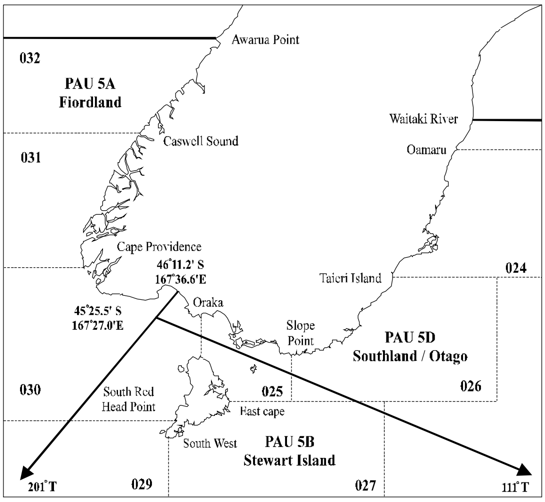
PAUA (PAU 5B) – Stewart Island

(*Haliotis iris*)



1. FISHERY SUMMARY

(a) Commercial fishery

Before 1995–96, PAU 5 was the most important QMA by number of quota holders and TACC. The TACC peaked in PAU 5 in 1991–92 at 492 t, having grown steadily from a provisional TACC of 390 t in 1985–86 as a result of the quota appeal process. Concerns about the status of the PAU 5 fishery led to a voluntary 10% reduction in the TACC in 1994–95. On 1 October 1995, PAU 5 was divided into three QMAs (5A, 5B, and 5D; see Figure above) and the TACC was subdivided equally among them. 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 reduction in catch in Stewart Island caused by subdivision cannot be determined with certainty because several Statistical Areas used to report catch and effort straddled 5B and 5D.

An assessment of the PAU 5B fishery (Breen et al., 2000a) confirmed fears of over-exploitation and the TACC was reduced by 5 t from 1 October 1999 and Industry agreed to shelve a further 25 t of quota. A subsequent assessment (Breen et al., 2000b) indicated further catch reductions were required and the TACC was reduced from 143.984 to 112.187 t from 1 October 2000, and shelving continued at the level of about 22 t. The commercial catch in 2001–02 was 89.96 t. This series of management interventions has reduced the commercial catch in PAU 5B by at least 40% since 1998–99, and probably by as much as 60% since 1994–95. In 2002, it was decided that quota shelving would be discontinued in PAU 5B, and that the TACC would be set at 90 t within a TAC of 105 t. The TAC included a 6 t customary allowance, a 6 t recreational allowance, and a 3 t allowance for other sources of mortality (illegal catch). This decrease was based on the consideration that it was important to set a TAC that would ensure the stock would move toward the desired target level; and that sustainability concerns outweighed the socio-economic impact.

Table 1: TACC and reported landings (t) of paua in PAU 5B from 1995–96 to 2004–05. Data reported from CELR returns.

Year	Landings	TACC
1995–96	143.66	148.98
1996–97	142.30	148.98
1997–98	145.34	148.98
1998–99	148.26	148.98
1999–00	118.19	143.98
2000–01	89.26	112.19
2001–02	89.96	112.19
2002–03	89.86	90.00
2003–04	90.00	90.00
2004-05	89.97	90.00

(b) Recreational fisheries

The 1996 national telephone diary survey estimated that 105,000 paua (27 t) were taken by recreational fishers in PAU 5. The 1999/2000 and 2000/2001 national recreational fishing surveys estimated 29,000 and 69,000 paua respectively were harvested by recreational fishers in PAU 5B. At an average weight of 357g, these numbers equate to a recreational harvest of 10.3 t in 1999/2000 and 24.6 t in 2000/2001. The Marine Recreational Fisheries Technical Working Group (RFTWG) has reviewed the harvest estimates from the national surveys. The RFTWG concluded that the 1996 harvest estimates were unreliable due to a methodological error. Harvest estimates from the 1999/2000 and 2000/2001 surveys for some fish stocks were considered to be unbelievably high. The Shellfish Fisheries Assessment Working Group accepted a harvest estimate of 10,000 paua for PAU 5B. This number was converted into weight using length-weight relationship by assuming a mean length of 125 mm. The estimate of recreational catch used in this assessment was 2531 kg. This catch estimate was used for the whole period modelled.

(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. The Minister of Fisheries provided an allowance for customary harvest of 6 t beginning in 1999/2000. Estimates of customary catch for the 2002 assessment were provided as numbers of paua by the Ministry of Fisheries. These were 90 and 86 paua for 2000 and 2001 respectively. This estimate was converted into 30 kg weight by assuming a mean individual weight of 333 g. This catch estimate was used for the whole period modelled.

(d) Illegal catch

Illegal catch was estimated by the Ministry of Fisheries to be 3 t. No historical estimates are available so these estimates were used for the whole period modelled.

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

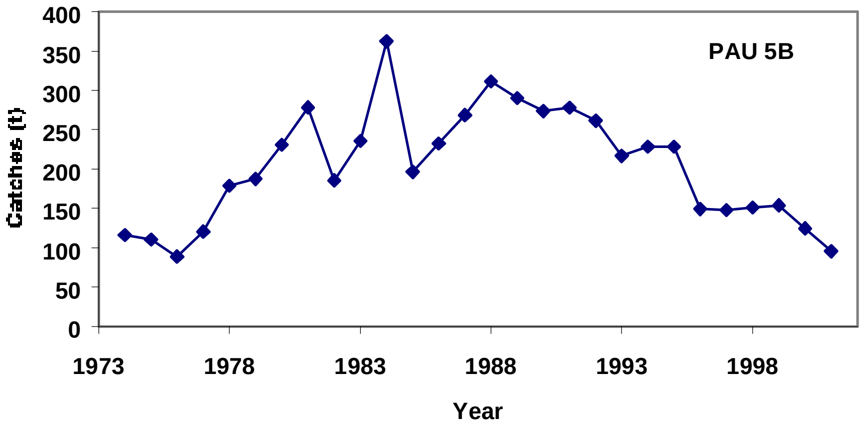


Figure 1: Catch (t) estimates used in the assessment.

(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 much 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. No attempt has been made to incorporate this source of mortality in the stock assessment.

2. BIOLOGY

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

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

	Estimate	Source
1. Natural mortality (M)		
	0.11 (0.10-0.14)	Median (5–95% range) of posteriors estimated by the model
2. Weight = a (length)^b (weight in g, shell length in mm)		
	a = 2.99 x 10^{-5} b = 3.303	Schiel and Breen (1991)
3. Size at maturity (shell length)		
	50% maturity at 91 mm	
	95% maturity at 105 mm	R. Naylor (NIWA) unpub. data
4. von Bertalanffy growth parameters (both sexes combined)		
K	**L_∞ (mm)**	
0.26 (0.24-0.27)	160.9 (159.1–162.9)	Median (5–95% range) of posteriors estimated by the model

3. STOCKS AND AREAS

PAU 5B 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 these areas were further subdivided into 17, 16 and 11 statistical areas respectively. The scale of reporting was further reduced from 1 October 2001, when it became mandatory to report catch and effort from the 96 small zones developed by the New Zealand Paua Management Company for their voluntary logbook.

4. STOCK ASSESSMENT

(a) Estimates of fishery parameters and abundance

Catch rates (CPUE data from CELR records – Table 3) appear relatively stable in recent years, although they declined between 1987 and 1996, and in 2001. In some circumstances commercial CPUE may not be proportional to abundance as 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.

Table 3: Unstandardised and standardised catch per unit effort (CPUE) in PAU 5B (kg per diver-day) (Breen et al., 2002b).

Year	Unstandardised CPUE	Standardised CPUE
1982–83	274.69	315.71
1983–84	279.58	282.87
1984–85	322.67	321.16
1985–86	342.13	321.02
1986–87	231.81	238.00
1987–88	213.79	235.67
1988–89	191.43	206.33
1989–90	172.19	192.22
1990–91	160.45	176.70
1991–92	160.55	166.41
1992–93	149.63	156.78
1993–94	142.79	138.61
1994–95	139.56	127.32
1995–96	126.49	114.49
1996–97	131.19	138.03
1997–98	141.23	132.78
1998–99	136.72	123.36
1999–00	143.65	133.22
2000–01	125.75	107.15

The relative abundance of paua in PAU 5B has been estimated from research surveys (Andrew et al. 2000a, 2000b, 2002) (Table 4). Relative abundance has increased since the last survey, in 1998.

Table 4: Standardised research diver survey indices and 95% confidence limits (1.96 standard errors) for sites surveyed in PAU 5B. – indicates no data collected.

Year	2.5%	mean	97.5%
1993–94	39.98	74.25	137.90
1994–95	16.54	25.02	37.83
1995–96	5.06	8.84	15.45
1996–97	–	–	–
1997–98	14.55	22.41	34.52
1998–99	–	–	–
1999–00	–	–	–
2000–01	25.81	38.66	57.93

(b) Revised assessment model for PAU 5B

i) Model structure

This assessment is made with a revision of the length-based model first used in 1999 for PAU 5B (Breen et al., 2000a), and used in revised form for subsequent assessments in PAU 5B and PAU 7 (Marlborough) (Breen et al., 2000b, Breen et al., 2001). This model is driven by reported commercial catches from 1974 through 2001 and is fitted to five sets of data: standardised CPUE, standardised research diver survey index (Andrew et al., 2000a, 2000b, 2002), proportion-at-length data from commercial catch sampling and from research diver surveys (Andrew et al., 2000a, 2000b, 2002), and a set of growth increment data (Naylor, unpub. data).

The assessment is based on the marginal posterior distributions of the parameters and derived parameters of interest, in turn based on Markov chain – Monte Carlo (McMC) simulations.

Growth is modelled as a stochastic transition matrix calculated from the von Bertalanffy growth parameters, which are estimated as parameters of the model, and the estimated relation between expected increment and its standard deviation, based on tagging data. A contribution to the total likelihood function comes from comparison of observed and expected increments in the tagging data.

Recruitment is modelled as a fixed mean with annual deviations, estimated as a vector of parameters. These have an assumed mean and standard deviation; this assumption makes the model Bayesian. No stock-recruit relation is estimated, but projections are made using the mean of the 1991–2000 recruitments as the assumed mean recruitment. Research diver selectivity-at-size is modelled with two estimated parameters.
The model estimates a standard deviation of observation error common to all data sets, which necessitated changing the likelihood functions used in previous assessments. The weights for data sets were adjusted with a term acting acted on the standard deviation of observation error for each set. Iterative re-weighting is used to obtain standard deviations of standardised residuals equal to unity; this replaces the arbitrary weighting of previous assessments.

Exploitation rate is calculated from observed catch and model biomass. A point estimate of the mode of the joint posterior distribution (MPD) served as the starting point for the Bayesian estimations, and as the basis for sensitivity tests. McMC simulations were used to estimate the marginal posterior distributions of model parameters.

In addition to model parameters, derived parameters such as population size and exploitation rate were calculated and their posterior distributions summarised. In the assessment of PAU 7 in 2001, indicators using virgin recruited and spawning biomass were poorly determined (Breen et al., 2001). These indicators were replaced with those from a reference period in which the fishery appeared to be operating at a sustainable level. For this assessment spawning and recruited biomass indicators S_{ref} and B_{ref} were also used. The period from which to take these means was chosen after examining various trajectories from preliminary results. 1985–1987 was chosen as a reference period because in these years spawning and recruited biomass had stabilised following a fishing down period that started in the early 1970's (Figure 3), and the exploitation rate was relatively moderate (15–30%), compared to later years. This period is a reference against which current and projected stock sizes and exploitation rates can be compared and should not be considered as a management target.

Performance indicators were provided for current (2002) and 5 year projections (2007). The indicators for current and projected recruited biomass, B_{02} and B_{07}, were the values for recruited biomass in those years. Spawning biomass indicators for the current and projected populations were called S_{02} and S_{07} and were calculated as the product of the maturity vector and numbers in each size class for each year. Exploitation rates in 2001 and 2007 were also used as indicators, and called U_{01} and U_{07}.

For the McMC simulations used in projections, additional indicators were the percentages of runs in which spawning biomass decreased during projections, recruited biomass decreased during projections, spawning biomass remained less than S_{ref}, and recruited biomass remained below B_{ref}.

Sensitivity tests involved removing each of the five data sets in turn, then removing all length data or all population index data in turn, changing the relative weights for data sets, using an alternative prior on M, and estimating the shape of the relation between CPUE and biomass. Retrospective analyses, in which years of data were sequentially removed and the model refitted were also used to analyse the sensitivity of the model to data.

ii) Data used in the assessment

The data used in this assessment of PAU 5B are summarised in a series of FARs. The fishery-independent survey and population length frequency data are presented in Andrew et al. (2000a, 2000b, 2002). Breen et al. (2000a, 2000b) summarise the previous assessments and Breen et al. (2002a) detail the current model and present the 2002 assessment for PAU 5B; Breen et al. (2002b) present the assessment for PAU 5D. Catch rate and catch history are presented in Kendrick & Andrew (2000) and Breen et al. (2002a, 2002b).

Generation of a catch vector required assumptions to be made about the division of catch from statistical areas 25 and 30 to PAU 5B prior to 1995. For this purpose, the fishery was divided into three periods: pre-1984, 1984–1995, and post-1995. In this assessment we used the 2000 Base Case series (Breen et al., 2000b):

1974–1983	52% of PAU 5 landings
1984–1995	75% of areas 25 and 30
1996–2001	As allocated to subdivided QMAs

A vector of standardised CPUE was generated using the raw catch rates as catch per diver-day (Kendrick and Andrew 2000) and a multiple regression model (Vignaux 1993). The standardisation model accounted for 36% of the total variation in observed CPUE and deviated little from the pattern of decline in raw CPUE through time (Figure 2).

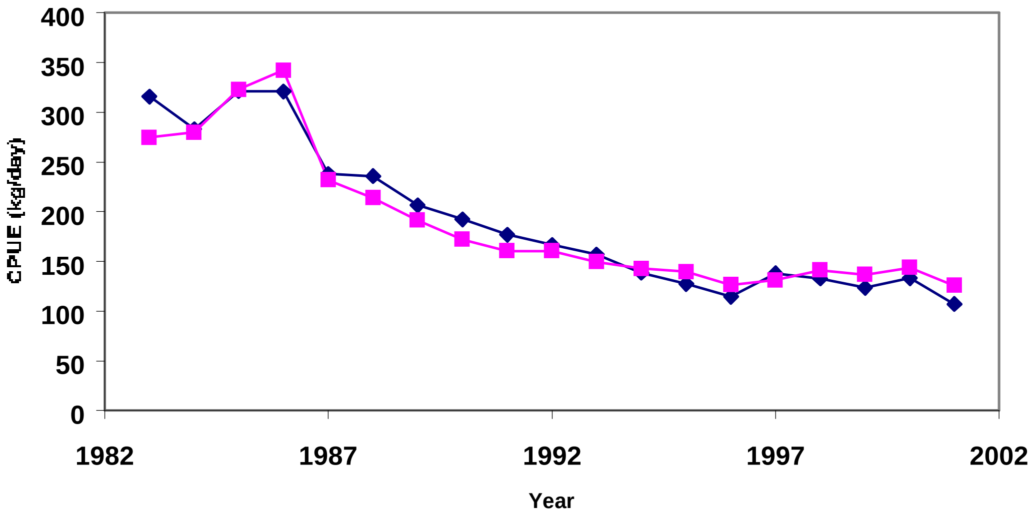


Figure 2: Normalised raw (broken line) and standardised (solid line) CPUE for PAU 5B. Standardisation procedures were described by Breen et al. (2002a).

Assessment model parameters and their priors and bounds are given in Table 5. Other biological assumptions were as follows: The length-weight relationship and growth parameters (derived from the model) are given in Table 2. Maturity is knife-edged at 90 mm. Vulnerability to the fishery is knife-edged at 126 mm.

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

Model parameters	Definition	Priors and bounds
$\ln(R0)$	Natural log(recruitment)	Uniform, 5, 50
M	Natural mortality	Cauchy with mean 0.1, CV 0.5, bounds 0.01, 0.50
$L_{¥}$	Asymptotic length	Uniform, 100, 250
K	Brody coefficient	Uniform, 0.01, 0.80
$S50$	Size at 50% selectivity by research divers	Uniform, 70, 125
$S95$	Difference in size between 95% and 50% selectivity	Uniform, 0.01, 35
e_t	Vector of recruitment deviations in log space	Normal, mean 0 bounds –23 and 23, CV 04
$\tilde{s}$	Common standard deviation of observation error	Uniform, 0.01, 1.0
a	CV of expected growth increments	Uniform, 0.001,1
s_{MIN}	Minimum standard deviation of growth increment	Uniform, 0.001,5

iii) Stock assessment results

The sensitivities of model outputs to inputs and assumptions (Table 6) were explored using the MPD point estimates.

Table 6: Results of sensitivity tests on MPD estimates to model inputs and assumptions.

Sensitivity test	Outcomes
To data sets: Removing each of the five data sets in turn from the fitting procedure, removing both abundance indices, and removing both length frequency data sets.	• Generally robust to indicators; growth estimates when tagging data or both length frequency data sets removed.
Alternative weighting of data sets.	• Reasonably robust; downweighting the length frequencies gives more optimistic assessment.
To the prior on natural mortality (M)*:* Changed the mean from 0.10 to 0.20	• Higher M but little other change.
Estimating the shape of the CPUE – abundance relation	• Little change.

The assessment was reasonably robust in sensitivity trials. Results were not especially sensitive to the relative weighting of various data sets (Table 6), except that downweighting or removing the proportions-at-length caused the model's growth estimates to change and the results to become more optimistic. The procedure of iterative re-weighting the data sets to obtain standardised residuals with a standard deviation of unity worked well in this assessment, and was used for the base case. This eliminated the arbitrary weights assigned in previous assessments.

The retrospective analyses did not suggest that bias or model mis-specification were problems with this assessment. The assessment did not change much with successive subtraction of one year's abundance and sampling data. The base case gave lower biomass estimates than the data series that ended in 2000, 1999 and 1998, which were all very similar to each other. This result was caused by the new growth increment data used in the base case assessment. Using the same tagging data, the production retrospective trajectories were also very similar until the most recent years.

The model provided reasonably good fits to the proportions-at-length and CPUE, but not as good a fit to the research diver survey index. Proportions-at-length from the commercial catch sampling and research diver survey were similar in each year. The model did not fit the tagging data very well – it increased the asymptotic length and decreased the Brody coefficient from the values obtained from the tag data alone. This may have resulted from the lack of larger paua tagged in the growth study. In any case, the growth data from tagging are over-ridden to some extent by the information contained in the proportions-at-age.

The posterior summaries (Table 7) suggest that current spawning and recruited biomass are both almost certainly less than in the reference period (1985–87), and that current exploitation rate is in the range 15–21%. Projections made with the current catch and MLS suggest that both biomass indicators will increase, perhaps as much as twice, from the current values, with a median expectation that they will be close to the reference values at the beginning of 2007. There is only a small percentage risk that either biomass indicator will decrease, and about a 50% chance that these indicators will remain below the reference biomass after 5 years.

Table 7: Performance indicators derived from posterior distributions generated from the base case assessment. B is recruited biomass (paua greater than 125 mm shell length) in tonnes, S is spawning biomass (based on numbers-at-size and maturity-at-size) in tonnes, U is exploitation rate. Sref and Bref are the mean biomass estimates for 1985-87. Biomass estimates in t. The table shows 5th percentile, median and 95th percentile for the parameters indicated, taken from the distribution of 5000 samples from 10 million simulations.

Parameter	0.05	Median	0.95
U_{01}	15.0%	17.7%	20.8%
U_{07}	5.2%	9.1%	13.4%
S_{ref}	1 315	1 425	1 563
S_{02}	823	988	1 204
S_{07}	951	1 433	2 628
B_{ref}	932	1 024	1 120
B_{02}	526	627	750
B_{07}	715	1 054	1 832
S_{02}/S_{ref}	59.4%	69.5%	81.3%
S_{07}/S_{ref}	67.4%	100.7%	181.0%
S_{07}/S_{02}	100.3%	143.8%	257.8%
B_{02}/B_{ref}	52.1%	61.2%	71.8%
B_{07}/B_{ref}	70.8%	102.7%	179.8%
B_{07}/B_{02}	120.7%	165.2%	291.5%
Percentage of runs where:			
$S_{07}<S_{02}$	4.8%		
$S_{07}<S_{ref}$	48.7%		
$B_{07}<B_{02}$	0.2%		
$B_{07}<B_{ref}$	46.2%		

(d) Estimation of Maximum Constant Yield (MCY)

No estimate of MCY has been made for PAU 5B.

(e) Estimation of Current Annual Yield (CAY)

No estimate of CAY has been made for PAU 5B.

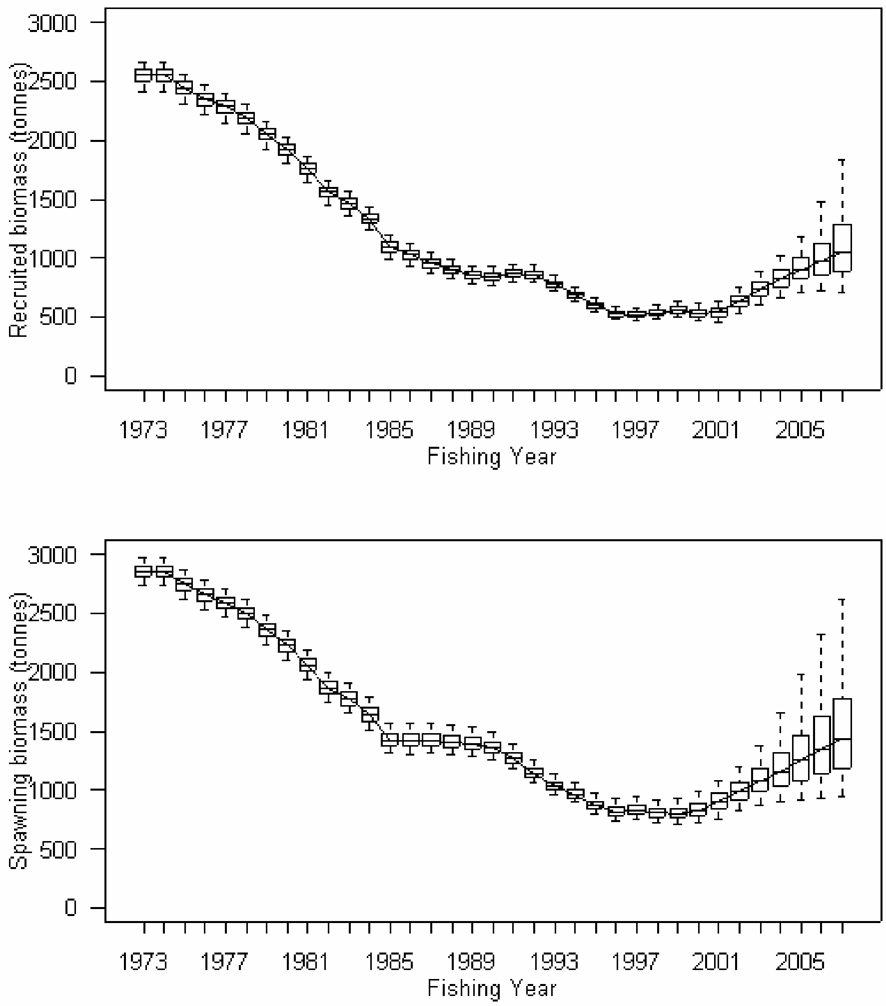


Figure 3: The posterior biomass trajectories for recruited (upper) and spawning (lower) biomass for the base case for PAU 5B. For each year, the figure shows the median of the posterior (horizontal bar), the 25th and 75th percentiles (box) and 5th and 95th percentiles of the posterior.

(f) Other yield estimates and stock assessment results

No projections of stock status under alternatives to the current TACC and MLS were done.

(g) Other factors

The model treats the whole of PAU 5B as if it were a single stock with homogeneous biology, habitat and fishing pressures. The PAU 5B stock in reality is highly heterogeneous with respect to all these factors. For example, there is evidence that the relative abundance of paua has increased on the northeastern and western coasts of the island but not in the southwest (Andrew et al. 2002). The effect of this simplification in the model, especially with respect to predictions, is unknown. This is a common problem in managing abalone fisheries, where the effective unit stock may be small, and typically much smaller than the scale at which the fishery is managed. Local stocks may be disproportionately depleted compared with the average depletion; in paua or abalone this can result in small-scale recruitment failure. Further, it is difficult to sample heterogeneous populations to obtain estimates that are representative of the whole population. These problems result from the mismatch between the spatial scales at which abalone fisheries can be practically managed and the much smaller scales at which population dynamics are thought to operate. Serial depletion, if it occurs, may cause model results to be overly optimistic with respect to the part of the population that is being fished or surveyed. Hyperstability in CPUE could also cause model results to be overly optimistic

5. STATUS OF THE STOCK

The assessment was not updated in 2005; the results from the 2002 assessment are reported below. The TACC was reduced from 1 October 2002 to 90 t.

A Bayesian length-based stock assessment model was applied to PAU 5B to estimate stock status and yield. 1985–1987 was chosen as a reference period because in these years spawning and recruited biomass had stabilised following a fishing down period that started in the early 1970's, and the exploitation rate during this period was relatively moderate (15–30%), compared to later years.

The current median recruited biomass estimate was 627 t (5th and 95th percentiles equal to 526–750 t, respectively); the current median spawning biomass estimate was 988 t (823–1204 t). The median and upper percentiles for both current recruited and spawning biomass are less than the reference years 1985–87. The assessment indicated that the current median exploitation rate is about 18% (15–21%).

Projections show that at the current levels of catch and MLS, in 2007 there is a 99.8% probability that recruited biomass will be greater than current biomass, and a 54% probability that it will exceed the recruited biomass estimated for the period between 1985–87. Similarly, in 2007 there is a 95.2% probability that spawning biomass will be greater than current spawning biomass, and a 51% probability that it will exceed the spawning biomass estimated for the period between 1985–87. Projections also indicate that the exploitation rate will decline to about half the current value by the end of 2007. These results suggest that the current catch level is sustainable and will likely allow the stock to increase towards the reference levels of biomass.

Sensitivities to data and uncertainties not explicitly addressed by the model were tested and indicate that these conclusions are robust to the range of assumptions tested.

Summary of TACC (t) and reported landings (t) of paua 5B for the 2004-05 fishing year.

QMA	Actual TACC	Reported commercial landings
PAU 5B	89.97	90.00

6. FOR FURTHER INFORMATION

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