

In response to a rebuilding of pāua biomass, the commercial and recreational fisheries were initially reopened for a limit three-month period in December 2021. The commercial fishery was later reopened on a permanent basis in January 2023, as well as a further two-month recreational season between April and June 2023.

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 accounts 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 2021–22. The PAU 3A reconstructed landings between 2001–02 and 2020–21 correspond to the PAU 3 estimated catch for statistical areas 301 to 310 which correspond to 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 2021–22. The PAU 3A reconstructed landings between 2001–02 and 2020–21 correspond to the PAU 3 estimated catch for statistical areas 301 to 310 which correspond to PAU 3A QMA created in 2021–22.

Year	PAU 3		PAU 3A		
	Landing s	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†				20.74	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 fine scale reporting statistical areas 301 to 310.

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 has been 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 Ocean 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, larger minimum harvest size, and fine scale catch reporting and monitoring. The Plan includes new voluntary management areas

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(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.

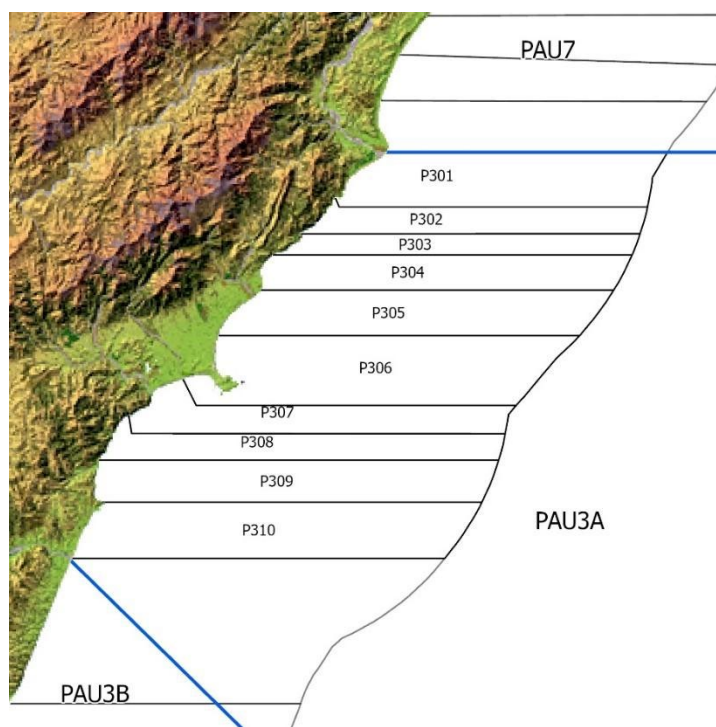


Figure 2: Map of fine scale statistical reporting areas for PAU 3.

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

Management zone (since 2021)	Area	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 of 3 pāua per person.

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.

Fishing year	Numbers		Fishing year	Numbers	
	Approved	Harvested		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	4 960	3 242
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 year	Numbers	
	Approved	Harvested
2021–22	3 639	3 058

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

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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 301, the habitat loss was 7 ha, which corresponds to 52% of the fished area. However, this area has contributed relatively little to the commercial catch. In area 302, 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).

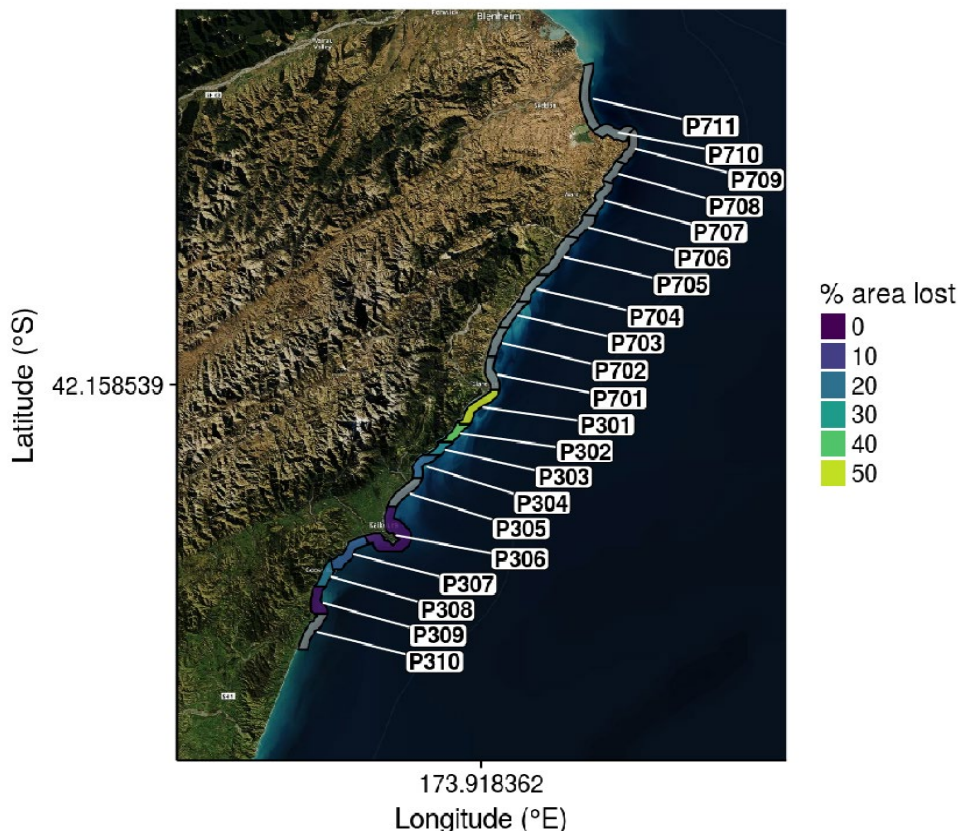


Figure 3: Percent fished area above the post-earthquake low tide mark for statistical areas within the Kaikōura earthquake fishery closure zone. Grey indicates that no post-earthquake elevation data were available.

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. <u>Natural mortality (<i>M</i>)</u>	0.135 (0.120–0.153)	Median (5–95% range) of posterior distribution for the base case model
2. <u>Weight = $a(\text{length})^b$ (Weight in g, length in mm shell length)</u>		
All	2.99×10^{-5}	a 3.303 b Schiel & Breen (1991)
3. <u>Size at maturity (shell length)</u>		
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

The last assessment for PAU 3 was conducted in 2014; however, given the potential effects of the earthquake, it is unclear how representative estimates from this assessment are for the current PAU 3A stock. Details of the PAU 3 stock assessment are given by Fu (2014).

Since the PAU 3A area has been closed to fishing, no stock assessment has been conducted. The fishery reopened in 2021–22 and several years of landing data will be necessary before a stock assessment can be attempted. A project was conducted between 2021 and 2023 to develop an operating model for the area and evaluate management options.

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, 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 has been extended for another three years until mid-2023.

As of Jan 2023, six further rounds of surveys of the 35 initially surveyed sites have been undertaken to monitor pāua abundance and recruitment trends, 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

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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 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).

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 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 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. This effect was likely even more pronounced in the 2022 post-season survey in the area, which encountered very difficult survey 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 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.

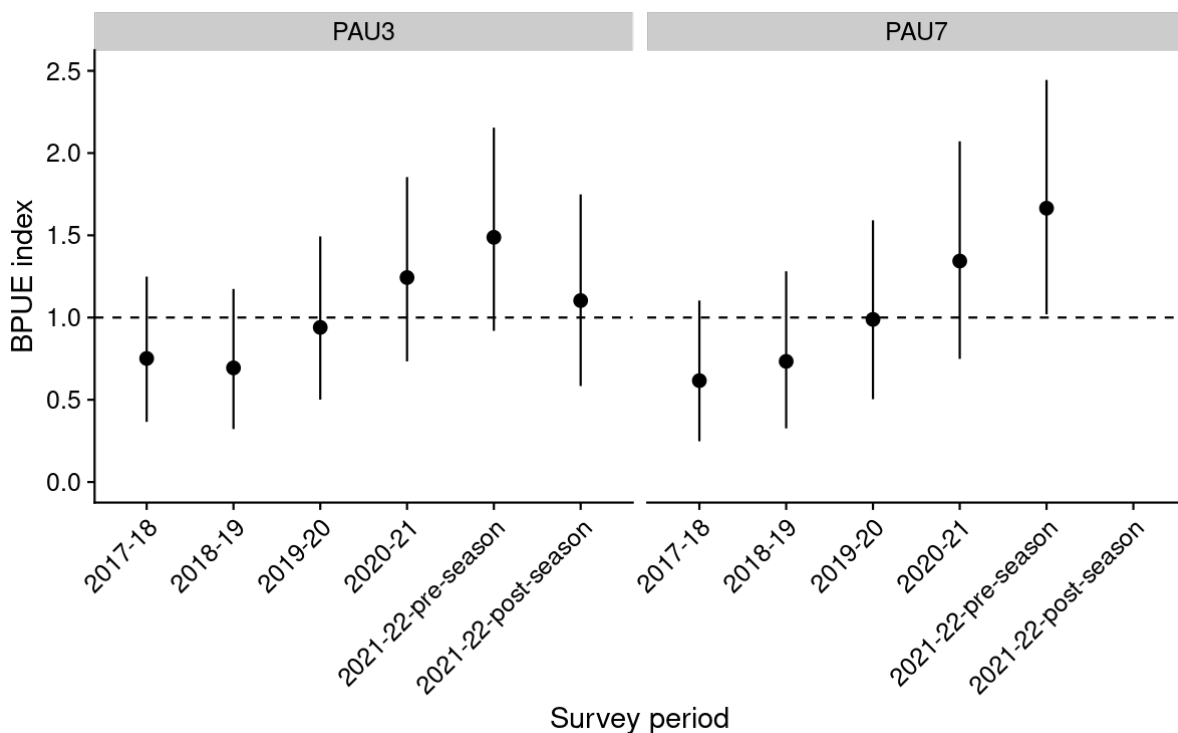


Figure 4: Marginal trend (relative to a geometric mean of 1) in biomass per unit effort (BPUE) across survey years for QMAs PAU 3 and PAU 7 from the BPUE model after accounting for confounding variables.

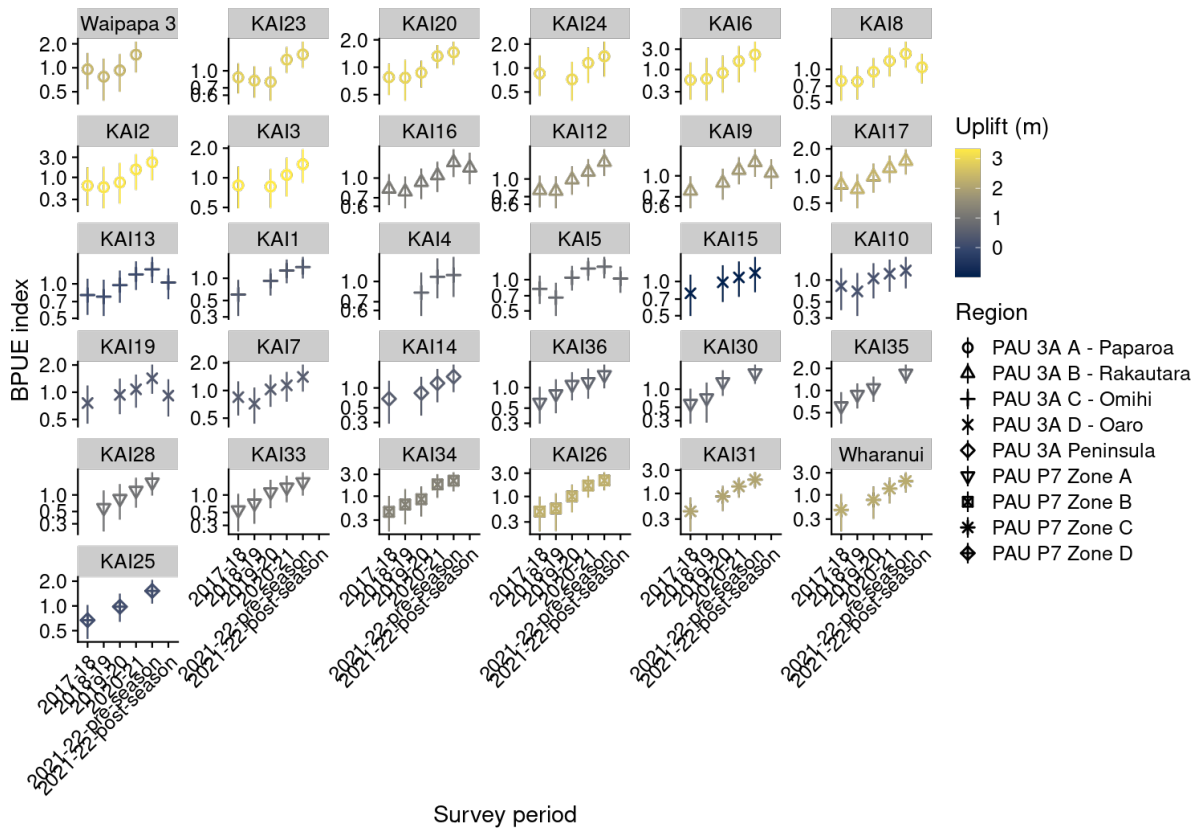


Figure 5: Marginal trend (relative to a geometric mean of 1 at each site) in biomass per unit effort (BPUE) across survey years for all sites, plotted across industry management zones (“Region”) in QMAs PAU 3A and PAU 7 from the BPUE model after accounting for confounding variables.

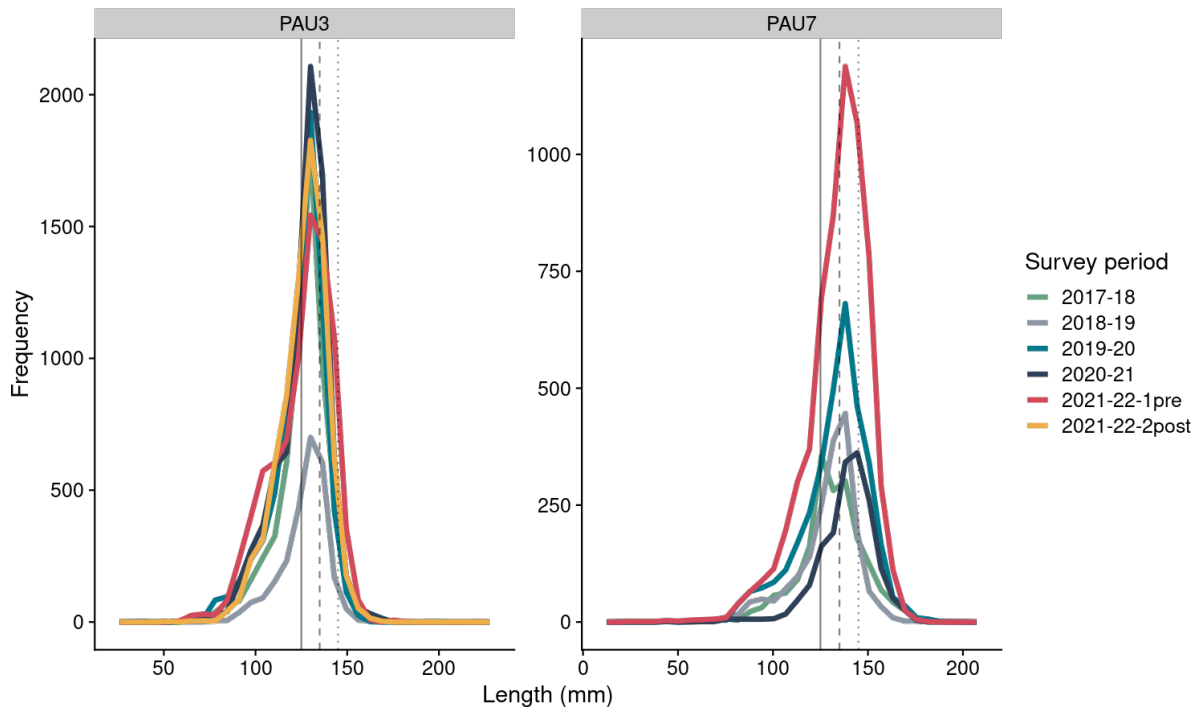


Figure 6: Length-frequency profiles for all pāua measured over four survey periods in PAU 3 and PAU 7. Vertical lines show the legal size of 125 mm (MLS; solid line), 135 mm (dashed line), and 145 mm (dotted line).

4.2 Operating model development and evaluation of management options post-reopening of PAU 3A

Prior to the earthquake, the PAU 3 quota management area was assessed on the basis of length-based statistical stock assessment. The stock was thought to be in healthy condition, although large uncertainties about stock status remained due to insufficient biological information that can inform about local stock productivity. Two projects conducted between 2021 and 2023 attempted to develop models and test management options for PAU 3A as the fishery rebuilds. The work focused on key uncertainties that remain for management of the fishery long term: modelling of earthquake impacts and recovery, and the developments of recreational catch over time.

Models used a range of simple assumptions about plausible earthquake impacts and attempted to integrate survey data directly into stock assessments. While available data do not provide a basis for determining the likelihood of earthquake impact scenarios, a range of scenarios were tested in terms of their implications for management. Similarly, recreational catch cannot be precisely controlled, and alternative recreational catch scenarios were explored to understand the trade-off between long-term recreational catch and the commercial fishery in the long term.

The newly developed models were able to fit the fishery and aspects of survey data (indices), suggesting that models are able to represent the fishery development despite the earthquake. While the simple earthquake impact assumptions were not able to capture more subtle trends in survey indices, providing relatively poor fits to survey length frequency data, they provide a starting point to modelling earthquake impacts in future assessments.

Depending on the model fitting strategy and earthquake impacts, tested commercial harvest strategies, combined with recreational harvest scenarios, led to relatively stable, or declining fisheries. The commercial fishery was especially affected by the trade-off with recreational harvest when recreational catch was not substantially reduced, leading to long-term reductions in commercial catch from reopening levels. While differences between scenarios were minor in the short term, uncertainties were large over long periods, leading to non-negligible risk in some models (Figure 7). Given uncertainties about stock trajectories and risks, the working group recommended ongoing monitoring of commercial and recreational catch and revisiting of management options in 2–3 years once trends and levels of recreational catch have stabilised and key uncertainties can be revisited to ensure fishery performance in the long term as the fishery develops.

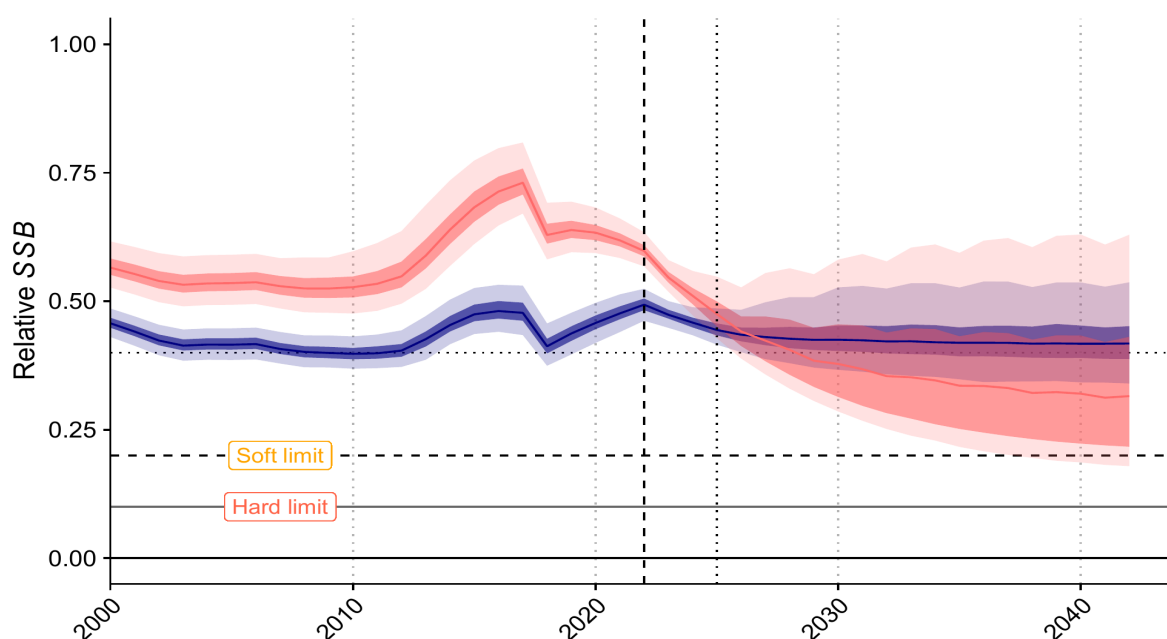


Figure 7: Simulated relative spawning stock biomass (*SSB*) trend for pāua, comparing base operating models, fitted (or not) to survey observations, with management according to the tested control rules for each management zone in quota management area PAU 3A. The dashed vertical line shows the beginning 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.

5. STATUS OF THE STOCKS

• PAU 3A – Kaikōura region

Stock Status	
Year of Most Recent Assessment	The most recent assessment for PAU 3, conducted in 2014, is thought to be of limited use for the PAU 3A area since the 2016 Kaikōura earthquake
Assessment Runs Presented	N/A
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B_0}$
Status in relation to Target	Unknown, but likely relatively high given CPUE levels are well above most other mainland QMAs, and a substantial biomass rebuild is evident in surveys post-earthquake
Status in relation to Limits	Unknown
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	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Survey length frequencies showed both post-earthquake recruitment and an increase in mean length.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	N/A	
Assessment Method	N/A	
Assessment Dates	Latest:	Next: unknown
Overall assessment quality (rank)	-	
Main data inputs (rank)	-	
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments:
The last assessment was conducted in 2014; however, given the potential effects of the earthquake, it is unclear how representative estimates from this assessment are for the current pāua stock.

Fishery Interactions
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