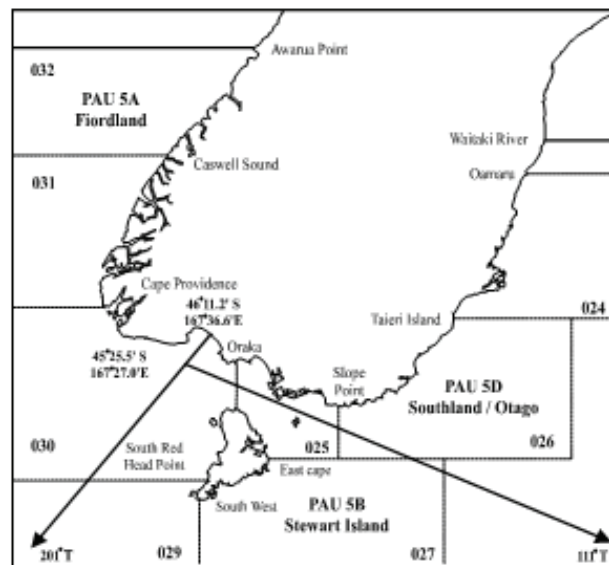


PAUA (PAU 5D) – Southland / Otago

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

1.1 Commercial fishery

PAU 5 was introduced into the Quota Management System in 1986–87 with a TACC of 445 t, which increased to 492 t by 1992 as a result of Quota appeals. Concerns about the status of the PAU 5 fishery led to a voluntary 10% reduction in the TACC in 1992–93. For 1995–96, PAU 5 was divided into three sub-stocks (see the figure above: PAU 5A, Fiordland, PAU 5B, Stewart Island, and PAU 5D, Otago).

The TACC was divided equally among the new stocks; the quota for PAU 5D was set at 147.66 t. It is widely considered that this led to a large redistribution of catch from Stewart Island to Fiordland and the Catlins/Otago coast (Elvey *et al.* 1997). The exact increase in catch in the new PAU 5D caused by subdivision cannot be determined with certainty because several Statistical Areas used to report catch and effort straddled 5B and 5D (Figure above, Kendrick & Andrew 2000). Commercial landings used in the assessment are shown in Table 1. In this report, the fishing year is referred to using the second part, *viz* 2002–03 is termed “2003”.

Table 1: TACC and reported landings (t) of paua in PAU 5D from 1995–96 to 2008–09. 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

In recent years the commercial paua fishery has implemented a number of voluntary management actions in most QMAs. Agreement to these actions has been formalised within each QMA through the development of an Annual Operational Plan (AOP) that is agreed to and signed by all Quota and ACE holders within the fishery. The plan explains the voluntary management actions that will be

PAUA (PAU 5D)

undertaken for the fishing year. The main actions of the AOP for PAU 5D for the 2009-10 fishing year are outlined below.

Total Allowable commercial catch (TACC)	89,000 kilos		
	North of Moeraki Boulders to Pau3 boundary	Warrington Beach North to Moeraki Boulders	Warrington Beach South to Pau5A boundary
Statistical Area	H44 to H47	H38 to H43	H37 to H1
Minimum harvest size	125mm	127mm	130mm
Data Collection – CATCH SAMPLING	Each fishing operation is asked to collect a minimum of 2 samples (“red bag” sample kits will be supplied) during the course of their fishing year.		
Data Collection – DATA LOGGERS	In the 2009/2010 year a select number of divers from each QMA will be asked to participate in the data logger project using the 2 nd generation loggers. This will lead to an expanded programme in the future.		
General Operating Procedures	Details of procedures are available in the AOP		

1.2 Recreational fisheries

The two National Marine Recreational Fishing Surveys estimated that 120,000 and 191,000 paua were taken by recreational fishers from PAU 5D in 1999-2000 and 2000-2001. An earlier survey in 1996 provided a recreational harvest for whole of PAU 5 and no estimate was available for PAU 5D. At an average weight of 357 g, these numbers equate to a recreational harvest of 42.8 t in 1999–00 and 68.2 t in 2000-01. The Marine Recreational Fisheries Technical Working Group considered that some harvest estimates from these two national surveys for some fish stocks were unbelievably high. The Shellfish Fisheries Working Group (SFWG) considered estimates from the national recreational surveys conducted in 1996 and 1999-2001. The SFWG considered that the estimates were unbelievably high, and agreed to assume that for the purpose of the stock assessment model that the 1974 recreational catch was 2 t, increasing linearly to 10 t in 2005.

On the catch and effort forms used since 2002, fishers can report paua they land as part of a recreational catch entitlement (destination code “F”). The sum of such catches for 2002 through the partial data for 2006 was only 173 kg for PAU 5D.

1.3 Customary non-commercial fisheries

There is an important customary use of paua by Maori for food, and the shells have been used extensively for decorations and fishing devices. Records of customary catch taken under the authority of customary fishing permits show that 0.7 t–1.3 t were taken annually between 1998–99 and 2004–05. 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.

1.4 Illegal catch

Illegal catch was estimated by the Ministry of Fisheries (MFish) to be 20 t. No historical estimates are available so these estimates were used for the whole period modelled. 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.

1.5 Other sources of mortality

Refer to the Paua introduction Working Group Report

2. BIOLOGY

Refer to the Paua introduction Working Group Report.

A summary of biological parameters used in the PAU 5D assessment is presented in Table 2.

Table 2: Estimates of biological parameters (*H. iris*).

Fishstock	Estimate	Source
1. Natural mortality (<i>M</i>)	0.114 (0.095–0.140)	Median (5–95% range) of posterior estimated by the model (run 053)
2. Weight = $a(\text{length})^b$ (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 80 mm (78–81) 95% maturity at 93mm (89–98)	Median (5–95% range) of posterior estimated by the model Median (5–95% range) of posterior estimated by the model
4. Estimated annual increments (both sexes combined)	at 75 mm 19.6 (18.8–20.8)	at 120 mm 8.2 (7.9–8.7)
		Median (5–95% range) of posteriors estimated by the model

3. STOCKS AND AREAS

PAU 5D was created in 1995 when PAU 5 was divided into three sub-areas, each with a TACC of 147.66 t. From 1 November 1997, catch in PAU 5D was reported in 11 statistical areas, and on 1 October 2001 it became mandatory to report catch and effort from 47 fine-scale reporting areas developed by the New Zealand Puaa Management Company for their voluntary logbook and subsequently adopted on MFish CELRs. The present fishstock boundaries may not represent a single discrete puaa stock.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

CPUE is available from two series of data: the CELR through 2001 and the subsequent PCELR series from 2002. The first series has coarse area and effort information: three statistical areas and diver day; the second series has 47 small reporting areas and effort in diver hours, and the divers are identified in the second series. The second series can be treated as a separate series by using an extra parameter for catchability; this was done in 2005 for PAU 7. For the 2006 PAU 5D assessment, after exploration of the CPUE data and discussion with the SFWG, it was agreed to standardise CPUE as a single series.

CPUE in PAU 5D declined for the first 15 years after the introduction of the QMS, but appears relatively stable since the creation of PAU 5D (Table 3). Because the uncertainty associated with early CPUE was very large, and the differences between raw and standardised CPUE were large for early years, only the indices for 1989 and later were used in the assessment.

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

The relative abundance of puaa in PAU 5D has also been estimated from research surveys (Andrew *et al.* 2000a, 2000b, 2002) (Table 4). This is called the research diver survey index (RDSI). Relative abundance increased between 1994 and 1997, decreased strongly to 1999 and increased again to 2004.

PAUA (PAU 5D)

Table 3: Unstandardised and standardised catch per unit effort (CPUE) in PAU 5D (kg per diver-day).

Year	Unstandardised CPUE	Standardised CPUE
1983–84	108.9	141.2
1984–85	74.5	107.5
1985–86	167.1	128.8
1986–87	103.8	110.3
1987–88	150.3	275.6
1988–89	171.5	166.5
1989–90	162.3	153.4
1990–91	161.5	149.9
1991–92	141.1	138.9
1992–93	160.6	160.2
1993–94	153.9	147.3
1994–95	147.5	136.7
1995–96	134.7	127.0
1996–97	128.1	120.3
1997–98	114.7	101.2
1998–99	160.7	145.0
1999–00	135.0	128.2
2000–01	129.9	118.2
2001–02	122.1	119.9
2002–03	113.5	112.7
2003–04	116.6	107.6
2004–05	135.4	118.4

Table 4: Raw and standardised research diver survey indices (kg/diver-day) and 95% confidence limits (1.96 standard errors) for sites surveyed in PAU 5D. – indicates no data collected.

Year	Raw	Standardised		
		2.5%	mean	97.5%
1993–94	107.7	79.4	129.3	210.6
1994–95	–	–	–	–
1995–96	–	–	–	–
1996–97	142.5	84.7	178.6	376.8
1997–98	–	–	–	–
1998–99	68.9	35.6	56.2	88.5
1999–00	–	–	–	–
2000–01	67.5	44.2	70.0	110.7
2001–02	–	–	–	–
2002–03	–	–	–	–
2003–04	113.2	57.0	89.1	139.3

4.2 Assessment model for PAU 5D

The model used for the 2006 assessment of PAU 5D was the same model used for the 2005 assessment of PAU 7 (Breen & Kim 2005). The model was published by Breen *et al.* (2003). In this assessment (Breen & Kim 2007), experimental fits were made with the previous model used to assess PAU 5D (Breen *et al.* 2003) using the new data, and using the old data set with the new model. These showed that changes in data, and new data, accounted for most of the changes in results.

4.2.1 Model structure

The model generates a population and simulates its dynamics through 32 years of fishing, growth, natural mortality and recruitment. The model’s mid-season recruited biomass is fitted to the observed CPUE indices, and an index of numbers above 90 mm shell length is fitted to the analogous observed index from research diver surveys. The model’s mid-season population length structure is fitted to observed length distributions from commercial catch sampling and research diver surveys. Outputs are the present and projected states of the stock. The assessment is based on the marginal posterior distributions of the parameters and derived parameters of interest. Males and females are not modelled separately.

Growth is modelled as a stochastic transition matrix calculated from the estimated growth parameters, which include parameters for variation in growth. A contribution to the total likelihood function comes from comparison of observed and expected increments in the tag-recapture data. Research diver and commercial fishery selectivity-at-size are modelled with two estimated parameters for each. Maturity-at-size is estimated with two parameters.

Recruitment is modelled as an estimated baseline value with estimated annual deviations. These have an assumed mean and standard deviation; this and other assumptions make the model Bayesian. No stock–recruit relationship is estimated and projections are made by re-sampling recruitment from the recent past.

The model was fitted to six data sets from PAU 5D: standardised CPUE, standardised research diver survey index (RDSI), length frequencies from catch sampling and population surveys (CSLF and RDLF), tag–recapture data and maturity data. The model estimates a common error term and each dataset can be given a relative weight that does not affect the model’s overall uncertainty. Iterative re-weighting is used to obtain standard deviations of standardised residuals equal to unity for each dataset.

The model is driven by catch: exploitation rate is calculated from observed catch and model biomass. A point estimate of the mode of the joint posterior distribution (MPD) serves as the starting point for the Bayesian estimations and as the basis for some sensitivity tests. MCMC simulations are used to estimate the marginal posterior distributions of model parameters, indicators and state of the stock. Indicators are based on current and projected states of the stock, and comparisons with a reference period, for both spawning and recruited biomass.

Sensitivity trials involved one of the five runs comprising the assessment, removing each of the six data sets in turn, using an alternative growth model and exploration of other modelling choices. Retrospective analyses were based on MPD estimates.

4.2.3 Data used in the assessment

Catch rate and catch history are presented in Kendrick & Andrew (2000). Generation of a catch vector for PAU 5D, before 1995, required assumptions to be made about the division of commercial catch from statistical areas 25 and 30 to PAU 5B. This assessment follows the methodology from the previous 2005 assessment.

For the assessment, the SFWG agreed to assume that 1974 recreational catch was 2 t for PAU 5D, increasing linearly to 10 t in 2005 and that customary and illegal catches have been constant at 2 t and 10 t, respectively.

The catch vector (sum of all these components) is shown in Figure 1.

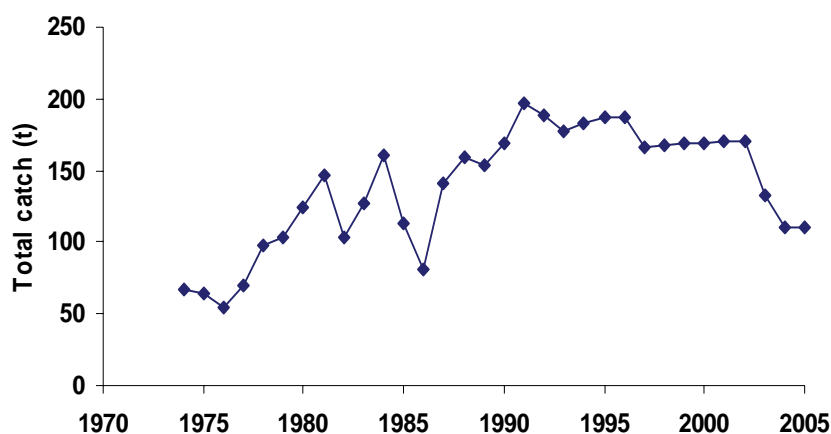


Figure 1: Assumed catch (t) used in the PAU 5D assessment in 2006.

A vector of standardised CPUE (Table 3) was generated using a multiple regression model (Vignaux 1993). The standardisation model accounted for 19% of the total variation in observed CPUE and deviated little from the pattern of decline in raw CPUE after 1989 (Figure 2). The research diver survey index (RDSI) was standardised similarly, accounting for 11% of the variation (Figure 3).

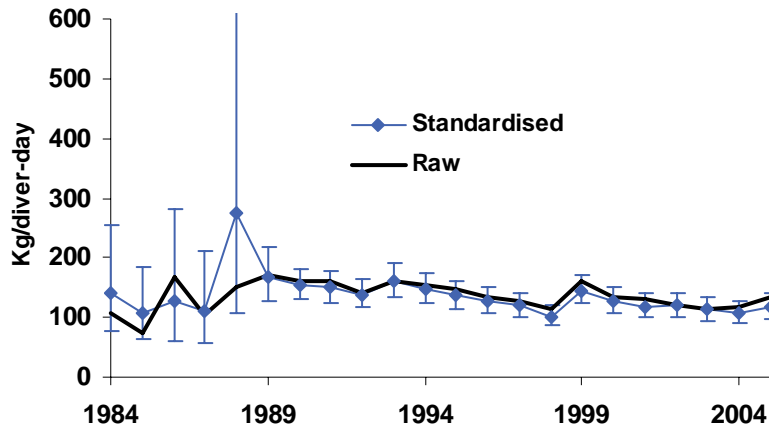


Figure 2: Raw (black line) and standardised (diamonds) CPUE (kg per diver-day), with 5% and 95% bars, for PAU 5D.

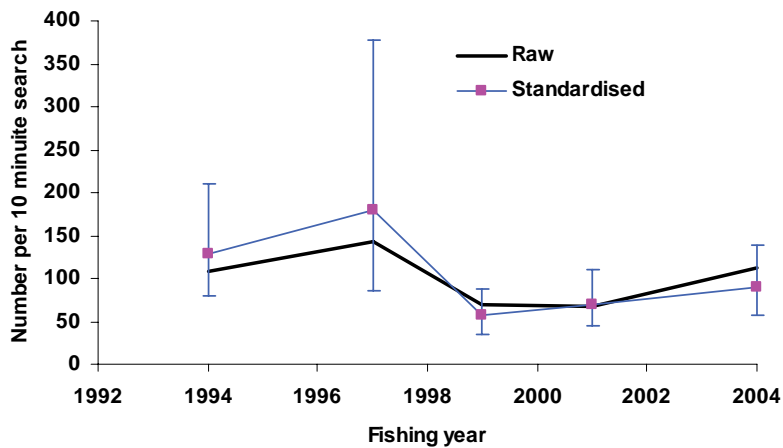


Figure 3: Raw (black line) and standardised (squares) RDSI (number per search), with 5% and 95% bars, for PAU 5D.

Assessment model parameters and their priors and bounds for run 053 are given in Table 5. Two growth parameters were fixed because experience had shown that the growth model was over-parameterised. The research diver selectivity parameters were fixed because the free parameter estimates were not credible. Results were sensitive to the value at which T50 was fixed, and the values chosen were those estimated for PAU 7 in 2005 (Breen & Kim 2005).

The length-weight relationship is given in Table 2. It was assumed that exploitation could not exceed 0.65; the MPD estimates did not reach this value; MCMC results rarely struck this value; projections sometimes struck this value. Weights for datasets were adjusted iteratively.

Table 5: Parameters estimated in the model and their prior distributions.

Model parameters	Definition	Priors and bounds
$\ln(R0)$	Natural logarithm of base recruitment	Uniform, bounds 5, 50
M	Natural mortality	Lognormal with mean 0.10, CV 0.35, bounds 0.01, 0.50
\mathcal{G}_{75}	Expected annual growth increment at 75 mm	Uniform, bounds 1, 50
\mathcal{G}_{120}	Expected annual growth increment at 120 mm	Uniform, bounds 0.01, 50
α	CV of expected growth increments	Uniform, 0.001, 1
σ_{MIN}	Minimum std. dev. of growth increment	Fixed to 1 in this assessment
σ_{obs}	Standard deviation of observation error for tags	Fixed to 0.25 in this assessment
T_{50}	Length at which research diver selectivity is 50%	Fixed to 100 in this assessment
T_{95-50}	Distance between lengths at which research diver selectivity is 95% and 50%	Fixed to 19 in this assessment
L_{50}	Length at which maturity is 50%	Uniform, bounds 70, 145
L_{95-50}	Distance between lengths at which maturity is 95% and 50%	Uniform, bounds 1, 50
D_{50}	Length at which commercial diver selectivity is 50%	Uniform, bounds 70, 145
D_{95-50}	Distance between lengths at which commercial selectivity is 95% and 50%	Uniform, bounds 0.01, 50
$\ln(q^I)$	Scalar between recruited biomass and CPUE	Uniform, bounds -30, 10
$\ln(q^J)$	Scalar for the RDSI	Uniform, bounds -30 and 0 Normal, mean 0
ε_t	Vector of recruitment deviations in log space	Bounds -2.3 and 2.3, CV 0.4
$\tilde{\sigma}$	Common standard deviation of observation error	Uniform, 0.01, 2.0
h	Shape of the relation between biomass and CPUE	Uniform bounds 0.01 and 2

4.2.4 Projections

The SFWG requested that both 3 and 5 year projections be made. Recruitment for projections were obtained by randomly re-sampling the model's estimates from 1992 through 2004. Projected catches were the 2005–06 catch estimates. The minimum legal size was set in projections at either the current value, 125 mm, or increased to 127 mm at the request of the SFWG.

4.2.5 Fishery indicators

The assessment is based on the following indicators calculated from their posterior distributions: the model's mid-season recruited and spawning biomass from 2005 (current biomass) (B_{05} and S_{05}), from 2008 and 2010 (projected biomass) (B_{08} , B_{10} , S_{08} and S_{10} , from the nadir of the population trajectory (B_{MIN} and S_{MIN}) and from a reference period, 1989–96. This was a period when exploitation rate and the recruited biomass were relatively stable. The means of values from this period were called S_{AV} and B_{AV} for spawning and recruited biomass respectively. We also used annual exploitation rate in 2005, U_{05} , and U_{08} and U_{10} . Ratios of these reference points are also used.

Additional indicators were calculated as the probability that, or percentage of runs in which:

- projected spawning biomass had decreased from 2005: $P(S_{08} < S_{05})$, $P(S_{10} < S_{05})$,
- projected spawning biomass was less than the reference level: $P(S_{08} < S_{AV})$, $P(S_{10} < S_{AV})$
- projected spawning biomass was less than the nadir: $P(S_{08} < S_{MIN})$, $P(S_{10} < S_{MIN})$
- projected recruited biomass had decreased from 2005: $P(B_{08} < B_{05})$, $P(B_{10} < B_{05})$
- projected recruited biomass was less than the reference level: $P(B_{08} < B_{AV})$, $P(B_{10} < B_{AV})$
- projected recruited biomass was less than the nadir: $P(B_{08} < B_{MIN})$, $P(B_{10} < B_{MIN})$

4.2.6 Stock assessment results

Research diver selectivity parameters were problematic in that the estimates were unrealistically high. This was addressed by fixing the parameters to the PAU 7 estimates. After that, the procedure of iteratively re-weighting the data sets to obtain normalised residuals with a standard deviation near one worked well.

PAUA (PAU 5D)

Five runs are shown in this report because results were sensitive to the growth model and to one data set in particular. The five runs result from using all data sets with the linear growth model (run1), using the linear growth and excluding the research diver survey length frequency data (run2), using all data sets with the exponential growth model (base3), using the linear model but excluding the tagging data (run4), and using the linear growth model but placing extra weight on last two years of both abundance indices (run5). For all runs except run2 and run3, M was near the mean of its prior. Fits were generally good, and the model estimated a substantial hyperstability.

Sensitivities of model outputs, inputs and assumptions were explored using run1 and the MPD estimates. Removal of the CPUE dataset had a small pessimistic effect, increasing the exploitation rate and decreasing biomass estimates. Removal of the RDSI dataset also had a somewhat pessimistic effect. Removal of the catch sampling length frequencies gave slightly more optimistic results. Removal of the research diver survey length data caused the most dramatic differences seen in these trials: estimated M became very large, biomass increased while exploitation rates decreased, and the current biomass was 30-45% larger than minimum biomass levels.

When both the research diver datasets were removed, the effect was similar to the exclusion of the length data. Conversely, when both commercial datasets were removed, the assessment became slightly more optimistic. Removal of the tag-recapture data led to an improvement in the fit to commercial length data (but not to other), increased growth rates but decreased growth variability, and a more pessimistic assessment.

These dataset trials are summarised in Table 6. The RDSI and tag-recapture datasets produce optimistic effects (when they are omitted the results are more pessimistic); other datasets and combinations produce more pessimistic results; CPUE has little effect. The RDLF dataset is the one to which the model is most sensitive.

Table 6: Summary of the effects of PAU 5D datasets as deduced from sensitivity trials.

Dataset Removed	Direction of effect	Magnitude of effect
CPUE	nil	nil
RDSI	optimistic	moderate
CSLF	pessimistic	slight
RDLF	pessimistic	very strong
RDSI+RDLF	pessimistic	very strong
CPUE+CSLF	pessimistic	slight
Tag-recapture	optimistic	slight

MPD retrospective analyses made from run1 suggested that bias or model mis-specification were not problems with this assessment.

The model provided reasonably good fits to CPUE and the proportions-at-length from commercial catch sampling, but not as good a fit to proportions-at-length from the research diver survey, and a poor fit to the research diver survey index.

MCMC diagnostics were generally good, and the posteriors showed few correlations among estimated parameters: three among the growth parameters, between $\ln(R0)$ and M , and between catchability and h . Posteriors were well-formed.

Assessment results are summarised in Table 7. For simplicity, only the projections made under the current MLS are shown. When the MLS was changed to 127 mm in projections (for run1 only), recruited biomass (calculated with $MLS = 125$ mm for both 2005 and 2010) and spawning biomass were both larger when the minimum legal size was 125. More often than not, exploitation rate hit the upper bound of 65% and the catch specified could not be taken. Thus a main effect of increased minimum legal size for these projections was probably a *de facto* decrease in TACC for most runs.

Two different results are seen in the five runs. Two of them (run1 and run4) were pessimistic, showing the current state of the stock (first group of indicators), B_{05} , just above B_{MIN} while the other three were optimistic, showing the current state of the stock as well above B_{MIN} (ranged from 128.3% to

159.1%). Recent recruitment patterns varied among these runs, with strong consequences: biomass tends to decline in two run projections but increases strongly in three of the others.

In the two pessimistic runs, the model reached B_{MIN} in 2005 in nearly half the runs while in optimistic run, less than 5% of runs reached B_{MIN} in 2005. In all runs, current stock is well below the reference level. Spawning biomass is similar: a majority of runs have the minimum in 2005, for pessimistic base cases, but for the optimistic runs, a majority of runs are above S_{MIN} in 2005. The current level is below the reference level in all runs. The median of current exploitation rate is ranged from 27.5% to 45.3%.

Table 7: Summary of indicators (median and 5th and 95th quantiles) from runs MCMCs with 125 mm MLS in projections. Biomass indicators are in tonnes.

Parameter	Linear growth			No RDLF			Exponential growth		
	0.05	Run1 Median	0.95	0.05	Run2 Median	0.95	0.05	Run3 Median	0.95
2005									
S_{MIN}	271	366	489	687	1 056	1 526	348	479	633
S_{AV}	768	841	922	998	1 545	2 253	782	941	1 240
S_{05}	271	371	508	845	1 390	2 218	395	636	1 026
B_{MIN}	114	162	194	187	259	365	175	232	315
B_{AV}	392	430	472	371	513	700	464	554	717
B_{05}	114	173	256	245	365	533	190	300	456
U_{05} (%)	33.1	45.2	61.3	16.7	23.5	33.0	19.4	28.0	41.0
S_{05}/S_{AV} (%)	32.5	44.0	59.5	69.3	90.6	117.6	45.0	66.8	97.3
S_{05}/S_{MIN} (%)	100.0	100.0	110.2	106.0	131.5	168.5	100.7	132.2	186.6
B_{05}/B_{AV} (%)	26.6	40.3	59.6	53.7	71.7	90.3	36.6	53.6	74.6
B_{05}/B_{MIN} (%)	100.0	105.8	135.2	120.7	140.2	160.9	103.0	128.3	157.0

Parameter	No Tags			Fit to recent increase		
	0.05	Run4 Median	0.95	0.05	Run5 Median	0.95
2005						
S_{MIN}	276	374	503	509	568	632
S_{AV}	793	886	992	765	846	938
S_{05}	276	378	520	560	652	770
B_{MIN}	116	165	204	177	198	223
B_{AV}	398	449	505	392	434	480
B_{05}	116	172	257	278	316	359
U_{05} (%)	33.0	45.3	60.5	24.6	27.5	30.5
S_{05}/S_{AV} (%)	31.7	42.7	58.0	68.8	76.9	88.1
S_{05}/S_{MIN} (%)	100.0	100.0	108.2	103.9	114.4	130.2
B_{05}/B_{AV} (%)	25.9	38.4	56.8	65.2	72.9	81.7
B_{05}/B_{MIN} (%)	100.0	102.4	131.1	148.7	159.1	170.9

In five-year projections with the current level of catch and current minimum legal size (the second group of indicators), the median expectation is that recruited biomass will be only 74% of that in 2005 (40% to 173%) in pessimistic run. In the optimistic runs the expectation is for recruited biomass to increase over 146% (95.3% to 249.7%). About 30% of the runs increased in recruited biomass in pessimistic runs and more than 90% of the runs increased in optimistic runs; almost all remained less than the reference level for pessimistic runs while more than 28% reached the reference level for optimistic runs. More than 55% of runs fell below B_{MIN} for pessimistic runs and less than 4% fell below B_{MIN} for optimistic runs. Spawning biomass had a slight median increase (range 76% to 172% of 2005 levels); more than 55% of runs increased but more than 60% remained below the reference level. More than 24% of runs had spawning biomass falling below S_{MIN} for pessimistic runs but less than 6% of runs had spawning biomass falling below S_{MIN} for optimistic runs.

Five-year biomass projections were more optimistic than 3-year projections. All the median and probability indicators were more favourable, but the lower 5% and minima for many indicators tended to be worse, reflecting a widening of the distribution.

In the most favourable combination for run1, $MLS=127$ with 5-year projections, the chance of decreased recruited biomass is almost 50%, of remaining below the reference level 98%, of falling below B_{MIN} 37%. Spawning biomass is only 12% likely to decrease and 11% likely to fall below S_{MIN} , although highly likely to remain below the reference level. However, more than half these runs struck the maximum exploitation rate.

Table 8: Summary of projected indicators (median and 5th and 95th quantiles) from run MCMCs with 125 mm MLS in projections. Biomass indicators are in tonnes.

Parameter	Linear growth			No RDLF			Gilbert growth		
	0.05	Median	0.95	0.05	Median	0.95	0.05	Median	0.95
2010									
S ₁₀	278	426	684	893	1 423	2 233	415	738	1 225
B ₁₀	73	146	345	330	538	855	218	463	813
U ₁₀ (%)	25.4	49.2	65.0	11.4	17.4	26.7	11.8	19.8	36.9
S ₁₀ /S ₀₅ (%)	83.2	115.0	164.8	77.2	102.2	139.4	77.9	113.8	169.7
S ₁₀ /S _{AV} (%)	33.2	50.7	80.6	65.5	92.4	131.9	45.4	76.6	123.2
B ₁₀ /B ₀₅ (%)	45.4	84.6	178.0	95.3	146.4	237.2	91.3	147.9	249.7
B ₁₀ /B _{AV} (%)	16.8	33.9	81.0	65.3	104.6	170.9	40.5	81.4	143.1
P(S ₁₀ <S ₀₅)				45.4			31.0		
P(S ₁₀ <S _{AV})				99.5			81.7		
P(S ₁₀ <S _{MIN})				23.9			5.7		
P(B ₁₀ <B ₀₅)				63.3			8.5		
P(B ₁₀ <B _{AV})				98.7			71.9		
P(B ₁₀ <B _{MIN})				54.9			3.8		

Parameter	No Tags			Fit to recent increase		
	0.05	Median	0.95	0.05	Median	0.95
2010						
S ₁₀	265	420	698	604	804	1060
B ₁₀	66	124	329	321	469	665
U ₁₀ (%)	26.5	54.4	65.0	14.6	19.9	27.6
S ₁₀ /S ₀₅ (%)	75.9	110.9	172.0	99.9	123.4	150.6
S ₁₀ /S _{AV} (%)	30.1	47.3	78.9	72.0	95.0	124.1
B ₁₀ /B ₀₅ (%)	40.1	74.1	172.6	102.2	148.4	211.3
B ₁₀ /B _{AV} (%)	14.7	27.7	73.2	74.5	108.0	154.2
P(S ₁₀ <S ₀₅)				34.1		
P(S ₁₀ <S _{AV})				99.2		
P(S ₁₀ <S _{MIN})				33.1		
P(B ₁₀ <B ₀₅)				71.1		
P(B ₁₀ <B _{AV})				98.9		
P(B ₁₀ <B _{MIN})				65.1		

4.3 Biomass Estimates

Biomass estimates are summarised in Table 7 and discussed above. The model biomass trajectories (Figure 4) suggest that both spawning and recruited biomass are near their historical lows, which has been reached quite recently: this was a common conclusion in all runs. In pessimistic runs, the recruited biomass trajectory (Figure 4) shows a tendency to decrease for two years, then increase. In optimistic runs, it increases strongly.

The posterior summaries (Table 7&8) suggest that current spawning and recruited biomass are both substantially less than reference levels, and that current exploitation rate is in the range 33-60%. Projections made with the current catch and MLS suggest that spawning biomass is more likely to increase than not, over five years, with a 5% to 45% chance of decreasing, depending on the run case chosen. The chance of recruited biomass increasing is entirely dependent on the run case chosen, and ranges from 29% to 96%. At the current catch and MLS, there is little chance that the indicators will be above reference values in 5 years.

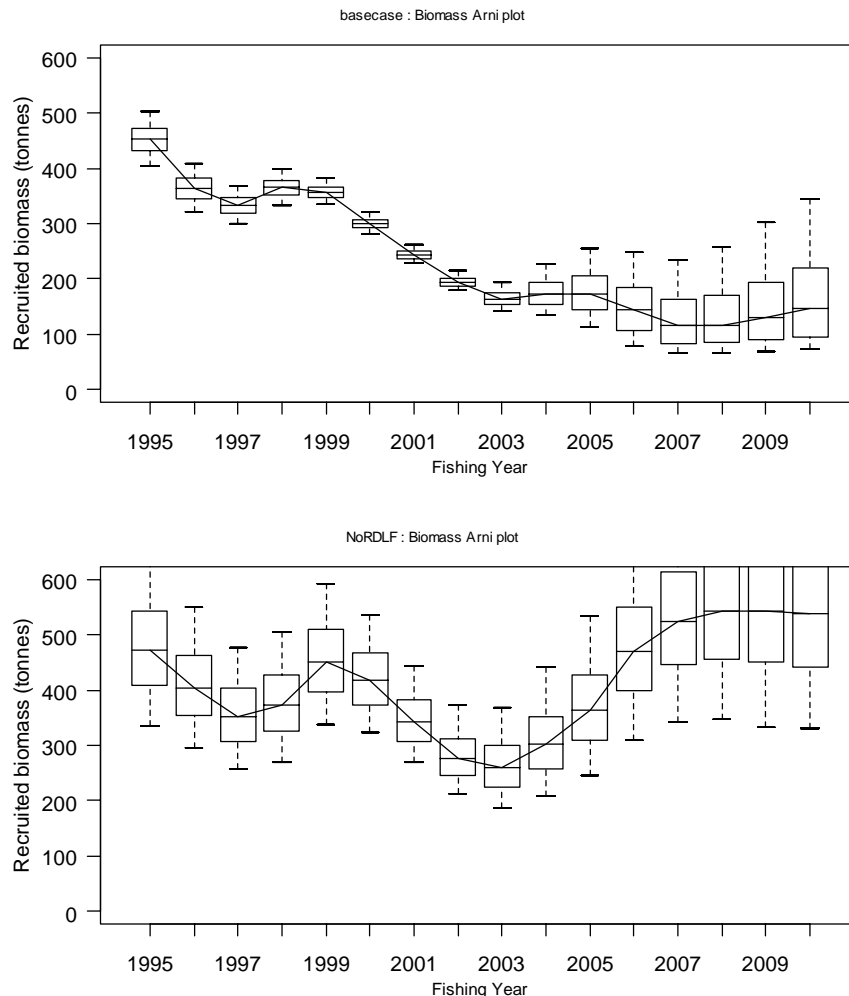


Figure 4: The posterior distributions of MCMC recruited biomass trajectory from 1995 onwards with a pessimistic run: linear growth model (base1, upper) and an optimistic run: no research diver survey data (base2, lower).

4.4 Estimation of Maximum Constant Yield (MCY)

No estimate of MCY has been made for PAU 5D. A range of more robust performance indicators is presented.

4.5 Estimation of Current Annual Yield (CAY)

No estimate of CAY has been made for PAU 5D. A range of more robust performance indicators is presented.

4.6 Other yield estimates and stock assessment results

Only the current catch was used in projections.

4.7 Other factors

The assessment results described above have more uncertainty than that reflected in the posterior distributions. Most uncertainty is associated with the RDLF data set, and much uncertainty also stems from the choice of growth model.

Another source of uncertainty is the data. The commercial catch before 1974 is unknown and, although we think the effect is minor, 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 may not reflect fully the average growth and range of growth in this population. Similarly, length frequency data collected from the commercial catch may not represent the commercial catch with high precision. The research diver survey data comprise five surveys, with large changes in the index that the model has trouble fitting. Length frequencies from these surveys are the source of much uncertainty in the model fitting.

In 2009 and 2010 several reviews were conducted by Cordue P.L. (2009) and Haist V. 2010 (in press) to assess, i) the reliability of the research diver survey index as a proxy for abundance and ii) if the RDS data, when used in the puaa stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The outcome of both reviews suggests that outputs from puaa stock assessments, that used the RDS data as input into the model, should be treated with caution. For a summary of the conclusions from the reviews refer to the PAUintro Working Group Report.

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 that growth has the same mean and variance. However it is known puaa in some areas are stunted, and some are fast-growing).

To what extent does a homogeneous model make biased predictions about a heterogeneous stock? 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 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, as 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.

The assumption made by the model that CPUE is an index of abundance is questionable. Literature on abalone suggest 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. In this assessment, the degree of hyperstability appeared reasonably well determined.

Another source of uncertainty is that fishing may cause spatial contraction of populations (e.g., 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

The last stock assessment was completed for PAU 5D in 2006. A Bayesian length-based stock assessment model was applied to PAU 5D to estimate stock status and yield. The period 1989–96 was chosen as a reference period because in this period, exploitation rate and the recruited biomass were relatively stable.

Five-year projections made with the 2006 levels of MLS and catch showed a 37–96% chance that recruited biomass would be greater than 2006 biomass (4–63% chance of decrease), a variable chance that it would be greater than the reference level, and variable chance that it would be above the minimum historical level. For spawning biomass there was a 75–95% chance of increase above the current level, 0–18% chance of exceeding the reference level, and a 2–24% chance of decreasing below the historical minimum. Median projected exploitation rate was 17.4–49% (11.4–65%).

The stock assessment results were equivocal. The Working Group at the time noted that the future direction of recruited biomass was uncertain because of the range of possible results that were dependent on modelling decisions. It was not known if the catch or the TACC levels would allow the stocks to move towards a size that would support the maximum sustainable yield.

TACCs and reported landings for the 2008–09 fishing year are summarised in Table 9.

Table 9: Summary of TACC (t) and reported landings (t) of PAU 5D for the 2008–09 fishing year.

QMA PAU 5D	Actual TACC 89.00	Reported commercial landings 88.77
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6. FOR FURTHER INFORMATION

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