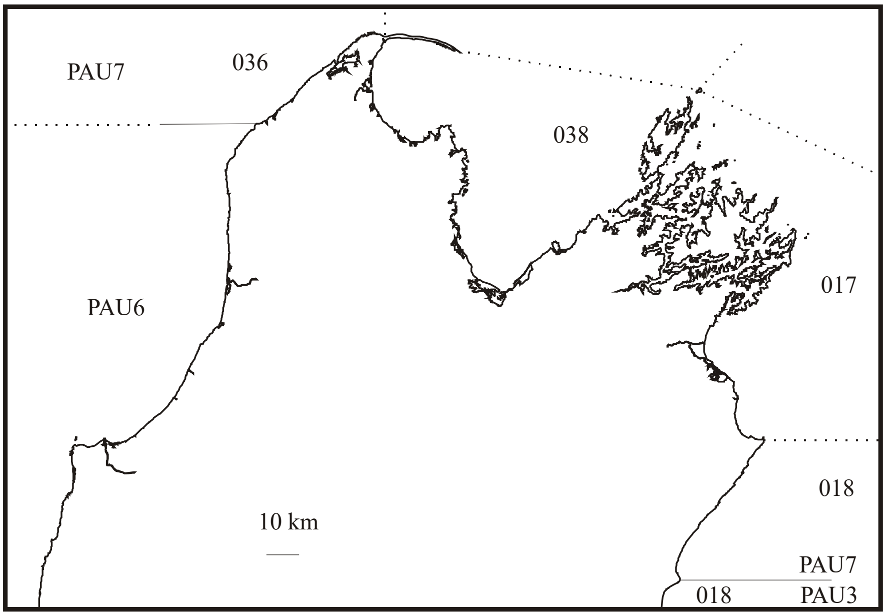
PĀUA (PAU 7) – Marlborough

(Haliotis iris)
Pāua



1. FISHERY SUMMARY

PAU 7 was introduced into the Quota Management System in 1986–87 with a TACC of 250 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 267.48 t by 1989. On 1st October 2001 a TAC of 273.73 t was set with a TACC of 240.73 t, customary and recreational allowances of 15 t each and an allowance of 3 t for other mortality. On 1 October 2002 the TAC was reduced to 220.24 t and the TACC was set at 187.24 t; no changes were made to the customary, recreational, or other mortality allowances. In 2016 the TACC was further reduced to 93.62 t, and the allowance for other mortality was increased to 10 t, setting the TAC to 133.62 t (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 7 since introduction into the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–89	–	–	–	–	250.00
1989–01	–	–	–	–	267.48
2001–02	273.73	15	15	3	240.73
2002–16	220.24	15	15	3	187.24
2016–Present	133.62	15	15	10	93.62

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September. In 2000–01 concerns about the status of the PAU 7 fishery led to a decision by the commercial sector to voluntarily shelve 20% of the TACC for that fishing year. From the 2003–04 to the 2006–07 fishing years, the industry proposed to shelve 15% of the TACC. In the 2012–13 and 2013–14, the industry shelved 20% of the 187.24 t TACC. In 2014–15, PAU 7 stakeholders again agreed to voluntarily shelve 30%. However, some only shelved 20% and some shelved 30%; an average of 28% was shelved overall. In October 2016 the TACC was reduced by 50%. Almost immediately following this, as a result of the Kaikōura earthquake of November 2016, the southern area of the fishery was closed under emergency provisions; this was later replaced by an official s11 closure. This area historically accounted for approximately 10% of the total PAU 7 catch.

From 1 October 2017 the TAC was reduced a further 10%, but this decision was set aside by agreement following a court injunction so the TAC is still set at 133.63 t for PAU 7. However, PAU 7 stakeholders agreed to a 10% shelving, and annual landings were on average 81.5 t since 2017–18. The customary and recreational allowances are still set at 15 t. The east coast fishery re-opened on 1 December 2021 and was subsequently fished according to pre-agreed geographical zone limits.

On 1 October 2001 it became mandatory to report catch and effort on PCELRs using fine-scale reporting areas (Figure 1) that had been developed by the New Zealand Pāua Management Company for their voluntary logbook programme. Reported landings and TACCs for PAU 7 are shown in Table 2 and Figure 2. The early catches from Schiel (1992) were not considered for the base case in the 2022 stock assessment (Neubauer 2023). Reporting switched to electronic reporting in 2019–20, with no explicit reporting of statistical areas, which were inferred from fishing locations until their explicit re-introduction in 2021–22.

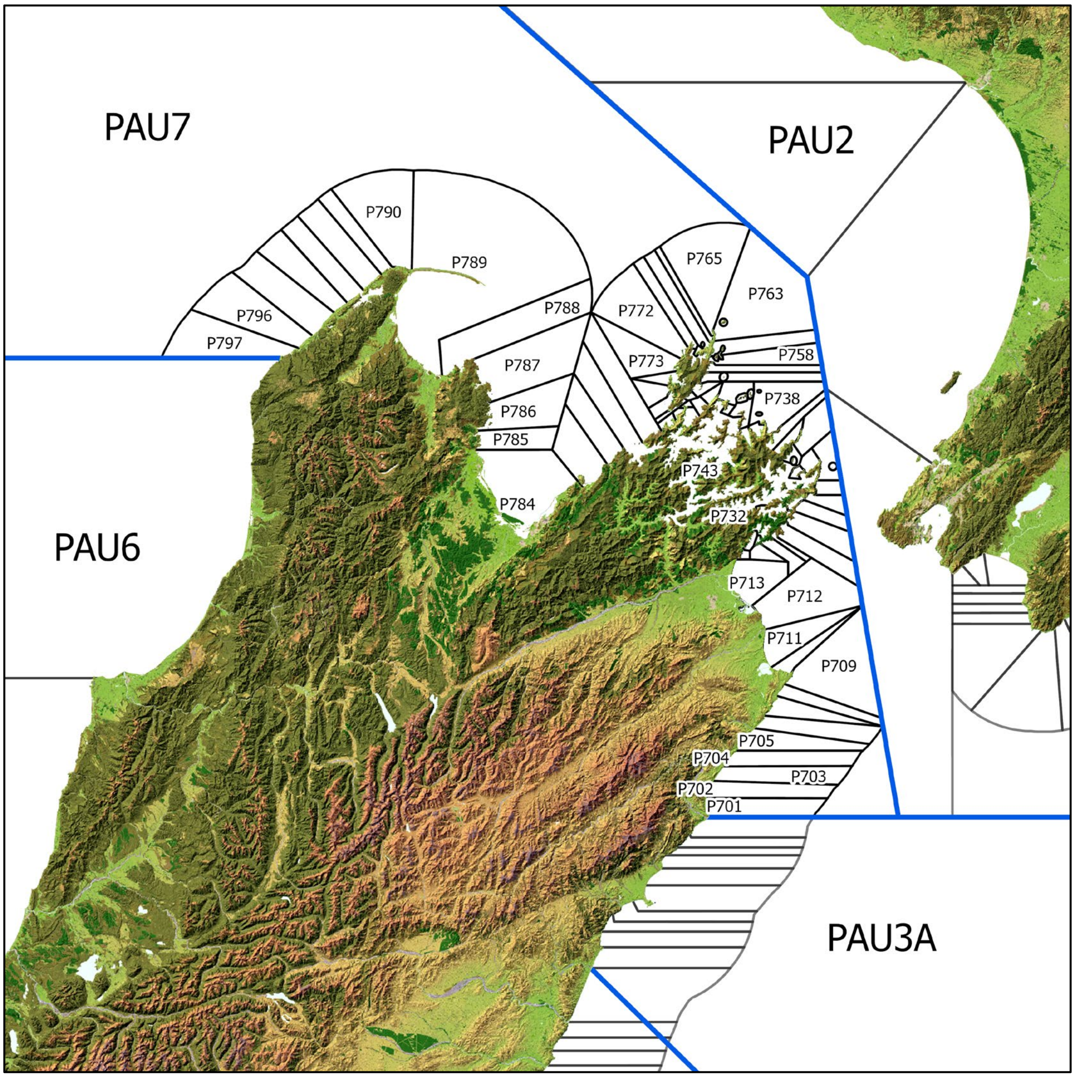


Figure 1: Map of fine scale statistical reporting areas for PAU 7.

1.2 Recreational fisheries

A nationwide panel survey of over 7000 marine fishers who reported their fishing activity over the fishing year from 1 October 2011 to 30 September 2012 was conducted by The National Research Bureau Ltd in close consultation with Marine Amateur Fishing Working Group (Wynne-Jones et al 2014). The survey was based on an improved survey method developed to address issues and to reduce bias encountered in past surveys. The survey estimated that 14.13 t (CV of 34%), were harvested by recreational fishers in PAU 7 for 2011–12. In 2017–18, the national panel survey was repeated and the estimated recreational catch was 3.02 t (CV of 36%) (Wynne-Jones et al 2019). The most recent national panel survey harvest estimate for PAU 7 is 2.87 t (CV 0.35) for 2022–23 (Heinemann & Gray in prep).

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

For the 2021 stock assessment, the SFWG agreed to assume that recreational catch was 5 t in 1974 and that it increased linearly to 15 t in 2000 and then remained at 15 t until 2008, with a subsequent decline to 2 t by 2018.

Table 2: Reported landings and TACC in PAU 7 from 1983–84 to the present. The last column shows the TACC after shelving has been accounted for. Catches from 1980–81 to 1986–85 appear to be from Schiel (1992).

Year	Landings (t)	TACC (t)	Shelving	Year	Landings (t)	TACC (t)	Shelving
1974–75	197.910	–	–	1999–00	264.642	267.48	267.48
1975–76	141.880	–	–	2000–01	215.920	267.48	*213.98
1976–77	242.730	–	–	2001–02	187.152	240.73	240.73
1977–78	201.170	–	–	2002–03	187.222	187.24	187.24
1978–79	304.570	–	–	2003–04	159.551	187.24	*159.15
1979–80	223.430	–	–	2004–05	166.940	187.24	*159.15
1980–81	490.000	–	–	2005–06	183.363	187.24	*159.15
1981–82	370.000	–	–	2006–07	176.052	187.24	*159.15
1982–83	400.000	–	–	2007–08	186.845	187.24	187.24
1983–84	330.000	–	–	2008–09	186.846	187.24	187.24
1984–85	230.000	–	–	2009–10	187.022	187.24	187.24
1985–86	236.090	–	–	2010–11	187.240	187.24	187.24
1986–87	242.180	250	–	2011–12	186.980	187.24	187.24
1987–88	255.944	250	–	2012–13	149.755	187.24	*149.80
1988–89	246.029	250	–	2013–14	145.523	187.24	*149.80
1989–90	267.052	267.48	–	2014–15	133.584	187.24	*134.80
1990–91	273.253	267.48	–	2015–16	138.790	187.24	187.24
1991–92	268.309	267.48	267.48	2016–17	93.610	93.620	93.620
1992–93	264.802	267.48	267.48	2017–18	81.880	93.620	*84.26
1993–94	255.472	267.48	267.48	2018–19	79.697	93.620	*84.26
1994–95	247.108	267.48	267.48	2019–20	81.983	93.620	*84.26
1995–96	268.742	267.48	267.48	2020–21	81.338	93.620	*84.26
1996–97	267.594	267.48	267.48	2021–22	87.787	93.620	*87.00
1997–98	266.655	267.48	267.48	2022–23	76.540	93.620	*85.39
1998–99	265.050	267.48	267.48				

* Voluntary shelving

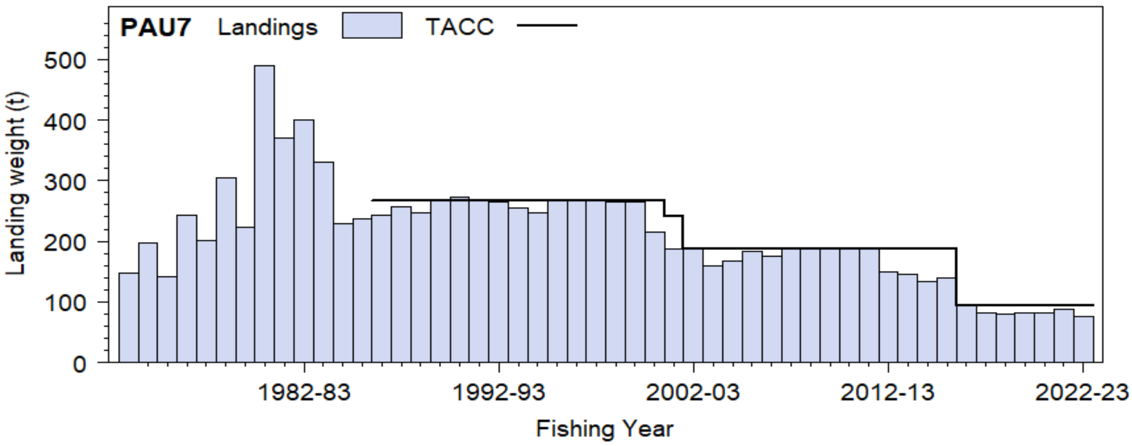


Figure 2: Reported commercial landings and TACC for PAU 7 from 1986–87 to present.

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.

Customary catch was incorporated into the PAU 7 TAC in 2002 as an allowance of 15 t. Estimates of customary catch for PAU 7 are shown in Table 3. These numbers are likely to be an underestimate of customary harvest because only the catch in numbers approved and harvested 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 (reported as numbers) of pāua in PAU 7 between 2007–08 and 2011–12. No reports since. – no data.

	Numbers	
Fishing year	**Approved**	**Harvested**
2007–08	1 110	808
2008–09	1 270	1 014
2009–10	1 085	936
2010–11	60	31
2011–12	20	20

Records of customary catch taken under the South Island Regulations show that about 20 to 1014 pāua were reported to have been collected each year from 2007–08 to 2011–12, with an average of 449 pieces each year. Those numbers were substantially lower than the annual allowances. There have not been any reports since.

For the 2021 stock assessment, the Working Group agreed to assume that customary catch was 1 t in 1974, increasing linearly to 2 t between 1974 and 2000 and then remaining at 2 t until 2015, with recent catches around 1 t.

1.4 Illegal catch

There are no estimates of illegal catch for PAU 7.

For the 2021 stock assessment, the Working Group agreed to assume that illegal catch was 1 t in 1974 and that it increased linearly to 15 t between 1974 and 2000, remaining at 15 t from 2000 to 2005, then decreasing linearly to 2.5 t in 2015, and remaining at 2.5 subsequently.

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.

On 16 November 2016, a 7.8 magnitude earthquake hit the upper east coast of the South Island, uplifting areas of the coast by as much as 4 m. In the PAU 7 fishery, pāua statistical areas P701 to P710 were impacted to varying degrees by the earthquake. The earthquake caused direct mortality of a large number of juvenile and adult pāua that became exposed to the terrestrial environment with no means of being able to return to the water. More indirect mortality occurred from the earthquake due to an immediate loss of pre-earthquake pāua habitat that now lies above the new post-earthquake high tide mark.

Impacts of the seabed uplift on pāua populations in PAU 7 will only become clear in the longer term. The immediate loss of area to the fishery, assumed to be good habitat for pāua, is only part of the impact that the seabed uplift associated with the earthquake will have on pāua populations. Juvenile pāua recruit in shallow water, and so the loss of juvenile habitat will have been higher than the loss of adult habitat. Recent surveys, however, have indicated large scale recovery of pāua populations in the affected areas (McCowan & Neubauer 2021, 2022).

2. BIOLOGY

For further information on pāua biology refer to the Introduction – Pāua chapter. A summary of biological parameters used in the PAU 7 stock 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*).

Fishstock		**Estimate**	**Source**
1. Natural mortality (*M*)			
All		0.02–0.25	Sainsbury (1982)
PAU 7		0.12	Fixed in the base case assessment model based on estimates of *M* in other areas
2. Weight = *a* (length)^b (weight in g, shell length in mm)			
	a = 2.59E–08	b = 3.322	Schiel & Breen (1991)
3. Size at maturity (shell length)			
Meta-analysis for fished areas (all QMAs)	50% mature	90.5 mm	Neubauer & Tremblay-Boyer (2019a)
4. Growth-increment estimates (both sexes combined)			
Assessment fit for main commercially fished area (Cook Strait)	G_{75}	17.38 mm (SE 1.44 mm)	Neubauer (2023)
	G_{125}	2.71 mm (SE 0.36 mm)	

4. STOCK ASSESSMENT

The stock assessment is implemented as a length-based Bayesian estimation model, with uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain-Monte Carlo simulations. In contrast to previous assessments, which assumed a single population across Statistical Areas 017 and 038, the most recent stock assessment split the area into finer scale units that align more closely with industry management units (Figure 3), due to strong differences in catch trends among these regions (Figure 4). In particular, D'Urville Island and Northern Faces statistical areas accounted for approximately 40 t of catch through the early 2000s, with subsequent declines in catch to very low levels in recent years. By contrast, statistical areas in Cook Strait have continuously yielded between 70 and 150 t per year since the early 2000s. This area constitutes over 80% of the fishery in recent years.

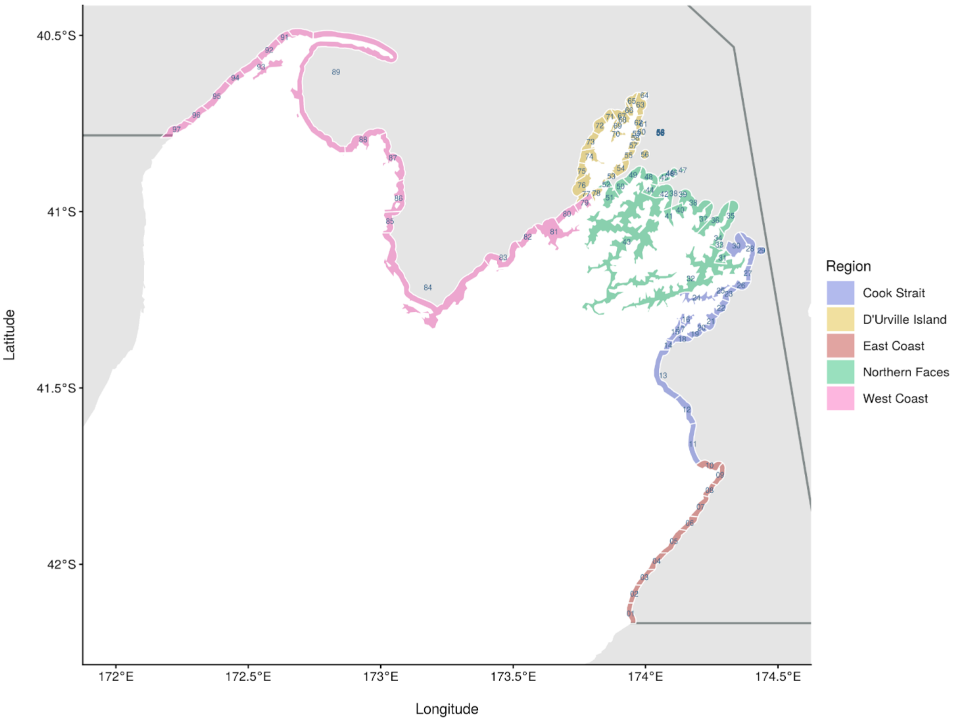


Figure 3: Region definition used in the stock assessment; the stock assessment was run for Cook Strait, Northern Faces, and D'Urville Island only. The East Coast area was closed following the 2016 Kaikōura earthquake; the West Coast is only sporadically fished with relatively small proportions of catch coming from the area.

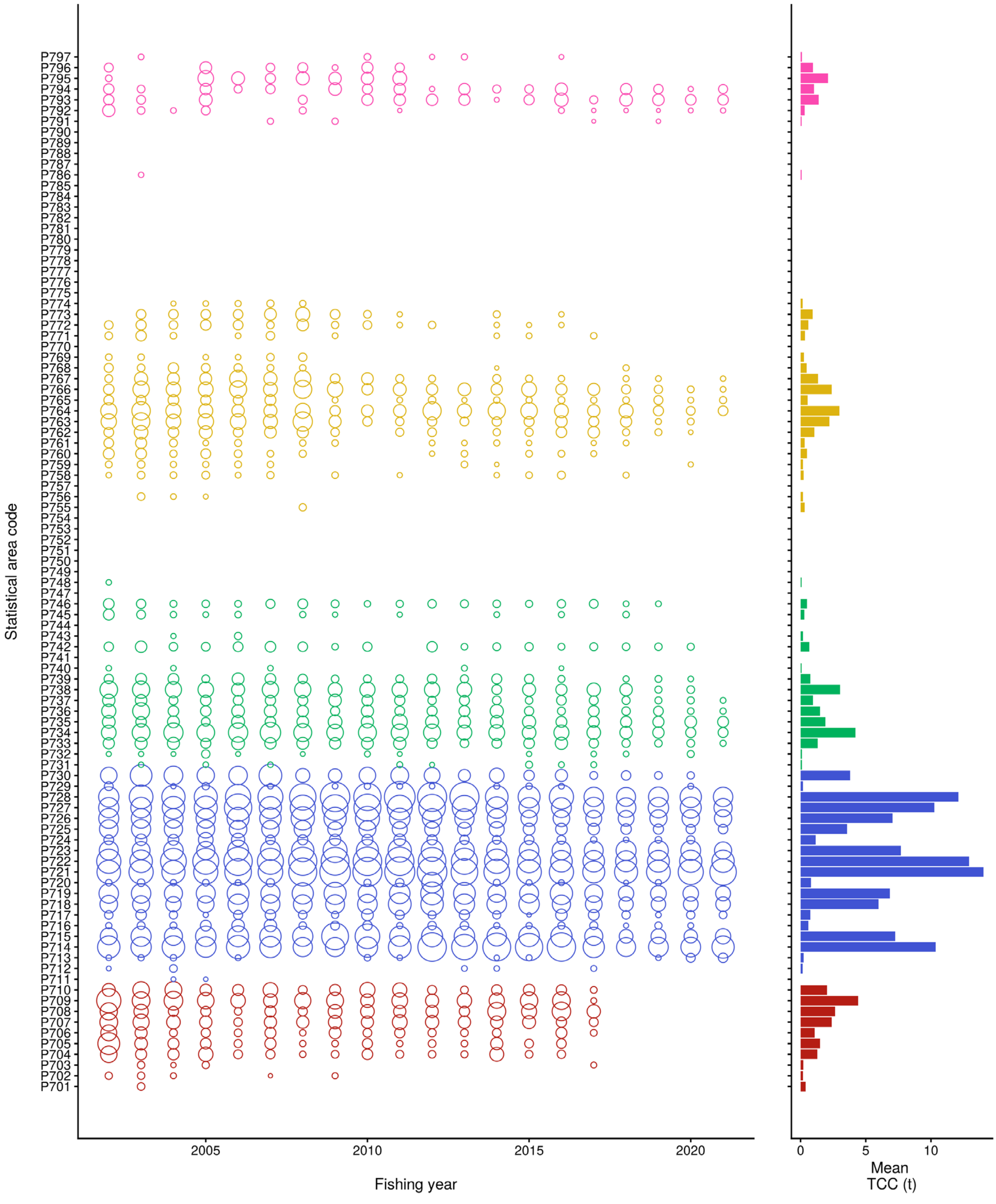


Figure 4: Trend in pāua catch (kg) over time by statistical areas in quota management area PAU 7 for the period from 2002 to 2021, with mean commercial catch over the same time period (right-hand side). Statistical reporting areas used for the stock assessment within PAU 7 are colour coded blue (Cook Strait); other areas were excluded from the stock assessment given limited recent catch (but included in catch per unit effort (CPUE) analyses).

4.1 Estimates of abundance indices

4.1.1 Relative abundance estimates from standardised CPUE analyses

PCELR and ERS data from 2002 were used to derive a standardised, fishery-dependent index of abundance. Previously used CELR data were not used in the present assessment; as for other recent assessments, changes to the composition of the fleet and gear during the 1990s, combined with inconsistent reporting, mean that the trends in CPUE from CELR data are questionable, and likely hyper-stable to an unknown degree.

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. Variables in the model were fishing year, estimated fishing effort, client number, research stratum, and diver ID (PCELR). Previous standardisation models for PCELR data routinely used small scale statistical areas as a standardising variable. For the present assessment, this variable was not available with sufficient precision for recent (ERS) data, where it is inferred from position data, and was therefore omitted. Nevertheless, follow-up work on the quality of ERS data for pāua CPUE suggested limited effects of spatial reporting and the inclusion, or not, of statistical areas in the standardisation made little difference to resulting indices for Cook Strait. Indices for other subareas were sensitive to the inclusion of statistical area.

Standardised CPUE in all areas suggested increases in recent years (Figure 5), with most notable increase in Cook Strait, and highly variable trends in raw CPUE in other areas. Although initial models were attempted for D'Urville Island and Northern Faces, the Shellfish Working Group decided that, due to recent reductions and spatial concentration of catch in these areas to a limited number of statistical areas, CPUE may not be representative of these areas as a whole anymore.

For Cook Strait, standardisation acted to reduce the rate of recent increases relative to raw CPUE alone. Client (ACE-holder) and diver ID had the strongest standardising effects for recent CPUE (Figure 6), due to concentration of ACE in the hands of a smaller number of efficient fishing operations in recent years. Nevertheless, recent increases in standardised CPUE are of the order of 50% since the TACC was reduced in 2016–17.

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of pāua in PAU 7 was also estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1992 and 2005. Concerns about the reliability of these data to estimate relative abundance instigated reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) 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 conclusions from the reviews refer to the Introduction – Pāua chapter.

4.1.3 Biomass survey and monitoring for earthquake affected areas

Following the 2016 Kaikōura earthquake, a biomass survey was implemented to estimate and monitor pāua abundance and recruitment in the earthquake-affected areas of PAU 7 and PAU 3 (now PAU 3A), to inform management decisions relating to the re-opening of the pāua fishery (McCowan & Neubauer 2018, 2022). To estimate abundance, novel methodologies using GPS dive loggers and underwater electronic callipers were developed. Thirty-five sites were initially surveyed to obtain baseline estimates of site- and fishery-level abundance and length frequency (LF).

Pāua were mostly found in aggregations, preferentially in shallow water. This was not just the case for small pāua but also for large individuals (i.e., over 120 mm), although smaller individuals (under 100 mm) showed a strongly decreasing trend with depth. Initially, estimated pāua density was 0.028 pāua per square metre (geometric mean; 95% confidence interval (CI) [0.009; 0.08]) across the earthquake-affected fishery closure. Scaling density estimates to total biomass or abundance was difficult due to the lack of robust estimates of habitat area for pāua. In the absence of a defensible solution, only density was calculated. After the first two years, the project has been extended for another three years until mid-2023. As of March 2022, four further rounds of surveys of the 35 initially surveyed sites have been undertaken to monitor pāua abundance and recruitment trends.

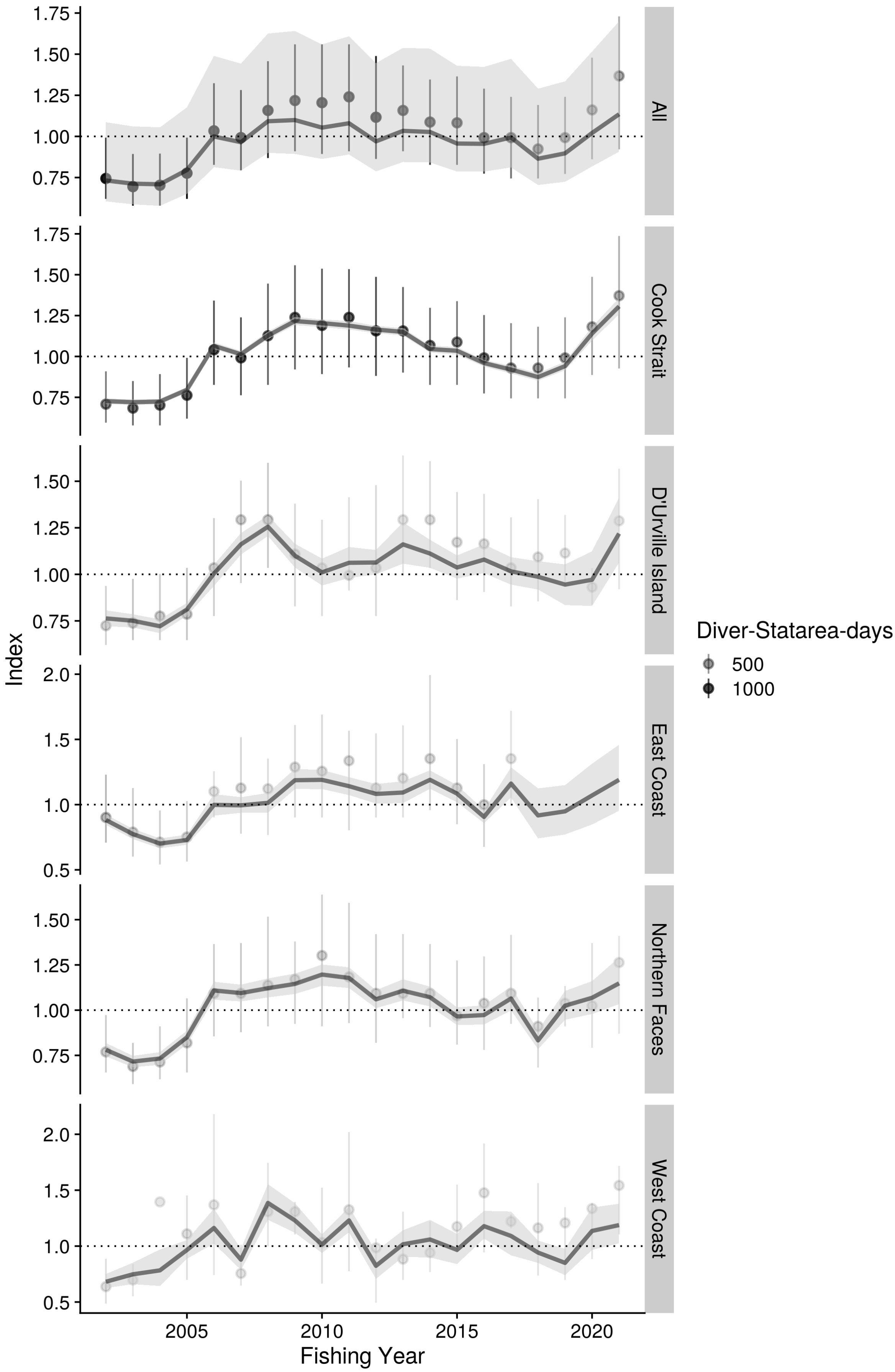


Figure 5: Raw CPUE (points are median with inter-quartile interval indicated by vertical intervals) and standardised CPUE index (line) with 95% confidence interval (shaded ribbon). Shading of points indicates the relative amount of data available for standardisation, showing low available data for D'Urville Island and Northern Faces in recent years.

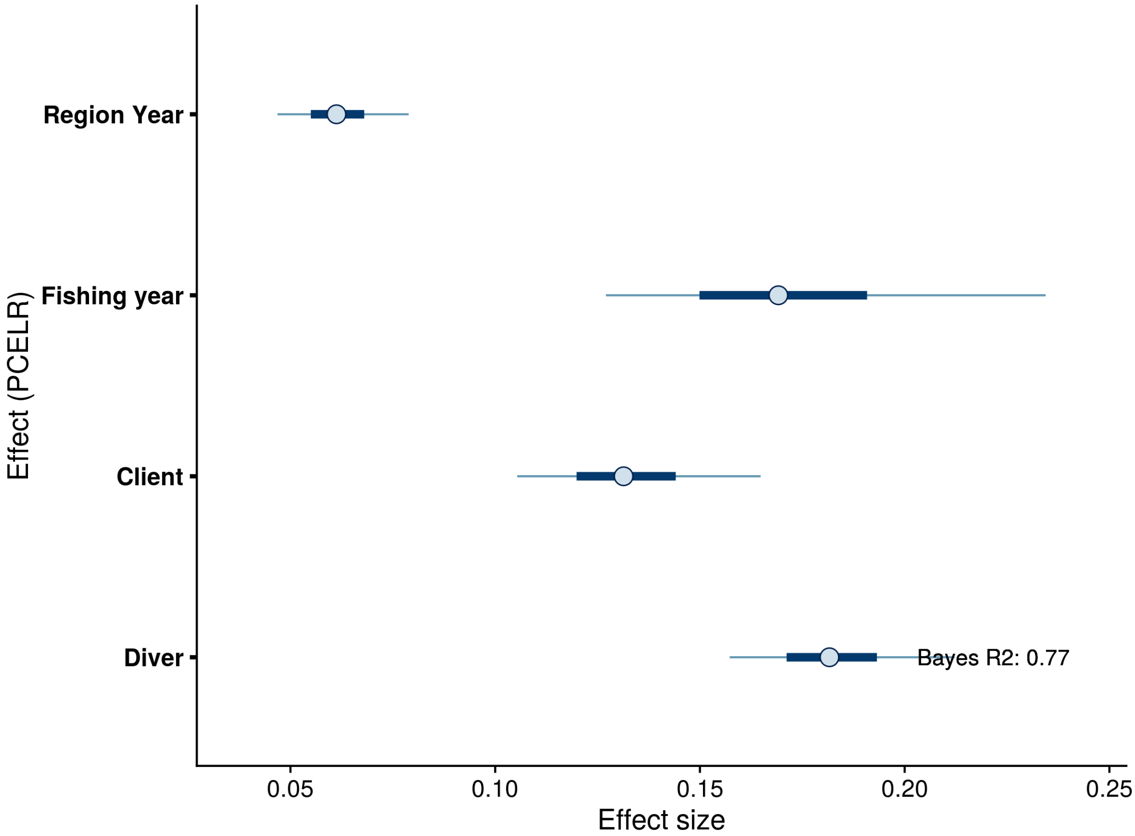


Figure 6: Relative importance (in terms of proportion of variance explained) of standardising variables in the GLMM used to standardise PAU 7 CPUE.

Initially an assessment was made of the appropriateness of using the number of measurements per unit effort (MPUE) as a proxy for pāua density to overcome issues with missing data from GPS dive units (originally used to delimit area to estimate density) and to enable the use of significantly larger data sets of measurements and counts of pāua at each site. The measurements per unit effort, as well as biomass per unit of survey effort (BPUE; number of measurements multiplied by the length frequency distribution of measured pāua), correlated well (R^2=0.86) with density. Therefore, MPUE and BPUE were used as indices of changes in pāua density.

An overall increase in pāua abundance was observed at a QMA-wide level in both QMAs over the four survey periods (Figure 7). Increased abundance was generally more pronounced in PAU 7 than in PAU 3. In PAU 3, abundance trended slightly downwards in the second survey period, which was likely due to the consistently poor survey conditions during the period, as well as a potential bias towards sampling sites with lower rates of increase due to weather conditions. There was high variability in abundance trends across sites. This variability was in part related to variability in the amount of uplift at each site, because sites with a larger increase in abundance were those with less uplift (Figure 8). Variability in abundance trends across sites could also be linked to habitat related factors and pre-earthquake abundance. Comparison of length frequency profiles across the four survey periods showed reasonably stable profiles in larger size classes (125–160 mm; Figure 9, with an increase in the number of individuals in the 80–100 mm size range in both QMAs, which is likely to be indicative of post-earthquake recruitment. Recruitment signals were variable between sites due to differences in available recruitment habitat and variability in uplift.

4.2 Stock assessment methods

The 2021 stock assessment for PAU 7 used an updated version of the length-based population dynamics model described by Breen et al (2003), and the most recent assessment uses catch and commercial length frequency data up to the 2019–20 fishing year, as well as the above-mentioned CPUE index for years 2002–2021. Although the overall population-dynamics model remained unchanged from Breen et al (2003), the PAU 7 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 modelled as taking pāua in proportion to abundance rather than according to commercial selectivity. Although commercial minimum harvest size (MHS) increased in recent years, recreational catch retained a logistic selectivity centred on the minimum legal size (MLS).

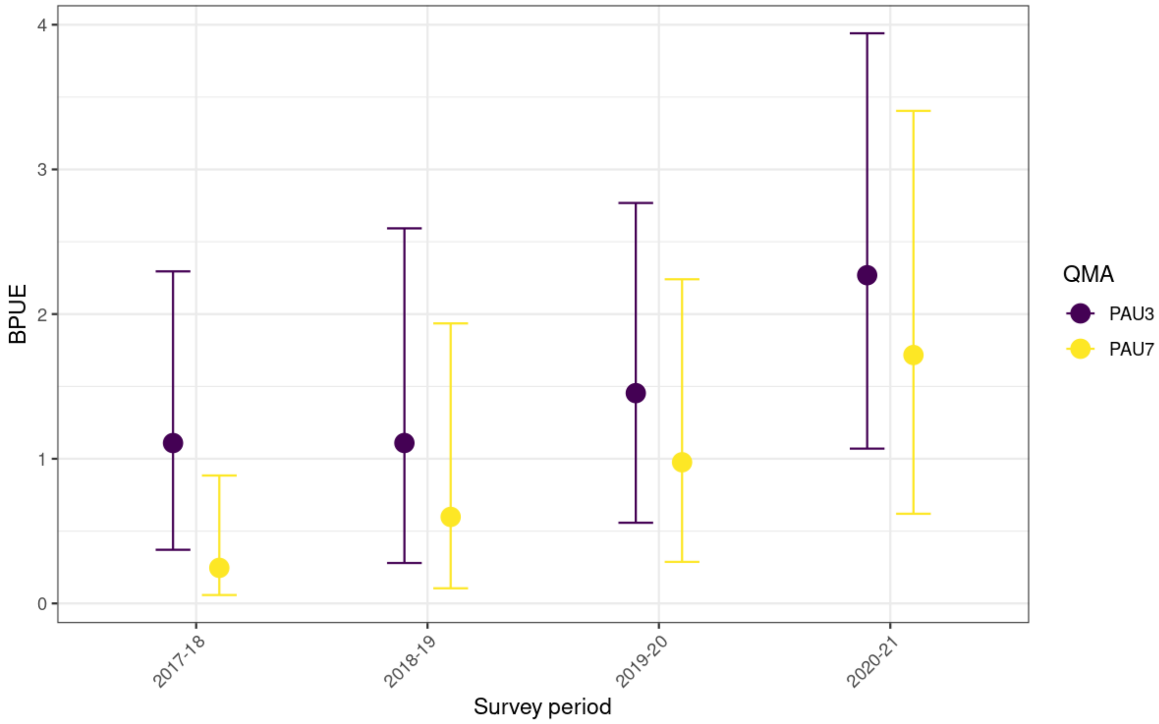


Figure 7: Marginal trend (relative to a geometric mean of 1) in biomass per unit effort (BPUE) across survey years for QMAs PAU 3 and PAU 7 from the BPUE model after accounting for confounding variables.

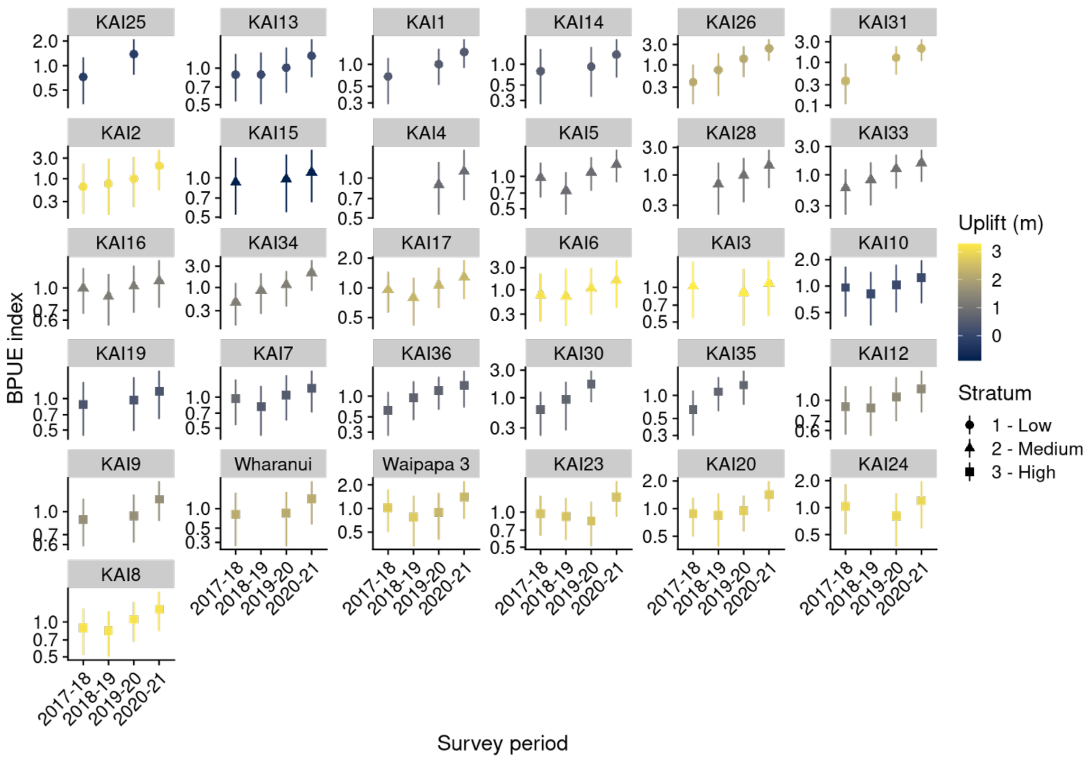


Figure 8: Marginal trend (relative to a geometric mean of 1 at each site) in biomass per unit effort (BPUE) across survey years for QMAs PAU 3 and PAU 7 from the BPUE model after accounting for confounding variables.

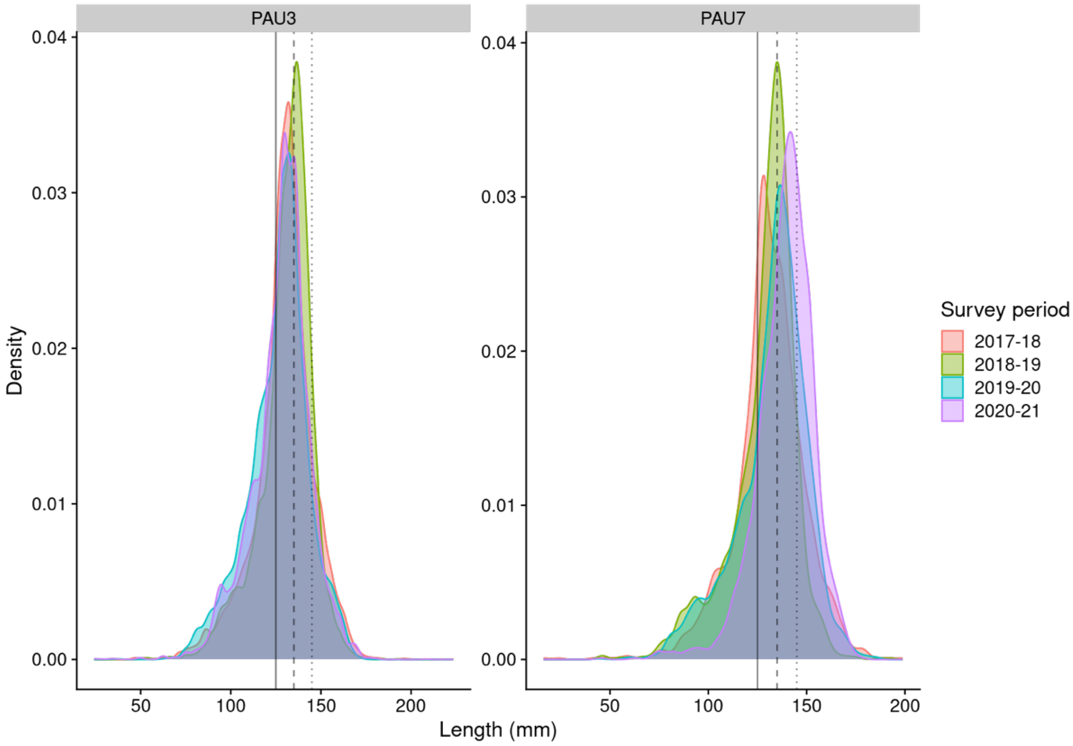


Figure 9: Length frequency profiles (as relative densities) for all pāua measured over four survey periods in PAU 3 and PAU 7. Vertical lines show the legal size of 125 mm (MLS; solid line), 135 mm (dashed line), and 140 mm (dotted line).

Due to substantial reductions in catch without evident effects on CPUE in D'Urville Island and Northern Faces, these areas were split from the Cook Strait area in initial assessment runs, which were performed using a spatial assessment model. In addition, the earthquake-affected area on the east coast of PAU 7 was excluded from the assessment, with surveys used to monitor rebuilding of the fishery in that area. Only the model for Cook Strait was accepted by the working group as a reasonable model for the current PAU 7 fishery. This model was subsequently run as a single area assessment. 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.

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.

The model simulated the population from 1965 to 2021. Catches were available for 1974–2021 at a broad spatial scale, although catches before the 1990s are considered highly uncertain. Catches were assumed to increase linearly from 0 in 1965 to the 1974 catch level (Figure 10). Detailed spatial reporting of catches is only available since 2002, when PCELR forms introduced recording of estimated catch for fine-scale statistical areas. Catches prior to 2002 were partitioned into regions using average catch splits for the first 4 years of PCELR data only (2002–2006), to avoid undue influences from reductions in catch from areas other than Cook Strait. Two different catch levels were initially tried to account for overall catch uncertainty in the assessment (Figure 10). 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, with recruitment deviates estimated from 1984 to 2017, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. Natural mortality in the base model was fixed at 0.12. 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. 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.

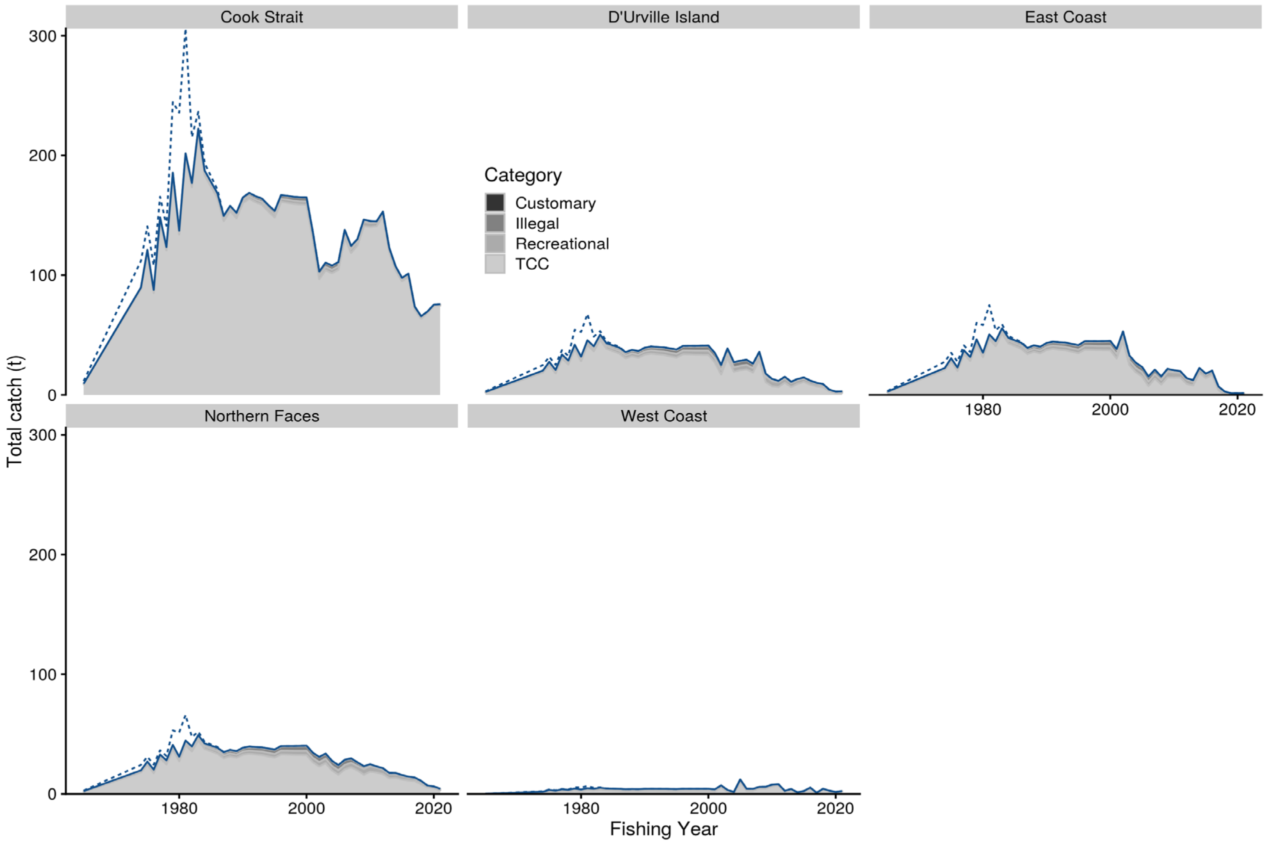


Figure 10: Assumed catch histories for industry management areas within PAU 7. Grey shading indicates components of the total catch, with the solid lines showing the base-case assumption of total catch (commercial, recreational, and illegal), including unreported catches prior to QMS entry of PAU 7, and the dashed line showing a sensitivity with high assumed pre-QMS catches.

The assessment calculated 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 2021 (SSB_{2021} and) and for the projection (*Proj*) period (SSB_{Proj} and B_{proj}^{Avail}). This assessment also reported 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_{2021} > 40% SSB_0)	Probability that the spawning stock biomass in 2021 was greater than 40% of the unfished spawning stock
P(SSB_{2021} < 20% SSB_0)	Probability that the spawning stock biomass in 2021 was less 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 less 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 summarised in Table 5.

Table 5: A summary of key model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal; Beta = beta distribution), mean and standard deviation of the prior. Bounds for fixed parameters represent model sensitivities.

Parameter	Prior	μ	sd	Bounds	
				Lower	Upper
ln(*R0*)	LN	13.5	10		
M	fixed	0.12		0.08	0.16
Steepness (h)	Beta(1,1) on (0.2;1)	0.6	0.23	0	1
Growth	MVN		From Neubauer & Tremblay-Boyer 2019b		
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; 1985–2017)	LN	0	0.4		-

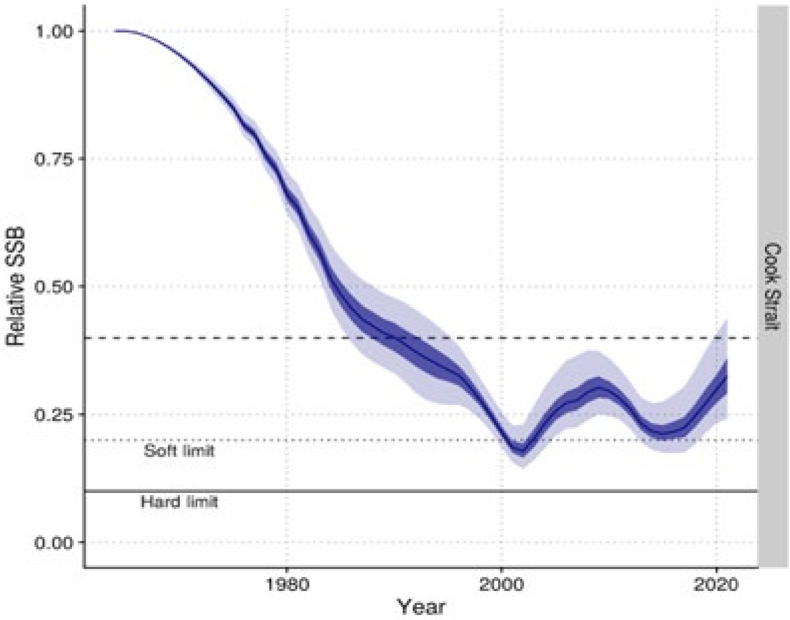
The observational data were:

- A standardised CPUE series covering 2002–2021 based on PCELR and ERS data.
- Commercial catch sampling length frequency from 1990 to 2020.
- Catches were assumed to be known without error, although a catch penalty was applied in the model.

4.3 Stock assessment results

The base model with *M*=0.12 estimated a steady reduction in spawning biomass from the beginning of the fishing history (assumed to be 1965) to the early 2000s (Figure 11), with a subsequent increase in biomass driven by trends in CPUE (see Figure 5) after considerable (40%) reductions in catch between 2001 and 2004 (Figure 10). The recovery largely stalled, and the stock started to decline again after a 15% shelving was lifted in 2007–08 (Figure 11). Although subsequent shelving from 2012–13 to 2014–15 reduced fishing pressure somewhat, these reductions did not lead to the desired increases in biomass. Current harvest rates, following the 50% TACC reduction in 2016–17, have approached target levels, and have led to a recent rebuild of the biomass to levels approaching target biomass levels.

The base model with *M*=0.12 and estimated growth gave a relatively good fit to CPUE and CSLF data. Although CPUE responded to reductions in catch in the early 2000s, leading to a strong subsequent increase in biomass, this initial increase in CPUE was partly explained by recruitment in the model. The latter suggests that the assumed productivity was not enough to explain the level of increase in CPUE in the early 2000s. By contrast, recent recruitment estimates were only slightly above average, suggesting that more recent increases were in line with assumed (and estimated) levels of productivity.



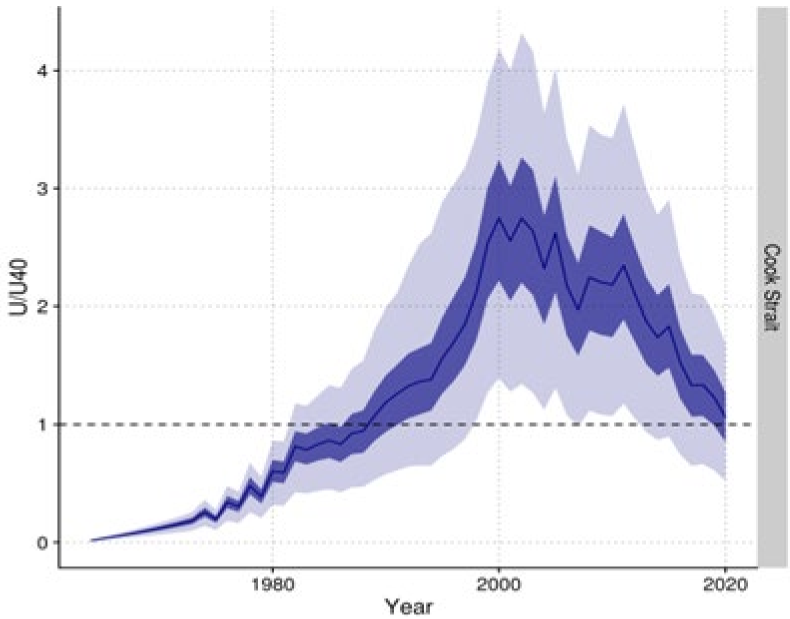


Figure 11: Posterior distributions of relative spawning stock biomass (*SSB*, top panel) and trends in relative commercial exploitation rate (bottom panel) in the base case model for Cook Strait in PAU 7. Exploitation rate (*U*) is relative to the exploitation rate that would result in a stock depletion 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.

Alternative models investigated uncertainty in *M*, early (pre-PCELR) catch levels, steepness, and data weights. All models estimated very similar trends in biomass, with slightly different outcomes in terms of recent stock status; low *M* and high early catch scenarios had the lowest estimates of recent biomass with 27% and 31% of unfished spawning biomass in 2021. Despite these differences, all models suggested recent increases in biomass, with relatively rapid expected rebuilding under the base model (by 2026, Table 6).

Table 6: 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 74.6 t). Other projection scenarios show 20% catch reduction to 56 t and a 20% TACC increase (89.5 t). Simulation to equilibrium (assumed to have been reached after 50 projection years) are indicated with Eq. in the year column.

Region	$TCC(t)$	$Year$	$P(SSB_y > 0.4 \cdot SSB_0)$	$P(SSB_y < 0.2 \cdot SSB_0)$	$P(SSB_y > SSB_{cur})$	SSB_y	B_y^{avail}	$P(H_y > H_{0.4 \cdot SSB})$
Cook Strait	60	2021	0.09	0	1.00	0.33	0.12	0.51
Cook Strait	60	2022	0.26	0	0.92	0.36	0.14	0.10
Cook Strait	60	2023	0.40	0	0.96	0.38	0.17	0.03
Cook Strait	60	2024	0.49	0	0.97	0.40	0.20	0.01
Cook Strait	60	2025	0.56	0	0.98	0.42	0.23	0.01
Cook Strait	60	2026	0.62	0	0.98	0.43	0.25	0.01
Cook Strait	60	Eq.	0.98	0	1.00	0.58	0.45	0.00
Cook Strait	75	2021	0.09	0	1.00	0.33	0.12	0.51
Cook Strait	75	2022	0.26	0	0.92	0.36	0.14	0.32
Cook Strait	75	2023	0.37	0	0.93	0.38	0.17	0.19
Cook Strait	75	2024	0.43	0	0.93	0.39	0.19	0.13
Cook Strait	75	2025	0.48	0	0.94	0.40	0.21	0.10
Cook Strait	75	2026	0.52	0	0.94	0.41	0.23	0.08
Cook Strait	75	Eq.	0.85	0	0.98	0.51	0.36	0.01
Cook Strait	90	2021	0.09	0	1.00	0.33	0.12	0.51
Cook Strait	90	2022	0.26	0	0.92	0.36	0.14	0.54
Cook Strait	90	2023	0.34	0	0.87	0.37	0.16	0.41
Cook Strait	90	2024	0.39	0	0.85	0.38	0.18	0.33
Cook Strait	90	2025	0.40	0	0.84	0.39	0.19	0.28
Cook Strait	90	2026	0.43	0.01	0.85	0.39	0.20	0.25
Cook Strait	90	Eq.	0.55	0.03	0.81	0.42	0.26	0.18

4.3.1 Other factors

The stock assessment model assumed homogeneity in recruitment, and that natural mortality does not vary by size or year, and that growth has the same mean and variance throughout the entire area. However, it is known that pāua fisheries are spatially variable and that apparent growth and maturity in pāua populations can vary over very short distances. Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on tagging data collected from a range of different locations. Similarly, the length frequency data are integrated across samples from many places. The effect of this integration across local areas is likely to make model results optimistic.

For instance, if some local stocks are fished very hard and others not fished, local recruitment failure can result due to the limited dispersal range of this species. Recruitment failure is a common observation in overseas abalone fisheries and may have been experienced in D'Urville and Northern Faces.

CPUE provides information on changes in relative abundance. However, CPUE is generally considered to be a poor index of stock abundance for pāua, due to the ability of divers to maintain catch rates by moving from area to area despite a decreasing biomass (hyperstability). Breen & Kim (2003) argued that standardised CPUE might be able to relate to the changes of abundance in a fully exploited fishery such as PAU 7, and a large decline in the CPUE is most likely to reflect a decline in the fishery. Analysis of CPUE currently relies on Pāua Catch Effort Landing Return (PCELR) forms and ERS, which record daily fishing time and catch per diver on a relatively small spatial scale. These data will likely remain the basis for stock assessments and formal management in the medium term.

Between October 2010 and 2018, a dive-logger data collection program was operated by the commercial industry to achieve fine-scale monitoring of pāua fisheries (Neubauer et al 2014, Neubauer & Abraham 2014). Using fishing data logged at fine spatial and temporal scales can substantially improve effort calculations and the resulting CPUE indices and allow complex metrics such as spatial CPUE to be developed (Neubauer & Abraham 2014). Data from the loggers have been analysed to provide comprehensive descriptions of the spatial extent of the fisheries and insight on relationships between diver behaviour, CPUE, and changes in abundance on various spatial and temporal scale (Neubauer et al 2014, Neubauer & Abraham 2014). However, the data-loggers, and recent changes to fine-scale electronic statutory reporting, can potentially change how the divers operate such that they may become more effective in their fishing operations (the divers become capable of avoiding areas that have been heavily fished or that have relatively low CPUE without them having to go there to discover this), therefore changing the meaning of diver CPUE (Butterworth et al 2015, Neubauer 2017).

Commercial catch length frequencies provide information on changes in population structure under fishing pressure. However, if serial depletion has occurred and fishers have moved from area to area, samples from the commercial catch may not correctly represent the population of the entire stock. For PAU 7, there has been a long time series of commercial catch sampling and the spatial coverage of the available samples is generally considered to be adequate throughout the years.

Areas outside Cook Strait are now poorly monitored by CPUE. The declines in CPUE in areas that are fished (D'Urville and Northern Faces) and contribute to CPUE therefore may substantially under-estimate the true extent of declines in these areas. While anecdotal evidence suggests that environmental factors have played a primary role in these declines, no firm conclusion can be reached about the relative contributions of environmental changes and fishing impacts on declines of pāua populations in the areas. Although these areas now only contribute very little to the commercial fishery, it is unclear whether these areas can be expected to recover, and in the absence of CPUE to monitor abundance there is currently a lack of information that can inform about local trends in these areas.

4.4 Future research considerations

- Monitoring of biomass in areas where CPUE does not provide an index of biomass (D'Urville Island and Northern Faces).
- Continued monitoring of growth and maturation to understand effects of changing environment, particularly with respect to SST. This might also be achieved by meta-analysis across stocks and could include consideration of SST effects on CPUE across stocks. Consider including more of the east coast in the assessment, noting that this would need to be considered as a separate fishery due to recent earthquake impacts and new management settings.
- Estimate recreational harvest using approaches linked to stock size.
- Explore use of smaller time steps within the assessment model to improve fits to LF data.

5. STATUS OF THE STOCKS

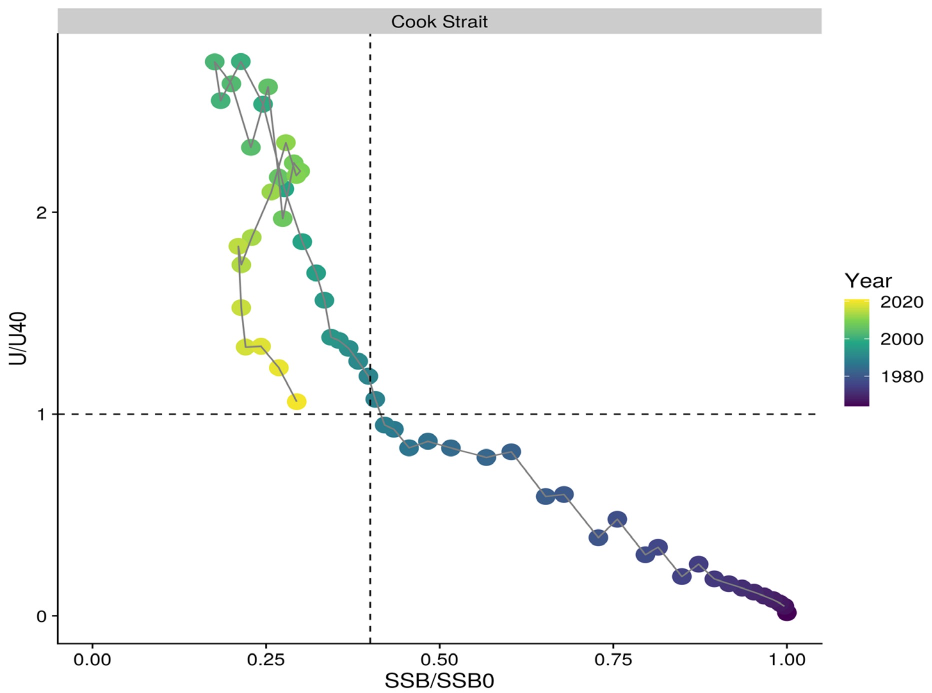
Stock Structure Assumptions

The 2022 assessment was conducted for Cook Strait (pāua statistical areas 711–730), but these include most (more than 90%) of the recent catch.

- **PAU 7- Marlborough**

Stock Status		
Most Recent Assessment Plenary Publication	2022	
Catch in most recent year of assessment	Year: 2020–21	Catch: -
Assessment Runs Presented	Base case MCMC	
Reference Points	Interim Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$	
Status in relation to Target	Spawning stock biomass was estimated to be 33% B_0 and is Unlikely (< 40%) to be at or above the target	
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits	
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring	

Historical Stock Status Trajectory and Current Status

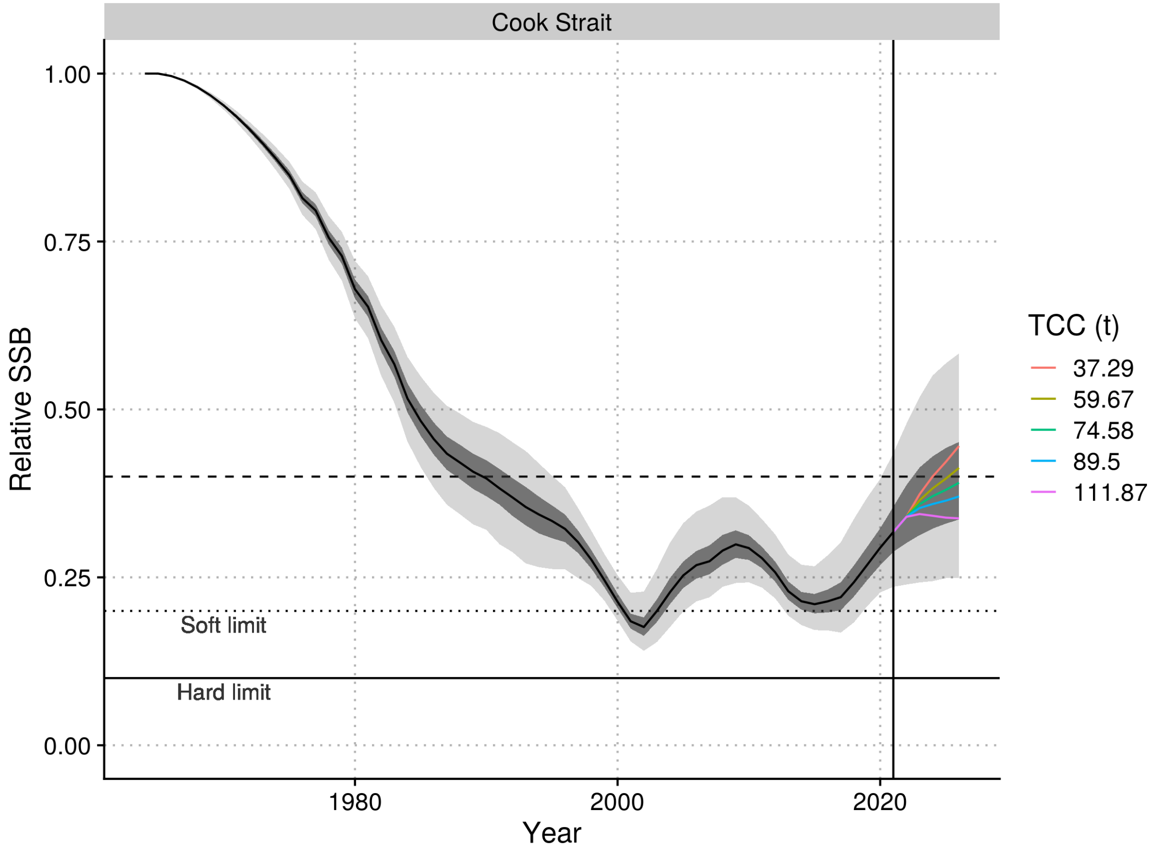


Posterior medians of relative stock status (spawning stock biomass (*SSB*) depletion level relative to unfished biomass (SSB_0)) and exploitation rate (*U*), relative to the exploitation rate that would result in a stock depletion to 40% of unfished biomass (U_{40}).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The stock has rebuilt substantially towards the target biomass level since 2017.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity peaked in the early 2000s but has subsequently declined steadily.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis



Stock trajectory and projected stock biomass (2022–2026), colours show median trajectories for current catch, (green) and 20% (50%) increase (decrease) from current catch. Uncertainty intervals show inter-quartile and 95% confidence from the base-case MCMC under observed catch (current catch for projected biomass).

Stock Projections or Prognosis	Five-year projections suggest that, at current catch levels, the biomass will be rebuilt to target levels by 2026.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)

Assessment Methodology & Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest assessment Plenary publication year: 2022	Next assessment: 2027
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE indices PCELR & ERS series	1 – High Quality
	- Commercial sampling length frequencies	1 – High Quality

	Growth estimate priors	2 – Medium or mixed quality: fine scale spatial (and potentially temporal) variation in growth rates
Data not used (rank)	CELR CPUE series	3 – Low Quality: variable catchability and changes in technology
	FSU CPUE series	3 – Low Quality: poor recording
Changes to Model Structure and Assumptions	- Assessment area reduced to Cook Strait only, due to poor representation of other areas in fishery-dependent data in recent years - Changed growth to use a prior derived from meta-analysis, model does not explicitly fit to PAU 7 growth data (deemed poorly representative of spatial growth variation) - Fixed *M* in base case (estimated *M* from this model is consistent with previous estimate and current fixed value) - Length frequency likelihood logistic normal, rather than multinomial	
Major Sources of Uncertainty	- Recruitment: length composition data available to the stock assessment provide little information about relative year class strengths - 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	

Qualifying Comments
-This assessment covers only the Cook Strait component of the catch. The stock appears to be depleted in D'Urville and Northern Faces. - The East Coast portion of the QMA was closed to fishing following the Kaikōura earthquake in 2016, and subsequent surveys suggest an appreciable increase.

Fishery Interactions
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