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Tini a Tangaroa

Operational management procedures for New Zealand rock lobster (*Jasus edwardsii*) stocks in 2019–20

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EXECUTIVE SUMMARY

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This document describes the operation of management procedures in November 2018 used to manage New Zealand red rock lobster (*Jasus edwardsii*) Quota Management Areas (QMAs) for the 2019–20 fishing year.

Management procedures are simulation-tested decision rules. Given an input (e.g., standardised offset-year catch per unit effort, CPUE), they return an output (e.g., Total Allowable Commercial Catch, TACC). They consist of a harvest control rule, which defines the relationship between CPUE and TACC, and other controls such as minimum change thresholds that modify the output. They are simulation-tested using an operating model, which is based on the most recent stock assessment model for each rock lobster QMA.

There are currently six rock lobster QMAs with management procedures (CRA 1, CRA 3, CRA 4, CRA 5, CRA 7, and CRA 8). CRA 2, CRA 6, and CRA 9 are managed without management procedures. For CRA 1, CRA 5 and CRA 7, the management procedures indicated no change. The management procedure for CRA 3 resulted in a decrease in TACC and Total Allowable Catch (TAC). The management procedures for CRA 4 and CRA 8 resulted in an increase in TACC and TAC. However, the proposed increase in TACC for CRA 4 was rejected by the Minister so the TACC and TAC remained the same.

This document contains the equations and specifications for the current management procedures and their recent histories. The original material is scattered among New Zealand Fisheries Assessment Reports, consultation documents, and other sources, so this document is updated every year to provide a central reference.

1. INTRODUCTION

The red rock lobster (*Jasus edwardsii*) supports the most valuable inshore commercial fishery in New Zealand, with exports worth NZ\$268 million in 2015 (Seafood New Zealand 2016), and is also valuable to customary Māori and recreational fishers. Commercial rock lobster fisheries have been managed since April 1990 with Individual Transferable Quotas (ITQs) in nine Quota Management Areas (QMAs) which are treated as independent stocks for stock assessment (Breen et al. 2016a) (Figure 1).

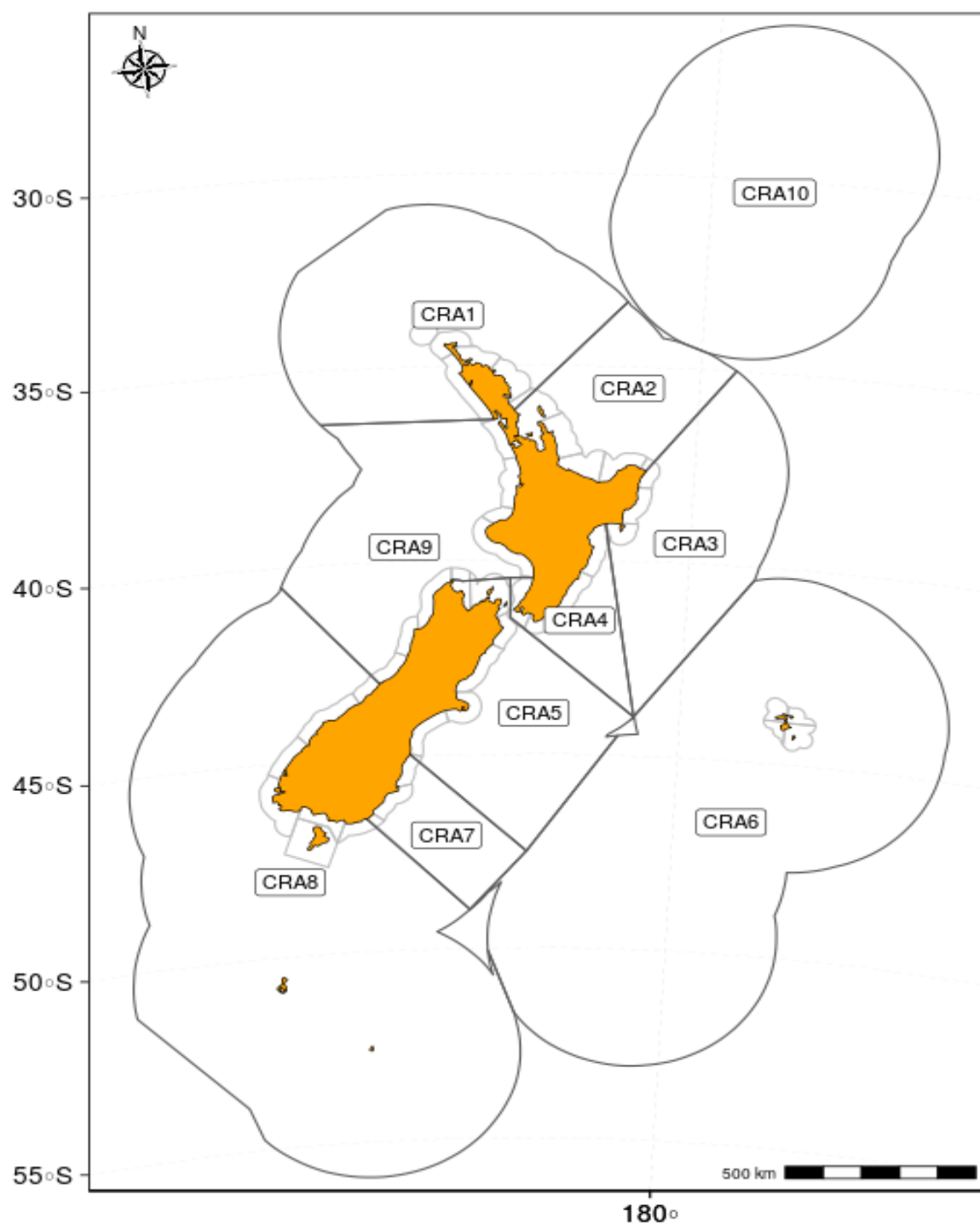


Figure 1: New Zealand red rock lobster (*Jasus edwardsii*) Quota Management Areas (QMAs).

This document describes the current (as of April 2019) operational management procedures (MPs) used to manage New Zealand stocks of red rock lobsters (Breen et al. 2016b). MPs are simulation-tested decision rules (Butterworth & Punt 1999). MPs are now a major part of New Zealand rock lobster management (Bentley et al. 2003b; Breen et al. 2009a, 2016a, 2016b; Bentley & Stokes 2009) and are becoming an important management tool globally (Edwards & Dankel 2016). They are used to manage rock lobsters in South Africa (Johnston & Butterworth 2005, Johnston et al. 2014), South Australia (Punt et al. 2012), and Victoria (Punt et al. 2013).

MPs are functions, often referred to as harvest control rules (HCRs), that specify one or more inputs and return an output value. New Zealand rock lobster MPs use standardised catch per unit effort (CPUE) as the input and a catch limit as the output¹. Other controls, such as minimum or maximum change thresholds, may also be used to modify the output.

Some work has investigated the use of MPs with additional inputs (e.g., settlement indices, Bentley et al. 2005), but so far other inputs have not been used formally for management in New Zealand. Before 2007, the input CPUE was from the preceding fishing year². This approach resulted in a one-year lag between observed CPUE and the resulting catch limit (i.e., the fishing year ends on the 31 March and any new catch limit from the MP is applied to the year beginning in April the following year). To shorten the lag to six months, "offset-year" CPUE was developed³. Much exploratory work has been done on CPUE and its standardisation (e.g., Starr 2012).

The first New Zealand MP and its successors were used to rebuild the depleted CRA 8 stock in New Zealand and to concurrently manage the volatile CRA 7 stock (Starr et al. 1997, Bentley et al. 2003a, Breen et al. 2008, Haist et al. 2013). There are now six rock lobster QMAs with MPs (CRA 1, CRA 3, CRA 4, CRA 5, CRA 7, and CRA 8). CRA 2, CRA 6, and CRA 9 are managed without MPs.

In the CRA 4 fishery, industry adopted a MP to reduce their catches voluntarily (quota "shelving", Breen 2009) prior to formal requirement by Fisheries New Zealand for catch reductions. A voluntary MP for CRA 5 was designed to maintain high abundance (Breen et al. 2009b).

The CRA 2 stock assessment in 2017 suggested that the stock was below the soft limit and therefore required a rebuilding plan (Webber et al. 2018). The chosen rebuilding plan used a fixed catch rather than a MP. A stock assessment for CRA 6 was done in 2018 (Rudd et al. 2019), but a MP was not developed for managing this QMA because planned changes to the collection of catch and effort data made it unlikely that offset-year CPUE would be available after November 2019 in its present form. A MP for CRA 9 was abandoned in 2016, after two years of operation, because analysis indicated that the CRA 9 CPUE was not sufficiently robust to support a stock assessment and a TACC-altering MP.

Much of the evolution of rock lobster MPs has occurred as each stock was assessed and subsequent management procedure evaluations (MPes) were conducted. Some generalised work has also been done (Bentley et al. 2003b, Breen et al. 2003). The industry-inspired "plateau" rules, described below, can impart great stability. However, because stable rules are less responsive to abundance changes, there are tradeoffs between stability and safety. Recent experience (e.g., in CRA 2 and CRA 4) suggests a need for caution in locating the lower plateau edge.

The impetus for adoption of MPs for rock lobsters in New Zealand originally came from the need to rebuild depleted stocks. This has been largely successful, particularly in Otago (CRA 7) and Fiordland (CRA 8). Both these stocks are now considered rebuilt, with standardised CPUE several times greater than the minimum observed in the late 1990s (Starr 2019). The total arithmetic CPUE for all New Zealand has nearly doubled since the late 1990s (Breen et al. 2016b). Fishing effort has declined in all QMAs with longstanding MPs (CRA 3, CRA 4, CRA 5, CRA 7, and CRA 8).

¹ Currently all New Zealand rock lobster MPs produce Total Allowable Commercial Catch (TACC) and allowances for other sectors are added to provide a Total Allowable Catch (TAC). Catch limits and allowances are always specified in metric tonnes.

² A fishing year runs from 1 April to 31 March of the following year and is named by the first year (i.e., 2016–17 is termed "2016").

³ An offset-year runs from 1 October to 30 September of the following year and is named by the second year (i.e., 2017–18 is termed "2018").

One measure of the success of these MPs is where they have rebuilt depleted stocks and then maintained healthy stocks. MPs also involve stakeholders in setting management goals and participating in the rebuilding process. This has allowed an emphasis on strategic planning for research and management of these fisheries, stepping beyond the usual tactical responses used to manage fisheries (Bentley & Stokes 2009). This shift is evidenced by the willingness of the New Zealand government to accept, in most instances, the recommendations made by the National Rock Lobster Management Group (NRLMG), which are usually based on MP results. In some instances, the NRLMG has rejected MP results:

- for CRA 5 in 2015–16, where the MP would have delivered a TACC reduction less than 5%;
- for CRA 9 in 2015–16, where the industry requested a delay pending the results of an audit and other analyses;
- for CRA 4 in 2016–17, where industry requested a larger decrease than was specified by the MP;
- for CRA 2 in 2016–17 and 2017–18, where industry voted to shelve 49 tonnes (25%) of their quota voluntarily, despite the MP result of no TACC change.

However, for CRA 4 in 2018–19, the Minister decided not to follow the advice provided by the NRLMG, nor the MP that would have increased the TACC. Instead the Minister retained the previous year's TACC.

This document is intended as a central reference containing all the specifications for the current MPs. The original documentation is scattered among New Zealand Fisheries Assessment Reports (FARs), consultation documents, ministerial decision letters, and other sources, so this document is updated every year. The most definitive documents for each rule are the relevant FARs describing the stock assessment and MPEs, the NRLMG Final Advice Paper or consultation document containing the basis on which the Minister of Fisheries signed off the MP, and the Minister's decision letter. The Fisheries Stock Assessment Plenary report for rock lobster also contains material relevant to each MP but is a year out-of-date (Fisheries New Zealand 2018).

This document does not attempt to describe the historical MPs before the current MP for each QMA was adopted, but these can be found in previous versions of this document (e.g., Breen et al. 2009a; Breen 2015, 2016, 2017; Webber & Starr 2018).

2. GENERALISED PLATEAU RULES

2.1 Step and slope harvest control rules

The six current MPs have either a "plateau step" harvest control rule or a "plateau slope" rule, illustrated in Figure 2 and Figure 3. CRA 3 has a modified plateau slope rule that is described in section 4.1. With respect to output TACC vs. input CPUE, step and slope rules have:

- a straight-line segment from zero TACC at some value of CPUE (not necessarily zero CPUE) up to a plateau,
- a plateau over which TACC stays the same as CPUE changes (the plateau could be of zero width, but all current rules have an actual plateau),
- and either:
 - a series of steps to the right of the plateau (step rules) or
 - an ascending function at CPUE values to the right of the plateau (slope rules).

Descriptions in this section assume that the MP determines the TACC, as do all current MPs for rock lobster in New Zealand. A TAC-determining MP was developed for CRA 5 in 2010, at the request of the Ministry of Fisheries (the name of the managing government agency in 2010, Haist et al. 2011). This had a TACC component plus components for non-commercial catch sectors. This approach was rejected by the Minister and a TACC-determining rule was developed and approved in the following year. There is concern that rules controlling only the commercial catch will divert catch away from the commercial sector into the non-commercial sectors, which can increase their relative catch share as

stocks increase. This outcome has been confirmed by simulation modelling (Breen et al. 2003) and remains a concern for commercial stakeholders, who are increasingly unwilling to be the only sector affected by TAC changes.

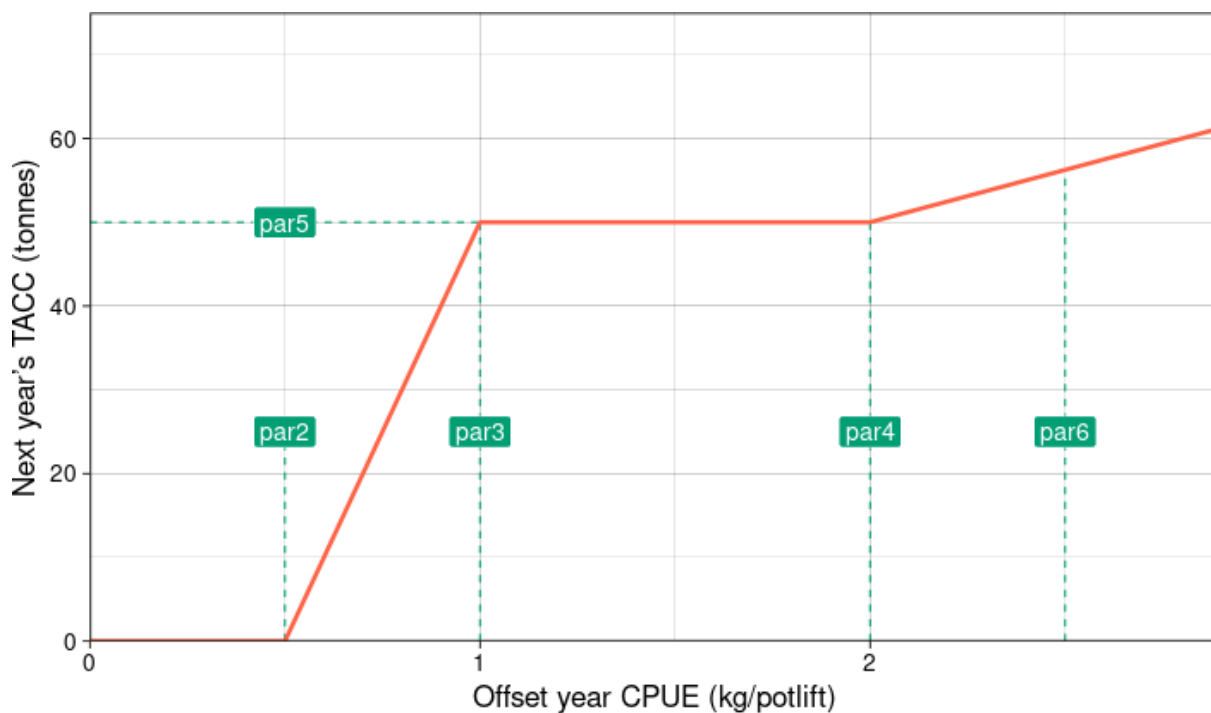


Figure 1: A generalised plateau step rule. See Table 1 for parameter definitions.

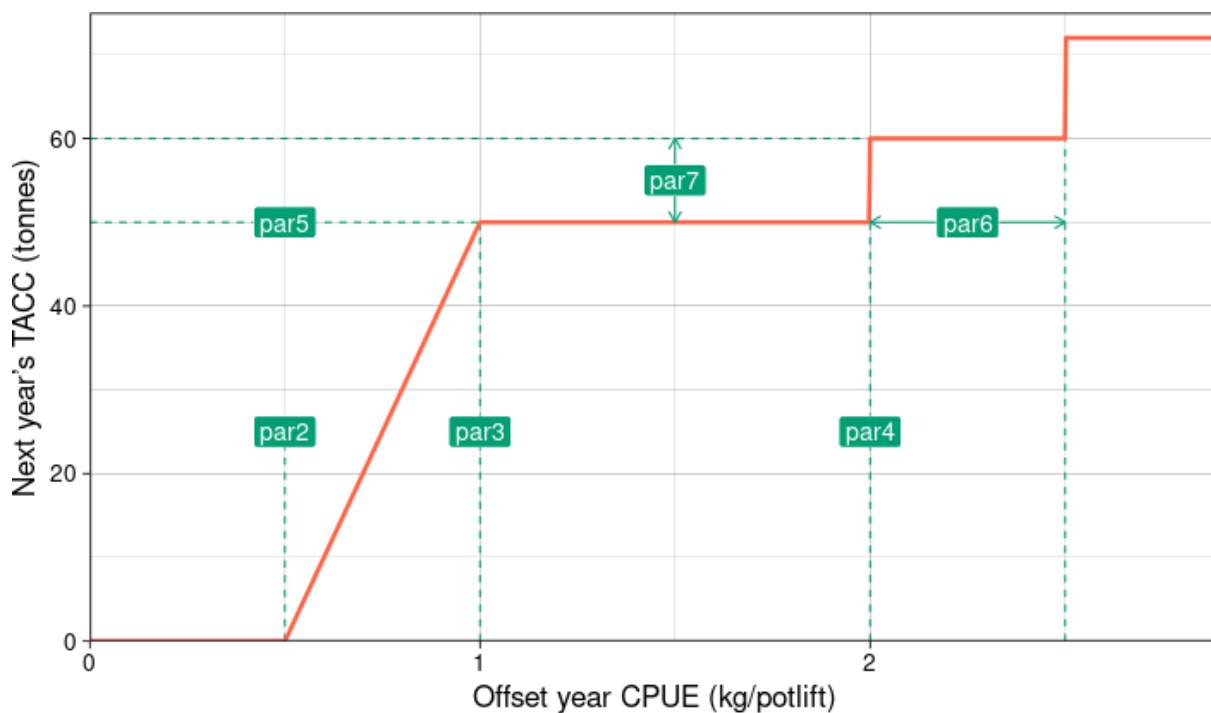


Figure 2: A generalised plateau slope rule. See Table 1 for parameter definitions.

2.2 Rule parameters

The generalised rule parameters are defined in Table 1.

Table 1: Parameters for the generalised plateau rules and the CRA 3 rule.

Parameter	Applies to	Function
<i>par1</i>	all	rule type
<i>par2</i>	all except CRA 3	CPUE at TACC = 0
<i>par2</i>	CRA 3 rule	CPUE at first inflection
<i>par3</i>	all	CPUE at plateau left
<i>par4</i>	all	CPUE at plateau right
<i>par5</i>	all	plateau height
<i>par6</i>	step rules	step width
<i>par6</i>	slope rules	slope
<i>par6</i>	CRA 3 rule	slope (defined differently)
<i>par7</i>	step rules	step height
<i>par8</i>	all	minimum change
<i>par9</i>	all	maximum change
<i>par10</i>	all	latent year switch

The rule type parameter (*par1*) is set to 1 for fixed catch rules, *par2* for slope rules (i.e., constant CPUE multiplier), *par3* for plateau slope rules, *par4* for plateau step rules, and *par6* for the modified CRA 3 rule; *par1*=5 is not used anymore. The CRA 3 rule is described in the CRA 3 section below; the description here is for rule types 3 and 4 only.

The point at which TACC becomes zero (*par2*) can be zero or non-zero but must be less than the left edge of the plateau (*par3*). The value for *par3* must be less than or equal to the right edge (*par4*). In plateau slope rules (*par6*) must be greater than *par4*. Thus, for an acceptable rule:

$$par2 < par3 \leq par4$$

$$par4 < par6 \quad \text{if} \quad par1 = 3$$

Step height for step rules (*par7*) is defined as a proportion of the TACC on the previous step, thus 0.1 would indicate that TACC on the first step is 10% higher than TACC on the plateau and that each step increases by 10% of the previous step. The slope parameter for slope rules (*par6*) is defined as the CPUE at which TACC is 1.5 times the plateau height (*par5*).

The minimum change parameter (*par8*) defines the minimum proportional change in TACC. When CPUE changes only slightly and the rule specifies a new TACC differing from the existing TACC by an amount less than *par8*, there is no change to the TACC. If the minimum change parameter and the step height are the same, then technically the TACC cannot be reduced from the second step to the first because the step downwards would be less than the minimum change threshold. Either it must be agreed that minimum change does not apply in the area of the steps, or the minimum change parameter must be set at less than $par7/(1 + par7)$.

The maximum change parameter (*par9*) specifies the maximum allowable proportional TACC change. When CPUE changes so much that the rule specifies a TACC change greater than *par9*, the TACC is changed only by the *par9* proportion. A value of zero for *par9* indicates that there is no maximum change threshold and that any TACC change is allowed.

A latent year component to the rule means that the TACC cannot be changed if it was changed in the previous year (*par10* = 1). An "asymmetric latent year" means that TACC can be decreased, but not increased, when it was changed in the previous year (*par10* = 2). If *par10* = 0 then no latent year is used.

2.3 Rule operation

For both rule forms, and for CPUE less than or equal to the right edge of the plateau ($par4$), the provisional TACC (before operation of thresholds $par8$, $par9$, and $par10$) is given by:

$$TACC_{y+1} = \begin{cases} 0 & \text{if } I_y \leq par2 \\ par5 \left(\frac{I_y - par2}{par3 - par2} \right) & \text{if } par2 < I_y \leq par3 \\ par5 & \text{if } par3 < I_y \leq par4 \end{cases}$$

where $TACC_{y+1}$ is the provisional TACC and I_y is the standardised offset-year CPUE in the preceding year. When CPUE is above the right edge of the plateau, the TACC for plateau step rules is given by:

$$TACC_{y+1} = par5 \left((1 + par7)^{\lfloor (I_y - par4)/par6 \rfloor + 1} \right) \quad \text{if } I_y > par4$$

and for plateau slope rules by:

$$TACC_{y+1} = par5 \left(1 + \frac{0.5(I_y - par4)}{par6 - par4} \right) \quad \text{if } I_y > par4$$

The provisional TACC that results from these equations may be modified by the operation of the minimum and maximum change thresholds, or by a latent year, to give the rule's recommended TACC. The change in TACC is defined as:

$$\Delta = \frac{TACC_{y+1} - TACC_y}{TACC_y}$$

The minimum change threshold is applied as:

$$TACC'_{y+1} = \begin{cases} TACC_y & \text{if } par8 > 0, |\Delta| < par8 \\ TACC_{y+1} & \text{if } par8 > 0, |\Delta| \geq par8 \end{cases}$$

and the maximum change threshold is applied as:

$$TACC'_{y+1} = \begin{cases} (1 - par9)TACC_{y+1} & \text{if } par9 > 0, |\Delta| > par9, \Delta < 0 \\ (1 + par9)TACC_{y+1} & \text{if } par9 > 0, |\Delta| > par9, \Delta > 0 \end{cases}$$

In the rule information given below for each stock, some definitions are:

- "review scheduled" is usually the year five years after development of the current rule; whether the review occurs is a matter for the NRLMG and reviews are sometimes brought forward;
- input CPUE is standardised offset-year CPUE for all stocks where the standardisation includes year, month, and statistical area coefficients; "F2-LFX" (now used for all stocks except CRA 8) defines the data extraction algorithm, which must be the same as that used in MPEs when the rule was developed;
- managers vary in the precision they use in recommending catch limits; the tables report at least the precision used by managers.

For more information on CPUE see Starr (2019).

3. CRA 1 MANAGEMENT PROCEDURE

3.1 Summary

A summary of MPs in CRA 1 is provided in Table 2. The CRA 1 MP is based on work done in 2014 by Webber & Starr (2015), using an operating model based on the CRA 1 stock assessment model. Rules evaluated were generalised plateau step rules. From the options recommended (National Rock Lobster Management Group 2015), the Minister adopted the rule specified in Table 3. In 2015 the Minister set allowances for non-commercial catches and a TAC was set for the first time for CRA 1. Before 2015 there had been only a TACC.

Table 2: Summary of CRA 1 MPs.

	CRA 1
First year with MP	2015
First year of current MP	2015
Review scheduled	2019
Input	F2-LFX offset-year CPUE
Output	TACC
Type of rule	generalised plateau step rule
Minimum change	5%
Maximum change	none
Latent year	none
2019–20 customary allowance	20 t
2019–20 recreational allowance	50 t
2019–20 other mortality allowance	72 t
2019–20 total non-commercial allowance	142 t
2019–20 TACC	131.062 t
2019–20 TAC	273.062 t

Table 3: Parameters for the CRA 1 generalised plateau step rule.

Parameter	Function	Value
<i>par1</i>	rule type	4
<i>par2</i>	CPUE at TACC = 0	0.1
<i>par3</i>	CPUE at plateau left	1.1
<i>par4</i>	CPUE at plateau right	1.7
<i>par5</i>	plateau height	131.062
<i>par6</i>	step width	0.25
<i>par7</i>	step height	0.05
<i>par8</i>	minimum change	0.05
<i>par9</i>	maximum change	0
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2015) for the 2015–16 fishing year described the rule as follows:

Some important elements of the CRA 1 management procedures are:

- *The output variable is TACC (tonnes);*
- *Offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April;*
- *CPUE is calculated using the 2012 F2-LFX procedure which uses landings to a licensed fisher receiver, along with recreational landings from a commercial vessel and the amount of rock lobsters returned to the water in accordance with Schedule 6 of the Act (i.e. high-graded rock lobsters), estimates, by vessel, of the ratio of annual landed catch divided by annual estimated catch to correct every landing record in a quota management area for the vessel;*
- *The management procedure is to be evaluated every year (no "latent year"), based on offset-year CPUE;*
- *The minimum change threshold for the TACC is 5%. There is no maximum change threshold for the TACC;*
- *For Rule 9d: between CPUEs of 0 to 0.1 kg/potlift the TACC is zero, the TACC then increases linearly with CPUE to 1.1 kg/potlift, and between CPUEs of 1.1 to 1.7 kg/potlift the TACC is 131.062 tonnes. As CPUE increases above 1.7 kg/potlift, the TACC increases in steps with a width of 0.25 kg/potlift and a height of 5% of the preceding TACC.*

3.2 History

This is the first MP for CRA 1 and the MP has operated as follows:

- In November 2014, standardised F2-LFX CPUE was 1.5803 kg/potlift (Table 4 and Figure 4), which gave a suggested TACC of 131.062 tonnes (Table 4 and Figure 5). The Minister accepted this MP and assigned the current allowances of customary 20 tonnes, recreational 50 tonnes, and other mortality 72 tonnes (Table 2).
- In November 2015, standardised F2-LFX CPUE was 1.3154 kg/potlift, which remained on the plateau so there was no change to the TACC. This result was accepted by the Minister.
- In November 2016, standardised F2-LFX CPUE was 1.4289 kg/potlift, which remained on the plateau so there was no change to the TACC. This result was accepted by the Minister.
- In November 2017, standardised F2-LFX CPUE was 1.2792 kg/potlift, which remained on the plateau so there was no change to the TACC. This result was accepted by the Minister.
- In November 2018, standardised F2-LFX CPUE was 1.4412 kg/potlift, which remained on the plateau so there was no change to the TACC. This result was accepted by the Minister.

Table 4: History of the current CRA 1 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2014	1.5803	2015–16	131.062	131.062	273.062
2015	1.3154	2016–17	131.062	131.062	273.062
2016	1.4289	2017–18	131.062	131.062	273.062
2017	1.2792	2018–19	131.062	131.062	273.062
2018	1.4412	2019–20	131.062	131.062	273.062

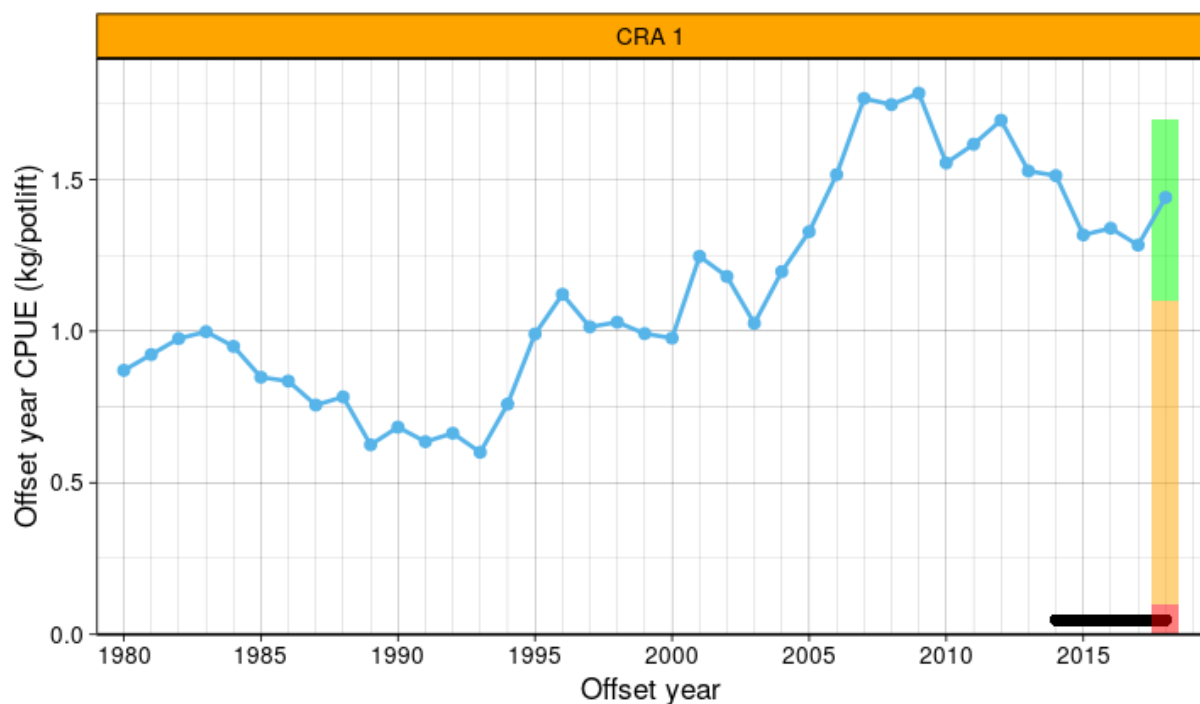


Figure 4: Offset-year CPUE (F2-LFX) (kg/potlift) for CRA 1. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated.

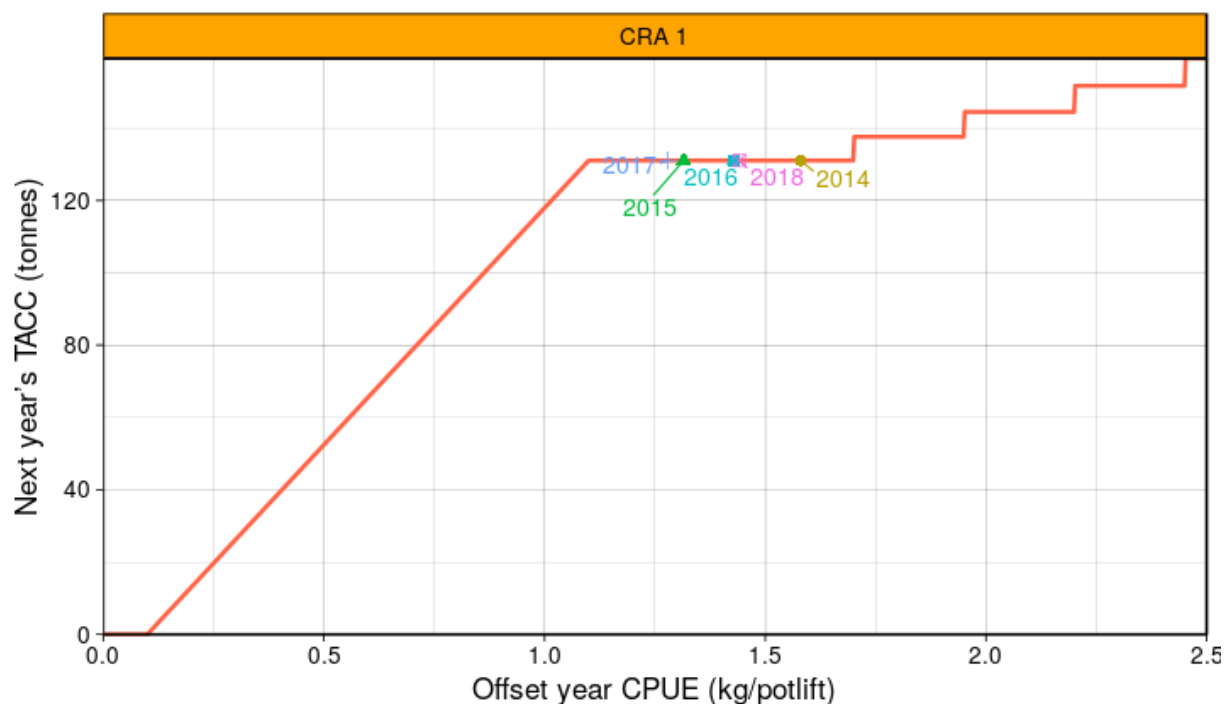


Figure 5: History of the current CRA 1 management procedure. The coloured symbols show the 2014 to 2018 offset-year CPUE and the resulting TACCs.

4. CRA 3 MANAGEMENT PROCEDURE

4.1 Summary

A summary of MPs in CRA 3 is provided in Table 5. The CRA 3 MP is based on work done in 2014 by Haist et al. (2015), using an operating model based on the CRA 3 stock assessment model. The harvest control rule is a modified plateau slope rule. The modification involves:

1. fixing the intercept to zero;
2. having two straight-line segments (instead of one) between zero and the left of the plateau; and
3. having a different slope equation from the generalised rule.

Therefore, rule parameters (Table 6) are defined differently from those in the other rules. The CRA 3 rule is described by:

$$TACC_{y+1} = \begin{cases} par7 \left(\frac{I_y}{par2} \right) & \text{if } I_y \leq par2 \\ par7 + (par5 - par7) \left(\frac{I_y - par2}{par3 - par2} \right) & \text{if } par2 < I_y \leq par3 \\ par5 & \text{if } par3 < I_y \leq par4 \\ par5 + par6 \left(\frac{I_y - par4}{0.5} \right) & \text{if } I_y > par4 \end{cases}$$

where $TACC_{y+1}$ is the provisional TACC (before thresholds operate) and I_y is the offset-year CPUE in the preceding year. The Minister adopted the rule specified in Table 6.

Table 5: Summary of CRA 3 MPs.

	CRA 3
First year with MP	2010
First year of current MP	2015
Review scheduled	2019
Input	F2-LFX offset-year CPUE
Output	TACC
Type of rule	modified plateau slope rule
Minimum change	5%
Maximum change	none
Latent year	none
2019–20 customary allowance	20 t
2019–20 recreational allowance	20 t
2019–20 other mortality allowance	89 t
2019–20 total non-commercial allowance	129 t
2019–20 TACC	222.9 t
2019–20 TAC	351.9 t

Table 6: Parameters for the CRA 3 plateau slope rule evaluated in 2014 and their values for the rule agreed by the Minister in 2015.

Parameter	Function	Value
<i>par1</i>	rule type	6
<i>par2</i>	CPUE at first inflection	1
<i>par3</i>	CPUE at plateau left	2
<i>par4</i>	CPUE at plateau right	3
<i>par5</i>	plateau height	260
<i>par6</i>	step width	50
<i>par7</i>	step height	180
<i>par8</i>	minimum change	0.05
<i>par9</i>	maximum change	0
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2015) for the 2015–16 fishing year described the rule as follows:

Some important elements of the proposed CRA 3 management procedures are:

- *The output variable is TACC (tonnes);*
- *Offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April;*
- *CPUE is calculated using the 2012 F2-LFX procedure which uses landings to a licensed fisher receiver, along with recreational landings from a commercial vessel and the amount of rock lobsters returned to the water in accordance with Schedule 6 of the Act (i.e. high-graded rock lobsters), estimates, by vessel, of the ratio of annual landed catch divided by annual estimated catch to correct every landing record in a quota management area for the vessel;*
- *The management procedure is to be evaluated every year (no "latent year"), based on offset-year CPUE;*
- *The minimum change threshold for the TACC is 5%. There is no maximum change threshold for the TACC.*
- *The proposed new Rule 4 CRA 3 management procedure is a non-standard rule, illustrated in [Figure 6]. For Rule 4: the TACC is zero at a CPUE of zero, the TACC increases linearly with CPUE, reaching 180 tonnes at a CPUE of 1.0 kg/potlift. The TACC then increases linearly to reach 260 tonnes at a CPUE of 2.0 kg/potlift. The TACC remains at 260 tonnes until CPUE reaches 3.0 kg/potlift, after which the TACC increases linearly again with a slope of 100 tonnes per 1 kg/potlift.*

4.2 History

The current rule is the second MP for CRA 3. Of the rules recommended in 2014 (National Rock Lobster Management Group 2015), the Minister chose rule 4 for the 2015–16 fishing year which has operated as follows:

- In November 2014, standardised offset-year CPUE was 2.2139 kg/potlift (Table 7 and Figure 6), which gave a suggested TACC of 260 tonnes (Table 7 and Figure 7). The Minister accepted this result and retained the previous non-commercial allowances of customary 20 tonnes, recreational 20 tonnes, and illegal 89 tonnes (Table 5).
- In November 2015, standardised F2-LFX offset-year CPUE decreased to 1.8842 kg/potlift and was no longer on the plateau; the preliminary rule result was a TACC of 250.736 tonnes. Because this would have been a TACC change of 3.9%, which was below the minimum change threshold of 5%, the MP result was no change in the TACC. This result was accepted by the Minister.
- In November 2016, standardised F2-LFX offset-year CPUE decreased again to 1.7232 kg/potlift; the preliminary rule result was a TACC of 237.857 tonnes. This TACC change was 8.95%, well

above the minimum change threshold of 5%, so the MP result was a decrease in the TACC. This result was accepted by the Minister.

- In November 2017, standardised F2-LFX offset-year CPUE increased to 1.7873 kg/potlift; the preliminary rule result was a TACC of 237.857 tonnes. The MP result was no change in the TACC. This result was accepted by the Minister.
- In November 2018, standardised F2-LFX offset-year CPUE decreased to 1.5368 kg/potlift; the preliminary rule result was a TACC of 222.942 tonnes. This TACC change was -6.3%, above the minimum change threshold of 5%, so the MP result was a decrease in the TACC. This result was accepted by the Minister.

Table 7: History of the current CRA 3 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2014	2.2139	2015–16	260.000	260.95	389.95
2015	1.8842	2016–17	260.000	260.95	389.95
2016	1.7232	2017–18	237.857	237.86	366.86
2017	1.7873	2018–19	237.857	237.86	366.86
2018	1.5368	2019–20	222.942	222.90	351.90

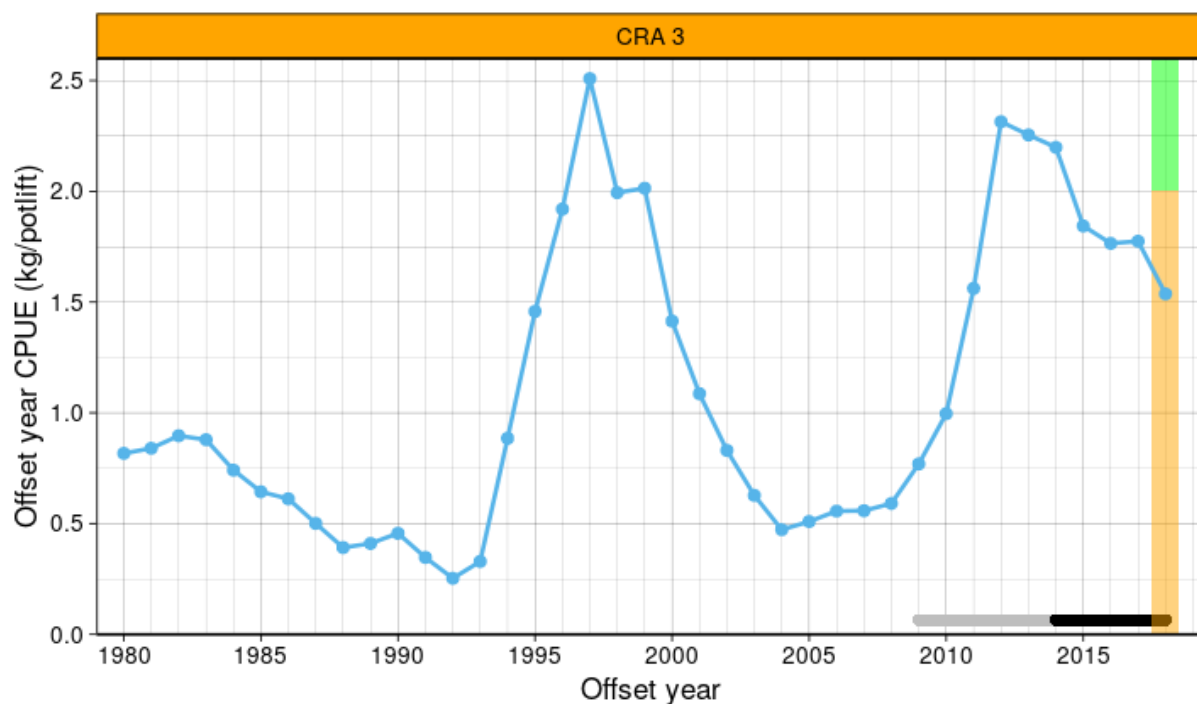


Figure 6: Offset-year CPUE (F2-LFX) (kg/potlift) for CRA 3. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated, the grey indicates the years that other MPs operated.

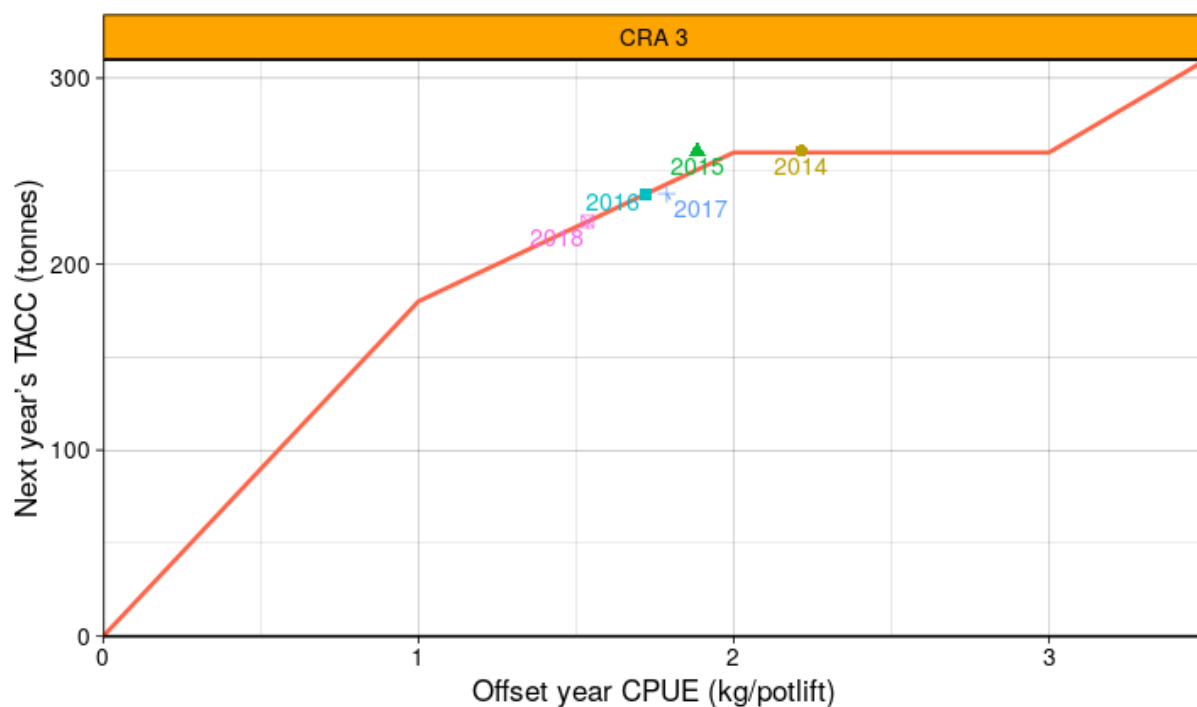


Figure 7: History of the current CRA 3 management procedure. The coloured symbols show the 2014 to 2018 offset-year CPUE and the resulting TACCs.

5. CRA 4 MANAGEMENT PROCEDURE

5.1 Summary

A summary of MPs in CRA 4 is provided in Table 8. The CRA 4 MP is based on work done in 2016 (Breen et al. 2017), using an operating model based on the CRA 4 stock assessment model. Rules evaluated were generalised plateau step rules. From the options recommended (National Rock Lobster Management Group 2017), the Minister adopted the rule specified in Table 9.

Table 8: Summary of CRA 4 MPs.

	CRA 4
First year with MP	2007
First year of current MP	2017
Review scheduled	2021
Input	F2-LFX offset year CPUE
Output	TACC
Type of rule	generalised plateau step rule
Minimum change	5%
Maximum change	none
Latent year	none
2019–20 customary allowance	35 t
2019–20 recreational allowance	85 t
2019–20 other mortality allowance	75 t
2019–20 total non-commercial allowance	195 t
2019–20 TACC	318.8 t
2019–20 TAC	513.8 t

Table 9: Parameters for the CRA 4 generalised plateau step rule.

Parameter	Function	Value
<i>par1</i>	rule type	4
<i>par2</i>	CPUE at TACC = 0	0
<i>par3</i>	CPUE at plateau left	0.9
<i>par4</i>	CPUE at plateau right	1.3
<i>par5</i>	plateau height	380
<i>par6</i>	step width	0.1
<i>par7</i>	step height	0.053
<i>par8</i>	minimum change	0.05
<i>par9</i>	maximum change	0
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2017) for the 2017–18 fishing year described the rule as follows:

- The output variable is TACC (tonnes);
- Offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April;
- CPUE is calculated using the 2012 F2_LFX procedure [...];
- The management procedure is to be evaluated every year (no “latent year”), based on offset-year CPUE; and
- The minimum change threshold for the TACC is 5%. There is no maximum change threshold for the TACC.

The proposed new CRA 4 management procedures are both generalised plateau step rules [...] For Rule 6: at a CPUE value of zero the TACC is zero; the TACC then increases linearly to 0.9 kg/potlift; between CPUEs of 0.9 and 1.3 kg/potlift the TACC is 380 tonnes; as CPUE increases above 1.3 kg/potlift, the TACC increases in steps with a width of 0.1 kg/potlift and a height of 5.3% of the preceding TACC.

5.2 History

The first MP for CRA 4 was voluntary (Breen et al. 2009b), based on the work of Breen & Kim (2006), and was used to guide ACE (Annual Catch Entitlement, related to quota) shelving for 2007 and 2008. The Minister adopted the current MP in March 2017 for the 2017–18 fishing year.

- In November 2016, standardised offset-year CPUE was 0.6851 kg/potlift (Table 10 and Figure 8), giving a TACC of 289.264 tonnes (Table 10 and Figure 9). This result was accepted by the Minister.
- In November 2017, standardised offset-year CPUE increased to 0.7550 kg/potlift, giving a TACC of 318.778 tonnes. This result was accepted by the Minister after rounding to 1 decimal place.
- In November 2018, standardised offset-year CPUE increased to 0.9012 kg/potlift, giving a TACC on the plateau of 380.0 tonnes. This TACC change was +19.2%, well above the minimum change threshold of 5%, so the MP result was an increase in the TACC. However, this result was not accepted by the Minister who decided to retain the previous year’s TACC of 318.8 tonnes.

Table 10: History of the current CRA 4 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2016	0.6851	2017–18	289.264	289.0	484.0
2017	0.7550	2018–19	318.778	318.8	513.8
2018	0.9012	2019–20	380.000	318.8	513.8

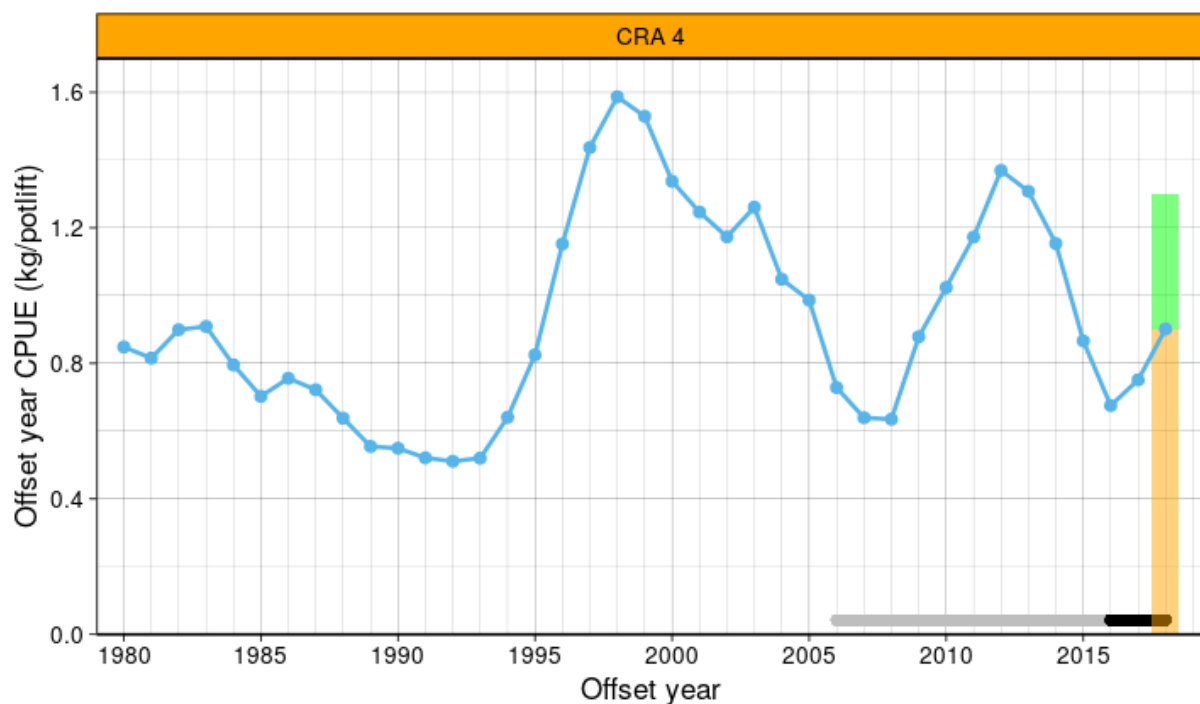


Figure 8: Offset-year CPUE (F2-LFX) (kg/potlift) for CRA 4. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated, the grey indicates the years that other MPs operated.

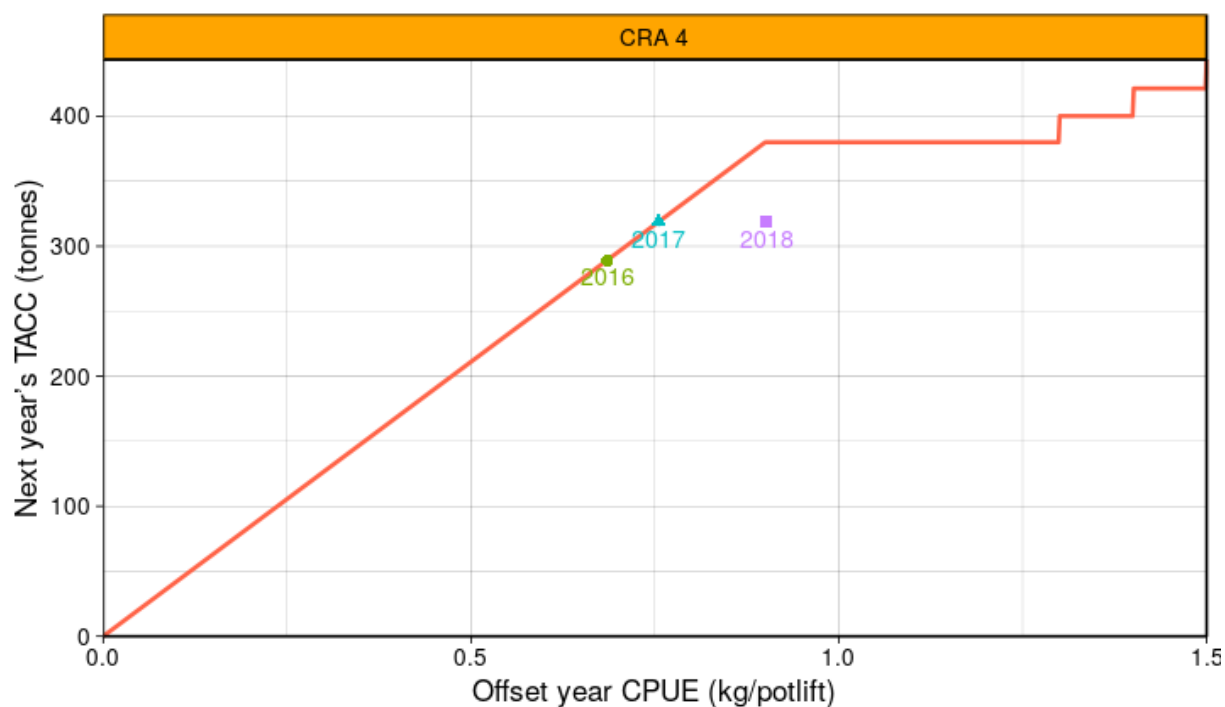


Figure 9: History of the current CRA 4 management procedure. The coloured symbols show the 2016 to 2018 offset-year CPUE and the resulting TACCs.

6. CRA 5 MANAGEMENT PROCEDURE

6.1 Summary

A summary of MPs in CRA 5 is provided in Table 11. The CRA 5 MP is based on MPEs done in 2015 (Starr & Webber 2016), using an operating model based on the CRA 5 stock assessment model. Rules evaluated were generalised plateau step rules. From the options recommended, the (National Rock Lobster Management Group 2016) chose, and the Minister accepted, the rule specified in Table 12. The Minister increased the recreational allowance from 40 to 87 tonnes.

Table 11: Summary of CRA 5 MPs.

	CRA 5
First year with MP	2009
First year of current MP	2016
Review scheduled	2020
Input	F2-LFX offset-year CPUE
Output	TACC
Type of rule	generalised plateau step rule
Minimum change	5%
Maximum change	none
Latent year	none
2019–20 customary allowance	40 t
2019–20 recreational allowance	87 t
2019–20 other mortality allowance	37 t
2019–20 total non-commercial allowance	164 t
2019–20 TACC	350 t
2019–20 TAC	514 t

Table 12: Parameters for the CRA 5 generalised plateau step rule.

Parameter	Function	Value
<i>par1</i>	rule type	4
<i>par2</i>	CPUE at TACC = 0	0.3
<i>par3</i>	CPUE at plateau left	1.2
<i>par4</i>	CPUE at plateau right	2.2
<i>par5</i>	plateau height	350
<i>par6</i>	step width	0.2
<i>par7</i>	step height	0.055
<i>par8</i>	minimum change	0.05
<i>par9</i>	maximum change	0
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2016) for the 2016–17 fishing year described the new harvest control rule as follows:

- The output variable is TACC (tonnes);
- Offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April;
- CPUE is calculated using the 2012 F2_LFX procedure which uses:
 - landings to a licensed fisher receiver, along with recreational landings from a commercial vessel and the amount of rock lobsters returned to the water in accordance with Schedule 6 of the Act (i.e. high-graded rock lobsters),
 - estimates, by vessel, of the ratio of annual landed catch divided by annual estimated catch to correct every landing record in a quota management area for the vessel;
- The management procedure is to be operated every year (no “latent year”), based on offset-year CPUE;
- The minimum change threshold for the TACC is 5%. There is no maximum change threshold for the TACC.

The proposed new CRA 5 management procedure is based on a generalised plateau step rule [...]. Between CPUEs of zero and 0.3 kg/potlift the TACC is zero, the TACC then increases linearly with CPUE to 350 tonnes at a CPUE of 1.2 kg/potlift. The TACC remains at 350 tonnes until CPUE reaches 2.2 kg/potlift and then increases by 5.5% in CPUE steps of 0.2 kg/potlift.

6.2 History

The current rule was adopted by the Minister for the 2016–17 fishing year. The Minister retained the customary allowance of 40 tonnes and the illegal allowance of 37 tonnes but increased the recreational allowance from 40 to 87 tonnes (Table 11).

- In November 2015, standardised F2-LFX offset-year CPUE was 1.7890 kg/potlift (Table 13 and Figure 10), which specified a TACC of 350 tonnes, on the plateau (Table 13 and Figure 11). This result was accepted by the Minister.
- In November 2016, standardised F2-LFX offset-year CPUE was 1.5902 kg/potlift, which specified a TACC of 350 tonnes, which remained on the plateau. This result was accepted by the Minister.
- In November 2017, standardised F2-LFX offset-year CPUE was 2.0482 kg/potlift, which specified a TACC of 350 tonnes, which remained on the plateau. This result was accepted by the Minister.
- In November 2018, standardised F2-LFX offset-year CPUE was 1.7977 kg/potlift, which specified a TACC of 350 tonnes, which remained on the plateau. This result was accepted by the Minister.

Table 13: History of the current CRA 5 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2015	1.7890	2016–17	350	350	514
2016	1.5902	2017–18	350	350	514
2017	2.0482	2018–19	350	350	514
2018	1.7977	2019–20	350	350	514

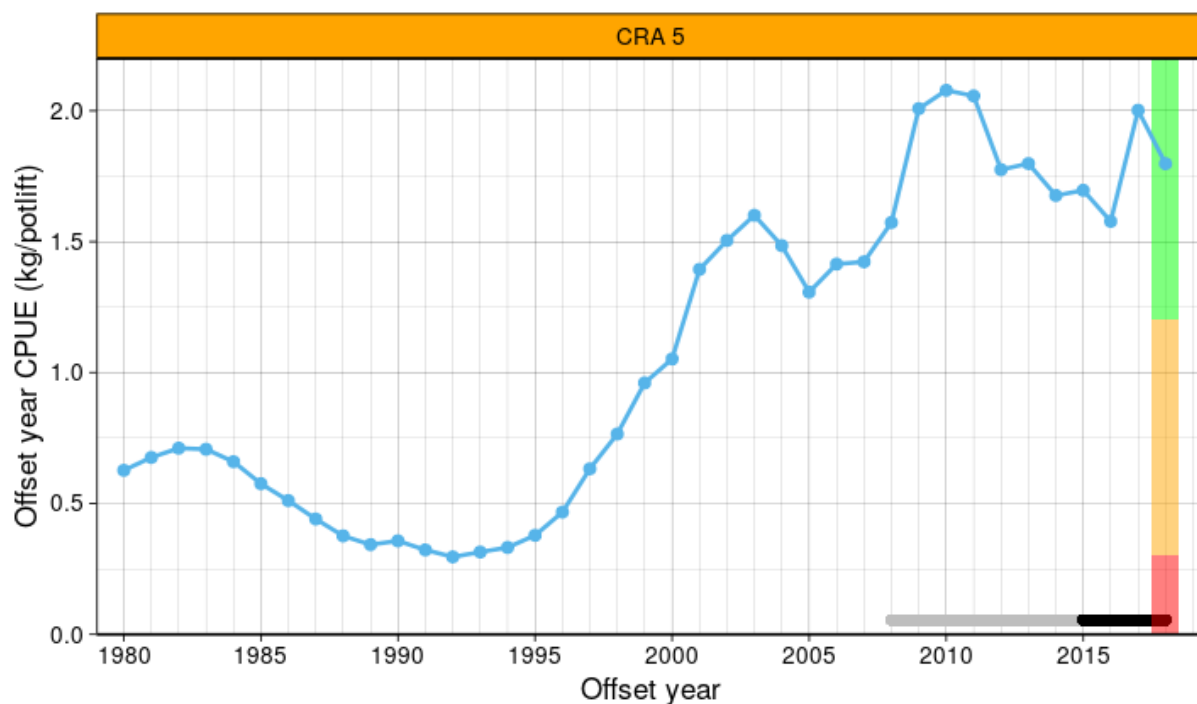


Figure 10: Offset-year CPUE (F2-LFX) (kg/potlift) for CRA 5. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated, the grey indicates the years that other MPs operated.

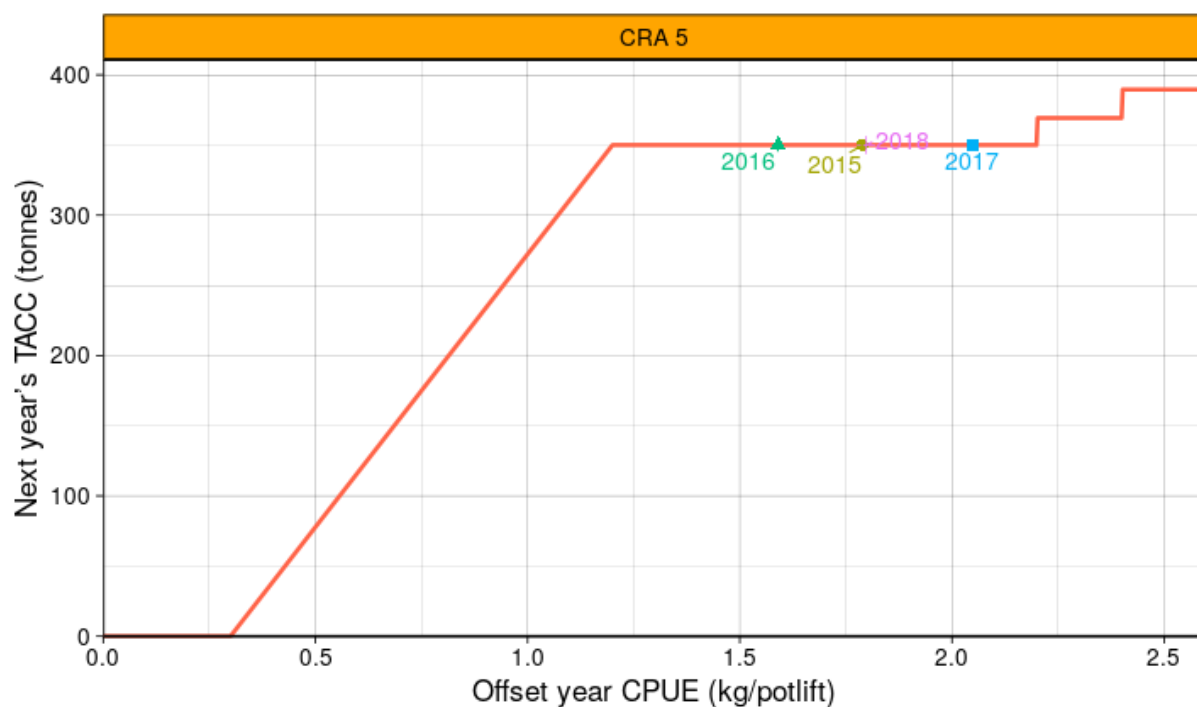


Figure 11: History of the current CRA 5 management procedure. The coloured symbols show the 2015 to 2018 offset-year CPUE and the resulting TACCs.

7. CRA 7 MANAGEMENT PROCEDURE

7.1 Summary

A summary of MPs in CRA 7 is provided in Table 14. The CRA 7 MP is based on MPEs done in 2012, which used an operating model based on the 2012 joint stock assessment for CRA 7 and CRA 8 (Haist et al. 2013). This MP was re-evaluated in 2015 after a new stock assessment (Haist et al. 2016) and was retained. Rules evaluated in 2012 and again in 2015 were generalised slope rules. From the options originally recommended (National Rock Lobster Management Group 2013), the Minister adopted the rule specified in Table 15. This rule replaced an earlier rule and is the latest in a series (Starr et al. 1997, Bentley et al. 2003a, Breen et al. 2008).

Table 14: Summary of CRA 7 MPs.

	CRA 7
First year with MP	1996
First year of current MP	2013
Review scheduled	2020
Input	F2-LFX offset-year CPUE
Output	TACC
Type of rule	generalised plateau slope rule
Minimum change	10%
Maximum change	50%
Latent year	none
2019–20 customary allowance	10 t
2019–20 recreational allowance	5 t
2019–20 other mortality allowance	5 t
2019–20 total non-commercial allowance	20 t
2019–20 TACC	97 t
2019–20 TAC	117 t

Table 15: Parameters for the CRA 7 generalised plateau slope rule.

Parameter	Function	Value
<i>par1</i>	rule type	3
<i>par2</i>	CPUE at TACC = 0	0.17
<i>par3</i>	CPUE at plateau left	1
<i>par4</i>	CPUE at plateau right	1.75
<i>par5</i>	plateau height	80
<i>par6</i>	slope	3
<i>par7</i>	n.a.	0
<i>par8</i>	minimum change	0.1
<i>par9</i>	maximum change	0.5
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2013) for the 2013–14 fishing year described the rule as follows:

Some important elements of the new Rule 39 CRA 7 Management Procedure are:

- *the output variable is TACC (tonnes) (non-commercial catch assumptions are made from the operating model).*
- *offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April.*
- *CPUE is calculated using the new "F2-LFX" procedure which uses:*
 - *Ministry for Primary Industries landings to a licensed fisher receiver, along with recreational landings from a commercial vessel and the amount of rock lobsters returned to the water in accordance with Schedule 6 of the Act (i.e. high-graded rock lobsters),*
 - *estimates, by vessel, of the ratio of annual landed catch divided by annual estimated catch to correct every landing record in a quota management area for the vessel.*
- *the management procedure is to be evaluated every year (no "latent year"), based on offset-year CPUE.*
- *the new CRA 7 Management Procedure is based on a generalised plateau rule. Below a CPUE of 0.17 kg/potlift, the TACC is zero; between a CPUE of [0.17] and 1.0 kg/potlift, the TACC increases linearly with CPUE to a plateau of 80 tonnes, which extends to a CPUE of 1.75 kg/potlift. As CPUE increases above 1.75 kg/potlift, TACC increases linearly. The minimum change threshold for the TACC is 10% and the maximum change threshold is 50%.*

7.2 History

The Minister adopted this rule in 2013 for the 2013–14 fishing year.

- In November 2012, the standardised offset-year CPUE was 0.625 kg/potlift (Table 16 and Figure 12), giving a TACC of 44.96 tonnes (Table 16 and Figure 13). The Minister accepted this result and retained the previous non-commercial allowances of customary 10 tonnes, recreational 5 tonnes, and other mortality 5 tonnes, to set a TAC of 64 tonnes (Table 14).
- In November 2013, the offset-year CPUE had more than doubled to 1.356 kg/potlift, which suggested a TACC of 80 tonnes. The increase was greater than the maximum allowed increase of 50%, so the TACC was increased by 50% to 66 tonnes. The Minister accepted this result and used the same allowances to set a TAC of 86 tonnes.
- In November 2014, the offset-year CPUE had increased to 2.304 kg/potlift, giving a TACC of 97.72 tonnes. The Minister accepted this result and retained the same allowances as before, giving a TAC of 117.72 tonnes.
- In November 2015, standardised F2-LFX offset-year CPUE had decreased slightly to 2.212 kg/potlift and the preliminary rule result was a TACC of 94.797 tonnes. Because this would be a change of only 2.9%, less than minimum change threshold of 10%, the MP result was no change to the TACC.
- In November 2016, standardised F2-LFX offset-year CPUE had increased to 2.766 kg/potlift and the preliminary rule result was a TACC of 112.512 tonnes. The increase of 25% was greater than the 10% minimum change threshold, so the MP result was an increase in the 2017–18 TACC to 112.512 tonnes. The Minister accepted this result.
- In November 2017, standardised F2-LFX offset-year CPUE decreased to 2.328 kg/potlift and the preliminary rule result was a TACC of 98.499 tonnes, a 12.5% decrease from the TACC of 112.52 tonnes. Because this is greater than the minimum change threshold of 10%, the result was a 12.5% decrease in the 2018–19 TACC to 98.499 tonnes. The Minister accepted this result and set the TACC at 97 tonnes.
- In November 2018, standardised F2-LFX offset-year CPUE decreased to 2.292 kg/potlift and the preliminary rule result was a TACC of 97.343 tonnes. This change in TACC is less than 1% and less than the minimum change threshold of 10%, resulting in no change to the TACC. The Minister accepted this result.

Table 16: History of the current CRA 7 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2012	0.625	2013–14	43.960	44.00	64.00
2013	1.356	2014–15	66.000	66.00	86.00
2014	2.304	2015–16	97.720	97.72	117.72
2015	2.212	2016–17	97.720	97.72	117.72
2016	2.766	2017–18	112.512	112.52	132.52
2017	2.328	2018–19	98.499	97.00	117.00
2018	2.292	2019–20	97.000	97.00	117.00

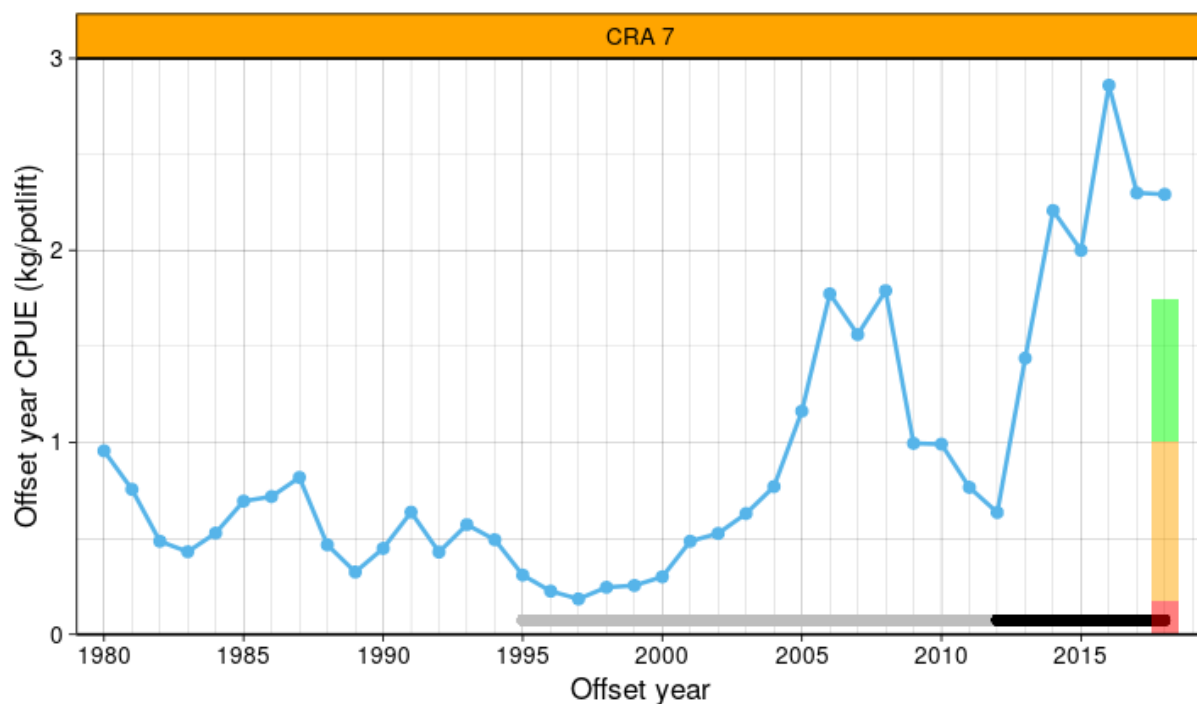


Figure 12: Offset-year CPUE (F2-LFX) (kg/potlift) for CRA 7. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated, the grey indicates the years that other MPs operated.

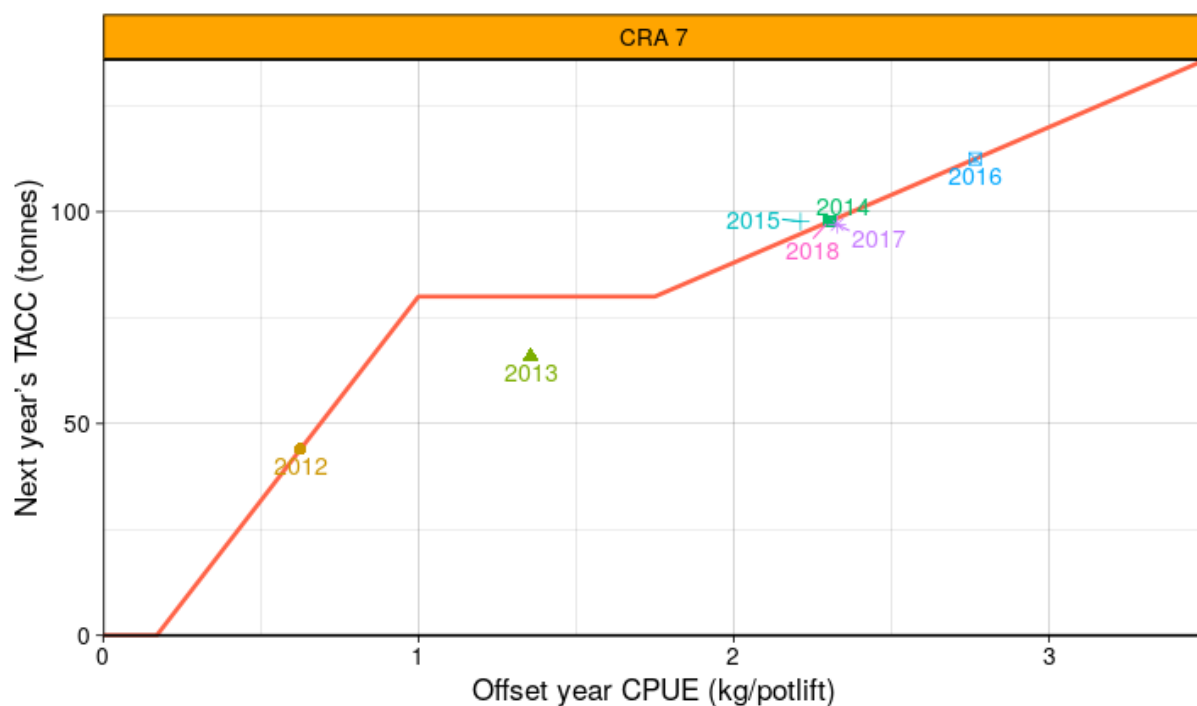


Figure 13: History of the current CRA 7 management procedure. The coloured symbols show the 2012 to 2018 offset-year CPUE and the resulting TACCs.

8. CRA 8 MANAGEMENT PROCEDURE

8.1 Summary

A summary of MPs in CRA 8 is provided in Table 17. The CRA 8 MP is based on MPEs done in 2015, using an operating model based on the combined CRA 7 and CRA 8 stock assessment (Haist et al. 2016). The input CPUE is based only on the sizes of fish that are landed, not on all sizes including the larger ones that are not economic. This was called "\$CPUE" or "money-fish CPUE" in the MPEs and is calculated using the F2-LF algorithm (see Starr 2019). The more usual F2-LFX procedure includes destination X (i.e., legal lobsters returned to the sea). From the options recommended, the National Rock Lobster Management Group (2016) chose, and the Minister adopted, the rule specified in Table 18. This rule replaced a similar rule and is the fifth in a series that began in 1996 (Starr et al. 1997; Bentley et al. 2003a, Breen et al. 2008, Haist et al. 2013). Except for an extended plateau and the altered input, the adopted rule is very similar to the previous CRA 8 MP, when the allowances are the same (the previous rule generated a TAC, this rule generates a TACC).

Table 17: Summary of CRA 8 MPs.

	CRA 8
First year with MP	1996
First year of current MP	2016
Review scheduled	2020
Input	F2-LF offset-year CPUE
Output	TACC
Type of rule	generalised plateau step rule
Minimum change	5%
Maximum change	none
Latent year	none
2019–20 customary allowance	30 t
2019–20 recreational allowance	33 t
2019–20 other mortality allowance	28 t
2019–20 total non-commercial allowance	91 t
2019–20 TACC	1129.6 t
2019–20 TAC	1220.6 t

Table 18: Parameters for the CRA 8 generalised plateau step rule.

Parameter	Function	Value
<i>par1</i>	rule type	4
<i>par2</i>	CPUE at TACC = 0	0.5
<i>par3</i>	CPUE at plateau left	1.9
<i>par4</i>	CPUE at plateau right	3.2
<i>par5</i>	plateau height	962
<i>par6</i>	step width	0.5
<i>par7</i>	step height	0.055
<i>par8</i>	minimum change	0.05
<i>par9</i>	maximum change	0
<i>par10</i>	latent year switch	0

The Final Advice Paper (National Rock Lobster Management Group 2016) for the 2016–17 fishing year described the rule as follows:

Some important elements of the proposed new CRA 8 management procedure are:

- *The output variable is TACC (tonnes);*
- *Offset-year standardised CPUE is used as an input to the rule to determine the TACC for the fishing year that begins in the following April;*
- *CPUE is calculated using the new “F2_LF” procedure, which gives the “money-fish” CPUE, or \$CPUE. This procedure uses:*
 - *landings to a licensed fisher receiver, along with recreational landings from a commercial vessel (it does not include the amount of rock lobsters returned to the water in accordance with Schedule 6 of the Act (i.e. high-graded rock lobsters) as does the F2_LFX procedure),*
 - *estimates, by vessel, of the ratio of annual landed catch divided by annual estimated catch to correct every landing record in a quota management area for the vessel;*
- *The management procedure is to be evaluated every year (no “latent year”), based on offset-year CPUE;*
- *The minimum change threshold for the TACC is 5%. There is no maximum change threshold for the TACC.*

The proposed new CRA 8 management procedure is based on a generalised plateau step rule [...]. Between CPUEs of zero and 0.5 kg/potlift the TACC is zero, the TACC then increases linearly with CPUE to 962 tonnes at a CPUE of 1.9 kg/potlift. The TACC remains at 962 tonnes until CPUE reaches 3.2 kg/potlift and then increases by 5.5% in CPUE steps of 0.5 kg/potlift.

8.2 History

The history of the CRA 8 MP is shown in Table 19.

- In November 2015, standardised offset-year F2-LF CPUE was 3.0620 kg/potlift (Table 19 and Figure 14), which gave a TACC on the plateau (Table 19 and Figure 15).
- In November 2016, standardised offset-year F2-LF CPUE was 3.0254 kg/potlift, which gave a suggested TACC on the plateau of 962.0 tonnes.
- In November 2017, standardised offset-year F2-LF CPUE was 3.7113 kg/potlift, which gave a suggested TACC above the plateau of 1070.7 tonnes. This TACC change was +11.3%, well above the minimum change threshold of 5%, so the MP result was an increase in the TACC. The Minister accepted this result and increased the TACC.
- In November 2018, standardised offset-year F2-LF CPUE was 4.2481 kg/potlift, which gave a suggested TACC above the plateau of 1129.6 tonnes. This TACC change was +5.5%, above the minimum change threshold of 5%, so the MP result was an increase in the TACC. The Minister accepted this result and increased the TACC.

Table 19: History of the current CRA 8 management procedure and its operation in 2018. "Rule result TACC" is the result of the management procedure. "Applied TACC" and "Applied TAC" are the catch limits decided by the Minister.

Offset year	Offset-year CPUE (kg/potlift)	Applied to fishing year	Rule result TACC (tonnes)	Applied TACC (tonnes)	Applied TAC (tonnes)
2015	3.0620	2016–17	962.0	962.0	1053.0
2016	3.0254	2017–18	962.0	962.0	1053.0
2017	3.7113	2018–19	1070.7	1070.7	1161.7
2018	4.2481	2019–20	1129.6	1129.6	1220.6

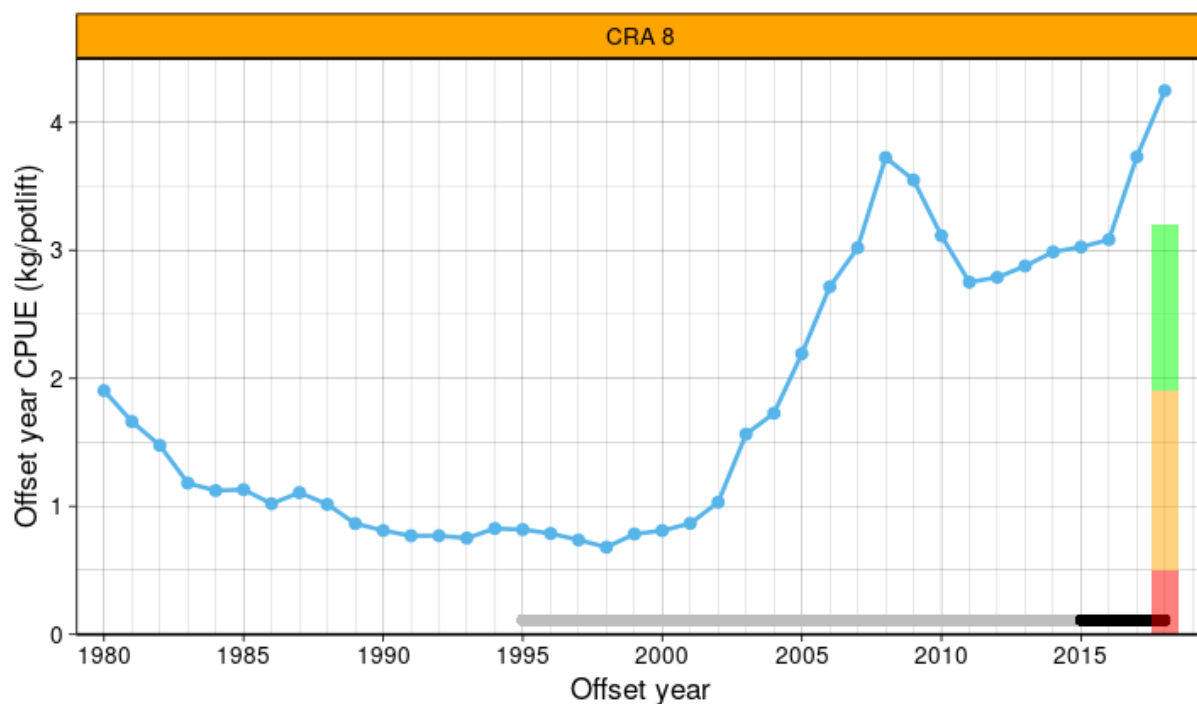


Figure 14: Offset-year CPUE (F2-LF) (kg/potlift) for CRA 8. The coloured bar represents the plateau (green), the slope (orange), and the CPUE at which the TACC = 0 (red). The horizontal black line indicates the years that the current MP has operated, the grey indicates the years that other MPs operated.

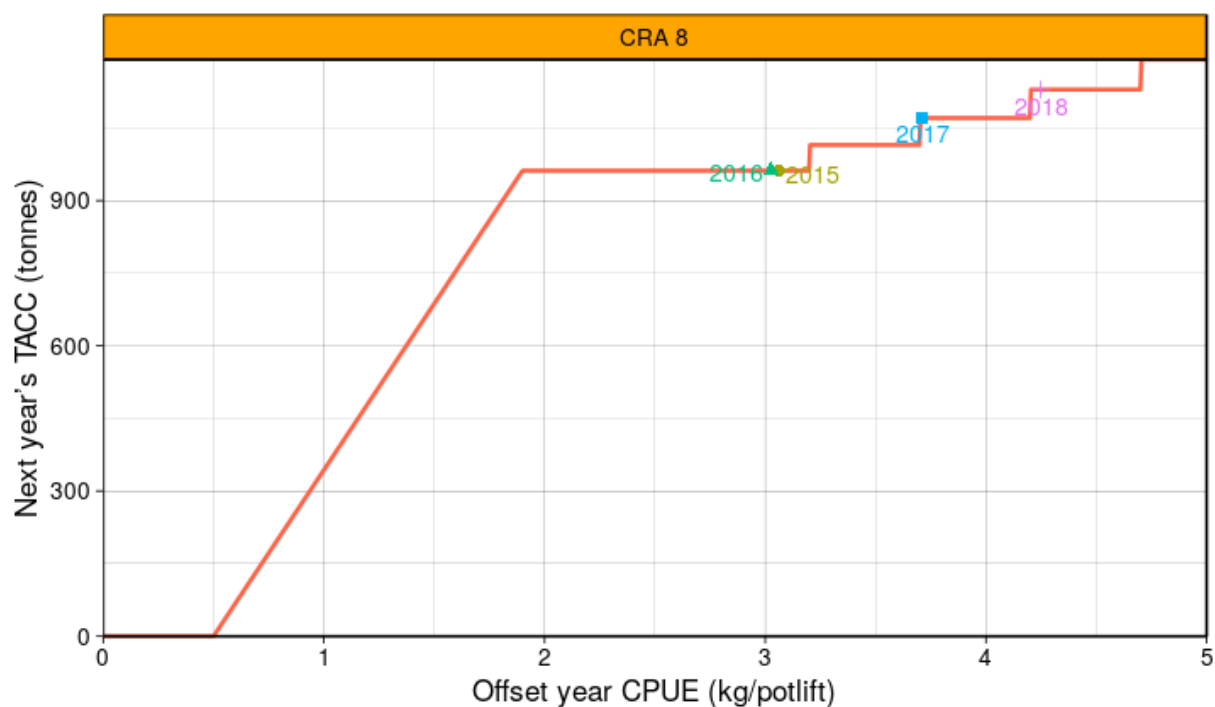


Figure 15: History of the current CRA 8 management procedure. The coloured symbols show the 2015 to 2018 offset-year CPUE and the resulting TACCs.

9. SUMMARY

Offset-year CPUE for each of the six QMAs managed using MPs is summarised in Figure 16 and the associated MPs are summarised in Figure 17.

Fisheries New Zealand is implementing electronic reporting of catch for rock lobster, from April 2019. It is not known how this change in the catch and effort data collection procedure will affect the CPUE used to drive current MPs, but past experience suggests that the new data will not necessarily be comparable with the previous paper-based data collection system. Given the phased implementation of the new system proposed by Fisheries New Zealand, it is likely that some of the existing MPs can be safely evaluated in November 2019. It is likely that the proposed changes to the collection of catch and effort data will require the development of new evaluation procedures beyond 2019.

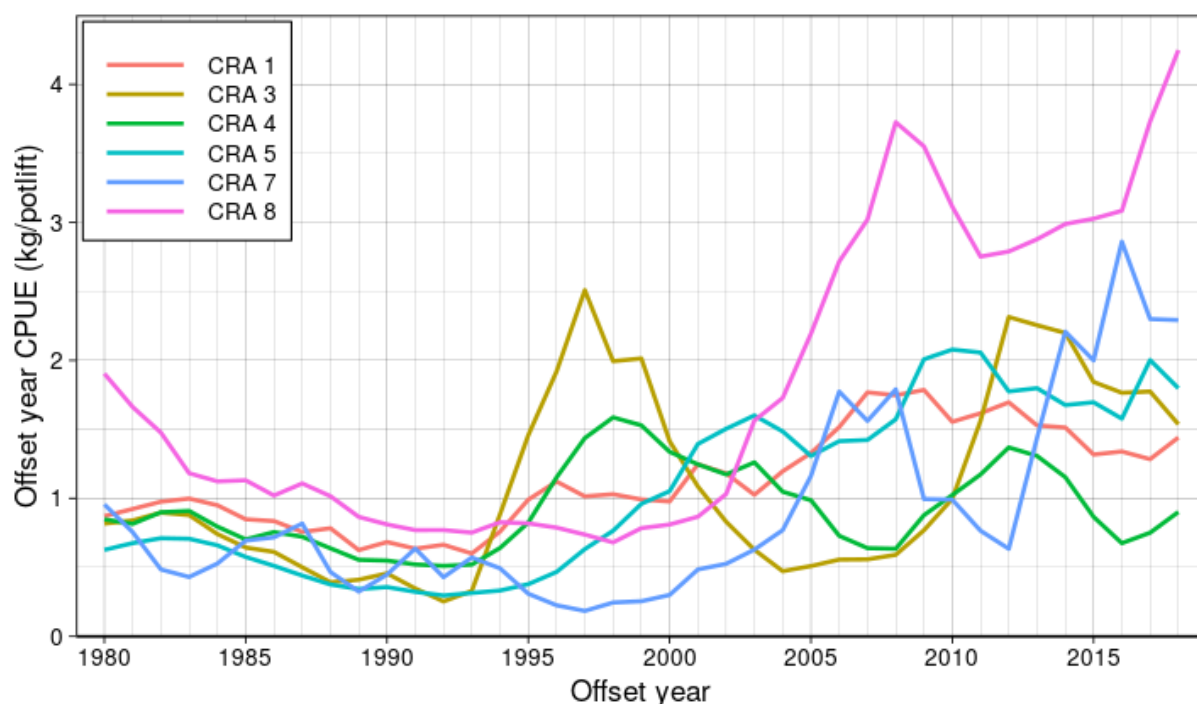


Figure 16: Offset-year CPUE (kg/potlift) for all QMAs managed using a management procedure.

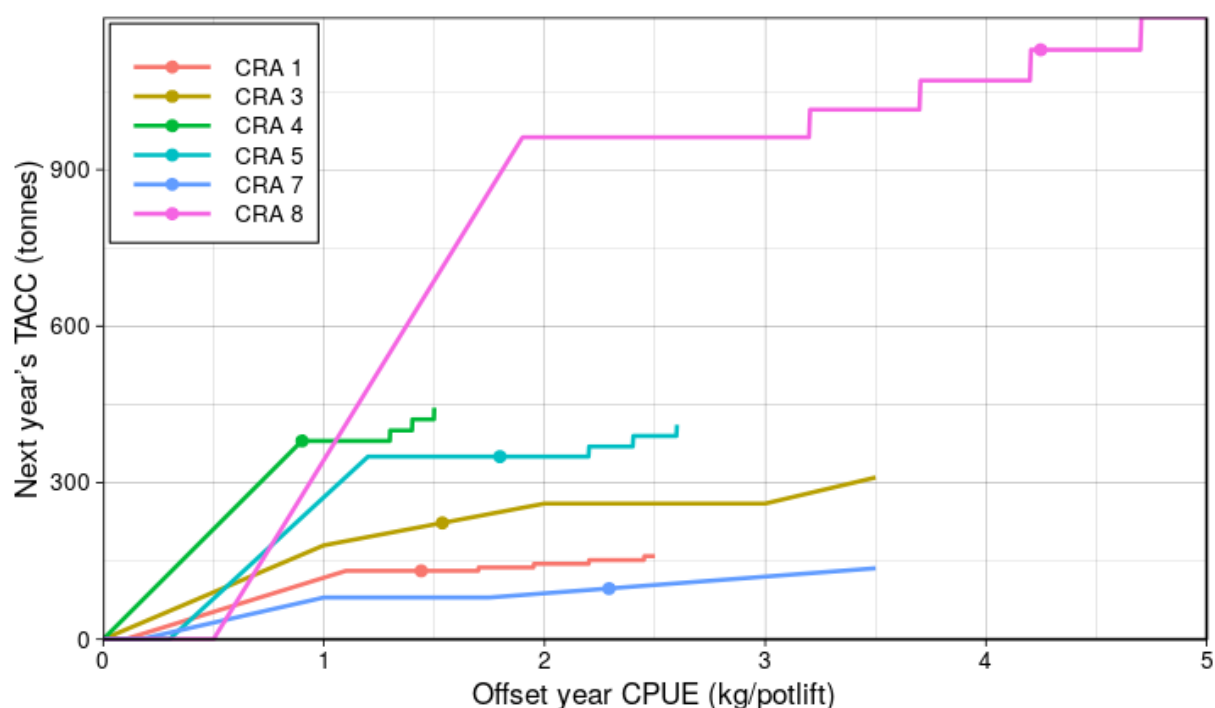


Figure 17: All current management procedures (lines) and the applied TACC (points).

10. ACKNOWLEDGMENTS

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12. APPENDIX

The Stan code (Stan Development Team 2017) used to operate the MPs is contained within the function "rule_tacc" which is provided below. This is the same function that is used in the LSD model for running MPES.

```
/**
 * Harvest Control Rule (HCR)
 *
 * par1: rule type (3=plateau with slope, 4=plateau with step)
 * par2: CPUE at TACC = 0 or CPUE at first inflection (CRA 3 only)
 * par3: CPUE at plateau left
 * par4: CPUE at plateau right
 * par5: plateau height
 * par6: step width or slope
 * par7: step height
 * par8: minimum change
 * par9: maximum change
 * par10: latent year
 *
 * @param y the current year (used for y-1 checks)
 * @param par a vector of the parameters as described above
 * @param cpue the input CPUE
 * @param tacc_y the TACC in the past
 * @return the TACC
 */
real rule_tacc(int y, int n_yr, vector par, real cpue, vector tacc_y) {
  real tacc;
  real nsteps;
  real diff;

  // Validation of several parameters
  if (par[1] < 1 || par[1] > 6) {
    reject("Error: par1 = ", par[1], " is not a valid harvest control
rule.");
  }
  if ((par[1] == 2 || par[1] == 3) && !(par[2] < par[3])) {
    reject("Error: par2 < par3 is not true.");
  }
  if ((par[1] == 2 || par[1] == 3) && !(par[2] < par[4])) {
    reject("Error: par2 < par4 is not true.");
  }
  if ((par[1] == 2 || par[1] == 3) && !(par[3] <= par[4])) {
    reject("Error: par3 <= par4 is not true.");
  }
  if (par[1] == 3 && !(par[4] < par[6])) {
    reject("Error: par4 < par6 is not true.");
  }
  if (par[10] > 2) {
    reject("Error: par10 = ", par[10], " is not a valid parameter.");
  }

  // Evaluate the rule
  if (par[1] == 1) { // Constant TACC rule
    tacc = par[2];
  } else if (par[1] == 2) { // Constant CPUE multiplier
    tacc = par[2] * cpue;
  } else if (par[1] == 3) { // Plateau rule with slope
    if (cpue <= par[2]) {
      tacc = 0.0;
    } else if (cpue > par[2] && cpue <= par[3]) {
      tacc = par[5] * ((cpue - par[2]) / (par[3] - par[2]));
    } else if (cpue > par[3] && cpue <= par[4]) {

```

```

    tacc = par[5];
  } else if (cpue > par[4]) {
    tacc = (cpue - par[4]) * 0.5 * par[5] / (par[6] - par[4]) + par[5];
  }
} else if (par[1] == 4) { // Plateau rule with step function
  if (cpue <= par[2]) {
    tacc = 0.0;
  } else if (cpue > par[2] && cpue <= par[3]) {
    tacc = par[5] * ((cpue - par[2]) / (par[3] - par[2]));
  } else if (cpue > par[3] && cpue <= par[4]) {
    tacc = par[5];
  } else if (cpue > par[4]) {
    nsteps = floor(((cpue - par[4]) / par[6]) + 1e-9) + 1.0; // add a
small constant because "floor" does strange things when = to int value
    tacc = par[5] * pow(1.0 + par[7], nsteps);
  }
} else if (par[1] == 6) {
  if (cpue <= par[2]) {
    tacc = par[7] * cpue / par[2]; // this rule has a 0 intercept
  } else if (cpue > par[2] && cpue <= par[3]) {
    tacc = par[7] + (par[5] - par[7]) * (cpue - par[2]) / (par[3] -
par[2]);
  } else if (cpue > par[3] && cpue <= par[4]) {
    tacc = par[5];
  } else if (cpue > par[4]) {
    tacc = par[5] + par[6] * (cpue - par[4]) / 0.5;
  }
}
}

if (par[1] >= 3) { // Changed this after discussion with Paul
  if (tacc_y[y] <= 0.0) {
    diff = (tacc - tacc_y[y]) / (tacc_y[y] + 1e-6);
  } else {
    diff = (tacc - tacc_y[y]) / (tacc_y[y]);
  }

  if (par[8] > 0.0 && sqrt(square(diff)) < par[8]) {
    // Minimum change - no change if prop. change < par[8]
    tacc = tacc_y[y];
  }

  if (par[9] > 0.0 && sqrt(square(diff)) > par[9] && diff < 0.0) {
    // Maximum change if change > par[9]
    tacc = (1.0 - par[9]) * tacc_y[y];
  }
  if (par[9] > 0.0 && sqrt(square(diff)) > par[9] && diff > 0.0) {
    tacc = (1.0 + par[9]) * tacc_y[y];
  }

  if (par[10] == 1 && tacc_y[y] != tacc_y[y-1]) {
    // Latent year, first year of MPE rule is last_yr + 2
    tacc = tacc_y[y];
  }
  if (par[10] == 2 && diff > 0.0 && tacc_y[y] != tacc_y[y-1]) {
    // Asymmetric latent year, the first year of MPE rule is last_yr +
2, only have latent year for TAC increases
    tacc = tacc_y[y];
  }
}

if (tacc < 0.0) tacc = 0.0;
return tacc;
}

```