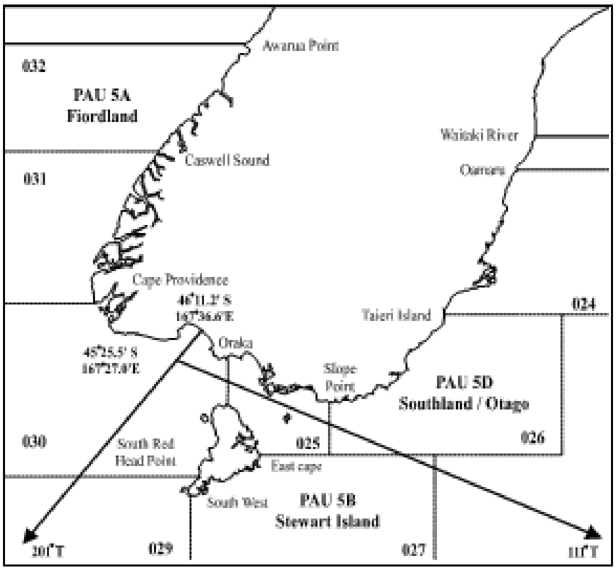
PAUA (PAU 5D) - Southland / Otago

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Before 1995, PAU 5D was part of the PAU 5 QMA, which was introduced to the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t by the 1991-92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994-95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see figure above) and the TACC was divided equally among them; the PAU 5D quota was set at 148.98 t.

On 1 October 2002 a TAC of 159 t was set for PAU 5D, comprising a TACC of 114 t, customary and recreational allowances of 3 t and 22 t respectively and an allowance of 20 t for other mortality. The TAC and TACC have been changed since then but customary, recreational and other mortality allowances have remained unchanged (Table 1).

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5D since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1991*	-	-	-	-	445
1991 - 1994*	-	-	-	-	492
1994 - 1995*	-	-	-	-	442.8
1995 -2002	-	-	-	-	148.98
2002 - 2003	159	3	22	20	114
2003- present	134	3	22	20	89

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September. On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs. Since 2010 the commercial industry has adopted some voluntary management initiatives which include raising the minimum harvest size for commercial fishers over specific statistical reporting areas. The industry has also voluntarily closed, to commercial harvesting, specific areas that are of high importance to recreational paua fishers.

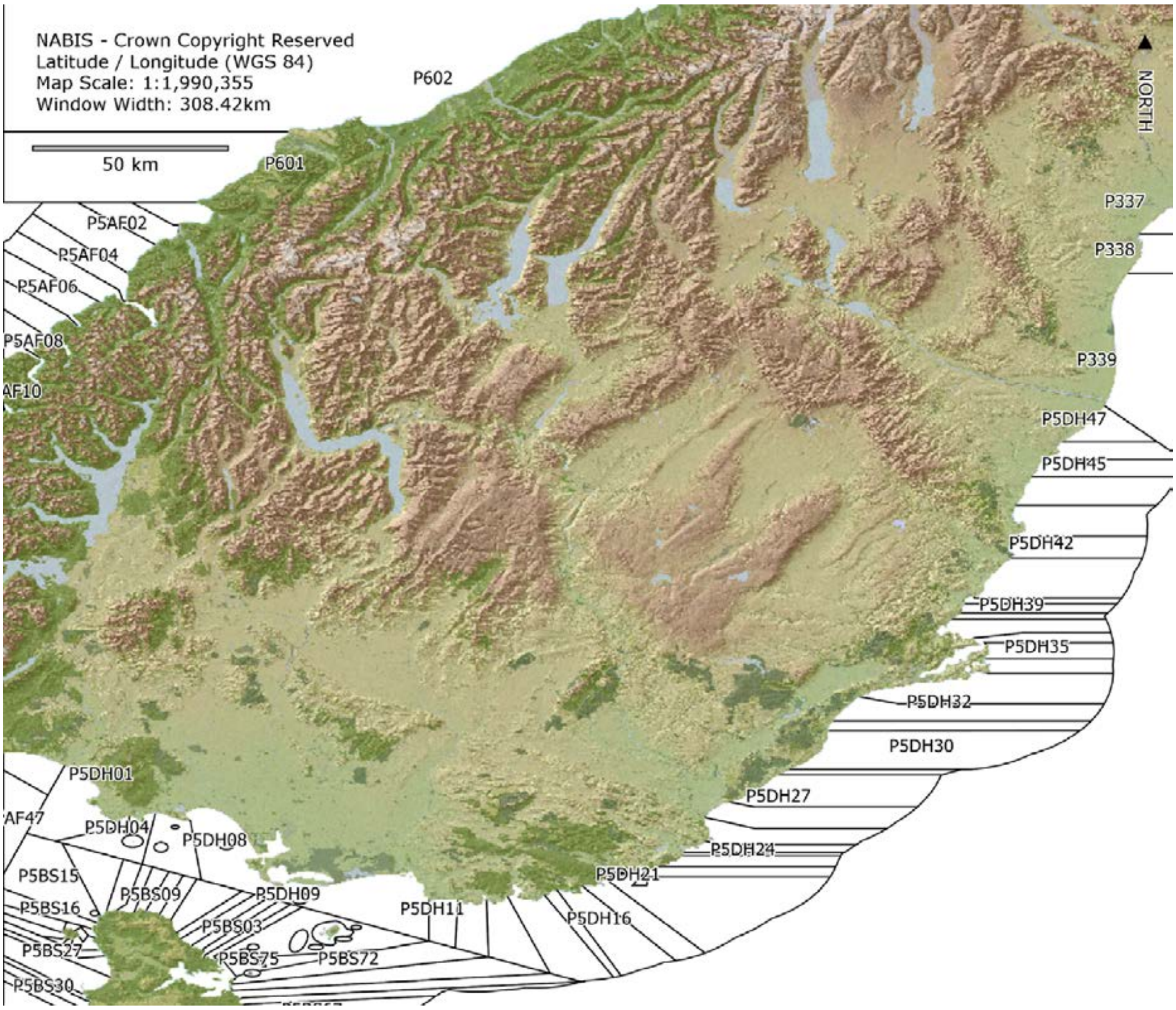


Figure 1: Map of fine scale statistical reporting areas for PAU 5D

Landings for PAU 5D are shown in Table 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported landings (t) of paua in PAU 5D from 1995-96 to present. Data were estimated from CELR and QMR returns.

Year	Landings	TACC
1995-96	167.42	148.98
1996-97	146.6	148.98
1997-98	146.99	148.98
1998-99	148.78	148.98
1999-00	147.66	148.98
2000-01	149.00	148.98
2001-02	148.74	148.98
2002-03	111.69	114.00
2003-04	88.02	89.00
2004-05	88.82	89.00
2005-06	88.93	89.00
2006-07	88.97	89.00
2007-08	88.98	89.00
2008-09	88.77	89.00
2009-10	89.45	89.00
2010-11	88.70	89.00
2011-12	89.23	89.00

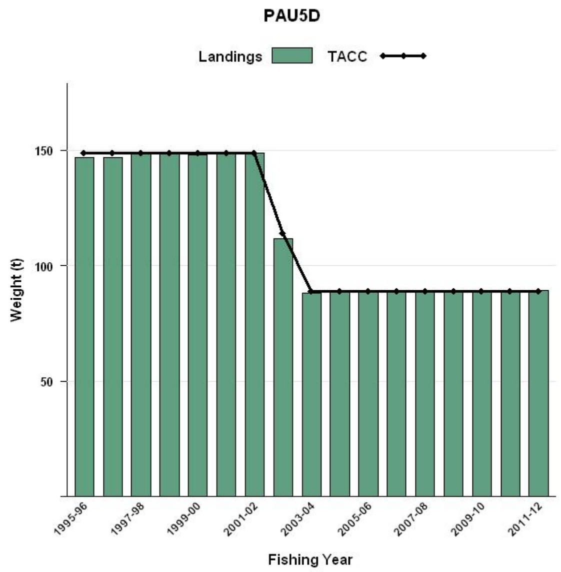


Figure 2: Historical landings and TACC for PAU5D from 1995-96 to present. For historical PAU5 landings prior to 1995-96 refer to the PAU introduction chapter, Figure 1 and Table 1.

1.2 Recreational fisheries

For the purpose of the stock assessment model, the SFWG agreed to assume that the 1974 recreational catch was 2 t increasing linearly to 10t by 2005. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

For the purpose of the stock assessment model, the SFWG agreed to assume that the customary catch has been constant at 2 t for PAU 5D. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

For the purpose of the stock assessment model, the SFWG agreed to assume that illegal catches have been constant at 10 t for PAU 5D. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 5D assessment is presented in Table 3.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

Table 3: Estimates of biological parameters (*H. iris*).

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
		0.149 (0.134-0.167)	Median (5-95% range) of posterior estimated by the base case model
2. Weight = a(length)^b (Weight in g, length in mm shell length)			
All	a	b	
	2.99×10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 79 mm (78-80)	Median (5-95% range) of posterior estimated by the base case model
		95% maturity at 93mm (89-97)	Median (5-95% range) of posterior estimated by the base case model
4. Estimated annual growth increments (both sexes combined)			
	at 75 mm	at 120 mm	Median (5-95% range) of posteriors estimated by the base case model
	29.3 (26.4-32.5)	7.4 (7.0-7.8)	

4. STOCK ASSESSMENT

The stock assessment was implemented as a length-based Bayesian estimation model, with point estimates of parameters based on the mode of the joint posterior distribution, and uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The most recent stock assessment was conducted for the fishing year ended 30 September 2012. A base case model (5.2 - referred to as the reference model hence forth) was chosen from the assessment. However, most data sets used in the model were from a limited number of locations, and were most likely not representative of the whole QMA therefore; to capture the uncertainty in the stock assessment, three sensitivity runs were conducted: run 5.5 where the early CPUE series was removed, run 6.3 where the growth was fixed high and run 6.5 where the growth was fixed low. All four runs were considered to be equally plausible and showed it was Very Unlikely the stock will fall below the soft or hard limits over the next three years at current levels of catch and suggested biomass would increase. However, the four runs differed in their assessment of the status of the stock relative to the target.

4.1 Estimates of fishery parameters and abundance indices

Parameters estimated in the assessment model and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal), mean and c.v. of the prior.

Parameter	Prior	μ	c.v.	Bounds	
				Lower	Upper
ln(*R0*)	U	–	–	5	50
M (Natural mortality)	LN	0.1	0.35	0.01	0.5
g_1*(Mean growth at 75 mm)*	U	–	–	1	50
g2(Mean growth at 120 mm)	U	–	–	0.01	50
φ (CV of mean growth)	U	–	–	0.001	1
$Ln(q^I)$ (catchability coefficient of CPUE)	U	–	–	-30	0
$Ln(q^J)$ (*catchability coefficient of PCPUE)*	U	–	–	-30	0
L_{50} (Length at 50% maturity)	U	–	–	70	145
L_{95-50}(Length between 50% and 95% maturity)	U	–	–	1	50
D_{50}(Length at 50% selectivity for the commercial catch)	U	–	–	70	145
D_{95-50}(Length between 50% and 95% selectivity the commercial catch)	U	–	–	0.01	50
ϵ (Recruitment deviations)	N	0	0.4	-2.3	2.3

The observational data were:

1. A standardised CPUE series covering 1990–2001 based on CELR data.
2. A standardised CPUE series covering 2002–2012 based on PCELR data.
3. A commercial catch sampling length frequency series for 1998, 2002–04, 07, 2009–2012.

4. Tag-recapture length increment data.
5. Maturity at length data

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2012 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2012. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, and they were entered into the model in the order that gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

For the CELR data, the unit of catch used was the total estimated daily catch for a vessel. Because the diver-hours field on the CELR forms contains errors and ambiguity, the unit of effort used was the total number of diver days (total number of divers on a vessel for a day). The catch effort records from Statistical Areas 025 and 030 before 30 September 1995 were not included in the standardizations as the stock source of the data was unknown. The standardised index is shown in the upper panel of Figure 3.

For the PCELR data, the Fisher Identification Number (FIN) was used in the standardisation instead of vessel, because the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN.

The FIN was used to select a core group of records from the CELR data, with the requirement that there be a minimum of 10 records per year for a FIN, for a minimum of 2 years. This retained 80% of the catch over 1990-2001. For the PCELR data the FIN was also used to select a core group of records, with the requirement that there be a minimum of 20 records per year for a minimum of 3 years. This retained 82% of the catch over the 2002-2012 time period.

The standardisation was done on the natural log of catch per diver day. Variables offered to the model were diver, diving condition, fishing duration, FIN (Fisher identification number), fishing year, month and statistical area; no interactions were included in the model and fishing year was forced to be in the model as an explanatory variable. The standardised index is shown in the lower panel of Figure 3.

The CELR data showed an overall decline in CPUE from 1990 through to the early 2000s. The CPUE estimated from PCELR data s showed a generally increasing trend from 2002 until 2011, with a slight decrease in 2012.

In some circumstances commercial CPUE may not be proportional to abundance because it is possible to maintain catch rates of paua despite a declining biomass. This occurs because paua tend to aggregate and divers move among areas to maximise their catch rates. Apparent stability in CPUE should therefore be interpreted with caution.

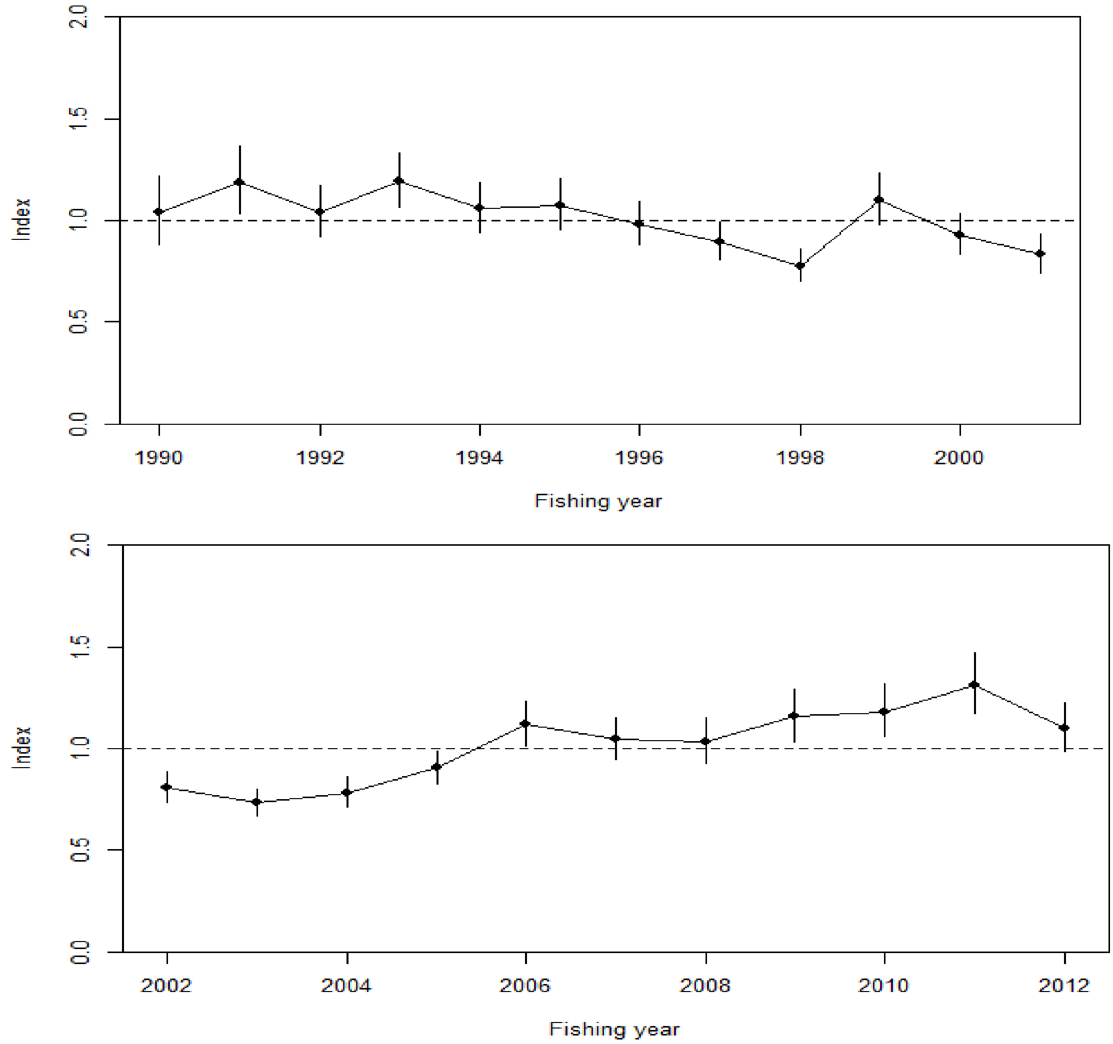


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series (upper panel) and the recent PCELR series (lower panel).

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 5D has also been estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1994 and 2004. The survey strata (Catlins East and Catlins West) cover the areas that produced about 25% of the recent catches in PAU 5D. This data was not included in the assessment because there is concern that the data is not a reliable index of abundance and the data is not representative of the whole PAU 5D QMA.

Concerns about the ability of the data collected in the independent Research Dive surveys to reflect relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed the reliability of the research diver survey index as a proxy for abundance and whether the RDSI, when used in the paua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report

4.2 Stock assessment methods

The 2012 PAU 5D stock assessment used the same length-based model used for the 2011 PAU 7 assessment (Fu 2012). The model was described by Breen *et al.* (2003). PAU 5D was last assessed in 2006 (Breen & Kim 2007) and the most recent assessment is 2012 (Fu 2013 in press).

The model structure assumed a single sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm, in groups of 2 mm. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class to change at each time step. Paua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

The model simulates the population from 1965 to 2012. Catches were available for 1974-2012 although catches before 1995 must be estimated from the combined PAU5A catch, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for paua (Shepherd *et al*. 2001). No explicit stock-recruitment relationship was modelled in previous assessments; however, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with steepness (H) of 0.75 for this assessment.

Maturity is not required in the population partition but is necessary for estimating spawning biomass. The model estimated proportions mature from length-at-maturity data. Growth and natural mortalities were also estimated within the model. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve and to reach an asymptote.

The assessment was conducted in several steps. First, the model was fitted to the data with arbitrary weights on the various data sets. The weights were then iteratively adjusted to produce balanced residuals among the datasets where the standardised deviation of the normalised residuals was close to one for each dataset. The length frequency data were further down-weighted using the method by Francis (2012). The fit obtained is the mode of the joint posterior distribution of parameters (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made with a set of agreed indicators obtained. Sensitivity trials were explored by comparing MPD fits made with alternative model assumptions.

The reference model (5.2) excluded the RDSI and RDLF data; fitted the two CPUE series and the CSLF data; estimated growth parameters within the model using an exponential growth curve with the c.v. fixed at 0.30; estimated M within the model; weighted the CSLF data using the TA1.8 method (Francis 2011). The effects of dropping the tag-recapture data from the model showed that the model is taking a lot of information about growth from the commercial catch length frequency (CSLF) data and it appears that the CSLF data is having the biggest effect on model outcomes.

The sensitivity trials carried out for the MCMC included Run 5.5 where the early CPUE series were dropped, and Run 6.3 and 6.5 where the growth parameters were fixed at values representing either fast growth ($g_1 = 32.5$ and $g_2 = 10$) or slow growth ($g_1 = 24.5$ and $g_2 = 5$) respectively. The sensitivity trials addressed uncertainties in various aspects of the input data.

The assessment calculates the following quantities from their posterior distributions: the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated (B_0,), and the mid-season spawning and recruited biomass for 2012 (B_{2012} and B^r_{2012}) and for the projection period (B_{proj} and B^r_{proj}). This assessment also reports the following fishery indictors:

- $B\%B_0$ Current or projected spawning biomass as a percentage of B_0
- $B\%B_{msy}$ Current or projected spawning biomass as a percentage of B_{msy}

- $\Pr(B_{proj} > B_{msy})$ Probability that projected spawning biomass is greater than B_{msy}
- $\Pr(B_{proj} > B_{2012})$ Probability that projected spawning biomass is greater than $B_{current}$
- $B\%B_0^r$ Current or projected recruited biomass as a percentage of B_0^r
- $B\%B_{msy}^r$ Current or projected recruited biomass as a percentage of B_{msy}^r
- $\Pr(B_{proj} > B_{msy}^r)$ Probability that projected recruit-sized biomass greater than B_{msy}^r
- $\Pr(B_{proj} > B_{2012}^r)$ Probability that projected recruit-sized biomass greater than B_{2012}^r
- $\Pr(B_{proj} > 40\%B_0)$ Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ Probability that projected spawning biomass less than 20% B_0
- $\Pr(B_{proj} < 10\%B_0)$ Probability that projected spawning biomass less than 10% B_0
- $\Pr(U_{proj} > U_{40\%B0})$ Probability that projected exploitation rate greater than $U_{40\%B0}$

4.3 Stock assessment results

The reference case model (5.2) estimated that the unfished spawning stock biomass (B_0) was about 2285 t (2099–2487 t) (Fig 5), and the spawning stock population in 2012 (B_{2012}) was about 35% (28–44%) of B_0 (Table 5). The model projection made for three years assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will increase to about 39% (27–54%) of B_0 over the next three years (Table 6). The projection also indicated that the probability of the spawning stock biomass being above the target (40% B_0) will increase from about 15% in 2012 to 43% by 2015.

The reference case model appeared to fit most data well, and there is no obvious indication of lack of fit. Natural mortality was estimated to be about 0.15. Estimated commercial catch selectivity was very steep with the 50% selectivity (D_{50}) being close to125 mm. The estimated recruitment was high in the mid-1990s and early 2000s. The estimated exploitation rate peaked in 2001 and since then has been decreasing, with the U_{2012} estimated at 21% and the exploitation required to achieve the target of 40%B0 ($U_{40\%B0}$) over the longterm was 16%.

When the early CPUE series were dropped (Run 5.5), the model estimated the unfished spawning stock biomass (B_0) to be about 2535t (2335-2742t) and showed a much steeper decline in biomass between 1990 and 2001(Fig 5). Estimated B_{2012} was about 26% (20–35%) of B0, current exploitation rate was 26% and $U_{40\%B0}$ was 13% (Table 5). The model projections (Table 7) suggested an increase in biomass over the next 3 years, with a 3% probability of being above the target of 40% B_0 by 2015.

When the growth parameters were fixed at higher values (Run 6.3), the unfished spawning stock biomass (B_0) was estimated at 1987t (1821-2158t) (Fig 5). B_{2012} was 22% (19–27%) of B_0, U_{2012} was 35% and $U_{40\%B0}$ was 16% (Table 5). The model projections (Table 8) suggested an increase in biomass over the next 3 years, with a 2% probability of being above the target by 2015.

When the growth parameters were fixed at lower values (Run 6.5), the unfished spawning stock biomass (B_0) was estimated at 3375t (3053-3841) (Fig 5). B_{2012} was estimated to be 60% (50–72%) of B_0, U_{2012} was 8% and $U_{40\%B0}$ was 16% (Table 5). The model projections (Table 9) suggest the stock biomass is currently above target and will increase over the next 3 years.

Projections made from all four assessment runs presented suggest the stock is Very Unlikely (<10%) to fall below the soft or hard limits at the current level of catch.

Deterministic B_{MSY} was also calculated in the 2012 assessment with B_{msy} estimated at 624t, 704t, 556t and 912t for the 5.2, 5.5, 6.3 and 6.5 assessment runs respectively (Table 5). The corresponding exploitation rates (U_{msy}) were estimated at 26%, 20%, 25% and 31% (Table 5). Projections from the different assessment runs estimated the probability of the biomass in 2015 being above B_{msy} to be 40-100% (Tables 6, 7, 8 and 9).

For a number of reasons (as outlined below) B_{msy} is not currently used as a reference point for managing paua stocks. However, because determining the most suitable target and limit reference points for managing paua stocks is still work in progress, B_{msy} is among the indicators that are being estimated.

There are several reasons why B_{MSY}, is not considered a suitable target for management of the paua fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TACC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical optimum; but the extent to which it needs to be above has not been determined.

Table 5: Summary of the marginal posterior distributions from the MCMC chain from Run 5.2 (base case), and sensitivity trials Run 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	MCMC 5.2	MCMC 5.5	MCMC 6.3	MCMC 6.5
B_0	2285 (2099–2487)	2535 (2335–2742)	1987 (1821–2158)	3375 (3053–3841)
B_{msy}	624 (569–684)	704 (640–771)	556 (506–609)	912 (825–1036)
B_{2012}	795 (640–1028)	647 (524–814)	444 (379–526)	2015 (1576–2702)
B_{2012} %B_0	35 (28–44)	26 20–32)	22 (19–27)	60 (50–72)
B_{2012} %B_{msy}	128 (103–161)	92 (73–118)	80 (66–97)	221 (185–266)
rB_0	1954 (1760–2158)	2241 (2025–2469)	1772 (1596–1951)	2650 (2358–3021)
rB_{msy}	361 (297–427)	467 (390–550)	385 (327–443)	342 (257–434)
rB_{2012}	514 (387–710)	414 (318–548)	279 (225–352)	1339 (1002–1863)
rB_{2012}/rB_0	0.26 (0.2–0.35)	0.19 (0.14–0.25)	0.16 (0.13–0.2)	0.51 (0.41–0.64)
rB_{2012}/rB_{msy}	1.43 (1.05–2.02)	0.89 (0.64–1.26)	0.73 (0.56–0.96)	3.91 (2.81–5.82)
MSY	121 (115–130)	113 (108–120)	119 (116–122)	156 (136–189)
$U_{40\%B0}$	16 (14-18)	13 (11-15)	16 (14-19)	16 (13-20)
U_{msy}	26 (22–32)	20 (17–24)	25 (22–29)	31 (24–41)
U_{2012}	21 (15–27)	26 (20–33)	35 (29–43)	8 (6–11)

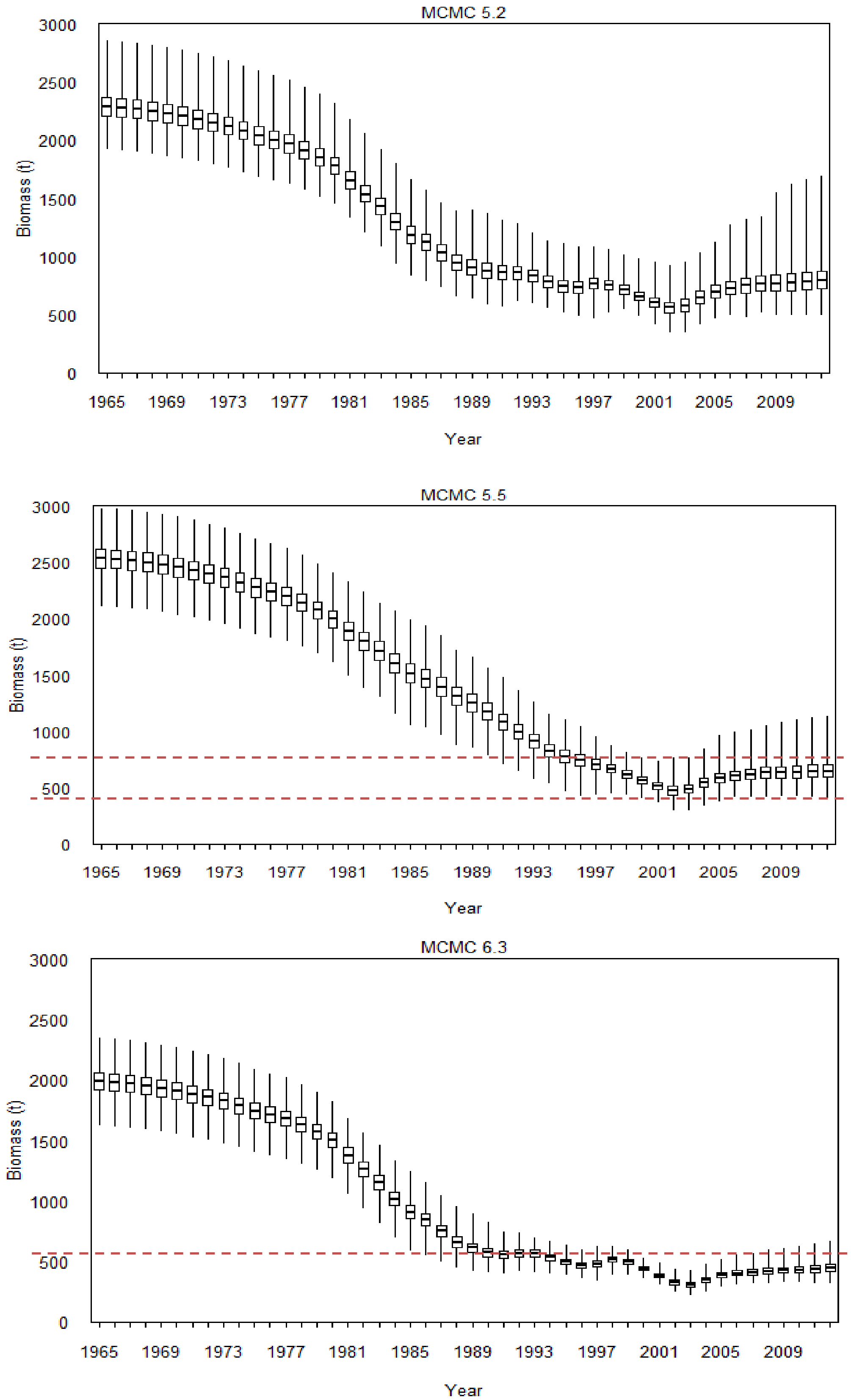


Figure 5: Posterior distributions of spawning stock biomass from MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The red horizontal line shows 40%B_0. [Continued on next page].

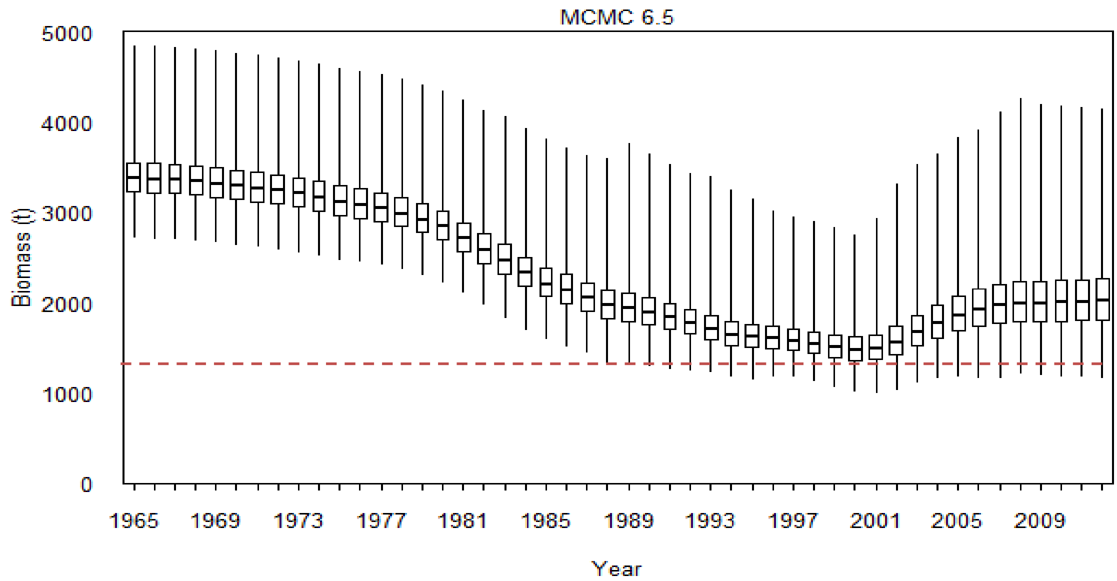


Figure 5 [Continued]: Posterior distributions of spawning stock biomass from MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The red horizontal line shows 40%B_0.

Table 6: Summary of current and projected indicators from the MCMCs for assessment run 5.2 with future commercial catch set to the current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	34.9(27.5-45.6)	38.8(27.3-53.8)
$B_{()}\ \%B_{msy}$	127.6(99.9-168.7)	141.9(98.8-198.7)
$\Pr(B_{()} > B_{msy})$	97.4	97.2
$\Pr(B_{()} > B_{2012})$		79.1
$\Pr(B_{()} > 40\%B_0)$	15.2	42.6
$\Pr(B_{()} < 20\%B_0)$	0.0	0.0
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B_0^r$	26.4(19.2-37.1)	28.7(19.9-40.7)
$B_{()}\%B_{msy}^r$	142.6(99.2-216.4)	155(102-236)
$\Pr(B_{()} > B_{msy}^r)$	97.3	98.1
$\Pr(B_{()} > B_{2012}^r)$	0.0	84.6
$\Pr(U_{()} > U_{\%40B0})$	91.7	84.9

Table 7: Summary of current and projected indicators from the MCMCs for assessment run 5.5 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	25.6(19.5-34.2)	28.2(18.9-40.3)
$B_{()}\ \%B_{msy}$	92.4(69.9-124.6)	101.7(67.7-147.1)
$\Pr(B_{()} > B_{msy})$	29.1	53.2
$\Pr(B_{()} > B_{2012})$		76.2
$\Pr(B_{()} > 40\%B_0)$	0.2	2.9
$\Pr(B_{()} < 20\%B_0)$	3.7	4.2
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B_0^r$	18.5(13.3-26.2)	19.8(13.0-29.3)
$B_{()}\%B_{msy}^r$	89(61-136)	94.9(59.2-150.6)
$\Pr(B_{()} > B_{msy}^r)$	28.2	41.4
$\Pr(B_{()} > B_{2012}^r)$		76.0
$\Pr(U_{()} > U_{\%40B0})$	99.9	99.8

Table 8: Summary of current and projected indicators from the MCMCs for assessment run 6.3 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	22.4(17.9-28.2)	26.7(17.2-39.5)
$B_{()}\ \%B_{msy}$	80.0(63.7-101.4)	95.4(61.1-141.8)
$\Pr(B_{()} > B_{msy})$	3.24	40.9
$\Pr(B_{()} > B_{2012})$		83.0
$\Pr(B_{()} > 40\%B_0)$	0	2.3
$\Pr(B_{()} < 20\%B_0)$	16.32	9.9
$\Pr(B_{()} < 10\%B_0)$	0	0.02
$B_{()}\%B_0^r$	15.8(11.9-21.2)	18.7(11.6-28.4)
$B_{()}\%B_{msy}^r$	73.1(53.5-101.4)	86.7(52.5-135.7)
$\Pr(B_{()} > B_{msy}^r)$	0.031	27.2
$\Pr(B_{()} > B_{2012}^r)$		83.9
$\Pr(U_{()} > U_{\%40B0})$	100	100

Table 9: Summary of current and projected indicators from the MCMCs for assessment run 6.5 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	59.8(48.6-73.6)	63.1(48.9-80.8)
$B_{()}\ \%B_{msy}$	221(179-272)	233(180-299)
$\Pr(B_{()} > B_{msy})$	100.0	100.0
$\Pr(B_{()} > B_{2012})$		74.0
$\Pr(B_{()} > 40\%B_0)$	100.0	100.0
$\Pr(B_{()} < 20\%B_0)$	0.0	0.0
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B_0^r$	50.6(38.8-66.2)	51.0(38.6-66.2)
$B_{()}\%B_{msy}^r$	391(266-626)	392(264-632)
$\Pr(B_{()} > B_{msy}^r)$	100.0	100.0
$\Pr(B_{()} > B_{2012}^r)$		50.2
$\Pr(U_{()} > U_{\%40B0})$	1.2	1.4

4.4 Other factors

The assessment used the CPUE as an index of abundance. The assumption that CPUE indexes abundance is questionable. The literature on abalone fisheries suggests that CPUE is difficult to use in abalone stock assessments because of serial depletion. This can happen when fishers can deplete unfished or lightly fished beds and maintain their catch rates, thus CPUE stays high while the biomass is actually decreasing. For PAU 5D, there is some additional uncertainty associated with the early CPUE: the standardisations suggested that there were different trends among statistical areas (the overall indices were unlikely to track abundance as the weights for each area cannot be easily determined); the level of decline in the CPUE indices appeared too small for the early stage of the fishery. The model results were sensitive to the inclusion/exclusion of the early CPUE indices.

Another source of uncertainty is the data. The commercial catch is unknown before 1974 and is estimated with uncertainty before 1995. Major differences may exist between the catches we assume and what was actually taken. In addition, non-commercial catch estimates are poorly determined and could be substantially different from what was assumed, although generally non-commercial catches appear to be relatively small compared with commercial catch. The estimate of illegal catch in particular is uncertain.

Tag-recapture data were mainly from the Catlin areas and therefore may not reflect fully the average growth in this population. Model estimates of stock status were sensitive to the range of possible growth values examined. Maturity data were collected from Catlin West and may not represent this population either. Length frequency data collected from the commercial catch may not represent the commercial catch with high precision. The research diver survey covered only the Catlin Area, the abundance indices and associated length frequencies were unlikely to represent the trend in the whole population.

The model treats the whole of the assessed area of PAU 5D as if it were a single stock with homogeneous biology, habitat and fishing pressures. The model assumes homogeneity in recruitment and natural mortality, and assumes that growth has the same mean and variance throughout. However it is known that paua in some areas have stunted growth, and others are fast-growing.

Heterogeneity in growth can be a problem for this kind of model (Punt 2003). Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different places; similarly the length frequency data are integrated across samples from many places.

The effect of these factors is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the depletion of spawners, because spawners must breed close to each other and the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries, so local processes may decrease recruitment, an effect that the current model cannot account for.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that some populations become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

5. STATUS OF THE STOCK

Stock Structure Assumptions
PAU5D is assumed in the model to be a discrete and homogenous stock

- **PAU 5D - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Reference case MCMC (5.2) Early CPUE data excluded MCMC (5.5) Growth fixed high MCMC (6.3) Growth fixed low MCMC (6.5) All assessment runs are considered equally valid
Reference Points	Interim Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2012} is estimated to be at 35%, 26% and 22% B_0 for assessment runs 5.2, 5.5 and 6.3 respectively. Run 6.5 estimates B_{2012} to be 60% $B_{0.}$
Status in relation to Limits	The stock is Very Unlikely (< 10%) to be below the soft and hard limits
Status in Relation to Overfishing	Assessment runs 5.2, 5.5 and 6.3 suggest a reduction in exploitation rate may achieve the interim target of 40%B0 more quickly. Run 6.5suggests current exploitation rate meets and exceeds the target.

Historical Stock Status Trajectory and Current Status

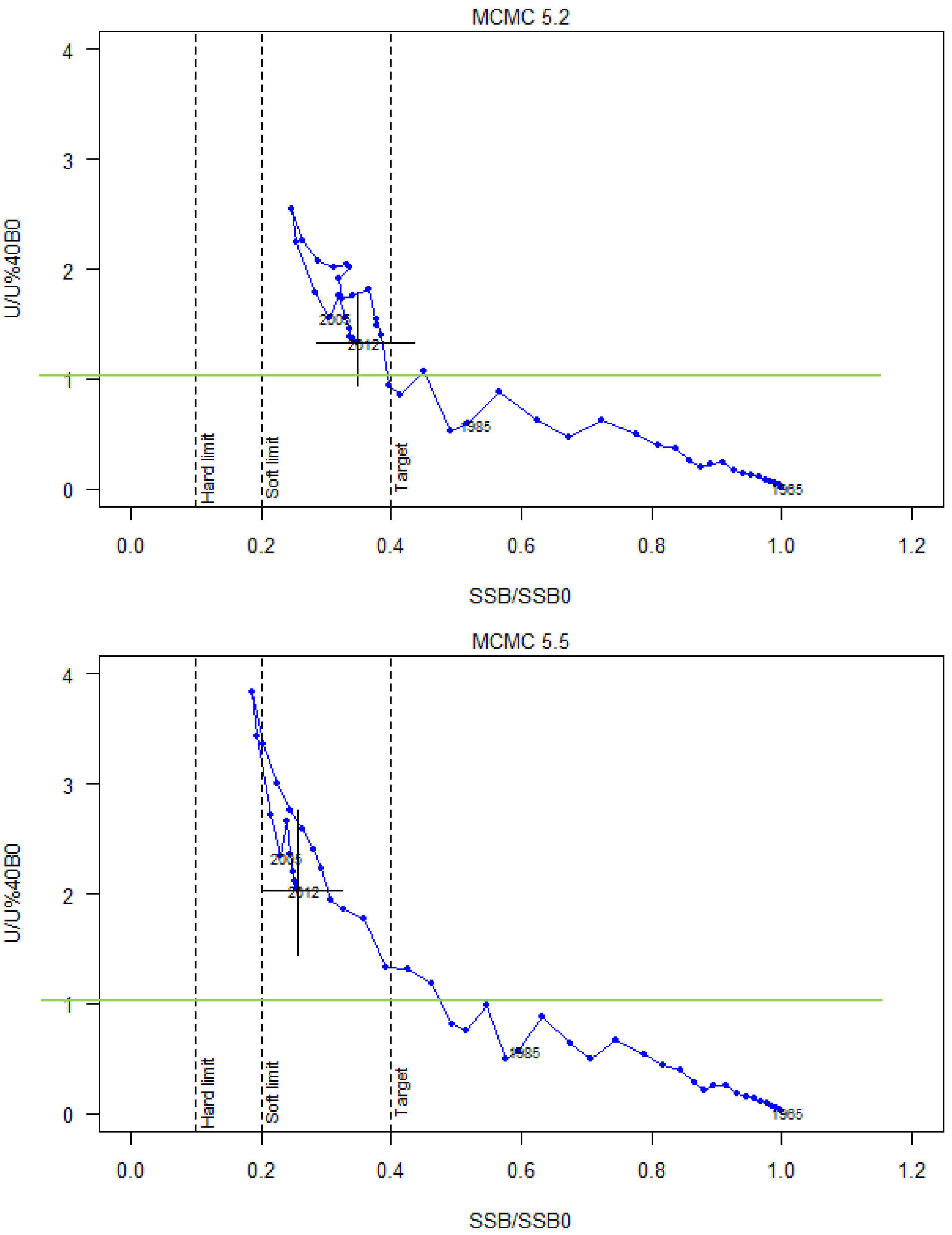
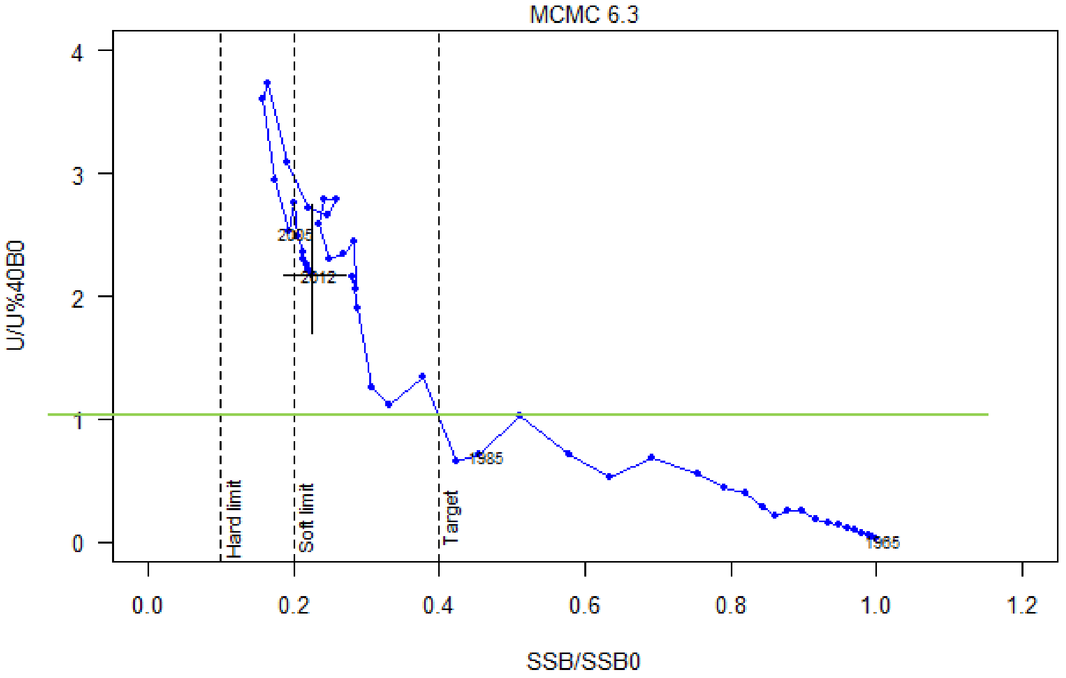


Figure 1: Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2012 for MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The vertical lines at 10%, 20%, 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. For all the models, the trajectory started in year 1965 when the SSB is close to B_0 and the exploitation rate is close to 0. The Estimates are based on MCMC median and the 2012 90% CI is shown by the cross line. [Continued on next page].



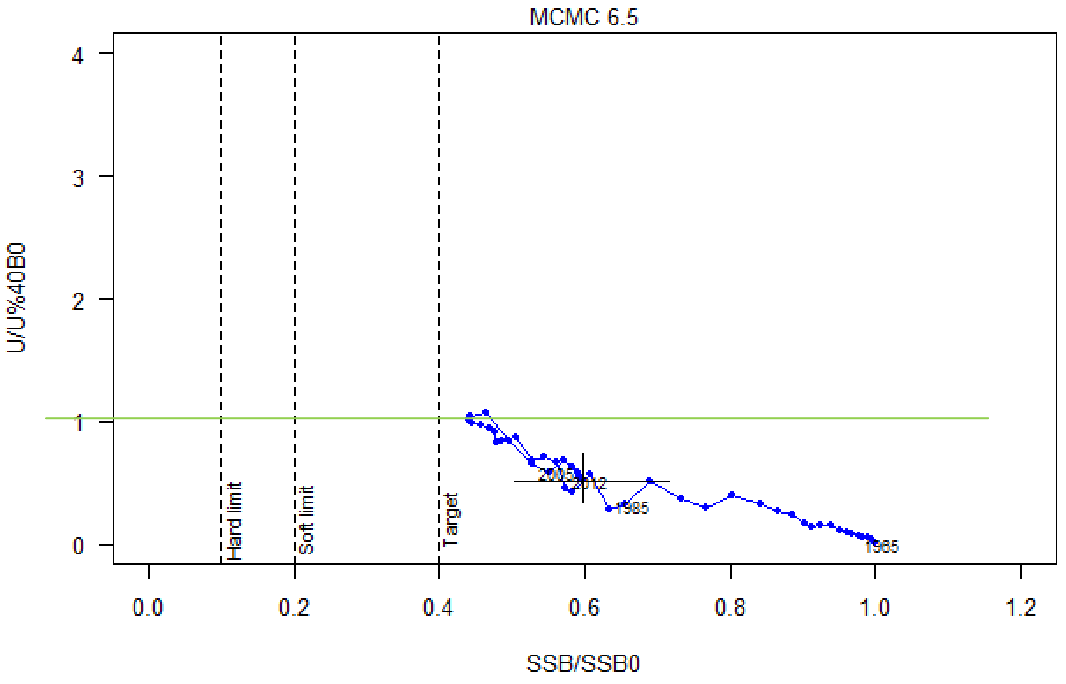


Figure 1 [Continued]: Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2012 for MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The vertical lines at 10%, 20%, 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. For all the models, the trajectory started in year 1965 when the SSB is close to B_0 and the exploitation rate is close to 0. The Estimates are based on MCMC median and the 2012 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased from about 2002 to 2008 and has since been stable.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate peaked in 2002 and has since declined.
Other Abundance Indices	Standardised CPUE generally declined until the early 2000s, but has shown a gradual increase since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low in the late 1990s, and high in the early 2000s, and since 2004 has been close to long average.

Projections and Prognosis	
Stock Projections or Prognosis	At the current catch level biomass is expected to increase over the next 3 years
Probability of Current Catch or TACC causing decline below Limits	Results from all models assessment runs presented suggest it is very unlikely (<10%) that current catch or TACC will cause a decline below the limits.

Assessment Methodology and Evaluation		
Assessment Type	1- Full Quantitative Stock Assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2013	Next: 2016
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Catch History	2 – Medium or Mixed Quality: not believed to be fully representative of catch history
	- CPUE Indices early series	2 – Medium or Mixed Quality: not believed to be fully representative of CPUE
	- CPUE Indices later series	1– High Quality
	- Commercial sampling length frequencies	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
	- Tag recapture data	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
	- Maturity at length data	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
Data not used (rank)	- Research Dive survey indices	3 – Low Quality: not believed to be a reliable indicator of abundance in the whole QMA
	- Research Dive length frequencies	3 – Low Quality: not believed to be a reliable indicator of length frequency in the whole QMA
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	- Growth data were limited and may not be representative of growth within the whole QMA. This was explored through models with alternative growth assumptions, which show the high degree of uncertainty about current stock status associated with uncertainty about growth. - Assuming CPUE is a reliable index of abundance - The model treats the whole of the assessed area of PAU 5D as if it were a single stock with homogeneous biology, habitat and fishing pressures. - Any effect of voluntary increases in MHS from 125mm to 132mm over the last five years may not have been adequately captured by the model, which could therefore be underestimating the spawning biomass in recent years.

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

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