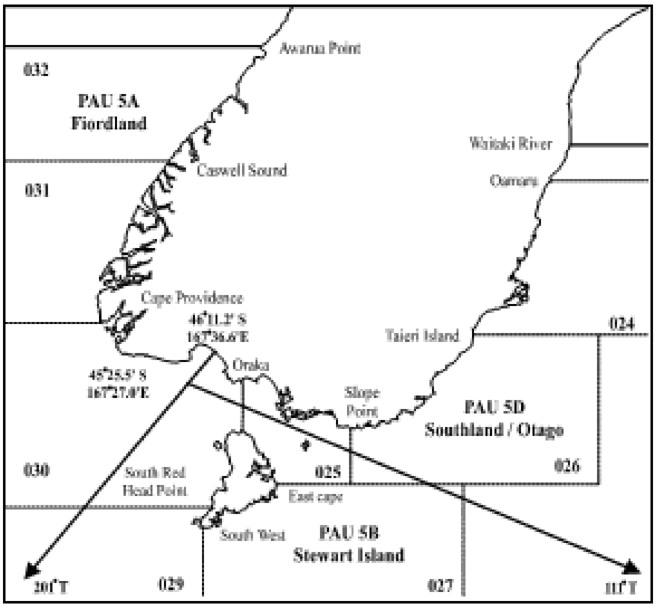
PĀUA (PAU 5D) – Southland / Otago

(*Haliotis iris*)
Pāua



1. FISHERY SUMMARY

Before 1995, PAU 5D was part of the PAU 5 QMA, which was introduced into the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t for the 1991–92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994–95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see figure above) and the TACC was divided equally among them; the PAU 5D quota was set at 148.98 t.

On 1 October 2002 a TAC of 159 t was set for PAU 5D, comprising a TACC of 114 t, customary and recreational allowances of 3 t and 22 t, respectively, and an allowance of 20 t for other mortality. The TAC and TACC have been changed since then, but customary, recreational, and other mortality allowances have remained unchanged (Table 1).

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5D since introduction to the QMS.

Year	TAC	Customary allowance	Recreational allowance	Other sources of mortality	TACC
1986–1991*	–	–	–	–	445
1991–1994*	–	–	–	–	492
1994–1995*	–	–	–	–	442.8
1995–2002	–	–	–	–	148.98
2002–2003	159	3	22	20	114
2003–present	134	3	22	20	89

*PAU 5 TACC figures.

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September. On 1 October 2001, it became mandatory to report catch and effort on Pāua Catch Effort Landing Return (PCELR) forms using fine-scale reporting areas that had been developed by the New Zealand Pāua Management Company for their voluntary logbook programme (Figure 1). Since 2010, the commercial industry has adopted some voluntary management initiatives which include raising the minimum harvest size for commercial fishers over specific statistical reporting areas. The industry has also voluntarily closed, to commercial harvesting, specific areas that are of high importance to recreational pāua fishers. In recent years commercial fishers have been voluntarily shelving a percentage of their Annual Catch Entitlement (ACE), which is reflected by the annual catch landings falling below the TACC (Figure 2, Table 2) These voluntary measures are now implemented under the PAU 5 Fisheries Plan approved under section 11A of the Fisheries Act by the Minister for Oceans and Fisheries.

Commercial landings for PAU 5D are shown in Table 2 and Figure 2. Landings matched the TACC until 2012–13, and then declined to an average of 65 t since 2013–14.

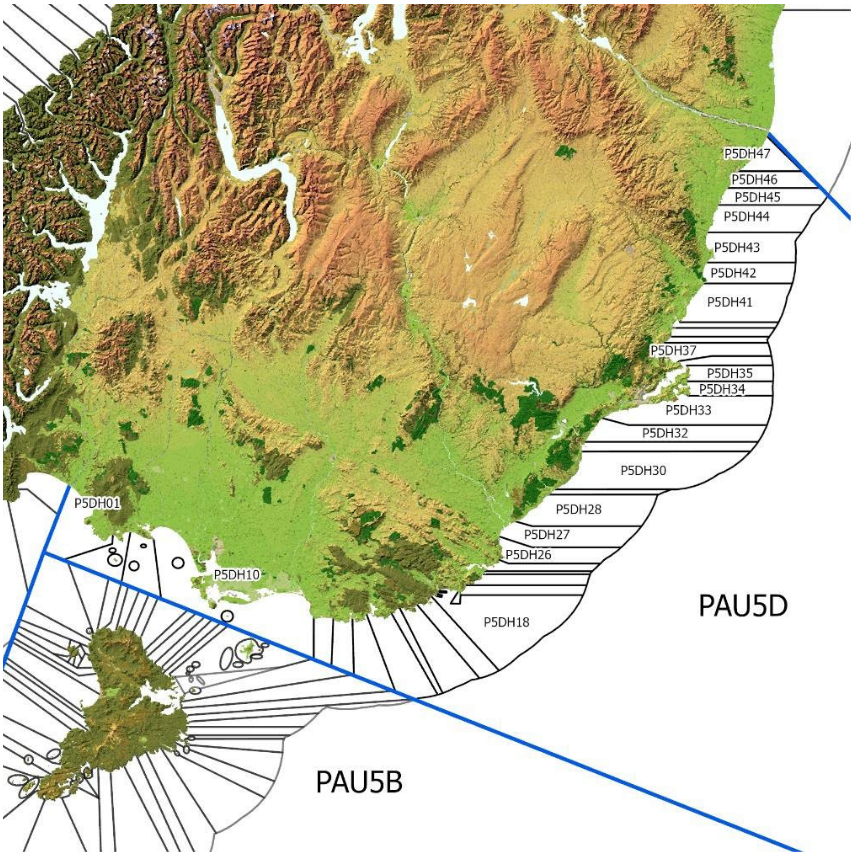


Figure 1: Map of fine scale statistical reporting areas for PAU 5D.

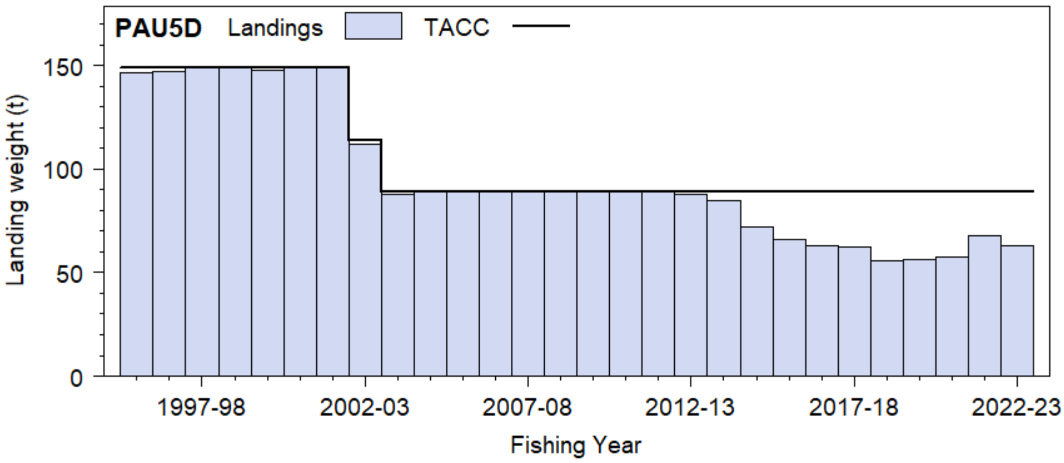


Figure 2: Reported commercial landings and TACC for PAU 5D from 1995–96 to present. For reported commercial landings in PAU 5 prior to 1995–96 refer to figure 1 and table 1 of the Introduction – Pāua chapter.

Table 2: TACC and reported landings (t) of pāua in PAU 5D from 1995–96 to the present.

Year	Landings	TACC	Year	Landings	TACC
1995–96	167.42	148.98	2009–10	89.45	89.00
1996–97	146.6	148.98	2010–11	88.70	89.00
1997–98	146.99	148.98	2011–12	89.23	89.00
1998–99	148.78	148.98	2012–13	87.91	89.00
1999–00	147.66	148.98	2013–14	84.59	89.00
2000–01	149.00	148.98	2014–15	71.87	89.00
2001–02	148.74	148.98	2015–16	65.95	89.00
2002–03	111.69	114.00	2016–17	63.12	89.00
2003–04	88.02	89.00	2017–18	62.48	89.00
2004–05	88.82	89.00	2018–19	55.55	89.00
2005–06	88.93	89.00	2019–20	56.55	89.00
2007–08	88.98	89.00	2020–21	57.78	89.00
2006–07	88.97	89.00	2021–22	67.57	89.00
2008–09	88.77	89.00	2022–23	62.76	89.00

1.2 Recreational fisheries

The 'National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates' estimated that the recreational harvest for PAU 5D was 80 290 pāua and of 22.45 t with a CV of 30% (Wynne-Jones et al 2014). The National Panel Survey was repeated in the 2017–18 fishing year (Wynne-Jones et al 2019). The estimated recreational catch for that year was 19.28 tonnes with a CV of 21%.

For the purpose of the 2023 stock assessment model, the SFWG agreed to assume that the recreational catch in 1974 was 2 t and that it increased linearly to 10 t by 2005, where it has remained unchanged to date. The estimate used within the assessment was lower than estimates from the National Panel Survey as only a portion of recreational activity overlaps with commercial fisheries.

The most recent national panel survey harvest estimate for PAU 5D is 20.65 t (CV 0.30) for 2022–23 (Heinemann & Gray in prep). For further information on recreational fisheries refer to the Introduction – Pāua chapter.

1.3 Customary fisheries

Pāua is a taonga species and as such there is an important customary use of pāua by Maori for food, and the shells have been used extensively for decorations and fishing devices. For information on customary catch regulations and reporting refer to the Introduction – Pāua chapter.

Estimates of customary catch for PAU 5D are shown in Table 3. These numbers are likely to be an underestimate of customary harvest as only the catch approved and harvested in numbers is reported in the table. In addition, many tangata whenua also harvest pāua under their recreational allowance and these are not included in records of customary catch.

Table 3: Fisheries New Zealand records of customary harvest of pāua (approved and reported in numbers) in PAU 5D since 2000-01. – no data.

	Numbers	
Fishing year	Approved	Harvested
2000–01	665	417
2001–02	5 530	3 553
2002–03	2 435	1 351
2003–04	–	–
2004–05	–	–
2005–06	1 560	1 560
2006–07	2 845	2 126
2007–08	5 600	5 327
2008–09	6 646	6 094
2009–10	4 840	4 150
2010–11	15 806	15 291
2011–12	7 935	7 835
2012–13	10 254	8 782
2013–14	5 720	5 358
2014–15	–	–
2015–16	15 922	13 110
2016–17	3 676	3 576
2017–18	3 588	3 310
2018–19	950	894
2019–20	6 905	6 439
2020–21	10 257	10 030
2021–22	1 730	1 670
2022–23	130	130

For the purpose of the 2023 stock assessment model, the SFWG agreed to assume that, for PAU 5D, the customary catch has been constant at 2 t from 1974 to the current stock assessment.

1.4 Illegal catch

For the purpose of the stock assessment model, the SFWG agreed to assume that, for PAU 5D, illegal catches have been constant at 10 t from 1974 to the current stock assessment. For further information on illegal catch refer to the Introduction – Pāua chapter.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the Introduction – Pāua chapter. Other sources of mortality are considered to be negligible, except in the case of occasional environmentally induced local freshwater inundation events.

2. BIOLOGY

For further information on pāua biology refer to the Introduction – Pāua chapter. A summary of biological parameters used in the PAU 5D assessment is presented in Table 4.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the Introduction – Pāua chapter.

Table 4: Estimates of biological parameters (*H. iris*).

		Estimate	Source
1. Natural mortality (*M*)			
		0.11 (0.09-0.14)	Median (5–95% range) of posterior estimated by the base case model
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 91 mm (89–93)	Median (5–95% range) estimated outside of the assessment
		95% maturity at 103 mm (103–105)	Median (5–95% range) estimated outside of the assessment
4. Estimated annual growth increments (both sexes combined)			
		Growth at 75 mm 25.70 (21.79–30.26)	Median (5–95% range) of posterior estimated by the base case model
		Growth at 125 mm 5.61 (4.35–7.28)	Median (5–95% range) of posterior estimated by the base case model

4. STOCK ASSESSMENT

The stock assessment was implemented as a length-based Bayesian estimation model representing the commercially fished area of PAU 5D, with uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain Monte Carlo simulations. The most recent stock assessment was conducted for the fishing year ended 30 September 2022. A base case model was chosen from the assessment. Spatial models were initially trialled for the area but were highly sensitive to assumptions due to data deficiencies in the southern region and were therefore not pursued further (models with reasonable parameter estimates were very close to single area models). Compared with previous analyses, the most recent stock assessment estimated lower stock status, due largely to the dropping of CELR CPUE. Estimates of growth were higher than in previous assessment, although QMA-specific growth patterns remain highly uncertain due to high spatial variability in growth and relatively low spatial coverage of the tag-recapture programme to estimate pāua growth. This uncertainty translates into uncertainty about stock status and stock trajectories.

4.1 Estimates of fishery parameters and abundance indices

Parameters estimated in the assessment model and their assumed Bayesian priors are summarised in Table 5.

Table 5: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal; Beta = beta distribution), mean and CV of the prior.

Parameter	Prior	μ	sd
$\ln(R_0)$	LN	exp(13.5)	3
D_{50} (Length at 50% selectivity for the commercial catch)	LN	log(123)	0.05
$D_{95\text{-}50}$ (Length between 50% and 95% selectivity the commercial catch)	LN	log(5)	0.5
Steepness (h)	Fixed	0.75	
Recruitment deviations (ϵ)	LN	0	0.4

The observational data were:
1. A standardised CPUE series covering 2002–2022 based on combined PCELR and ERS data.
2. A commercial catch sampling length frequency series for 2002–2022.
3. Tag-recapture length increment data.
4. Maturity at length data.

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2022 stock assessment used a combined series of PCELR data covering 2002–2019, and ERS data from 2019 to 2022. These data were combined, but due to concerns with ERS data reporting in the area (see Neubauer 2023), a number of sensitivities were run:
- ERS and PCELR data were treated as a single time series,
- ERS reported data were subsetted to clients for which reporting showed no substantial difference from PCELR reporting, as measured by the likelihood of differences between the reporting periods exceeding 0.5, or 0.05, leading to two sensitivity runs as detailed by Neubauer (2023),
- fishing duration was dropped from the analysis, such that CPUE was analysed as catch-per-day in a given statistical area.

CPUE standardisation was carried out using a Bayesian Generalised Linear Mixed Model (GLMM) which partitioned variation among management zones within QMAs, and statistical areas within management zones, while accounting for effects of ACE-holders and individual divers. Unlike previous assessments for PAU 5D, CELR data prior to 2002 were considered unreliable and unlikely to reflect abundance trends, in accordance with recent assessments in PAU 7 and PAU 2. Gear improvements and fisher turnover in the fishery during the late 1980s to the late 1990s likely caused substantial hyper-stability in CELR CPUE indices for pāua. In addition, spatial reporting during CELR years was at the scale of CELR statistical areas, which do not line up with QMA boundaries. As a result, large amounts of CELR catch-per-unit effort data cannot be used for CPUE analyses at the QMA scale because the data cannot be unambiguously attributed to a single QMA.

CPUE was defined as the log of daily catch-per-unit-effort. Variables in the model were fishing year, FIN (Fisher Identification Number), management zone, diver ID, and fine-scale statistical area. Sensitivities for the CPUE data showed little variation from the base model (Figure 3), apart from model runs removing fishing duration from the analysis. The latter was taken as a sensitivity analysis for stock assessment runs.

Variability in CPUE was mostly explained by differences among divers (Figure 4). CPUE trends showed some similarity among management zones, which showed an increasing trend from 2002 to about 2011. However, CPUE subsequently declined to below-average levels, with a low point between 2015 and 2017, and substantial subsequent increases since 2017 (Figure 5). In nearly all models and regions, recent CPUE was near or above the highest CPUE in the time series.

In some circumstances, commercial CPUE may not be proportional to abundance because it is possible to maintain catch rates of pāua despite a declining biomass, with divers searching larger areas. This occurs because pāua tend to aggregate and divers move among areas to maximise their catch rates. Apparent stability in CPUE should therefore be interpreted with caution. The assumption of CPUE being proportional to biomass was investigated using the assessment model.

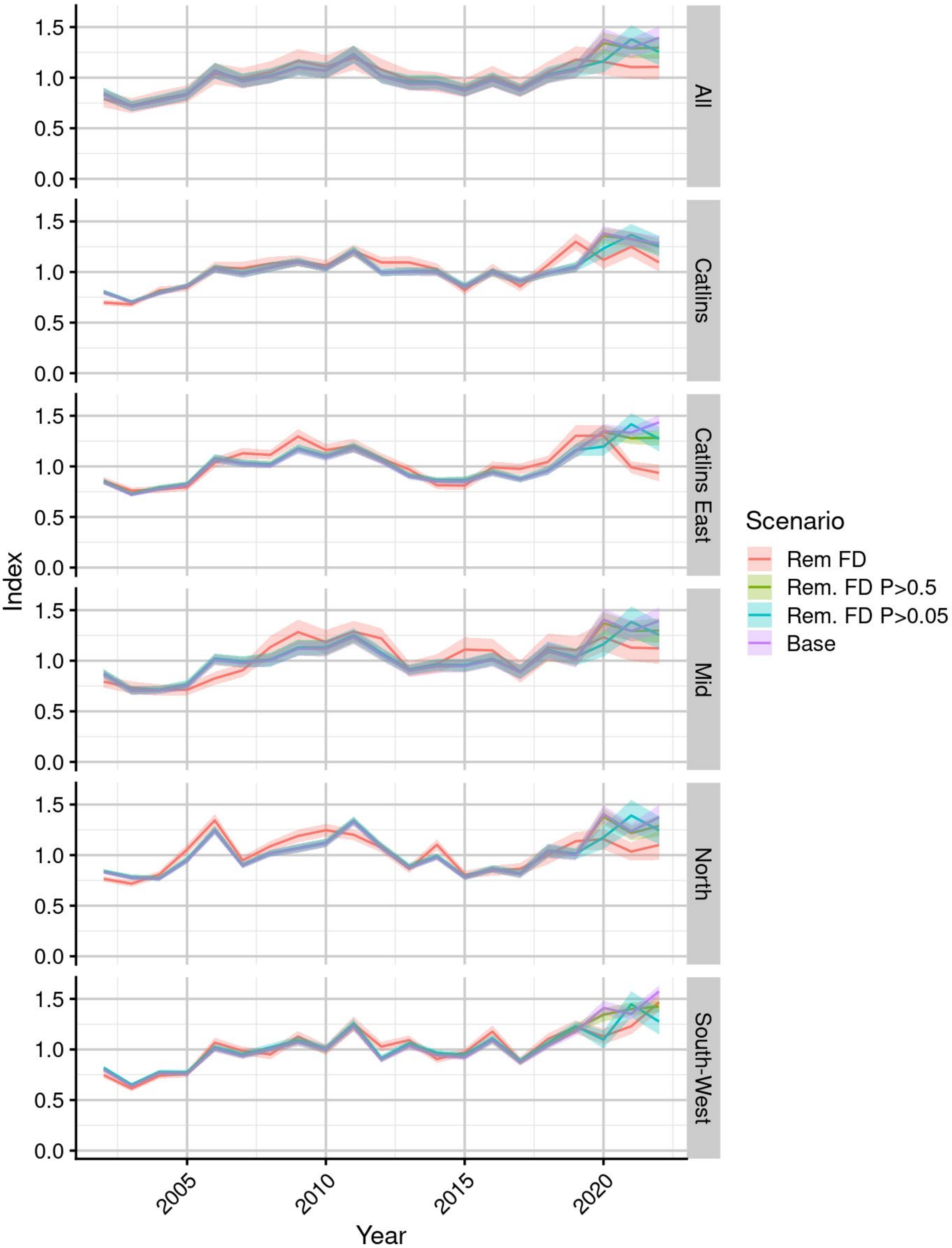


Figure 3: Standardised CPUE indices with 95% confidence intervals (solid line and ribbon) for the combined PCELR and ERS time series. Base uses all available CPUE data (after grooming procedures were applied), REM FD removed fishing duration from the analysis, and REM FD P>0.5 and P>0.05 removed clients unless reporting was as likely as not (0.5) and highly likely (0.05) to have remained the same.

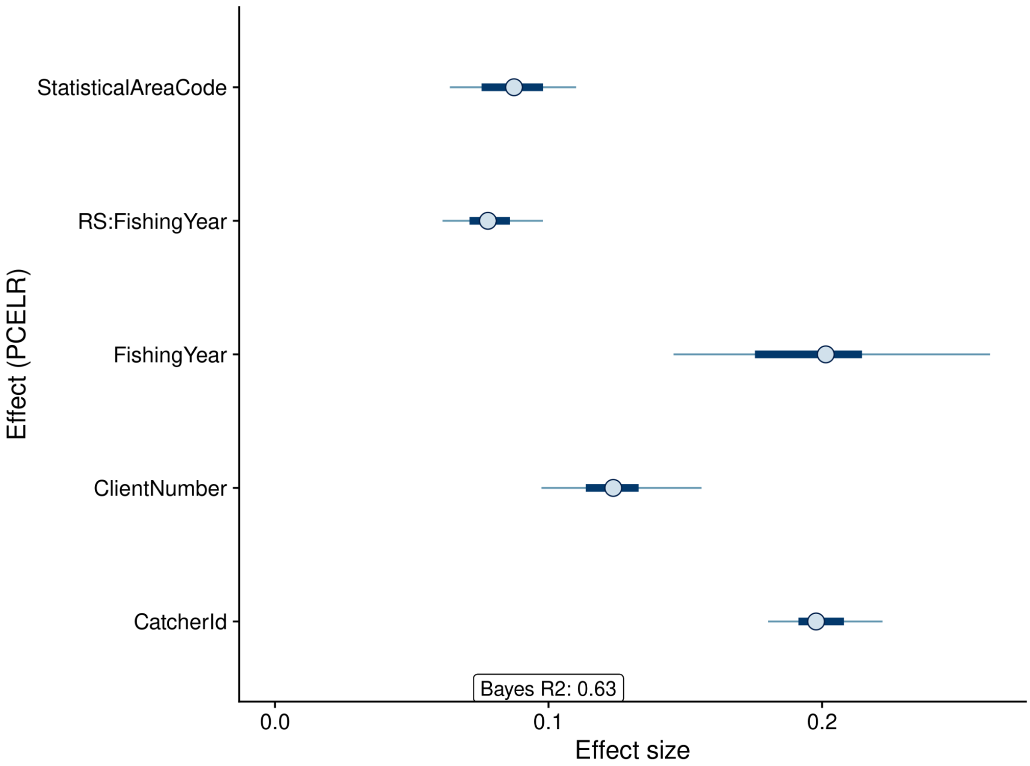


Figure 4: Effect size for the CPUE index standardisation model used for the base-case stock assessment model. RS: management zone (research stratum), CatcherID: diver number.

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of pāua in PAU 5D has also been estimated from a number of independent research diver surveys undertaken in various years between 1994 and 2004. The survey strata (Catlins East and Catlins West) cover the areas that produced about 25% of the recent catches in PAU 5D. These data were not included in the assessment because there is concern that the data are not a reliable enough index of abundance and the data are not representative of the entire PAU 5D QMA.

Concerns about the ability of the data collected in the independent Research Dive surveys to reflect relative abundance instigated reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed the reliability of the research diver survey index (RDSI) as a proxy for abundance and whether the RDSI, when used in the pāua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from pāua stock assessments using the RDSI should be treated with caution. For a summary of the review's conclusions refer to the Introduction – Pāua chapter.

4.2 Stock assessment methods

The 2023 PAU 5D stock assessment used the length-based population dynamics model first described by Breen et al (2003). PAU 5D was last assessed using data up to the 2017–18 fishing year (Neubauer & Tremblay-Boyer 2019), and the most recent assessment uses data up to the 2021–22 fishing year. Although the overall population-dynamics model remained unchanged, the most recent iteration of the PAU 5D stock assessment incorporates a number of changes to the previous methodology:

1. CELR data were dropped from the analysis, in order to avoid potential confounding from efficiency creep in the fishery in the 1990s.
2. Length-frequency data were standardised using an improved model (Neubauer et al in prep) to better estimate uncertainty in estimated removals.
3. Selectivity was allowed to vary in time, along an estimated offset parameterised by the mean minimum harvest size in the QMA for each year. Due to changes in the spatial extent of the fishery among years, and variable harvest sizes, selectivity cannot be assumed to be stationary.
4. Both spatial and single-area models were trialled, but spatial models were highly sensitive to assumptions due to a lack of length-frequency data from southern areas, and only single area models were therefore retained.

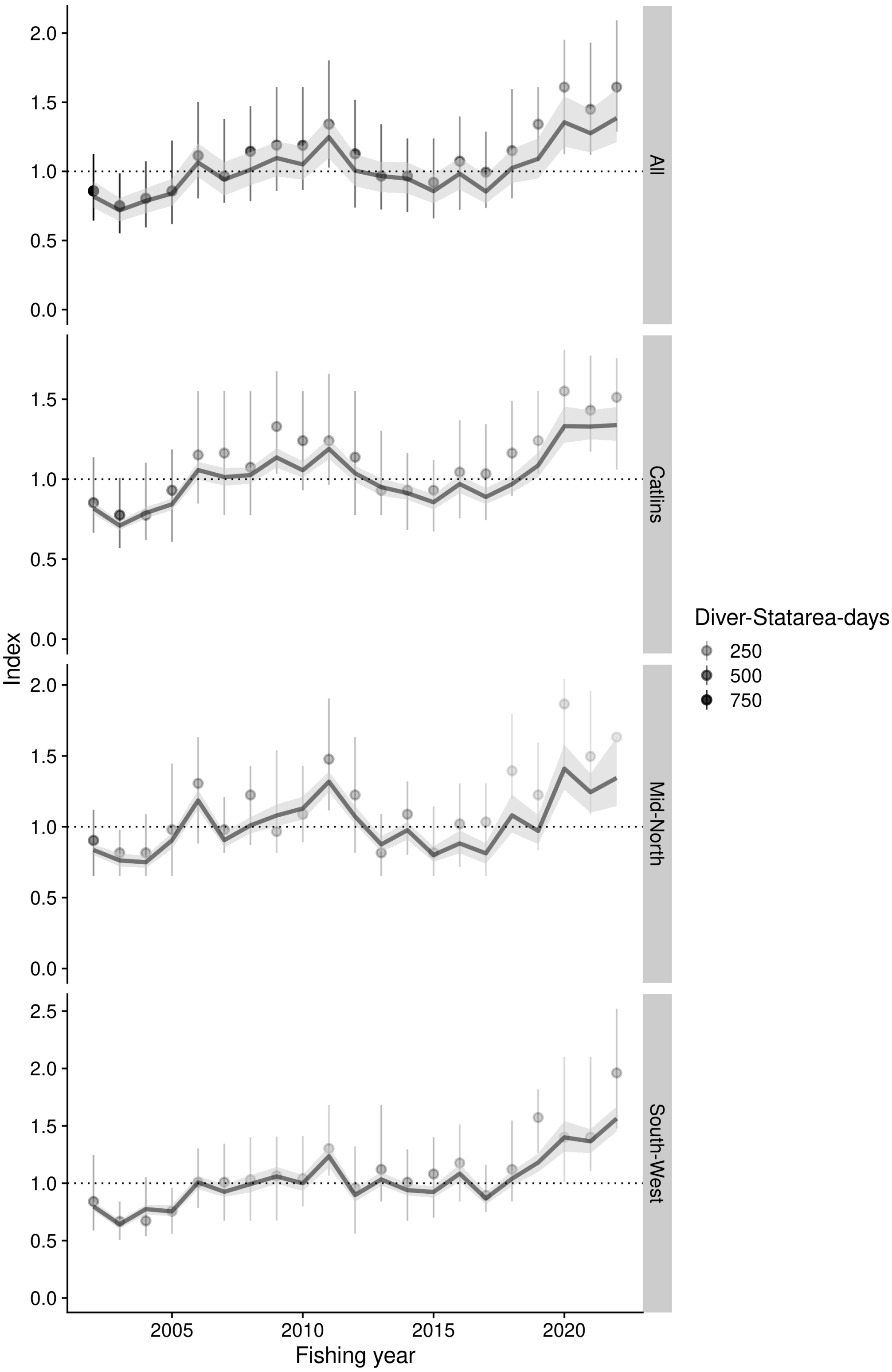


Figure 5: Standardised CPUE indices with 95% confidence intervals (solid line and ribbon) and unstandardised geometric CPUE and variability (points and error bars) for the combined PCELR and ERS time series used in the base-case assessment model.

The model structure assumed a single sex population within each area (defined as management zones for spatial models, and the whole QMA for single-area models), with length classes from 70 mm to 170 mm, in groups of 2 mm. Growth was length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class changing in each year. Pāua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

The model simulated the population from 1965 to 2022. Catches were available for 1974–2022, although catches before 1995 must be estimated from the combined PAU 5 catch and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for pāua. However, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship, with steepness (h) fixed at 0.75 for this assessment.

Growth, maturation, and natural mortality were also estimated within the model, although no fitting to raw data was performed, and all inputs were provided as priors with mean and observation error. The model estimated the commercial fishing selectivity, which was assumed to follow a logistic curve and to reach an asymptote. The selectivity was estimated as varying in time, with a random effect describing deviations from an estimated offset parameterised by the mean minimum harvest size in the QMA for each year.

The assessment initially attempted to fit both spatial and non-spatial models. However, length-composition data from the Southern area of the QMA is sparse until recently, and models were found to be highly sensitive to assumptions and inputs, with models often estimating unrealistically high stock status (low depletion levels). The single area models did not share this sensitivity and were therefore retained. Single area models were used to explore sensitivity to natural mortality (fitted in the base case), selectivity assumptions and CPUE scenarios, as well as hyper-stability scenarios.

The reference model (model 0) excluded the RDSI and Research Diver Length Frequency data, fitted the combined CPUE series for PCELR and ERS data (excluding CELR data) and the mean Catch Sampling Length Frequency (CSLF) and observation error, estimated process error for CPUE and CSLF, updated growth estimates within the model, and estimated *M* within the model. The data weights in this model led to satisfactory fits to both datasets.

The assessment calculates the following quantities from the marginal posterior distributions of various partitions of the biomass: the equilibrium (unfished) spawning stock biomass (SSB_0) assuming that recruitment is equal to the average recruitment, and the relative spawning and available biomass for 2022 (SSB_{2022} and $B_{2022}^{Avail} B_{Proj}^{Avail}$) and for the projection (*Proj*) period (SSB_{Proj} and B_{proj}^{Avail}. This assessment also reports the following fishery indicators:

Relative *SSB*	Estimated spawning stock biomass in the final year relative to unfished spawning stock biomass
Relative B^{Avail}	Estimated available biomass in the final year relative to unfished available stock biomass
P(SSB_{2022} > 40% SSB_0)	Probability that the spawning stock biomass in 2022 was greater than 40% of the unfished spawning stock
P(SSB_{2022} > 20% SSB_0)	Probability that the spawning stock biomass in 2022 was greater than 20% of the unfished spawning stock (soft limit)
P(SSB_{Proj} > 40% SSB_0)	Probability that projected future spawning stock biomass will be greater than 40% of the unfished spawning stock given assumed future catches
P(SSB_{Proj} > 20% SSB_0)	Probability that projected future spawning stock biomass will be greater than 20% of the unfished spawning stock given assumed future catches
P(B_{Proj} > B_{2022})	Probability that projected future biomass (spawning stock or available biomass) is greater than estimated biomass for the 2022 fishing year given assumed future catches

4.3 Stock assessment results

The base case model suggested a recent increase from low levels in spawning stock biomass over the past seven years, following a slow downwards trend from 2010 to 2015 (Figure 6). The base case also indicated that although the stock is currently as likely as not at the interim target spawning stock biomass of 40% *SSB* (Table 6), there is little to no probability that it is below the soft limit of 20% *SSB*. Relative available biomass was markedly lower than the spawning stock biomass, meaning that a considerable part of the spawning biomass was below the minimum harvest size and is therefore not accessible to the fishery.

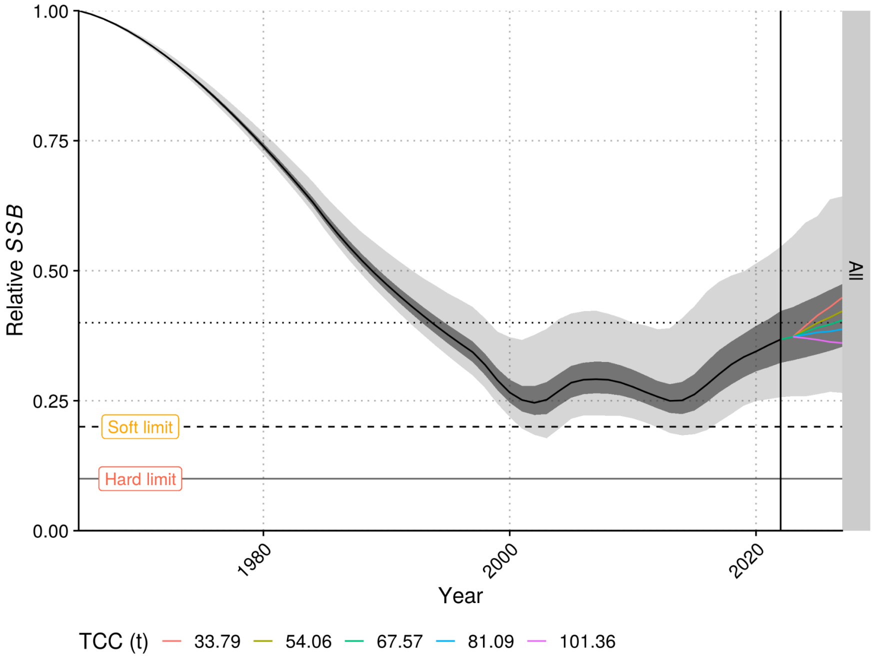


Figure 6: Posterior distributions of spawning stock biomass from the base case model. The black line shows the median of the posterior distribution; the 25th and 75th percentiles are indicated by the dark grey band, with the light grey representing the 95% confidence range of the posterior distribution. Coloured lines for projections relate to alternative future catch levels indicated in the legend.

Table 6: Model sensitivity runs for the stock assessment of pāua in management area PAU 5D. Stock status (posterior mean relative spawning stock biomass), relative available biomass and probability of the stock status being above the soft limit (P(SSB_{proj} > 20% SSB_0). Numbers are posterior medians.

Sensitivity	Stock status	Available	P(SSB_{proj} > 20% SSB_0)
Base	0.38	0.28	1.00
M=0.1	0.33	0.24	1.00
M=0.16	0.66	0.46	1.00
No time-varying selectivity	0.34	0.26	1.00
CPUE without fishing duration	0.39	0.28	1.00

High shelving rates up to > 35% and increased minimum harvest sizes for many areas in PAU 5D since 2015 have led to a strong reduction in exploitation rate (Figure 7), which is currently below U_{40}. It is likely that this reduction in catch has led to the current increase in biomass from previously low levels near the soft limit of 20% *SSB*.

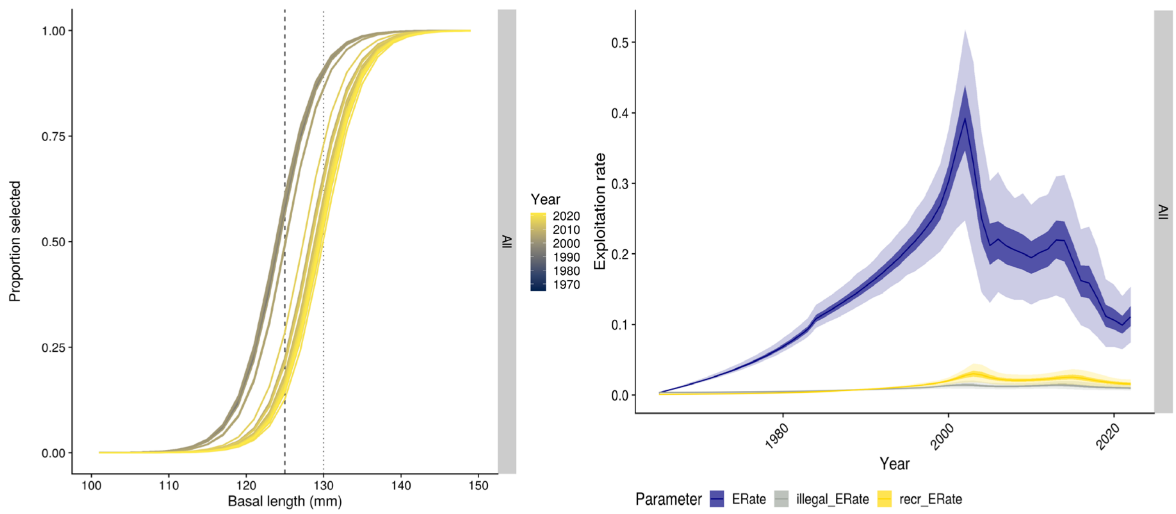


Figure 7: Estimated selectivity by year (left) and exploitation rate (right) for commercial (ERate), illegal (illegal_ERate), and recreational fishery components assumed in the model. Vertical dashed and dotted lines show the minimum legal size and 130 mm as a reference.

Projections suggested increasing *SSB* for scenarios of current catch and 20% increased or decreased catch (Table 7); however, the estimated equilibrium biomass at 89 t (i.e., the current TACC) appears close to 40% *SSB* whereas at current catch (67.5 t), *SSB* is projected to increase further and is projected to be more likely than not to be above target by 2026, with a long-term likelihood of exceeding target harvest rates (U_{40}) of 8%, compared to a risk of exceeding target harvest rates near 60% for projections at the TACC (89 t).

Sensitivities were set up to investigate the robustness of the model to key assumptions about CPUE and time-varying selectivity, as well as specific values of *M*. For CPUE, an alternative CPUE time series derived from CPUE without fishing duration (no-FD) was used to fit the model but resulted in only very minor deviation from the base case model, with slightly lower stock status estimated. Models without time-varying selectivity and fixed *M* at 0.1 gave a similar result, whereas a model with high *M* at 0.16 produced a far more optimistic estimate of stock status across the time series.

For a number of reasons, reference points based on deterministic *MSY* or B_{MSY} are not currently used for managing pāua stocks and were therefore not calculated. B_{MSY} is not considered a suitable target for management of the pāua fishery. Deterministic *MSY* is commonly much higher than realised catch for pāua stocks (e.g., Marsh & Fu 2017) and deterministic B_{MSY} is estimated at biomass levels corresponding to very low available biomass levels. Management based on deterministic *MSY*-based reference points would likely lead to biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical deterministic biomass, but the extent to which it needs to be above has not been determined.

In the meantime, an interim target of 40% B_0 is used as a proxy for a more realistic interpretation of B_{MSY}.

Table 7: Projections for key fishery indicators from the base case model: probabilities of being above 40% and 20% of unfished spawning biomass (*SSB*) [P(SSB_{Proj} > 40% SSB_0) and P(SSB_{Proj} > 20% SSB_0)], the probability that *SSB* in the projection year is above current *SSB*, the posterior median relative to *SSB*, the posterior median relative available spawning biomass B^{Avail}_{Proj}, and the probability that the exploitation rate (*U*) in the projection year is above $U_{40\%\ SSB0}$, the exploitation rate that leads to 40% SSB_0. The total commercial catch (TCC) marked with * corresponds to current commercial catch under 25% shelving of the current TACC (89 t). Other scenarios show projections at the current TACC and 20% decreased catch relative to current catch. Simulations to equilibrium (assumed to have been reached after 50 projection years) are indicated with Eq. in the year column.

TACC (t)	Year	P(SSB_{Proj} > 40% SSB_0)	P(SSB_{Proj} > 20% SSB_0)	P(SSB_{Proj} > SSB_{2022})	Median rel. SSB_{Proj}	Median rel. B^{Avail}_{Proj}	P(U > $U_{40\%\ SSB0}$)
54	2023	0.37	1.00	0.67	0.38	0.28	0.13
	2024	0.47	1.00	0.90	0.40	0.30	0.11
	2025	0.56	1.00	0.94	0.42	0.32	0.10
	2026	0.65	1.00	0.96	0.44	0.33	0.09
	2027	0.73	1.00	0.98	0.46	0.35	0.09
	Eq.	1.00	1.00	1.00	0.79	0.69	0.03
67.5*	2023	0.37	1.00	0.67	0.38	0.28	0.31
	2024	0.43	1.00	0.80	0.40	0.29	0.29
	2025	0.50	1.00	0.85	0.41	0.30	0.28
	2026	0.55	1.00	0.88	0.42	0.31	0.27
	2027	0.61	1.00	0.90	0.44	0.32	0.24
	Eq.	0.99	1.00	1.00	0.68	0.58	0.08
89	2023	0.33	1.00	0.66	0.38	0.28	0.63
	2024	0.35	1.00	0.58	0.38	0.27	0.63
	2025	0.37	0.99	0.57	0.38	0.27	0.62
	2026	0.38	0.99	0.57	0.38	0.27	0.62
	2027	0.38	0.99	0.57	0.38	0.27	0.61
	Eq.	0.62	0.91	0.70	0.44	0.33	0.51

4.4 Other factors

To run the stock assessment model a number of assumptions must be made, one of these being that CPUE is a reliable index of abundance. Recent empirical data (Abraham & Neubauer 2015, McCowan & Neubauer 2021) provide some evidence of linear relationships between CPUE and abundance, albeit at spatial scales that are smaller than that of the overall fishery.

The commercial catch is unknown before 1974 and is estimated with uncertainty before 1995. Differences may exist between assumed catches and what was actually taken. Non-commercial catch estimates, including illegal catch, are also poorly determined and could be substantially different from what was assumed. Sensitivities to alternative catch histories are considered.

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 pressure. The model assumes homogeneity in recruitment and natural mortality.

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. Thus, length frequency data collected from the commercial catch may not represent the available biomass represented in the model with high precision.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that it may result in some populations becoming 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.

The effect of these factors is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the depletion of spawners, as 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 does not account for.

4.5 Testing management procedures

Management procedures have been operating in the PAU 5D fishery since 2016. A harvest control rule developed with commercial fisheries stakeholders was tested at the time using the available stock assessment model as an operating model. The control rule was updated in the context of the 2023 stock assessment for PAU 5D to introduce further safeguards (a lag year on increases, allowing increases in catch only if two successive increases in CPUE are observed), and allowing a maximum of 5% increase in catch per year.

Testing of the control rule included testing against a range of sensitivities used in the stock assessment process (levels of natural mortality), as well as scenarios of poor recruitment. The control rule was able to maintain steady exploitation rates, and maintained the stock at or above the interim target by applying catch that was fluctuating between current catch levels and the TACC. The control rule was highly likely to maintain biomass above limit reference points.

5. FUTURE RESEARCH CONSIDERATIONS

- Consider sensitivity analyses with alternative catch histories.
- Improve estimates of growth. Expand collection of tagging and environmental data to investigate drivers of growth.
- Further investigate data weighting procedures for pāua stocks. Replace use of likelihood multipliers using observational errors to set initial data weights.
- Re-examine the historical diver surveys and length frequencies to determine their utility.
- Collect additional data to update the length-weight relationship.
- Explore alternative selectivity parameterisation, considering non symmetrical ogives and allowing both L_{50} and a_{95} to vary over time.

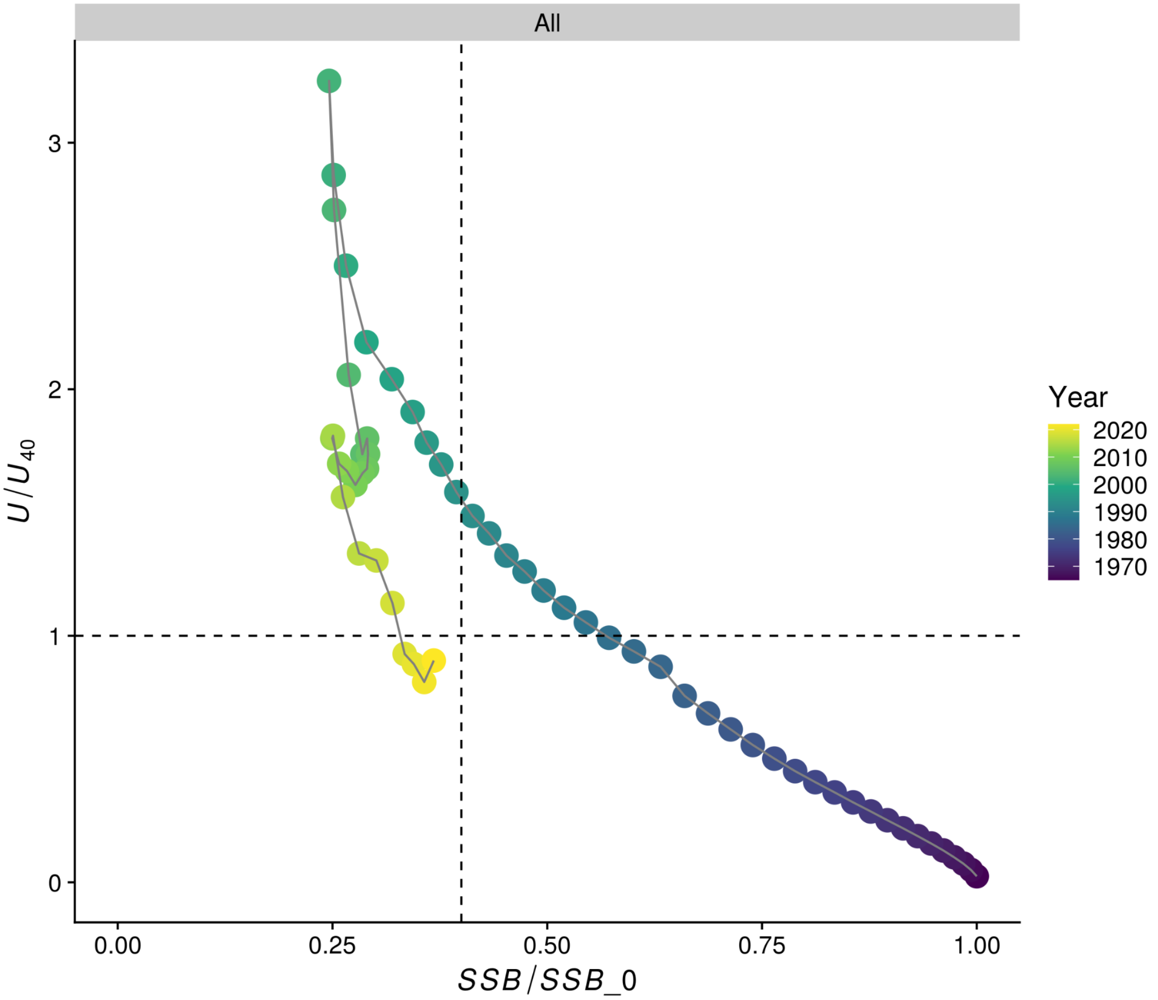
6. STATUS OF THE STOCK

Stock Structure Assumptions
PAU 5D is assumed in the model to be a discrete and homogenous stock within the area of PAU 5D that is commercially fished.

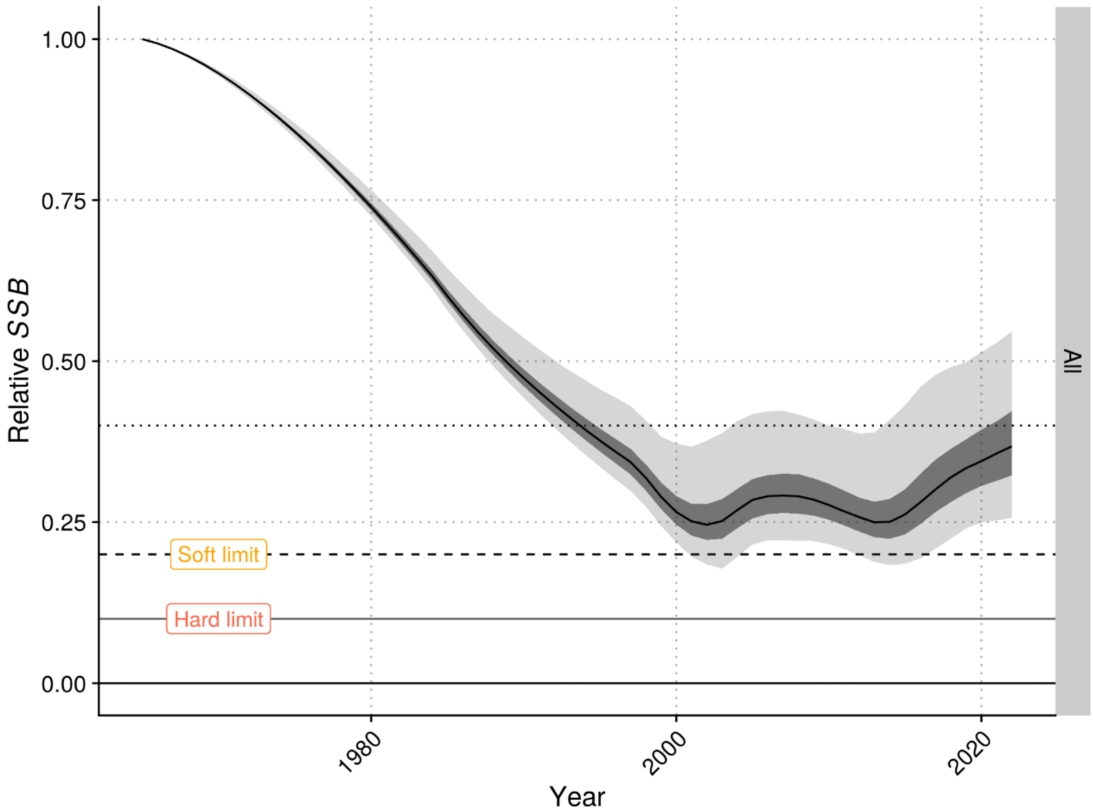
PAU 5D - Southland / Otago

Stock Status		
Year of Most Recent Assessment	2023	
Catch in most recent year of assessment	Year: 2021–22	Catch: 68 t
Assessment Runs Presented	Base case MCMC	
Reference Points	Interim Target: 40% SSB_0 Soft Limit: 20% SSB_0 Hard Limit: 10% SSB_0 Overfishing threshold: $U_{40\%SSB0}$	
Status in relation to Target	SSB_{2022} was estimated to be 38% SSB_0. About as Likely as Not (40–60%) to be at or above the target	
Status in relation to Limits	Very Unlikely (< 10%) to be below both the soft and hard limits	
Status in Relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring	

Historical Stock Status Trajectory and Current Status



Plot of *SSB* relative to unfished spawning biomass (*SSB_0*), and exploitation rate (*U*) relative to exploitation rate at 40% of *SSB_0*.



Posterior distributions of spawning stock biomass from the base case model. The line shows the median of the posterior distribution; the 25th and 75th percentiles are indicated by the dark grey, and the light grey represents the 95% confidence range of the distribution.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased up to about 2015 and has been increasing recently towards the interim target reference point.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate peaked in 2002 and has since declined.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At the current catch level, biomass is About as Likely as Not (40–60%) to rebuild above the interim target reference biomass. At the current TACC, biomass is About as Likely as Not (40–60%) to remain at the interim target in the short term.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Results from all model assessment runs presented suggest it is Unlikely (< 40%) that current levels of catch or the TACC will cause a decline below the soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (<40%) for current catch; About as Likely as Not (40–60%) for current TACC.

Assessment Methodology and Evaluation		
Assessment Type	1 - Full Quantitative Stock Assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest assessment Plenary publication year: 2023	Next: 2028

Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Catch History - CPUE Indices PCELR & ERS series - Commercial sampling length frequencies - Tag recapture data - Maturity at length data	2 – Medium or Mixed Quality: not believed to be fully representative of catch in the QMA 1 – High Quality 2 – Medium or Mixed Quality: not believed to be representative of the whole fishery 2 – Medium or Mixed Quality: not believed to be representative of the whole QMA 1 – High Quality
Data not used (rank)	- Research Dive survey indices - Research Dive length frequencies CPUE (CELR series years)	3 – Low Quality: not believed to be a reliable indicator of abundance in the whole QMA 3 – Low Quality: not believed to be a reliable indicator of length frequency in the whole QMA 3 – Low Quality: not believed to be fully representative of CPUE in the QMA
Changes to Model Structure and Assumptions	- CELR data were dropped from the analysis, to avoid potential confounding from efficiency creep in the fishery in the 1990s. - Length frequency data were standardised using an improved model to better estimate uncertainty in estimated removals. - Selectivity was allowed to vary over time through an estimated offset to L_{50} parameterised by the fishery minimum harvest size.	
Major Sources of Uncertainty	- Growth estimates were informed by a weakly informed prior - Influence of changes in reporting due to ERS on CPUE indices may have a small effect on stock status determinations.	

Qualifying Comments
Uncertainties in the input data and model structure necessitate caution in the interpretation of the assessed status of the stock. However, the high minimum harvest size relative to length-at-maturity (along with closed areas) means that a relatively large proportion of the spawning stock is not available to the fishery and provides a buffer from the effects of fishing for the stock.

Fishery Interactions
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7. FOR FURTHER INFORMATION

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