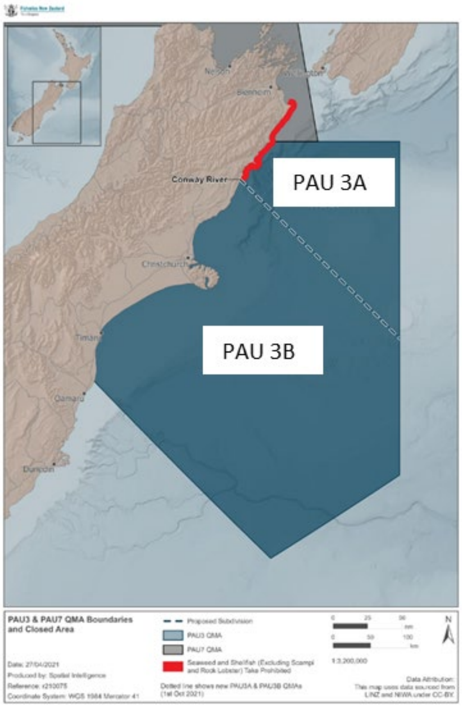
PĀUA (PAU 3A) – Kaikōura

(*Haliotis iris*)
Pāua



1. FISHERY SUMMARY

Prior to October 2021, PAU 3A was part of the PAU 3 QMA. The PAU 3 fishery was introduced into the QMS on 1 October 1986 with a TACC of 57 t and later increased to 91.62 t in 1995 as a result of appeals to the Quota Appeal Authority (Table 1).

The coastline between the Clarence River and Conway River was closed to commercial and recreational pāua fishing to protect the surviving pāua populations and associated habitats (see coastline in red in Figure above) due to a significant loss of pāua habitat resulting from coastal uplift following the 2016 Kaikōura earthquakes. In addition, the TACC for PAU 3 was lowered to 45.8 t, and the TAC was set at 79.3 t with a customary allowance of 15 t, a recreational allowance of 8.5 t, and other sources of mortality were at 10 t (Table 1). The closure of the Kaikōura coastline to fishing caused fishing effort to move onto the unaffected open Canterbury coastline (now PAU 3B).

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 3 and PAU 3A since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1995*	–	–	–	–	57.0
1995–2017*	–	–	–	–	91.62
2017–2021*	79.3	15	8.5	10	45.8
2021–2024	40.5	7.5	5	5	23.0
2024–	78.5	7.5	18	7	46.0

*PAU 3 figures

On 1 October 2021, the PAU 3 QMA was subdivided into two smaller QMAs—PAU 3A (Kaikōura) and PAU 3B (Canterbury)—in response to the changed nature of the fishery (see Figure above). At that time, a new TAC, TACC, and allowances were set to reflect the QMA subdivision, pre-earthquake catch levels, and the need to adopt a precautionary approach to enable the fishery to rebuild to continue while providing for utilisation opportunities.

In response to a rebuilding of pāua biomass, the commercial and recreational fisheries were initially reopened for a limited three-month period in December 2021. The commercial fishery was later reopened on a permanent basis in January 2023, and the recreational fishery for a two-month season between April and June 2023. The 2024 TAC and TACC were increased for the 2024–25 fishing year. The allowance for recreational fishing was also increased at this time and the timing of the recreational fishing seasons in the following years has changed to reflect this (details are provided in section 1.2).

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September.

Commercial fishers in PAU 3A gather pāua by hand while freediving. The commercial sector accounted for most of the harvest in the previous PAU 3 fishery. Prior to the 2016 earthquakes, commercial catches predominantly came from the northern part of the QMA, now PAU 3A, between the northern end of Pegasus Bay and the Clarence River, and from the southern side of Banks Peninsula. Annual commercial catches were generally evenly distributed between these two fishing areas with about 45 tonnes (50% of the 91.6 tonne TACC) being caught in each area.

Reported landings for PAU 3 are shown in Figure 1 and Table 2 between 1983–84 and 2020–21. Landings in PAU 3 closely followed the TACC between the fishing year 1991–92 and the 2016 earthquake closure. Following the 2016 earthquake, the coastline from Clarence Point in the north to the Conway River in the south was closed to all commercial (and recreational) pāua fishing. This caused all commercial catches to be taken entirely from the open unaffected Canterbury areas, mainly the southern side of Banks Peninsula but also from the Motunau and Gore Bay areas. The reported landings in 2020–21 totalled 47.10 t, with a TACC of 45.8 t, all of which came from areas unaffected by the earthquake, which remained open to commercial fishing. These areas now make up the PAU 3B QMA.

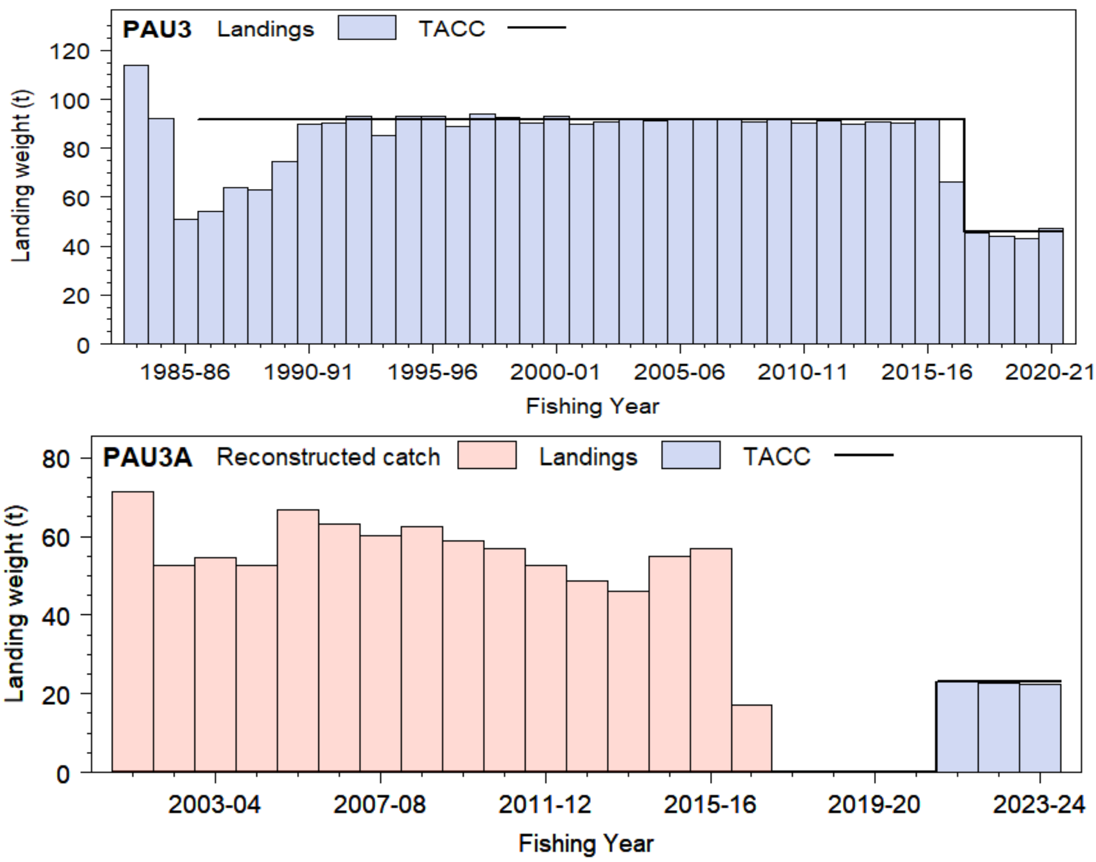


Figure 1: Reported commercial landings and TACC for PAU 3 (top) from 1983–84 to 2020–21 (last year before the QMA subdivision) and PAU 3A (bottom) from 2001–02 to present. The PAU 3A reconstructed landings between 2001–02 and 2020–21 correspond to the PAU 3 estimated catch for Pāua Statistical Areas P301 to P310 which correspond to the PAU 3A QMA created in 2021–22. No catch from 2017–18 to 2020–21 reflects the fishery closure following the 2016 Kaikōura earthquake.

Table 2: TACC and reported landings (t) of pāua in PAU 3 between 1983–84 and 2020–21 and in PAU 3A from 2022–23. The PAU 3A reconstructed landings between 2001–02 and 2020–21 correspond to the PAU 3 estimated catch for Pāua Statistical Areas P301 to P310 which correspond to the PAU 3A QMA created in 2021–22.

	PAU 3		PAU 3A		
Year	Landings	TACC	Reconstructed estimated catch	Landings	TACC
1983–84*	114.00	–			
1984–85*	92.00	–			
1985–86*	51.00	–			
1986–87*	54.02	57.00			
1987–88*	62.99	60.49			
1988–89*	57.55	66.48			
1989–90	73.46	69.43			
1990–91	90.68	77.24			
1991–92	90.25	91.50			
1992–93	94.52	91.50			
1993–94	85.09	91.50			
1994–95	93.26	91.50			
1995–96	92.89	91.62			
1996–97	89.65	91.62			
1997–98	93.88	91.62			
1998–99	92.54	91.62			
1999–00	90.30	91.62			
2000–01	93.19	91.62			
2001–02	89.66	91.62	71.36		
2002–03	90.92	91.62	52.47		
2003–04	91.58	91.62	54.64		
2004–05	91.43	91.62	52.50		
2005–06	91.60	91.62	66.66		
2006–07	91.61	91.62	63.27		
2007–08	91.67	91.62	60.34		
2008–09	90.84	91.62	62.38		
2009–10	91.61	91.62	59.01		
2010–11	90.40	91.62	56.93		
2011–12	91.14	91.62	52.78		
2012–13	90.01	91.62	48.54		
2013-14	90.85	91.62	46.03		
2014–15	90.44	91.62	55.08		
2015–16	91.73	91.62	56.90		
2016–17	66.29	91.62	17.03		
2017–18	45.59	45.80	0		
2018–19	44.05	45.80	0		
2019–20	43.09	45.80	0		
2020–21	47.10	45.80	0		
2021–22†				22.96	23.00
2022–23				22.71	23.00
2023–24				22.45	23.00

* FSU data.
† The 2021–22 season was 1 December 2021 to 28 February 2022.

On 1 October 2001 it became mandatory to report catch and effort on Pāua Catch Effort Landing Returns (PCELRs) using fine-scale reporting areas that had been developed by the New Zealand Pāua Management Company for their voluntary logbook programme (Figure 2). The PAU 3A QMA effective since 1 October 2021 corresponds to the Pāua Statistical Areas P301 to P310.

Table 2 shows the reconstructed estimated catch equivalent to PAU 3A from the estimated PAU 3 catch between 2001–02 and 2020–21. Table 2 also shows the reported landings for PAU 3A since 2021–22, noting the fishing season for 2021–22 was only 3 months (1 December 2021 to 28 February 2022).

Since 2001, a redistribution of fishing effort within PAU 3 was undertaken by the industry as a response to fears that the more accessible northern part of the fishery was being overfished. A voluntary subdivision was agreed by PāuaMAC3 which divided PAU 3 into four management zones. A voluntary harvest cap was placed on each management zone and this cap was reviewed annually. Minimum harvest sizes (MHS) were also agreed each year for each zone in addition to the legislated minimum legal size (MLS). These management initiatives were officially in place until 2020–21.

In 2021, the Minister for Oceans and Fisheries approved a Fisheries Plan for the PAU 3 fishery under s11A of the Fisheries Act 1996 to better manage commercial harvest activity across the wider fishery.

This Plan prescribes an 'adaptive rebuild' approach in response to the Kaikōura earthquakes using a number of tools including catch spreading arrangements, harvest control rules, a larger minimum harvest size, and fine scale catch reporting and monitoring. The Plan includes new voluntary management areas (Table 3). On the basis of survey information (see section 4.1), the fishery was reopened in December 2021 with a commercial total allowable catch (TACC) of 23 t, a figure that was thought of as precautionary (catch prior to the earthquake was regularly in excess of 50 t).

Following the biomass survey of the adult pāua population conducted in 2021-22 as well as a survey of the recreational catch during that short 2021/22 fishing season, the Minister approved the permanent reopening of the PAU 3A commercial fishery from 5 January 2023. The TACC was increased to 46 t in 2024–25.

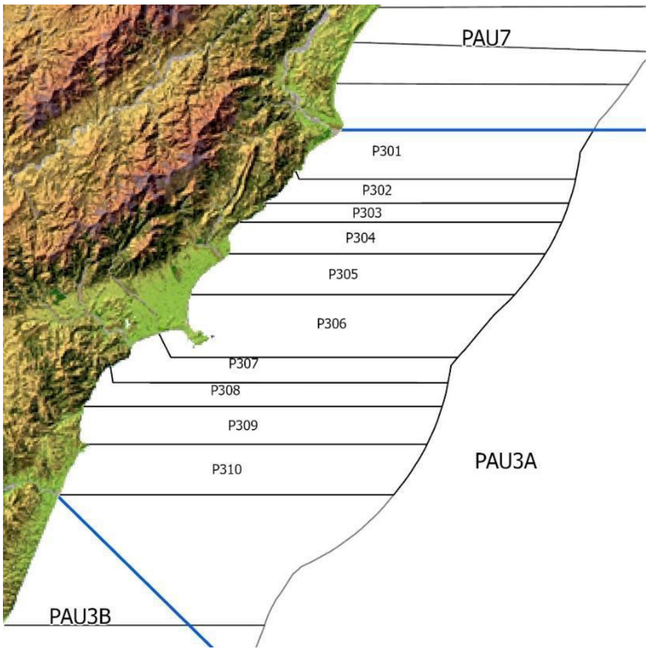


Figure 2: Map of fine scale Pāua Statistical Areas for PAU 3.

Table 3: Summary of the management zones within PAU 3A as initiated by PāuaMAC3.

Management zone (since 2021)	Area	Pāua Statistical Area zone
3A1	Paparoa	P301–P302
3A2	Rakautara	P303–P304
3A3	Omihi	P307–P308
3A4	Oaro	P309–P310

1.2 Recreational fisheries

For further information on recreational fisheries refer to the Introduction – Pāua chapter. The 'National Panel Survey of Marine Recreational Fishers 2017–18: Harvest Estimates' estimated that the recreational harvest for PAU 3 was 8.8 t with a CV of 35% (Wynne-Jones et al 2019). For the 2013 stock assessment, the Shellfish Working Group (SFWG) agreed to assume that the recreational catch rose linearly from 5 t in 1974 to 17 t in 2013.

Following initial high levels of mortality related to the earthquake, local pāua abundance recovered significantly, and the pāua fishery was re-opened on 1 December 2021, until 1 March 2022. The significant local interest in the fishery and high numbers of easily accessible pāua were considered likely to lead to a very active recreational fishery, once reopened. Therefore, a recreational harvest estimation survey (Holdsworth 2021) using a roving access design was implemented over the December to March fishing period. The survey estimated a recreational take of 42 tonnes (CV 17.5%) over the three-month open season (Holdsworth 2022). Pre- and post-fishery surveys indicated significant removal of legal sized pāua in the most popular recreational fishing sites during the fishery, but high densities of sub-legal sized pāua remained (Gerrity & Schiel 2023).

After reviewing the results of the recreational catch survey and the biomass survey of the adult pāua population conducted in 2021–22, the Minister agreed to reopen the recreational fishery between 15 April 2023 and 15 June 2023 with a daily limit of 3 pāua per person. Subsequent surveys during the open season estimated recreational of 11.66 t (CV 25%) in 2024 (Holdsworth et al 2023) and 15.83 t (CV 18%) in 2024 (Holdsworth et al 2025).

In the 2023–24 fishing year, the recreational fishing season was again open for a short period (22 April to 21 June 2024). The Kaikōura pāua fishery opened to recreational pāua-gathering with a larger minimum legal size of 130 mm, for a slightly longer four-month season from 1 May 2025 until 31 August along with the increased recreational allowance.

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 3 until 2020–21 are shown in Table 4. These numbers are likely to be an underestimate of customary harvest because only the catch approved and harvested in 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.

Landings before 2010–11 do not include the area between the Hurunui River and the South Shore (just north of Banks Peninsula), because tangata tiaki were not appointed there until November 2009.

Estimates of customary take before the 2016 earthquakes ranged from about 7 to 13 tonnes. Customary take then initially declined, given the immediate loss of significant pāua abundance along the Kaikōura coastline, but increased in 2019–20 in response to feeding the local communities during the Covid-19 event. Information is not available at the PAU 3A level up to 2020–21 and customary estimates since 2021–22 for PAU 3A are given in Table 5.

Table 4: Fisheries New Zealand records of customary harvest of pāua (approved and reported in numbers) in PAU 3 between 2000–01 and 2020-21. Landings data before 2010–11 exclude the area between the Hurunui River and Pegasus Bay. – no data.

	Numbers			Numbers	
Fishing year	Approved	Harvested	Fishing year	Approved	Harvested
2000–01	300	230	2011–12	5 675	4 242
2001–02	6 239	4 832	2012–13	15 036	12 874
2002–03	3 422	2 449	2013–14	10 259	7 566
2003–04	–	–	2014–15	8 761	7 035
2004–05	–	–	2015–16	14 801	11 808
2005–06	1 580	1 220	2016–17	11 374	9 217
2006–07	5 274	4 561	2017–18	2 708	1 725
2007–08	7 515	5 790	2018–19	480	278
2008–09	10 848	8 232	2019–20	30 288	21 527
2009–10	8 490	6 467	2020–21	11 462	8 609
2010–11	8 360	7 449			

Table 5: Fisheries New Zealand records of customary harvest of pāua (approved and reported in numbers) in PAU 3A since 2021–22. – no data.

Fishing	Numbers	
year	Approved	Harvested
2021–22	9 228	7 905
2022–23	–	–
2023–24	–	–

1.4 Illegal catch

For further information on illegal catch refer to the Introduction – Pāua chapter.

For the purpose of the 2013 stock assessment and recent operational models (Neubauer & Kim 2023), the SFWG agreed to assume that illegal catches rose linearly from 5 t in 1974 to 15 t in 2000 and remained at 15 t between 2001 and 2013.

1.5 Other sources of mortality

The Working Group agreed that handling mortality would not be included in the model.

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, causing extensive uplift of about 110 km of coastline by as much as 6 m in some areas. This resulted in the widespread mortality of marine organisms, changes to the structure of intertidal and subtidal rocky reefs, and significant alterations to the structure of nearshore reef communities (Alestra et al 2019). Ongoing monitoring of these nearshore reef communities has revealed signs of recovery in the low intertidal zones, whereas sub-tidally there has been little recovery in areas that were de-vegetated and previously abundant algal stands appear to have become sparser and more fragmented (Alestra et al 2020).

The whole northern part of the PAU 3 fishery (Pāua Statistical Areas P301 to P310, now PAU 3A, Figure 3) was impacted to varying degrees by the earthquake. The earthquake caused the 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 is also expected from the earthquake due to an immediate loss of pre-earthquake pāua habitat that now lies above the new post-earthquake high tide mark.

Although the impacts of the seabed uplift on pāua populations around Kaikōura will only become clear in the longer term, work was undertaken to evaluate the area utilised by the pāua fishery that is now above the post-earthquake low tide mark (Neubauer 2017). The results suggested that the seabed uplift led to a loss of up to 50% of the pre-earthquake fished area in the pāua statistical areas P301 to P310. In area P301, the habitat loss was 7 ha, which corresponds to 52% of the fished area. However, this area contributed relatively little to the commercial catch. In area P302, which has contributed a larger proportion of the PAU 3 commercial catch, the area lost was 43 ha, which corresponds to 43% of the fished area. In other affected areas, the area lost was generally less than 10%. Across PAU 3 statistical areas, a total of 21% of the fished area (24% of catch weight as recorded on PCELR forms) was impacted by uplift (Figure 3).

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 Kaikōura 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. This will impact on the number of juvenile pāua growing into the fishery over the coming years. Recent surveys have indicated large scale recovery of pāua populations in the affected areas (McCowan & Neubauer 2021, 2022, 2023).

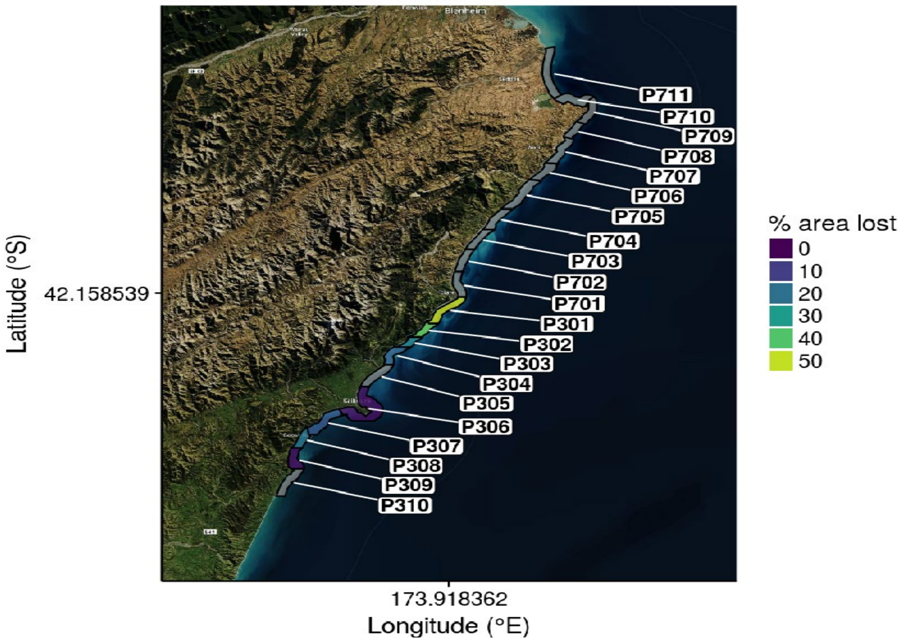


Figure 3: Percent fished area above the post-earthquake low tide mark for statistical areas within the Kaikōura earthquake fishery closure zone. Grey indicates that no post-earthquake elevation data were available.

2. BIOLOGY

For further information on pāua biology refer to the Introduction – Pāua chapter. A summary of published estimates of biological parameters for PAU 3 is presented in Table 6. Note that these values are from the most recent stock assessment covering the whole of PAU 3 and may therefore not be appropriate for PAU 3A. No area-specific, representative biological data are available for PAU 3A.

Table 6: Estimates of biological parameters (*H. iris*) in PAU 3.

		Estimate	Source
1. Natural mortality (M)			
		0.13 (0.120–0.14)	Median (5–95% range) of posterior distribution for the base case model
2. Weight = a(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 82 mm (80–84)	Median (5–95% range) of posterior distribution for the base case model
		95% maturity at 102 mm (96–108)	Median (5–95% range) of posterior distribution for the base case model

3. STOCKS AND AREAS

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

4. STOCK ASSESSMENT

Since 2018, the recovery of the PAU 3A fishery area has been monitored with biomass surveys. The fishery reopened in 2021–22. Since 2021, models have been under development to assess and simulate the PAU 3A fishery, and an assessment has been accepted in 2024.

4.1 Biomass survey and monitoring

Following the 2016 Kaikōura earthquake, a biomass survey was implemented to estimate and monitor pāua abundance and recruitment in the earthquake-affected area, to inform management decisions relating to the re-opening of the pāua fishery (McCowan & Neubauer 2018, 2021, 2022, 2023). 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.

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 was extended for another three years until mid-2023.

As of March of 2024, six further rounds of surveys of the 35 initially surveyed sites have been undertaken to monitor pāua abundance and recruitment trends (Figure 4), although not all sites could be surveyed in each round due to adverse weather conditions. Surveys in 2021–22 were split into pre- and post-season surveys in an attempt to assess impacts of fishing after re-opening the fishery. The post-season survey, however, encountered difficult survey conditions, and only some sites in PAU 3A could be surveyed. As a result, apparent declines in abundance in the post-season survey are likely to be confounded by the dive conditions and non-random subset of sites that were re-surveyed. As a result, these results are unlikely to provide a reliable index of abundance (McCowan & Neubauer 2023); these results are therefore excluded from survey indices used in models to evaluate management procedures.

The number of measurements per unit effort (MPUE) was initially used 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. An assessment of the appropriateness of MPUE, as well as biomass per unit of survey effort (BPUE, number of measurements multiplied by the weights inferred from the length frequency distribution of measured pāua), showed that both correlated well (R^2=0.86) with density. Therefore, BPUE has since been used as the main index of changes in pāua abundance.

An overall increase in pāua abundance was observed at a QMA-wide level in both QMAs over the seven survey periods (Figure 4). 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 to be 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. Since the reopening of the fishery, the survey index has declined slightly.

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 5). 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 6), 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.

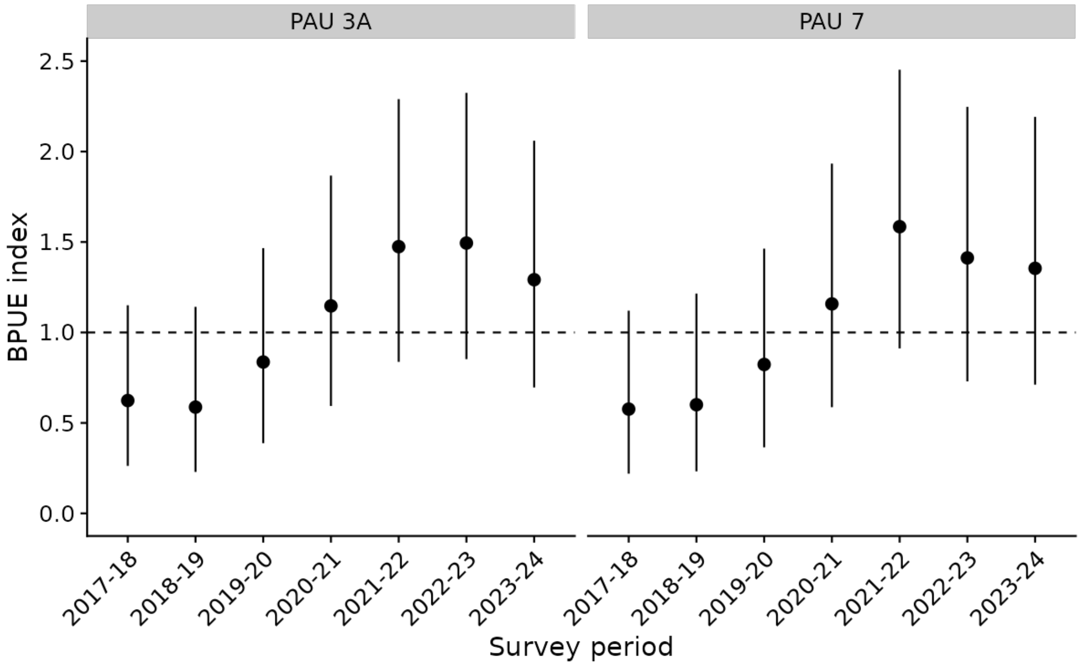


Figure 4: Marginal trend (relative to a geometric mean of 1) in biomass per unit effort (BPUE) across survey years for QMAs PAU 3 and PAU 7 from the BPUE model after accounting for confounding variables.

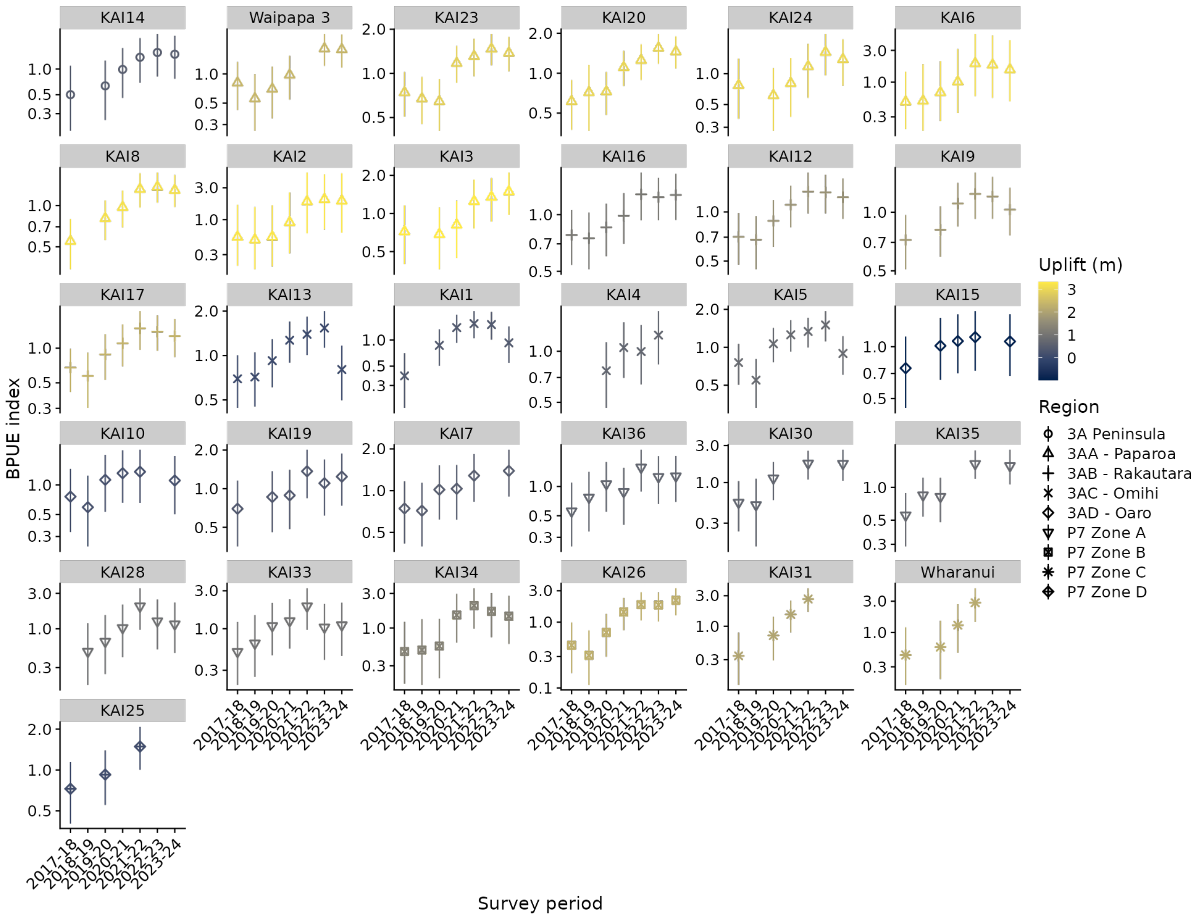


Figure 5: Marginal trend (relative to a geometric mean of 1 at each site) in biomass per unit effort (BPUE) across survey years for all sites, plotted across industry management zones ("Region") in QMAs PAU 3A and PAU 7 from the BPUE model after accounting for confounding variables.

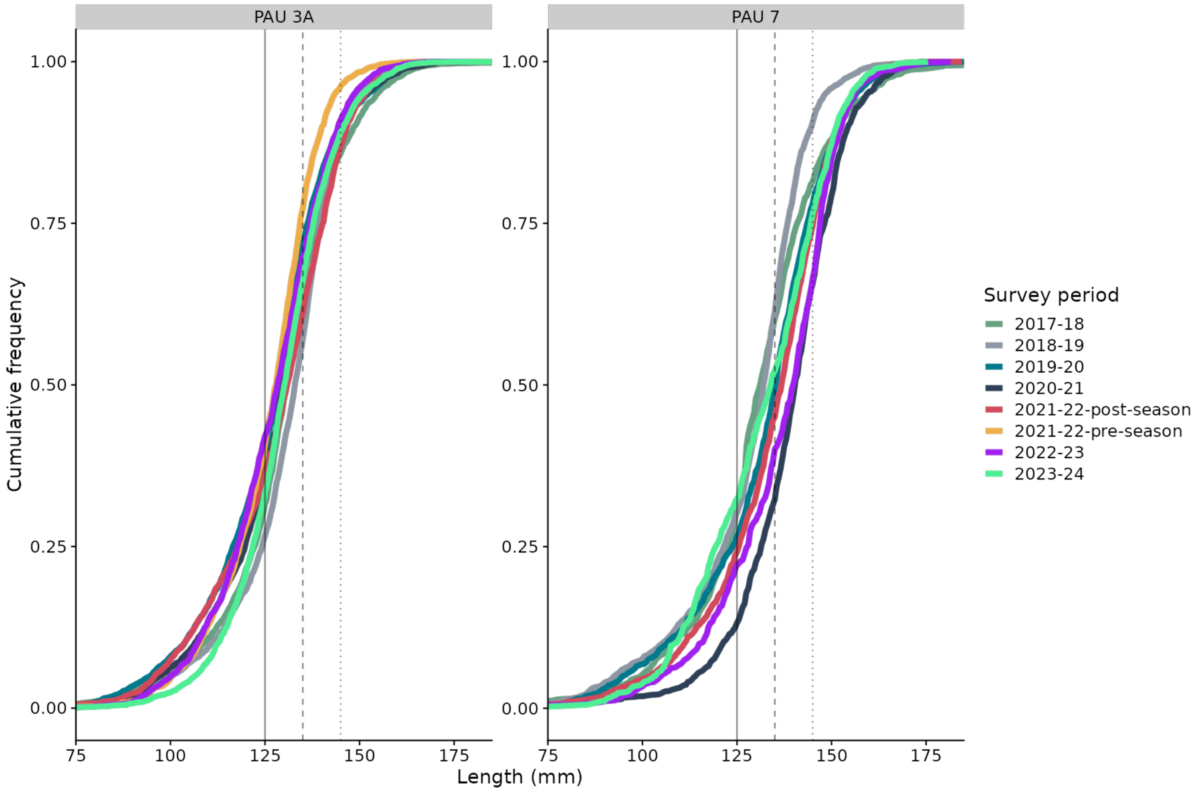


Figure 6: Cumulative length-frequency profiles for all pāua measured over four survey periods in PAU 3 and PAU 7. Vertical lines show the legal size of 125 mm (MLS; solid line), 135 mm (dashed line), and 145 mm (dotted line).

4.2 Stock assessment model

Prior to the earthquake, the PAU 3 quota management area was assessed on the basis of a length-based statistical stock assessment (Fu 2014). The stock was thought to be in healthy condition, although large uncertainties about stock status remained due to insufficient biological information that can inform understanding of local stock productivity. Two projects conducted since 2021 attempted to develop assessment models and test management options for PAU 3A as the fishery rebuilds. The work focused on key uncertainties that remained for management of the fishery long term: modelling of earthquake impacts and recovery, and the development of estimates of recreational catch over time.

The most recent model, developed in 2024, was accepted as a stock assessment and to evaluate management procedures. The model was spatially explicit across four main sub-areas (A – Paparoa, B – Rakautara, C – Omihi, and D - Oaro), based on length-based assessment models used in other areas, and tested a range of simple assumptions about plausible earthquake impacts. The model excluded areas around the Kaikoura peninsula (Pāua Statistical Areas P305 and P306), which are not currently commercially fished. It was fitted to commercial CPUE as well as length compositions from commercial shed sampling and (post-earthquake) onboard sampling of catch compositions. Survey data were integrated into the model by fitting to the survey index for each of the four sub-areas and to survey length frequencies summarised across survey sites falling within each of the four sub-areas.

Commercial catch is only known with certainty since 2002 (Table 2). Catch prior to 2002 was reconstructed based on the catch proportions coming from PAU 3A statistical areas in the first four years of PCELR reporting (2002–2006). For catch between 1974 and 1984, catch was taken from Murray & Ackroyd (1984) with the same catch proportions applied. Recreational catch is poorly known prior to the earthquake, and alternative recreational catch scenarios were explored, either fixing recreational catch at 24 t, or applying a ramp from 12 t to 24 t. Alternative models were run with an assumed catch at 12 t. For these models, catch proportions estimated from effort in recent recreational surveys were applied to all recreational catch. Illegal catch was assumed to be high in the 1990s and early 2000s, with high compliance effort leading to lower illegal catch in recent years. Although customary catch reporting has been highly variable, it was assumed to be steady at 5 t in the assessment. The model was initiated at the equilibrium biomass with no catch in 1964, with all catches ramping up linearly to 1974. The assumed catch history for all sub-areas is shown in Figure 7.

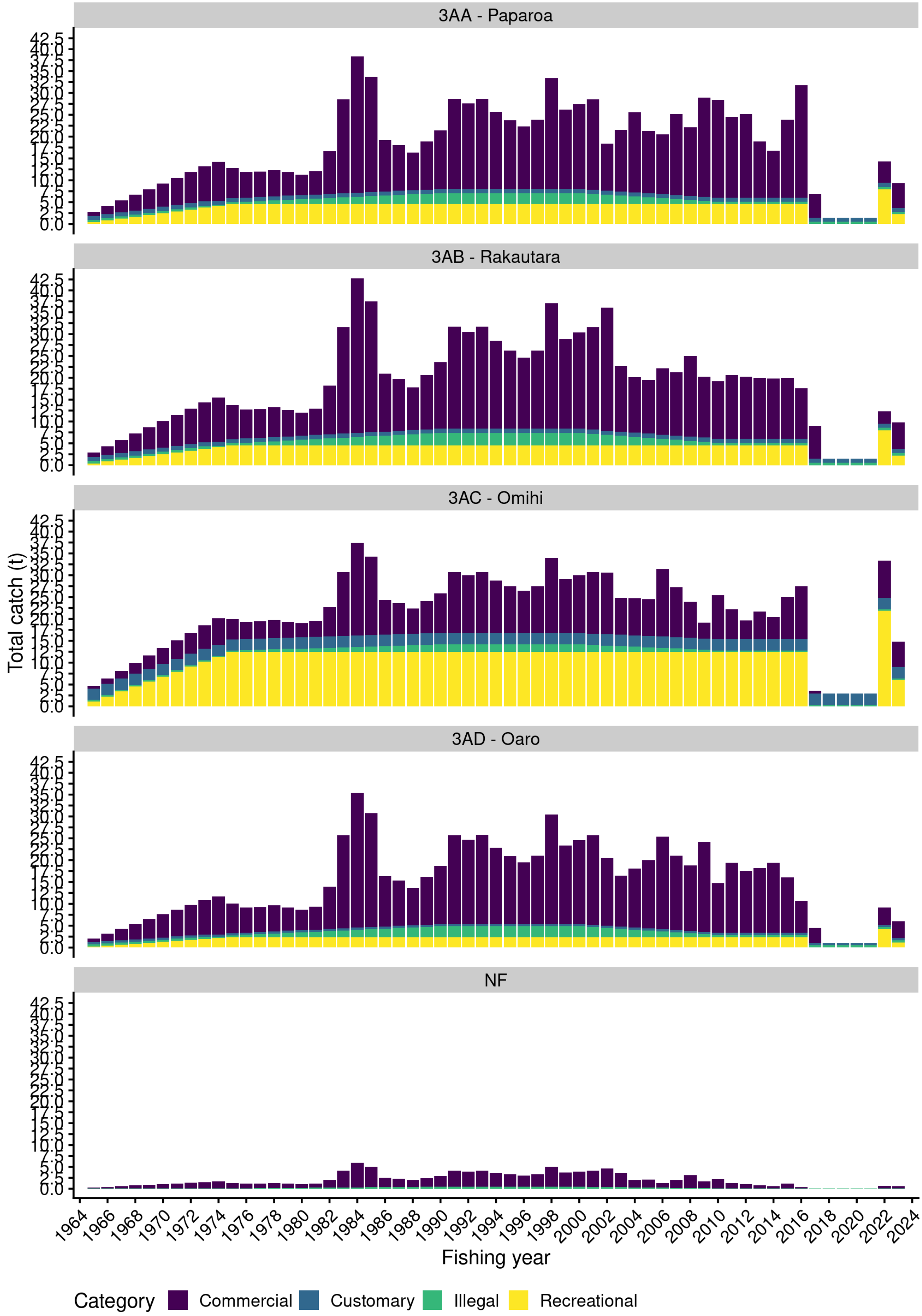


Figure 7: Assumed catch history for the base model for PAU 3A, by sub-areas. NF represents the area around the Kaikoura peninsula that is not currently commercially fished, and was not part of the stock assessment.

4.2.1 Relative abundance estimates from standardised CPUE analyses

The 2024 stock assessment used a combined series of PCELR data covering 2002–2016, and ERS data from 2022–2023. These data were combined in a single index. The 2017 fishing year, which includes some data prior to the earthquake in that fishing year, was included in the estimation of the CPUE index, but was not used in the stock assessment.

CPUE standardisation was carried out using a Bayesian Generalised Linear Mixed Model (GLMM) which partitioned variation among sub-areas within QMAs, and statistical areas within sub-areas, while accounting for effects of ACE-holders and individual divers. CELR data prior to 2002 cannot be attributed to PAU 3A because General Statistical Area 018 straddles PAU 7, PAU 3A and PAU 3B, and therefore these data were not used.

CPUE was defined as the log of daily catch, standardized for effort defined as time per statistical area and day (formulated as a cubic spline within the model). Other variables in the model were fishing year, FIN (Fisher Identification Number), sub-areas, diver ID, and fine-scale statistical area, as well as the interaction between sub-areas and year to derive an index by area. Variability in CPUE was mostly explained by differences among ACE-holders and individual divers (Figure 8). CPUE prior to the earthquake showed little directional trend, but post-earthquake CPUE was substantially higher, mirroring signs of biomass recovery seen in the surveys (Figure 9). In all regions, recent CPUE was above the highest CPUE in the time-series seen prior to the earthquake.

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.

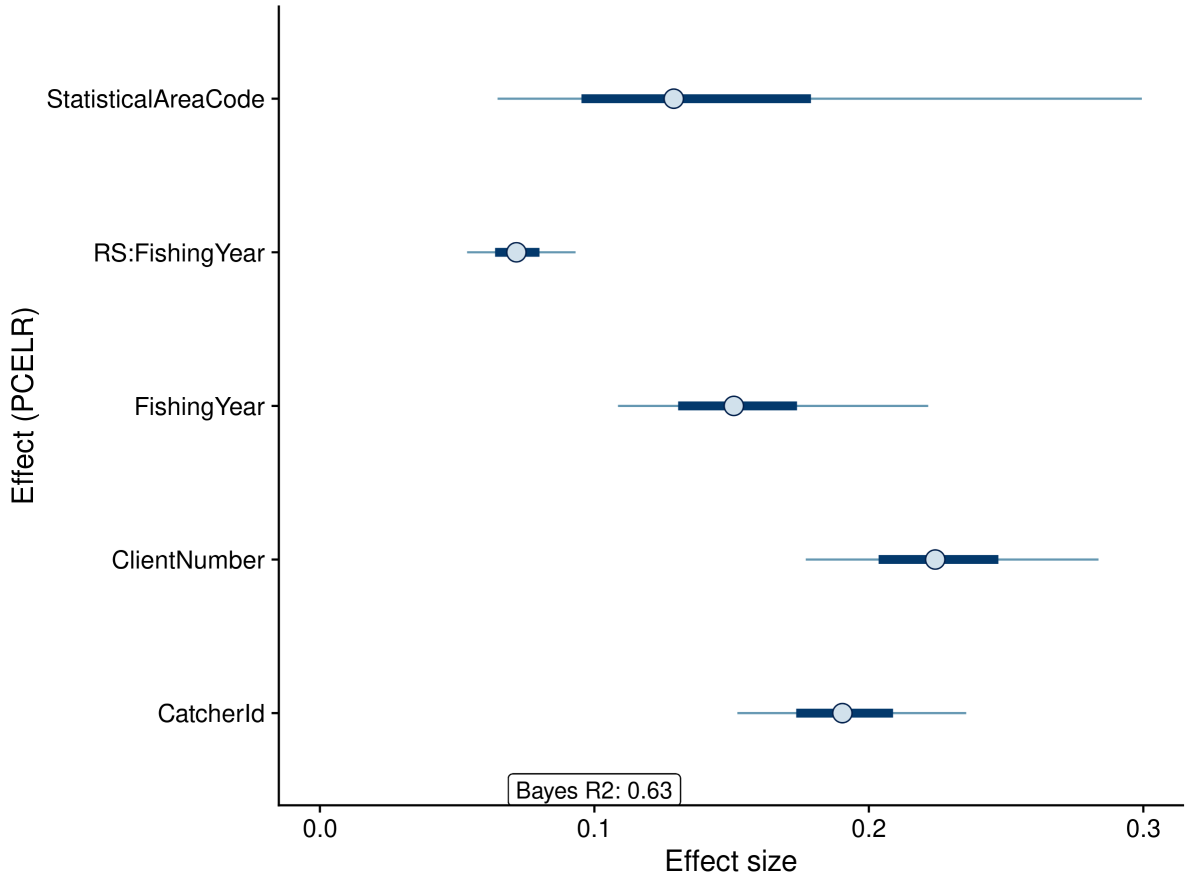


Figure 8: Effect size for the CPUE index standardisation model used for the base-case stock assessment model. RS: management zone (research stratum), CatcherID: diver number.

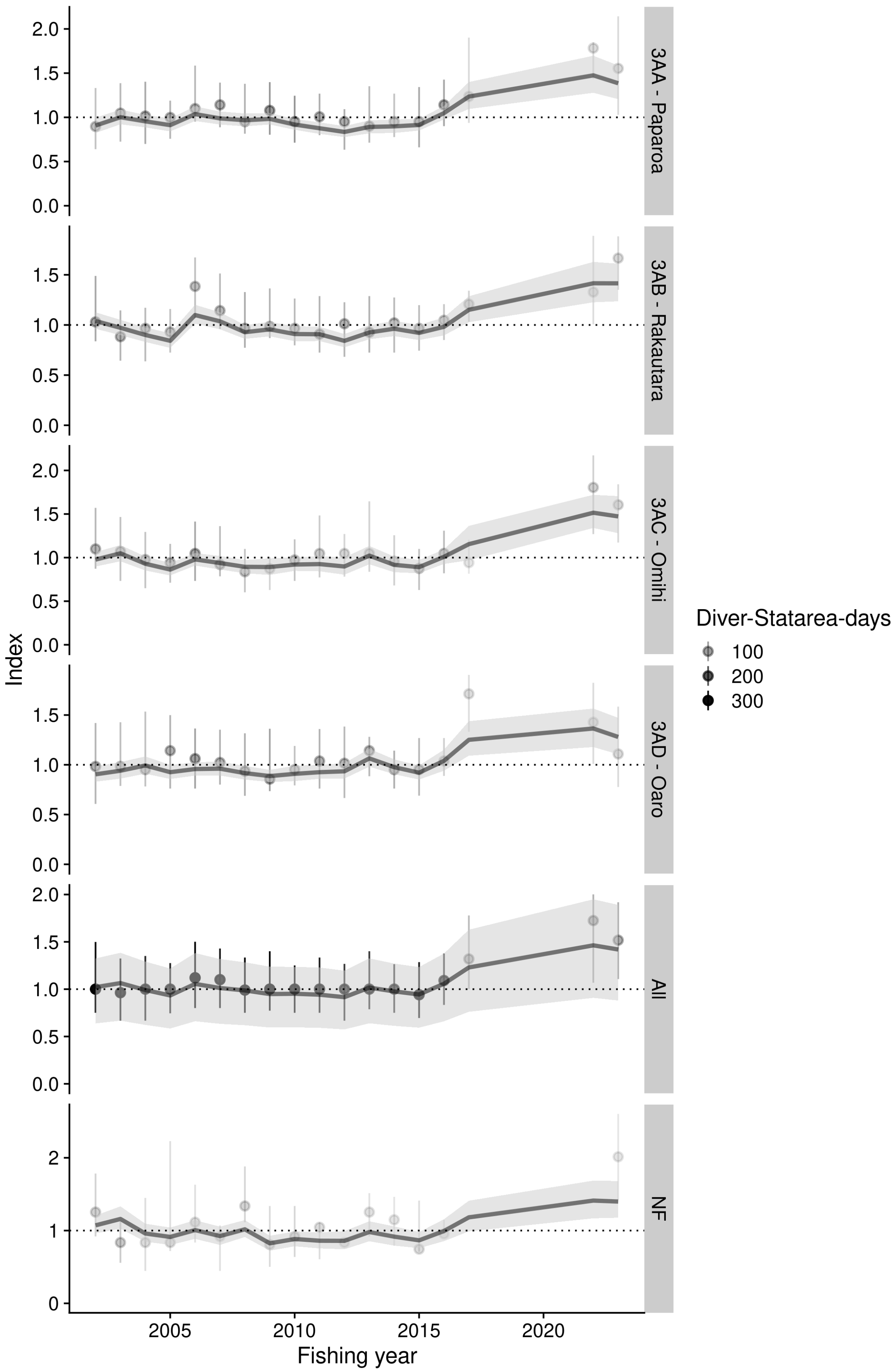


Figure 9: Standardised CPUE indices with 95% confidence intervals (solid line and ribbon) and unstandardized geometric CPUE and variability (points and inter-quartile error bars) for the combined PCELR and ERS time-series used in the base-case assessment model. Series presented by sub-area, NF represents the area around the Kaikoura peninsula that is not currently commercially fished, and was not part of the stock assessment.

4.2.2 Stock assessment methods

The 2024 PAU 3A stock assessment used the length-based population dynamics model first described by Breen et al (2003). Although the overall population-dynamics model remained unchanged, the 2024 assessment of the PAU 3A stock incorporated a number of changes from the previous models used in PAU 3.

1. Catch sampling length-frequency (CSLF) data were standardised using an improved model (Neubauer & Kim 2023) to better estimate uncertainty in removals.
2. Selectivity was allowed to vary in time, along an estimated offset parameterised by the mean minimum harvest size 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 constant.
3. The model was spatially explicit.

The model simulated the population from 1965 to 2023. The model structure assumed a single sex population within each area (defined as management zones for spatial models), with length classes from 70 mm to 170 mm, in bins 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. The transition matrix was estimated in the model from a meta-analysis derived informative prior and length compositions. Pāua entered the partition following recruitment and were removed by natural mortality and fishing mortality, as well as enforced earthquake assumptions.

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; the assessment used a Beverton-Holt stock-recruitment relationship, with steepness (h) fixed at 0.7 for the 2024 stock assessment.

Growth, maturation and natural mortality were estimated within the model, although no fitting to raw data was performed, and all inputs were provided as priors with mean and uncertainty. 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. Survey selectivity was also estimated, with vague priors centered around the age of emergence for pāua. Catchability was parameterised as a nuisance parameter with a flat prior. All other parameters were given either informative (M, growth) or vaguely informative priors, and likelihood profiles were constructed to inspect for potentially unintended consequences of priors on stock size. Parameters estimated in the assessment model and their assumed Bayesian priors are summarised in Table 7.

Table 7: A summary of estimated model parameters and type of prior, (N, normal; LN = lognormal; MVN = multivariate normal, MA = prior derived from meta-analysis), mean and standard deviation of the prior.

Parameter	Prior	μ	SD	CV
Unfished recruitment [ln($R0$)]	N	12		2
D_{50} (Length at 50% selectivity for the commercial catch)	LN	125		1
$D_{95\text{-}50}$ (Length between 50% and 95% selectivity the commercial catch)	LN	5		1
SD of time varying selectivity	LN	1		1
Survey L_{50} (Length at 50% selectivity for the survey)	LN	90		0.2
Survey $L_{95\text{-}50}$ (Length between 50% and 95% survey selectivity)	LN	2		1
Natural mortality (M)	LN	0.12		0.2
Recruitment deviations [ln(ϵ)]	N	0	0.4	
Growth transition matrix	MVN	MA	MA	

The observational data were:

1. A standardised CPUE series covering 2002–2023 (with a break from 2017–2021 when the fishery was closed) based on combined PCELR and ERS data.
2. A commercial catch sampling length frequency series for 2002–2023 (with a break from 2017–2021 when the fishery was closed)
3. Survey length frequencies (2018–2023)
4. Survey index (2018–2023)

Assumptions about earthquake impacts were tested using the model and evaluated on the basis of fits to survey and commercial data. While the Plenary acknowledged that this does not provide a strong basis for definitively modeling earthquake impacts, it provides a way to discard assumptions that are incompatible with observations to date. Models used either i) no earthquake impact (hypothesizing that models can deal with earthquake impacts by estimating low recruitment deviates), ii) a high but exponentially declining earthquake mortality (scaled by the level of uplift observed in each management area), or iii) an exponentially declining temporary reduction in recruitment (also scaled by the amount of coastline uplift).

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 2023 (SSB_{2023} and B^{Avail}_{2023}). 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_{2023} > 40% SSB_0)	Probability that the spawning stock biomass in 2023 was greater than 40% of the unfished spawning stock
P(SSB_{2023} > 20% SSB_0)	Probability that the spawning stock biomass in 2023 was greater than 20% of the unfished spawning stock (soft limit)

4.2.3 Model results

Although most models could fit increases in post-earthquake survey indices (Figure 10), assumptions about lower recruitment from the earthquake (assumption iii) did not fit with the observed levels of increase in the most impacted sub-area (A - Paparoa). This assumption was therefore not retained further when evaluating model sensitivities. The weight placed on length compositions was influential for the estimated stock trajectory and stock status (especially in sub-area B - Rakautara; Figure 11), as were assumptions about natural mortality and earthquake mortality (especially in sub-area A - Paparoa).

The Plenary accepted the high CSLF weight (highCSLFw) model without explicit earthquake impacts as the base assessment model, noting that recent estimated recruitment was low and likely proxying for earthquake impacts in the model. The base model provided good fits to survey data (Figure 10) and reasonable fits to CPUE trends and could fit CSLF data reasonably well (Figure 12), reflecting commercial selectivity for large pāua since the earthquake. It estimated a natural mortality of 0.13 (95% CI: 0.12–0.14), with relatively fast growth (compared with the meta-analysis derived prior mean, estimated from other QMAs).

The estimated stock status for the model was 46% [95% CI: 41–51%] of unfished spawning biomass and very low risk of being below limit reference points (0% estimated; Figure 13), reflecting a large rebuild of biomass post-earthquake from below target levels. Other model sensitivities showed a similar status, with estimates ranging from 0.36 to 0.51 (Figure 11), and similarly low risk, with earthquake mortality assumptions leading to the lowest status estimates of stock status in sub-area A (Paparoa).

Estimates of relatively low pre-earthquake biomass relative to current levels were largely driven by commercial catch compositions that were dominated by small individuals (relative to sizes seen post-earthquake) in years prior to the earthquake, especially in Rakautara (Figures 11, 12). The estimated commercial exploitation rate was relatively high in this area, whereas in Omihi, the recreational exploitation rate was as high as the commercial one, meaning that the combined exploitation rate was estimated to be relatively high pre-earthquake as well (Figure 14). Post-earthquake exploitation rates were low by comparison to pre-earthquake years in all areas except Omihi, where the bulk of the recreational harvest was estimated to have occurred post-reopening.

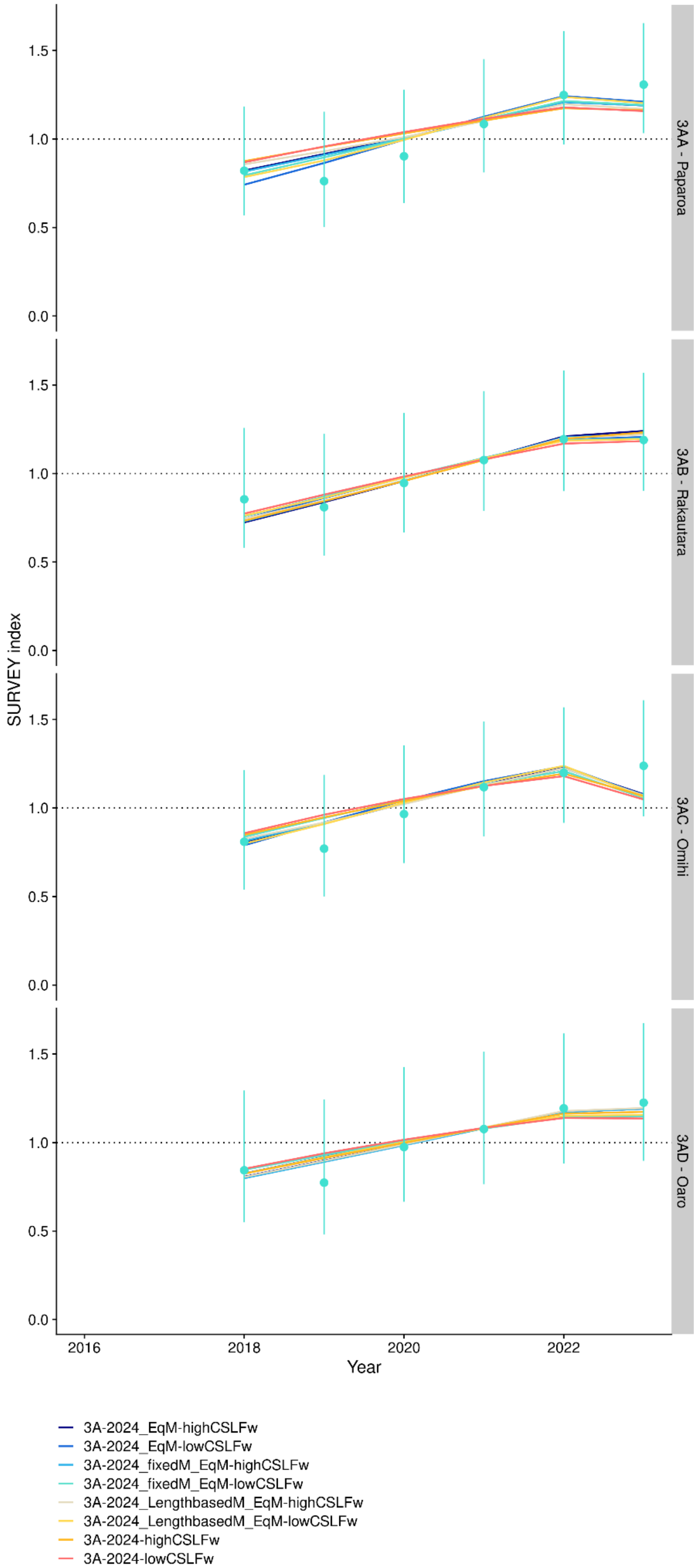


Figure 10: Estimated fit to survey indices generated from post-earthquake surveys for pāua in four management zones in the PAU 3A fishery, comparing plausible operating models with different assumptions about model weights for commercial length frequencies CSLFw [high vs low weight]; natural mortality [fixed at 0.12, length-based (estimated) or length-invariant (estimated)]; and explicit earthquake mortality (EqM).

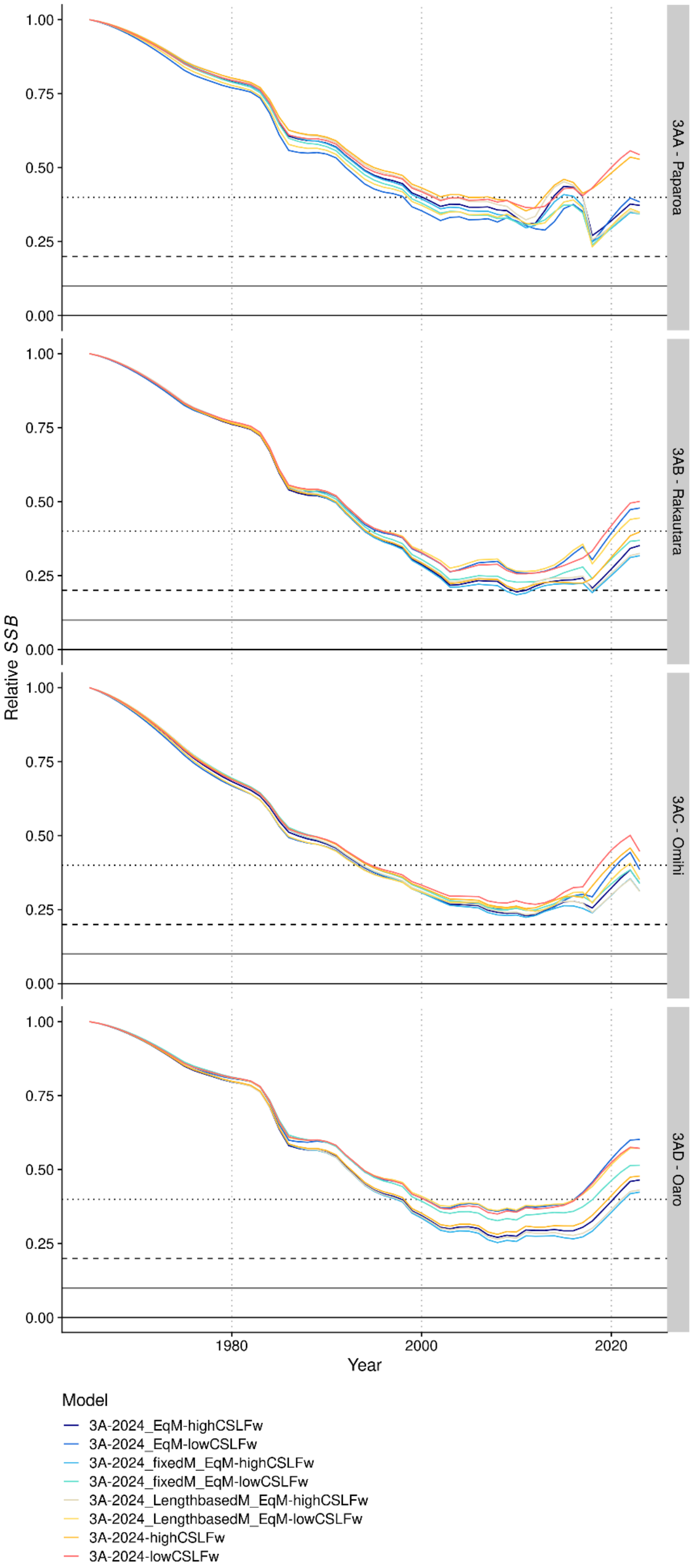


Figure 11: Estimated relative spawning stock biomass (SSB) trend for pāua in four management zones in the PAU 3A fishery, comparing plausible operating models with different assumptions about model weights for commercial length frequencies CSLFw [high vs low weight; natural mortality [fixed at 0.12, length-based (estimated) or length-invariant (estimated)]; and explicit earthquake mortality (EqM).

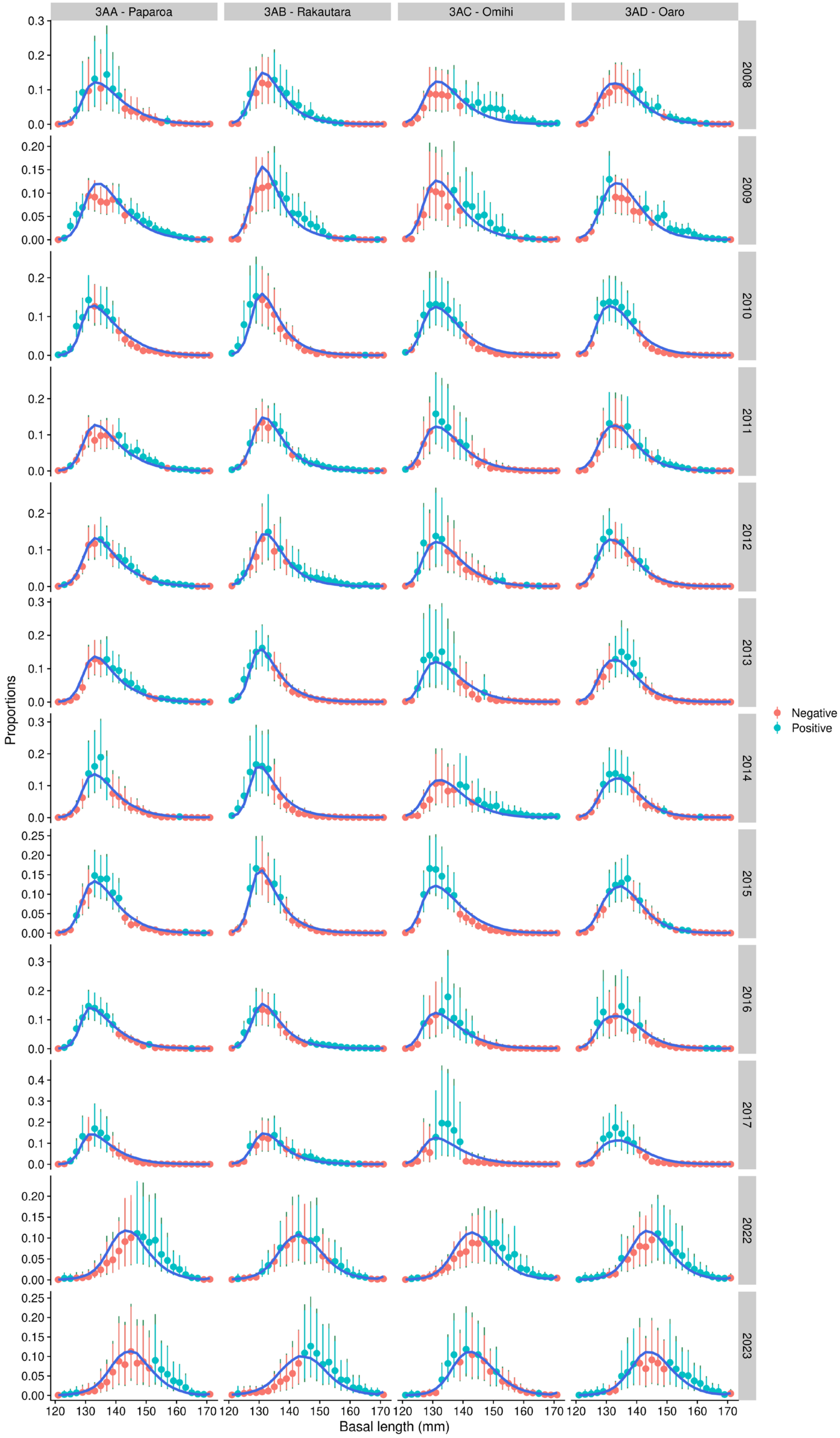


Figure 12: Estimated length composition (blue line) and corresponding model inputs (points and uncertainty by length bin) for the base model for the 2024 PAU 3A stock assessment. Residuals are marked as positive (blue) and negative (red).

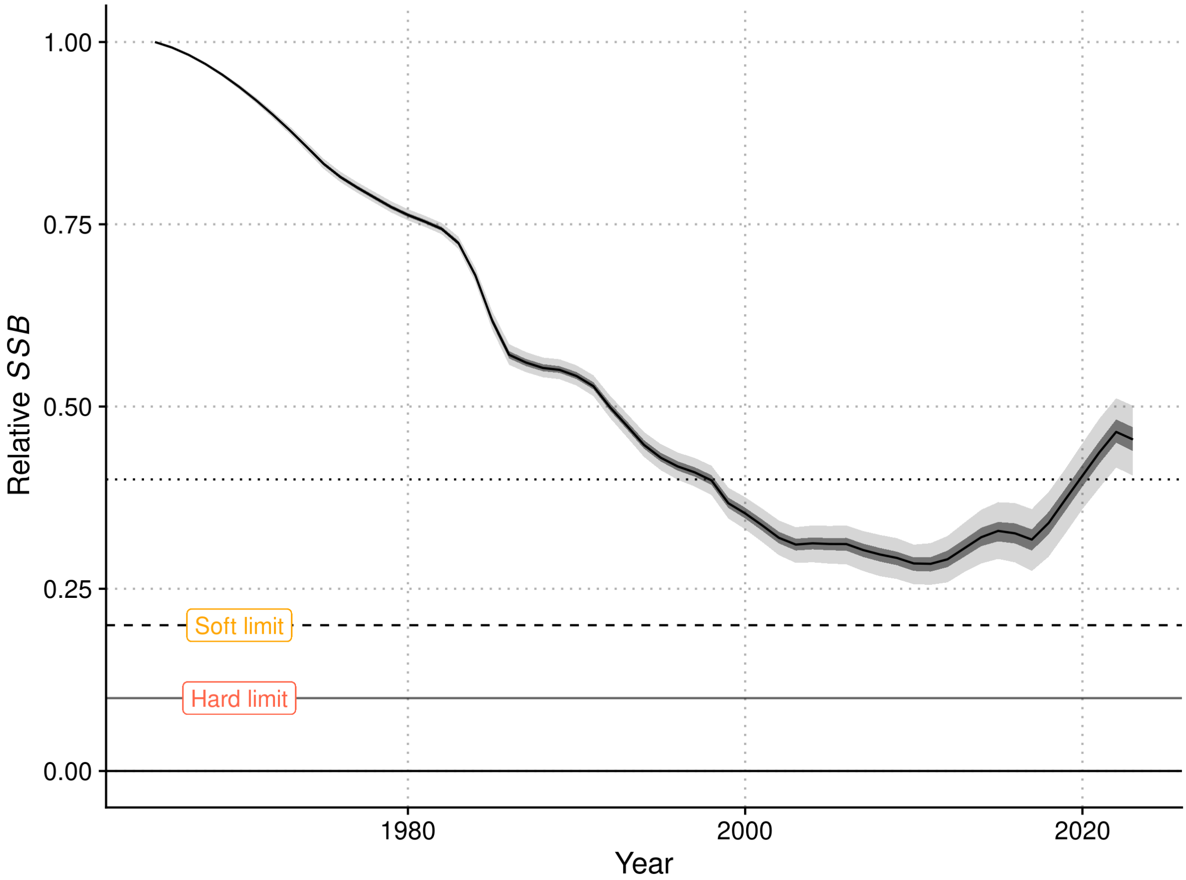


Figure 13: Estimated stock trajectory for relative spawning biomass (relative to unfished spawning biomass). Shown are the posterior median (black line), and interquartile (dark shade) and 95% confidence bounds (light shade).

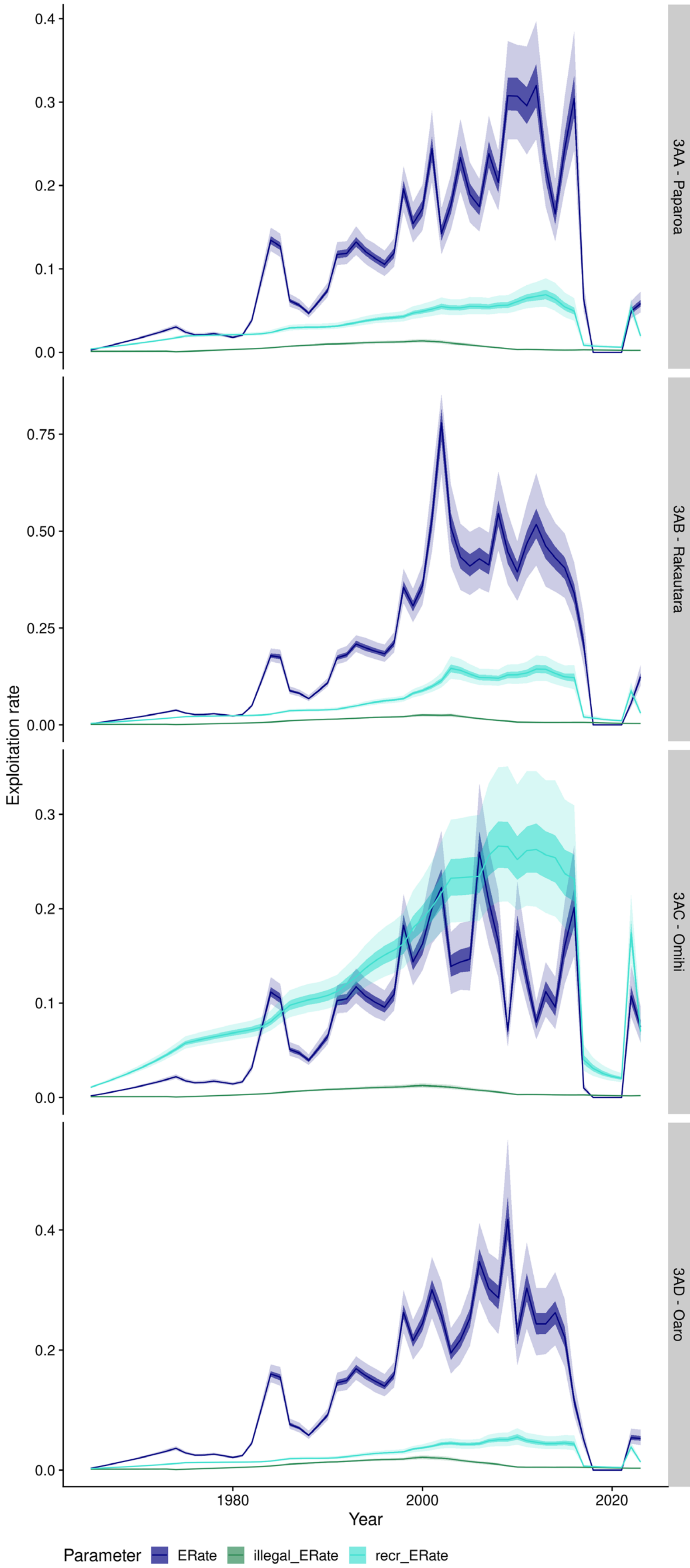


Figure 14: Estimated exploitation rate for commercial (ERate), illegal (illegal_ERate) and recreational+customary (recr_ERate) fishery components assumed in the model.

4.3 Evaluation of management procedures for PAU 3A

New management procedures were developed in 2024 on the basis of length-based estimators of spawning potential ratio (SPR; Hordyk et al 2016) and CPUE. These rules set a spawning potential target and use CPUE or survey indices to indicate the "direction of travel", adjusting catch to drive biomass towards the target SPR (Figure 15). The SPR can be estimated from commercial or survey data. The combination of SPR and indices was aimed at offsetting the relatively slow response of SPR to changes in exploitation and recruitment. The target SPR was set at 50% to reflect a precautionary target for pāua.

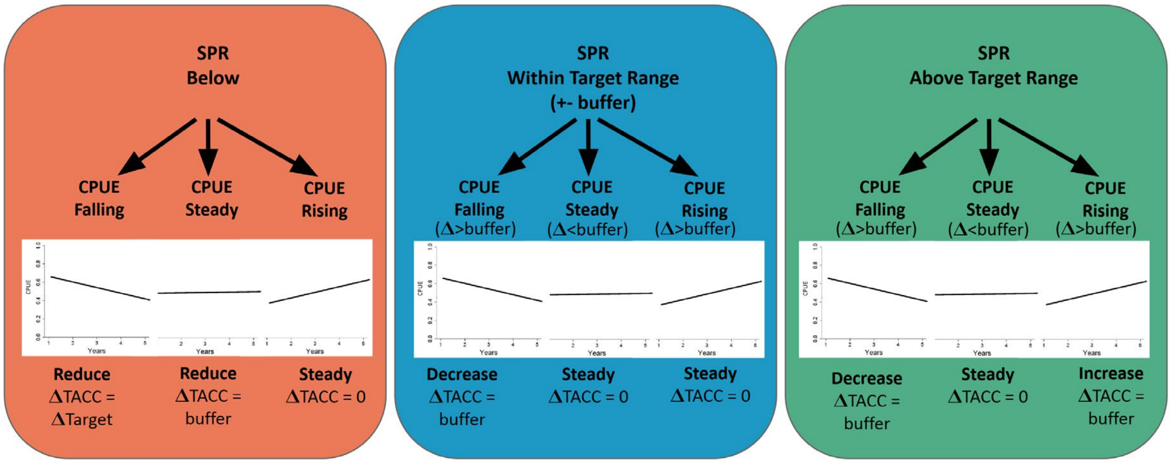
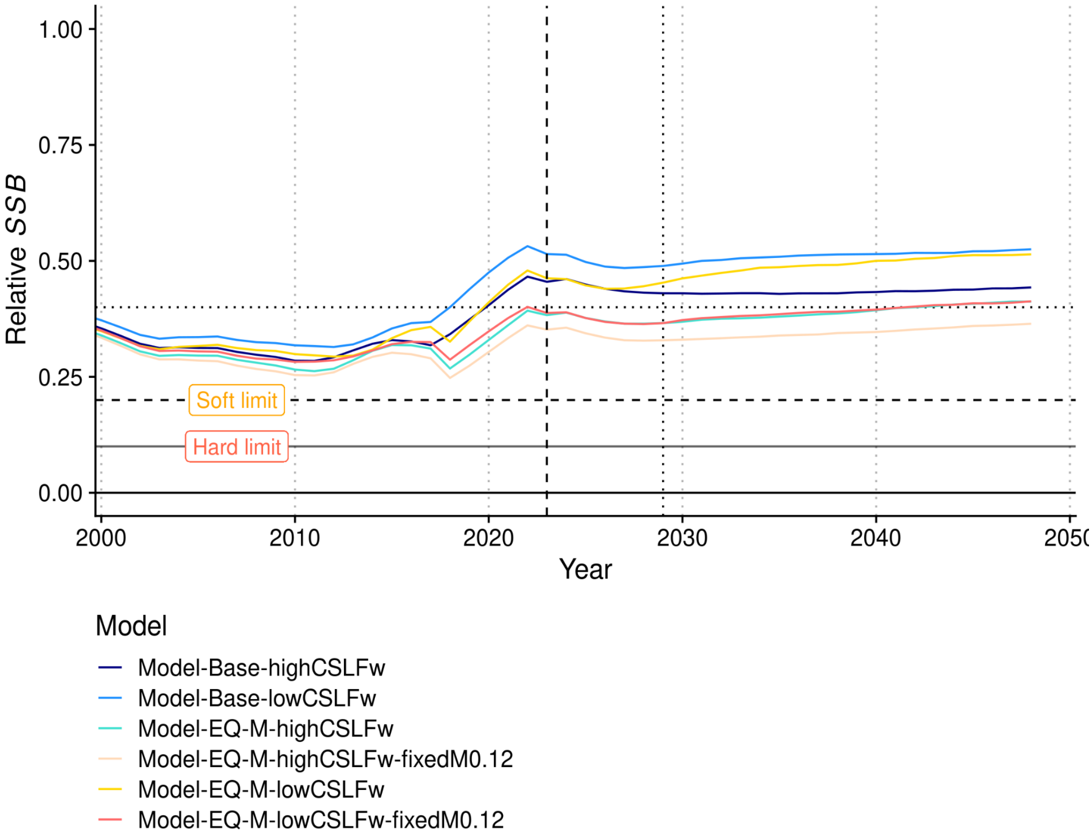


Figure 15: SPR control rule for pāua in PAU 3A. The spawning potential ratio target is set and TACCs are adjusted to steer CPUE in the direction of the target SPR.

Control rules were tested against a range of models and with a range of "base settings", including starting commercial and recreational catch levels, as well as minimum legal sizes for pāua harvest. All models used for testing suggested substantial recovery post-earthquake of pāua biomass, however, the models did so under different productivity assumptions and with different estimated stock status levels. These models were used to test the robustness of starting settings and subsequent management under the length-based SPR management procedure under different productivity and status assumptions.

Performance of the control rules in terms of catch and risk was only minimally influenced by the rule settings over the short-medium term, but catch trends were strongly influenced by initial TACC settings. The largest differences in medium to long-term outcomes were seen under alternative model assumptions, with lower initial stock status leading to lower average stock status and catch (Figure 16). However, no combination of models, initial management settings and control rules led to overfishing risk, largely due to the high minimum commercial harvest size which protects nearly 20% of the spawning biomass by virtue of making a large proportion of spawning biomass inaccessible to commercial fisheries. Although recreational and customary fisheries can still access smaller fish under settings of unchanged legal harvest sizes, the assumed levels of catch combined with a responsive commercial fishery catch do not appear to lead to risk in the medium or long-term.



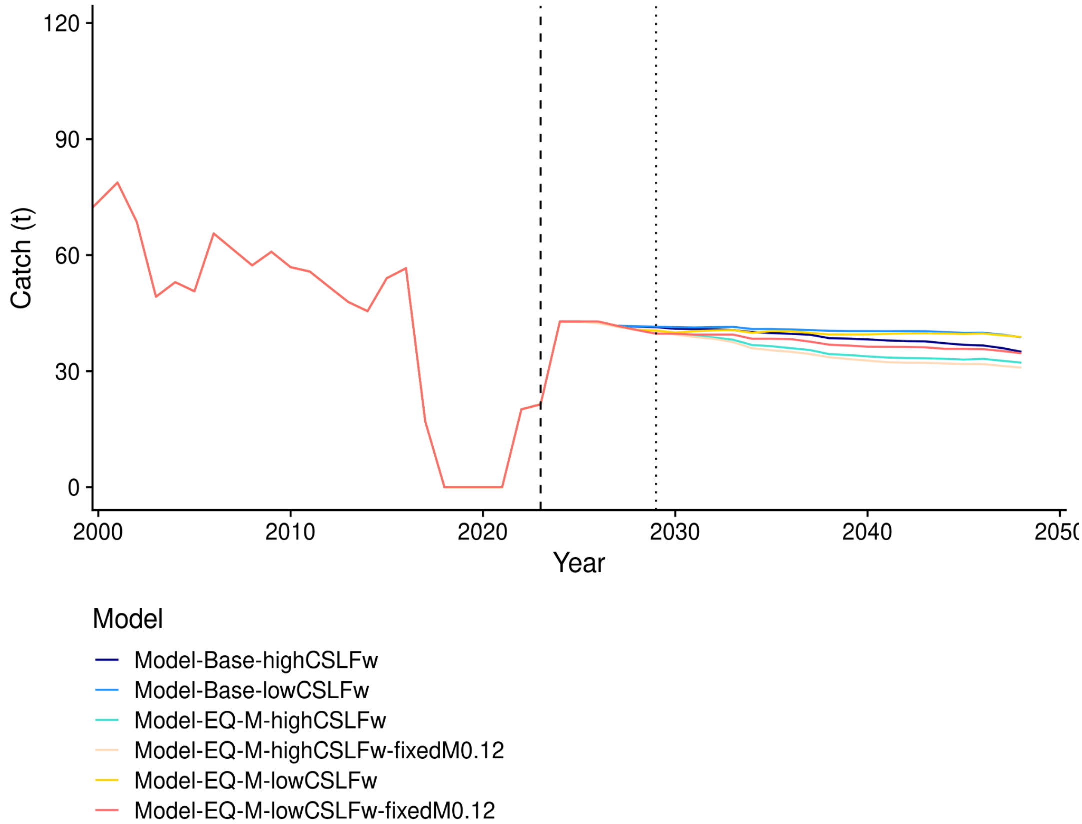


Figure 16: Simulated total catch (top) and relative spawning stock biomass (*SSB*; bottom) trends for pāua, comparing operating models with different assumptions about model weights for commercial length frequencies CSLFw [high vs low weight]; natural mortality [fixed at 0.12 or estimated]; and explicit earthquake mortality (EqM). Management was applied according to the tested control rules for each management zone in quota management area PAU 3A. The dashed vertical line shows the beginning of simulated trends based on the assessed harvest control rule, the dotted vertical line shows the tested limit of validity (3 years) of the tested rule. The last projection year is 2041.

Future research considerations

Recreational harvest
Regular estimates of recreational harvest are required to evaluate the effects of this important component of the fishery.

Surveys
Evaluate alternative survey designs to increase effort in each subarea on a rotational basis to improve precision.

CPUE
In CPUE models investigate fisher specific relationships with catch per hour.

Stock assessment
Exploration of the sensitivity to pre 2002 harvests, and potentially starting the model in 2002.
Exploration of approaches to the timing of the survey within the model year the assessment model.
Use strata specific (rather than global) in the length frequency regression analysis.

Harvest control rule
Evaluating HCR with different historical harvest (including different levels of recreational harvest).
Investigate the implications of autocorrelation in CPUE abundance indices.
Investigate available data on earthquake impact to identify potential alternative hypotheses.

5. STATUS OF THE STOCKS

● PAU 3A – Kaikōura region

Stock Status		
Most Recent Assessment Plenary Publication Year	2024	
Intrinsic Productivity Level	Low	
Catch in most recent year of assessment	Year: 2022–23	Catch: 22.71 t
Assessment Runs Presented	One base run (High CSLFw)	
Reference Points	Default Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$	
Status in relation to Target	B_{2023} was estimated to be 46% B_0; About as Likely as Not (40–60%) at or above the target	
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below the Soft Limit Hard Limit: Very Unlikely (< 10%) to be below the Hard Limit	
Status in relation to Overfishing	Unknown	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Recent trends in the survey index provide evidence of a substantial recovery of biomass since the 2016 earthquake.
Recent Trend in Fishing Intensity or Proxy	Little trend since the fishery was reopened in December 2021.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Slight increase in abundance under current (2023) catch

	settings	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) at current catch settings Hard Limit: Very Unlikely (< 10%) at current catch settings	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown	

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length based Bayesian integrated assessment in STAN	
Assessment Dates	Latest assessment Plenary publication year: 2024	Next: 2029
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Catch history - CPUE (PCELR & ERS) - Commercial length samples - Survey biomass index - Survey length samples	1 – High Quality; catch history prior to 2002 requires an assumption of a catch split between adjacent QMAs. Pre 2016 recreational harvest highly uncertain 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or mixed Quality: low sample sizes in some strata / years
Data not used (rank)	Recreational length samples	2 – Medium or mixed Quality: short time series, post earthquake only, that might not represent recreational selectivity
Changes to Model Structure and Assumptions	No previous assessment for PAU 3A. Previously assessed as PAU 3.	
Major Sources of Uncertainty	Impact of earthquake on medium term stock productivity Pre earthquake recreational harvest	

Qualifying Comments:
Recreational harvest currently exceeds recreational allowance.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Alestra, T; Gerrity, S; Dunmore, R A; Marsden, I; Pirker, J; Schiel, D R (2019) Rocky reef impacts of the Kaikōura earthquake: quantification and monitoring of nearshore habitats and communities. *New Zealand Aquatic Environment and Biodiversity Report No. 212*. 120 p.

Alestra, T; Gerrity, S; Dunmore, R A; Schiel, D R (2020) Rocky reef impacts of the Kaikōura earthquake: extended monitoring of nearshore habitats and communities – Year 1 results. *New Zealand Fisheries Assessment Report 2019/01*. 40 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research 54(5)*: 619–634.

Fu, D (2013) The 2012 stock assessment of paua (*Haliotis iris*) for PAU 5D. *New Zealand Fisheries Assessment Report 2013/57.*

Fu, D (2014) The 2013 stock assessment of paua (*Haliotis iris*) for PAU 3. *New Zealand Fisheries Assessment Report 2014/44*.

Gerring, P K; Andrew, N L; Naylor, J R (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Gerrity, S T; Schiel, D R (2023) Recreational fishing effects on wadeable pāua populations along the Kaikōura coast, 2021–22. *New Zealand Fisheries Assessment Report 2023/01*. 27 p.

Gorfine, H K; Dixon, C D (2000) A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. *Journal of Shellfish Research 19*: 515–516.

Holdsworth, J C (2021) Pāua amateur harvest survey design for the Kaikōura Marine Area. *New Zealand Fisheries Assessment Report 2021/63.* 13 p.

Holdsworth, J (2022) Harvest estimates from land-based amateur fishers—Kaikōura Marine Area to Marfells Beach. *New Zealand Fisheries Assessment Report 2022/40*. 27 p.

Holdsworth, J C; Curtis, S; Neubauer, P (2023) Pāua harvest estimates by land-based amateur fishers—Kaikōura Marine Area in 2023. *New Zealand Fisheries Assessment Report 2023/62*. 21 p.

Holdsworth, J C; Curtis, S; Neubauer, P (2025) Estimates of pāua harvest by land-based amateur fishers—Kaikōura Marine Area in 2024. *New Zealand Fisheries Assessment Report 2025/08*. 23 p.

Hordyk, A R; Ono, K, Prince, J D, Walters, C J (2016) A simple length-structured model based on life history ratios and incorporating size-dependent selectivity: application to spawning potential ratios for data-poor stocks. *Canadian Journal of Fisheries and Aquatic Sciences*, *73*(12), 1787–1799.

Kim, S W (2004) CPUE analysis of fine-scale logbook data for PAU 3. Ministry of Fisheries Research Report PAU 2001/01 Obj. 7. (Unpublished report held by Fisheries New Zealand, Wellington.)

McCowan, T; Neubauer, P (2018) Paua biomass estimates and population monitoring in areas affected by the November 2016 Kaikoura earthquake. *New Zealand Fisheries Assessment Report 2018/54*. 24 p.

McCowan, T; Neubauer, P (2021) Pāua abundance trends and population monitoring in areas affected by the November 2016 Kaikōura earthquake. *New Zealand Fisheries Assessment Report 2021/26*. 23 p.

McCowan, T A; Neubauer, P (2022) Pāua abundance trends and population monitoring in areas affected by the November 2016 Kaikōura earthquake, December 2021 update. *New Zealand Fisheries Assessment Report 2022/15.* 20 p.

McCowan, T A; Neubauer, P (2023) Pāua population monitoring in areas affected by the November 2016 Kaikōura earthquake, February 2023 update. *New Zealand Fisheries Assessment Report 2023/26.* 19 p.

McKenzie, A; Naylor, J R; Smith, N H (2009) Characterisation of PAU 2 and PAU 3. Final Research Report. 58 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Murray, T; Ackroyd, J (1984) The New Zealand paua fishery. An update and review of biological considerations to be reconciled with management goals. Internal Report No. 5. Fisheries Research Division. 25 p.

Naylor, J R; Andrew, N L (2000) Determination of growth, size composition, and fecundity of paua at Taranaki and Banks Peninsula. *New Zealand Fisheries Assessment Report 2000/51*. 25 p.

Naylor, J R; Andrew, N L; Kim, S W (2006) Demographic variation in the New Zealand abalone *Haliotis iris. Marine and Freshwater Research 57*: 215–224.

Neubauer, P (2017) Area lost to the paua fishery from the November 2016 Kaikoura earthquake, 7 p. (Unpublished report held by Fisheries New Zealand.)

Neubauer, P; Kim, K (2023) Operating model and management procedure evaluation for pāua (*Haliotis iris*) fisheries in PAU 3A. *New Zealand Fishery Assessment Report 2023/28*. 109 p.

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. (MSc thesis, University of Canterbury.) 165 p.

Poore, G C B (1972) Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 3. Growth. *New Zealand Journal of Marine and Freshwater Research 6*: 534–59.

Poore, G C B (1973) Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 4. Reproduction. *New Zealand Journal of Marine and Freshwater Research 7* (*1&2)*: 67–84.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research 16*: 147–161.

Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.), *Abalone of the World: Biology, fisheries, and culture*. Blackwell Scientific, Oxford.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris. Fishery Bulletin 89*: 681–691.

Shepherd, S A; Partington, D (1995) Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. *Marine and Freshwater Research 46*: 669–680.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. (Unpublished report for GEN2007A, held by Fisheries New Zealand, Wellington.) 37 p.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.