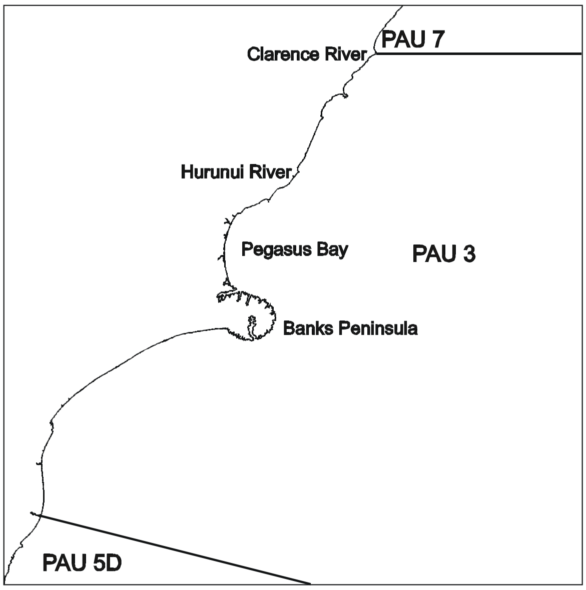
PAUA (PAU 3) – Canterbury / Kaikoura

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

1.1 Commercial fisheries

PAU 3 was introduced into the Quota Management System in 1986–87 with a TACC of 57 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 91.62 t in 1995 and has remained unchanged to the current fishing year (Table 1).

There is no TAC for PAU 3 (Table 1): before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC. No allowances have been made for customary, recreational or other mortality.

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 3 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1995	-	-	-	-	57
1995–present	-	-	-	-	91.615

The fishing year runs from 1 October through 30 September.

Most of the commercial catch comes from the northern part of the QMA between the northern end of Pegasus Bay and the Clarence River, and from the southern side of Banks Peninsula.

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). Reported landings for PAU 3 are shown in Table 2 and Figure 2.

Since 2001, a redistribution of fishing effort within PAU 3 has been undertaken by the industry as a response to fears that the more accessible northern part of the fishery was being overfished. A voluntary subdivision was agreed by PauaMAC 3 which divided PAU 3 into four management zones (Table 3). A voluntary harvest cap is placed on each management zone and this cap is reviewed annually. Minimum harvest sizes (MHS) are also agreed for each zone in addition to the legislated Minimum Legal Size (MLS). These are also reviewed annually.

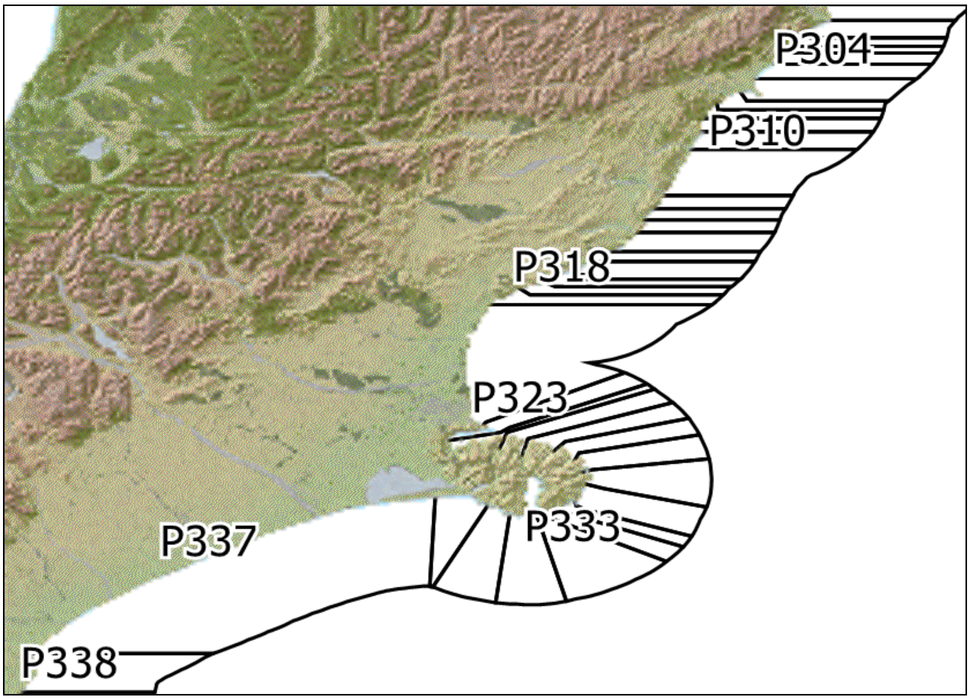


Figure 1: Map of fine scale statistical reporting areas for PAU 3.

Landings for PAU 3 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 3 from 1983–84 to present.

Year	Landings	TACC
1983–84*	114	–
1984–85*	92	–
1985–86*	51	–
1986–87*	54.02	57
1987–88*	62.99	60.49
1988–89*	57.55	66.48
1989–90	73.46	69.43
1990–91	90.68	77.24
1991–92	90.25	91.5
1992–93	94.52	91.5
1993–94	85.09	91.5
1994–95	93.26	91.5
1995–96	92.89	91.62
1996–97	89.65	91.62
1997–98	93.88	91.62
1998–99	92.54	91.62
1999–00	90.3	91.62
2000–01	93.19	91.62
2001–02	89.66	91.62
2002–03	90.92	91.62
2003–04	91.58	91.62
2004–05	91.43	91.62
2005–06	91.6	91.62
2006–07	91.61	91.62
2007–08	91.67	91.62
2008–09	90.84	91.62
2009–10	91.61	91.62
2010–11	90.4	91.62
2011–12	91.14	91.62
2012–13	90.01	91.62
2013-14	90.85	91.62
2014–15	90.44	91.62
2015–16	91.73	91.62

* FSU data.

Table 3: Summary of the management zones within PAU3 as initiated by PauaMac3

Management zone (since 2001)	Area	Statistical area zone
3A	Clarence to Hapuku	P301–P304
3B	Hapuku to Conway	P305–P310
3D	Conway to Waipar	P311–P321
3E	Waipara to Witaki	P322–P329

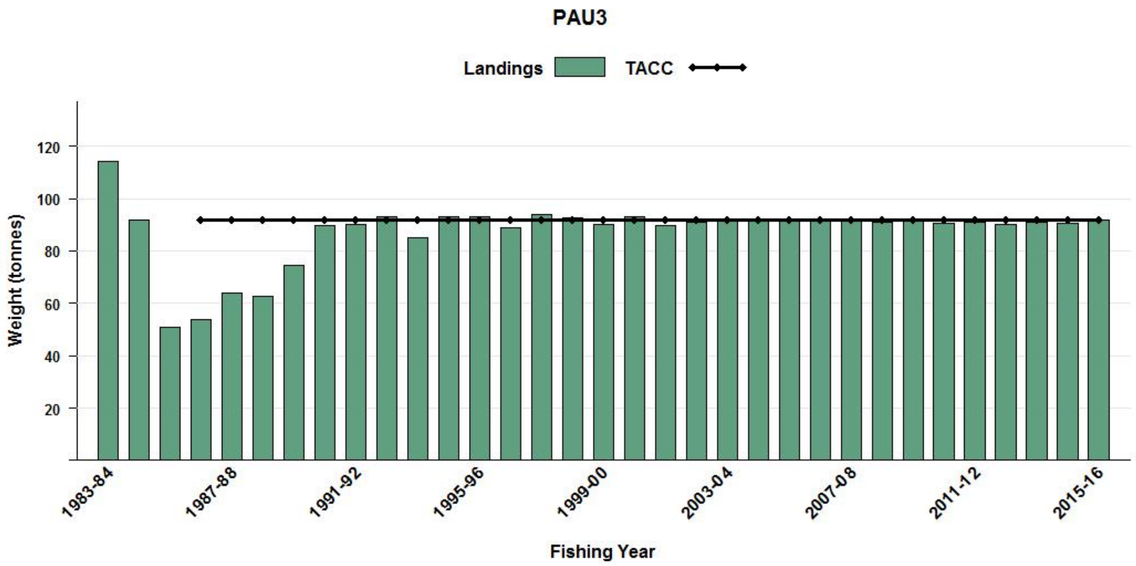


Figure 2: Reported commercial landings and TACC for PAU 3 from 1983–84 to present. QMS data from 1983–present.

1.2 Recreational fisheries

For further information on recreational fisheries refer to the introductory PAU Working Group Report. The 'National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates' estimated the recreational harvest for PAU 3 was 16.98 ton with a C.V. of 30%. For the purpose of the 2013 stock assessment, the Shellfish Working Group (SFWG) agreed to assume that the recreational catch rose linearly from 5t in 1974 to 17 t in 2013.

1.3 Customary fisheries

Estimates of customary catch for PAU 3 over the period where reliable estimates are available are shown in Table 4. Landings before 2010–11 do not include the area between the Hurunui River and the South Shore (just north of Banks Peninsula), as Tangata Tiaki were not appointed there until November 2009. Many tangata whenua also harvest paua under their recreational allowance and these are not included in records of customary catch.

Table 4: Reported customary landings (t) of paua in PAU 3 from 2000–01 to 2013-14. Landings data before 2010–11 exclude the area between the Hurunui and Pegasus Bay.

Year	Landings (t)
2000–01	1.64
2001–02	5.67
2002–03	3.84
2003–04	5.83
2004–05	1.95
2005–06	1.90
2006–07	4.56
2007–08	5.79
2008–09	8.23
2009–10	6.47
2010–11	7.45
2011–12	4.24
2012–13	12.87
2013–14	7.57

1.4 Illegal catch

For further information on illegal catch refer to the introductory PAU Working Group Report. For the purpose of the 2013 stock assessment, the SFWG agreed to assume that illegal catches rose linearly from 5t in 1974 to 15 t in 2000, and remained at 15 t between 2001 and 2013.

1.5 Other sources of mortality

The Working Group agreed that handling mortality would not be included in the model. For further information on other sources of mortality refer to the introductory PAU Working Group Report.

On 16 November 2016 a 7.8 magnitude earthquake hit the upper east coast of the South Island, uplifting areas of the coast by as much as 4 m. The whole northern part of the PAU3 fishery (paua statistical areas P301 to P310, Figure 3a) were impacted to varying degrees by the earthquake. The earthquake caused direct mortality of a large number of juvenile and adult paua that became exposed to the terrestrial environment with no means of being able to return to the water. More indirect mortality is also expected from the earthquake due to an immediate loss of pre-earthquake paua habitat that now lies above the new post-earthquake high tide mark.

Although the impacts of the seabed uplift on paua populations around Kaikoura will only become clear in the longer term, work was undertaken to evaluate the area utilised by the paua fishery that is now above the post earthquake low-tide mark (Neubauer 2016). The results estimated that the seabed uplift led to a loss of up to 50% of the pre-earthquake fished area in the paua statistical areas P301 to P310. In area 301, the habitat loss was 7 ha, which corresponds to 52% of the fished area. However, this area has contributed relatively little to the commercial catch. In area 302, which has contributed a larger proportion of the PAU 3 commercial catch, the area lost was 43 ha, which corresponds to 43% of the fished area. In other affected areas, the area lost was generally less than 10%. Across PAU 3 statistical areas, a total of 21% of the fished area (24% of catch weight as recorded on PCELR forms)**,** was impacted by uplift (Figure 3a).

The immediate loss of area to the fishery, assumed to be good habitat for pāua, is only part of the impact that the seabed uplift associated with the Kaikoura earthquake will have on pāua populations. Juvenile pāua recruit in shallow water, and so the loss of juvenile habitat will have been higher than the loss of adult habitat. This will impact on the number of juvenile pāua growing into the fishery over the coming years. This impact will be more difficult to quantify directly, but may affect pāua populations and fisheries over a span of multiple years.

2. BIOLOGY

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

Table 5: Estimates of biological parameters (*H. iris*) in PAU 3.

		Estimate	Source
1. Natural mortality (M)			
		0.135 (0.120-0.153)	Median (5-95% range) of posterior distribution for 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 82 mm (80-84)	Median (5-95% range) of posterior distribution for the base case model
		95% maturity at 102 mm (96-108)	Median (5-95% range) of posterior distribution for the base case model

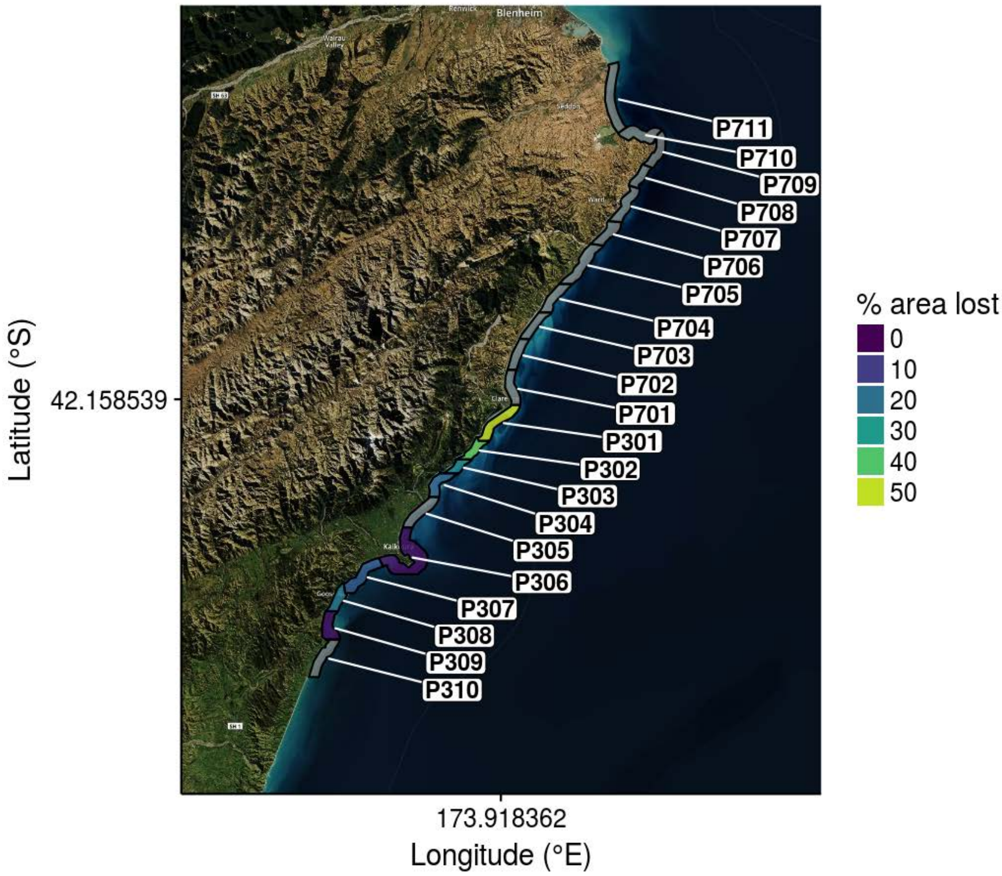


Figure 3a: Percent fished area above the post-earthquake low tide mark for statistical areas within the Kaikoura earthquake fishery closure zone. Grey indicates that no post-earthquake elevation data was available.

3. STOCKS AND AREAS

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

4. STOCK ASSESSMENT

The stock assessment was implemented using a length-based Bayesian estimation model, with parameter point estimates based on the mode of the joint posterior distribution and uncertainty based on marginal posterior distributions generated from Markov chain-Monte Carlo (MCMC) simulations. The most recent stock assessment was conducted in 2014 for the fishing year ended 30 September 2013. The Shellfish WG determined a set of model runs where growth and natural mortality parameter values were fixed. The parameter values were thought to cover the plausible range of productivity assumptions for the stock. Markov chain-Monte Carlo (MCMC) simulations were conducted on a model agreed to by the SFWG. This particular model (6.1) estimated *M* within the model (with a lognormal prior with a mean of 0.1) but fixed the growth parameters at the medium value (g_1=20 mm, g_2=6 mm). On reviewing the results of the MCMC simulations the SFWG chose model 6.1 as the base case. The lack of comprehensive growth and length frequency data for PAU 3 and the lack of contrast in the CPUE series mean's uncertainty in the model outputs is higher than preferred.

4.1 Estimates of fishery parameters and abundance indices

Assumed prior distributions for model parameters are summarized in Table 6.

Table 6: 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
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 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 2000, 2002–2012.
4. 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 into 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 therefore daily fishing duration 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 >= 6 hours and number of divers >=2. This data subset was used for the CELR standardisation, using estimated daily catch and effort measured as either number of divers or 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. The diver duration measures the number of hours fished per diver day.

FIN codes were used to select a core group of fishers from the CELR data, with the requirement that there be a minimum of 6 records per year for a minimum of 2 years to qualify for the core fisher group. This retained 84% 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 2 years. This retained 84% 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 (018, 020, 022), month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. Variables accepted into the model were fishing year, month, FIN, and fishing duration. Following previous standardisations, no interaction of fishing year with area was entered into the model as the stock assessment for PAU 3 is a single area model. However, a separate standardisation is also done where a year:area interaction is forced in. Forcing in a year:area interaction indicates that there are differences in standardised CPUE between the area 018 and the two areas 020 and 022. However, in the years where they differ there are very few records to estimate the year effects for areas 020 and 022.

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. All the variables were accepted into the final model.

The standardised CPUE from the CELR data is flat from 1990 to 1994, shows a rise of 20% from 1995 to 1998, then declines for the next three years to 2001 (Figure 3–top). The standardised CPUE from the PCELR data shows a gradual decline of 10% from 2002 to 2013 (Figure 3–bottom).

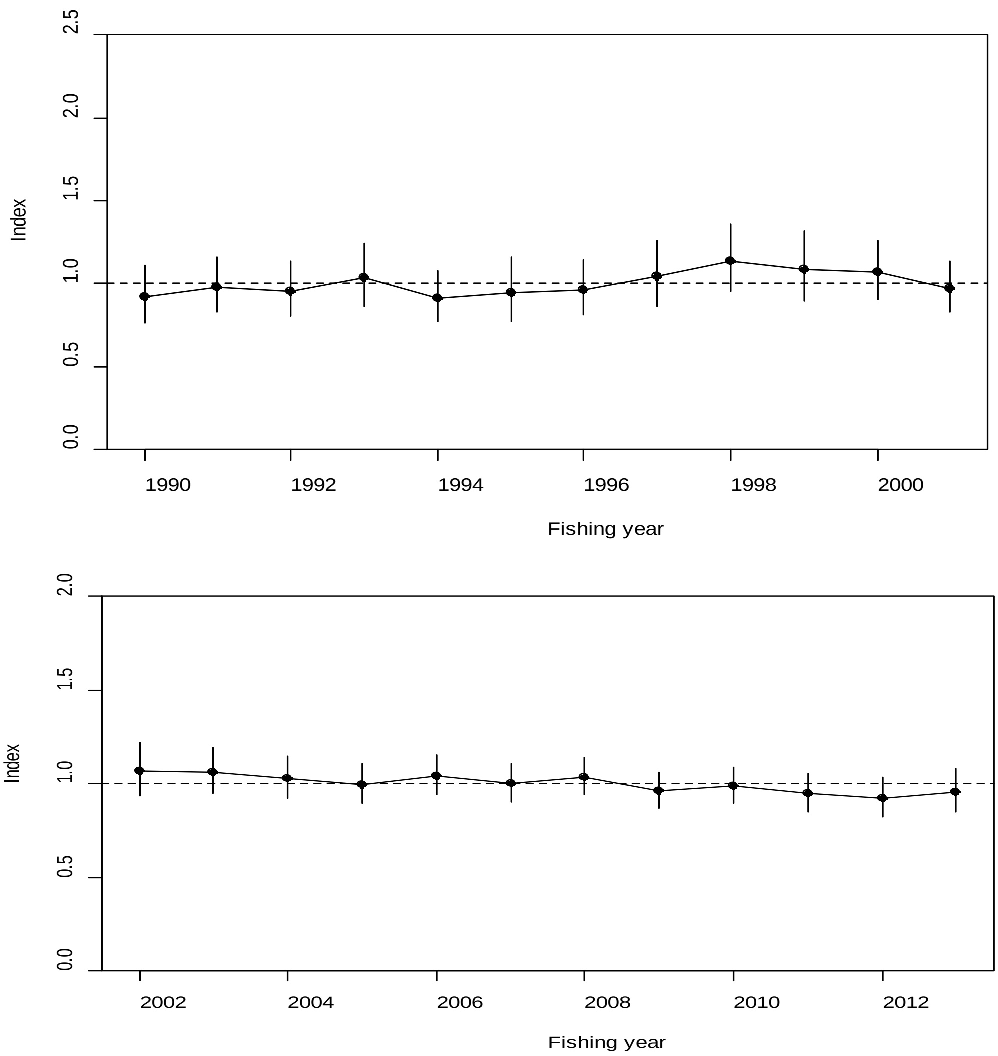


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series (top panel) and the recent PCELR series (bottom panel).

4.2 Stock assessment methods

The 2013 PAU 3 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). This is the first assessment for PAU 3 using the length based Bayesian model (Fu 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 transition among length classes at each time step. Paua enter the model following recruitment and are removed by natural mortality and fishing mortality.

The models were run for the years 1965–2013. Catches were collated for 1974–2013, 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 at 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. A relationship may exist on small geographical scales, but not be apparent when large geographical scales are modelled (Breen et al 2003). 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 growth data available to the PAU 3 assessment were collected from several sites in Banks Peninsula. Because most of the paua measured in this experiment were stunted, incorporating these data in the assessment would under-estimate the growth for the whole stock. There were also some growth measurements from an experiment conducted in Cape Campbell (within PAU 7) which is close to the northern boundary of PAU 3, but the sample size is too small to be useful. Therefore the growth parameters were fixed in this assessment.

The growth parameter were fixed at low ($g_1=15$ mm, $g_2=4.5$ mm), median ($g_1=20$ mm, $g_2=6$ mm), and high ($g_1=25$ mm, $g_2=7.5$ mm) values. The median values were based on the estimates of growth using the tag-recapture data from Cape Campbell (Fu 2014). The low and high values were loosely based on the range of growth estimates from assessments of other paua stocks. For each fixed value of the growth parameters, natural mortality was fixed at three levels, 0.1, 0.15, and 0.2. These values were considered to have covered the plausible range of natural mortality for paua. In total nine model runs were carried out. The growth and natural mortality parameter values aimed to evaluate the sensitivity of model results to key productivity assumptions and to estimate uncertainty in stock status. Each model run was considered an equally likely scenario. The models were fitted to the data with parameters estimated at the mode of their joint posterior distribution (MPD).

Markov chain-Monte Carlo (MCMC) simulations were conducted on a model agreed to by the SFWG in order to obtain a large set of samples from the joint posterior distribution. This particular model (6.1) estimated *M* within the model (with a lognormal prior with a mean of 0.1) but fixed the growth parameters at the medium value (g_1=20 mm, g_2=6 mm).

The assessment calculates the following quantities from the posterior distributions: the equilibrium spawning stock biomass with recruitment equal to the average recruitment over the period for which recruitment deviations were estimated (B_0,); and 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}
- $\Pr(B_{proj} > B_{2013})$ — 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}
- $\Pr(B_{proj} > B^r_{2013})$ — 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

For the nine model runs in which growth and natural mortality were fixed B_0 ranged from 1500 t to 2900 t, and $B_{current}$ ranged from 21% to 66% of B_0 (Table 7). All model runs showed an overall deceasing trend in spawning stock biomass but this trend has become slower in recent years (Figure 4). In general, models with higher values for *M* and growth had higher estimates of initial and current biomass, and models with lower *M* and growth had lower estimates of biomass.

When *M* was fixed at 0.1, the models fitted the CSLF and CPUE data poorly. Model fits improved markedly when *M* was increased to 0.15 or 0.20. The SFWG believed that 0.15 is probably more credible than 0.2 for the natural mortality of paua. Model fits and likelihood function values did not provide a clear distinction among low, median, or high growth values. Estimates of stock depletion levels were sensitive to the assumed value of the growth parameters.

For model (6.1), the posterior of *M* had a median of 0.14 with a 90% credible interval between 0.12 and 0.15. The posterior distributions of spawning stock biomass showed a gradual declining trend (Figure 5), estimated B_0 was about 2670 t (2470–2960t) and $B_{current}$ was about 52% (45–60%) of B_0 (Table 8). The SFWG agreed for this model to be adopted as the base case model, but noted that the model underestimates uncertainty in stock biomass and status because of uncertainty in growth.

The estimates of recruitment deviations showed a period of relatively low recruitment between 1980 the 1990 and recruitment in recent years (after 2002) has been above the long term average. Exploitation rates showed a gradual upward trend since the 2000s, and the estimated exploitation rate in 2013 was about 0.16 (0.09–0.14) (Table 8).

Model projections, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will slightly decrease to about 51% (41–63) of B_0 over the next three years (Table 9). The projections indicated that the probability of the spawning stock biomass being above the target (40% B_0) over the next three years is close to 100%

Table 7: MPD estimates of B_0, B_{2013}, and U_{2013} for models 3.1–3.3, 4.1–4.3, and 5.1–5.3.

Model	M	g_1	g_2	B_0	B_{2013}	B_{2013}/B_0	U_{2013}
3.1	0.10	25	7.5	2344	488	0.21	0.32
3.2	0.10	20	6	2460	672	0.27	0.26
3.3	0.10	15	4.5	2916	1231	0.42	0.17
4.1	0.15	25	7.5	1795	474	0.26	0.39
4.2	0.15	20	6	1965	718	0.37	0.30
4.3	0.15	15	4.5	2452	1262	0.51	0.21
5.1	0.20	25	7.5	1497	520	0.35	0.40
5.2	0.20	20	6	1767	848	0.48	0.30
5.3	0.20	15	4.5	2594	1708	0.66	0.18

Table 8: Summary of the marginal posterior distributions of key biomass indicators from the MCMC chain from the base case (Model 6.1). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	5%	Median	95%
B_0	2470	2666	2957
B_{msy}	687	741	834
B_{2013}	1133	1390	1727
B_{2013} $\%B_0$	45	52	60
B_{2013} $\%B_{msy}$	163	187	214
B_{msy} $\%B_0$	27	28	29
rB_0	1700	1880	2100
rB_{msy}	78	126	195
rB_{2013}	502	657	874
rB_{2013}/rB_0	0.28	0.35	0.43
rB_{2013}/rB_{msy}	3.22	5.17	9.32
rB_{msy}/rB_0	0.04	0.07	0.09
MSY	116	131	155
$U_{40\%B0}$	0.39	0.56	0.79
U_{msy}	0.19	0.25	0.34
U_{2013}	0.12	0.16	0.21

Table 9: Summary of current and projected indicators for the base case with future commercial catch set to current TACC: 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).

	2013	2014	2015
Bt	1390 (1088–1858)	1379 (1067–1855)	1371 (1041–1847)
$\%B_0$	52 (43.9–62.0)	51.5 (42.9–62.0)	51.3 (41.2–63.1)
$\%B_{msy}$	187 (158–218)	185 (155–220)	184 (149–224)
$Pr(>B_{msy})$	1.00	1.00	1.00
$Pr(>B_{current})$	0.35	0.32	0.32
$Pr(>40\%B_0)$	1.00	0.99	0.99
$Pr(<20\%B_0)$	0.00	0.00	0.00
$Pr(<10\%B_0)$	0.00	0.00	0.00
rB_t	657 (481–946)	643 (462–926)	626 (443–915)
$\%rB_0$	34.9 (26.7–45.5)	34.1 (25.2–44.6)	33.2 (24.1–43.9)
$\%rB_{msy}$	517 (295–1045)	504 (283–1035)	491 (273–1019)
$Pr(>rB_{msy})$	1.00	1.00	1.00
$Pr(>rB_{current})$	0.12	0.09	0.05
$Pr(U_{proj>}U_{40\%B0})$	0.03	0.04	0.05

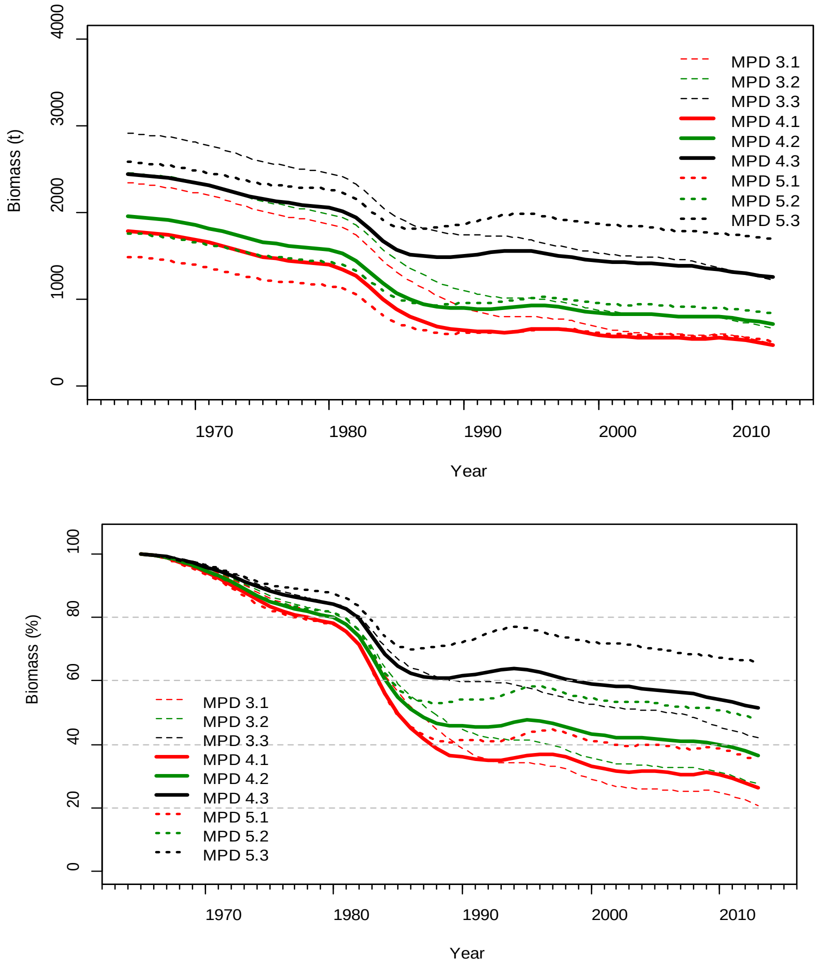


Figure 4: Estimates of spawning stock biomass (top panel) and spawning stock biomass as a ratio of B_0 (bottom panel) for MPD models 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, and 5.3.

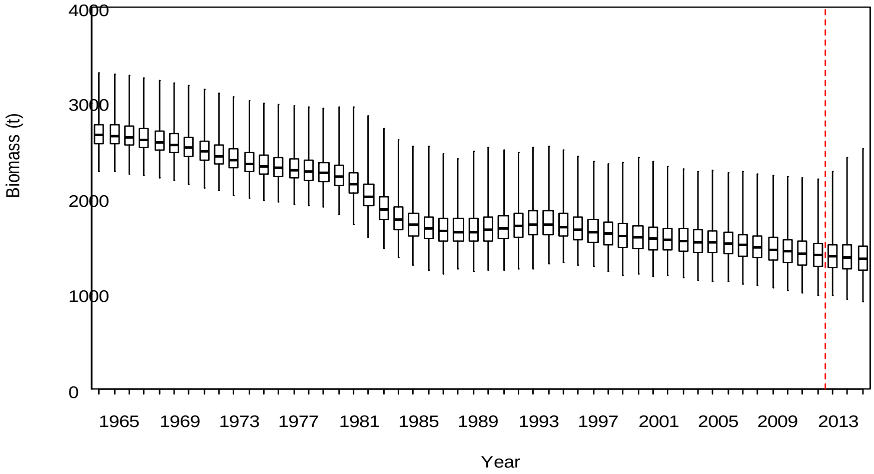


Figure 5: Posterior distributions of spawning stock biomass (top panel) and spawning stock biomass as a percentage of virgin level (bottom panel) from MCMC 6.1 (including projections). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution [Continued on the next page]

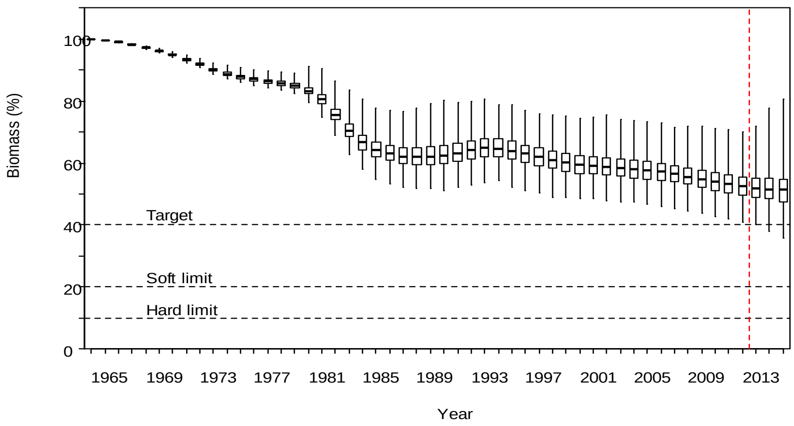


Figure 5 [Continued]: Posterior distributions of spawning stock biomass (top panel) and spawning stock biomass as a percentage of virgin level (bottom panel) from MCMC 6.1 (including projections). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

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 suggests that CPUE is difficult to use in abalone 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 decreasing. In PAU 3, both the early and recent CPUE indices have shown a relatively flat trend (the recent CPUE decreased slightly). It is unknown to what extent the CPUE series tracks stock abundance in PAU 3. Information from commercial fishers indicates that the stock is in relatively good shape suggesting that the trend in CPUE series may be credible.

Even if the CPUE indices are credible, they are not very useful in informing estimates of B_0 in this case because they have shown a relatively flat trend. Therefore the catch sampling length frequencies are the most important observations that provide information on the initial size of the stock. The catch sampling coverage in PAU 3 is considered to be reasonably adequate and the CSLF data are likely to have been representative of the stock.

Another source of uncertainty is the catch data. The commercial catch is known with accuracy since 1985, but is probably not well estimated before that. In addition, non-commercial catch estimates are poorly determined. The estimate of illegal catch is uncertain. Anecdotal evidence suggested the recreational catch in PAU 3 is very likely to have increased substantially in recent years and could be much higher than what was assumed in the model. However, the increase in non-commercial catch (if it is true) has not been reflected in the recent CPUE indices, which showed an almost flat trend. One possible reason is that the commercial divers may have fished deeper than recreational fishers, and could be fishing on different sections of the population. If there is substantial bias in estimates of catches, the model could significantly under-estimate the stock depletion level. Therefore better information on the scale and trend in recreational catch needs to be collated for more accurate assessment of the stock status.

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

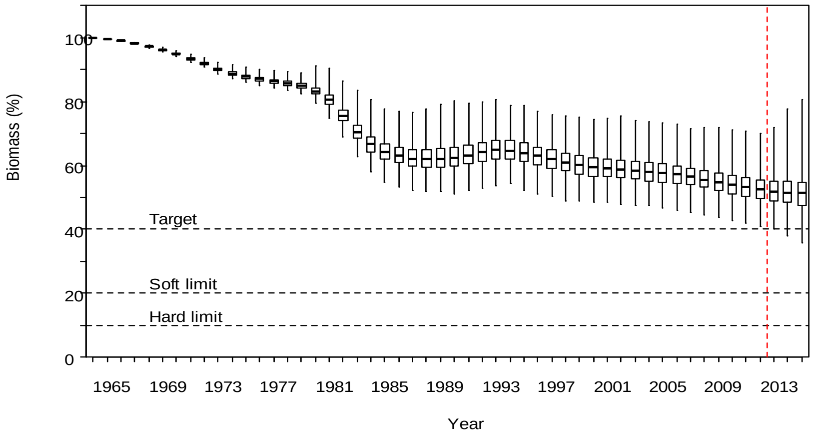
Stock Structure Assumptions

PAU 3 is assumed to be a homogenous stock for purposes of the stock assessment however there is evidence to show this may not be correct (Naylor et al 2006).

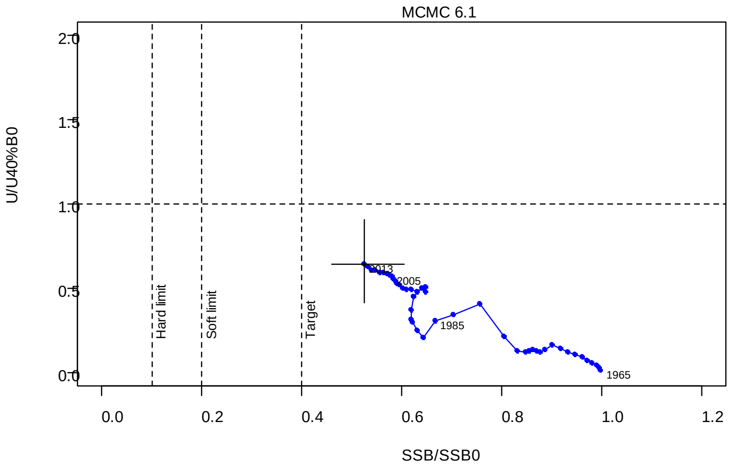
- **PAU 3 - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MCMC 6.1 base case (*M* estimated, g_1 fixed at 20 mm and g_2 fixed at 6.0 mm)
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} estimated to be 52% B_0 : Very Likely (> 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 of spawning stock biomass as a percentage of virgin level from MCMC 6.1 (including projections). 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 6.1 (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 B0) 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 median and the 2013 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning stock biomass has shown an overall deceasing trend but this has become much slower in recent years.
Recent Trend in Fishing Intensity or Proxy	The exploitation rate has shown a gradual upward trend since the 2000s and was about 0.16 (0.09–0.14) in 2013.
Other Abundance Indices	Standardised CPUE remained relatively flat until the early 2000s, and has declined only slightly since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low between 1980 and 1990 but since 2002 has been above the long term average.

Projections and Prognosis	
Stock Projections or Prognosis	The projected spawning stock abundance will slightly decrease over the next three years but will still be remaining above the target
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Results from all model runs suggest it is very unlikely (< 10%) that current catch or TACC will cause a decline below the limits.
Probability of Current Catch or TACC causing 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: 2017
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 catch, which is not believed to be fully representative over the history of the fishery
	- CPUE indices early series	2 – Medium or Mixed Quality: not believed to proportional to abundance
	- CPUE indices later series	1 – High Quality
	- Commercial sampling length frequencies	1 – High Quality
	- Tag recapture data (to estimate growth)	2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA
	- Maturity at length data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	- Very little growth data available and growth is not well known. - CPUE may not be a reliable index of abundance. - The model treats the whole of the assessed area of PAU 3 as if it were a single stock with homogeneous biology, habitat and fishing pressures. - Recreational catch in PAU 3 is very likely to have increased substantially in recent years and could be much higher than what was assumed in the model.	

Qualifying Comments:
-The lack of comprehensive growth and length frequency data for PAU 3 and the lack of contrast in the CPUE series cause uncertainty in the model outputs.

-The SFWG agreed to adopt model 6.1 as the base case model, but noted that the model underestimates uncertainty in stock biomass and stock status because of uncertainty in growth.

Fishery Interactions
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6. FOR FURTHER INFORMATION

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