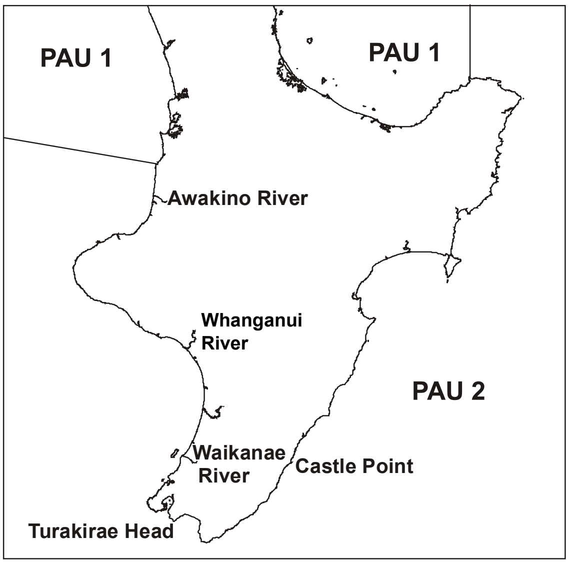
PĀUA (PAU 2) – Wairarapa / Wellington / Taranaki

(*Haliotis iris*)
Pāua



1. FISHERY SUMMARY

PAU 2 was introduced into the Quota Management System in 1986–87 with a TACC of 100 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 121.19 t in 1989. On 1 October 2023, a TAC of 192.19 t was set with a TACC of 121.19 t, a customary allowance of 12 t, a recreational allowance of 48 t and and an allowance of 11 t for other sources of mortality.

Table 1: Total allowable catches (TAC, t), allowances for customary fishing, recreational fishing, and other sources of mortality (t), and Total Allowable Commercial Catches (TACC, t) declared for PAU 2 since introduction to the Quota Management System (QMS).

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1989	–	–	–	–	100
1989–2023	–	–	–	–	121.19
2023- present	192.19	12	48	11	121.19

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September. Most of the commercial catch comes from the Wairarapa and Wellington South coasts between Castlepoint and Turakirae Head. The western areas between Tirua Point and the Whanganui River, and Turakirae Head and the Waikanae River, and the eastern area between Cape Runaway and Blackhead Lighthouse are closed to commercial fishing.

On 1 October 2001 it became mandatory to report catch and effort on PCELRs using the fine-scale reporting areas that had been developed by the New Zealand Pāua Management Company for their voluntary logbook programme (Figure 1). Landings for PAU 2 are shown in Table 2 and Figure 2. Landings have been at or very close to the TACC since 1988–89.

1.2 Recreational fisheries

The most recent recreational fishery survey "The National Panel Survey of Marine Recreational Fishers 2022–23: Harvest Estimates" Heinemann & Gray (in prep), estimated that about 33 t of pāua were harvested by recreational fishers in PAU 2 in 2022–23.

Because pāua around Taranaki are naturally small and never reach the minimum legal size (MLS) of 125 mm, a new MLS of 85 mm was introduced for recreational fishers from 1 October 2009. The new length was on a trial basis for five years and now applies between the Awakino and Wanganui rivers.

In September 2023, the recreational daily bag limit for pāua in PAU 2 was reduced from 10 yellowfoot pāua and 10 blackfoot pāua per fisher per day to 5 of each species per fisher, per day.

For further information on recreational fisheries refer to the Introduction – Pāua chapter.

Figure 1: Map of fine-scale statistical reporting areas for PAU 2.

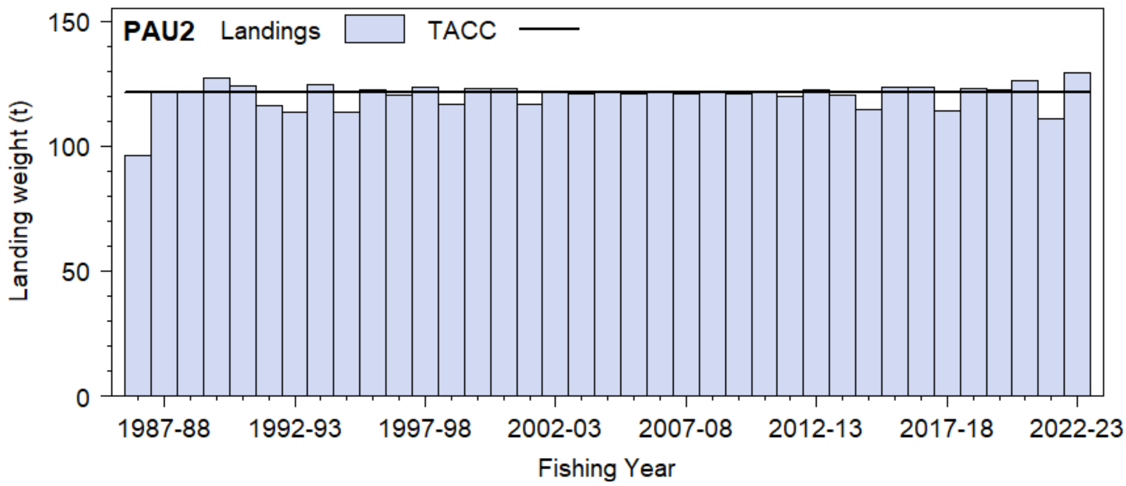


Figure 2: Historical landings and TACC for PAU 2 from 1983–84 to the present. QMS data from 1986 to present.

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

Fishing year	Landings	TACC	Fishing year	Landings	TACC
1983–84*	110	–	2003–04	121.06	121.19
1984–85*	154	–	2004–05	121.19	121.19
1985–86*	92	–	2005–06	121.14	121.19
1986–87*	96.2	100	2006–07	121.20	121.19
1987–88*	122.11	111.33	2007–08	121.06	121.19
1988–89*	121.5	120.12	2008–09	121.18	121.19
1989–90	127.28	121.19	2009–10	121.13	121.19
1990–91	125.82	121.19	2010–11	121.18	121.19
1991–92	116.66	121.19	2011–12	120.01	121.19
1992–93	119.13	121.19	2012–13	122.00	121.19
1993–94	125.22	121.19	2013–14	120.00	121.19
1994–95	113.28	121.19	2014–15	115.00	121.19
1995–96	119.75	121.19	2015–16	123.74	121.19
1996–97	118.86	121.19	2016–17	123.69	121.19
1997–98	122.41	121.19	2017–18	113.87	121.19
1998–99	115.22	121.19	2018–19	122.89	121.19
1999–00	122.48	121.19	2019–20	122.28	121.19
2000–01	122.92	121.19	2020–21	126.26	121.19
2001–02	116.87	121.19	2021–22	110.91	121.19
2002–03	121.19	121.19	2022–23	129.39	121.19

* FSU data.

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 2 are given in Table 3. These numbers are likely to be an underestimate of customary harvest because only the catch in kilograms and numbers are 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 as weight (kg) and in numbers) in PAU 2 since 1998-99 (no reports since 2018-19). – no data.

	Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested
1998–99	40	40	–	–
1999–00	–	–	1 400	820
2000–01	–	–	–	–
2001–02	–	–	–	–
2002–03	–	–	–	–
2003–04	–	–	4 805	4 685
2004–05	–	–	2 780	2 440
2005–06	–	–	5 349	4 385
2006–07	–	–	7 088	3 446
2007–08	–	–	11 298	6 164
2008–09	–	–	30 312	24 155
2009–10	–	–	5 505	4 087
2010–11	–	–	20 570	17 062
2011–12	243	243	29 759	23 932
2012–13	10	6	51 275	27 653
2013–14	–	–	61 486	30 129
2014–15	–	–	25 215	16 449
2015–16	–	–	11 540	6 383
2016–17	100	100	13 698	6 877
2017–18	–	–	6 960	1 942
2018–19	–	–	8 585	3 189
2019–20	–	–	–	–
2020–21	–	–	–	–
2021–22	–	–	–	–
2022–23	–	–	–	–

1.4 Illegal catch

It is widely believed that the level of illegal harvesting is high around Wellington and on the Wairarapa coast. 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.

2. BIOLOGY

For further information on pāua biology refer to the Introduction – Pāua chapter. A summary of published estimates of biological parameters for PAU 2 is presented in Table 4.

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

Area			**Estimate**	**Source**
1. Size at maturity (shell length)				
Wellington	50% mature		71.7 mm	Naylor et al (2006)
Taranaki	50% mature		58.9 mm	Naylor & Andrew (2000)
Meta-analysis for fished areas (all QMAs)	50% mature		90.5 mm	Neubauer & Tremblay-Boyer (2019a)
2. Fecundity = a (length)^b (eggs, shell length in mm)				
Taranaki		a = 43.98	b = 2.07	Naylor & Andrew (2000)
3. Exponential growth parameters (both sexes combined)				
Wellington	g_{50}		30.58 mm	Naylor et al (2006)
	g_{100}		14.8 mm	
Taranaki	G_{25}		18.4 mm	Naylor & Andrew (2000)
	G_{75}		2.8 mm	
Assessment fit for commercially fished area	G_{75}		14.01 mm (SE 1.36mm)	Neubauer (2022b)
	G_{125}		2.00 mm (SE 0.30 mm)	

3. STOCKS AND AREAS

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

4. STOCK ASSESSMENT

In 2020, the Shellfish Fisheries Assessment Working Group evaluated the overall CPUE trend and concluded (given experience with other QMAs) that the data were potentially sufficient to conduct a full length-based stock assessment in line with those run for other QMAs (e.g., Neubauer & Tremblay-Boyer 2019b, Neubauer 2022). However, the Fisheries Assessment Plenary considered the stock assessment results to be insufficiently robust given concerns about the choice of the base-case scenario and sensitivities, and issues with use of the early CPUE data (i.e., FSU and CELR data). Concerns were also raised about the validity of region-wide CPUE and Catch Sampling Length-Frequency (CSLF) trends given the fine-scale stock structure of pāua. An updated model addressing concerns raised in the 2020 plenary was presented to plenary in May 2021, including updated data to the 2020 fishing year.

4.1 Relative abundance estimates from standardised CPUE analyses

A combined series of standardised CPUE indices CELR (1990–2001) data and PCELR (2002–2020) data was considered for the 2021 stock assessment. However, the Plenary concluded that the CELR analysis was unlikely to represent biomass trends and also that the 2019–2020 PCELR data were likely to be inconsistent with earlier years in the series, because of COVID-19 effects on export markets and Electronic Reporting System (ERS) reporting issues, and should therefore be excluded.

There was little evidence in the data for serial depletion at statutory reporting scales; all main areas (i.e., excluding sporadically fished northern areas) were fished consistently throughout the time series (Figure 3).

CPUE standardisation was carried out using Bayesian Generalised Linear Mixed Models (GLMM) which partitioned variation among fixed (research strata) and random variables. CPUE was defined as the log of daily catch within a statistical area. Variables in the model were fishing year, estimated fishing effort, client number, research stratum, dive condition, diver ID (PCELR), and fine-scale statistical area.

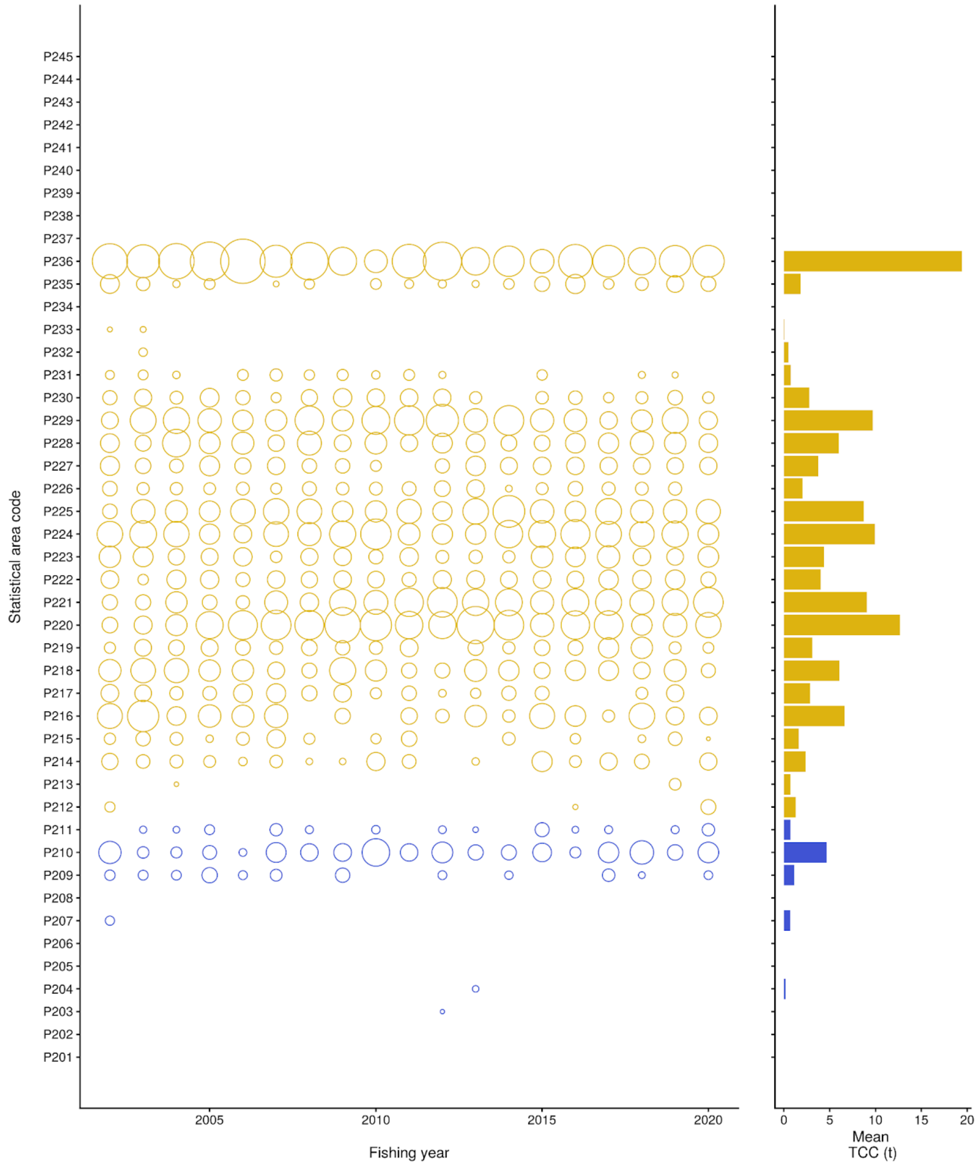


Figure 3: Relative trend in pāua catch (kg) over time by statistical areas in quota management area PAU 2 for the period from 2002 to 2020, with mean commercial catch over the same time period (right-hand side). Statistical areas used for the stock assessment within PAU 2 are colour-coded as gold for Statistical Areas 015 & 016 and blue for the northern Statistical Area 014; the latter area is small and less consistently fished, and was excluded from the stock assessment (but included in CPUE analyses).

Following recommendations from the 2020 plenary, the 2021 CPUE analysis introduced a client experience effect, estimated as a smoothing spline across years that individual clients (usually referring to ACE-holders/boat-owners) had been active in the fishery. The latter was determined across CELR and PCELR data. This effect was found to have a large influence on the CPUE index for CELR data, and the plenary chose not to retain this index because it is unclear to what degree changes in abundance and changes in the fishery at the time are confounded, and in how far the standardisation model can correct for the latter, even in the presence of an experience effect (this effect may itself be confounded with trends in biomass).

For the retained PCELR index, changes over time in ACE-holders present in the fishery had the strongest influence on CPUE (Figure 4). An initial decline was evident from the early part of the PCELR time series, with relatively stable but fluctuating CPUE since 2007 (Figure 5). 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. This occurs because pāua tend to aggregate and divers move between areas to maximise their catch rates. The apparent stability in the CPUE should therefore be interpreted with caution.

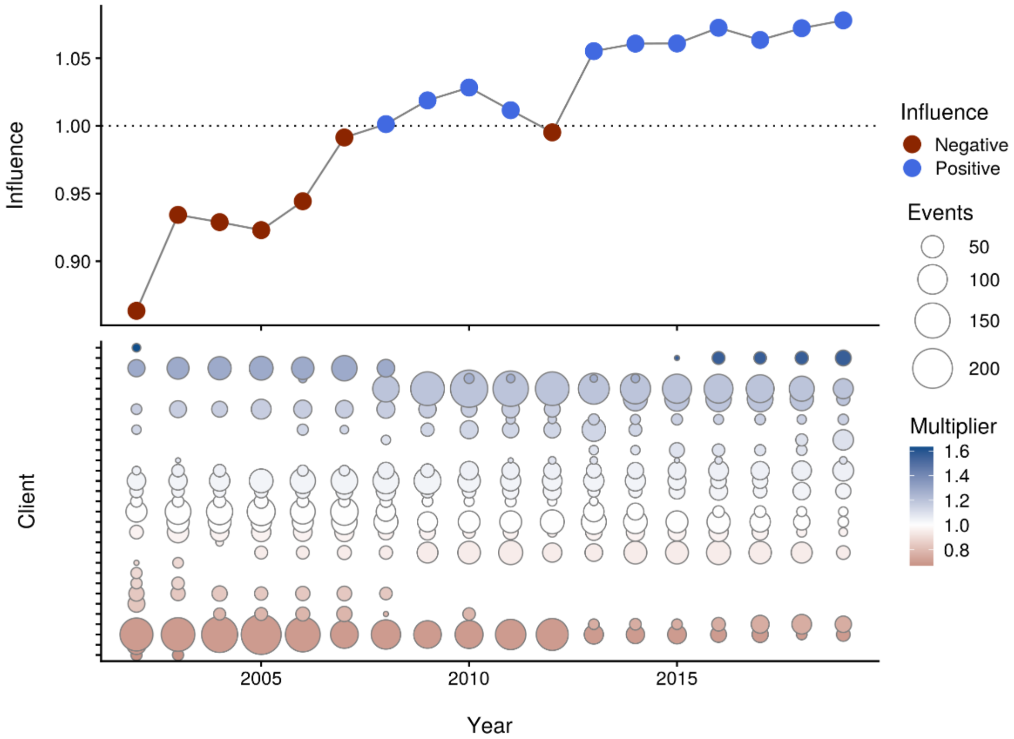


Figure 4: Influence of client number (usually ACE holders) turnover on the PCELR CPUE index through time. A positive influence for any given year suggests that the raw CPUE is inflated because most effort came from clients with higher catch rates in the fishery.

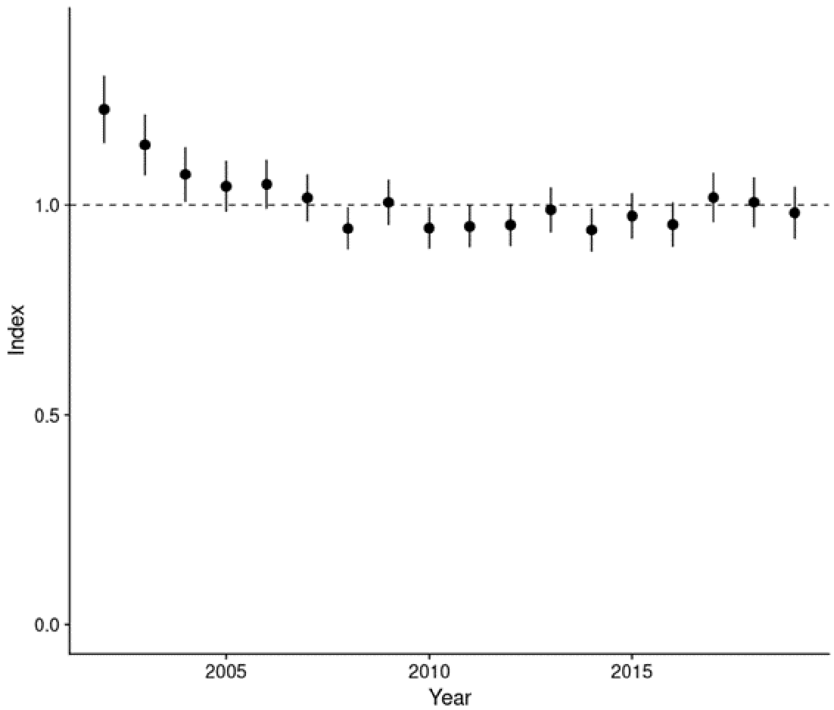


Figure 5: Standardised CPUE index for PCELR data, with posterior mean and standard errors.

4.2 Stock assessment methods

The 2021 stock assessment for PAU 2 used an updated version of the length-based population dynamics model described by Breen et al (2003), catch and commercial length-frequency data up to the 2019–20 fishing year, as well as the above-mentioned CPUE index for fishing years 2002–2019 (Neubauer 2020). Although the overall population dynamics model remained unchanged from Breen et al (2003), the PAU 2 stock assessment incorporates changes to the previous methodology first introduced in the 2018 assessment of PAU 5D (Neubauer & Tremblay-Boyer 2019b). In addition, illegal and recreational catch were, for the first time, split from commercial catch, and illegal catch was modeled as taking pāua in proportion to abundance rather than according to commercial selectivity.

The model structure assumed a single-sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm in groups of 2 mm, although a spatial version of the assessment model (Neubauer 2022) was also tried in 2019. The latter provided near identical results to the non-spatial model and was not pursued in 2021.

Growth was length-based, without reference to age, mediated through an estimated growth transition matrix that describes the probability of each length class to change at each time step. A growth prior was formulated from a meta-analysis of pāua growth across fished areas in New Zealand (Neubauer & Tremblay-Boyer 2019a), and the functional form of the resulting growth was encoded in a multivariate normal (Gaussian process) prior on the growth transition matrix. Pāua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

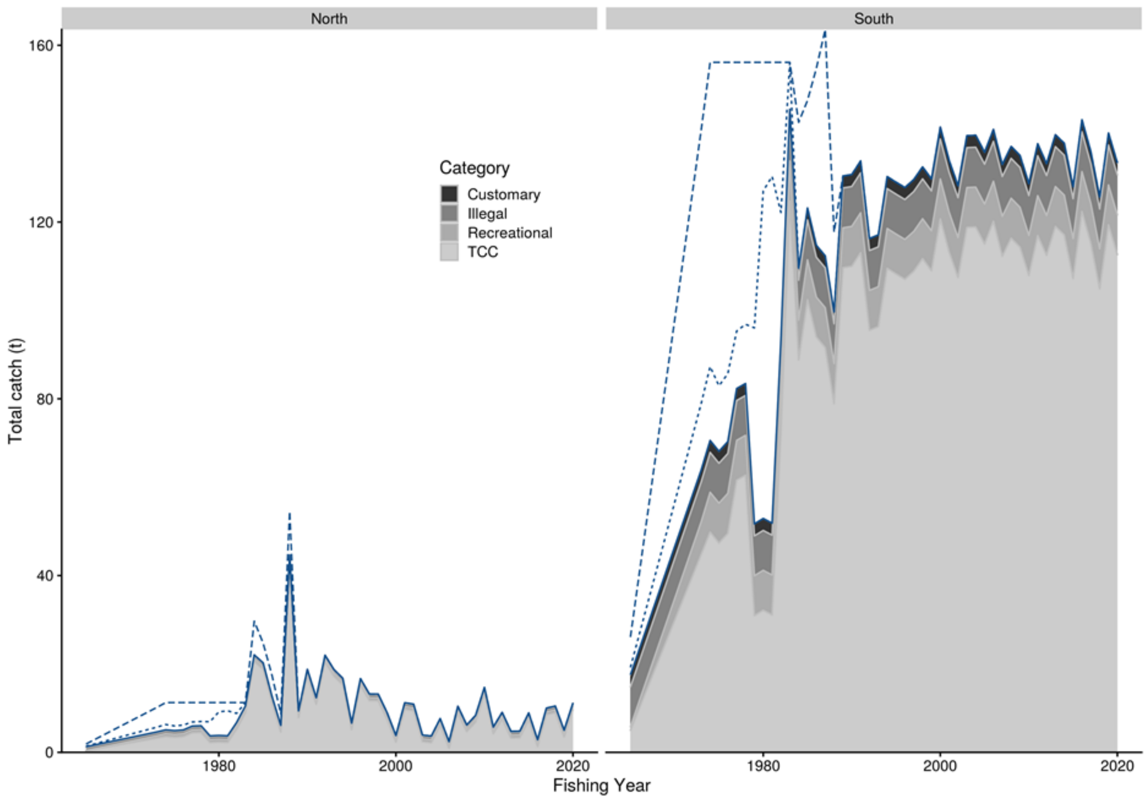


Figure 6: Assumed catch histories for southern (gold circles in Figure 3) and northern (blue circles in Figure 3) statistical areas. Grey shading indicates components of the total catch, with the dotted line showing the base case assumption of total catch, including unreported catches prior to QMS entry of PAU 2, and the dashed line showing a sensitivity with high assumed pre-QMS catches. The reported catches (grey area only) were taken as a second sensitivity.

The model simulates the population from 1965 to 2020. Catches were available for 1974–2020, though catches before 1990 are considered highly uncertain. Interviews with divers at the time suggested that misreporting was prevalent in early years preceding the Quota Management System (i.e., before 1986), and that a considerable amount of catch was unreported at the time. Three different catch levels were tried to account for this uncertainty in the assessment, and catches were assumed to increase linearly from 0 in 1965 to the 1974 catch level (Figure 6). Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step. Illegal catch was assumed to be constant at 10 t for the commercially fished area (South Wairarapa), whereas recreational catch increased from the start of the fishery to 1974 and remained at 10 t for the remainder of the time series.

Recruitment was assumed to take place at the beginning of the annual cycle, with recruitment deviates estimated from 2000 to 2017, and length-at-recruitment was defined by a uniform distribution with a range between 70 and 80 mm. Natural mortality was fixed at 0.11, with sensitivities at 0.06 and 0.16 bracketing *a priori* assumptions about natural mortality. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve, with increases in recent years due to changes in the minimum harvest size in some areas. Models with variable (random effect) selectivity were also tried, and though they improved fits to commercial length frequency data, they did not markedly change the overall assessment of biomass trends. The model was initiated with likelihood weights that were found to lead to subjectively appropriate fits to both CPUE and CSLF inputs in other areas (PAU 5, PAU 7), and relative fits for CPUE and CSLF data were examined, based on model fits and residuals.

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 2019 (SSB_{2019} and $\mathrm{B}_{\mathrm{Proj}}^{\mathrm{Avail}}$) 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_{2019} > 40% SSB_0)	Probability that the spawning stock biomass in 2019 was greater than 40% of the unfished spawning stock
P(SSB_{2019} > 20% SSB_0)	Probability that the spawning stock biomass in 2019 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_{2018})	Probability that projected future biomass (spawning stock or available biomass) is greater than estimated biomass for the 2018 fishing year given assumed future catches

4.2.1 Estimated parameters

Parameters estimated in the assessment model and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of key model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal; Beta = beta distribution), and mean and standard deviation of the prior.

				Bounds	
Parameter	**Prior**	**μ**	**sd**	**Lower**	**Upper**
ln(R_0)	LN	14	10		
ln(q)	LN	-14	100		
M	fixed	0.11		0.06	0.16
Steepness (h)	Beta	0.8	0.17	0	1
Growth	MVN	From Neubauer & Tremblay-Boyer (2019)			
D_{50} (Length at 50% selectivity for recreational and commercial catch before adjustments for commercial minimum harvest size)	LN	125	6.25	100	145
D_{95-50} (Length between 50% and 95% selectivity the commercial catch)	LN	5.6	3	0.01	50
$ln(\epsilon)$ (Recruitment deviations; 2000-2017)	LN	0	0.4		-

The observational data were:

- A standardised CPUE series covering 2002–2019 based on PCELR data.

- Commercial catch sampling length frequency from 2006 to 2020
- Catches were assumed known at three levels

4.3 Stock assessment results

The base model with M=0.11 and estimated growth gave a relatively good fit to CPUE and CSLF data, although the first year of PCELR CPUE was not fitted well by this model or any sensitivities. This lack of fit is due to constraints on recruitment deviations that were estimated from 2000, given LF data are available in sufficient numbers since 2006. Since recruitment into the model occurs between 70 and 80 mm (assumed to be 3 year olds), these individuals would only appear in the commercial data as about 6 year olds, and recruitment would likely need to be freed up back to 1996 to fit these points. Fits to recent CSLF data (2019, 2020) were also slightly worse than for other years, potentially due to changes in markets and resulting selectivity. Model sensitivities with low M (0.06) fitted CSLF data poorly, and estimated very slow growth, indicating that this assumption is not consistent with data and assumptions about growth in fished areas.

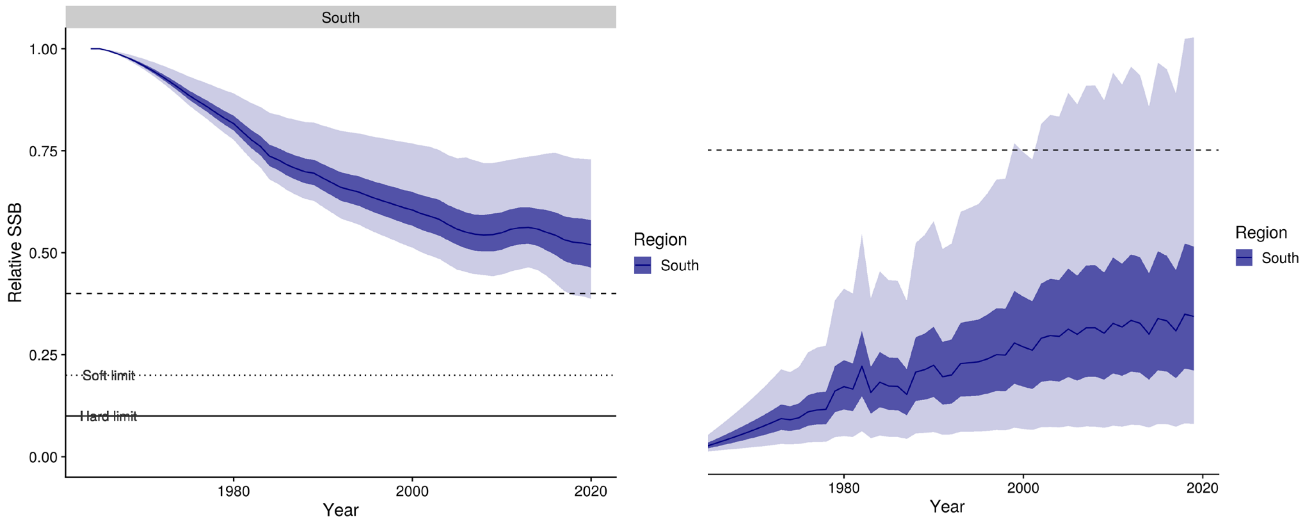


Figure 7: Posterior distributions of relative spawning stock biomass (*SSB*, left panel) and trends in relative commercial exploitation rate (right panel) in the base case model. Exploitation rate (*U*) is relative to the exploitation rate that would result in a stock depletion to 40% of unfished spawning biomass (U_{40}). The dark purple line shows the median of the posterior distribution, the 25th and 75th percentiles are shown as dark ribbons, with light ribbons representing the 95% confidence range of the distribution.

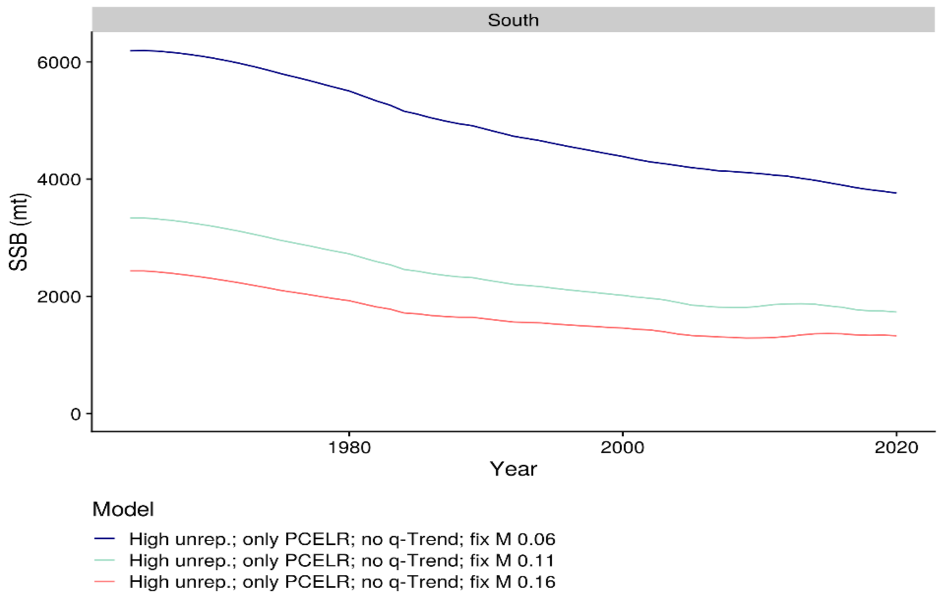


Figure 8: Posterior median of spawning stock biomass (*SSB*; left panel) from model with different levels of natural mortality.

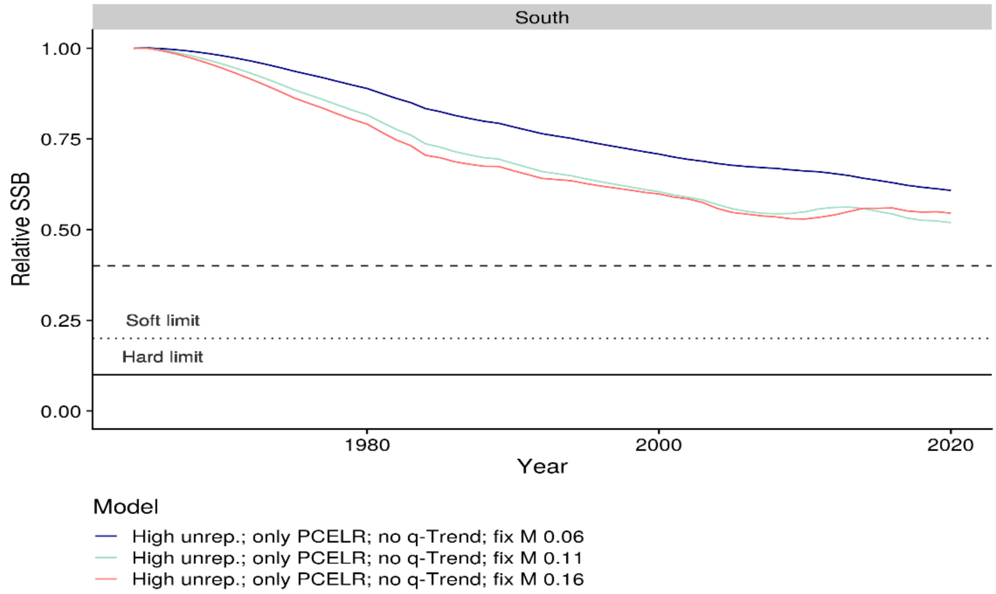


Figure 9: Posterior median of relative spawning stock biomass (SSB; left panel) from model with different levels of natural mortality.

Table 5: 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 mean relative to *SSB*, the posterior mean relative available spawning biomass B_{Proj}^{Avail}, 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 (TACC at 121 t). Other projection scenarios show 20% catch reduction to 97 t and a 20% TACC increase (145 t).

TACC (t)	Year	P(SSB_{Proj} > 40% SSB_0)	P(SSB_{Proj} > 20% SSB_0)	P(SSB_{Proj} > SSB_{2020})	Median rel. SSB_{Proj}	Median rel. B_{Proj}^{Avail}	P(U > $U_{40\%\ SSB0}$)
97	2021	0.96	1	0.04	0.53	0.37	0.04
	2022	0.96	1	0.27	0.53	0.37	0.04
	2023	0.96	1	0.44	0.54	0.38	0.04
	2024	0.96	1	0.54	0.54	0.38	0.03
	2025	0.96	1	0.57	0.55	0.39	0.03
121	2021	0.96	1	0.04	0.53	0.37	0.08
	2022	0.95	1	0.13	0.53	0.37	0.08
	2023	0.94	1	0.22	0.53	0.36	0.09
	2024	0.93	1	0.28	0.53	0.36	0.09
	2025	0.92	1	0.32	0.53	0.36	0.09
145	2021	0.96	1	0.04	0.53	0.37	0.14
	2022	0.94	1	0.05	0.52	0.36	0.16
	2023	0.92	1	0.11	0.52	0.35	0.19
	2024	0.89	1	0.14	0.51	0.34	0.21
	2025	0.86	1	0.15	0.5	0.33	0.23

The base model estimated a steady reduction in spawning biomass from the beginning of the fishing history (assumed to be 1965) to the mid-2000s (Figure 7), with a relatively steady biomass since, reflecting the relatively stable CPUE (Figure 5) and catch (Figure 6) since then. The model estimates that the stock stabilised near 50% of the unfished spawning biomass, with a relatively stable recent exploitation rate (Figure 8).

Alternative models investigated uncertainty in *M*. These models differed in the estimated growth, with the low-*M* model estimating very slow growth to fit commercial length frequency data. As a consequence, the model estimates much higher biomass than at higher *M* to sustain observed catches at stable CPUE. Despite these differences, all models suggest that current stock status is above the target of 40% of unfished biomass. Projections for the base case model suggest unchanged biomass at current exploitation levels (121 t of commercial catch, Table 5).

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. The literature on abalone fisheries suggests that this assumption is questionable and that CPUE is difficult to use in abalone stock assessments due to the serial depletion behaviour of fishers along with the aggregating behaviour of abalone. Serial depletion is when fishers consecutively fish-down beds of pāua but maintain their catch rates by moving to new unfished beds; thus CPUE stays high while the overall population biomass is actually decreasing. The aggregating behaviour of pāua results in the timely re-colonisation of areas that have been fished down, as the cryptic pāua, that were unavailable at the first fishing event, move to and aggregate within the recently depleted area. Both serial depletion and aggregation behaviour cause CPUE to have a hyperstable relationship with abundance (i.e., abundance is decreasing at a faster rate than CPUE) thus potentially making CPUE a poor proxy for abundance. The strength of the effect that serial depletion and aggregating behaviour have on the relationship between CPUE and abundance in PAU 2 is difficult to determine. However, because fishing has been consistent in for a number of years and effort has been reasonably well spread, it could be assumed that CPUE is not as strongly influenced by these factors, relative to the early CPUE series.

The assumption of CPUE being a reliable index of abundance in PAU 2 can also be upset by exploitation of spatially segregated populations of differing productivity. This can conversely cause non-linearity and hyper-depletion in the CPUE-abundance relationship, making it difficult to accurately track changes in abundance by using changes in CPUE as a proxy.

Another source of uncertainty is the data. The commercial catch is unknown before 1974 and is estimated with uncertainty before 1990. The model assumes that catches were higher than those reported for the early period of the fishery (1980s) to account for large discrepancy between export and reported catch by QMA. Major differences may exist between the catches assumed in the model and what was actually taken. Non-commercial catch trends, including illegal catch, are also very poorly determined and could be substantially different from what was assumed.

The model treats the whole of the assessed area of PAU 2 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). Nevertheless, the spatial three area model trialed in 2019 showed near identical trends to the single area model, and variation in growth is likely addressed to some extent by having a stochastic growth transition matrix; similarly the length frequency data are integrated across samples from many places. Nevertheless, length frequency data collected from the commercial catch may not represent the available biomass represented in the model with high precision.

The effect of these factors is likely to make model results imprecise at a local scale. 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 the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries, and the current model does not account for such local processes that may decrease recruitment.

4.5 Future research considerations

The Plenary considered that the stock assessment model was promising, but that it needed extra work before it could be accepted. Accordingly, the following research considerations are split into those that should be implemented using existing data, and those related to longer term considerations (most of which are also applicable to other PAU stocks).

<u>Short term</u>

- Investigation of alternative non-informative priors in CPUE analysis

- Explore changes in fisher catachability over time (including changing fisher experience, new technology, increasing professionalism) across all PAU fisheries
- Describe effective scaling, and how it's used to estimate size composition of removals (relevant for all PAU assessments). Explore the potential of incorporating seasonal effects into the standardisation model for length compositions.
- More tagging is needed in a larger number of representative strata/areas to estimate growth.
- It is unclear whether a single area model (and an aggregate CPUE index) can adequately represent biomass trends for the many sub-populations in PAU stocks. Spatial use trends and variability in biomass trends can induce both positive and negative bias in CPUE, and more sophisticated models may be needed to counter these biases (e.g., spatio-temporal models, Neubauer 2017). Similarly, finer-scale assessment models should be considered to account for potentially different trends within small-scale populations components, although this is difficult when there are inadequate data to support spatial assessments.
- Re-investigation of value of fishery-independent data (timed swim surveys) for PAU, with view to develop series for PAU 2. This might include sub legal population surveys/sampling.
- Explore sensitivity to alternative growth assumptions and growth rates.
- Investigate implications of non-stationary selectivity

Longer term
- It is unclear to what degree large scale aggregate statistics of commercial length frequency distributions represent changes in the overall length composition of the fishery. Although standardisation of CSLF was carried out for the attempted stock assessment, systematic deviations from stock assessment model expectations point to potential problems with the use of aggregate CSLF data.
- Paua growth is known to be temperature dependent. With warming and increasing heat waves linked to global warming, pāua fisheries could see reductions in long-term productivity linked with direct (physiological) and indirect (bottom-up) changes in the environment. The extent of these changes and potential fishery interactions should be investigated.

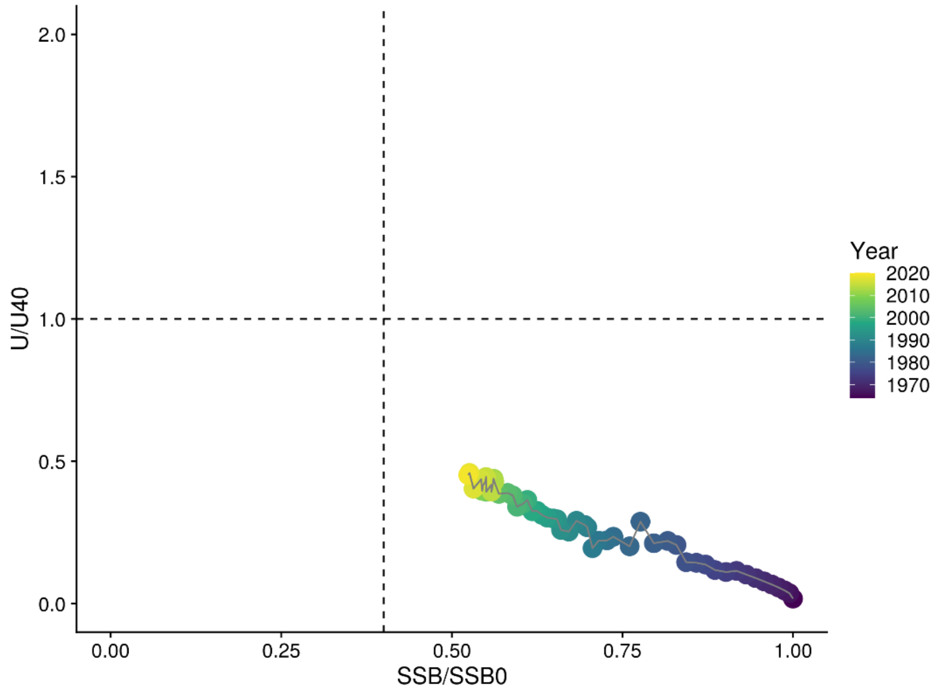
5. STATUS OF THE STOCKS

Stock Structure Assumptions
A genetic discontinuity between North Island and South Island pāua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

The PAU 2 assessment described here applies to the south east component of the region (Wairarapa coast), encompassed by the region between pāua statistical reporting areas P212–P236.

- **PAU 2 - Wairarapa**

Stock Status		
Most Recent Assessment Plenary Publication Year	2021	
Catch in most recent year of assessment	Year: 2019–20	Catch: 129 t
Assessment Runs Presented	Base case: length-based Bayesian stock assessment	
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$	
Status in relation to Target	Likely (> 60%) to be at or above	
Status in relation to Limits	B_{2020} is Very Unlikely (< 10%) to be below the soft and hard limits	
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring	

Historical Stock Status Trajectory and Current Status

Posterior medians of relative stock status (spawning stock biomass (*SSB*) depletion level relative to unfished biomass (SSB_0)) and exploitation rate (*U*), relative to the exploitation rate that would result in a stock depletion to 40% of unfished biomass (U_{40}).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning stock biomass has fluctuated without a long-term trend since the early 2000s.
Recent Trend in Fishing Mortality or proxy	Fluctuating without trend
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Commercial length frequency data (CSLF) have shown stable length frequency distributions since the early 2000s, with slight increases in recent CSLF lengths possibly due to market demands and catch-spreading arrangements.

Projections and Prognosis	
Stock Projections or Prognosis	At current catch levels and given the recent trend, the stock would continue to fluctuate without trend.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Bayesian length-based stock assessment	
Period of Assessment	Latest assessment: 2021	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE indices PCELR series	1 – High Quality

	- Commercial sampling length frequencies	1 – High Quality
Data not used (rank)	CELR CPUE series FSU CPUE series	3 – Low Quality: variable catchability and changes in technology 3 – Low Quality: poor recording
Changes to Model Structure and Assumptions	This represents the first accepted assessment model for PAU 2	
Major Sources of Uncertainty	Growth is known to vary spatially over small scales, and it is unclear how representative the available samples are of the PAU 2 fishery area. Recruitment: length composition data available to the stock assessment provide little information about relative year class strengths. The assessment model is sensitive to natural mortality, which is poorly quantified. Early catch history: Pre QMS pāua exports exceeded catches reported to FMAs, and it is unclear which areas these catches came from. Selectivity in the commercial fishery has varied spatially and over time as voluntarily agreed Minimum Harvest Size (MHS) has changed. Different MHSs have been applied to different statistical areas within the assessed area in the same year.	

Qualifying Comments
A large proportion of PAU 2, including the Wellington south coast and west of Turakirae, is either a marine reserve or voluntarily closed to commercial fishing. This means that the data collected from the commercial fishery are exclusive of this large area and therefore the assessment only applies to the south east component of PAU 2 (Wairarapa). Lack of contrast in catch, CPUE, and length frequency makes estimation of stock status and biomass trajectories difficult. The 2019–20 year was excluded from the PCELR CPUE series owing to concerns about the comparability with previous years due to the effects of COVID-19 on export markets, and ERS reporting issues. This may continue into the future.

Fishery Interactions
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