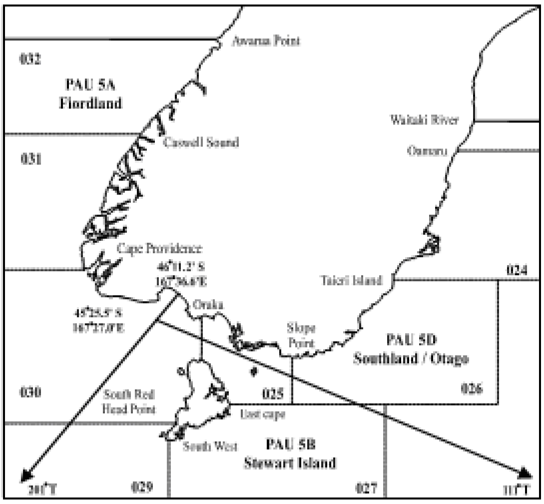
PAUA (PAU 5B) - Stewart Island

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Before 1995, PAU 5B was part of the PAU 5 QMA, which was introduced into 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 in 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 the figure above) and the TACC was divided equally among them; the PAU 5B TACC was set at 148.98 t.

On 1 October 1999 a TAC of 155.98 t was set for PAU 5B, comprising a TACC of 143.98 t (a 5 t reduction) and customary and recreational allowances of 6 t each. The TAC and TACC have been reduced twice since then and the current TAC is 105 t with a TACC of 90 t, customary and recreational allowances at 6 t each and an allowance of 3 t for other mortality (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 5B since introduction into the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1991*	-	-	-	-	445
1991–1994*	-	-	-	-	492
1994–1995*	-	-	-	-	442.8
1995–1999	-	-	-	-	148.98
1999–2000	155.9	6	6	-	143.98
2000–2002	124.87	6	6	-	112.187
2002–present	105	6	6	3	90

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September.

Concerns about the status of the stock led to the commercial fishers agreeing to voluntarily reduce their Annual Catch Entitlement (ACE) by 25t for the 1999/00 fishing year. This shelving continued for the 2000/01and 2001/02 fishing years at a level of 22 t but was discontinued at the beginning of the 2002/03 fishing year (Table 2).

On 1 October 2001 it became mandatory to report catch and effort on Paua Catch Effort Landing Returns (PCELRs) using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1).

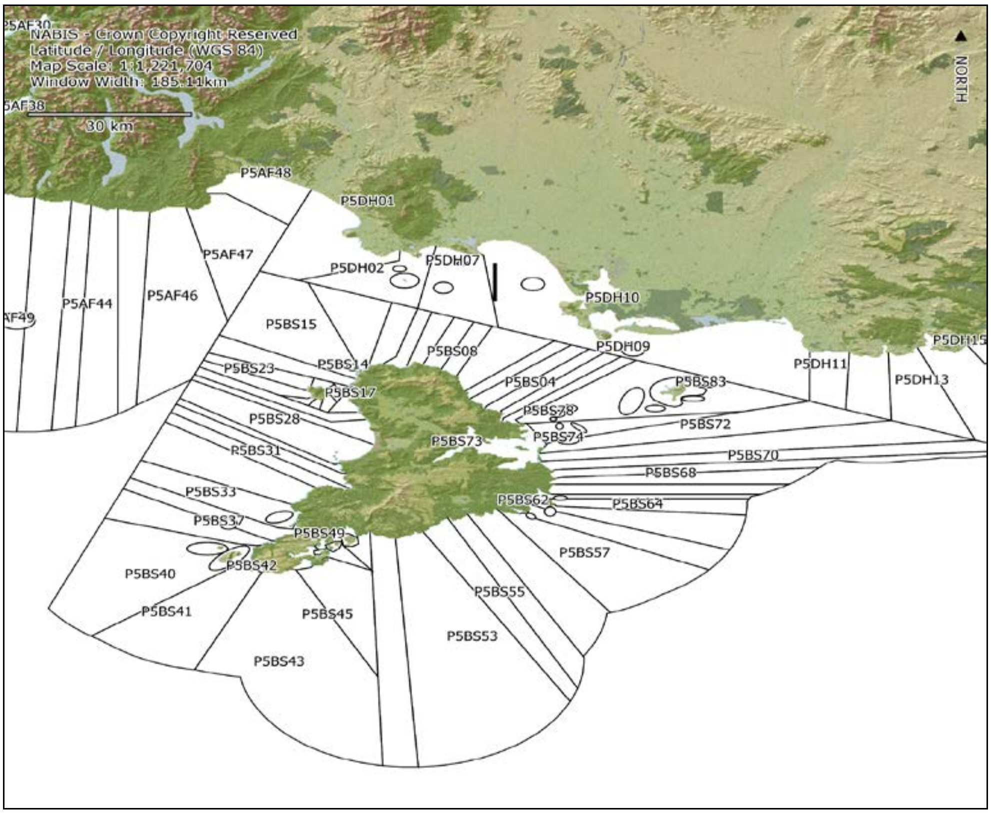


Figure 1: Map of fine scale statistical reporting areas for PAU 5B.

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

Table 2: TACC and reported commercial landings (t) of paua in PAU 5B, 1995–96 to present, from QMR and MHR returns.

Year	Landings	TACC
1995–96	144.66	148.98
1996–97	142.36	148.98
1997–98	145.34	148.98
1998–99	148.55	148.98
1999–00	118.07	143.98
2000–01	89.92	112.19
2001–02	89.96	112.19
2002–03	89.86	90.00
2003–04	90.00	90.00
2004–05	89.97	90.00
2005–06	90.47	90.00
2006–07	89.16	90.00
2007–08	90.21	90.00
2008–09	90.00	90.00
2009–10	90.23	90.00
2010–11	89.67	90.00
2011–12	89.59	90.00
2012–13	90.58	90.00
2013–14	88.84	90.00
2014–15	89.45	90.00
2015–16	88.39	90.00

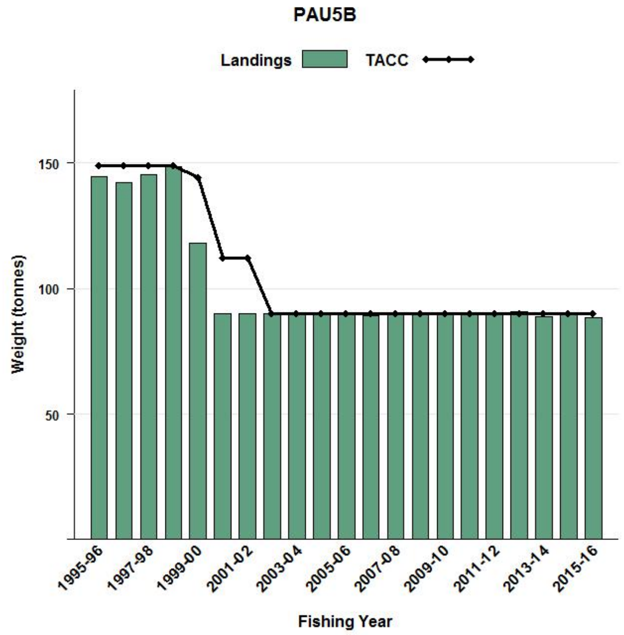


Figure 2: Reported commercial landings and TACC for PAU 5B from 1995–96 to present. For reported commercial landings in PAU 5 before 1995–96 refer to figure 1 and table 1 in the introductory PAU Working Group Report.

1.2 Recreational fisheries

The ‘National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates’ estimated that the recreational harvest for PAU 5B was 0.82 t with a CV of 50%. For the 2013 assessment, the SFWG agreed to assume that the recreational catch rose linearly from 1t in 1974 to 5 t in 2006, and remained at 5 t between 2007 and 2013. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

The SFWG agreed to assume for the 2013 assessment that customary catch has been 1 t for the whole period modelled. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

Illegal catch was estimated by the Ministry of Fisheries to be 15 t, but “Compliance express extreme reservations about the accuracy of this figure.” The SFWG agreed to assume for the 2013 assessment that illegal catch was zero before 1986, then rose linearly from 1 t in 1986 to 5 t in 2006, and remained constant at 5 t between 2007 and 2013. 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 5B 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*).

		Estimate	Source
1. Natural mortality (M)		0.10 (CV 0.10)	Assumed prior probability distribution
2. Weight = a(length)^b (Weight in g, length in mm shell length).			
	All		
	a	b	
	2.99 x 10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 91 mm	Naylor (NIWA unpub. data)
		95% maturity at 133mm	Naylor (NIWA unpub. data)
4. Growth parameters (both sexes combined)			
	Growth at 75 mm	Growth at 120 mm	Median (5–95% range) of posterior distributions estimated by the assessment model
	26.1 mm (24.8 to 27.2)	6.9 mm (6.5–7.3)	

4. STOCK ASSESSMENT

The stock assessment was done with a length-based Bayesian estimation model, with parameter point estimates based on the mode of the joint posterior distribution and uncertainty estimated from marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The most recent stock assessment was conducted in 2014 for the fishing year ended 30 September 2013. A base case model (0.1) was chosen from the assessment. The SFWG also suggested a sensitivity run (model 0.4) which assumed a uniform prior on *M* to explore the influence of this prior on the estimates of stock status.

4.1 Estimates of fishery parameters and abundance

Parameters estimated in the assessment model and their Bayesian prior distributions 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 CV of the prior.

Parameter	Prior	μ	CV	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 for the commercial catch)	U	–	–	0.01	50
ϵ (Recruitment deviations)	N	0	0.4	-2.3	2.3

The observational data were:
1. A 1990–2001 standardised CPUE series based on CELR data.
2. A 2002–2012 standardised CPUE series 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 2013 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2013. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, with variables entering the model in the order that gave the maximum decrease in the residual deviance. Predictor variables were accepted in the model only if they explained at least 1% of the deviance.

For both the CELR and PCELR data, the Fisher Identification Number (FIN) was used in the standardisations 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.

For the CELR data there is ambiguity in what is recorded for estimated daily fishing duration, and it has not been used in past standardisations as a measure of effort, instead the number of divers has been used. However, there is evidence that the fishing duration for a diver changes over time, and because of this a subset of the data was selected for which the recorded fishing duration was less ambiguous. The criteria used to subset the data were: (i) just one diver or (ii) fishing duration >= 8 hours and number of divers >=2. This data subset was used for the CELR standardisation using estimated daily catch and effort as either number of divers or estimated fishing duration (both were offered to the standardisation model).

For the PCELR data the unit of catch was diver catch, with effort as diver duration.

FIN codes were used to select a core group of fishers from the CELR data, with the requirement that there be a minimum of 5 records per year for a minimum of 2 years to qualify for the core fisher group. This retained 80% of the catch over 1990–2001. For the PCELR data the FIN was also used to select a core group of fishers, with the requirement that there be a minimum of 20 records per year for a minimum of 3 years. This retained 89% of the catch over 2002–2013.

For the CELR data year was forced into the model and other predictor variables offered to the model were FIN, statistical area (024, 025, 026, 030), month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. For the PCELR data fishing year was forced into the model and variables offered to the model were month, diver key, FIN statistical area, diver duration (third degree polynomial), and diving conditions.

The standardised CPUE from the CELR data have a bump in 1991 but is relatively flat for the first four years, then declines to 40–50% of its initial level (Figure 3-top). The standardised CPUE from the PCELR data show a 60% increase from 2002 to 2013 (Figure 3-bottom).

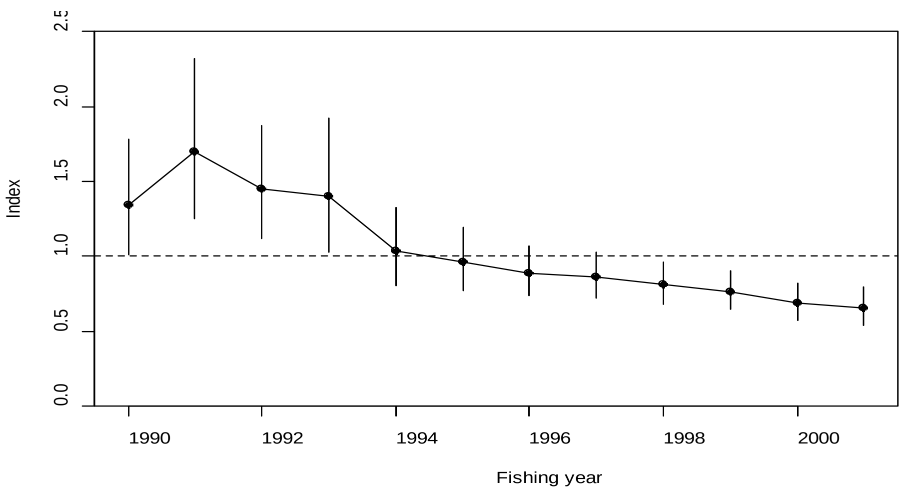


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series [Continued on next page].

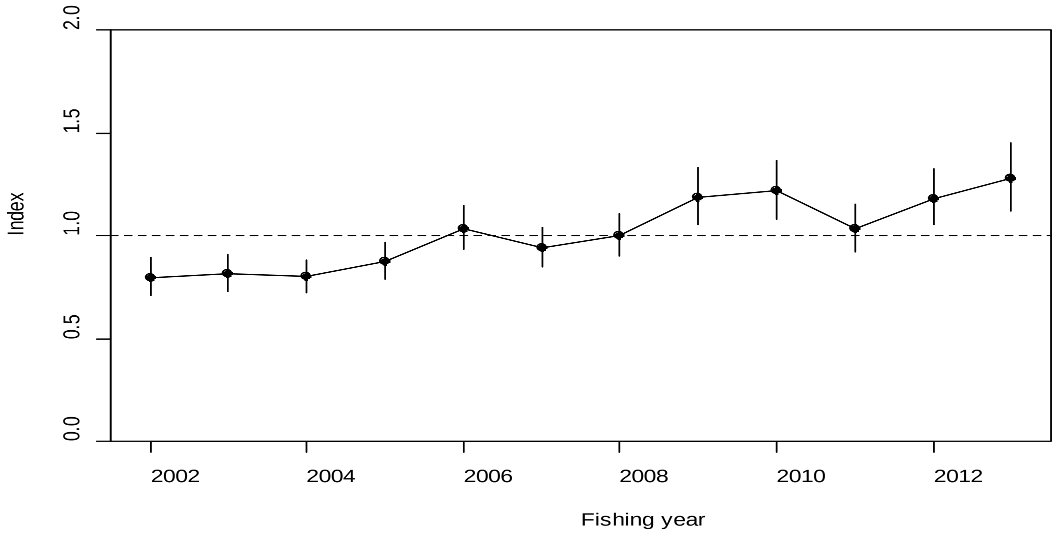


Figure 3 [Continued]: The standardised CPUE indices with 95% confidence intervals for the recent PCELR series

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 5B has also been estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1993 and 2007. The survey strata included Ruggedy, Waituna, Codfish, Pegasus, Lords, and East Cape. These data were not included in the assessment because there is concern that the data are not a reliable index of abundance.

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 an index of 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 2013 PAU 5B stock assessment used the same length-based model as the 2012 PAU 5D assessment (Fu 2013). The model was described by Breen *et al.* (2003). PAU 5B was last assessed in 2007 (Breen & Smith 2008) and the most recent assessment is 2013 (Fu et al 2014).

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

The model simulates the population from 1965 to 2013. Catches were available for 1974–2013 although catches before 1995 must be estimated from the combined PAU 5 catch. Catches 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. 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 asymptote at 1. The increase in Minimum Harvest Size between 2006 and 2011 was modelled as an annual shift in fishing selectivity.

The assessment was conducted in several steps. First, the model was fitted to the data with parameters estimated at the mode of their joint posterior distribution (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 and an agreed set of biological indicators obtained. Model sensitivity was explored by comparing MPD fits made under alternative model assumptions.

The base case model excluded the RDSI and RDLF data, used the methods recommended by Francis (2011) to determine the relative weights for the proportion-at-length and abundance data, and estimated *M* assuming a lognormal prior with a mean of 0.1. When the RDSI and RDLF data were included in the model, they had almost no influence on model results. This suggested that the RDSI and RDLF were probably not in conflict with other observations, but this could also be related to their small model weights.

The sensitivity trials included an alternative prior on *M*, alternative catch history estimates with lower catches between 1985 and 1995, the use of inverse-logistic growth model, and the exclusion of the early or the recent CPUE indices. The sensitivity trials addressed uncertainties associated with various aspects of the input data and model assumptions. MCMCs were carried out for the base case and model run 0.4, which used a uniform prior on *M*.

The assessment calculates the following quantities from their posterior distributions: the equilibrium spawning stock biomass with recruitment equal to the average recruitment from the period for which recruitment deviation were estimated (B_0,), the mid-season spawning and recruited biomass for 2013 (B_{2013} and B^r_{2013}) 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 $B_{current}$
- $B\%B^r_0$ — Current or projected recruited biomass as a percentage of B^r_0
- $B\%B^r_{msy}$ — Current or projected recruited biomass as a percentage of B^r_{msy}
- $\Pr(B_{proj} > B^r_{msy})$ — Probability that projected recruit-sized biomass is greater than B^r_{msy}
- $\Pr(B_{proj} > B^r_{2012})$ — Probability that projected recruit-sized biomass is greater than B^r_{2012}
- $\Pr(B_{proj} > 40\%B_0)$ — Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ — Probability that projected spawning biomass is less than 20% B_0
- $\Pr(B_{proj} < 10\%B_0)$ — Probability that projected spawning biomass is less than 10% B_0
- $\Pr(U_{proj} > U_{40\%B0})$ — Probability that projected exploitation rate is greater than $U_{40\%B0}$

4.3 Stock assessment results

The base case model (0.1) estimated that the unfished spawning stock biomass (B_0) was about 3625 t (3390–3870 t) (Figure 4), and the spawning stock population in 2013 (B_{2013}) was about 44% (36–54%) of (B_0 Table 5). The base case indicated that spawning biomass increased rapidly after 2002 when the stock was at its lowest level. The 3-year model projection, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will increase to about 48% (0.38–0.61) 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 80% in 2013 to 93% by 2016. The projection assumed the Minimum Harvest Size will remain at 135 mm for the next three years; the projected stock status changed very little if an MHS of 125 mm was assumed

The MCMC simulation started at the MPD parameter values and the traces show good mixing. MCMC chains starting at either higher or lower parameter values also converged after the initial burn-in phase. The base case model estimated an *M* of 0.12 with a 90% credible interval between 0.11 and 0.14. The midpoint of the commercial fishery selectivity (pre-2006), where selectivity is 50% of the maximum, was estimated to be about 125 mm and the selectivity ogive was very steep. The model estimated an annual shift of about 1.9 mm in selectivity, with a total increase of about 10 mm between 2006 and 2011.

The estimated recruitment deviations showed a period of relatively low recruitment through the 1990s to the early 2000s and the recruitment in recent years (after 2002) has been above the long term average. Exploitation rates peaked around 2002, but have decreased since then. The base case estimated exploitation rate in 2013 to be about 0.11 (0.09–0.14).

When a uniform prior on *M* was used (MCMC 0.4), the posterior median of *M* was estimated to be 0.15, and the posterior distribution had a much wider range, with a 90% credible interval between 0.13 and 0.19. This model run produced a more rapid increase in spawning biomass after 2002 with $B_{current}$ estimated to be about 55% (43–73%) of B_0. Model fits to both CPUE and CSLF changed very little from when the uninformative prior on *M* was used.

Deterministic B_{msy} was calculated using posterior samples of estimated parameters assuming constant recruitments and a B-H stock-recruitment relationship with a steepness of 0.75. The median of B_{msy} was estimated to be about 28% B_0 for both MCMC 0.1 and 0.4. The corresponding exploitation rate (U_{msy}) was estimated to be 37% for MCMC 0.1 and 67% for MCMC 0.4. The MHS was fixed at 135 mm in the calculation and U_{msy} was sensitive to this value: U_{msy} was estimated to be 22% for MCMC 0.1 and 31% for MCMC 0.4 when an MHS of 125 mm was used. However both MSY and B_{msy} were less sensitive to the values of MHS. Assuming an MHS of 135 mm, $U_{\%40B0}$ was estimated to be 19% and 30% for MCMC 0.1 and 0.4 respectively. 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 the base case (Model 0.1), and sensitivity trial (model 0.4). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	MCMC 0.1	MCMC 0.4

B_0	3635 (3392–3872)	3366 (3063–3691)
B_{msy}	1021 (960–1086)	967 (887–1119)
B_{2013}	1592 (1293–1975)	1855 (1441–2486)
$B_{2013}\,\%B_0$	44 (36–53)	55(43–73)
$B_{2013}\,\%B_{msy}$	156 (128–156)	194 (152–231)
$B_{msy}\,\%B_0$	28 (28–29)	28 (28–34)
rB_0	3194 (2952–3440)	2838 (2490–3185)
rB_{msy}	664 (587–737)	534 (448–648)
rB_{2013}	1210 (953–1534)	1375 (1045–1851)
rB_{2013}/rB_0	0.38 (0.30–0.47)	0.49 (0.37–0.67)
rB_{2013}/rB_{msy}	1.82 (1.40–2.39)	2.64 (1.79–3.48)
rB_{msy}/rB_0	0.21 (0.19–0.22)	0.19 (0.17–0.21)
MSY	166 (156–182)	190 (167–234)
$U_{40\%B0}$	19 (16–24)	30 (20–56)
U_{msy}	37 (29–0.50)	67 (39–98)
U_{2013}	11 (9–14)	10 (7–13)

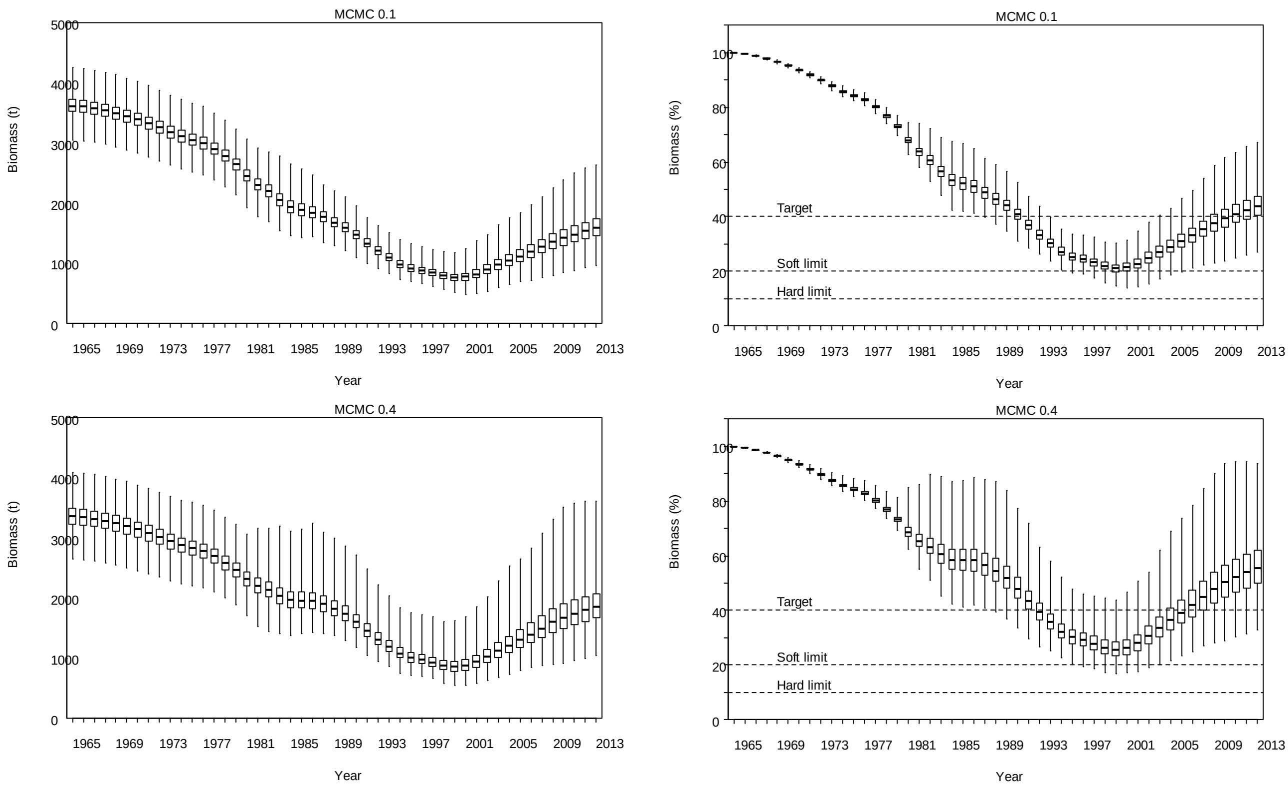


Figure 4: Posterior distributions of spawning stock biomass and spawning stock biomass as a percentage of the virgin level from MCMC 0.1 and 0.4. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

Table 6: Summary of current and projected indicators for the base case with future commercial catch set to current TACC and future minimum harvest size set to 135 mm or 125 mm: 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).

	135 mm		125 mm	
	2013	2015	2013	2015
$B_{()}\%B_0$	44 (35–55)	48 (38–61)	44 (35–55)	47 (37–61)
$B_{()}\ \%B_{msy}$	156 (124–197)	169 (132 –218)	159 (126–203)	172 (134–223)
$\Pr(B_{()} > B_{msy})$	1.00	1.00	1.00	1.00
$\Pr(B_{()} > B_{2012})$	–	0.92	–	0.91
$\Pr(B_{()} > 40\%B_0)$	0.80	0.93	0.79	0.92
$\Pr(B_{()} < 20\%B_0)$	0.00	0.00	0.00	0.00
$\Pr(B_{()} < 10\%B_0)$	0.00	0.00	0.00	0.00
$B_{()} / B_0^r$	0.38 (0.29–0.49)	0.42 (0.33–0.53)	0.38 (0.29–0.49)	0.419 (0.33–0.53)
$B_{()} / B_{msy}^r$	1.82 (1.34–2.53)	2.02 (1.51–2.74)	1.87 (1.36–2.62)	2.07 (1.54–2.84)
$\Pr(B_{()} > B_{msy}^r)$	1.00	1.00	1.00	1.00
$\Pr(B_{()} > B_{2012}^r)$	–	1.00	–	1.00
$\Pr(U_{()} > U_{\%40B0})$	0.14	0.02	0.14	0.00

4.4 Other factors

The assessment used CPUE as an index of abundance. The assumption that CPUE indexes abundance is questionable. The literature on abalone fisheries suggests that CPUE is problematic for stock assessments because of serial depletion. This can happen when fishers deplete unfished or lightly fished beds and maintain their catch rates by moving to new areas. Thus CPUE stays high while the biomass is actually decreasing. For PAU 5B, the model estimate of stock status was strongly driven by the trend in the recent CPUE indices. It is unknown to what extent the CPUE series tracks stock abundance. The SFWG believed that the increasing trend in recent CPUE series may be credible, corroborating anecdotal evidence from the commercial divers in PAU 5B that the stock has been in good shape in recent years.

Natural mortality is an important productivity parameter. It is often difficult to estimate *M* reliably within a stock assessment model and the estimate is strongly influenced by the assumed prior. For the paua assessment, the choice of prior has been based on current belief on the plausible range of the natural mortality for paua, and therefore it is reasonable to incorporate available evidence to inform the estimation of *M*. The sensitivity of model results to the assumptions on *M* could be assessed through the use of alternative priors.

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.

The model treats the whole of the assessed area of PAU 5B 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 localized depletion of spawners. Spawners must be close to each other to breed 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

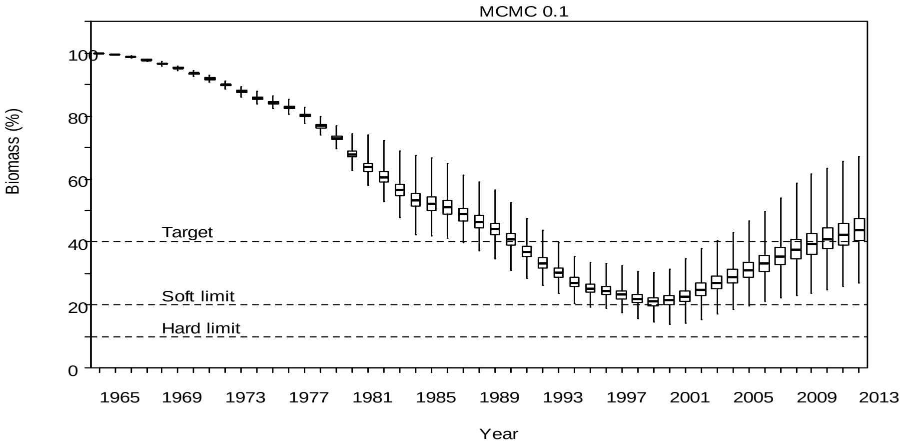
Stock Structure Assumptions

PAU 5B is assumed to be a homogenous stock for purposes of the stock assessment.

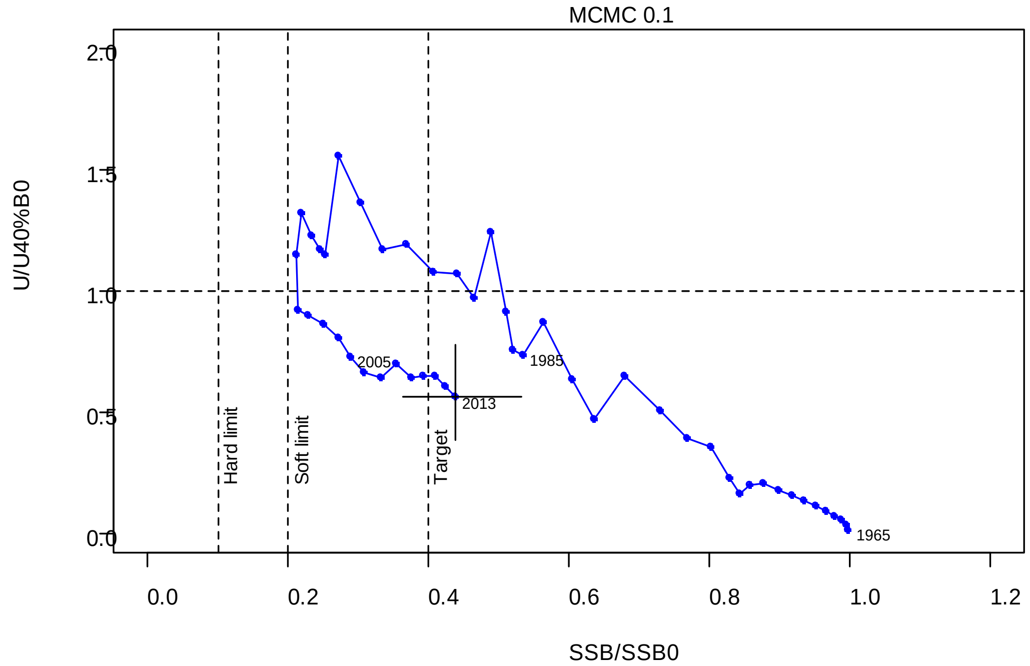
- **PAU 5B - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MCMC 0.1 (base case)
Reference Points	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_{2013} was estimated to be 44% B_0 for the base case; About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in Relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Posterior distributions spawning stock biomass as a percentage of the virgin level from MCMC 0.1. 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.



Trajectory of exploitation rate as a ratio $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2013 for MCMC 0.1 (base case). 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. The estimates are based on MCMC medians and the 2012 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased to its lowest level in 2002 but has increased since then.
Recent Trend in Fishing Intensity or Proxy	Exploitation rate peaked in late 1990s and has since declined.
Other Abundance Indices	Standardised CPUE generally declined until the early 2000s, but has shown an increase since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low through the 1990s to the early 2000s and since 2002 has been close to the long term 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 Biomass to remain below or to decline below Limits	Results from all models suggest it is Very Unlikely (< 10%) that current catch or TACC will cause a decline below the limits.	
Probability of Current Catch or TACC to cause Overfishing to continue or to commence	-	
Assessment Methodology and Evaluation		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2014	Next: 2018
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	-Catch history	1 – High Quality for commercial catch 2 – Medium or Mixed Quality for recreational, customary and illegal as catch histories are not believed to

	-CPUE indices early series -CPUE indices later series -Commercial sampling length frequencies -Tag recapture data (for growth estimation) -Maturity at length data	be fully representative of the QMA 2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA 1 – High Quality 2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA 1 – High Quality 1 – High Quality
Data not used (rank)	-Research Dive Survey Indices -Research Dive Length Frequencies	3 – Low Quality: not believed to index the stock 3 – Low Quality: not believed to be representative of the entire QMA
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	-*M* may not be estimated accurately. There is information in the data that has informed the estimation of *M* and the prior has also strongly influenced the estimate. - CPUE may not be a reliable index of abundance. -The model treats the whole of the assessed area of PAU 5B as if it were a single stock with homogeneous biology, habitat and fishing pressure. -Any effect of voluntary increases in MHS from 125 mm to 135 mm between 2006 and 2011 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

Andrew, N L; Naylor, J R; Gerring, P (2000a) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Andrew, N L; Naylor, J R; Gerring, P; Notman, P R (2000b) Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. *New Zealand Fisheries Assessment Report 2000/3*. 21 p.

Andrew, N L; Naylor, J R; Kim, S W; Doonan, I J (2002) Fishery independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5B and PAU 5D. *New Zealand Fisheries Assessment Report 2002/41*. 25 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Breen, P A; Andrew, N L; Kendrick, T H (2000a) Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. *New Zealand Fisheries Assessment Report 2000/33*. 37 p.

Breen, P A; Andrew, N L; Kendrick, T H (2000b) The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. *New Zealand Fisheries Assessment Report 2000/48*. 36 p.

Breen, P A; Andrew, N L; Kim, S W (2001) The 2001 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2001/55*. 53 p.

Breen, P A; Kim, S W (2005) The 2005 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2005/47*. 114 p.

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

Breen, P A; Smith, A N H (2008) The 2007 assessment for paua (*Haliotis iris)* stock PAU 5B (Stewart Island). *New Zealand Fisheries Assessment Report 2008/05*. 64 p

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5. (Unpublished report held by Ministry for Primary Industries, Wellington.) 45 p.

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

Fu, D; McKenzie, A; Naylor, R (2014) The 2013 stock assessment of paua (*Haliotis iris*) for PAU 5B. *New Zealand Fisheries Assessment Report 2014/45.*

Gerring, P K (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*.

Gorfine, H K; Dixon, C D (2000) A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. *Journal of Shellfish Research* 19: 515–516.

Haist, V (2010) Paua research diver surveys: review of data collected and simulation study of survey method. *New Zealand Fisheries Assessment Report 2010/38*. 54 p.

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report 2000/47*. 25 p.

Punt, A E (2003) The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. *Fisheries Research* 65: 391–409.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. *Fishery Bulletin* 89: 681–691.

Shepherd, S A; Partington, D (1995) Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. *Marine and Freshwater Research* 46: 669–680.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)