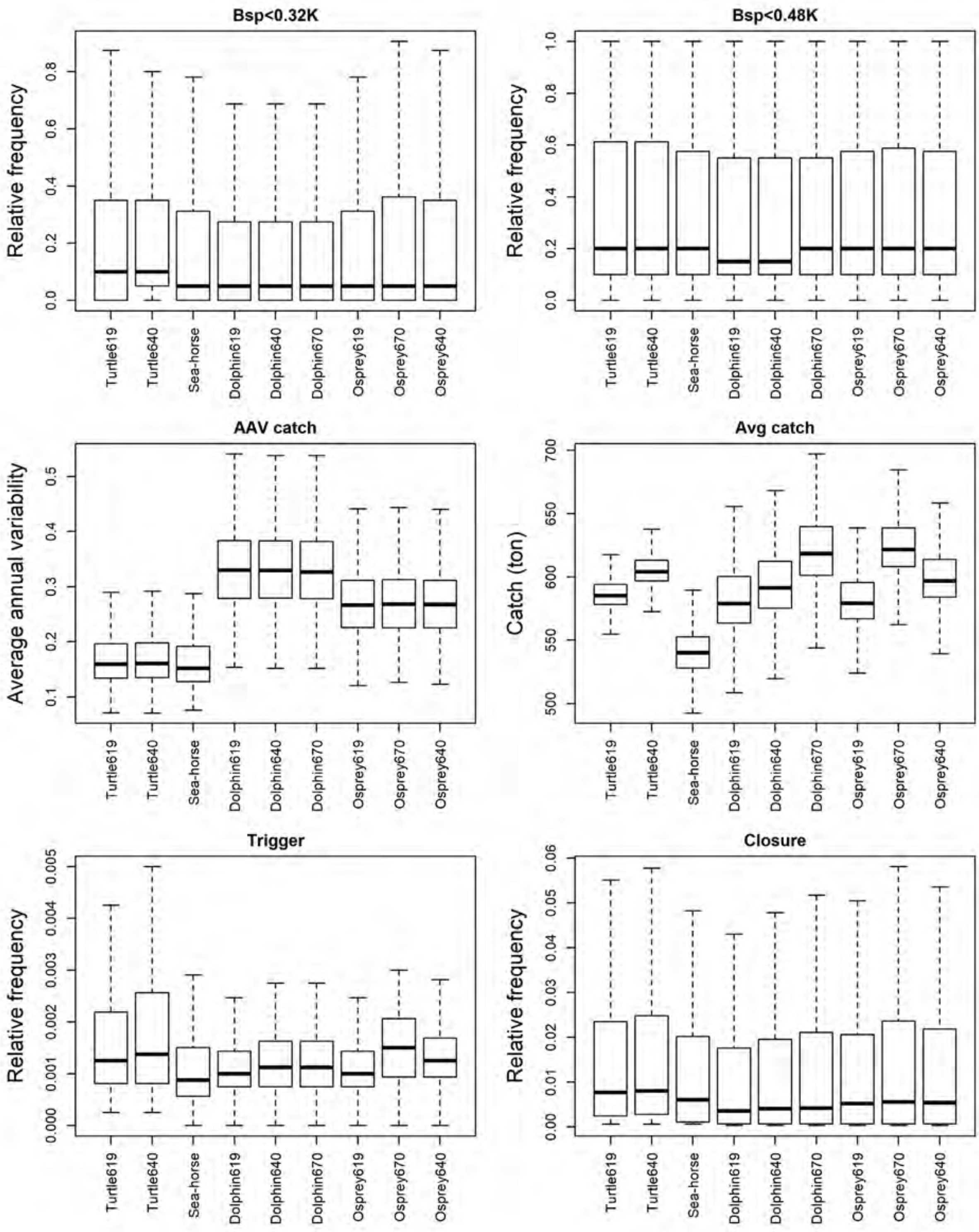


Figure S5- 42: Bar plots of the risks/probabilities of the resources regarding to the limit reference point, the trigger point, annual catch variation, fishery closure and trigger reaction from all simulations for using Osprey rule (Osprey670). The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values including outliers.



A.5.4 Risks comparison of the eHCRs

Figure S5- 43: Bar plots of the risk related variables from all simulations for using different rules. The central line shows the median, the box the 75th and 25th percentiles and the whiskers represent the full range of projected values excluding outliers.



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Considerations	**Dolphin**	**Seahorse**	**Osprey**
1. Sustainability	Meets objectives under TRL HS • Places more weighting on most recent pre-season 1+ lobster index in 5yr ave, therefore adjusts the RBC more rapidly and responsively • Accounts for pre-season survey precision and adjusts weighting if less precise survey • Could be more important as we transition to a new TRL survey/assessment provider	Meets objectives under TRL HS	Meets objectives under TRL HS • Places more weighting on most recent pre-season 1+ lobster index in 5yr ave, therefore adjusts the RBC more rapidly and responsively • Accounts for pre-season survey precision and adjusts weighting if less precise survey • Could be more important as we transition to a new TRL survey/assessment provider
2. Maximise value	Yes - median RBC is higher - higher peaks (outweighing lower troughs)	No - substantially lower median RBC - lower peaks (mitigated by higher troughs)	Moderate peaks and troughs - smaller increases in TAC in good years and smaller decreases in poor years compared to dolphin rule - overall on average larger increases and decreases in TAC than seahorse
3. Protecting the traditional way of life and livelihoods	Less so – higher commercial may result in *lower traditional catch* CPUE Balanced by overall precaution of TRP (65%) and LRP (32%) Supports higher employment generally	Yes – lower commercial catch may result in higher traditional catch CPUE Less so regarding employment	Balances extremes of seahorse vs dolphin Supports higher employment generally
4. Increase TIB participation	Overall yes – - Higher TAC offers better commercialisation opportunities and market benefits under (5) below	Short term – no difference. TAC slightly undercaught anyway	Yes – moderate variability in TAC year to year provides more certainty for new fishery entrants

Considerations	Dolphin	Seahorse	Osprey
	However, - Higher catch = lower freedive CPUE (balanced by moontide hookah closures) - Lower TACs may drive out 'weekend warriors'	Long term – removes/reduces development opportunities as well as options such as leasing. Could expect in a good year with lower TAC that an increase in new fishery entrants (due to good abundance) exacerbates risk of early TIB sector closure	Better supports market costs with on average higher catches
5. Market costs/ infrastructure	Greater volume of catch 'spreads' fixed costs over greater volume and number of transactions Greater TIB TAC provides better opportunities to develop TIB owned marketing and support infrastructure Can create redundancy if infrastructure created in good years and not used in average or poor years	Sacrifices economy of scale (regardless of who does the marketing). Higher cost per volume of transaction has negative impact on beach prices to fishers Lower average TAC encourages reliance on existing marketing and support infrastructure)discourages new investment)	Greater volume of catch 'spreads' fixed costs over greater volume and number of transactions Moderately higher TIB TAC provides better opportunities to develop TIB owned marketing and support infrastructure
6. Compliance	Overall higher median TAC = less incentive for non-compliance However, lower troughs in TAC make periodic domestic non-compliance more likely Increased PNG fishing activity = increased concern = increased compliance costs	Generally lower TAC in a good year = increased incentive for non-compliance But greater stability = easier planning and reduced variability in compliance costs Increased PNG fishing activity in lower TAC years = increased concern = increased compliance costs	Overall higher median TACs (than the seahorse) likely to result in less incentive for non-compliance

PZJA agreed management objectives for the TRL Fishery

The management objectives for the Tropical Rock Lobster Fishery are:

- to maintain the fishing mortality at a level below that which produces the Maximum Sustainable Yield (F MSY) (accounting for all sources of fishing mortality)
- to protect the traditional way of life and livelihood of Traditional Inhabitants, in particular in relation to their traditional fishing for Tropical Rock Lobster in accordance with the Torres Strait Treaty
- to provide for the optimal utilisation, co-operative management with Queensland and PNG and for catch sharing to occur with PNG
- to monitor interactions between the prawn and lobster fisheries
- to maintain appropriate controls on fishing gear allowed in the fishery to minimise impacts on the environment
- to promote economic development in the Torres Strait area with an emphasis on providing the framework for commercial opportunities for Traditional Inhabitants and to ensure that the opportunities available to all stakeholders are socially and culturally appropriate for the Torres Strait and the wider Queensland and Australian community, and
- optimise the value of the fishery.

Objectives of the *Torres Strait Fisheries Act 1984*

Section 8 - Objectives to be pursued

In the administration of this Act, regard shall be had to the rights and obligations conferred on Australia by the Torres Strait Treaty and in particular to the following management priorities:

a) to acknowledge and protect the traditional way of life and livelihood of traditional inhabitants, including their rights in relation to traditional fishing;

b) to protect and preserve the marine environment and indigenous fauna and flora in and in the vicinity of the Protected Zone;

c) to adopt conservation measures necessary for the conservation of a species in such a way as to minimise any restrictive effects of the measures on traditional fishing;

d) to administer the provisions of Part 5 of the Torres Strait Treaty (relating to commercial fisheries) so as not to prejudice the achievement of the purposes of Part 4 of the Torres Strait Treaty in regard to traditional fishing;

e) to manage commercial fisheries for optimum utilisation;

f) to share the allowable catch of relevant Protected Zone commercial fisheries with Papua New Guinea in accordance with the Torres Strait Treaty;

g) to have regard, in developing and implementing licensing policy, to the desirability of promoting economic development in the Torres Strait area and employment opportunities for traditional inhabitants.