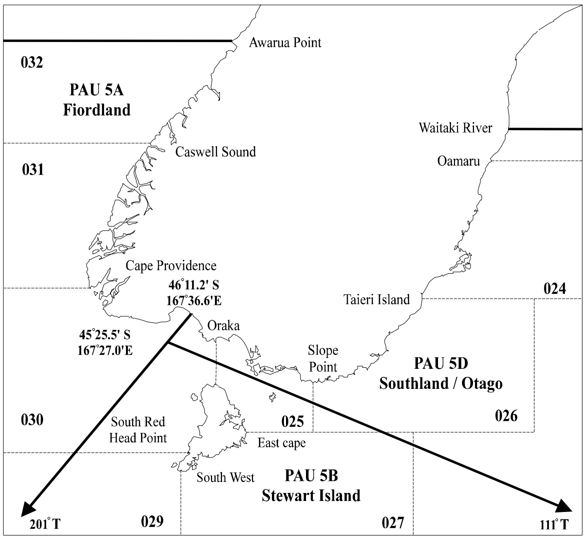
PAUA (PAU 5D) – Southland / Otago

(*Haliotis iris*)



1. FISHERY SUMMARY

(a) 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 2005–06. Data were estimated from CELR and QMR returns.

Year	Landings	TACC
1995–96	167.42	148.98
1996–97	146.60	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

(b) 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 1999/200 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 1999/200 and 68.2 t in 2000/2001. 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.

(c) Maori customary 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 1998/1999 and 2004/2005. 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.

(d) Illegal catch

Illegal catch was estimated by the Ministry of Fisheries 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.

(e) Other sources of mortality

Sub-legal paua may be subject to handling mortality by the fishery if they are removed from the substrate to be measured. Paua may die from wounds caused by removal, desiccation or osmotic and temperature stress at the surface or indirectly from being returned to unsuitable habitat or being lost to predators or bacterial infection. Gerring (2003) estimated that in PAU 7, 37% of paua removed from the reef by commercial divers were undersize and were returned to the reef. Their estimate of incidental mortality associated with fishing in PAU 7 was 0.3% of the landed catch. The low estimate was attributed to improved handling behaviour by divers and their use of a benign removal tool. Incidental fishing mortality may be higher in other areas where these practices have not been adopted. Pirker (1992) reported that in some fisheries, as many as 54% of paua removed from the reef may be undersize. Of these paua, up to 13% were damaged in some way and field estimates suggest up to 80% of these may fall victim to predation by wrasses or starfishes following their return to the reef. After discussion by the SFWG, it was agreed not to incorporate this source of mortality in the stock assessment.

2. BIOLOGY

Growth, morphometry, mortality and recruitment can vary over short distances and may be influenced by factors such as wave exposure, predation and food availability. Natural mortality was estimated in the assessment with a lognormal prior. A summary of biological parameters used in the PAU 5D assessment is presented in Table 2.

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

	Estimate	Source
1. Natural mortality (M)		
	0.114 (0.095–0.140)	Median (5–95% range) of posterior estimated by the model (run 053)
2. Weight = a (length)^b (weight in g, shell length in mm)		
	a = 2.99 x 10 $^{-5}$ b = 3.303	Schiel & Breen (1991)
Table 2 cont.		
3. Size at maturity (shell length)		
	50% maturity at 80 mm (78–81)	Median (5–95% range) of posterior estimated by the model
	95% maturity at 93 mm (89–98)	Median (5–95% range) of posterior estimated by the model
4. Estimated annual increments (both sexes combined)		
at 75 mm	**at 120 mm**	
19.6 (18.8–20.8)	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 Paua Management Company for their voluntary logbook and subsequently adopted on MFish CELRs. The present fishstock boundaries may not represent a single discrete paua stock.

4. STOCK ASSESSMENT

(a) <u>Estimates of fishery parameters and abundance</u>

CPUE is available from two series of data: the CELR through 2001 and the newer 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 this 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 paua despite a declining biomass. This occurs because paua tend to aggregate and divers move among areas to maximise their catch rates. Apparent stability in CPUE should therefore be interpreted with caution.

The relative abundance of paua 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.

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
1999–2000	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.

		Standardised		
Year	Raw	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
1999–2000	–	–	–	–
2000–01	67.5	44.2	70.0	110.7
2001–02	–	–	–	–
2002–03	–	–	–	–
2003–04	113.2	57.0	89.1	139.3

(b) 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.

i) 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 relation 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. Markov chain – Monte Carlo (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.

ii) 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 what was done previously.

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.

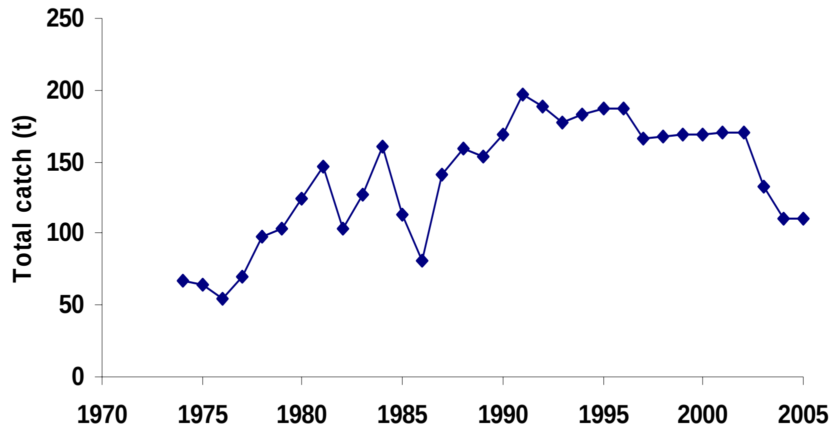


Figure 1: **Assumed catch (t) used in the PAU 5D assessment in 2006.**

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).

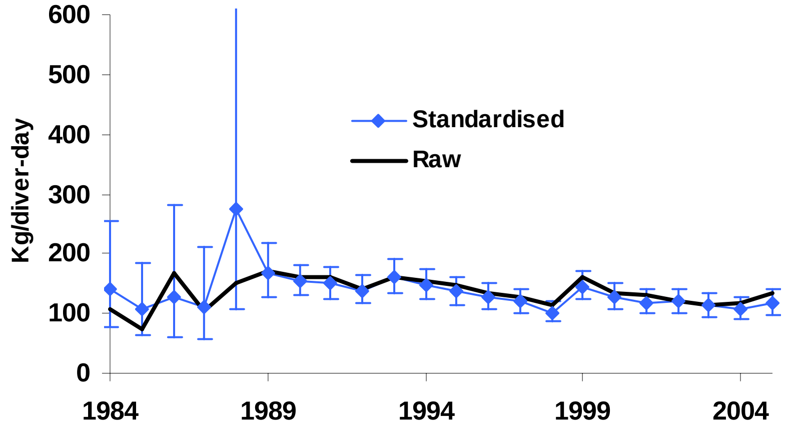


Figure 2: Raw (black line) and standardised (diamonds) CPUE (kg per diver-day), with 5% and 95% bars, for PAU 5D.

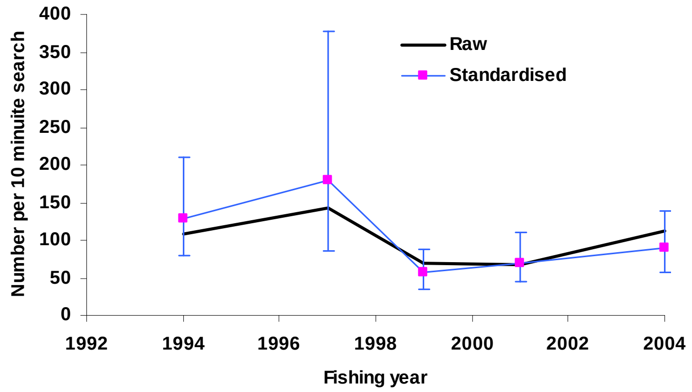


Figure 3: Raw (black line) and standardised (squares) RDSI (number per search), with 5% and 95% bars, for PAU 5D.

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 T_{50} 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
g_{75}	Expected annual growth increment at 75 mm	Uniform, bounds 1, 50
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
ε_t	Vector of recruitment deviations in log space	Normal, mean 0 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

iii) Projections

The SFWG requested that both 3 and 5-year projections be made. Recruitment for projections was obtained by randomly re-sampling the model's estimates from 1992 through 2004. Projected catches were the 2005-06 catch estimates, and 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.

iv) 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) (*B05* and *S05*), from 2008 and 2010 (projected biomass) (*B08*, *B10*, *S08* and *S10*, 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, *U05*, and *U08* and *U10*. 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(S08<S05), P(S10<S05),*
- projected spawning biomass was less than the reference level: $P(S08<S_{av})$, $P(S10<S_{av})$
- projected spawning biomass was less than the nadir: $P(S08<S_{min})$, $P(S08<S_{min})$
- projected recruited biomass had decreased from 2005: *P(B08<B05), P(B10<B05)*
- projected recruited biomass was less than the reference level: $P(B08<B_{av})$, $P(B10<B_{av})$
- projected recruited biomass was less than the nadir: $P(B08<B_{min})$, $P(B10<B_{min})$

vi) Stock assessment results

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

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 (rune2), 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 to inputs and assumptions were explored using run1 and the MPD estimates. Removal of the CPUE dataset had a small pessimistic effect (i.e., increasing 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 when just the length data were excluded. 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 (but not to other) data, 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

A second group of trials suggested that various choices made in the path to choosing the run, such as using the linear growth model and ordinary priors, either had little effect or were the correct choice. 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 (run1and run4) were pessimistic, showing the current state of the stock (first group of indicators), *B05*, 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.

		Run1	Linear growth		Run2	No RDLF		Run3	Exponential growth
Parameter	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**
2005									
Smin	271	366	489	687	1056	1526	348	479	633
Sav	768	841	922	998	1545	2253	782	941	1240
S05	271	371	508	845	1390	2218	395	636	1026
Bmin	114	162	194	187	259	365	175	232	315
Bav	392	430	472	371	513	700	464	554	717
B05	114	173	256	245	365	533	190	300	456
U05 (%)	33.1	45.2	61.3	16.7	23.5	33.0	19.4	28.0	41.0
S05/Sav (%)	32.5	44.0	59.5	69.3	90.6	117.6	45.0	66.8	97.3
S05/Smin (%)	100.0	100.0	110.2	106.0	131.5	168.5	100.7	132.2	186.6
B05/Bav (%)	26.6	40.3	59.6	53.7	71.7	90.3	36.6	53.6	74.6
B05/Bmin (%)	100.0	105.8	135.2	120.7	140.2	160.9	103.0	128.3	157.0

		Run4	No Tags		Run5	Fit to recent increase
Parameter	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**
2005						
Smin	276	374	503	509	568	632
Sav	793	886	992	765	846	938
S05	276	378	520	560	652	770
Bmin	116	165	204	177	198	223
Bav	398	449	505	392	434	480
B05	116	172	257	278	316	359
U05 (%)	33.0	45.3	60.5	24.6	27.5	30.5
S05/Sav (%)	31.7	42.7	58.0	68.8	76.9	88.1
S05/Smin (%)	100.0	100.0	108.2	103.9	114.4	130.2
B05/Bav (%)	25.9	38.4	56.8	65.2	72.9	81.7
B05/Bmin (%)	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.

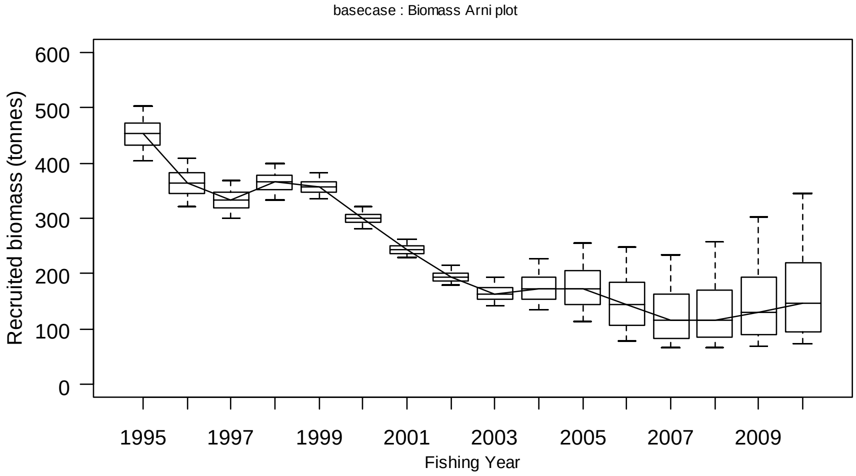
			Linear growth			No RDLF			Gilbert growth
Parameter	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**
2010									
S10	278	426	684	893	1423	2233	415	738	1225
B10	73	146	345	330	538	855	218	463	813
U10 (%)	25.4	49.2	65.0	11.4	17.4	26.7	11.8	19.8	36.9
S10/S05 (%)	83.2	115.0	164.8	77.2	102.2	139.4	77.9	113.8	169.7
S10/Sav (%)	33.2	50.7	80.6	65.5	92.4	131.9	45.4	76.6	123.2
B10/B05 (%)	45.4	84.6	178.0	95.3	146.4	237.2	91.3	147.9	249.7
B10/Bav (%)	16.8	33.9	81.0	65.3	104.6	170.9	40.5	81.4	143.1
P(S10<S05)	24.9			45.4			31.0		
P(S10<Sav)	99.5			64.1			81.7		
P(S10<Smin)	23.9			5.4			5.7		
P(B10<B05)	63.3			7.5			8.5		
P(B10<Bav)	98.7			44.7			71.9		
P(B10<Bmin)	54.9			0.3			3.8		

			No Tags			Fit to recent increase
Parameter	**0.05**	**Median**	**0.95**	**0.05**	**Median**	**0.95**
2010						
S10	265	420	698	604	804	1060
B10	66	124	329	321	469	665
U10 (%)	26.5	54.4	65.0	14.6	19.9	27.6
S10/S05 (%)	75.9	110.9	172.0	99.9	123.4	150.6
S10/Sav (%)	30.1	47.3	78.9	72.0	95.0	124.1
B10/B05 (%)	40.1	74.1	172.6	102.2	148.4	211.3
B10/Bav (%)	14.7	27.7	73.2	74.5	108.0	154.2
P(S10<S05)	34.1			5.2		
P(S10<Sav)	99.2			62.3		
P(S10<Smin)	33.1			1.7		
P(B10<B05)	71.1			4.0		
P(B10<Bav)	98.9			35.8		
P(B10<Bmin)	65.1			0.1		

(c) 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.



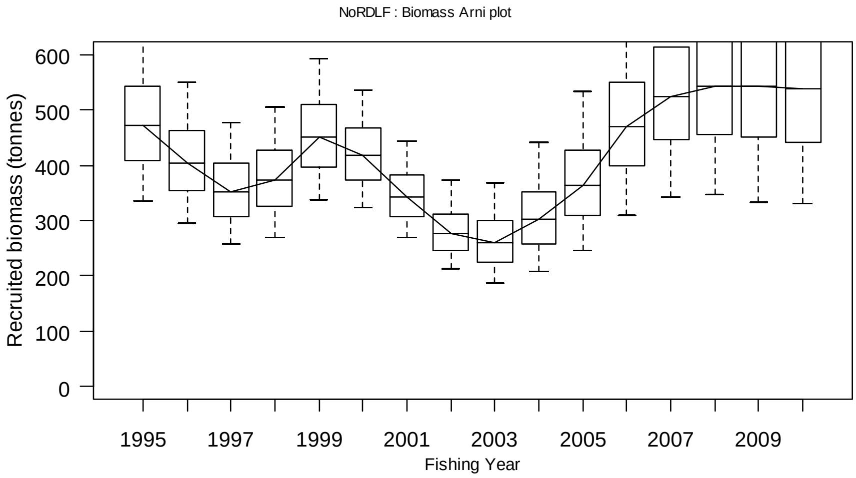


Figure 4: The posterior distributions of MCMC recruited biomass trajectory from 1995 onwards with a pessimistic run: linear growth model (base1, upper) and an optimistic run: no research diver survey data (base2, lower).

(d) 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.

(e) 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.

(f) Other yield estimates and stock assessment results

Only the current catch was used in projections.

(g) 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 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 relatively small compared with commercial catch. The illegal catch is particularly suspect.

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.

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 (we know this is violated for paua generally because some areas are stunted and some are fast-growing).

To what extent does a homogenous 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, because spawners must breed close to each other and because 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 could be suspect. A large literature for abalone suggests that CPUE is difficult to use in abalone stock assessments because of serial depletion. This can happen when fishers can deplete unfished or lightly fished beds and maintain their catch rates, thus CPUE stays high while the biomass is actually decreasing. 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 assessment was updated 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.

The current median mid-year recruited biomass estimate ranged from 172 t to 362 t depending on which run was looked at (5th and 95th percentiles 114–533 t, across all base cases); the current median spawning biomass estimate ranged from 371 t to 1390 t (271–2218 t). The median and upper percentiles for both current recruited and spawning biomass are less than the reference years 1989–96. The assessment indicated that the current median exploitation rate ranged from 23.5% to about 45% (17–61%).

Five-year projections made with current levels of MLS and catch show a 37–96% chance that recruited biomass will be greater than current biomass (4–63% chance of decrease), a variable chance that it will be greater than the reference level, and variable chance that it will be above the minimum historical level. For spawning biomass there is 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 is 17.4–49% (11.4–65%).

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

TACCs and reported landings for the 2005/06 fishing year are summarised in Table 9.

Table 9: Summary of TACC (t) and reported landings (t) of paua 5D for the 2005–06 fishing year.

QMA	Actual TACC	Reported commercial landings
PAU 5D	89.00	88.93

6. FOR FURTHER INFORMATION

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