Fisheries New Zealand

Tini a Tangaroa

Development and evaluation of management procedures in pāua quota management areas 5A, 5B and 5D

New Zealand Fisheries Assessment Report 2019/37

P. Neubauer

ISSN 1179-5352 (online)
ISBN 978-1-99-000823-8 (online)

September 2019

New Zealand Government

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

EXECUTIVE SUMMARY

Neubauer, P. (2019). Development and evaluation of management procedures in pāua quota management areas 5A, 5B and 5D.

***New Zealand Fisheries Assessment Report 2019/37*. 63 p.**

This project was a first attempt at introducing formal management procedures (MPs) based on control rules in pāua fisheries in New Zealand. Stakeholders in pāua quota management area PAU 5 requested that science-based management procedures be investigated in order to ensure long-term sustainability of pāua fisheries in lower South Island and Stewart Island. The MPs were to be used for voluntary management within the industry in the medium term (e.g., for the next 3–5 years) to trial the process. Once the process and the MPs were refined and meeting stakeholders' expectations, they could be used for setting the total allowable commercial catch (TACC).

The development process for the MPs included three phases: initially, the current pāua stock assessment model was used to produce up-to-date status estimates for all stocks, and an added MP evaluation loop was used to test preliminary rules. The outcome of this pilot run was the basis for the development of a web application that was used to consult with fishers and inspect the outcomes of individual model runs.

A series of meetings was held with fishers and quota-owners in PAU 5 to quantify objectives and identify control rules that are acceptable to stakeholders. Management objectives were stated qualitatively as low risk/high biomass objectives, and rules were discussed that fishers considered as leading to desirable outcomes (i.e., high biomass and low risk in the context of the management objectives).

Agreed rules were simulation-tested based on the period 2016–2036 using the pāua stock assessment model. This testing involved a number of scenarios, including scenarios that were explicitly requested by PAU 5 stakeholders (e.g., scenarios relating to increased recreational catch). The MP evaluations showed that rules suggested by fishers are likely robust, and near optimal with respect to identified objectives for PAU 5A and PAU 5B. For both these fisheries, the proposed rules led to likely outcomes of biomass levels above 40% of virgin spawning stock biomass SSB_0.

In PAU 5B, the proposed rule could be used to motivate an increase in TACC, as all scenarios suggest continued rebuilding of biomass towards a level near 60% of spawning stock biomass and catch-per-unit-effort (CPUE) around 50 kg/h. In PAU 5A, the proposed control rules would likely lead to steady increases in biomass to levels well above 40% of SSB_0. Nevertheless, the rules also suggested that the current shelving needs to be maintained under conservative management objectives.

The proposed control rule for PAU 5D likely leads to steady rebuilding, but there is only a small chance that biomass levels will be above 40% of SSB_0 in the medium term, despite current shelving of 30% of the TACC. Under the proposed control rule, shelving levels would likely be reduced relatively quickly, and an agreement to maintain current shelving levels would help faster rebuilding. The evaluation of the MPs thus suggested a difficult trade-off in PAU 5D between continued catch and rapid rebuilding to target levels.

The proposed control rules appear to be a robust starting point for managing PAU 5 fisheries on the basis of formal, but voluntary, management procedures. Most sensitivities, including those with increased recreational catch, had limited impact for the sustainability of the PAU 5 fisheries under the proposed rules. Increased recreational catch did lead to lower commercial catch in these scenarios, but overall, reduced productivity (through low future recruitment) had the strongest impact on performance of control rules and often led to declines in biomass under rules considered here. However, only in PAU 5D did simulated declines under reduced productivity lead to high probability of triggering limit reference points.

1. INTRODUCTION

Management procedures (MPs) link resource assessments to a set of rules, collectively called a control rule, that formalise the setting of allowable catches (e.g., total allowable catch (TAC), catch allocations). MPs are increasingly being used for both information-rich and information-deficient stocks (Butterworth 2007, Dowling et al. 2015b), and usually aim to balance conflicting objectives of high yield, stable yield and low probabilities of resource collapse in a formal way (Butterworth 2007). To identify a suitable MP, a set of candidate MPs are usually simulation-tested to identify a set of rules that produces the best possible outcomes under a range of uncertainties (Butterworth 2007). Once identified, a suitable MP is agreed on by stakeholders prior to its implementation and application.

To establish an MP, stakeholders first need to identify and agree on a set of management priorities. These priorities can be formalised by applying weights to a set of performance metrics (e.g., average catch, low probability of fishery collapse; Bentley et al. 2003b, Rademeyer et al. 2007). Performance metrics quantify sometimes conflicting objectives, such as mean catch and catch-per-unit-effort (Starr et al. 1997). Elicitation of priorities from stakeholders can be difficult: it involves quantitatively summarising stakeholder priorities in an objective (or utility) function that allows MP comparison (Bentley et al. 2003b).

MP evaluation (MPE) is a simulation procedure to test the MP performance or the agreed set of management objectives. The simulations are designed to account for a range of uncertainties inherent in the assessment of natural resources, and fisheries in particular (Francis & Shotton 1997). These uncertainties relate to model fitting (distributional assumptions and estimation error), process error (variability around average values for natural processes, e.g., expected recruitment for a given biomass level), observation error/bias (e.g., bias in catch-per-unit-effort (CPUE) or survey results), implementation uncertainty (e.g., uncertainty in actual shelving percentages or real future recreational/customary catch; Butterworth & Punt 1999) and model uncertainty (e.g., uncertainty in operating model specification, error in current status estimates; Butterworth & Punt 1999). Given these uncertainties, a control rule is sought that maximises the utility function or gives satisfactory performance as defined by the (weighted combination of) agreed performance indicators (Bentley et al. 2003b).

MPEs generally test the rules linking resource assessment and management by means of applying these rules to a simulation model, the operating model. Sometimes, the complete chain of the MPE (management plus resource model) is referred to as the operating model (Wiedenmann et al. 2013), but for the purpose of this document, the operating model is defined as the simulation model that simulates the fishery and resource dynamics. Fishery and resource dynamics can also be separated into operating model components, especially if fishery dynamics are themselves influenced by management decisions in a predictable way.

The operating model is a crucial component in MPEs, since it summarises available knowledge of resource dynamics. Simulations from the model for a fishery managed according to the MP under investigation are thought to be indicative of how the real system will perform under the same MP. Often, an existing assessment model is used as an operating model (Bentley et al. 2003a, Haist et al. 2006, Rademeyer et al. 2007), and alternative assessment scenarios (e.g., based on varying fishery selectivity, or scenarios of migration) are used to explore sensitivities of the MPE outcomes to operating model assumptions. This approach is the most straightforward way to perform an MPE, as the assessment model is fitted to data, and sensitivities have often been thoroughly explored. In cases where the resource dynamics are more uncertain (i.e., where model uncertainty is high), alternative model structures can be explored to increase the representation of these uncertainties in the MPE (Butterworth & Punt 1999, Rademeyer et al. 2007).

To implement an MP, the stock status needs to be assessed both before the simulation-testing and selection of the MP (i.e., as a reference), and as part of the MP itself to inform the control rule. The assessment used to inform the control rule may be model-based, or empirical (Rademeyer et al. 2007, Dowling et al. 2015a). While model-based assessments involve a form of stock assessment using population models, empirical estimators can involve a variety of indicators linked to stock status, such as CPUE, catch-per-unit-area (CPUA) and length-based indicators. Importantly, for simulation-testing of the MP within an operating model, empirical estimators of stock status must be clearly linked to stock status in the simulations. Model-based estimation is in many cases more accurate as it may reveal shortcomings in empirical estimators, whereas the empirical estimators are more cost effective and more easily simulation-tested. In both cases, there may be considerable uncertainty associated with stock status.

This study made a first attempt at identifying, testing and implementing control rules in pāua quota management area 5 (PAU 5), within each of the sub-areas PAU 5A (Fiordland), PAU 5B (Stewart Island), and PAU 5D (Otago and Southland east coast). These three sub-areas within PAU 5 have differing qualitative characteristics, but many fishers fish more than one of these areas on a regular basis. Sub-area PAU 5A was split into two assessment areas, the northern and southern zones. The most recent fishery assessment (Fu 2015a, 2015b) suggested that both sub-areas were at or above 40% of virgin spawning stock biomass (SSB_0). In PAU 5B, the fishery has been steadily rebuilding following a considerable reduction in total allowable commercial catch (TACC) in 2002, and is now estimated to be above 40% of virgin biomass (Fu 2014). In contrast, the fishery in PAU 5D was estimated to be below 40% of virgin biomass in the most recent assessment (Fu 2013), and fishers decided to shelve (i.e., not fish) 20% of the current TACC of 89 t for the 2014–15 and 30% for the 2015–16 and 2016–17 fishing years.

This project was akin to a pilot project aimed at providing stakeholders in PAU 5 with the possibility of running a formalised MP in a virtual setting: the MP would indicate shelving levels (i.e., operate within the TACC), and potentially identify when stakeholders could request a TACC increase. In PAU 5B, a control rule would likely provide information about the consequences of a hypothetical increase in TACC, and outline possible long-term management options for the fishery. For PAU 5D, an MP needs to assure that the fishery does not decline further, and encourage rebuilding of the fishery to target levels. The MP for PAU 5D will thus be aimed at rebuilding the fishery through shelving of quota under the current TACC. In PAU 5A, QMA-wide shelving and areal catch limits will be informed by the MP. To achieve the latter, the MP was split into two control rules for each of the independent assessment areas (north and south). These areas are currently managed within a single TACC, but voluntary management within the industry assigns catch limits to each area in accordance with fisher perception. (Note that in the following sections, the term TACC is used loosely, referring to total commercial catch, regardless of whether this catch is set by industry internal shelving within limits of the legislated TACC, or by changes in the legislated TACC itself. This lack of distinction recognises that, in the near future, MPs will likely inform shelving decisions, but could support setting of the TACC in the longer term.)

In New Zealand, the harvest strategy standard sets the minimum requirement for MPs, namely "a specified target based on MSY[maximum-sustainable-yield]-compatible reference points or better, a soft limit, and a hard limit, all with associated acceptable probabilities and management actions" (Ministry of Fisheries 2008). For this reason, MPs need to be tested to ensure that minimum requirements are met. In this context, MPs have been implemented for rock lobster fisheries (Bentley et al. 2003b, Starr et al. 1997, Bentley et al. 2003a, Breen et al. 2009) and evaluated for a growing number of stocks (Haist & Middleton 2014, Haist et al. 2006). In most cases, the operating model for the MPE was taken to be the assessment model (Starr et al. 1997, Haist et al. 2006), and CPUE was used as an empirical measure of abundance in harvest control rules. CPUE is currently used as the main indicator of abundance in pāua stock assessments, and is the most direct empirical measure of abundance. This approach was also followed in the present study.

This project was split into three stages. First, stock assessments were re-run for all PAU 5 QMAs using the length-based assessment model (Breen et al. 2003) to obtain a current status estimate for each QMA. The assessment model was extended to include a management procedure evaluation loop, and preliminary results from applying this MPE were visualised using a web-application framework. Second, this framework was used to consult with fishers and elicit management objectives and potential control rules for each QMA. These control rules were then tested in the MPE framework, using a range of assessment model sensitivities and simulation scenarios.

2. METHODS

2.1 Operating model

The operating model is the simulation basis for MPEs, it estimates current stock status and is used to project the stock forward under various management regimes. To date, the only model that has been fitted to recent pāua fisheries data in PAU 5 is the length-based assessment model (Breen et al. 2003). This model does not have a notion of space (i.e., it assumes a single stock across QMAs), but recommendations from the Shellfish Fisheries Working Group concluded that a model that is fitted to data is preferable to using a simulation model that is only qualitatively informed by data. I, therefore, used the current assessment model as a simulation model. This choice also suggests using CPUE as an empirical estimator of abundance, despite potential bias in pāua CPUE (e.g., Prince 1989), as it is the only quantity that is directly tied to abundance in the assessment model. The length-based assessment model of Breen et al. (2003) was used in its most current form (Fu 2016), incorporating recommendations from the 2015 review of the model and its application (Butterworth et al. 2015) (for a detailed description of the model and recent applications, see Breen et al. 2003 and Fu 2016).

Model fitting was performed as for standard stock assessments, using maximum posterior density (MPD) estimates to explore model fit, and using full Markov chain Monte Carlo (MCMC) for final model fitting and the MPE. Estimates throughout were based on 1000 samples from the posterior distribution (using runs of 1.2×10^5 iterations, discarding the first 2×10^4 iterations and keeping parameter values at every 1000th iteration as a sample), using the last 300 samples for MPE simulations. The full set of MCMC samples could not be used for MPEs due to memory management limitations in the AD model builder that could not be resolved.

2.2 Model inputs

The assessment model was taken to be the most recent assessment model, however, model inputs were updated to reflect the most recent data. For this update, CPUE from Paua Catch Effort Landing Return (PCELR) forms (2001 onward) was standardised and replaced the previous CPUE index. Furthermore, data from the commercial length-frequency sampling programme were updated to include data up to the 2014–15 fishing year.

2.2.1 CPUE

CPUE is the most direct measure of biomass in the length-based model in its current form. CPUE from PCELR forms was standardised using a linear mixed model, with log(CPUE) (estimated catch divided by estimated time in water) as the dependent variable and fishing year (fixed effect), dive condition (fixed effect), diver and statistical area (random effects) taken as predictors of CPUE. More specifically:

$$\log(\mathrm{CPUE}_{k,i,s}) = \beta X_k + \omega_s + \nu_i + \epsilon_{k,i,s}, \tag{1}$$

$$\epsilon_{k,i,s} \sim \mathrm{Normal}(0,\sigma), \tag{2}$$

$$\tau_i \sim \mathrm{Normal}(0,\tau), \tag{3}$$

$$\omega_s \sim \mathrm{Normal}(0,\zeta). \tag{4}$$

Here, $\mathrm{CPUE}_{k,i,s}$ is the CPUE on day k by diver i in statistical area s, β is a row vector of fixed effect coefficients and X is a column matrix of dummy variables encoded as binary contrasts. The random effects for statistical area ω_s, and diver, ν_i are normally distributed with estimated variance components ζ and τ, respectively. Residuals $\epsilon_{k,i,s}$ are also normally distributed with variance σ.

2.2.2 Offset CPUE

Management decisions are usually made some time before the new fishing year. For pāua fisheries, annual general meetings (AGMs) of stakeholders are generally held in June, and voluntary management measures are usually agreed at this time. Decisions for the following year are thus based on incomplete information of the current fishing year. The offset CPUE is a standardised CPUE time series for which the fishing year definition is changed so that the standardised index represents the year from 1 April to 31 March the following year. This change provides an index that includes data from the first six months of the current fishing year. The standardisation of the offset CPUE was performed as for the standard CPUE, but was not used for model fitting. Nevertheless, predicted offset CPUE was inspected to verify that the model provided an adequate fit to the index (i.e., that the index is linked to biomass estimates in the model).

2.2.3 Natural mortality (M) prior

Specifically, the model included new priors for natural mortality (M) as a sensitivity for PAU 5A North and PAU 5D, and as the base case for PAU 5A South and PAU 5B. The 2015 stock assessment review panel (Butterworth et al. 2015) suggested conducting the assessment with a uniform prior on M for all stocks except the stock that is assessed, and then using the resulting posterior distribution to construct a prior for the stock to be assessed. Fu (2016) reported that the uniform prior only provided plausible results in PAU 5A South and PAU 5B. The assessment model was, therefore, applied with this uniform prior for these stocks (as this prior seemed preferable to informative priors), and a new prior derived from these estimates was used as a sensitivity for PAU 5A North and PAU 5D. Specifically, a log-normal distribution with mean 0.14 and coefficient of variation (CV) of 0.2 was an adequate fit for the resulting posterior distributions from PAU 5B and PAU 5A South (Figure 1).

In practice, I found that these priors led to unrealistically high estimates for M for the other two assessments (PAU 5A North and PAU 5D; see Results), and the base case was, therefore, set to a mean of 0.1 and a CV of 0.1.

2.3 Management procedure

The technical implementation of the management procedure and its evaluation within the current stock assessment model was greatly influenced by past research for New Zealand rock lobster fisheries (e.g., Breen et al. 2009). Consultation with Vivian Haist (Haist Consultancy) and Paul Breen (Breen Consulting) provided the initial starting point, and much of the code and rationale of the PAU 5 management procedure elicitation and evaluation followed the rock lobster example (rock lobster code was provided and annotated by Vivian Haist).

2.3.1 Eliciting objectives and feasible control rules

Three meetings (on 26 November 2015, 11 May and 8 June 2016) were held in Invercargill with stakeholders (i.e., fishers, quota owners, and representatives from the Pāua Industry Council Limited) to discuss management procedures, and to formally identify management objectives. While the first meeting was an informal discussion introducing the concept of management procedures to stakeholders in the context of a general harvesters meeting, the meeting in May 2016 was specifically convened to discuss management objectives and potential control rules. The subsequent June meeting was in the context of the AGM for PAU 5, and discussed preliminary implementation and testing of rules identified in May.

2.3.2 Performance indicators

A suite of performance indicators was identified as potential performance measures against which control rules could be tested (Table 1). These measures included performance measures that assure that manage-

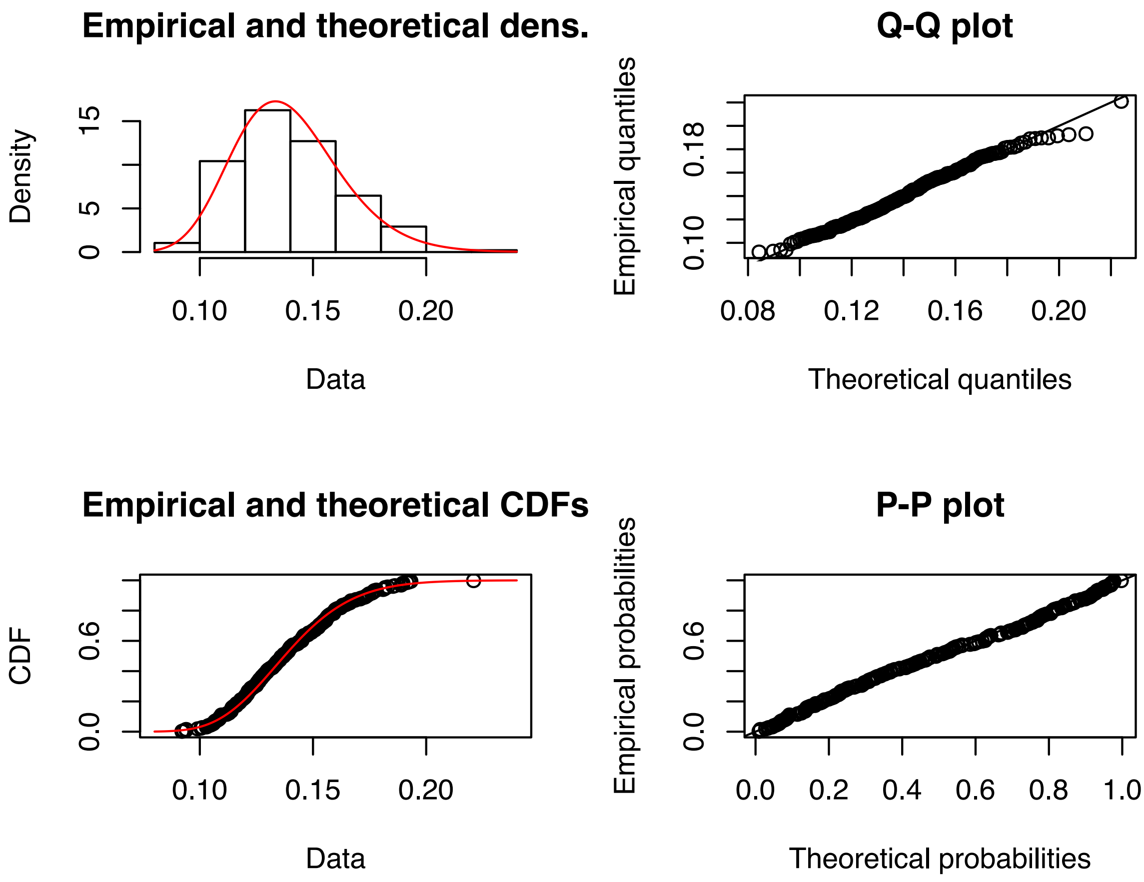


Figure 1: Summaries of the log-normal distribution fit to posterior draws for the natural mortality parameter M from the Markov chain Monte Carlo (MCMC) of the length-based assessment model applied to pāua quota management sub-areas PAU 5A South and PAU 5B. The histogram (top left) shows the empirical distribution of MCMC draws for M, with the theoretical fit overlayed as a red line. The other panels show the quantile-quantile plot (top right), the observed and expected (red) cumulative distribution (bottom left), and observed and theoretical probabilities (bottom right).

Table 1: Performance metrics proposed to evaluate control rules in pāua quota management area 5. Metrics include: avB, available biomass; SSB, spawning stock biomass; SSB_0; virgin stock biomass; y denotes years in the management procedure evaluation projections (i.e., 2016–2036); I is an indicator function that is 1 when its argument is greater than zero, and is zero otherwise (CPUE, catch-per-unit-effort; TACC; total allowable commercial catch).

Group	Label	Definition
Biomass (B)	average avB (vs 2015 level)	$1/\text{years} \sum_y \text{avB}_y/\text{avB}_{2015}$
	minimum avB (vs 2015 level)	$\min_y(\text{avB}_y)/\text{avB}_{2015}$
	Probability SSB < 0.2SSB	$P(\text{SSB} < 0.2\text{SSB})$
	Probability SSB < 0.1SSB	$P(\text{SSB} < 0.1\text{SSB})$
	relative biomass at 10y	$\text{SSB}_{2026}/\text{SSB}_0$
	relative biomass at 5y	$\text{SSB}_{2021}/\text{SSB}_0$
Catch	minimum catch	$\min_y(\text{Catch}_y)$
	average catch	$1/\text{years} \sum_y \text{Catch}_y$
CPUE	minimum CPUE	$\min_y(\text{CPUE}_y)$
	average CPUE	$1/\text{years} \sum_y \text{CPUE}_y$
TACC change	TACC changes	$1/\text{years} \sum_y I(\lvert\text{TACC}_y - \text{TACC}_{y-1}\rvert)$

ment according to a specific control rule is compatible with the New Zealand harvest strategy standard (i.e., low probability of reaching soft (20% of SSB_0, the virgin spawning stock biomass) and hard (10% of SSB_0) limits; Ministry of Fisheries 2008). Other measures, such as the spawning stock biomass after five and ten years of management under a control rule, quantify rebuilding potential. Measures that are directly informative (especially to fishers) about fishery performance include CPUE and catch-related measures.

2.3.3 Testing control rules

Evaluation of management procedures was performed within the assessment model, using MCMC draws from the marginal posterior distribution of model parameters to project the model forward under different management scenarios (Figure 2). For each MCMC draw, a set of projection parameters, consisting of auto-correlated recruitment deviations and CPUE observation error, were drawn. For each of these parameters, the moments (mean, standard deviation and auto-correlation) of the error distribution were calculated from parameter values (i.e., recruitment deviations and CPUE residuals) at the MCMC iteration.

Control rules were tested using MCMC samples from assessment models, conducted with two types of sensitivities (Table 2): sensitivities to model parameters (i.e., sensitivities to the model setup; hereafter termed sensitivities) and sensitivities to projection scenarios (hereafter termed scenarios). The former type tests sensitivities to assumptions in the model, especially those that can give rise to different stock status and productivity estimates (it is of limited use to conduct sensitivities that give qualitatively similar results to the base case scenario). Sensitivities included scenarios of hyper-stable CPUE to test potential non-linear relationships between CPUE and abundance, low Beverton-Holt steepness (h), and wider priors for M (Table 2). Scenarios consider assumptions about future stock and harvest dynamics (e.g., future recreational catch and productivity), which may differ from those inferred from the retrospective data to which the model is fit.

2.3.4 The pāua MPE shiny application

A Shiny (Chang et al. 2016) web application based on the statistical computing language R (R Core Team 2018) was developed to evaluate and illustrate management procedure outcomes. The application is based on a reactive framework that lets the user choose management objective (i.e., performance metrics) weights, as well as sensitivities, scenarios and management procedure parameters (Figures 3,

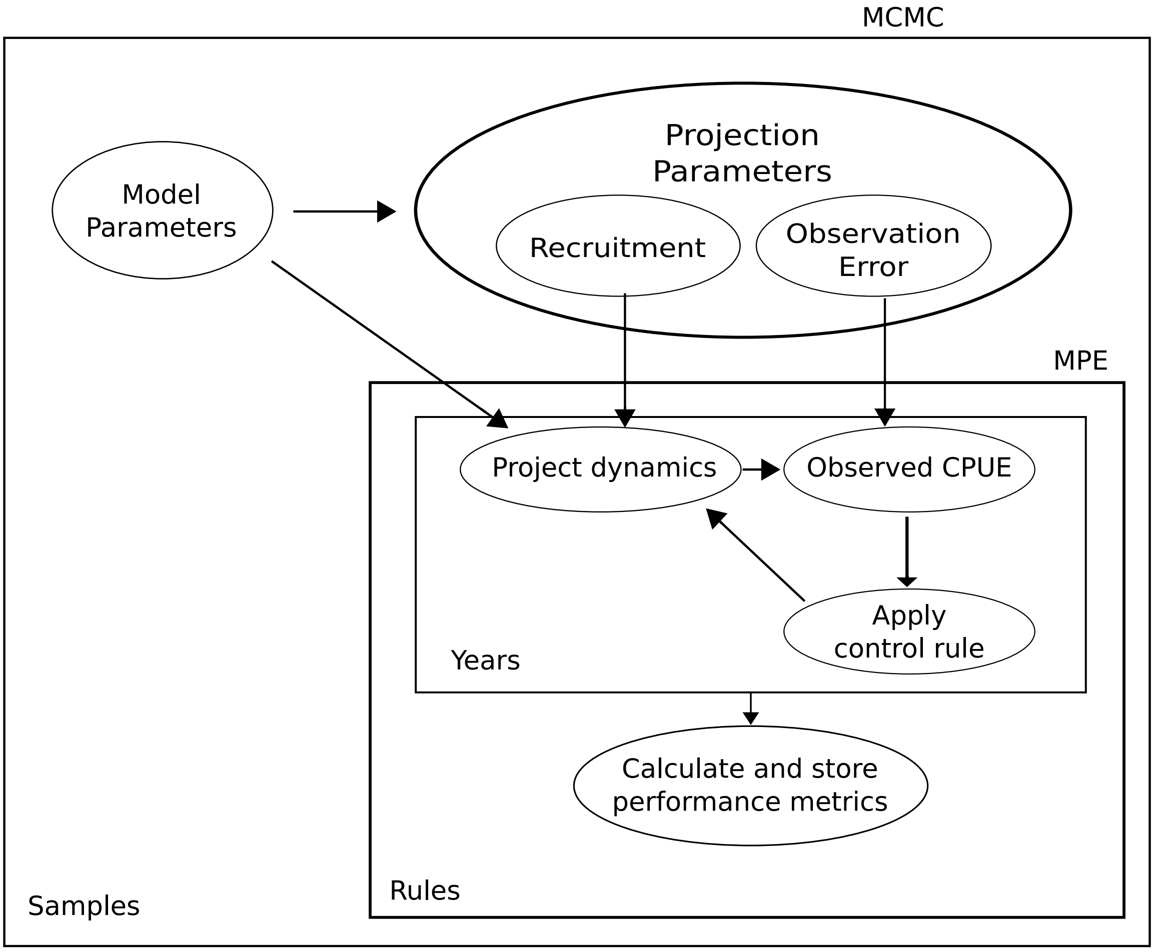


Figure 2: Schematic of the management procedure evaluation (MPE) setup for pāua quota management area 5 (PAU 5). Squares indicate loops, with the dimension of the loop indicated in the bottom left corner of the square. Ellipses are sub-components of the enclosing square or ellipse. Each Markov chain Monte Carlo (MCMC) draw (or iteration) is associated with a set of model parameters, which form the basis for projections together with randomly drawn projection parameters. Projection parameters include recruitment (deviations) and catch-per-unit-effort (CPUE) observation error, which are randomly drawn from a distribution defined by moments calculated from the model run. Given a set of model and projection parameters, for each control rule, stock dynamics are projected forward for each projection year and the control rule is applied based on simulated observed CPUE.

Table 2: Markov chain Monte Carlo sensitivities and projection scenarios considered for each pāua quota management sub-area (CPUE, catch-per-unit-effort; M, mortality).

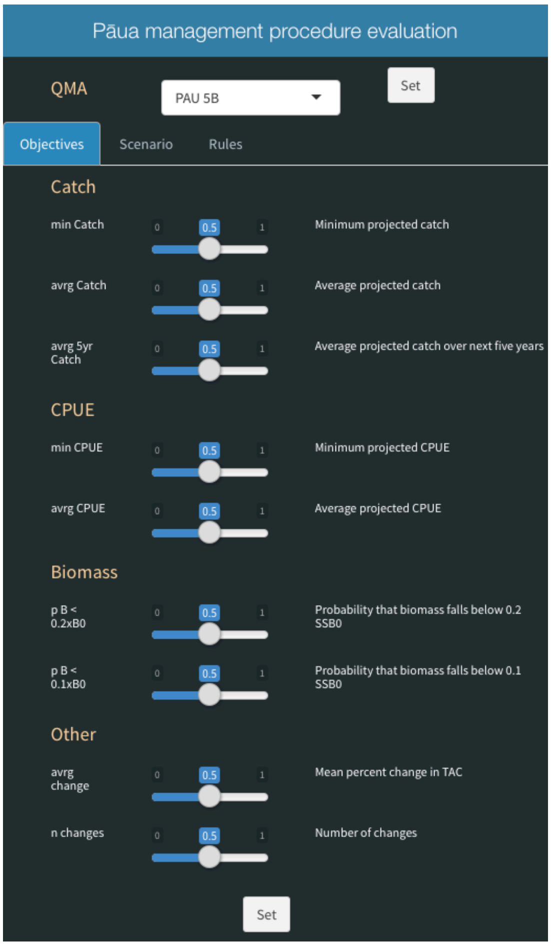
Sensitivity	Scenario	Parameter values
Base case	Base case	
	Recreational catch increase	$r_{C_{rec}}=\{2,5\}\%$
	Recreational catch multiplyer	$m_{C_{rec}}=\{0.5,0.8,1.2,1.5,2\}$
	Recruitment deviation mean multiplyer	$m_{Rdev}=\{0.6,0.8\}$
	Natural mortality increase	$r_M=\{0.5,1,1.5\}\%$
	CPUE observation error multiplyer	$m_{\partial_{CPUE}} = 1.5$
	Catchability increase	$r_q=\{0.5,1,1.5\}\%$
Hyper-stable CPUE	Base case	ß = {0.5,0.8}
Low steepness	Base case	$h = 0.6$
M prior	Base case	$\mu = 0.14$, cv = 0.2

4). The application automatically identifies a best rule, against which particular control rules can be compared. The best rule is determined by the maximum utility U (or objective function), which is itself determined by the weighted set of performance metrics p. The application allows two options to define the overall utility for each rule i:

1. by difference $U_i = \sum_p w_p(m_p - m_{p_{\text{best}}})/m_{p_{\text{best}}}$,
2. by rank $U_i = \sum_p w_p(1 + p - \text{rank}(m_p))$.

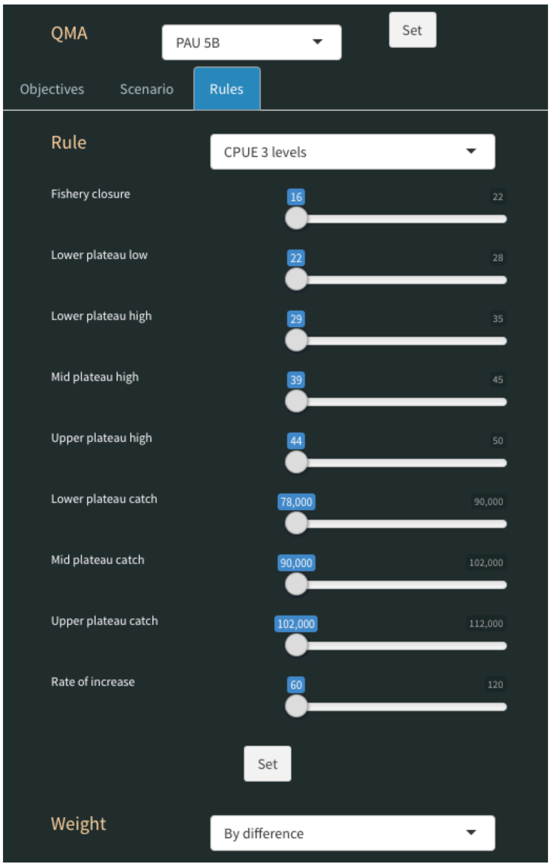
Here, w_p is the weight given to performance metric p, m_p is the value of performance metric p, with $m_{p_{\text{best}}}$ the value of the best rule for performance metric p. The rank function ranks control rules according to their numerical value for each metric. Other utility definitions are possible, but the utility serves here only as a means to construct a comparative tool for fisher-defined control rules, and is thus not an essential part of the MPE (i.e., there was no attempt to find an optimal MP under some utility function).

(a) Performance metrics



(b) Sensitivities & scenarios

(c) Control rules



(d) Rule visualisation

Figure 3: Screenshots from input menus of the Shiny management procedure evaluation application for pāua quota management area 5 (PAU 5). a) The weight of performance metrics can be set to influence the utility function and determine a best rule for comparison. Setting weights to zero allows for performance metrics to be taken out of the comparison. b) MCMC sensitivities and scenarios can be selected to investigate the impact of assumptions on simulated performance metrics and catch, CPUE and biomass trajectories. c) Control rules and their parameters are set to compare against best-case scenarios, and to evaluate individual performance criteria. d) Control rules defined by parameters in c) are visualised, along with the best rule as derived from the performance metric weights.

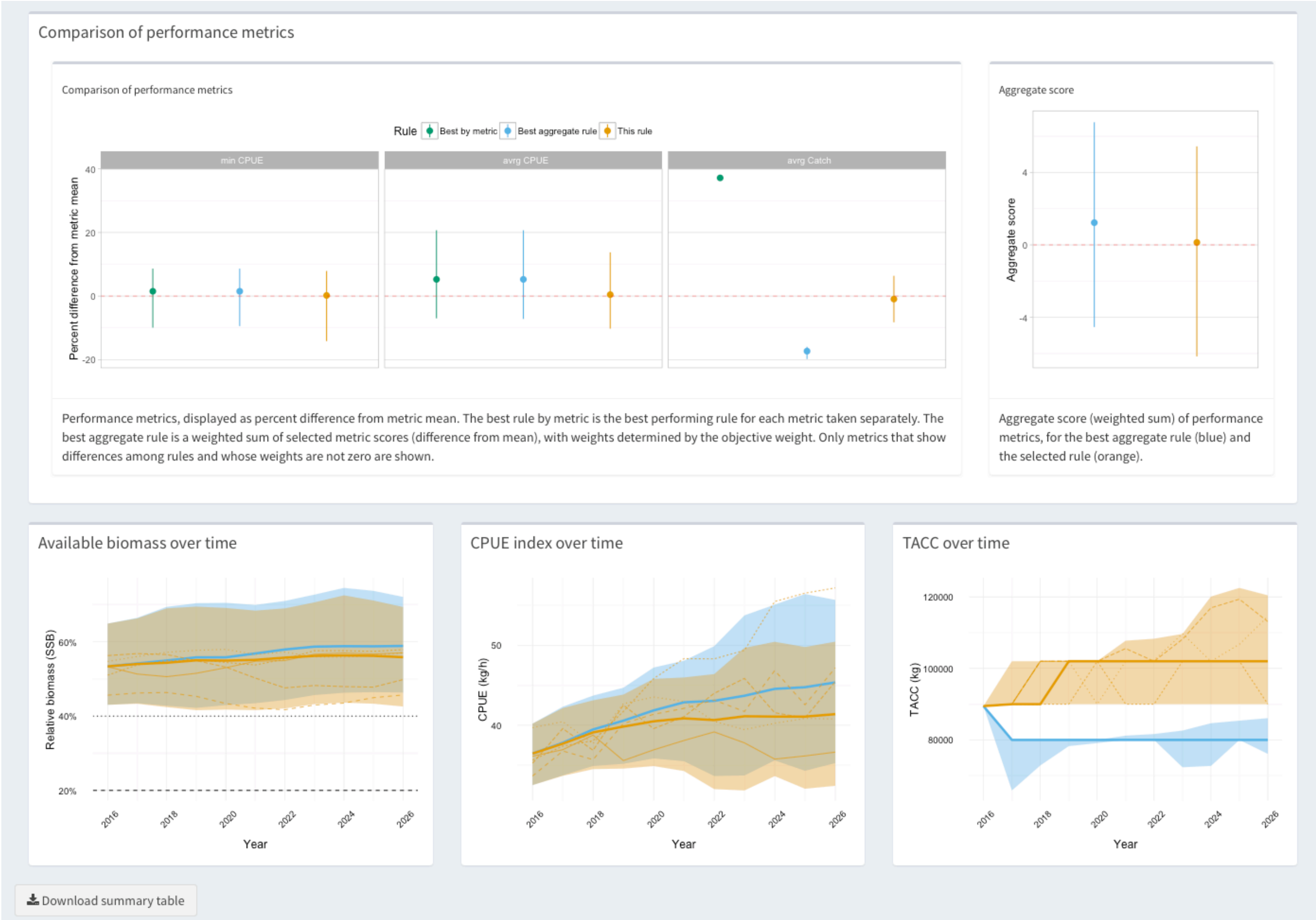


Figure 4: Screenshots from output panel of the Shiny management procedure evaluation application, showing performance of the control rule defined by the user-set parameters (orange), and the best rule determined from performance metric weights (blue). The panel on the upper left allows the user to compare individual performance metrics (only those with non-null weights and variability between simulations (i.e., Markov chain Monte Carlo draws) are visualised), with the best score for each metric shown in green. The aggregate utility score is presented in the top right panel. The bottom graphs show (left to right) relative spawning stock biomass, observed catch-per-unit-effort (CPUE) and total allowable commercial catch (TACC) over time (with 95% confidence envelopes).

Table 3: Estimates of stock status and natural mortality for stocks in sub-areas of pāua quota management area 5 under different assumptions (sensitivities).

QMA	Sensitivity	Status	M
		Median (5%, 95%)	Median (5%, 95%)
5A South	Base case	0.43 (0.34,0.59)	0.13 (0.1,0.17)
5A South	Hyper-stable CPUE (ß = 0.5)	0.57 (0.38,0.97)	0.14 (0.09,0.29)
5A South	Hyper-stable CPUE (ß = 0.8)	0.43 (0.31,0.67)	0.12 (0.09,0.17)
5A South	Low steepness (h=0.6)	0.43 (0.34,0.56)	0.14 (0.11,0.18)
5A North	Base case	0.47 (0.39,0.56)	0.15 (0.13,0.17)
5A North	Hyper-stable CPUE (ß = 0.5)	0.47 (0.39,0.56)	0.15 (0.13,0.17)
5A North	Hyper-stable CPUE (ß = 0.8)	0.47 (0.39,0.56)	0.15 (0.13,0.17)
5A North	Low steepness (h=0.6)	0.47 (0.39,0.56)	0.15 (0.13,0.17)
5A North	M prior (μ = 0.14, cv = 0.2)	0.64 (0.5,0.79)	0.23 (0.18,0.29)
5B	Base case	0.53 (0.39,0.71)	0.15 (0.12,0.22)
5B	Hyper-stable CPUE (ß = 0.5)	0.53 (0.39,0.73)	0.15 (0.12,0.2)
5B	Hyper-stable CPUE (ß = 0.8)	0.52 (0.38,0.7)	0.15 (0.12,0.2)
5B	Low steepness (h=0.6)	0.53 (0.39,0.7)	0.17 (0.14,0.23)
5D	Base case	0.23 (0.2,0.28)	0.15 (0.13,0.17)
5D	Hyper-stable CPUE (ß = 0.5)	0.2 (0.16,0.25)	0.14 (0.12,0.16)
5D	Hyper-stable CPUE (ß = 0.8)	0.23 (0.19,0.27)	0.15 (0.13,0.16)
5D	Low steepness (h=0.6)	0.22 (0.19,0.27)	0.17 (0.15,0.19)
5D	M prior (μ = 0.14, cv = 0.2)	0.32 (0.25,0.44)	0.2 (0.17,0.26)

3. RESULTS

3.1 Operating model runs

The stock assessment model applied to up-to-date fishery data produced reasonable fits to updated CPUE (Appendix A, Figures A-1 to A-4), and produced similar outputs to the most recent stock assessments for comparable time spans (Figure 5).

In PAU 5B, the spawning stock biomass continued to rebuild under the current TACC of 90 t, to a level of above 50% (posterior median 53%; 95% confidence interval (c.i.): 39–71%) of virgin spawning stock biomass (SSB_0; Table 3, Figure 5). This result was irrespective of the sensitivity applied—all sensitivities led to similar biomass levels (Table 3, Figure A-7), but different estimates of natural mortality (Table 3, Figure A-11).

For PAU 5A South, the assessment model suggested that the spawning stock biomass level is likely slightly above 40% of SSB_0 (posterior median 43%, 95% c.i.: 34–59%; Table 3), with a steady or slightly declining trend. As for PAU 5B, sensitivities did not change this conclusion (Table 3, Figures A-7, A-11), although the sensitivity with high non-linearity (i.e., $\beta = 0.5$) between CPUE and abundance did not converge.

In PAU 5A North, the assessment model outcome was highly dependent on assumptions about natural mortality (Table 3, Figure A-10), but all status estimates suggested a relative spawning stock biomass level of above 40% of SSB_0 (posterior median 47%, 95% c.i.: 39–56%; Table 3, Figure 5).

For PAU 5D, for which the most recent assessment dated back to 2012, the current model suggested continued low biomass at just above the soft limit (posterior median 23%, 95% c.i.: 20–28%, Table 3), with a slight upward trend in the last two years. As for PAU 5A North, the prior for M affected the outcome, with the empirical prior for M giving a more optimistic estimate for the current status (posterior median 32%, 95% c.i.: 25–44%; Table 3).

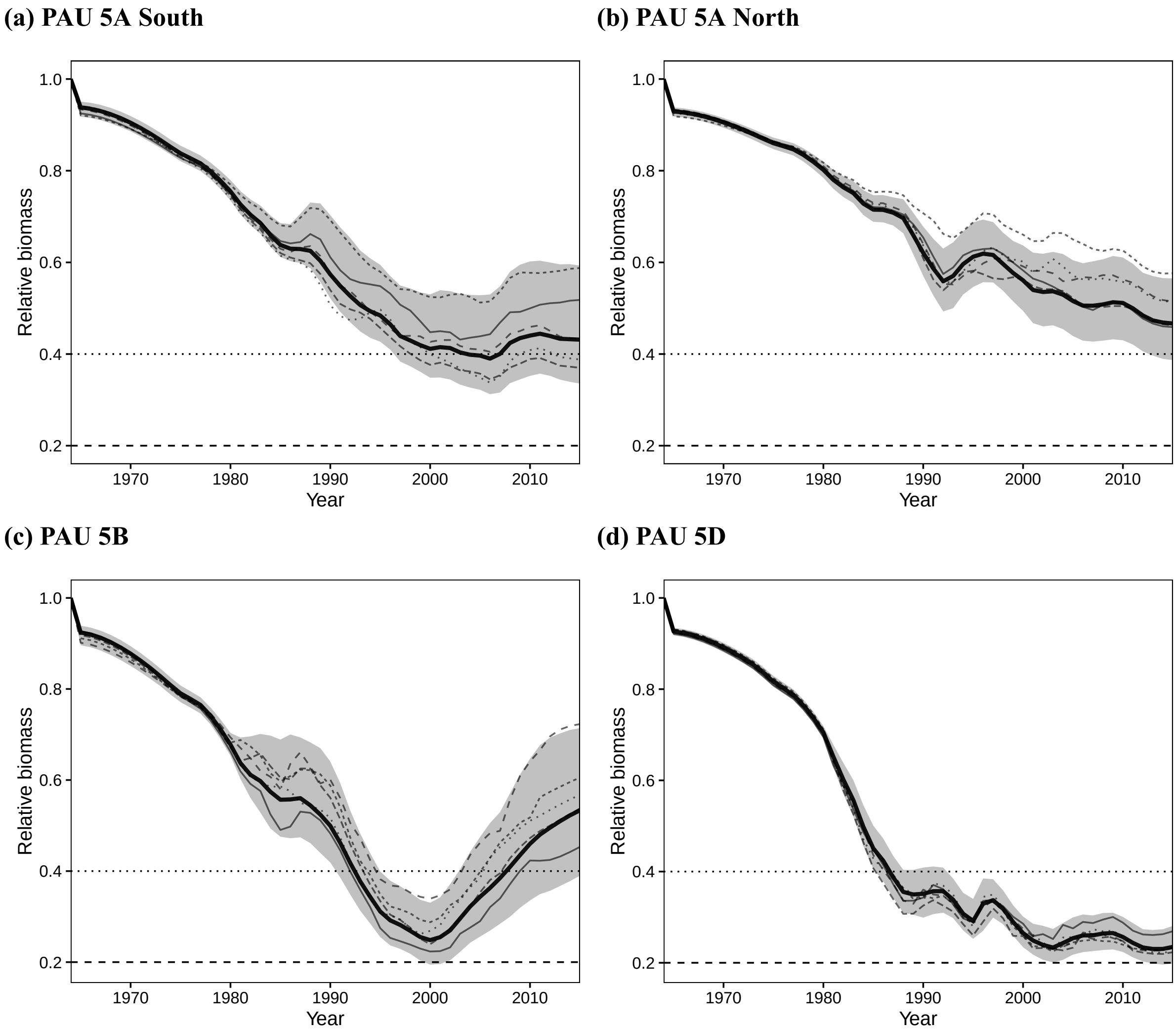


Figure 5: Estimated posterior distributions for pāua spawning stock biomass relative to virgin spawning stock biomass (SSB_0) from base-case simulation runs in sub-areas of quota management area 5 (PAU 5).

Table 4: Control rule settings for different sub-areas in pāua quota management area (QMA) 5, derived from consultation with PAU 5 stakeholders. Parameters correspond to catch-per-unit-effort (CPUE) limits (C1–5), catch limits (L1–3) and total allowable commercial catch increase (P1) when CPUE is estimated to be above the highest catch plateau (defined between C4 and C5). (For an illustration of limits see Figure 6.)

QMA	Parameter setting								
	C1	C2	C3	C4	C5	L1 (t)	L2 (t)	L3 (t)	P1
5A South	16	25	32	42	48	36	48	61	90
5A North	16	25	32	42	48	46	58	70	90
5B	16	25	32	42	48	80	90	100	90
5D	16	27	32	42	48	62	72	89	90

3.2 Consultation and agreed management procedures

Stakeholders were inclined to adopt a management procedure as long as it guaranteed conservative decision making with respect to biomass levels. Many of the stakeholders advocated high biomass levels and low exploitation rates as insurance against uncertainty and assurance of a steady fishery. In the consultation process, the Shiny application was used to communicate potential outcomes of management procedures, and the stakeholders' conservative goals were emulated in the application by putting low weight on catch performance metrics, and high weight on CPUE and biomass metrics.

Consultation with stakeholders of all PAU 5 QMAs resulted in a set of control rules to be evaluated (Figure 6, Table 4). The set of rules was generally the same for all QMAs, with identical CPUE reference points, reflecting the stakeholders' idea that all PAU 5 fisheries ought to be able to operate at similar catch rates. The catch-rate reference points correspond to three levels with QMA-specific settings for total commercial catch within each QMA (Figure 6, Table 4). The rule can be written as:

$$\mathrm{TACC\ (t)} = \begin{cases} 0, & \text{if } \mathrm{CPUE}^{o}_{obs} \leq \mathrm{C1} \\ \mathrm{L1}\frac{\mathrm{CPUE}^{o}_{obs}-\mathrm{C1}}{\mathrm{C2}-\mathrm{C1}}, & \text{if } \mathrm{C1} < \mathrm{CPUE}^{o}_{obs} \leq \mathrm{C2} \\ \mathrm{L1}, & \text{if } \mathrm{C2} < \mathrm{CPUE}^{o}_{obs} \leq \mathrm{C3} \\ \mathrm{L2}, & \text{if } \mathrm{C3} < \mathrm{CPUE}^{o}_{obs} \leq \mathrm{C4} \\ \mathrm{L3}, & \text{if } \mathrm{C4} < \mathrm{CPUE}^{o}_{obs} \leq \mathrm{C5} \\ \mathrm{L3}(1. + 0.5 * \frac{\mathrm{CPUE}^{o}_{obs}-\mathrm{C5}}{\mathrm{P1}-\mathrm{C5}}), & \text{if } \mathrm{C5} < \mathrm{CPUE}^{o}_{obs}, \end{cases}$$

where CPUE^{o}_{obs} is the observed offset CPUE (i.e., the predicted offset CPUE with observation error in MPE simulations; all other parameters are defined in Table 4 and illustrated in Figure 6).

For PAU 5B and 5D, the middle catch level was set close to last reported catch, reflecting shelving of 20% of the TACC in PAU 5D for the 2014–15 fishing year, and fishing at the TACC in PAU 5B. In PAU 5D, the lower plateau was set at the current (2015–16 and 2016–17) shelving levels of 30%, but options with a lower catch limit were also explored for this level in PAU 5D.

For PAU 5B, the rule included a region with suggested commercial catch higher than the current TACC. While the MP is currently only set to operate within the TACC, this feature was incorporated to let stakeholders explore the potential for requesting a TACC increase and potential consequences of such an increase. Similarly, in PAU 5A, the sum of catches in the control rule was allowed to be substantially higher than the fished proportion (70%) of the current TACC, which would allow exploring the potential for unshelving part of the long-running 30% shelving.

3.3 Management procedure evaluation

The management procedure evaluation suggested that the proposed rules would likely lead to biomass levels above 40% of SSB_0 for all QMAs but PAU 5D (Table 5). In all cases, scenarios with reduced future

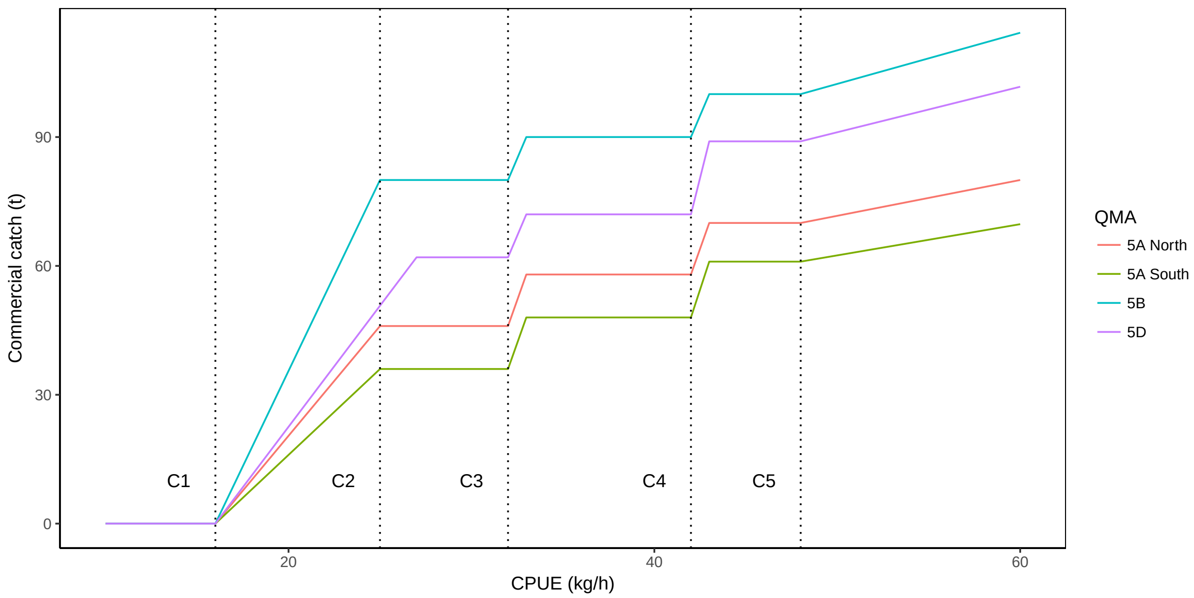


Figure 6: Control rules proposed for sub-areas of pāua quota management area (QMA) 5, as suggested by PAU 5 stakeholders. Control rules have three catch levels, with the middle level near current commercial take. Levels are delimited by previously agreed catch-per-unit-effort (CPUE) thresholds.

recruitment (i.e., with a mean recruitment set at 60% of past average levels), led to the most pessimistic outcomes for nearly all performance metrics. However, only in PAU 5D did this scenario lead to a high probability of reaching the soft limit of 20% of SSB_0. Nevertheless, in all QMAs, this scenario led to marked declines in simulated biomass and CPUE levels under the proposed rules. But even under these scenarios of stock decline, the decline is relatively slow and would likely trigger a timely science and management review to respond to changes in the fishery.

3.3.1 PAU 5A

Managing under the proposed control rules (Table 4) would likely lead to increases in biomass, with spawning stock biomass levels 40–50% of SSB_0 for each sub-component of this QMA (Table 5). This increase may lead to the possibility of reductions in shelving over time, although the sum of both average TACC levels (105 t, 95% c.i.: 91–124) under this assumption rarely approached the current TACC of 148 t in the simulations (Figure 7). This finding suggests that the current TACC may be too high and not compatible with low risk and high biomass management objectives in PAU 5.

The probability of biomass levels below soft or hard limits was low under the proposed rule, with a relatively steady biomass and CPUE (Figure 7). An increase in natural mortality led to the "worst-case" outcomes for most performance measures, and may lead to declines in biomass and average CPUE under the control rule. Nevertheless, there were no scenarios that led to a risk of exceeding the hard or soft limit (Table 4).

3.3.2 PAU 5B

In PAU 5B, base case simulations under the proposed rule lead to further increases in biomass (Figure 8, Table 5). In this scenario, the TACC could theoretically increase as biomass continues to increase from present-day levels, until an apparent equilibrium is reached at about 60% of SSB_0 at a TACC of around 110 t and a CPUE near 50 kg/h. The lower bound for TACC, CPUE and biomass levels in PAU 5B in the base case simulations was close to 2014–15 levels (Figure 8), with a markedly low risk of exceeding soft (20% of SSB_0) or hard (10% of SSB_0) limits. Results for PAU 5B were most affected by a hypothetical increase in natural mortality (Table 5), but even under worst-case scenarios, all performance indicators

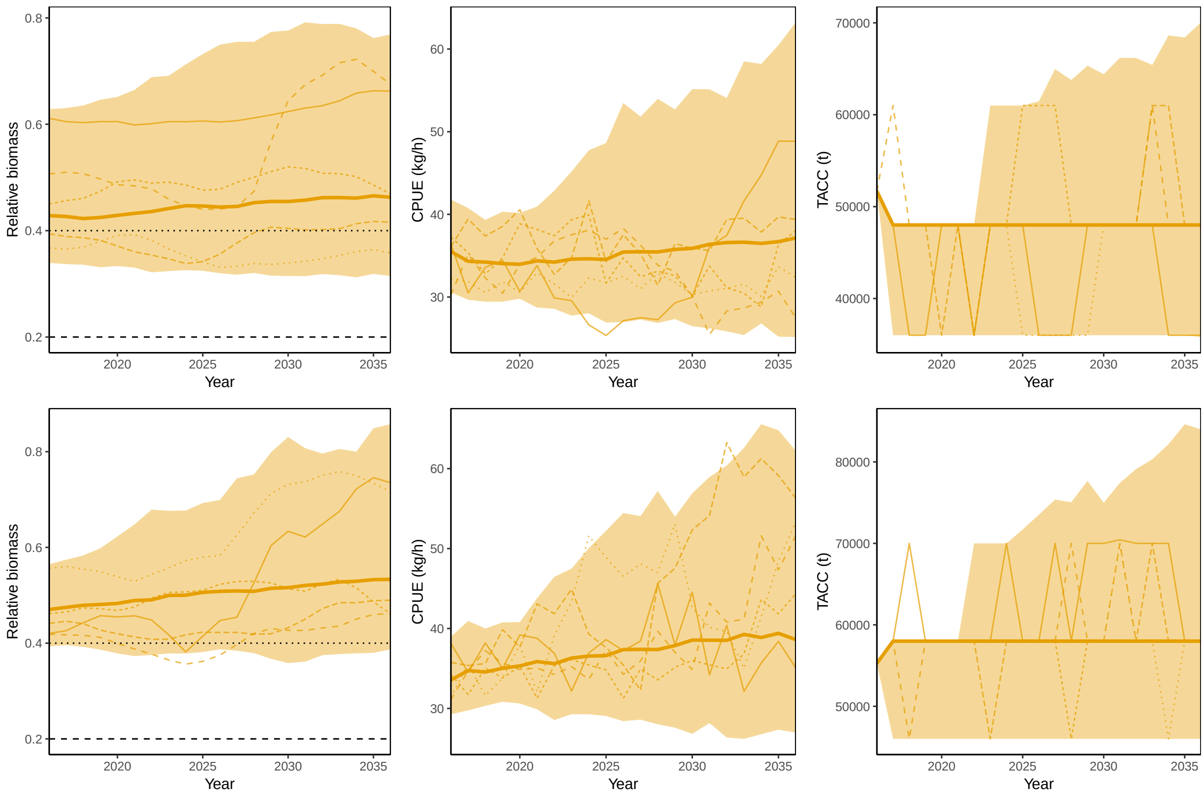


Figure 7: Time series of simulated relative biomass (in proportion of virgin spawning stock biomass SSB_0), observed catch-per-unit-effort (CPUE) and total allowable commercial catch (TACC) for base-case simulations in pāua quota management sub-area PAU 5A South (top row) and North (bottom row).

stayed near or above current levels.

3.3.3 PAU 5D

Results for PAU 5D suggested that a control rule with the lower catch level (L1) at 70% of the current TACC would likely support current plans to retain this level of shelving to allow rebuilding (Figure 9, Table 5). The stock rebuilding is projected to be slow but steady under this rule, with biomass likely remaining below 40% of SSB_0 over the simulated period.

Further reductions in catch and slower increase of catches during the rebuild would, therefore, be needed to accelerate rebuilding (Figure 9, see also best-case scenarios in Appendix C, Table C-2) and reduce uncertainty in rebuilding trajectories. This is illustrated by two alternative control rules that are shown here for illustrative purposes (Figure B-13, Table B-1). The alternative control rules set more conservative harvest levels around a lower catch plateau corresponding to approximately 40% (40-30-20 rule) and 50% (50-30-20 rule) shelving, with progressive unshelving to 30% and 20%. CPUE limits were also moved so as to delay unshelving and aid rebuilding. Under these rules, rebuilding is accelerated and biomass approaches target levels of 40% of SSB_0.

For most sensitivities, the likelihood of the SSB declining below soft or hard limits remains low. Nevertheless, a scenario of recruitment failure led to a high likelihood of the stock falling below the soft limit of 20% of SSB_0 (Table 5). Furthermore, increased recreational catch levels (e.g., recreational catch increases to twice its currently assumed amount of 22 t), the commercial catch declines by up to 12 t to allow rebuilding (Table C-2).

Table 5: Management procedure outcomes for sub-areas in pāua quota management area 5. Reported are base-case outcomes and outcomes from the simulation scenario that produced the worst outcome for each performance metric.

QMA	Base case		Sensitivity	
	Metric	Median (5%, 95%)	Metric	Median (5%, 95%)
5A South	Average Biomass	0.98 (0.86,1.18)	m_{Rdev} (m_{Rdev}=0.6)	0.71 (0.65,0.81)
5A North	Average Biomass	1.06 (0.94,1.32)	m_{Rdev} (m_{Rdev}=0.6)	0.76 (0.71,0.88)
5B	Average Biomass	1.3 (1.08,1.71)	m_{Rdev} (m_{Rdev}=0.6)	0.91 (0.77,1.12)
5D	Average Biomass	1.49 (1.26,2.06)	m_{Rdev} (m_{Rdev}=0.6)	0.88 (0.82,1.07)
5A South	Minimum Biomass	0.88 (0.72,0.96)	m_{Rdev} (m_{Rdev}=0.6)	0.54 (0.46,0.67)
5A North	Minimum Biomass	0.96 (0.79,1.01)	m_{Rdev} (m_{Rdev}=0.6)	0.58 (0.51,0.73)
5B	Minimum Biomass	1.05 (0.97,1.13)	m_{Rdev} (m_{Rdev}=0.6)	0.71 (0.55,0.99)
5D	Minimum Biomass	1.08 (1.03,1.13)	m_{Rdev} (m_{Rdev}=0.6)	0.69 (0.6,0.84)
5A South	P($SSB < 0.2SSB$)	<0.005 (0,-)		
5A North	P($SSB < 0.2SSB$)	<0.005 (0,-)		
5B	P($SSB < 0.2SSB$)	<0.005 (0,-)		
5D	P($SSB < 0.2SSB$)	<0.005 (0,-)	m_{Rdev} (m_{Rdev}=0.6)	0.75 (0.2,0.95)
5A South	P($SSB < 0.1SSB$)	<0.005 (0,-)		
5A North	P($SSB < 0.1SSB$)	<0.005 (0,-)		
5B	P($SSB < 0.1SSB$)	<0.005 (0,-)		
5D	P($SSB < 0.1SSB$)	<0.005 (0,-)		
5A South	Relative Biomass at 10y	0.45 (0.33,0.68)	m_{Rdev} (m_{Rdev}=0.6)	0.29 (0.22,0.44)
5A North	Relative Biomass at 10y	0.51 (0.4,0.65)	m_{Rdev} (m_{Rdev}=0.6)	0.33 (0.25,0.42)
5B	Relative Biomass at 10y	0.66 (0.51,0.98)	m_{Rdev} (m_{Rdev}=0.6)	0.44 (0.34,0.6)
5D	Relative Biomass at 10y	0.31 (0.24,0.45)	m_{Rdev} (m_{Rdev}=0.6)	0.16 (0.13,0.23)
5A South	Relative Biomass at 5y	0.43 (0.34,0.62)	m_{Rdev} (m_{Rdev}=0.6)	0.36 (0.29,0.52)
5A North	Relative Biomass at 5y	0.48 (0.39,0.59)	m_{Rdev} (m_{Rdev}=0.6)	0.41 (0.33,0.49)
5B	Relative Biomass at 5y	0.61 (0.47,0.82)	m_{Rdev} (m_{Rdev}=0.6)	0.5 (0.4,0.63)
5D	Relative Biomass at 5y	0.29 (0.22,0.38)	m_{Rdev} (m_{Rdev}=0.6)	0.21 (0.17,0.27)
5A South	Minimum Catch	44.8 (44.43,56.8)	m_{Rdev} (m_{Rdev}=0.6)	21.4 (10.35,40.85)
5A North	Minimum Catch	37.2 (37.2,49.2)	m_{Rdev} (m_{Rdev}=0.6)	11.28 (0,35.82)
5B	Minimum Catch	90 (90,90)	m_{Rdev} (m_{Rdev}=0.6)	80 (35.02,90)
5D	Minimum Catch	62 (50.65,62)	m_{Rdev} (m_{Rdev}=0.6)	18.82 (5.44,43.37)
5A South	Average Catch	55.65 (48.4,64.97)	m_{Rdev} (m_{Rdev}=0.6)	40.84 (34.3,49.02)
5A North	Average Catch	49.8 (43.2,58.53)	m_{Rdev} (m_{Rdev}=0.6)	34.36 (27.14,42.19)
5B	Average Catch	100.2 (90.5,115.4)	m_{Rdev} (m_{Rdev}=0.6)	86.17 (71.92,95)
5D	Average Catch	78.65 (69.03,97.19)	m_{Rdev} (m_{Rdev}=0.6)	44.78 (35.69,60.13)
5A South	Minimum CPUE	31.62 (25.56,35.51)	m_{Rdev} (m_{Rdev}=0.6)	19.87 (17.24,24.36)
5A North	Minimum CPUE	33.24 (27.17,36.56)	m_{Rdev} (m_{Rdev}=0.6)	20.85 (18.24,25.55)
5B	Minimum CPUE	38.38 (33.28,42.7)	m_{Rdev} (m_{Rdev}=0.6)	25.76 (20.02,36.83)
5D	Minimum CPUE	29.21 (26.82,31.75)	m_{Rdev} (m_{Rdev}=0.6)	19.56 (17.11,23.27)
5A South	Average CPUE	35.56 (30.33,43.49)	m_{Rdev} (m_{Rdev}=0.6)	25.82 (23.37,29.88)
5A North	Average CPUE	37.34 (31.85,46.86)	m_{Rdev} (m_{Rdev}=0.6)	26.74 (24.53,31.27)
5B	Average CPUE	47.93 (37.25,61.94)	m_{Rdev} (m_{Rdev}=0.6)	33.45 (27.03,41.92)
5D	Average CPUE	41.44 (33.86,58.64)	m_{Rdev} (m_{Rdev}=0.6)	24.54 (22.48,29.34)
5A South	Number of TACC changes	6 (3,12)	m_{Rdev} (m_{Rdev}=0.6)	13 (7,17)
5A North	Number of TACC changes	7 (3,14)	m_{Rdev} (m_{Rdev}=0.6)	13 (7,17)
5B	Number of TACC changes	12 (3,17)	Catchability (r_q = 1.5%)	15 (7,19)
5D	Number of TACC changes	10 (4,17)	m_{Rdev} (m_{Rdev}=0.6)	16 (12,18)

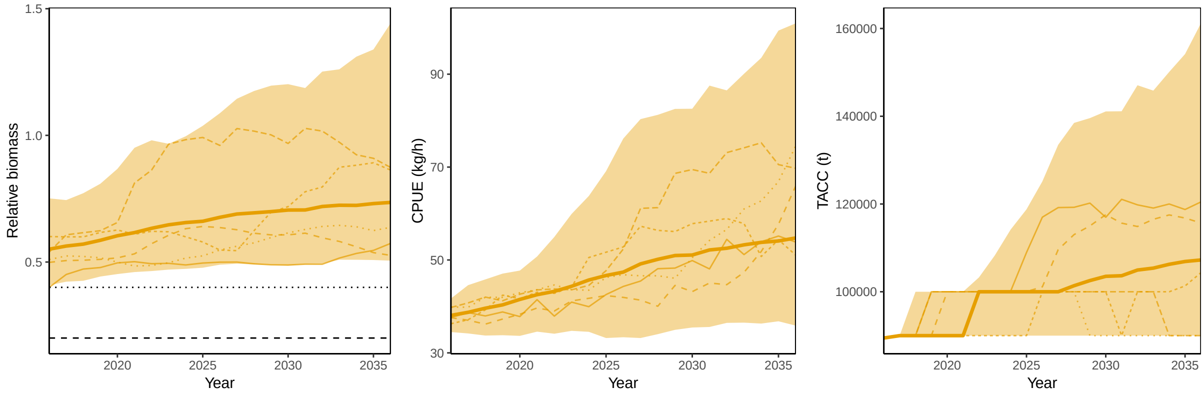


Figure 8: Time series of simulated relative biomass (in proportion of virgin spawning stock biomass SSB_0), observed catch-per-unit-effort (CPUE) and total allowable commercial catch (TACC) for base-case simulations in pāua quota management sub-area PAU 5B.

4. DISCUSSION

The present project was designed to provide the PAU 5 fisheries with the opportunity to trial management procedures that formalise some of the decision making currently used on an annual basis at AGMs. The pāua fishing industry works within the TACC to self-manage stocks by shelving (i.e., not fishing) portions of its quota and increasing minimum harvest sizes (i.e., agreed minimum sizes) regionally. Furthermore, web-based dashboards have recently been introduced that enable different levels of data sharing in the different QMAs. In addition, fishers in PAU 2 have agreed rules to indicate small-scale statistical areas based on catch and CPUE relative to past catch/CPUE. These rules do not lead to mandatory closures; they are supposed to initiate discussion and potential voluntary closures of identified areas. These measures are often intended to aid rebuilding and increase catch rates to desired levels.

The MP framework can thus be seen as a more formal tool in a set of measures used by the industry to enhance sustainability. The advantage of the MP framework is that the likely response in terms of biomass- and catch-related indicators can be explicitly simulated to assess the utility of a management procedure. For instance, in PAU 5D, the MPE suggested that the current level of catch and the proposed control rule would lead to relatively slow rebuilding towards target biomass levels.

Elicitation of control rules can proceed in more formal ways than performed in the current study. Although it was initially proposed that a more formal elicitation process may be necessary to identify management objectives (e.g., a Delphi process), it was apparent at the meetings that stakeholders were willing to delegate the quantitative aspects of the assessment, as long as their goal for conservative management was met. Another important aspect for stakeholders was the reliability of the MPE projections under scenarios of variable harvest sizes and other scenarios, such as changes in the areas fished (e.g., through the establishment of marine reserves). Although future development of the MPE can account for these aspects, the evaluation of the proposed MPs is subject to the same uncertainties as the stock assessment. The uncertainties related to highly uncertain estimates of recreational, customary, and illegal catch, as well as unknown but potentially substantial bias from the assumption of a single stock within each QMA (or sub-area in PAU 5A).

Pāua (*Haliotis iris*) populations are likely structured as meta-populations, meaning they are made up of a series of small-scale populations connected by limited dispersal (Prince 1989, McShane 1998, Prince 2005). To date, biological data are not available on these scales, and populations in individual quota management areas are currently managed as single stocks using TACs and minimum legal sizes (MLS). Assessments are performed on a three-yearly basis in most QMAs (e.g., Fu 2012), although, to date, not all QMAs with large fisheries have been formally assessed. Thus, although it is well understood that pāua populations are highly spatially structured, assessments to date are limited by the scale of available data. While recently developed methods involving data-loggers for the pāua fishery provide CPUE and other

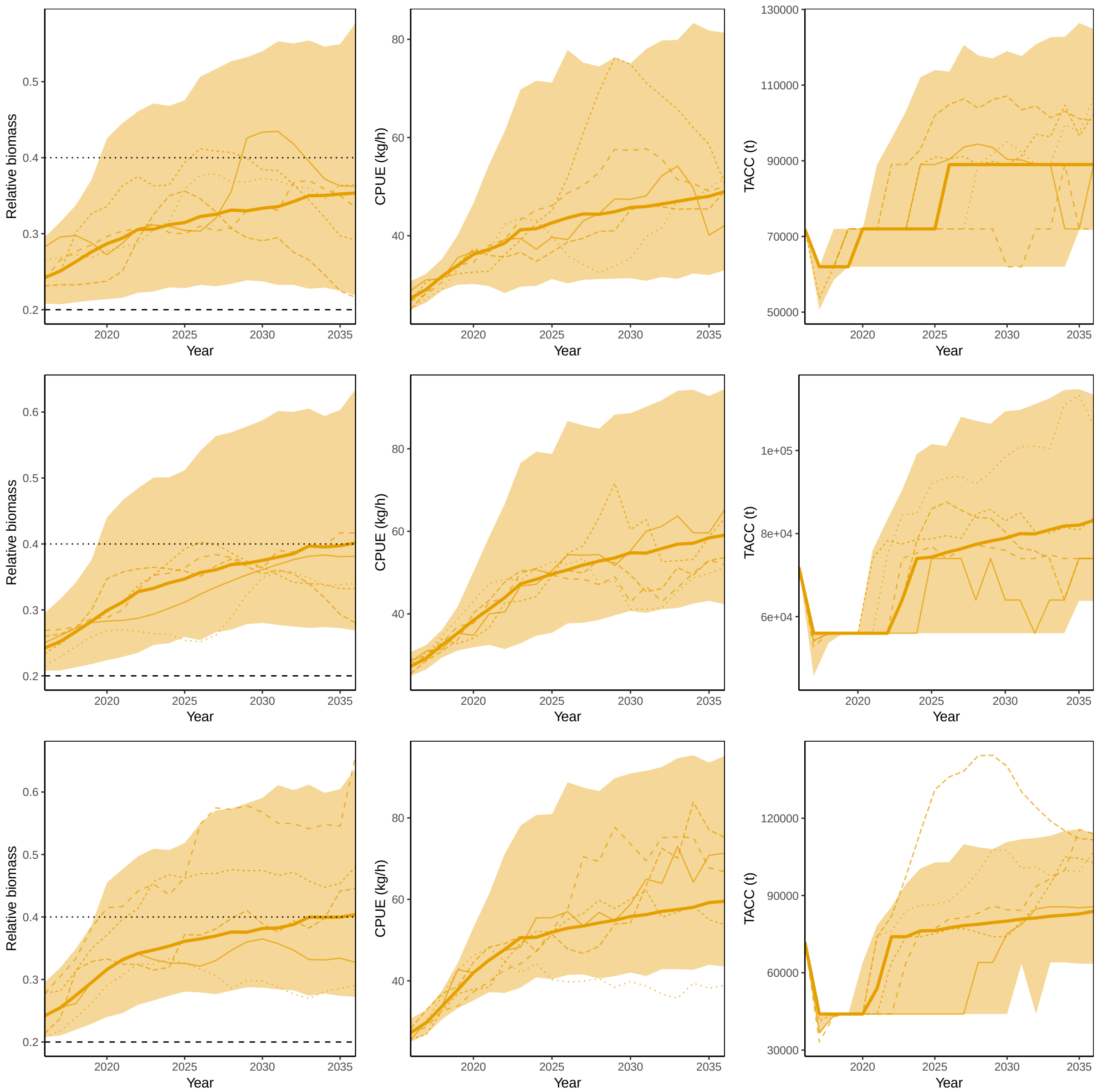


Figure 9: Time series of simulated relative biomass (in proportion of virgin spawning stock biomass SSB_0), observed catch-per-unit-effort (CPUE; kg per hour) and total allowable commercial catch (TACC; kg) for base-case simulations in in pāua quota management sub-area PAU 5D (top row), and rebuilding scenarios under the alternative control rules (outlined in Figure B-13 and Table B-1). The alternative control rule set more conservative harvest levels around a lower catch plateau corresponding to approximately 40% (40-30-20 rule; middle row) and 50% (50-30-20 rule; bottom row) shelving, with progressive un-shelving to 30% and 20%. CPUE limits were also moved so as to delay un-shelving and aid rebuilding.

performance metrics on small scales (Neubauer & Abraham 2014, Neubauer et al. 2014), the assessment methodology is currently not adapted to process spatially structured data.

Internationally and within New Zealand, few MPEs have been performed for abalone MPs. Haddon & Helidoniotis (2013) investigated the effect of different large-scale (e.g., QMA-scale) legal size limits on small-scale pāua stocks in Tasmania, Australia. They found that single size limits tend to overprotect a range of stocks, but allow other sub-populations to be overfished. This result reflects results from other studies (Prince 2005, McShane & Naylor 1995), which collectively suggest that abalone (and pāua) management strategies should account for the metapopulation structure of the resource. For MPs in general, Butterworth & Punt (1999) suggest that MPs developed for spatially structured stocks based on the assumption of a single stock may perform poorly. This notion suggests potential limits for the present study, and a future priority should be to move the assessment and MPE framework towards a spatially explicit structure.

Nevertheless, a spatially explicit assessment and MPE model may lead to additional complexity, both in terms of model fitting and complexity of spatially explicit control rules. In recent research for an MPE in the PAU 7 fishery, Helidoniotis & Haddon (2015) explored management strategies to aid the recovery of this fishery from low biomass levels. Their operating model includes an arbitrary (e.g., 40 stocks) spatial structure, and the model is conditioned to data using empirical methods rather than statistical model fitting. However, despite attempts to use all available data to condition the model, the lack of statistical model fitting has led to difficulties in reproducing observed trends even in qualitative ways, thus reducing confidence in the predictions from the model. The design and implementation of an appropriate operating model for pāua MPEs is thus an important question that needs addressing.

While it is desirable that operating models are fit to data in the same way that stock assessments are, this fitting has not always been the case in MPEs (Haist & Middleton 2014, Haddon & Helidoniotis 2013, Bentley et al. 2003a). For this reason, there is potential that MPEs provide misleading results, because parameter estimates are context-dependent. For example, estimates of life-history parameters may be scale-dependent, and applying a model estimated over a large scale to small-scale stocks may, therefore, not be appropriate. The challenge is to produce an operating model that accounts for spatially variable demographic rates, yet remains tractable for statistical model fitting (Butterworth & Punt 1999, Rademeyer et al. 2007).

Although CPUE is often related to abundance on small spatial scales (Prince 1989, Abraham & Neubauer 2015), this relationship does not necessarily lead to unbiased CPUE on larger scales (Dowling et al. 2004, Prince 1989). Based on potential bias from spatial resource use, pāua aggregating behaviour and other influences on catch rates, CPUE has in the past not been considered a reliable indicator of abalone abundance in Tasmania and other regions (Prince & Hilborn 1998, Dowling et al. 2004). Biased estimates of biomass can lead to poor performance in selected MPs (e.g., Wiedenmann et al. 2013, Punt et al. 2001) if this bias is not accounted for in MPEs. Nevertheless, some studies show that adding length-based indicators considerably improves the performance of empirical MPs (Prince et al. 2011, Punt et al. 2001, Bedford et al. 2013). Although commercial length-frequency (LF) data are available for pāua in most QMAs, it is unclear whether LF data have value as an empirical performance measure. This uncertainty is related to minimum harvest sizes that are often region specific, and to targeting behaviour that can change depending on market demand for particular products. Nevertheless, length-based indicators may prove a valuable addition, especially in the context of a more spatial approach to assessing stocks and MPs.

5. ACKNOWLEDGMENTS

First, I would like to acknowledge the stakeholders of PAU 5, and especially those attending the meetings in Invercargill, for their vision for a sustainable and well-managed fishery. The feedback at these meetings was invaluable in making this research relevant. I also thank Jessica Terril for relating fishers' concerns, and for helping to organise the stakeholder meetings.

I would like to thank Julie Hills (MPI) for her efforts and enthusiasm in coordinating and conceptualising this project on behalf of the Ministry for Primary Industries. This project would not have been possible without the support of Storm Stanley (Pāua Industry Council Limited, PICL) and Jeremy Cooper (PICL) who enabled communication with PAU 5 stakeholders. Their enthusiasm to enable best-practice management and sustainability of the pāua fisheries was a fundamental driver of this research. Tom McCowan (PICL) and Edward Abraham (Dragonfly) provided valuable feedback during various stages of this project. Yvan Richard (Dragonfly) wrote the first instance of the the Shiny web-app, and his continued support with the app is much appreciated.

6. REFERENCES

Abraham, E.R.; Neubauer, P. (2015). Relationship between small-scale catch-per-unit-effort and abundance in New Zealand abalone (pāua, *Haliotis iris*) fisheries. *PeerJ Preprints 3*: e1733. doi:10.7287/peerj.preprints.1388v2.

Bedford, R.A.; Hearne, J.W.; Wang, Y.; Gorfine, H.K.; Taylor, B. (2013). Evaluating Alternative Management Strategies for Abalone. *Natural Resource Modeling 26 (4)*: 628–647. doi:10.1111/nrm.12017.

Bentley, N.; Breen, P.A.; Starr, P.J. (2003a). Design and evaluation of a revised management decision rule for red rock lobster fisheries (*Jasus edwardsii*) in CRA 7 and CRA 8. *New Zealand Fisheries Assessment Report 2003/30*. 44 p.

Bentley, N.; Breen, P.A.; Starr, P.J.; Sykes, D.R. (2003b). Development and evaluation of decision rules for management of New Zealand rock lobster fisheries. *New Zealand Fisheries Assessment Report 2003/29*. 14 p.

Breen, P.A.; Kim, S.W.; Andrew, N.L. (2003). A length-based Bayesian stock assessment model for the New Zealand abalone *Haliotis iris*. *Marine and Freshwater Research 54 (5)*: 619–634.

Breen, P.A.; Haist, V.; Starr, P.J. (2009). New Zealand decision rules and management procedures for rock lobsters (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2009/43*. 18 p.

Butterworth, D.S.; Haddon, M.; Haist, V.; Helidoniotis, F. (2015). Report on the New Zealand paua stock assessment model; 2015. *New Zealand Fisheries Science Review 2015/4*: 31 p. Retrieved from https://fs.fish.govt.nz/Doc/23947/FSR_2015_04_2015_Paua_review.pdf.ashx.

Butterworth, D.S.; Punt, A.E. (1999). Experiences in the evaluation and implementation of management procedures. *ICES Journal of Marine Science: Journal du Conseil 56 (6)*: 985–998.

Butterworth, D.S. (2007). Why a management procedure approach? Some positives and negatives. *ICES Journal of Marine Science: Journal du Conseil 64 (4)*: 613–617. doi:10.1093/icesjms/fsm003.

Chang, W.; Cheng, J.; Allaire, J.; Xie, Y.; McPherson, J. (2016). Shiny: Web application framework for r. R package version 0.13.2. Retrieved from https://CRAN.R-project.org/package=shiny.

Dowling, N.A.; Hall, S.J.; McGarvey, R. (2004). Assessing population sustainability and response to fishing in terms of aggregation structure for greenlip abalone (*Haliotis laevigata*) fishery management. *Canadian Journal of Fisheries and Aquatic Sciences 61 (2)*: 247–259.

Dowling, N.A.; Dichmont, C.M.; Haddon, M.; Smith, D.C.; Smith, A.D.M.; Sainsbury, K. (2015a). Empirical harvest strategies for data-poor fisheries: A review of the literature. *Fisheries Research 171*: 141–153. doi:10.1016/j.fishres.2014.11.005.

Dowling, N.A.; Dichmont, C.M.; Haddon, M.; Smith, D.C.; Smith, A.D.M.; Sainsbury, K. (2015b). Guidelines for developing formal harvest strategies for data-poor species and fisheries. *Fisheries Research 171*: 130–140.

Francis, R.I.C.C.; Shotton, R. (1997). Risk in fisheries management: A review. *Canadian Journal of Fisheries and Aquatic Sciences 54*: 1699–1715.

Fu, D. (2012). The 2011 stock assessment of paua (*Haliotis iris*) for PAU 7. *New Zealand Fisheries Assessment Report 2012/27*. 60 p.

Fu, D. (2013). The 2012 stock assessment of paua (*Haliotis iris*) for PAU 5D. *New Zealand Fisheries Assessment Report 2013/57*. 51 p.

Fu, D. (2014). The 2013 stock assessment of paua (*Haliotis iris*) for PAU 5B. *New Zealand Fisheries Assessment Report 2014/45*. 51 p.

Fu, D. (2015a). The 2014 stock assessment of paua (*Haliotis iris*) for Chalky and South Coast in PAU 5A. *New Zealand Fisheries Assessment Report 2015/64*. 63 p.

Fu, D. (2015b). The 2014 stock assessment of paua (*Haliotis iris*) for Milford, George, Central, and Dusky in PAU 5A. *New Zealand Fisheries Assessment Report 2015/65*. 63 p.

Fu, D. (2016). The 2015 stock assessment of paua (*Haliotis iris*) for PAU 7. *New Zealand Fisheries Assessment Report 2016/35*. 52 p.

Haddon, M.; Helidoniotis, F. (2013). Legal minimum lengths and the management of abalone fisheries. *Journal of Shellfish Research 32 (1)*: 197–208.

Haist, V.; Francis, R.I.C.C.; Stokes, K. (2006). Management strategy evaluation for New Zealand hoki fisheries: Results of initial analyses. *New Zealand Fisheries Assessment Report 2006/31*. 45 p.

Haist, V.; Middleton, D.A.J. (2014). Management strategy evaluation for the Coromandel scallop fishery. *New Zealand Fisheries Assessment Report 2014/48*. 66 p.

Helidoniotis, F.; Haddon, M. (2015). Testing alternative management strategies for the recovery of the PAU 7 fishery. Unpublished report held by Ministry for Primary Industries, Wellington.

McShane, P.E.; Naylor, J.R. (1995). Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone *Haliotis iris*. *New Zealand Journal of Marine and Freshwater Research 29 (4)*: 603–612.

McShane, P.E. (1998). Assessing stocks of abalone (*Haliotis* spp.): Methods and constraints. *Canadian Special Publication of Fisheries and Aquatic Sciences*: 41–48.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries.

Neubauer, P.; Abraham, E. (2014). Using GPS logger data to monitor change in the PAU7 pāua (*Haliotis iris*) fishery. *New Zealand Fisheries Assessment Report 2014/31*. 29 p.

Neubauer, P.; Abraham, E.; Knox, C.; Richard, Y. (2014). Assessing the performance of pāua (*Haliotis iris*) fisheries using GPS logger data. Final Research Report for Ministry for Primary Industries project PAU2011-03 (Unpublished report held by Ministry for Primary Industries, Wellington).

Prince, J. (2005). Combating the tyranny of scale for haliotids: Micro-management for microstocks. *Bulletin of Marine Science 76 (2)*: 557–578.

Prince, J.D. (1989). The fisheries biology of the Tasmanian stocks of *Haliotis rubra*. Doctoral dissertation, University of Tasmania, Australia.

Prince, J.D.; Dowling, N.A.; Davies, C.R.; Campbell, R.A.; Kolody, D.S. (2011). A simple cost-effective and scale-less empirical approach to harvest strategies. *ICES Journal of Marine Science: Journal du Conseil 68 (5)*: 947–960.

Prince, J.; Hilborn, R. (1998). Concentration profiles and invertebrate fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences 125*: 187–196.

Punt, A.E.; Campbell, R.A.; Smith, A.D. (2001). Evaluating empirical indicators and reference points for fisheries management: Application to the broadbill swordfish fishery off eastern Australia. *Marine and Freshwater Research 52 (6)*: 819–832.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

Rademeyer, R.A.; Plagányi, É.E.; Butterworth, D.S. (2007). Tips and tricks in designing management procedures. *ICES Journal of Marine Science: Journal du Conseil 64 (4)*: 618–625.

Starr, P.J.; Breen, P.A.; Hilborn, R.H.; Kendrick, T.H. (1997). Evaluation of a management decision rule for a New Zealand rock lobster substock. *Marine and Freshwater Research 48 (8)*: 1093–1101.

Wiedenmann, J.; Wilberg, M.J.; Miller, T.J. (2013). An evaluation of harvest control rules for data-poor fisheries. *North American Journal of Fisheries Management 33 (4)*: 845–860.

APPENDIX A: DIAGNOSTICS AND SENSITIVITIES

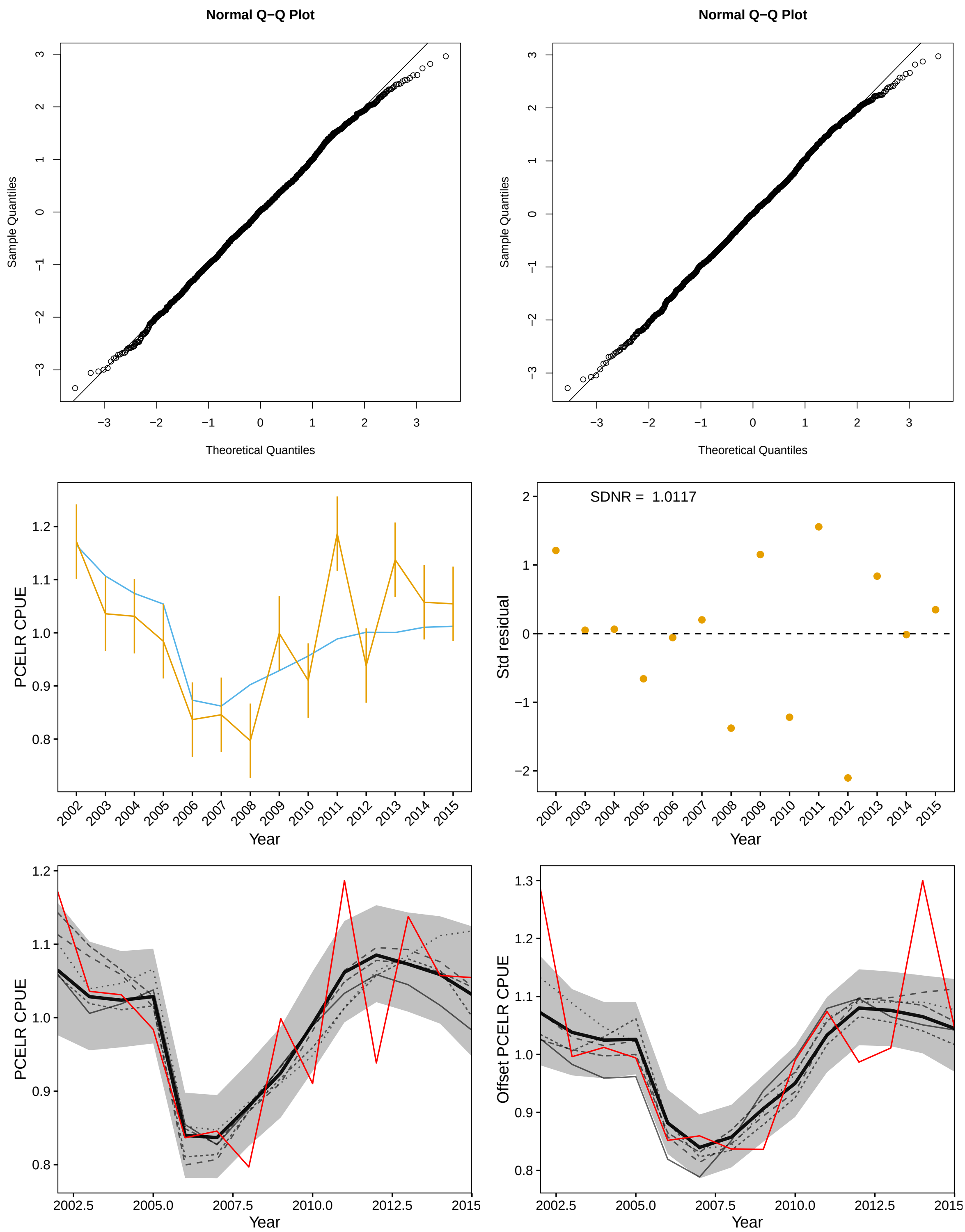


Figure A-1: Summaries of model fit to catch-per-unit-effort (CPUE) in pāua quota management sub-area PAU 5A South (PCELR, Pāua Catch Effort Landing Return). CPUE standardisation model fit (top row) for standard (left) and offset (right) CPUE, maximum posterior density (MPD) fits to standardised CPUE (middle row, left; predicted CPUE in blue, standardised index with standard errors in yellow), standardised normal residuals (SDNR) from MPD fits (middle row, right), Markov chain Monte Carlo (MCMC) fits (thick dark line, posterior median; 95% confidence interval light grey; five individual random draws from the distribution as thin dotted or dashed lines).

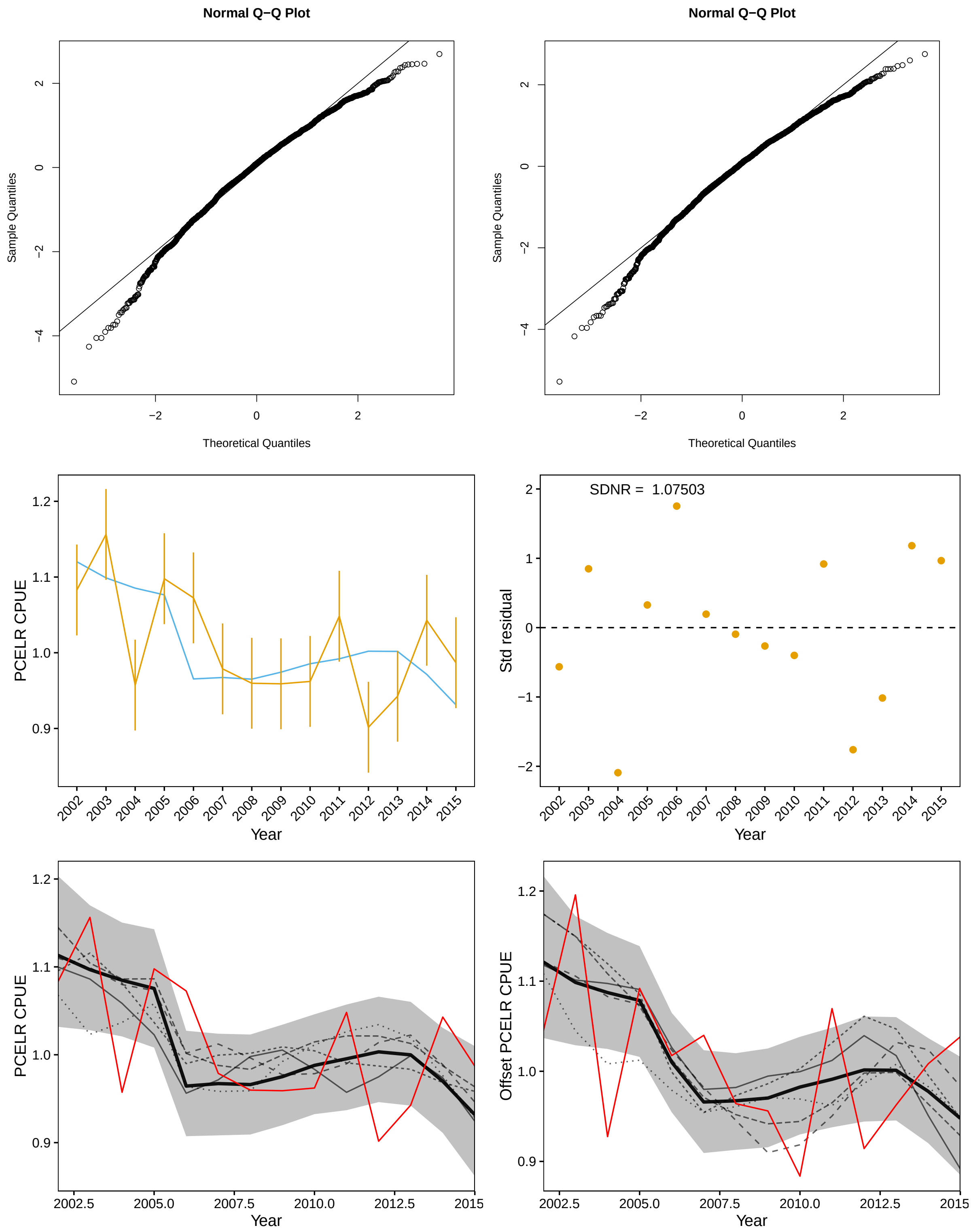


Figure A-2: Summaries of model fit to catch-per-unit-effort (CPUE) in pāua quota management sub-area PAU 5A North (PCELR, Pāua Catch Effort Landing Return). CPUE standardisation model fit (top row) for standard (left) and offset (right) CPUE, maximum posterior density (MPD) fits to standardised CPUE (middle row, left; predicted CPUE in blue, standardised index with standard errors in yellow), standardised normal residuals (SDNR) from MPD fits (middle row, right), Markov chain Monte Carlo (MCMC) fits (thick dark line, posterior median; 95% confidence interval light grey; five individual random draws from the distribution as thin dotted or dashed lines).

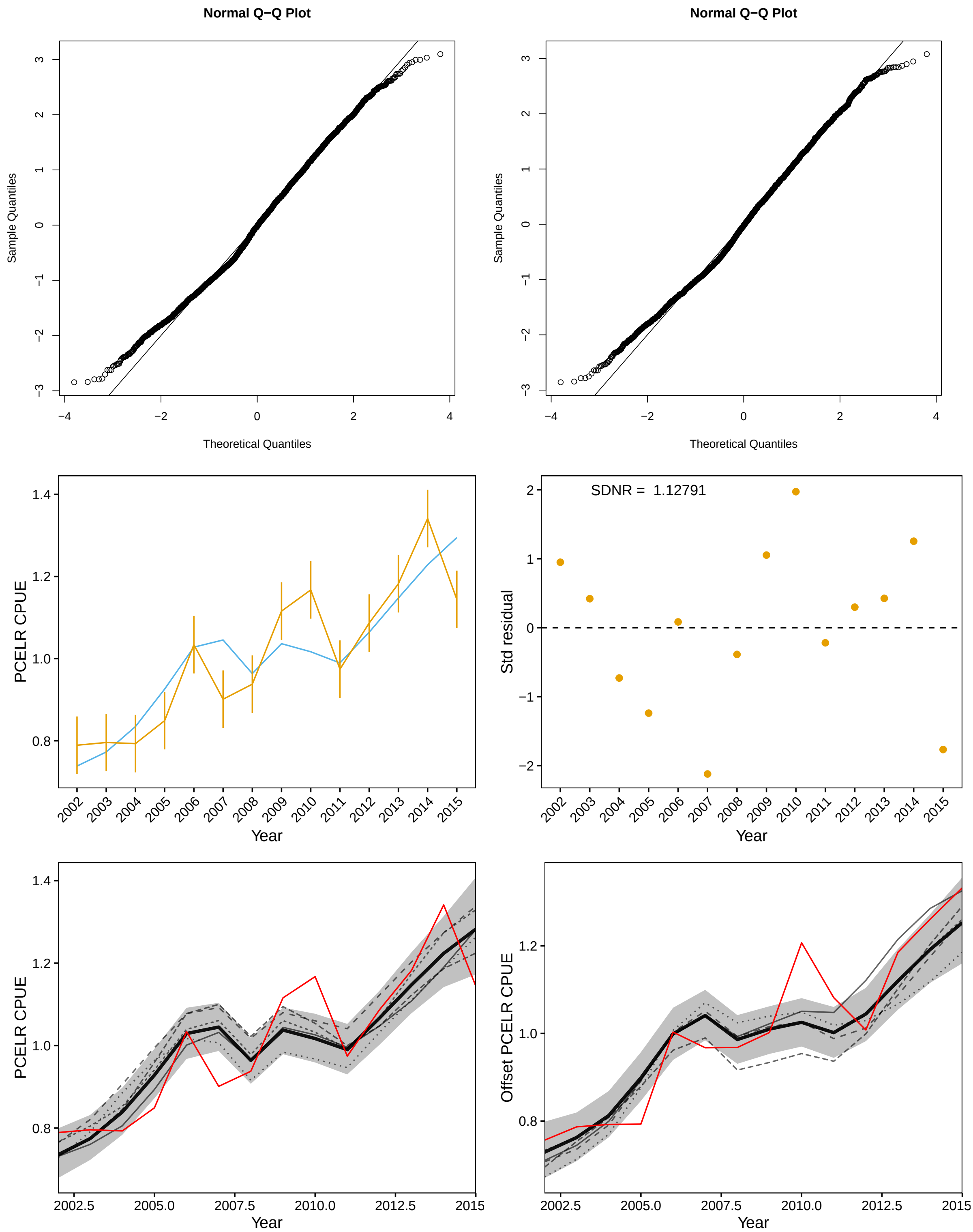


Figure A-3: Summaries of model fit to catch-per-unit-effort (CPUE) in pāua quota management sub-area PAU 5B (PCELR, Pāua Catch Effort Landing Return). CPUE standardisation model fit (top row) for standard (left) and offset (right) CPUE, maximum posterior density (MPD) fits to standardised CPUE (middle row, left; predicted CPUE in blue, standardised index with standard errors in yellow), standardised normal residuals (SDNR) from MPD fits (middle row, right), Markov chain Monte Carlo (MCMC) fits (thick dark line, posterior median; 95% confidence interval light grey; five individual random draws from the distribution as thin dotted or dashed lines).

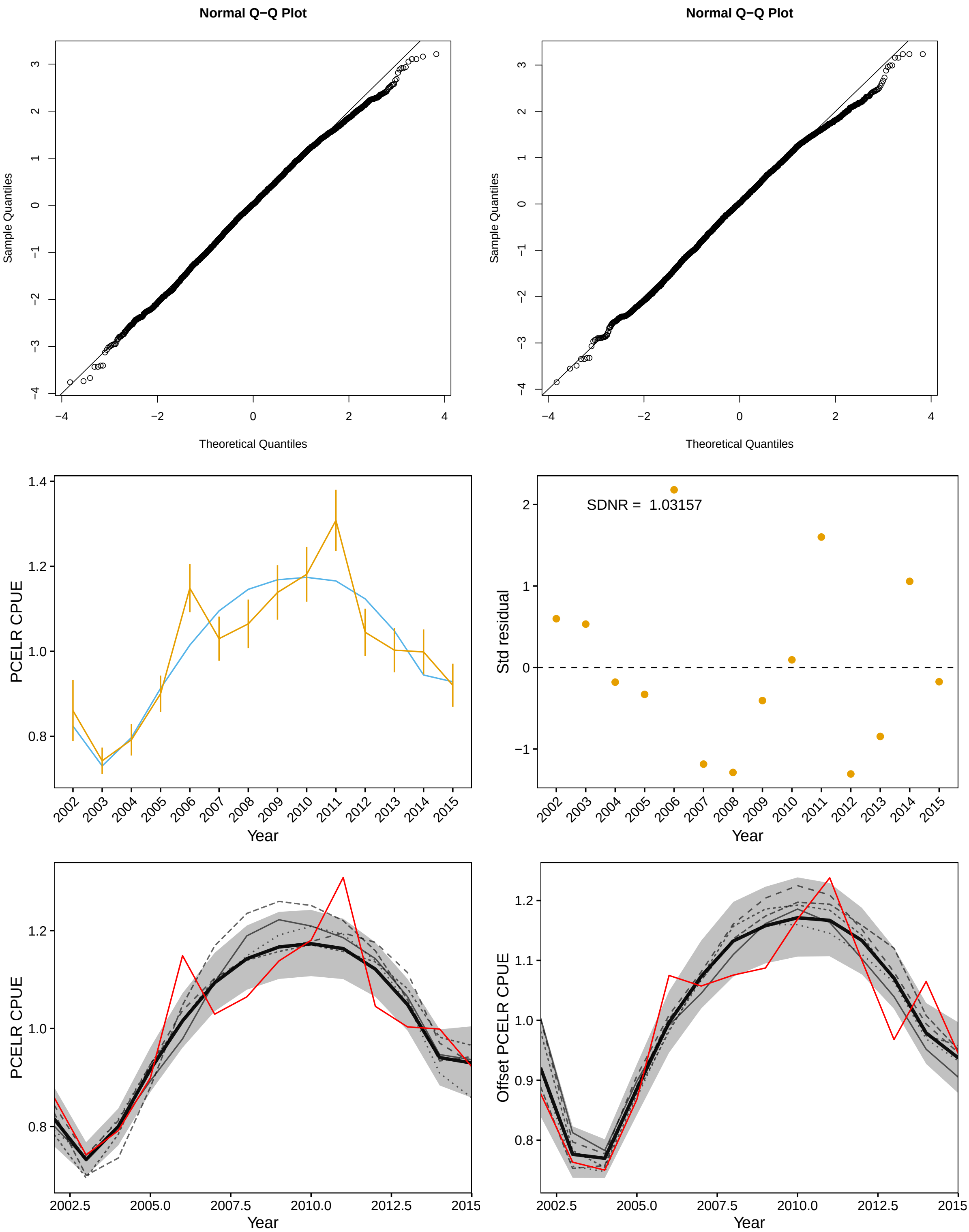


Figure A-4: Summaries of model fit to catch-per-unit-effort (CPUE) in pāua quota management sub-area PAU 5D (PCELR, Pāua Catch Effort Landing Return). CPUE standardisation model fit (top row) for standard (left) and offset (right) CPUE, maximum posterior density (MPD) fits to standardised CPUE (middle row, left; predicted CPUE in blue, standardised index with standard errors in yellow), standardised normal residuals (SDNR) from MPD fits (middle row, right), Markov chain Monte Carlo (MCMC) fits (thick dark line, posterior median; 95% confidence interval light grey; five individual random draws from the distribution as thin dotted or dashed lines).

(a) Low steepness **(b) Hyper-stability** **(c) Strong hyper-stability**

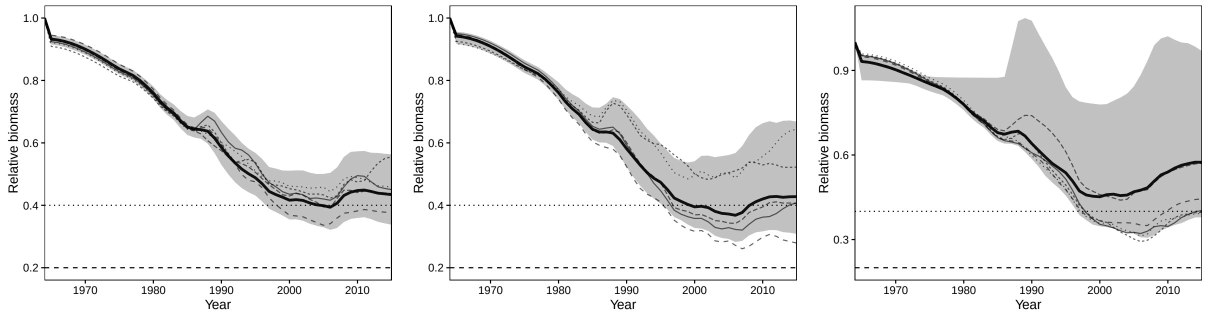


Figure A-5: Estimated posterior distributions for spawning stock biomass relative to virgin spawning stock biomass SSB_0 from sensitivity runs in pāua quota management sub-area PAU 5A South.

(a) Low steepness **(b) Hyper-stability** **(c) M prior**

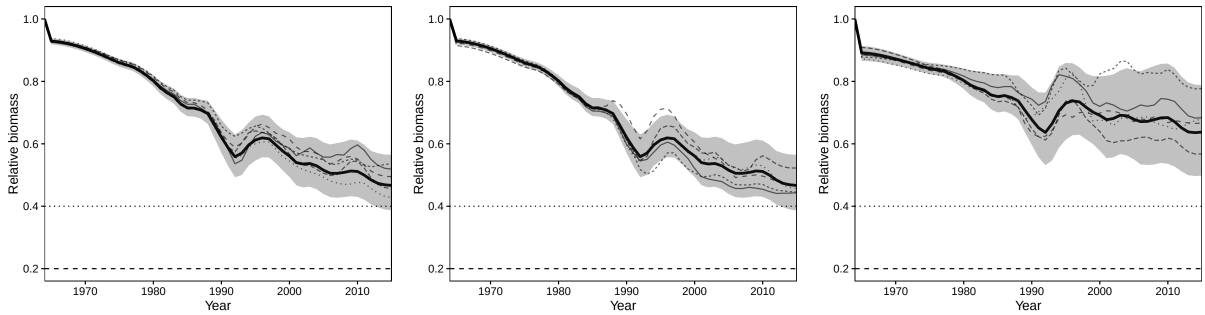


Figure A-6: Estimated posterior distributions for spawning stock biomass relative to virgin spawning stock biomass SSB_0 from sensitivity runs in pāua quota management sub-area PAU 5A North (M, natural mortality).

(a) Low steepness **(b) Hyper-stability**

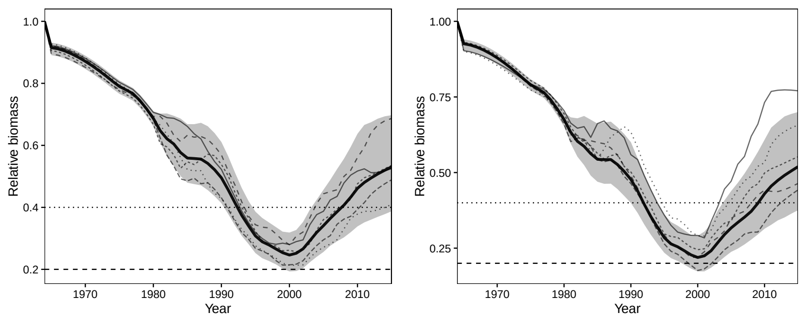


Figure A-7: Estimated posterior distributions for spawning stock biomass relative to virgin spawning stock biomass SSB_0 from sensitivity runs in pāua quota management sub-area PAU 5B.

(a) Low steepness (b) Hyper-stability (c) M prior

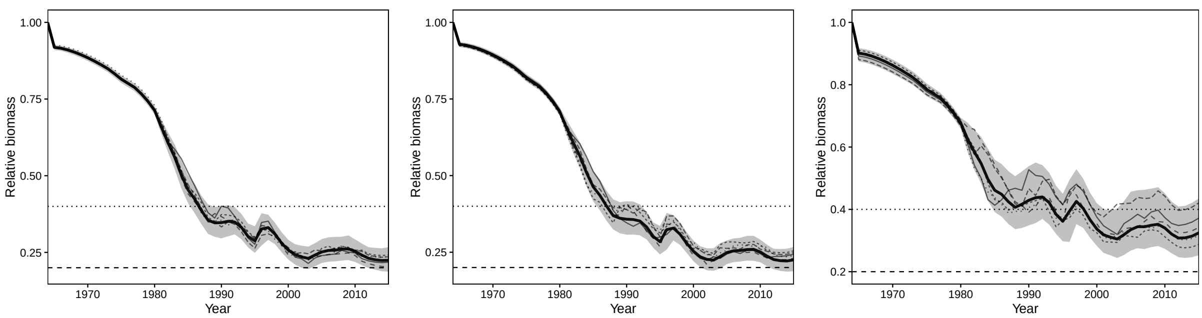


Figure A-8: Estimated posterior distributions for spawning stock biomass relative to virgin spawning stock biomass SSB_0 from sensitivity runs in pāua quota management sub-area PAU 5D (M, natural mortality).

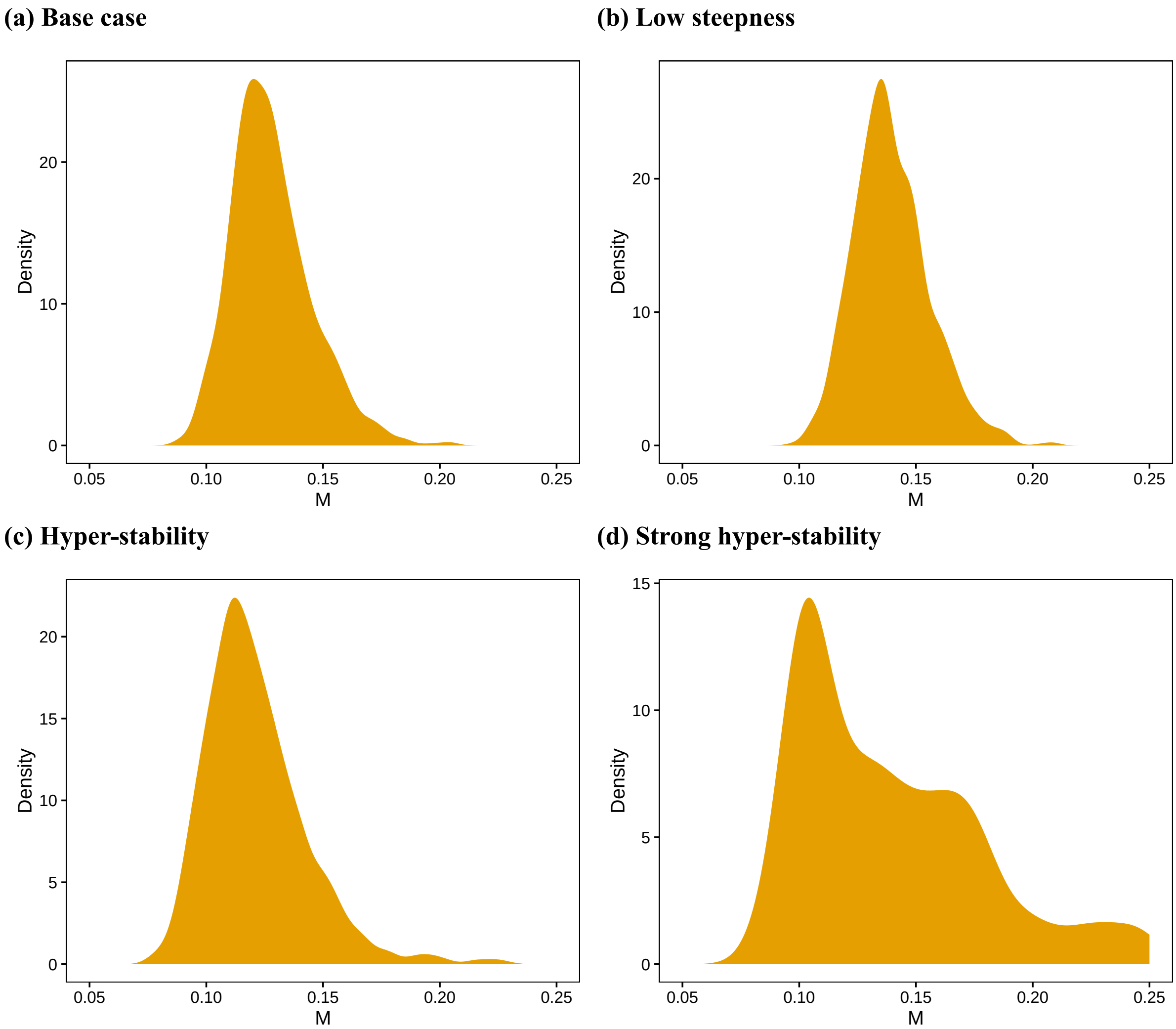


Figure A-9: Estimated posterior distributions for natural mortality M from sensitivity runs in pāua quota management sub-area PAU 5A South.

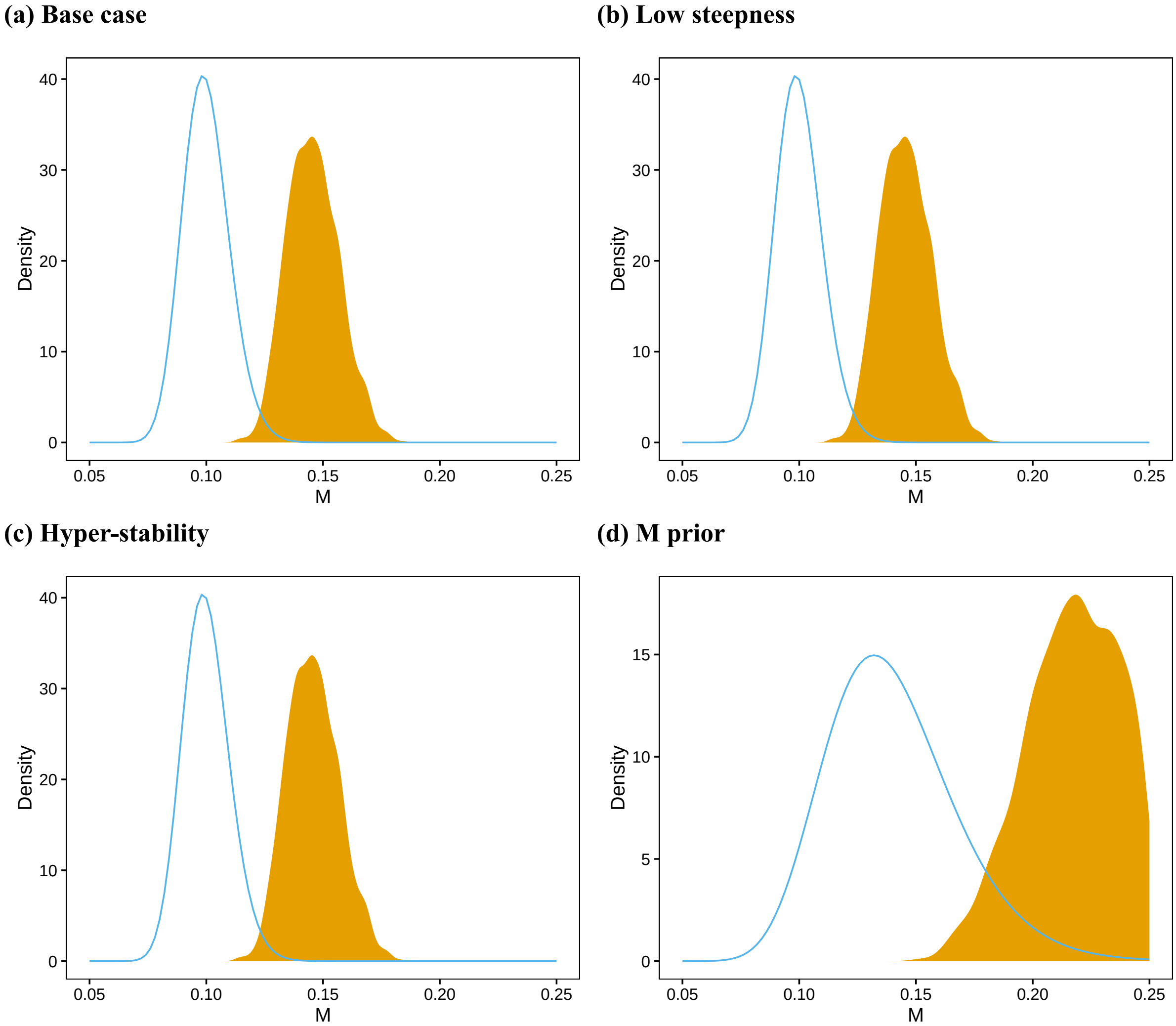


Figure A-10: Estimated posterior distributions for natural mortality M from sensitivity runs in pāua quota management sub-area PAU 5A North, compared with prior distributions (blue line).

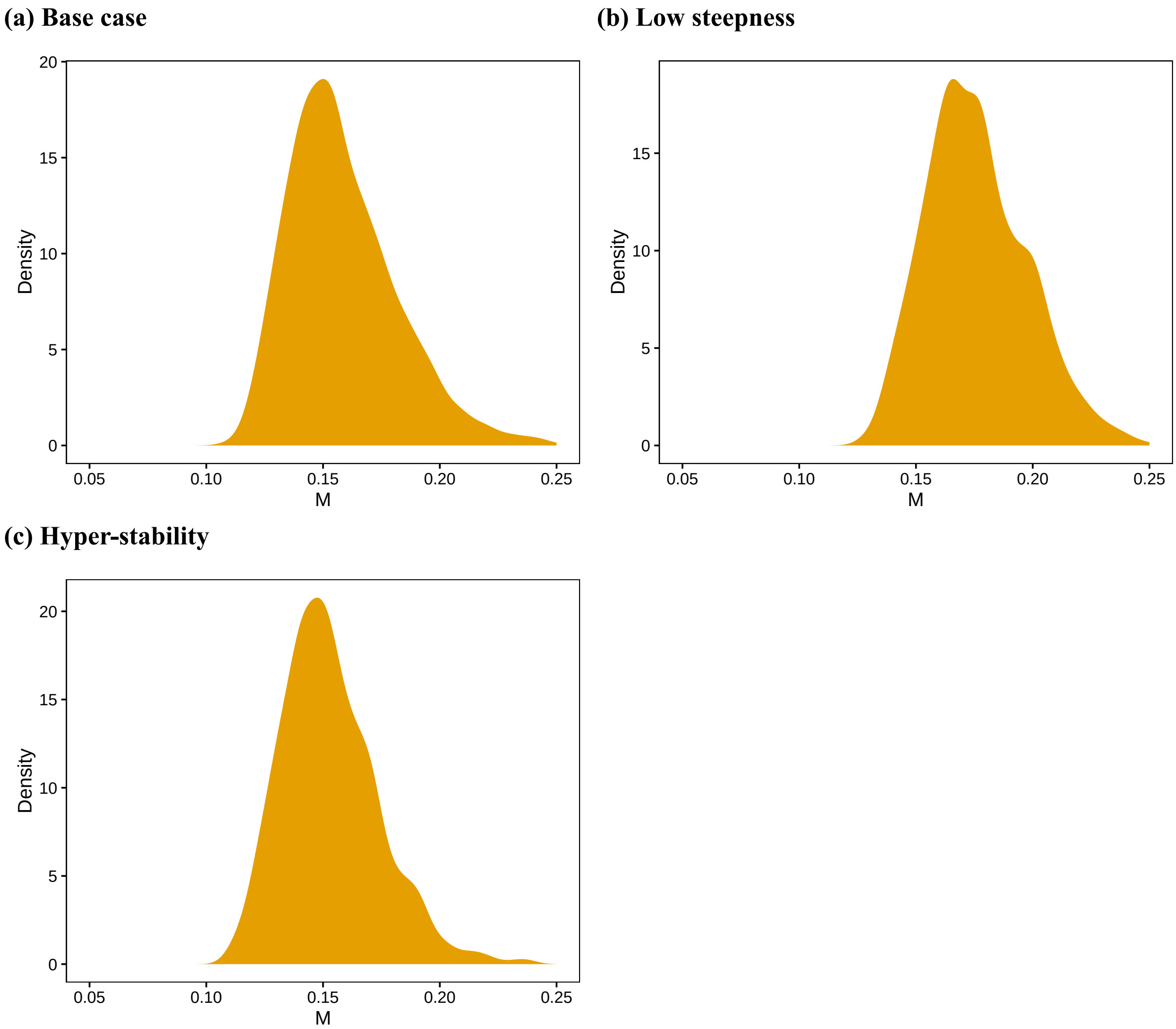


Figure A-11: Estimated posterior distributions for natural mortality M from sensitivity runs in pāua quota management sub-area PAU 5B.

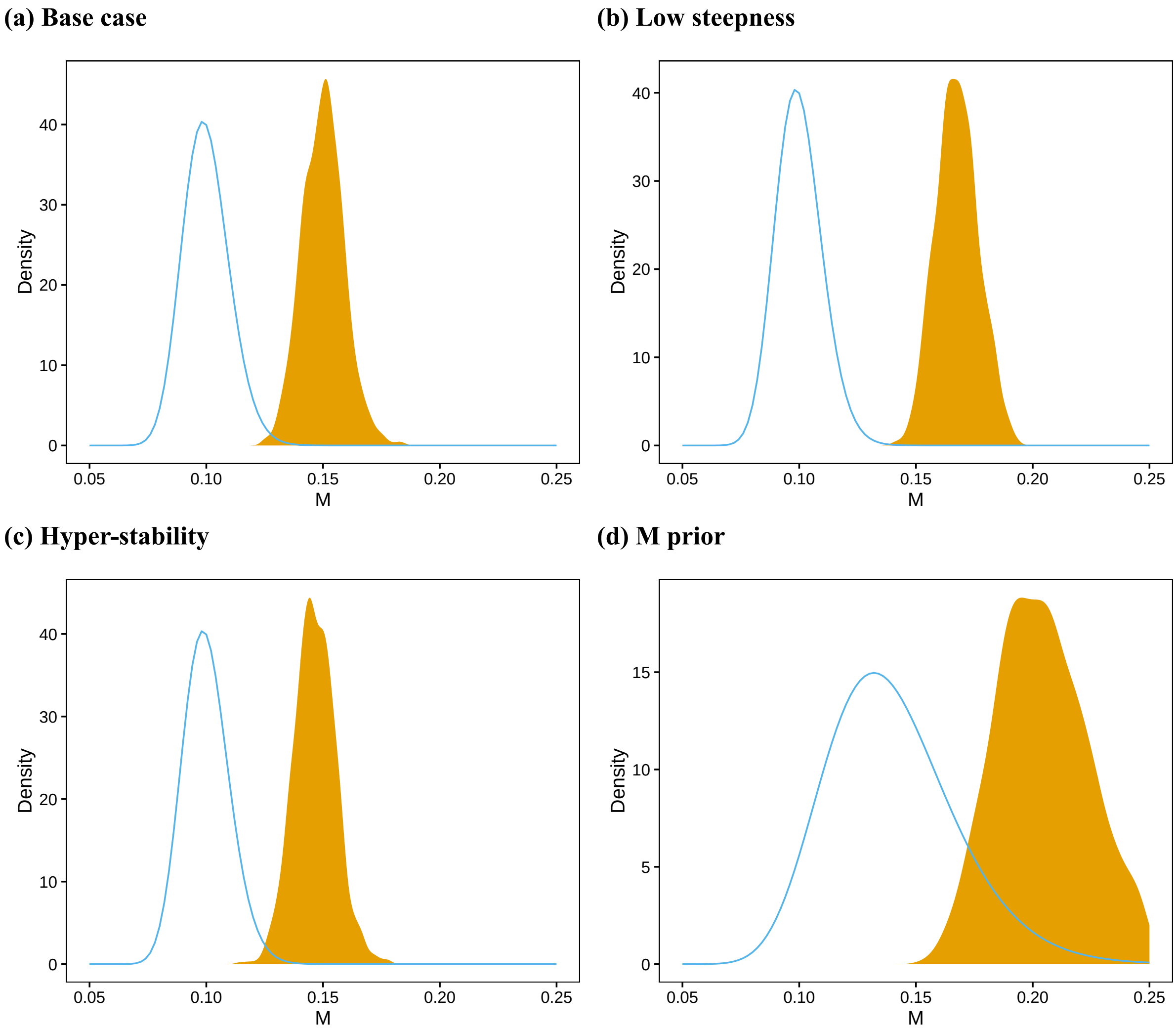


Figure A-12: Estimated posterior distributions for natural mortality M from sensitivity runs in pāua quota management sub-area PAU 5D, compared with prior distributions (blue line).

APPENDIX B: ALTERNATIVE RULES TO ACCELERATE REBUILDING IN PAU 5D

Table B-1: Alternative control rules that lead to accelerated rebuilding in management procedure evaluation simulations for pāua quota management area (QMA) PAU 5D. Parameters correspond to catch-per-unit-effort (CPUE) limits (C1–5), catch limits (L1–3) and total allowable commercial catch increase (P1) when CPUE is estimated to be above the highest catch plateau (defined between C4 and C5). The alternative control rules set more conservative harvest levels around a lower catch plateau corresponding to approximately 40% (40-30-20 rule) and 50% (50-30-20 rule) shelving, with progressive un-shelving to 30% and 20%. CPUE limits were also moved so as to delay un-shelving and aid rebuilding. (Note these scenarios are for illustrative purposes only.)

QMA	Parameter setting								
	C1	C2	C3	C4	C5	L1 (t)	L2 (t)	L3 (t)	P1
40-30-20	16	27	42	45	48	56	64	74	90
50-30-20	16	27	42	45	48	44	64	74	90

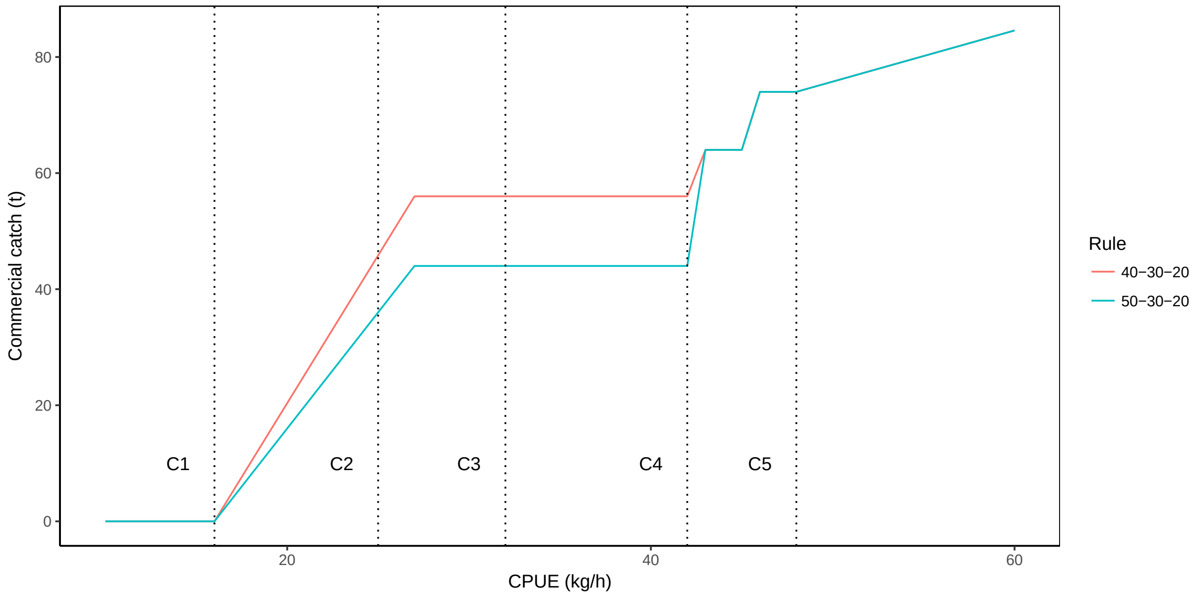


Figure B-13: Alternative control rules that lead to accelerated rebuilding in management procedure evaluation simulations for pāua quota management area (QMA) PAU 5D. Control rules have three catch levels, with the middle level near current commercial take (CPUE, catch-per-unit-effort). Alternative control rules set more conservative harvest levels around a lower catch plateau corresponding to approximately 40% (40-30-20 rule) and 50% (50-30-20 rule) shelving, with progressive un-shelving to 30% and 20%.

APPENDIX C: DETAILED MANAGEMENT PROCEDURE EVALUATION RESULTS

Table C-2: Summary of management procedure evaluation performance metrics for all Markov chain Monte Carlo sensitivities and simulation scenarios for different sub-areas in pāua quota management area (QMA) PAU 5. Metrics are for rules proposed by stakeholders (Proposed rule) and the best-tested rules for the performance metric (for a given QMA, sensitivity and simulation scenario).

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%,95%)	Median (5%,95%)
5A South	Average Biomass	Base case	Base case	0.98 (0.86,1.18)	1.07 (0.93,1.35)
5A South	Average Biomass	Base case	Catchability (r_q = 0.5%)	0.96 (0.84,1.16)	1.06 (0.91,1.34)
5A South	Average Biomass	Base case	Catchability (r_q = 1.0%)	0.95 (0.82,1.14)	1.06 (0.91,1.33)
5A South	Average Biomass	Base case	Catchability (r_q = 1.5%)	0.93 (0.8,1.13)	1.06 (0.89,1.32)
5A South	Average Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.98 (0.85,1.18)	1.07 (0.94,1.35)
5A South	Average Biomass	Base case	M increase (r_M=0.5%)	0.92 (0.81,1.11)	1 (0.89,1.26)
5A South	Average Biomass	Base case	M increase (r_M=1%)	0.87 (0.77,1.05)	0.94 (0.85,1.17)
5A South	Average Biomass	Base case	M increase (r_M=1.5%)	0.83 (0.73,0.98)	0.9 (0.82,1.09)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.97 (0.85,1.17)	1.06 (0.92,1.34)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.95 (0.83,1.15)	1.04 (0.91,1.32)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1 (0.88,1.19)	1.1 (0.95,1.38)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.98 (0.87,1.18)	1.08 (0.94,1.36)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.96 (0.85,1.17)	1.05 (0.92,1.34)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.95 (0.83,1.16)	1.04 (0.91,1.31)
5A South	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.93 (0.81,1.13)	1.02 (0.9,1.28)
5A South	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.71 (0.65,0.81)	0.81 (0.75,0.89)
5A South	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.83 (0.74,0.99)	0.92 (0.84,1.08)
5A South	Average Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.08 (0.93,1.47)	1.17 (1.02,1.6)
5A South	Average Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	0.99 (0.84,1.26)	1.1 (0.94,1.42)
5A South	Average Biomass	Low steepness (h=0.6)	Base case	0.97 (0.86,1.18)	1.07 (0.93,1.31)
5A South	Average Catch	Base case	Base case	55.65 (48.4,64.97)	85.61 (67.98,88.8)
5A South	Average Catch	Base case	Catchability (r_q = 0.5%)	56.95 (49.6,66.56)	85.61 (67.98,88.8)
5A South	Average Catch	Base case	Catchability (r_q = 1.0%)	58.75 (51.39,67.86)	85.61 (67.98,88.8)
5A South	Average Catch	Base case	Catchability (r_q = 1.5%)	60.1 (52.6,69.64)	85.61 (67.98,88.8)
5A South	Average Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	55.65 (48.44,65.07)	85.61 (67.98,88.8)
5A South	Average Catch	Base case	M increase (r_M=0.5%)	53.25 (46.6,62.36)	82.29 (65.79,87.8)
5A South	Average Catch	Base case	M increase (r_M=1%)	51.3 (44.8,59.4)	79.19 (63.59,85.8)
5A South	Average Catch	Base case	M increase (r_M=1.5%)	48.89 (42.1,56.9)	76.19 (61.23,87.8)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=2%)	56.68 (48.88,65.88)	85.67 (67.95,89.88)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=5%)	57.81 (50.43,67.75)	85.71 (67.89,92.11)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.5)	55.1 (47.84,64.2)	85.86 (68.74,87.1)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.8)	55.18 (48.32,64.48)	85.75 (68.31,88.12)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.2)	56.28 (48.48,65.46)	85.42 (67.65,89.48)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.5)	56.2 (48.9,66.11)	85.01 (67.29,88.5)
5A South	Average Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=2)	56.7 (49.4,66.97)	84.36 (66.6,88.2)
5A South	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	40.84 (34.3,49.02)	58.05 (46.73,73.8)
5A South	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	49 (42.7,56.85)	71.61 (56.86,88.8)
5A South	Average Catch	Hyper-stable CPUE (ß = 0.5)	Base case	57.45 (54.4,64.67)	88.8 (80.43,88.8)
5A South	Average Catch	Hyper-stable CPUE (ß = 0.8)	Base case	56.8 (49,66.13)	86.47 (63.09,88.8)
5A South	Average Catch	Low steepness (h=0.6)	Base case	55.6 (47.74,63.42)	86.15 (63.57,88.8)
5A South	Average CPUE	Base case	Base case	35.56 (30.33,43.49)	39.52 (33.2,49.87)
5A South	Average CPUE	Base case	Catchability (r_q = 0.5%)	36.83 (31.17,45.49)	41.64 (34.18,52.59)
5A South	Average CPUE	Base case	Catchability (r_q = 1.0%)	38.33 (32.03,47.29)	43.95 (35.49,55.54)
5A South	Average CPUE	Base case	Catchability (r_q = 1.5%)	39.59 (32.85,49.44)	46.43 (36.71,58.64)
5A South	Average CPUE	Base case	∂_{CPUE} ($m_{\partial_{\text{CPUE}}}$=0.015)	35.59 (30.2,43.46)	39.69 (33.44,49.88)
5A South	Average CPUE	Base case	M increase (r_M=0.5%)	33.56 (28.68,40.97)	36.83 (32.12,46.72)
5A South	Average CPUE	Base case	M increase (r_M=1%)	31.89 (27.01,38.65)	34.81 (31.06,43.77)
5A South	Average CPUE	Base case	M increase (r_M=1.5%)	30.09 (25.78,36.42)	33.25 (30,40.88)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=2%)	35.22 (29.87,43.13)	39.04 (32.99,49.35)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=5%)	34.54 (29.2,42.42)	38.25 (32.56,48.4)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.5)	36.37 (31.16,44.23)	40.76 (33.8,51.32)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.8)	35.84 (30.51,43.94)	39.98 (33.43,50.39)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.2)	35.15 (29.88,43.03)	38.97 (32.96,49.27)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.5)	34.57 (29.42,42.35)	38.34 (32.63,48.38)
5A South	Average CPUE	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=2)	33.82 (28.07,41.79)	37.15 (32.1,47.15)
5A South	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	25.82 (23.37,29.88)	30.27 (28.05,33.53)
5A South	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	30.36 (25.96,36.6)	33.61 (30.53,40.85)
5A South	Average CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	37.6 (33.66,44.19)	39.4 (35.52,45.97)
5A South	Average CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	36.53 (31.03,45.82)	40.33 (33.52,50.42)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5A South	Average CPUE	Low steepness (h=0.6)	Base case	35.11 (30.18,42.34)	38.78 (32.85,48.31)
5A South	Minimum Biomass	Base case	Base case	0.88 (0.72,0.96)	0.93 (0.81,0.99)
5A South	Minimum Biomass	Base case	Catchability (r_q = 0.5%)	0.86 (0.71,0.95)	0.93 (0.8,0.99)
5A South	Minimum Biomass	Base case	Catchability (r_q = 1.0%)	0.84 (0.66,0.94)	0.93 (0.78,0.99)
5A South	Minimum Biomass	Base case	Catchability (r_q = 1.5%)	0.82 (0.63,0.94)	0.93 (0.76,0.99)
5A South	Minimum Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.88 (0.72,0.96)	0.93 (0.82,0.99)
5A South	Minimum Biomass	Base case	M increase (r_M=0.5%)	0.82 (0.64,0.93)	0.91 (0.77,0.98)
5A South	Minimum Biomass	Base case	M increase (r_M=1%)	0.75 (0.58,0.9)	0.84 (0.7,0.95)
5A South	Minimum Biomass	Base case	M increase (r_M=1.5%)	0.66 (0.52,0.86)	0.77 (0.64,0.93)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.87 (0.71,0.95)	0.93 (0.81,0.99)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.85 (0.68,0.95)	0.93 (0.8,0.99)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.9 (0.74,0.97)	0.94 (0.84,0.99)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.89 (0.74,0.96)	0.94 (0.83,0.99)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.87 (0.7,0.95)	0.93 (0.81,0.99)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.86 (0.69,0.94)	0.92 (0.8,0.98)
5A South	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.84 (0.66,0.93)	0.91 (0.78,0.97)
5A South	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.54 (0.46,0.67)	0.69 (0.61,0.79)
5A South	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.71 (0.56,0.88)	0.81 (0.71,0.93)
5A South	Minimum Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	0.96 (0.8,1.05)	0.99 (0.89,1.05)
5A South	Minimum Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	0.88 (0.69,0.99)	0.94 (0.81,1.02)
5A South	Minimum Biomass	Low steepness (h=0.6)	Base case	0.87 (0.72,0.96)	0.93 (0.81,1)
5A South	Minimum Catch	Base case	Base case	44.8 (44.43,56.8)	84.8 (38.88,84.8)
5A South	Minimum Catch	Base case	Catchability (r_q = 0.5%)	44.8 (44.8,56.8)	84.8 (38.88,84.8)
5A South	Minimum Catch	Base case	Catchability (r_q = 1.0%)	44.8 (44.8,56.8)	84.8 (38.88,84.8)
5A South	Minimum Catch	Base case	Catchability (r_q = 1.5%)	56.8 (44.8,56.8)	84.8 (38.88,84.8)
5A South	Minimum Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	44.8 (40.82,56.8)	84.8 (38.88,84.8)
5A South	Minimum Catch	Base case	M increase (r_M=0.5%)	44.8 (34.21,56.8)	80.8 (37.29,80.8)
5A South	Minimum Catch	Base case	M increase (r_M=1%)	44.8 (25.72,44.8)	75.8 (34.87,75.8)
5A South	Minimum Catch	Base case	M increase (r_M=1.5%)	40.96 (19.79,44.8)	71.8 (33.33,71.8)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	45.27 (43.73,56.89)	83.89 (39.14,83.89)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	46.04 (42.94,57.02)	82.03 (39.57,82.03)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	43.1 (43.1,55.1)	85.1 (39.7,85.1)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	44.12 (44.12,56.12)	84.53 (39.09,85.12)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	45.48 (43,57.48)	84.48 (38.67,84.48)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	46.5 (41.27,58.5)	83.5 (38.65,83.5)
5A South	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	48.2 (37.07,60.2)	83.2 (37.83,83.2)
5A South	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	21.4 (10.35,40.85)	54.8 (21.69,54.8)
5A South	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	43.78 (22.74,44.8)	69.8 (29.54,69.8)
5A South	Minimum Catch	Hyper-stable CPUE (ß = 0.5)	Base case	56.8 (44.8,56.8)	88.8 (47.19,88.8)
5A South	Minimum Catch	Hyper-stable CPUE (ß = 0.8)	Base case	44.8 (44.8,56.8)	84.8 (35.69,84.8)
5A South	Minimum Catch	Low steepness (h=0.6)	Base case	44.8 (41.78,56.8)	85.8 (31.43,85.8)
5A South	Minimum CPUE	Base case	Base case	31.62 (25.56,35.51)	34.16 (29.57,38.24)
5A South	Minimum CPUE	Base case	Catchability (r_q = 0.5%)	32.42 (26.78,36.88)	34.69 (30.22,39.05)
5A South	Minimum CPUE	Base case	Catchability (r_q = 1.0%)	33.48 (27.64,37.76)	35.09 (29.79,39.37)
5A South	Minimum CPUE	Base case	Catchability (r_q = 1.5%)	34.35 (28.18,38.35)	35.49 (30.93,39.7)
5A South	Minimum CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	31.77 (25.44,35.84)	34.26 (29.8,38.24)
5A South	Minimum CPUE	Base case	M increase (r_M=0.5%)	29.89 (22.94,34.59)	33.07 (28.3,37.01)
5A South	Minimum CPUE	Base case	M increase (r_M=1%)	27.51 (20.97,32.93)	30.88 (26.56,35.95)
5A South	Minimum CPUE	Base case	M increase (r_M=1.5%)	24.1 (19.11,31.41)	28.67 (24.5,34.06)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	31.34 (24.85,35.32)	34.02 (29.46,38.22)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	30.98 (23.46,35.24)	33.81 (28.93,37.71)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	32.37 (26.74,36.28)	34.63 (30.19,38.44)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	31.93 (26.15,35.77)	34.34 (29.83,38.32)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	31.35 (24.56,35.38)	33.91 (29.35,38.04)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	30.9 (24.42,34.82)	33.66 (29.01,37.47)
5A South	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	30.16 (23.18,34.35)	32.95 (28.48,36.93)
5A South	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	19.87 (17.24,24.36)	26.09 (23.73,29.3)
5A South	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	25.91 (20.34,32.34)	30.01 (26.51,34.76)
5A South	Minimum CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	35.44 (31.24,38)	36.26 (33.59,38.51)
5A South	Minimum CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	33.1 (27.12,38.29)	35.13 (30.38,40.37)
5A South	Minimum CPUE	Low steepness (h=0.6)	Base case	31.32 (24.86,36.18)	33.61 (29.04,37.53)
5A South	Number of TACC changes	Base case	Base case	6 (3,12)	1 (1,1)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A South	Number of TACC changes	Base case	Catchability (r_q = 0.5%)	7 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	Catchability (r_q = 1.0%)	7 (3,14)	1 (1,1)
5A South	Number of TACC changes	Base case	Catchability (r_q = 1.5%)	8 (3,15)	1 (1,1)
5A South	Number of TACC changes	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	8 (4,14)	1 (1,1)
5A South	Number of TACC changes	Base case	M increase (r_M=0.5%)	7 (2,13)	1 (1,1)
5A South	Number of TACC changes	Base case	M increase (r_M=1%)	7 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	M increase (r_M=1.5%)	8 (4,14)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	7 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	7 (3,12)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	6 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	6 (3,12)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	7 (3,12)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	7 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	7 (3,13)	1 (1,1)
5A South	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.6)	13 (7,17)	1 (1,1)
5A South	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.8)	8 (3,14)	1 (1,1)
5A South	Number of TACC changes	Hyper-stable CPUE (ß = 0.5)	Base case	4 (1,11)	1 (1,10)
5A South	Number of TACC changes	Hyper-stable CPUE (ß = 0.8)	Base case	6 (1,13)	1 (1,1)
5A South	Number of TACC changes	Low steepness (h=0.6)	Base case	7 (3,12)	1 (1,1)
5A South	P($SSB < 0.1SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A South	P($SSB < 0.1SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.1SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	Catch$_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,0.3)	<0.005 (-,0.3)
5A South	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	P($SSB < 0.2SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A South	Relative Biomass at 10y	Base case	Base case	0.45 (0.33,0.68)	0.48 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	Catchability (r_q = 0.5%)	0.44 (0.33,0.68)	0.48 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	Catchability (r_q = 1.0%)	0.44 (0.33,0.67)	0.48 (0.36,0.72)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5A South	Relative Biomass at 10y	Base case	Catchability (r_q = 1.5%)	0.43 (0.33,0.66)	0.48 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.45 (0.33,0.68)	0.48 (0.37,0.72)
5A South	Relative Biomass at 10y	Base case	M increase (r_M=0.5%)	0.43 (0.32,0.65)	0.46 (0.35,0.69)
5A South	Relative Biomass at 10y	Base case	M increase (r_M=1%)	0.42 (0.31,0.62)	0.44 (0.34,0.67)
5A South	Relative Biomass at 10y	Base case	M increase (r_M=1.5%)	0.4 (0.3,0.6)	0.43 (0.33,0.64)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.44 (0.33,0.67)	0.48 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.44 (0.33,0.67)	0.47 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.45 (0.34,0.69)	0.49 (0.37,0.73)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.45 (0.34,0.68)	0.48 (0.37,0.73)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.44 (0.33,0.67)	0.48 (0.36,0.72)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.44 (0.33,0.67)	0.47 (0.36,0.71)
5A South	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.43 (0.32,0.66)	0.46 (0.35,0.71)
5A South	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.29 (0.22,0.44)	0.32 (0.26,0.47)
5A South	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.37 (0.27,0.55)	0.4 (0.31,0.59)
5A South	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.5)	Base case	0.52 (0.36,0.87)	0.55 (0.39,0.9)
5A South	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.8)	Base case	0.43 (0.31,0.67)	0.47 (0.34,0.7)
5A South	Relative Biomass at 10y	Low steepness (h=0.6)	Base case	0.44 (0.32,0.6)	0.47 (0.34,0.64)
5A South	Relative Biomass at 5y	Base case	Base case	0.43 (0.34,0.62)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	Catchability (r_q = 0.5%)	0.43 (0.34,0.62)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	Catchability (r_q = 1.0%)	0.43 (0.34,0.62)	0.44 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	Catchability (r_q = 1.5%)	0.43 (0.34,0.62)	0.44 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.43 (0.34,0.63)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	M increase (r_M=0.5%)	0.42 (0.34,0.61)	0.44 (0.35,0.63)
5A South	Relative Biomass at 5y	Base case	M increase (r_M=1%)	0.42 (0.33,0.61)	0.44 (0.35,0.62)
5A South	Relative Biomass at 5y	Base case	M increase (r_M=1.5%)	0.42 (0.33,0.6)	0.43 (0.35,0.61)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.43 (0.34,0.62)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.43 (0.34,0.62)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.43 (0.35,0.63)	0.45 (0.37,0.64)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.43 (0.34,0.63)	0.45 (0.36,0.64)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.43 (0.34,0.62)	0.45 (0.36,0.63)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.42 (0.34,0.62)	0.44 (0.35,0.63)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A South	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.42 (0.33,0.61)	0.44 (0.35,0.63)
5A South	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.36 (0.29,0.52)	0.38 (0.31,0.55)
5A South	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.4 (0.32,0.58)	0.41 (0.33,0.59)
5A South	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.5)	Base case	0.49 (0.36,0.7)	0.51 (0.38,0.72)
5A South	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.8)	Base case	0.42 (0.31,0.6)	0.44 (0.32,0.61)
5A South	Relative Biomass at 5y	Low steepness (h=0.6)	Base case	0.43 (0.33,0.57)	0.44 (0.34,0.58)
5A North	Average Biomass	Base case	Base case	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	Base case	Catchability (r_q = 0.5%)	1.05 (0.93,1.31)	1.15 (0.99,1.48)
5A North	Average Biomass	Base case	Catchability (r_q = 1.0%)	1.03 (0.91,1.29)	1.15 (0.97,1.49)
5A North	Average Biomass	Base case	Catchability (r_q = 1.5%)	1.02 (0.9,1.27)	1.15 (0.97,1.49)
5A North	Average Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	1.06 (0.94,1.33)	1.16 (1.01,1.49)
5A North	Average Biomass	Base case	M increase (r_M=0.5%)	1 (0.88,1.24)	1.08 (0.96,1.38)
5A North	Average Biomass	Base case	M increase (r_M=1%)	0.94 (0.84,1.17)	1.01 (0.92,1.29)
5A North	Average Biomass	Base case	M increase (r_M=1.5%)	0.88 (0.79,1.1)	0.96 (0.88,1.2)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	1.06 (0.94,1.32)	1.15 (1,1.49)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	1.06 (0.94,1.32)	1.15 (1,1.49)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	1.06 (0.94,1.32)	1.15 (1,1.49)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	1.06 (0.94,1.32)	1.15 (1,1.48)
5A North	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	1.05 (0.94,1.32)	1.15 (1,1.48)
5A North	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.76 (0.71,0.88)	0.87 (0.81,0.97)
5A North	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.9 (0.81,1.09)	0.98 (0.9,1.21)
5A North	Average Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	Low steepness (h=0.6)	Base case	1.06 (0.94,1.32)	1.16 (1,1.49)
5A North	Average Biomass	M prior (μ = 0.14, cv = 0.2)	Base case	1.06 (0.95,1.29)	1.11 (0.98,1.35)
5A North	Average Catch	Base case	Base case	49.8 (43.2,58.53)	71.2 (71.2,71.2)
5A North	Average Catch	Base case	Catchability (r_q = 0.5%)	51.13 (45.6,60.05)	71.2 (71.2,71.2)
5A North	Average Catch	Base case	Catchability (r_q = 1.0%)	52.85 (46.2,62.11)	71.2 (71.2,71.2)
5A North	Average Catch	Base case	Catchability (r_q = 1.5%)	54.66 (48,64.38)	71.2 (71.2,71.2)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A North	Average Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	49.8 (43.33,58.29)	71.2 (71.2,71.2)
5A North	Average Catch	Base case	M increase (r_M=0.5%)	48 (40.26,56.91)	71.2 (69.07,71.2)
5A North	Average Catch	Base case	M increase (r_M=1%)	45 (38,54.7)	71.2 (66.15,71.2)
5A North	Average Catch	Base case	M increase (r_M=1.5%)	42.6 (34.48,51.6)	71.2 (63.07,71.2)
5A North	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	49.92 (43.32,58.63)	71.32 (71.32,71.32)
5A North	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	50.17 (43.57,58.84)	71.57 (71.57,71.57)
5A North	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	54.5 (48.5,63.29)	75.9 (75.9,75.9)
5A North	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	51.68 (45.68,60.43)	73.08 (73.08,73.08)
5A North	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	47.92 (41.32,56.63)	69.32 (69.32,69.32)
5A North	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	45.1 (38.5,53.77)	66.5 (66.5,66.5)
5A North	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	40.4 (33.8,49.02)	61.8 (61.8,61.8)
5A North	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	34.36 (27.14,42.19)	59.66 (46.72,71.2)
5A North	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	43.19 (36.87,51.6)	71.2 (60.02,71.2)
5A North	Average Catch	Hyper-stable CPUE (ß = 0.5)	Base case	49.8 (43.2,58.53)	71.2 (71.2,71.2)
5A North	Average Catch	Hyper-stable CPUE (ß = 0.8)	Base case	49.8 (43.2,58.53)	71.2 (71.2,71.2)
5A North	Average Catch	Low steepness (h=0.6)	Base case	49.8 (43.2,58.53)	71.2 (71.2,71.2)
5A North	Average Catch	M prior (μ = 0.14, cv = 0.2)	Base case	50.4 (44.4,58.35)	71.25 (62.47,81.53)
5A North	Average CPUE	Base case	Base case	37.34 (31.85,46.86)	41.03 (34.75,52.89)
5A North	Average CPUE	Base case	Catchability (r_q = 0.5%)	38.95 (32.99,49.37)	43.35 (36.02,56.13)
5A North	Average CPUE	Base case	Catchability (r_q = 1.0%)	40.57 (34.35,51.81)	45.77 (37.68,59.42)
5A North	Average CPUE	Base case	Catchability (r_q = 1.5%)	42.31 (36.04,54)	48.52 (39.05,63.83)
5A North	Average CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	37.38 (32.06,47.18)	41.29 (34.99,52.91)
5A North	Average CPUE	Base case	M increase (r_M=0.5%)	35.07 (30.43,43.83)	38.35 (33.23,49.58)
5A North	Average CPUE	Base case	M increase (r_M=1%)	33.07 (28.64,41.15)	35.95 (31.92,46.17)
5A North	Average CPUE	Base case	M increase (r_M=1.5%)	31.21 (27.17,38.74)	34.02 (30.71,42.87)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	37.31 (31.81,46.82)	41 (34.73,52.86)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	37.26 (31.75,46.75)	40.93 (34.69,52.8)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	37.42 (31.96,46.97)	41.12 (34.81,53)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	37.37 (31.89,46.9)	41.07 (34.78,52.93)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	37.31 (31.8,46.81)	40.99 (34.73,52.85)
5A North	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	37.25 (31.74,46.74)	40.93 (34.69,52.79)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A North	Average CPUE	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=2)	37.17 (31.85,46.62)	40.85 (34.62,52.69)
5A North	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	26.74 (24.53,31.27)	31.01 (28.95,34.88)
5A North	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	31.63 (27.59,38.74)	34.58 (31.52,43.46)
5A North	Average CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	37.34 (31.85,46.86)	41.03 (34.75,52.89)
5A North	Average CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	37.34 (31.85,46.86)	41.03 (34.75,52.89)
5A North	Average CPUE	Low steepness (h=0.6)	Base case	37.34 (31.85,46.86)	41.03 (34.75,52.89)
5A North	Average CPUE	M prior (μ = 0.14, cv = 0.2)	Base case	37.96 (32.24,46.11)	39.75 (33.6,48.61)
5A North	Minimum Biomass	Base case	Base case	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	Catchability (r_q = 0.5%)	0.95 (0.78,1.01)	0.98 (0.87,1.02)
5A North	Minimum Biomass	Base case	Catchability (r_q = 1.0%)	0.93 (0.76,1)	0.98 (0.86,1.02)
5A North	Minimum Biomass	Base case	Catchability (r_q = 1.5%)	0.92 (0.74,1)	0.98 (0.86,1.02)
5A North	Minimum Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.96 (0.79,1.01)	0.98 (0.89,1.02)
5A North	Minimum Biomass	Base case	M increase (r_M=0.5%)	0.89 (0.73,0.99)	0.97 (0.82,1.01)
5A North	Minimum Biomass	Base case	M increase (r_M=1%)	0.81 (0.63,0.97)	0.89 (0.76,0.99)
5A North	Minimum Biomass	Base case	M increase (r_M=1.5%)	0.71 (0.57,0.91)	0.81 (0.69,0.97)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($r_{C_{rec}}$=2%)	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($r_{C_{rec}}$=5%)	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=0.5)	0.96 (0.8,1.01)	0.98 (0.89,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=0.8)	0.96 (0.8,1.01)	0.98 (0.89,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=1.2)	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=1.5)	0.95 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	$\mathrm{Catch_{rec}}$ ($m_{C_{rec}}$=2)	0.95 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.58 (0.51,0.73)	0.74 (0.66,0.84)
5A North	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.78 (0.62,0.92)	0.87 (0.76,0.99)
5A North	Minimum Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	Low steepness (h=0.6)	Base case	0.96 (0.79,1.01)	0.98 (0.88,1.02)
5A North	Minimum Biomass	M prior (μ = 0.14, cv = 0.2)	Base case	0.95 (0.82,1.01)	0.98 (0.86,1.03)
5A North	Minimum Catch	Base case	Base case	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Base case	Catchability (r_q = 0.5%)	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Base case	Catchability (r_q = 1.0%)	49.2 (37.2,49.2)	71.2 (71.2,71.2)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A North	Minimum Catch	Base case	Catchability (r_q = 1.5%)	49.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	37.2 (34.48,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Base case	M increase (r_M=0.5%)	37.2 (27.38,49.2)	71.2 (52.9,71.2)
5A North	Minimum Catch	Base case	M increase (r_M=1%)	37.2 (15.24,49.2)	71.2 (42.93,71.2)
5A North	Minimum Catch	Base case	M increase (r_M=1.5%)	35.87 (6.43,37.2)	71.2 (33.48,71.2)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	37.25 (37.21,49.21)	71.21 (71.21,71.21)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	37.34 (37.23,49.23)	71.22 (71.22,71.22)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	41.9 (41.9,53.9)	75.9 (75.9,75.9)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	39.08 (39.08,51.08)	73.08 (73.08,73.08)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	35.32 (35.32,47.32)	69.32 (69.32,69.32)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	32.5 (32.5,44.5)	66.5 (66.5,66.5)
5A North	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	27.8 (27.8,39.8)	61.8 (61.8,61.8)
5A North	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	11.28 (-3.14,35.82)	56.2 (18.3,56.2)
5A North	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	37.2 (12.98,37.2)	71.2 (30.35,71.2)
5A North	Minimum Catch	Hyper-stable CPUE (ß = 0.5)	Base case	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Hyper-stable CPUE (ß = 0.8)	Base case	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	Low steepness (h=0.6)	Base case	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum Catch	M prior (μ = 0.14, cv = 0.2)	Base case	37.2 (37.2,49.2)	71.2 (71.2,71.2)
5A North	Minimum CPUE	Base case	Base case	33.24 (27.17,36.56)	34.48 (30.74,37.51)
5A North	Minimum CPUE	Base case	Catchability (r_q = 0.5%)	34 (27.9,37.32)	34.94 (31.37,37.8)
5A North	Minimum CPUE	Base case	Catchability (r_q = 1.0%)	34.65 (29.2,37.95)	35.36 (32.13,38.15)
5A North	Minimum CPUE	Base case	Catchability (r_q = 1.5%)	35.09 (30.55,38.31)	35.67 (32.45,38.57)
5A North	Minimum CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	33.34 (27.22,36.59)	34.59 (30.99,37.51)
5A North	Minimum CPUE	Base case	M increase (r_M=0.5%)	31.27 (24.71,35.54)	33.77 (28.77,36.9)
5A North	Minimum CPUE	Base case	M increase (r_M=1%)	28.51 (21.53,34.16)	31.54 (27.03,36.05)
5A North	Minimum CPUE	Base case	M increase (r_M=1.5%)	24.9 (19.78,32.26)	29.14 (24.97,35.06)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	33.24 (27.14,36.56)	34.47 (30.69,37.51)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	33.21 (27.1,36.56)	34.45 (30.62,37.51)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	33.27 (26.99,36.58)	34.5 (30.82,37.52)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	33.19 (27.22,36.57)	34.49 (30.77,37.51)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	33.23 (27.11,36.55)	34.46 (30.7,37.5)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	33.22 (27.03,36.54)	34.43 (30.65,37.49)
5A North	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	33.13 (26.9,36.43)	34.39 (30.56,37.47)
5A North	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	20.85 (18.24,25.55)	27.01 (24.36,29.88)
5A North	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	27.48 (21.83,32.77)	31.04 (27.16,35.53)
5A North	Minimum CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	33.24 (27.17,36.56)	34.48 (30.74,37.51)
5A North	Minimum CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	33.24 (27.17,36.56)	34.48 (30.74,37.51)
5A North	Minimum CPUE	Low steepness (h=0.6)	Base case	33.24 (27.17,36.56)	34.48 (30.74,37.51)
5A North	Minimum CPUE	M prior (μ = 0.14, cv = 0.2)	Base case	33.74 (28.19,37.01)	34.56 (29.69,38.13)
5A North	Number of TACC changes	Base case	Base case	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	Catchability (r_q = 0.5%)	8 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	Catchability (r_q = 1.0%)	8 (3,15)	1 (1,1)
5A North	Number of TACC changes	Base case	Catchability (r_q = 1.5%)	10 (4,16)	1 (1,1)
5A North	Number of TACC changes	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	10 (5,15)	1 (1,1)
5A North	Number of TACC changes	Base case	M increase (r_M=0.5%)	7 (3,13)	1 (1,1)
5A North	Number of TACC changes	Base case	M increase (r_M=1%)	8 (3,13)	1 (1,1)
5A North	Number of TACC changes	Base case	M increase (r_M=1.5%)	8 (4,13)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	7 (3,13)	1 (1,1)
5A North	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.6)	13 (7,17)	1 (1,1)
5A North	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.8)	8 (3,12)	1 (1,9)
5A North	Number of TACC changes	Hyper-stable CPUE (ß = 0.5)	Base case	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Hyper-stable CPUE (ß = 0.8)	Base case	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	Low steepness (h=0.6)	Base case	7 (3,14)	1 (1,1)
5A North	Number of TACC changes	M prior (μ = 0.14, cv = 0.2)	Base case	7 (2,13)	1 (1,1)
5A North	P($SSB < 0.1SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5A North	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.1SSB$)	M prior (μ = 0.14, cv = 0.2)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A North	P($SSB < 0.2SSB$)	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$\mathrm{m_{Rdev}}$ ($\mathrm{m_{Rdev}}$=0.6)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Base case	$\mathrm{m_{Rdev}}$ ($\mathrm{m_{Rdev}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	P($SSB < 0.2SSB$)	M prior (μ = 0.14, cv = 0.2)	Base case	<0.005 (-,-)	<0.005 (-,-)
5A North	Relative Biomass at 10y	Base case	Base case	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	Catchability ($\mathrm{r_q}$ = 0.5%)	0.5 (0.39,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	Catchability ($\mathrm{r_q}$ = 1.0%)	0.5 (0.39,0.64)	0.54 (0.43,0.68)
5A North	Relative Biomass at 10y	Base case	Catchability ($\mathrm{r_q}$ = 1.5%)	0.5 (0.38,0.64)	0.54 (0.43,0.68)
5A North	Relative Biomass at 10y	Base case	∂_{CPUE} ($\mathrm{m_{\partial_{CPUE}}}$=0.015)	0.51 (0.4,0.65)	0.54 (0.44,0.69)
5A North	Relative Biomass at 10y	Base case	M increase ($\mathrm{r_M}$=0.5%)	0.49 (0.38,0.62)	0.52 (0.42,0.66)
5A North	Relative Biomass at 10y	Base case	M increase ($\mathrm{r_M}$=1%)	0.47 (0.37,0.6)	0.5 (0.4,0.63)
5A North	Relative Biomass at 10y	Base case	M increase ($\mathrm{r_M}$=1.5%)	0.45 (0.36,0.58)	0.48 (0.39,0.61)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{r_{C_{rec}}}$=2%)	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{r_{C_{rec}}}$=5%)	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=0.5)	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=0.8)	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=1.2)	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=1.5)	0.5 (0.4,0.65)	0.54 (0.43,0.68)
5A North	Relative Biomass at 10y	Base case	$\mathrm{Catch_{rec}}$ ($\mathrm{m_{C_{rec}}}$=2)	0.5 (0.4,0.65)	0.54 (0.43,0.68)
5A North	Relative Biomass at 10y	Base case	$\mathrm{m_{Rdev}}$ ($\mathrm{m_{Rdev}}$=0.6)	0.33 (0.25,0.42)	0.36 (0.3,0.45)
5A North	Relative Biomass at 10y	Base case	$\mathrm{m_{Rdev}}$ ($\mathrm{m_{Rdev}}$=0.8)	0.41 (0.32,0.53)	0.44 (0.36,0.56)
5A North	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.5)	Base case	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.8)	Base case	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	Low steepness (h=0.6)	Base case	0.51 (0.4,0.65)	0.54 (0.43,0.69)
5A North	Relative Biomass at 10y	M prior (μ = 0.14, cv = 0.2)	Base case	0.71 (0.55,0.96)	0.73 (0.57,0.98)
5A North	Relative Biomass at 5y	Base case	Base case	0.48 (0.39,0.59)	0.5 (0.41,0.61)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5A North	Relative Biomass at 5y	Base case	Catchability (r_q = 0.5%)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	Catchability (r_q = 1.0%)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	Catchability (r_q = 1.5%)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.48 (0.4,0.6)	0.5 (0.42,0.62)
5A North	Relative Biomass at 5y	Base case	M increase (r_M=0.5%)	0.48 (0.39,0.59)	0.49 (0.41,0.6)
5A North	Relative Biomass at 5y	Base case	M increase (r_M=1%)	0.47 (0.39,0.58)	0.49 (0.4,0.6)
5A North	Relative Biomass at 5y	Base case	M increase (r_M=1.5%)	0.46 (0.38,0.57)	0.48 (0.4,0.59)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.48 (0.4,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.41 (0.33,0.49)	0.43 (0.35,0.5)
5A North	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.45 (0.37,0.54)	0.46 (0.38,0.56)
5A North	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.5)	Base case	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.8)	Base case	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	Low steepness (h=0.6)	Base case	0.48 (0.39,0.59)	0.5 (0.41,0.61)
5A North	Relative Biomass at 5y	M prior (μ = 0.14, cv = 0.2)	Base case	0.68 (0.52,0.88)	0.69 (0.54,0.88)
5B	Average Biomass	Base case	Base case	1.3 (1.08,1.71)	1.39 (1.12,1.86)
5B	Average Biomass	Base case	Catchability (r_q = 0.5%)	1.3 (1.07,1.7)	1.39 (1.12,1.86)
5B	Average Biomass	Base case	Catchability (r_q = 1.0%)	1.29 (1.06,1.68)	1.39 (1.12,1.86)
5B	Average Biomass	Base case	Catchability (r_q = 1.5%)	1.28 (1.06,1.67)	1.39 (1.12,1.86)
5B	Average Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	1.3 (1.08,1.71)	1.39 (1.12,1.86)
5B	Average Biomass	Base case	M increase (r_M=0.5%)	1.21 (0.99,1.6)	1.29 (1.01,1.73)
5B	Average Biomass	Base case	M increase (r_M=1%)	1.13 (0.89,1.48)	1.19 (0.91,1.57)
5B	Average Biomass	Base case	M increase (r_M=1.5%)	1.05 (0.82,1.36)	1.09 (0.83,1.45)
5B	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	1.3 (1.07,1.7)	1.38 (1.11,1.86)
5B	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	1.29 (1.07,1.7)	1.38 (1.11,1.85)
5B	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1.32 (1.09,1.72)	1.4 (1.12,1.87)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5B	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	1.31 (1.08,1.71)	1.39 (1.12,1.87)
5B	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	1.3 (1.07,1.7)	1.38 (1.11,1.85)
5B	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	1.29 (1.07,1.69)	1.38 (1.11,1.85)
5B	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	1.28 (1.06,1.68)	1.36 (1.1,1.83)
5B	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.91 (0.77,1.12)	0.97 (0.84,1.18)
5B	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	1.1 (0.92,1.4)	1.16 (0.94,1.51)
5B	Average Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.42 (1.19,1.85)	1.48 (1.23,1.96)
5B	Average Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	1.37 (1.13,1.73)	1.45 (1.18,1.87)
5B	Average Biomass	Low steepness (h=0.6)	Base case	1.37 (1.13,1.81)	1.45 (1.18,1.94)
5B	Average Catch	Base case	Base case	100.2 (90.5,115.4)	140 (140,140)
5B	Average Catch	Base case	Catchability (r_q = 0.5%)	103 (92.5,119.2)	140 (140,140)
5B	Average Catch	Base case	Catchability (r_q = 1.0%)	105.4 (94.5,122.9)	140 (140,140)
5B	Average Catch	Base case	Catchability (r_q = 1.5%)	108.3 (95.52,126.8)	142.9 (122.2,179.1)
5B	Average Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	100.2 (90.5,115.5)	140 (140,140)
5B	Average Catch	Base case	M increase (r_M=0.5%)	97.25 (88.5,111)	140 (140,140)
5B	Average Catch	Base case	M increase (r_M=1%)	94.5 (85.5,106.7)	140 (140,140)
5B	Average Catch	Base case	M increase (r_M=1.5%)	91.08 (81.05,103.2)	140 (140,140)
5B	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	101.3 (91.7,116.5)	141.2 (141.2,141.2)
5B	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	103.5 (93.68,118.7)	143.7 (143.7,143.7)
5B	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	103.8 (93.5,118.9)	143 (143,143)
5B	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	101.7 (91.7,116.8)	141.2 (141.2,141.2)
5B	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	98.79 (89.3,114.1)	138.8 (138.8,138.8)
5B	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	96.77 (87,112)	137 (137,137)
5B	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	93.36 (84,108.6)	134 (134,134)
5B	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	86.17 (71.92,95)	140 (127.3,140)
5B	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	92.52 (85,105)	140 (140,140)
5B	Average Catch	Hyper-stable CPUE (ß = 0.5)	Base case	95 (90,100.7)	140 (140,140)
5B	Average Catch	Hyper-stable CPUE (ß = 0.8)	Base case	99.07 (92.62,111.2)	140 (140,140)
5B	Average Catch	Low steepness (h=0.6)	Base case	101.9 (92.49,121.6)	140 (140,140)
5B	Average CPUE	Base case	Base case	47.93 (37.25,61.94)	51.53 (38.7,68.62)
5B	Average CPUE	Base case	Catchability (r_q = 0.5%)	50.5 (39.32,65.37)	54.66 (41,73.11)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule Median (5%, 95%)	Best rule Median (5%, 95%)
5B	Average CPUE	Base case	Catchability (r_q = 1.0%)	53.14 (41.66,69.26)	58.12 (43.47,77.89)
5B	Average CPUE	Base case	Catchability (r_q = 1.5%)	55.85 (43.8,73.19)	61.76 (46.1,83.02)
5B	Average CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	47.9 (37.25,62.11)	51.53 (38.7,68.62)
5B	Average CPUE	Base case	M increase (r_M=0.5%)	44.76 (34.42,57.73)	47.64 (35.8,62.87)
5B	Average CPUE	Base case	M increase (r_M=1%)	41.56 (32,53.35)	43.99 (33.01,58.68)
5B	Average CPUE	Base case	M increase (r_M=1.5%)	38.6 (29.57,49.9)	40.61 (31.69,53.79)
5B	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	47.79 (37.12,61.77)	51.31 (38.57,68.41)
5B	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	47.52 (36.88,61.43)	51.04 (38.31,68.02)
5B	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	48.35 (37.63,62.48)	52.06 (39.08,69.25)
5B	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	48.1 (37.4,62.16)	51.73 (38.85,68.87)
5B	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	47.76 (37.1,61.73)	51.29 (38.54,68.37)
5B	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	47.55 (36.89,61.57)	51.01 (38.31,67.99)
5B	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	47.15 (36.7,61.04)	50.47 (37.93,67.36)
5B	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	33.45 (27.03,41.92)	35.83 (30.39,44.89)
5B	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	40.78 (31.79,51.71)	43.21 (32.8,56.25)
5B	Average CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	42.37 (37.49,48.51)	43.4 (38.18,49.68)
5B	Average CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	46.78 (39.97,58.33)	49.38 (41.24,62.14)
5B	Average CPUE	Low steepness (h=0.6)	Base case	49.81 (39.98,67.58)	53.07 (42.02,73.69)
5B	Minimum Biomass	Base case	Base case	1.05 (0.97,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	Catchability (r_q = 0.5%)	1.05 (0.96,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	Catchability (r_q = 1.0%)	1.05 (0.96,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	Catchability (r_q = 1.5%)	1.05 (0.96,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	1.05 (0.97,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	M increase (r_M=0.5%)	1.04 (0.84,1.12)	1.05 (0.86,1.13)
5B	Minimum Biomass	Base case	M increase (r_M=1%)	1.01 (0.69,1.1)	1.03 (0.71,1.12)
5B	Minimum Biomass	Base case	M increase (r_M=1.5%)	0.87 (0.57,1.08)	0.93 (0.57,1.1)
5B	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	1.05 (0.97,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	1.05 (0.96,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1.06 (0.97,1.13)	1.06 (0.99,1.13)
5B	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	1.05 (0.97,1.13)	1.06 (0.98,1.13)
5B	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	1.05 (0.97,1.13)	1.05 (0.98,1.13)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5B	Minimum Biomass	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.5)	1.05 (0.96,1.13)	1.05 (0.98,1.13)
5B	Minimum Biomass	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=2)	1.05 (0.96,1.12)	1.05 (0.97,1.13)
5B	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.71 (0.55,0.99)	0.82 (0.68,1.05)
5B	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	1 (0.76,1.11)	1.04 (0.79,1.12)
5B	Minimum Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.09 (0.99,1.19)	1.09 (1,1.19)
5B	Minimum Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	1.07 (1,1.16)	1.07 (1.01,1.16)
5B	Minimum Biomass	Low steepness (h=0.6)	Base case	1.06 (0.99,1.12)	1.06 (0.99,1.12)
5B	Minimum Catch	Base case	Base case	90 (90,90)	140 (140,140)
5B	Minimum Catch	Base case	Catchability (r_q = 0.5%)	90 (90,90)	140 (140,140)
5B	Minimum Catch	Base case	Catchability (r_q = 1.0%)	90 (90,90)	140 (140,140)
5B	Minimum Catch	Base case	Catchability (r_q = 1.5%)	90 (90,90)	140 (140,140)
5B	Minimum Catch	Base case	∂_{CPUE} ($m_{\partial_{\text{CPUE}}}$=0.015)	90 (80,90)	140 (140,140)
5B	Minimum Catch	Base case	M increase (r_M=0.5%)	90 (80,90)	140 (140,140)
5B	Minimum Catch	Base case	M increase (r_M=1%)	90 (80,90)	140 (140,140)
5B	Minimum Catch	Base case	M increase (r_M=1.5%)	90 (47.06,90)	140 (140,140)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=2%)	90.1 (90.1,90.1)	140.1 (140.1,140.1)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($r_{C_{rec}}$=5%)	90.25 (90.25,90.25)	140.2 (140.2,140.2)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.5)	93 (93,93)	143 (143,143)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=0.8)	91.2 (91.2,91.2)	141.2 (141.2,141.2)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.2)	88.8 (88.8,88.8)	138.8 (138.8,138.8)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=1.5)	87 (87,87)	137 (137,137)
5B	Minimum Catch	Base case	$\text{Catch}_{\text{rec}}$ ($m_{C_{rec}}$=2)	84 (84,84)	134 (134,134)
5B	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	80 (35.02,90)	140 (79.97,140)
5B	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	90 (80,90)	140 (140,140)
5B	Minimum Catch	Hyper-stable CPUE (ß = 0.5)	Base case	90 (90,90)	140 (140,140)
5B	Minimum Catch	Hyper-stable CPUE (ß = 0.8)	Base case	90 (90,90)	140 (140,140)
5B	Minimum Catch	Low steepness (h=0.6)	Base case	90 (90,90)	140 (140,140)
5B	Minimum CPUE	Base case	Base case	38.38 (33.28,42.7)	38.5 (34.11,42.95)
5B	Minimum CPUE	Base case	Catchability (r_q = 0.5%)	38.7 (34.25,43.05)	38.9 (34.63,43.3)
5B	Minimum CPUE	Base case	Catchability (r_q = 1.0%)	39.09 (34.79,43.55)	39.22 (34.92,43.66)
5B	Minimum CPUE	Base case	Catchability (r_q = 1.5%)	39.43 (35.11,43.91)	39.54 (35.25,44.02)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5B	Minimum CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	38.38 (33.28,42.69)	38.51 (34.2,42.95)
5B	Minimum CPUE	Base case	M increase (r_M=0.5%)	38.05 (29.71,42.55)	38.36 (30.94,42.73)
5B	Minimum CPUE	Base case	M increase (r_M=1%)	36.46 (25.59,41.84)	37.67 (25.69,42.56)
5B	Minimum CPUE	Base case	M increase (r_M=1.5%)	32.01 (20.94,40.76)	34.7 (25.15,41.49)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	38.38 (33.28,42.7)	38.5 (34.11,42.95)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	38.37 (33.27,42.7)	38.5 (33.86,42.95)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	38.47 (33.54,42.79)	38.6 (34.3,43.04)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	38.42 (33.31,42.73)	38.54 (34.21,42.98)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	38.34 (33.24,42.67)	38.47 (34.06,42.91)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	38.29 (33.19,42.62)	38.4 (33.77,42.86)
5B	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	38.19 (33.09,42.53)	38.32 (33.66,42.77)
5B	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	25.76 (20.02,36.83)	30.39 (24.94,38.71)
5B	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	36.68 (26.52,41.62)	37.83 (27.44,42.78)
5B	Minimum CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	36.71 (33.65,40.1)	36.78 (33.97,40.14)
5B	Minimum CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	38.24 (34.72,42.11)	38.36 (34.94,42.21)
5B	Minimum CPUE	Low steepness (h=0.6)	Base case	37.94 (33.69,42.68)	38.08 (34.11,42.82)
5B	Number of TACC changes	Base case	Base case	12 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	Catchability (r_q = 0.5%)	14 (3,18)	1 (1,1)
5B	Number of TACC changes	Base case	Catchability (r_q = 1.0%)	15 (5,18)	1 (1,1)
5B	Number of TACC changes	Base case	Catchability (r_q = 1.5%)	15 (7,19)	1 (1,1)
5B	Number of TACC changes	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	12 (3,18)	1 (1,1)
5B	Number of TACC changes	Base case	M increase (r_M=0.5%)	8 (2,17)	1 (1,1)
5B	Number of TACC changes	Base case	M increase (r_M=1%)	6 (1,16)	1 (1,1)
5B	Number of TACC changes	Base case	M increase (r_M=1.5%)	5 (2,14)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	12 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	11 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	12 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	12 (2,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	12 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	11 (3,17)	1 (1,1)
5B	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	11 (2,17)	1 (1,1)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5B	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.6)	6 (2,12)	1 (1,1)
5B	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.8)	5 (1,14)	1 (1,1)
5B	Number of TACC changes	Hyper-stable CPUE (ß = 0.5)	Base case	5 (1,13)	1 (1,1)
5B	Number of TACC changes	Hyper-stable CPUE (ß = 0.8)	Base case	11 (2,17)	1 (1,1)
5B	Number of TACC changes	Low steepness (h=0.6)	Base case	13 (3,17)	1 (1,1)
5B	P($SSB < 0.1SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.1SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5B	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	P($SSB < 0.2SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5B	Relative Biomass at 10y	Base case	Base case	0.66 (0.51,0.98)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	Catchability (r_q = 0.5%)	0.66 (0.51,0.98)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	Catchability (r_q = 1.0%)	0.66 (0.51,0.97)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	Catchability (r_q = 1.5%)	0.66 (0.51,0.97)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.66 (0.52,0.98)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	M increase (r_M=0.5%)	0.64 (0.5,0.94)	0.66 (0.52,0.96)
5B	Relative Biomass at 10y	Base case	M increase (r_M=1%)	0.61 (0.48,0.9)	0.63 (0.5,0.92)
5B	Relative Biomass at 10y	Base case	M increase (r_M=1.5%)	0.59 (0.46,0.86)	0.6 (0.48,0.88)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.66 (0.51,0.98)	0.69 (0.54,1)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.66 (0.51,0.98)	0.69 (0.54,1)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.67 (0.52,0.98)	0.69 (0.55,1.01)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.67 (0.52,0.98)	0.69 (0.54,1.01)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.66 (0.51,0.98)	0.69 (0.54,1)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.66 (0.51,0.97)	0.69 (0.54,1)
5B	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.65 (0.51,0.97)	0.68 (0.53,1)
5B	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.44 (0.34,0.6)	0.45 (0.36,0.62)
5B	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.55 (0.43,0.78)	0.57 (0.45,0.8)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5B	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.5)	Base case	0.7 (0.54,0.99)	0.72 (0.56,1.01)
5B	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.8)	Base case	0.66 (0.51,0.96)	0.69 (0.53,0.98)
5B	Relative Biomass at 10y	Low steepness (h=0.6)	Base case	0.68 (0.51,1.02)	0.7 (0.53,1.05)
5B	Relative Biomass at 5y	Base case	Base case	0.61 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	Catchability (r_q = 0.5%)	0.61 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	Catchability (r_q = 1.0%)	0.61 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	Catchability (r_q = 1.5%)	0.6 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.61 (0.47,0.82)	0.62 (0.48,0.83)
5B	Relative Biomass at 5y	Base case	M increase (r_M=0.5%)	0.6 (0.46,0.8)	0.61 (0.47,0.81)
5B	Relative Biomass at 5y	Base case	M increase (r_M=1%)	0.59 (0.46,0.79)	0.6 (0.47,0.79)
5B	Relative Biomass at 5y	Base case	M increase (r_M=1.5%)	0.58 (0.45,0.77)	0.59 (0.46,0.78)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.61 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.61 (0.47,0.82)	0.62 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.61 (0.47,0.82)	0.62 (0.48,0.83)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.61 (0.47,0.82)	0.62 (0.48,0.83)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.6 (0.47,0.82)	0.61 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.6 (0.47,0.82)	0.61 (0.48,0.82)
5B	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.6 (0.46,0.81)	0.61 (0.47,0.82)
5B	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.5 (0.4,0.63)	0.51 (0.41,0.64)
5B	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.55 (0.43,0.71)	0.56 (0.44,0.72)
5B	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.5)	Base case	0.62 (0.48,0.82)	0.63 (0.49,0.83)
5B	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.8)	Base case	0.59 (0.45,0.79)	0.6 (0.46,0.8)
5B	Relative Biomass at 5y	Low steepness (h=0.6)	Base case	0.6 (0.45,0.82)	0.61 (0.46,0.83)
5D	Average Biomass	Base case	Base case	1.49 (1.26,2.06)	2.08 (1.75,2.81)
5D	Average Biomass	Base case	Catchability (r_q = 0.5%)	1.46 (1.24,2.03)	2.06 (1.66,2.87)
5D	Average Biomass	Base case	Catchability (r_q = 1.0%)	1.43 (1.2,1.99)	2.06 (1.66,2.87)
5D	Average Biomass	Base case	Catchability (r_q = 1.5%)	1.4 (1.17,1.94)	2.06 (1.66,2.87)
5D	Average Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	1.49 (1.26,2.06)	2.09 (1.75,2.8)
5D	Average Biomass	Base case	M increase (r_M=0.5%)	1.4 (1.18,1.92)	1.93 (1.62,2.62)
5D	Average Biomass	Base case	M increase (r_M=1%)	1.3 (1.1,1.79)	1.79 (1.5,2.45)
5D	Average Biomass	Base case	M increase (r_M=1.5%)	1.21 (1.04,1.67)	1.66 (1.38,2.27)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	1.47 (1.24,2.03)	2.05 (1.72,2.77)
5D	Average Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	1.42 (1.19,1.98)	1.99 (1.67,2.71)
5D	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1.56 (1.33,2.15)	2.18 (1.76,3)
5D	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	1.52 (1.29,2.1)	2.12 (1.78,2.84)
5D	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	1.46 (1.23,2.02)	2.04 (1.72,2.77)
5D	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	1.42 (1.2,1.98)	1.99 (1.67,2.71)
5D	Average Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	1.35 (1.12,1.9)	1.9 (1.57,2.62)
5D	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.88 (0.82,1.07)	1.26 (1.15,1.48)
5D	Average Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	1.13 (0.99,1.51)	1.6 (1.36,2.17)
5D	Average Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.78 (1.27,2.42)	2.55 (1.93,3.28)
5D	Average Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	1.58 (1.27,2.2)	2.23 (1.8,2.95)
5D	Average Biomass	Low steepness (h=0.6)	Base case	1.48 (1.17,2.33)	2.05 (1.68,2.96)
5D	Average Biomass	M prior (µ = 0.14, cv = 0.2)	Base case	1.43 (1.2,1.83)	1.81 (1.5,2.39)
5D	Average Catch	Base case	Base case	78.65 (69.03,97.19)	100 (80.55,100)
5D	Average Catch	Base case	Catchability (r_q = 0.5%)	80.29 (70.54,99.57)	100 (80.55,100)
5D	Average Catch	Base case	Catchability (r_q = 1.0%)	82.16 (71.93,101.9)	100 (80.55,100)
5D	Average Catch	Base case	Catchability (r_q = 1.5%)	83.98 (72.99,104.2)	100 (80.55,100)
5D	Average Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	78.77 (68.89,97.26)	100 (80.55,100)
5D	Average Catch	Base case	M increase (r_M=0.5%)	75.02 (65.43,93.28)	97.46 (76.8,100)
5D	Average Catch	Base case	M increase (r_M=1%)	71.35 (62.56,89.51)	92.55 (73.75,95)
5D	Average Catch	Base case	M increase (r_M=1.5%)	68.15 (57.56,85.92)	87.58 (70.03,95)
5D	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	79.81 (70.53,98.84)	102.3 (80.41,102.4)
5D	Average Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	83.12 (72.55,102.2)	102.5 (80.3,107.4)
5D	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	87.65 (77.88,105.3)	106 (92.91,106)
5D	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	82.27 (72.56,100.4)	102.4 (85.38,102.4)
5D	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	74.82 (65.72,93.89)	97.28 (75.73,97.6)
5D	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	69.6 (59.55,88.82)	90.58 (68.62,94)
5D	Average Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	60.41 (49.81,80.18)	79.27 (57.25,83)
5D	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	44.78 (35.69,60.13)	55.19 (43.48,60)
5D	Average Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	64.32 (53.61,81.08)	78.38 (62.71,80)
5D	Average Catch	Hyper-stable CPUE (ß = 0.5)	Base case	72.57 (63.99,82.28)	96.18 (68.03,100)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Average Catch	Hyper-stable CPUE (ß = 0.8)	Base case	76.92 (66.71,90.2)	99.27 (76.91,100)
5D	Average Catch	Low steepness (h=0.6)	Base case	77.62 (64.91,102.8)	99.26 (72.31,100)
5D	Average Catch	M prior (μ = 0.14, cv = 0.2)	Base case	76.95 (67.29,91.82)	100 (94,100)
5D	Average CPUE	Base case	Base case	41.44 (33.86,58.64)	61.15 (50.21,79.88)
5D	Average CPUE	Base case	Catchability (r_q = 0.5%)	42.78 (35.54,61.06)	64.38 (48.99,92.79)
5D	Average CPUE	Base case	Catchability (r_q = 1.0%)	44.27 (36.55,63.49)	68.61 (52.12,98.86)
5D	Average CPUE	Base case	Catchability (r_q = 1.5%)	45.72 (37.41,65.92)	73.32 (55.69,105.4)
5D	Average CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	41.27 (33.9,58.6)	61.19 (50.11,79.76)
5D	Average CPUE	Base case	M increase (r_M=0.5%)	38.76 (32.17,54.48)	56.83 (46.87,74.46)
5D	Average CPUE	Base case	M increase (r_M=1%)	36.11 (29.98,50.38)	52.61 (43.4,69.22)
5D	Average CPUE	Base case	M increase (r_M=1.5%)	33.43 (28.44,46.42)	48.48 (39.79,64.19)
5D	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	40.75 (33.41,57.75)	60.28 (49.19,78.85)
5D	Average CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	39.03 (32.03,56.02)	58.36 (47.23,76.84)
5D	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	43.85 (36.59,61.26)	63.89 (49.99,91.08)
5D	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	42.4 (35.18,59.69)	62.21 (51.5,81.12)
5D	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	40.59 (33.32,57.56)	60.12 (48.99,78.64)
5D	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	39.18 (32.06,55.93)	58.41 (47.46,76.78)
5D	Average CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	37.09 (29.98,53.56)	55.52 (44.4,73.81)
5D	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	24.54 (22.48,29.34)	36.45 (33.56,43.12)
5D	Average CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	30.99 (26.85,42.2)	46.89 (38.13,61.53)
5D	Average CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	37.37 (30.88,44.15)	45.52 (39.54,52.14)
5D	Average CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	39.9 (32.87,52.13)	55.04 (45.13,68.16)
5D	Average CPUE	Low steepness (h=0.6)	Base case	40.83 (31.23,66.39)	58.97 (47.08,87.83)
5D	Average CPUE	M prior (μ = 0.14, cv = 0.2)	Base case	40.49 (33.19,53.45)	53.88 (43.81,71.54)
5D	Minimum Biomass	Base case	Base case	1.08 (1.03,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	Catchability (r_q = 0.5%)	1.08 (1,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	Catchability (r_q = 1.0%)	1.08 (0.99,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	Catchability (r_q = 1.5%)	1.08 (0.97,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	1.08 (1.03,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	M increase (r_M=0.5%)	1.07 (0.97,1.12)	1.08 (1.04,1.12)
5D	Minimum Biomass	Base case	M increase (r_M=1%)	1.06 (0.86,1.11)	1.07 (1.04,1.12)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Minimum Biomass	Base case	M increase (r_M=1.5%)	0.98 (0.75,1.09)	1.07 (1.02,1.12)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	1.08 (1,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	1.08 (0.97,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	1.1 (1.05,1.14)	1.1 (1.06,1.14)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	1.09 (1.04,1.13)	1.09 (1.05,1.13)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	1.07 (1.02,1.12)	1.07 (1.04,1.12)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	1.06 (0.97,1.11)	1.07 (1.03,1.11)
5D	Minimum Biomass	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	1.05 (0.88,1.1)	1.05 (1.02,1.1)
5D	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.69 (0.6,0.84)	1.05 (0.94,1.1)
5D	Minimum Biomass	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.93 (0.76,1.09)	1.08 (1.04,1.12)
5D	Minimum Biomass	Hyper-stable CPUE (ß = 0.5)	Base case	1.07 (0.98,1.11)	1.07 (1.01,1.11)
5D	Minimum Biomass	Hyper-stable CPUE (ß = 0.8)	Base case	1.08 (1.01,1.13)	1.08 (1.04,1.13)
5D	Minimum Biomass	Low steepness (h=0.6)	Base case	1.04 (0.99,1.08)	1.04 (1.01,1.09)
5D	Minimum Biomass	M prior (μ = 0.14, cv = 0.2)	Base case	1.12 (0.95,1.15)	1.12 (1.09,1.16)
5D	Minimum Catch	Base case	Base case	62 (50.65,62)	100 (50.6,100)
5D	Minimum Catch	Base case	Catchability (r_q = 0.5%)	62 (52.15,62)	100 (50.6,100)
5D	Minimum Catch	Base case	Catchability (r_q = 1.0%)	62 (52.4,62)	100 (50.6,100)
5D	Minimum Catch	Base case	Catchability (r_q = 1.5%)	62 (52.66,62)	100 (50.6,100)
5D	Minimum Catch	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	62 (47.63,62)	100 (50.6,100)
5D	Minimum Catch	Base case	M increase (r_M=0.5%)	62 (49.65,62)	95 (45.9,95)
5D	Minimum Catch	Base case	M increase (r_M=1%)	61.59 (42.76,62)	90 (41.43,90)
5D	Minimum Catch	Base case	M increase (r_M=1.5%)	55.34 (29.37,62)	85 (38.89,85)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	62.2 (50.91,62.2)	100.2 (50.23,100.2)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	62.5 (51.15,62.5)	95.5 (51.23,95.5)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	68 (58.37,68)	106 (63.77,106)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	64.4 (53.69,64.4)	102.4 (55.72,102.4)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	59.6 (47.84,59.6)	93.78 (45.37,97.6)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	55.87 (42.88,56)	89 (39.4,89)
5D	Minimum Catch	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	47.78 (27.83,50)	78 (28.2,78)
5D	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.6)	18.82 (5.44,43.37)	50.35 (15.65,55)
5D	Minimum Catch	Base case	m_{Rdev} (m_{Rdev}=0.8)	51.62 (26.88,62)	75 (33.87,75)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Minimum Catch	Hyper-stable CPUE (ß = 0.5)	Base case	62 (50.44,62)	95 (42.7,95)
5D	Minimum Catch	Hyper-stable CPUE (ß = 0.8)	Base case	61.37 (49.4,62)	95 (46.97,95)
5D	Minimum Catch	Low steepness (h=0.6)	Base case	59.39 (46.47,62)	95 (38.19,95)
5D	Minimum Catch	M prior (μ = 0.14, cv = 0.2)	Base case	62 (51.8,62)	100 (74.2,100)
5D	Minimum CPUE	Base case	Base case	29.21 (26.82,31.75)	30.97 (28.68,33.2)
5D	Minimum CPUE	Base case	Catchability (r_q = 0.5%)	29.41 (27.04,32)	31.23 (28.9,33.45)
5D	Minimum CPUE	Base case	Catchability (r_q = 1.0%)	29.7 (27.25,32.25)	31.49 (29.12,33.72)
5D	Minimum CPUE	Base case	Catchability (r_q = 1.5%)	29.92 (27.45,32.5)	31.75 (29.35,33.99)
5D	Minimum CPUE	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	29.24 (26.91,31.75)	30.96 (28.63,33.14)
5D	Minimum CPUE	Base case	M increase (r_M=0.5%)	28.98 (26.12,31.54)	30.88 (28.61,33.11)
5D	Minimum CPUE	Base case	M increase (r_M=1%)	28.28 (23.56,31.17)	30.79 (28.48,33.02)
5D	Minimum CPUE	Base case	M increase (r_M=1.5%)	26.71 (21.34,30.38)	30.69 (28.41,32.89)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	29.2 (26.61,31.63)	30.96 (28.67,33.19)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	28.99 (25.53,31.62)	30.95 (28.61,33.18)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	29.75 (27.5,32.28)	31.52 (29.21,33.79)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	29.38 (27.02,31.96)	31.19 (28.91,33.41)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	28.94 (26.57,31.53)	30.77 (28.45,32.99)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	28.58 (25.69,31.08)	30.48 (28.11,32.69)
5D	Minimum CPUE	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	27.73 (23.57,30.58)	29.9 (27.64,32.24)
5D	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.6)	19.56 (17.11,23.27)	30.11 (27.86,32.23)
5D	Minimum CPUE	Base case	m_{Rdev} (m_{Rdev}=0.8)	25.72 (21.18,30.35)	30.85 (28.53,33.05)
5D	Minimum CPUE	Hyper-stable CPUE (ß = 0.5)	Base case	28.26 (25.8,30.51)	29.22 (27.2,31.41)
5D	Minimum CPUE	Hyper-stable CPUE (ß = 0.8)	Base case	28.47 (26.04,30.75)	30.07 (27.86,32.13)
5D	Minimum CPUE	Low steepness (h=0.6)	Base case	27.9 (25.35,30.52)	29.66 (27.38,32.16)
5D	Minimum CPUE	M prior (μ = 0.14, cv = 0.2)	Base case	30.27 (26.64,32.69)	32 (29.89,34.28)
5D	Number of TACC changes	Base case	Base case	10 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	Catchability (r_q = 0.5%)	11 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	Catchability (r_q = 1.0%)	12 (5,18)	1 (1,1)
5D	Number of TACC changes	Base case	Catchability (r_q = 1.5%)	13 (6,18)	1 (1,1)
5D	Number of TACC changes	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	11 (5,18)	1 (1,1)
5D	Number of TACC changes	Base case	M increase (r_M=0.5%)	8 (4,17)	1 (1,1)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Number of TACC changes	Base case	M increase (r_M=1%)	7 (3,17)	1 (1,1)
5D	Number of TACC changes	Base case	M increase (r_M=1.5%)	8 (3,16)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	10 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	8 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	11 (4,18)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	11 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	9 (5,17)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	8 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	8 (4,17)	1 (1,1)
5D	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.6)	16 (12,18)	1 (1,1)
5D	Number of TACC changes	Base case	m_{Rdev} (m_{Rdev}=0.8)	9 (3,16)	1 (1,15)
5D	Number of TACC changes	Hyper-stable CPUE (ß = 0.5)	Base case	6 (2,13)	1 (1,11)
5D	Number of TACC changes	Hyper-stable CPUE (ß = 0.8)	Base case	8 (3,16)	1 (1,1)
5D	Number of TACC changes	Low steepness (h=0.6)	Base case	10 (4,17)	1 (1,1)
5D	Number of TACC changes	M prior (µ = 0.14, cv = 0.2)	Base case	8 (3,16)	1 (1,1)
5D	P($SSB < 0.1SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	<0.005 (-,-)	<0.005 (-,-)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	P($SSB < 0.1SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.1SSB$)	M prior (μ = 0.14, cv = 0.2)	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 0.5%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.0%)	<0.005 (-,0.05)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	Catchability (r_q = 1.5%)	<0.005 (-,0.05)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	M increase (r_M=0.5%)	<0.005 (-,0.1)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1%)	<0.005 (-,0.2)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	M increase (r_M=1.5%)	<0.005 (-,0.4)	<0.005 (-,0.15)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	<0.005 (-,0.1)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	<0.005 (-,-)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	<0.005 (-,0.05)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	<0.005 (-,0.15)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.75 (0.2,0.95)	<0.005 (-,0.55)
5D	P($SSB < 0.2SSB$)	Base case	m_{Rdev} (m_{Rdev}=0.8)	<0.005 (-,0.65)	<0.005 (-,0.4)
5D	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.5)	Base case	<0.005 (-,0.5)	<0.005 (-,0.15)
5D	P($SSB < 0.2SSB$)	Hyper-stable CPUE (ß = 0.8)	Base case	<0.005 (-,0.1)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	Low steepness (h=0.6)	Base case	<0.005 (-,0.15)	<0.005 (-,-)
5D	P($SSB < 0.2SSB$)	M prior (μ = 0.14, cv = 0.2)	Base case	<0.005 (-,-)	<0.005 (-,-)
5D	Relative Biomass at 10y	Base case	Base case	0.31 (0.24,0.45)	0.4 (0.31,0.54)
5D	Relative Biomass at 10y	Base case	Catchability (r_q = 0.5%)	0.31 (0.24,0.44)	0.4 (0.31,0.54)
5D	Relative Biomass at 10y	Base case	Catchability (r_q = 1.0%)	0.31 (0.24,0.44)	0.4 (0.31,0.53)
5D	Relative Biomass at 10y	Base case	Catchability (r_q = 1.5%)	0.31 (0.23,0.44)	0.39 (0.31,0.53)
5D	Relative Biomass at 10y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.31 (0.25,0.44)	0.4 (0.31,0.54)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Relative Biomass at 10y	Base case	M increase (r_M=0.5%)	0.3 (0.23,0.43)	0.39 (0.3,0.52)
5D	Relative Biomass at 10y	Base case	M increase (r_M=1%)	0.29 (0.23,0.41)	0.37 (0.29,0.5)
5D	Relative Biomass at 10y	Base case	M increase (r_M=1.5%)	0.28 (0.22,0.4)	0.35 (0.28,0.48)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.31 (0.24,0.44)	0.4 (0.31,0.54)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.31 (0.24,0.44)	0.39 (0.3,0.53)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.32 (0.25,0.46)	0.41 (0.33,0.55)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.32 (0.25,0.45)	0.41 (0.32,0.54)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.31 (0.24,0.44)	0.4 (0.31,0.53)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.31 (0.23,0.43)	0.39 (0.3,0.52)
5D	Relative Biomass at 10y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.29 (0.22,0.42)	0.37 (0.29,0.51)
5D	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.16 (0.13,0.23)	0.23 (0.19,0.3)
5D	Relative Biomass at 10y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.23 (0.18,0.33)	0.31 (0.24,0.42)
5D	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.5)	Base case	0.3 (0.2,0.44)	0.4 (0.3,0.53)
5D	Relative Biomass at 10y	Hyper-stable CPUE (ß = 0.8)	Base case	0.31 (0.22,0.44)	0.39 (0.3,0.54)
5D	Relative Biomass at 10y	Low steepness (h=0.6)	Base case	0.31 (0.22,0.49)	0.38 (0.29,0.57)
5D	Relative Biomass at 10y	M prior (μ = 0.14, cv = 0.2)	Base case	0.41 (0.31,0.55)	0.49 (0.38,0.64)
5D	Relative Biomass at 5y	Base case	Base case	0.29 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	Catchability (r_q = 0.5%)	0.29 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	Catchability (r_q = 1.0%)	0.28 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	Catchability (r_q = 1.5%)	0.28 (0.22,0.38)	0.33 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	∂_{CPUE} ($m_{\partial_{CPUE}}$=0.015)	0.29 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	M increase (r_M=0.5%)	0.28 (0.22,0.37)	0.34 (0.27,0.42)
5D	Relative Biomass at 5y	Base case	M increase (r_M=1%)	0.28 (0.22,0.37)	0.33 (0.27,0.42)
5D	Relative Biomass at 5y	Base case	M increase (r_M=1.5%)	0.27 (0.22,0.36)	0.33 (0.26,0.41)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=2%)	0.29 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($r_{C_{rec}}$=5%)	0.28 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.5)	0.29 (0.23,0.38)	0.35 (0.28,0.44)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=0.8)	0.29 (0.22,0.38)	0.34 (0.28,0.43)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.2)	0.28 (0.22,0.38)	0.34 (0.27,0.43)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=1.5)	0.28 (0.22,0.37)	0.33 (0.26,0.42)
5D	Relative Biomass at 5y	Base case	$Catch_{rec}$ ($m_{C_{rec}}$=2)	0.27 (0.21,0.36)	0.33 (0.26,0.42)

Continued on next page

Table C-2 – *Continued from previous page*

QMA	Metric	Sensitivity	Scenario	Proposed rule	Best rule
				Median (5%, 95%)	Median (5%, 95%)
5D	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.6)	0.21 (0.17,0.27)	0.26 (0.22,0.32)
5D	Relative Biomass at 5y	Base case	m_{Rdev} (m_{Rdev}=0.8)	0.25 (0.19,0.32)	0.3 (0.25,0.37)
5D	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.5)	Base case	0.24 (0.19,0.35)	0.31 (0.25,0.41)
5D	Relative Biomass at 5y	Hyper-stable CPUE (ß = 0.8)	Base case	0.27 (0.21,0.37)	0.33 (0.27,0.43)
5D	Relative Biomass at 5y	Low steepness (h=0.6)	Base case	0.27 (0.21,0.37)	0.31 (0.26,0.42)
5D	Relative Biomass at 5y	M prior (μ = 0.14, cv = 0.2)	Base case	0.39 (0.3,0.52)	0.44 (0.36,0.57)